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ORIGINAL ARTICLE

Dental age assessment for Kuwaiti children using Demirjian's method

MUAWIA A. QUDEIMAT & FARAJ BEHBEHANI

Department of Developmental and Preventive Sciences, Faculty of Dentistry, Kuwait University, Kuwait

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Abstract

Background: Dental age can be estimated based on the level of tooth mineralization during the developmental process. Various methods of determining chronological and radiographical stages have been used for dental age estimation.

Aim: To test the validity of the standards of dental maturation of Demirjian and Goldstein (Ann Hum Biol 3:411–421, 1976) when applied to Kuwaiti children.

Subjects and methods: The sample was selected from healthy Kuwaiti children attending the routine and emergency dental clinics of the Faculty of Dentistry, Kuwait University. Good quality rotational pantomographs were obtained for 509 children (263 girls and 246 boys) between 3 and 14 years. Maturation of the seven permanent teeth on the left side of the mandible was determined according to the crown and root development stages described by Demirjian et al. (Hum Biol 45:211–227, 1973).

Results: There were statistically significant differences in the mean of dental maturation between Kuwaiti and French–Canadian children ($p<0.0001$). Kuwaiti children were dentally delayed compared to the Canadian standards (mean dental maturation difference of 0.69 year, SD=1.25 years, CI=0.58–0.80). The mean delay in girls was 0.67 year (SD=1.30 years, CI=0.51–0.83) and in boys it was 0.71 year (SD=1.18 years, CI=0.56–0.86). Using a non-linear regression model, function formulae were developed for Kuwaiti girls and boys.

Conclusion: The standards of dental maturation described by Demirjian and Goldstein (1976) may not be suitable for Kuwaiti children.

Keywords: *Demirjian, dental age, Kuwaiti, children, radiographs*

Introduction

In dental and medical practices, age estimation is considered to be of great importance. For both the paediatric dentist and the orthodontist, to be able to know a child's growth and developmental status is especially important in diagnosis and treatment planning (Sahin

Correspondence: Dr Muawia A. Qudeimat Department of Developmental and Preventive Sciences, Faculty of Dentistry, Kuwait University, PO Box 24923, Safat, 13110 Kuwait. E-mail: mqudeimat@hsc.edu.kw

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Saglam and Gazilerli 2002). In forensic medicine, age determination is not only helpful in the identification of deceased victims or human remains but also in age estimation of living persons which might be required in such cases that chronological age plays a critical role, e.g. criminal liability, school attendance and social benefits (Schmeling et al. 2000; Maber et al. 2006).

Dental age can be assessed radiographically and clinically. Radiographic methods make it possible to follow the formation of tooth crown and root, which is a continuous process. Different dental radiographic developmental stages have been defined by several authors (Gleiser and Hunt 1955; Moorrees et al. 1963; Demirjian et al. 1973; Kullman et al. 1992). The Demirjian et al. (1973) method of assessing dental maturity is based on ratings of radiographs of the seven left side teeth of the mandible (excluding the third molar), which were shown to be representative of all the teeth in the mandible. Eight stages (A through H) of tooth calcification were described and each allocated a score. The sum of these scores for an individual provides an estimate of dental maturity on a scale of 0–100 (Demirjian et al. 1973). Scores and percentile standards were given separately for boys and girls for the age range 3–16 years (Demirjian and Goldstein 1976).

One major concern of practical relevance to age estimation from dental radiographs is whether the reference data, derived from an ethnic group, can be applied to members of other ethnic groups. Although, the accuracy of Demirjian's method has generally been considered by many investigators as fairly high for populations of European descents (Hägg and Matsson 1985; Nykänen et al. 1998; Nyström et al. 2007), recent investigations using this method on several groups suggested some ethnic differences (Davis and Hägg 1994; Koshy and Tandon 1998; Liversidge et al. 1999; Frucht et al. 2000; Al-Emran 2008; Moananui et al. 2008; Rózylo-Kalinowska et al. 2008; Tunc and Koyuturk 2008). These reports demonstrate the necessity of establishing reference data representative to each population. It was therefore the aim of this cross-sectional study to test the reliability of Demirjian's method of age estimation when used for Kuwaiti children and to establish specific dental age maturity function formulae if deemed necessary.

