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Dental age estimation using Demirjian and Willems methods: Cross sectional study on children from the Former Yugoslav Republic of Macedonia

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ABSTRACT

To evaluate applicability of Demirjian and Willems methods for calculating dental age of children in the Former Yugoslav Republic of Macedonia we analyzed panoramic radiographs of 966 children (485 female and 481 male, aged 6–13 years) treated at the University and Community Dental Clinics in Skopje using four Demirjian methods and a Willems method for determining dental ages. Intra-rater and inter-rater agreement of mineralization stages were 0.86 and 0.82, respectively. All methods significantly overestimated dental age when compared to the chronological age ($p < 0.001$). In males, the lowest overestimation was shown using Willems method (0.52 ± 0.87 years), followed by Demirjian methods from 1976 using PM_1, PM_2, M_1, M_2 teeth (0.69 ± 0.92 years) and using I_2, PM_1, PM_2, M_2 teeth (0.80 ± 0.98 years). The greatest overestimation were shown using Demirjian methods using 7 teeth from 1976 (0.92 ± 0.99 years) and method from 1973 (1.06 ± 1.07 years). In females, the lowest overestimation was shown using Willems method (0.33 ± 0.83 years) than the Demirjian method using PM_1, PM_2, M_1, M_2 teeth (1.00 ± 1.01 years), following methods from 1976 using 7 teeth (1.03 ± 1.01 years) and I_2, PM_1, PM_2, M_2 teeth (1.12 ± 0.96 years). The greatest overestimation was for method from 1973 using 7 teeth (1.17 ± 0.98 years). Willems method was the most accurate while Demirjian's methods for dental age calculation are not suitable on children from the Former Yugoslav Republic of Macedonia.

1. Introduction

Teeth development in humans begins in the intrauterine period and lasts till adulthood. When compared to development of other organs, mineralizations of teeth shows the highest correlation with chronological age of young individuals. Therefore methods which evaluate it are used for both clinical and archaeological purposes [1–4]. These methods for evaluating teeth mineralization and development however differ in referenced samples and the combinations of teeth on which the estimations are based [1–6]. Generally speaking, an ideal method would have both the smallest difference between estimated dental age (DA) and chronological age (CA) and would explain most variance in the findings of tested populations (samples) [4,7,8].

In 1973 Demirjian introduced a method (Dem1973) which estimated chronological age based on developments of seven teeth from the left side of the mandible. This method was similar to that of Tanner, Whitehouse and Healy who estimated chronological age based on maturity of hands and wrists [9,10]. In 1976, Demirjian developed three more methods. First (Dem1976) was based on the same seven teeth; second (Dem1976PM_1) on 4 teeth, specifically the first premolar (PM_1), second premolar (PM_2), first molar (M_1) and second molar (M_2); and the third (Dem1976IN_2) on 4 teeth, specifically the second incisive (I_2), first premolar (PM_1), second premolar (PM_2) and second molar (M_2). In the cases where a single tooth was missing or rating was not possible, Demirjian and

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Table 1
Distribution of the panoramic radiographs of the children from the Former Yugoslav Republic of Macedonia.

Age group	Males	Females	Both
6.00–6.99	39	35	74
7.00–7.99	59	78	137
8.00–8.99	99	112	211
9.00–9.99	82	78	160
10.00–10.99	66	53	119
11.00–11.99	68	59	127
12.00–12.99	36 (1)	38 (4)	74 (5)
13.00–13.99	32 (13)	32 (27)	64 (40)
Total	481 (14)[a]	485 (31)[a]	966 (45)[a]

[a] The number in parentheses represents the number of images where completed mineralization of the root of the second molar.

Goldstein suggested creation of a separate scoring system for each combination of six remaining teeth, however, they selected two previously mentioned 4-teeth sub-systems [5]. In all four methods each tooth was scored based on its observed developmental stage, following which the sum of each tooth score are converted to maturity score according to standardized tables or 50th percentile to dental age [5,10]. Original Demirjian methods were based on so called French-Canadian standards (children), which many studies have shown to overestimate chronological age by up to over a year [11–16]. Reasons or the overestimation are attributed to different unreliable statistical procedures, manual matching of population curves, sample and scoring biases, as well as differences in environmental, habitual and nutritional characteristics of populations [11–13]. Researchers have therefore suggested that dental age estimates of chronological ages be determined for each specific population [14–17]. Although Demirjian methods published in 1976 were devised to overcome deficiencies and reliability of the Demirjian 1973 methods, modern studies still use them for evaluation and comparison with other dental age estimation methods. For example, Demirjian methods using seven teeth were tested on children in many populations, including the countries in region where the FYR Macedonia is situated [18,19], European Union [6,20–28] and in populations from India, Africa, Australia, Middle East, China and South America [14,15,17,18,29–35]. The only study which compared all four Demirjian methods and found difference among mean results was done by Flood et al. [33]. Willems proposed a new method based on Belgian children which adapted and simplified Demirjian scoring system, and which showed increased accuracy of determining chronological ages [6,8,15,28,30,36–38].