Subjects and methods

Sample

The sample of this study consisted of 509 panoramic radiographs of healthy Kuwaiti children attending the routine and emergency dental clinics of the Department of Developmental and Preventive Sciences, Faculty of Dentistry, Kuwait University.

Children were excluded from the study if they had any of the following: (1) agenesis of teeth, (2) distinctive retardation in dental development (except of third molars), (3) systemic diseases affecting the growth and development of the teeth, or (4) poor quality panoramic radiograph.

Panoramic radiographs

The digital panoramic radiographs used in this study were taken with Planmeca PM 2002 EC Proline panoramic system (Planmeca Oy, Helsinki, Finland). The radiographic parameters adopted were per manufacturer instructions. Images were captured and processed using Planmeca Dimaxis software. The resolutions of the images were 9.0 l/mm (pixel size 66 m). All radiographs were assessed using the same monitor with same LCD resolution and under the same lighting conditions.

Data collection and processing

A special data capture form for collecting patient's demographic information and radiographic findings was designed. The validity of the capture form was tested on 15 patient's records and panoramic radiographs.

A pilot study for the training and calibration of the main investigator was then carried out on 75 patients' records and panoramic radiographs that fulfilled the inclusion criteria. The parameters date of birth and date of radiograph were used to calculate the chronological age.

The stages of dental maturity of the mandibular left seven permanent teeth for each child using the eight radiographic dental maturity stages described by Demirjian et al. (1973) were assessed by the same investigator without prior knowledge of age or gender of the subject. Each tooth formation stage of the seven teeth was allocated a biologically weighted score (Demirjian et al. 1973). The sum scores for each subject provided an estimate of the dental maturity, measured on a scale from 0 to 100. The overall dental maturity score was then converted to a dental age by using available tables and/or percentile curves (Demirjian et al. 1973; Demirjian and Goldstein 1976).

Statistical analysis

To assess reproducibility, 55 randomly selected radiographs were re-scored 1 month after the initial examination by the same investigator. The percentage agreement of the two readings was calculated by examining 55 radiographs with 385 readings. The difference in dental development stage scoring between the two readings was tested for significance with Kappa test (0.82).

Dental age (DA) was calculated from reference tables (Demirjian and Goldstein 1976) and compared to chronological age (CA) for boys and girls separately. The difference between DA and CA was tested for statistical significance.

The data were statistically analysed using XLSTAT (version 7.5, Addinsoft, New York, NY, USA) and the SPSS 15.0 software for windows. Analyses were made for the entire group as well as for each gender and cohort (i.e. children between 4.00 and 4.99 years of age would be included in the 4.5 years cohort). Paired *t*-test, Friedman's test, and independent sample *t*-test were used to investigate statistical significance. Also, a logistic function was adapted based on an equation with the two parameters pr1 and pr2 and with the variables age and score sum. Using non-linear regression analysis methods similar to those employed by earlier investigators from south-western Germany and central Poland (Frucht et al. 2000; Rózylo-Kalinowska et al. 2008) and in order to use the equation for assessing dental age without referring to the reference data tables, a function formula was developed as follow:

$$\text{Dental age} = (\ln(\text{Score Sum}/(100 - \text{Score Sum})) + \text{pr1})/\text{pr2}$$

The parameters pr1 and pr2 for girls and boys, respectively, were determined from the medians of the scores recorded in this study.

Results

The age mean and range and standard deviation for boys and girls are presented in Table I. Girls constituted 52% of the total sample and boys 48%. The distribution of boys and girls into different age groups are shown in Table II. Fewer numbers of children were included in

Table I. Mean, minimum and maximum and standard deviation of the chronological age for the study sample.

	Mean (CI)	Minimum (years)	Maximum (years)	SD	Total (%)
Girls	8.91 (8.60–9.21)	3.21	13.92	2.52	263 (52)
Boys	8.39 (8.08–8.69)	3.20	13.77	2.43	246 (48)
Total	8.65 (8.44–8.87)	3.20	13.92	2.49	509 (100)

the younger age groups. This is due to the policy of the paediatric dentistry department, where radiographs are not usually prescribed before the mixed dentition stage.

Differences in the mean between dental and chronological ages for Kuwaiti and French–Canadian children were statistically significant ($p<0.0001$). Kuwaiti children as a group were dentally delayed compared to the Canadian standards (mean dental maturation difference of 0.69 years (SD = 1.25, 95% CI = 0.58–0.80)). In addition, both genders taken separately were delayed in dental maturity as compared with the reference sample. The mean delay in girls was 0.67 years (SD = 1.30 years, CI = 0.51–0.83) and in boys it was 0.71 years (SD = 1.18 years, CI = 0.56–0.86). Tables III and IV demonstrate the difference between the dental ages estimated according to Demirjian's standards and chronological ages for boys and girls. The mean difference between the dental and the chronological ages ranged from 0.18 to 1.70 years in boys and from 0.03 to 1.63 years in girls. The least differences between the estimated and chronological ages were observed in the 5–10 year age group for boys and the 3–10 year age group for girls. However, the differences in the mean were not statistically significant in the 9–10-year-old and 13–14-year-old groups for boys, and in the 3–4-year-old and 7–9-year-old age groups for girls.

Mean age, standard error, standard deviation and total number of boys and girls and combined groups in 'a tooth formation stage' for each tooth are shown in Table V. The Demirjian's stage 'H' was omitted because it is not possible to predict how much time has passed since the child entered this stage.

Generally, the mean ages of children for most teeth developmental stages were earlier in girls as compared to boys.

Demirjian's standard used to evaluate the dental age were clearly not appropriate for Kuwaiti population, therefore, and to be able to achieve a more reliable age estimate from panoramic radiographs, function formulae that could be used in evaluating dental age of

Table II. Age and gender distribution of the study subjects.

Chronological age	Boys	Girls	Total (%)
3–3.9	10	2	12 (2.3)
4–4.9	13	12	25 (4.9)
5–5.9	24	18	42 (8.3)
6–6.9	32	31	63 (12.4)
7–7.9	25	46	71 (14.0)
8–8.9	44	36	80 (15.7)
9–9.9	29	33	62 (12.2)
10–10.9	28	21	49 (9.6)
11–11.9	24	27	51 (10.0)
12–12.9	14	15	29 (5.7)
13–13.9	3	22	25 (4.9)
Total	246	263	509 (100)

Table III. Differences between the mean dental age estimated using Demirjian's method and the chronological age of the study sample for Kuwaiti boys.

Age group (years)	n	DA – CA	CI	SD	*p*
3–3.9	10	1.0	0.48 to 1.52	0.73	0.002
4–4.9	13	1.14	0.74 to 1.55	0.67	0.000
5–5.9	24	0.75	0.55 to 0.96	0.49	0.000
6–6.9	32	0.57	0.31 to 0.83	0.72	0.000
7–7.9	25	0.18	−0.03 to 0.39	0.51	0.09
8–8.9	44	0.48	0.09 to 0.87	1.27	0.02
9–9.9	29	0.29	−0.26 to 0.84	1.45	0.29
10–10.9	28	0.88	0.28 to 1.48	1.55	0.006
11–11.9	24	1.19	0.59 to 1.79	1.42	0.000
12–12.9	14	1.70	0.92 to 2.47	1.35	0.000
13–13.9	3	1.01	−2.11 to 4.13	1.26	0.30

DA, Dental age; CA, chronological age.

Kuwaiti girls and boys were developed. The method of adaptation of Demirjian's scores was based on establishing a function formula (using a non-linear regression model), where the score sum was obtained from Demirjian's standards and parameters pr1 and pr2 were obtained from the medians of the scores recorded in the current study (for girls pr1 = –4.076; pr2 = 0.639 and for boys pr1 = – 3.512; pr2 = 0.551).

For girls the function was:

$$\text{Dental age} = (\ln(\text{Score Sum}/(100 - \text{Score Sum})) + 4.076)/0.639$$

While for boys the function was:

$$\text{Dental age} = (\ln(\text{Score Sum}/(100 - \text{Score Sum})) + 3.512)/0.551$$

The function formulae were then used to develop a table of predicted ages for Kuwaiti children based on the maturity sum score derived from panoramic radiographs. Predicted ages for boys and girls are presented in Table VI.