No studies so far have evaluated any of these methods on children from the Former Yugoslav Republic of Macedonia (FYR of Macedonia), which this study aimed to do.

2. Materials and methods

The approval for the study was given by the Ethical Council of the Dental Clinic at the University of Skopje. Panoramic radiographs (OPGs) of children aged 6–13 years who from 2000 to 2010 visited the University of Skopje Dental Clinic and local dental offices from the city of Skopje, FYR of Macedonia were included in the study. OPGs without accompanying childrens' full dental records, lack of birth dates and time when the OPGs were taken, as well as those of children with proven hereditary or systematic illnesses, malnutrition, or hypodontia of permanent teeth were excluded from the study.

One of the eighth developmental stages (A–H) of the seven teeth in the left mandible were evaluated by IG according to Demirjian methods of 1973 and 1976 [5,10], those of four teeth according to methods published in 1976 [5], and Willems methods based on the 2001 study [6]. Evaluations for randomly selected 60 OPGs were conducted by IG second time, following 2 weeks of initial evaluations, as well as by VA. Based on these 60 OPGs, intra- and inter-rater agreement of mineralization stages were calculated using Kappa scores and intra- and inter-rater agreement of dental age were calculated using intraclass correlation coefficient (ICC) [39]. CA of children was calculated as a difference between date of OPG and date of birth (rounded to two decimal places), with age groups based on one year increments. Five OPGs from 12 years old children and forty OPGs from 13 years olds were excluded due to finished mineralizations of all required teeth. In total 966 OPGs of children aged 6.05–13.96 years were included in the study (Table 1). Genders difference between mean ages were tested using independent-samples *t*-test, with paired samples *t*-test for differences between DA and CA. Mean difference between dental ages and chronological ages (DA-CA) of all five methods were compared using repeated-measures ANOVA and post hoc tests with the Bonferrioni adjustment. Mean absolute error (MAE) of time distance from real age of children was also calculated. Statistical significance was set to 0.05. For data management and statistical analysis we used MS Excel 2003 (Microsoft Office 2003, Microsoft, and Redmond, WA) and SPSS Statistics 17.0 for Windows (SPSS Inc., Chicago, IL).

3. Results

There were no differences in the mean ages of males and females in our sample (9.70 ± 1.94 vs. 9.59 ± 1.93, $p = 0.376$, Table 1). Intra-rater agreement for stages of dental mineralization of 60 randomly selected OPGs varied from 0.70 for the first molar to 0.94 for the second incisor, while that of inter-rater agreement of the same sample varied from 0.70 for the first and second molar to 0.96 for the second incisor (Table 2). ICC of intra and inter raters agreement of dental age ranged between 0.841 for Dem1976Pm1 method for inter-rater to 0.978 for Dem1976 method for intra-rater agreement (Table 2). Mean ages for mineralization stages for all seven teeth for the full sample ($n = 966$) are shown in Table 3. For all four Demirjian methods, as well as Willems method (excluding females aged 9 and 10) we found significant differences between the chronological and dental ages, with mean differences between DA and CA and overestimation of DA for both genders being highest for Dem1973 (1.07 ± 0.96) and lowest for Willems method (0.42 ± 0.86) (Table 4).

Table 2
Intra and inter rater agreement of Demirjian's stages of tooth mineralization with inter class coefficients (ICC) of dental age for 60 randomly selected OPGs from FYR Macedonia children.

	Kappa scores							
Tooth	1st incisor (I1)	2nd incisor (I2)	Canines (C)	1st premolar (PM1)	2nd premolar (PM2)	1st molar (M1)	2nd molar (M2)	Mean
Intra-rater	0.92	0.94	0.91	0.88	0.88	0.71	0.80	0.86
Inter-rated	0.87	0.96	0.89	0.82	0.79	0.70	0.70	0.82

	ICC (95%CI)				
Dental age	Dem1973	Dem1976	Dem1976Pm1	Dem1976In2	Willems2001
Intra-rater	0.974 (0.955, 0.985)	0.978 (0.963, 0.987)	0.969 (0.947, 0.982)	0.973 (0.954, 0.984)	0.972 (0.952, 0.984)
Inter-rater	0.886 (0.811, 0.932)	0.887 (0.813, 0.933)	0.841 (0.742, 0.904)	0.862 (0.775, 0.918)	0.938 (0.895, 0.963)