Table IV. Differences between the mean dental age estimated using Demirjian's method and the chronological age of the study sample for Kuwaiti girls.

Age group (years)	*n*	DA – CA	CI	SD	*p*
3–3.9	2	0.25	−0.30 to 0.79	0.06	0.11
4–4.9	12	0.60	0.20 to 1.00	0.63	0.007
5–5.9	18	0.35	0.07 to 0.63	0.56	0.017
6–6.9	31	0.36	−0.05 to 0.76	1.09	0.08
7–7.9	46	0.03	−0.16 to 0.23	0.66	0.75
8–8.9	36	0.17	−0.20 to 0.54	1.09	0.36
9–9.9	33	0.76	0.27 to 1.22	1.35	0.003
10–10.9	21	1.63	0.83 to 2.44	1.78	0.000
11–11.9	27	0.99	0.29 to 1.70	1.79	0.008
12–12.9	15	1.53	0.71 to 2.53	1.48	0.001
13–13.9	22	1.59	0.17 to 2.01	0.95	0.000

DA, Dental age; CA, chronological age.

Table V. Mean ages of Kuwaiti boys and girls in 'a tooth formation stage'.

		Girls				Boys				Boys and girls			
Tooth	Stage	Mean	SE	SD	*n*	Mean	SE	SD	*n*	Mean	SE	SD	*n*
I_1	D					4.36	0.58	1.29	5				
	E	5.21	0.18	0.85	23	5.01	0.14	0.82	37	5.08	0.11	0.83	60
	F	6.68	0.11	0.87	59	6.89	0.14	0.96	46	6.77	0.09	0.91	105
	G	7.62	0.20	0.80	16	7.98	0.20	0.98	24	7.83	0.15	0.92	40
I_2	C					3.84	0.35	0.85	6				
	D	4.72	0.19	0.74	15	5.03	0.22	0.92	18	4.89	0.15	0.85	33
	E	6.26	0.14	0.89	42	6.01	0.17	1.15	48	6.13	0.11	1.04	90
	F	7.35	0.15	0.99	42	7.64	0.14	0.92	41	7.49	0.11	0.96	83
	G	8.63	0.15	1.01	45	9.06	0.15	1.02	45	8.85	0.11	1.03	90
C	B					3.77	0.45	0.63	2				
	C	4.91	0.23	0.87	15	4.91	0.15	0.91	39	4.91	0.12	0.89	54
	D	5.96	0.17	0.97	31	6.56	0.16	0.93	35	6.28	0.12	0.99	66
	E	7.17	0.11	0.81	52	8.00	0.15	1.03	46	7.56	0.10	1.01	98
	F	9.10	0.12	1.17	88	9.82	0.14	1.37	99	9.84	0.10	1.33	187
	G	10.88	0.28	1.42	26	11.41	0.27	1.06	15	11.08	0.20	1.31	41
P_1	B					3.73	0.19	0.43	5				
	C	5.38	0.14	0.83	34	5.32	0.13	0.93	53	5.35	0.10	0.89	87
	D	6.95	0.11	0.81	55	7.36	0.12	0.78	41	7.12	0.08	0.82	96
	E	8.38	0.13	0.90	47	8.67	0.39	1.04	56	8.54	0.10	0.18	103
	F	9.62	0.16	1.16	54	10.24	0.15	1.20	65	9.96	0.11	1.22	119
	G	11.30	0.27	1.41	27	11.52	0.30	1.11	14	11.38	0.20	1.30	41
P_2	A	3.50	0.29	0.41	2	4.33	0.49	1.61	11	4.20	0.43	1.53	13
	B	5.09	0.19	0.77	17	5.09	0.21	0.87	18	5.09	0.14	0.81	35
	C	6.56	0.12	0.89	57	6.29	0.13	0.98	54	6.43	0.09	0.94	111
	D	7.80	0.14	0.87	41	8.44	0.17	1.10	43	8.12	0.11	1.04	84
	E	8.98	0.16	0.98	38	8.83	0.15	1.03	48	8.90	0.11	1.01	86
	F	10.44	0.18	1.43	65	10.70	0.15	1.10	54	10.55	0.12	1.29	119
	G	11.94	0.25	1.07	18	12.21	0.20	0.86	18	12.07	0.16	0.96	36
M_1	C					4.40	0.48	0.68	2				
	D	3.98	0.51	0.88	3	3.57	0.14	0.35	6	3.71	0.19	0.56	9
	E	4.98	0.19	0.76	16	5.01	0.17	0.86	26	5.00	0.13	0.82	42
	F	6.65	0.10	0.80	69	6.75	0.13	1.02	63	6.70	0.08	0.91	132
	G	8.55	0.17	1.13	45	8.68	0.15	1.08	50	8.62	0.11	1.10	95
M_2	A	4.32	0.34	0.84	6	3.75	0.16	0.49	9	3.98	0.18	0.69	15
	B	5.46	0.22	0.99	20	5.21	0.13	0.75	35	5.30	0.11	0.85	55
	C	7.03	0.11	0.96	79	7.27	0.14	1.09	65	7.14	0.09	1.03	144
	D	8.37	0.22	1.08	24	8.47	0.21	1.12	29	8.42	0.15	1.09	53
	E	9.15	0.14	0.92	46	9.59	0.14	1.05	59	9.40	0.10	1.02	105
	F	11.08	0.16	1.24	58	11.37	0.17	1.13	43	11.21	0.12	1.20	101
	G	12.79	0.18	0.85	23	12.29	0.38	0.93	6	12.69	0.16	0.87	29

Discussion

Dental age is defined as the estimated age of the subject based on the level of tooth mineralization or calcification during the developmental process (Gustafson and Koch 1974). In dentistry and medicine, two methods are commonly used to assess dental age: Assessment of tooth eruption through tooth count and evaluation of the mineralization of permanent teeth based on panoramic radiographs. Permanent teeth eruption dates vary widely among children of the same ethnic background, making it an unreliable method for

Table VI. Predicted age per maturity score in Kuwaiti boys and girls using the developed function formula.

	Predicted age	
Score	Boys	Girls
12	2.76	3.26
14.5	3.15	3.60
17	3.50	3.90
19.5	3.80	4.16
22	4.08	4.40
24.5	4.33	4.62
27	4.57	4.82
29.5	4.79	5.02
32	5.01	5.20
34.5	5.21	5.38
37	5.41	5.55
39.5	5.60	5.71
42	5.79	5.87
44.5	5.97	6.03
47	6.16	6.19
49.5	6.34	6.35
52	6.52	6.50
54.5	6.70	6.66
57	6.89	6.82
59.5	7.07	6.98
62	7.26	7.14
64.5	7.46	7.31
67	7.66	7.49
69.5	7.87	7.67
72	8.09	7.86
74.5	8.32	8.06
77	8.57	8.27
79.5	8.83	8.50
82	9.13	8.75
84.5	9.45	9.03
87	9.82	9.35
89.5	10.26	9.73
92	10.81	10.20
94.5	11.54	10.83
97	12.68	11.82
99.5	15.98	14.66

estimating age (Posen 1965; Kumar and Sridhar 1990; Nyström et al. 2000). Other methods are based on radiographic shape criteria and proportion of root length, using the relative value to crown height, therefore, foreshortened or elongated projections of developing teeth will not affect the reliability of assessment (Demirjian et al. 1973; Demirjian and Goldstein 1976). Other advantages of the later method include reliability and feasibility to estimate an individual's age because teeth can be preserved for a long time after all other tissues have disintegrated (Gustafson 1950). The developmental stages of permanent teeth might be considered as a valuable indicator of chronological age for Kuwaiti population, given the scarcity of other available age indicators.

Various methods of determining chronological and radiographical stages have been used for dental age estimation (Gleiser and Hunt 1955; Moorrees et al. 1963; Demirjian et al. 1973; Gustafson and Koch 1974; Kullman et al. 1992). Demirjian's eight-stage method is one of the principal methods used to quantify the degree of maturity. It is one of the

simplest, practical, and widely employed methods (Orhan et al. 2007). Recent studies have verified that Demirjian's classification system performs well in terms of both observer agreement and correlation between estimated and true age (Davis and Hägg 1994; Koshy and Tandon 1998; Nykänen et al. 1998; Frucht et al. 2000; Maber et al. 2006; Al-Emran 2008; Rózylo-Kalinowska et al. 2008; Tunc and Koyuturk 2008). This is in agreement with this study, where intra-observer reliability was calculated by re-scoring 55 radiographs and the Kappa test was found to be equal to 0.82. Values between 0.81 and 1.00 indicate high association between the two ratings (Altman 1991). However, a common finding in research conducted in different countries including Western Europe is that Demirjian and Goldstein's (1976) French–Canadian standards do not accurately estimate the dental age of studied subjects. While some studies reported an overestimation of dental age, reaching a difference of 3 years (Davis and Hägg 1994; Koshy and Tandon 1998; Liversidge 1999; Maber et al. 2006), others reported an underestimation of the predicted dental age (Nykänen et al. 1998; Liversidge et al. 1999; Al-Emran 2008; Moananui et al. 2008; Rózylo-Kalinowska et al. 2008; Tunc and Koyuturk 2008). In the current work, the use of Demirjian's reference data led to an overestimation in the dental development of Kuwaiti children. As a group, Kuwaiti children were dentally delayed compared to the French–Canadian standards by 0.69 year. When examined separately, both genders were delayed in dental maturity as compared with the reference sample. The mean delay in girls was 0.67 year and in boys it was 0.71 year. These differences were all statistically significant. However, it must be noted that, in attempting to compare the findings of this study with previous research on accuracy of dental age assessment methods it was clear that such comparisons are complicated by different sample sizes, age structures, grouping and statistical analysis used, making comparisons difficult (Maber et al. 2006).

In a previous study, researchers reported that significant variability in individual dental age increased with age (Nykänen et al. 1998). This is in disagreement with the current work where statistically significant differences were observed in younger and older age groups with no tendency towards such variability. It was also previously stated that sex differences do exist and need to be taken into account. With most maturational events, the tempo of maturation is faster in girls (Blankenship et al. 2007). This is in agreement with the findings of this study where girls were dentally more advanced than boys for the majority of tooth formation stages.

As stated in earlier studies, the difference in dental maturation between groups using a single score such as Demirjian's does not provide a clear picture of where and how these differences occur. Demirjian's scoring system relies on weighted scores of tooth formation stages. Differences in the timing of one or more of these stages relative to other stages or teeth are usually hidden (Moananui et al. 2008). When comparing the mean ages of Kuwaiti children with those of children from Australia, Belgium, Canada, England, Finland, France, South Korea and Sweden as presented in a recent meta-analysis study by Liversidge et al. (2006), it is worth mentioning that for most of the teeth there seem to be a close similarity in children's mean ages in a given tooth formation stage. Appreciating the limitation of such comparison due to the difference in the sample size of the current study (509 subjects) and that of the previous study (9002 subjects), statistically significant differences were observed in 37 of 73 tooth/stage comparisons. There was no clear trend towards an early or delayed development in 'a given tooth formation stage' between the two studies. In addition, in 30/38 comparisons for boys and 25/35 comparisons for girls, differences in the mean age in 'a specific tooth formation stage' were less than 6 months. This is in agreement with findings from a histological study, where the authors concluded that there are fewer differences and smaller ranges of variation in the timing of human

enamel formation worldwide than previously postulated from radiographic studies (Reid and Dean 2006).

Finally, like many other countries in the world, dental radiographs in Kuwait are taken as part of diagnosis and/or treatment and a randomized prospective case study with equally distributed age and gender groups would not receive ethical clearance. It would be difficult to anticipate how a larger and evenly distributed sample would have influenced the findings of this study, therefore, interpretation of results and conclusion drawn from this study should be done with caution.

Conclusion

The results suggest a difference in dental maturation, expressed by dental age, between Kuwaiti children and the French–Canadian standards with a tendency for delayed dental maturation in Kuwaiti children.

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