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# Applicability of Demirjian's four methods and Willems method for age estimation in a sample of Turkish children

Nursel Akkaya [a,*], Hümeyra Özge Yilanci [b], Dinçer Göksülük [c]

[a] Department of Dentomaxillofacial Radiology, Faculty of Dentistry, Hacettepe University, 06100 Sıhhiye, Ankara, Turkey
[b] İzmir Dental Training Hospital, 35260 Konak, İzmir, Turkey
[c] Department of Biostatistics, Faculty of Medicine, Hacettepe University, 06100 Sıhhiye, Ankara, Turkey

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ABSTRACT

The aim of this study was to evaluate applicability of five dental methods including Demirjian's original, revised, four teeth, and alternate four teeth methods and Willems method for age estimation in a sample of Turkish children. Panoramic radiographs of 799 children (412 females, 387 males) aged between 2.20 and 15.99 years were examined by two observers. A repeated measures ANOVA was performed to compare dental methods among gender and age groups. All of the five methods overestimated the chronological age on the average. Among these, Willems method was found to be the most accurate method, which showed 0.07 and 0.15 years overestimation for males and females, respectively. It was followed by Demirjian's four teeth methods, revised and original methods. According to the results, Willems method can be recommended for dental age estimation of Turkish children in forensic applications.



## 1. Introduction

Age estimation is one of the important applications both for deceased and living people in Forensic sciences. Estimating chronological age is necessary for identification of criminal cases, victims of mass disasters and investigations of human remains in archeological studies. Age determination for living individuals is required to assess criminal responsibilities, which is crucial to decide whether accused individual or victim is below or above the age threshold for that criminal law. It is also frequently used for civil purposes and social issues such as school attendance, immigration, adoption, marriage and incorrect birth records [1,2].

Dental age estimation can be made using a number of methods, which are based on developmental features [3,4] or age-related changes in teeth, such as attrition, secondary dentin apposition, periodontosis, cementum apposition, root resorption, and root transparency [5,6]. Other approaches for age estimation include the evaluation of racemization of aspartic acid in dentine [7], telomere shortening in pulp DNA [8], the amount of radiocarbon in enamel [9].

Dental development is widely used as an indicator of chronological age in sub-adults. Dental age estimation methods and other methods including bone development, secondary sex characters, stature or weight can be applied separately or together to estimate a minor's age [3,10]. Since dental development is less affected by environmental factors in comparison with the growth of the skeletal, somatic or sexual systems, dental age estimation methods are more reliable and accurate than the other methods, especially for children under 10 years old [1,11,12].

Several methods have been introduced for dental age estimation based on radiographic tooth development [1]. Demirjian dental development method [3,13] is one of the most commonly used techniques for age estimation in children [14].

Demirjian et al. [3,13] established four methods for dental age estimation based on eight calcification stages from calcification of the cusps to closure of the apex. The original Demirjian technique includes seven left mandibular teeth except for third molar. Disadvantage of this method is to require the existence of all seven teeth. In case of bilaterally absence of teeth, the method cannot be used. In 1976, Demirjian and Goldstein [13] presented three more methods: revised seven teeth method; four teeth method ($M_2$, $M_1$, $PM_2$, $PM_1$); and alternate four teeth method ($M_2$, $PM_2$, $PM_1$, $I_1$). In these methods, each tooth is rated based on its developmental stage, each stage is allocated a score, then sum of each score (maturity score) are converted to dental age by using standardized tables or percentile curves (50th percentile) for each gender separately.

* Corresponding author at: Hacettepe Üniversitesi Diş Hekimliği Fakültesi, Ağız, Diş ve Çene Radyolojisi Anabilim Dalı, 06100 Sıhhiye, Ankara, Turkey. Tel.: +90 3123052205; fax: +90 3123113741.

*E-mail addresses:* ynursel@hacettepe.edu.tr (N. Akkaya), ozgeerbudak@yahoo.com (H.Özge Yilanci), dincer.goksuluk@hacettepe.edu.tr (D. Göksülük).

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Demirjian method is based on the radiographs of French–Canadian children. The technique has been widely applied in other populations, but revealed general overestimation in most of the studies [15–26]. Several studies have pointed out that generation of new standard curves, which are specific to the population, is required [20,21,23,27,28]. Based on Demirjian scoring system, Willems et al. [29] proposed a new method that includes new tables for each sex and age score, which directly expresses in years. The adapted method was validated and resulted in more accurate dental age estimations in a Belgian Caucasian population.

Previous studies generally used Demirjian's seven teeth methods [16–26]. Also in a few researches, Demirjian's four teeth methods were investigated [15,30,31]. In Turkish population, previous studies showed overestimation of the chronological age, which were conducted based on seven teeth methods of Demirjian [27,32–35]. Demirjian's four teeth methods and Willems method have not been tested before in Turkish children and adolescents. Therefore, the aim of this study was to evaluate the applicability of Demirjian's four methods; original, revised, four teeth and alternate four teeth methods, and Willems method for age estimation in a sample of Turkish children.

## 2. Materials and methods

Investigational protocol described herein was approved by Non-Interventional Clinical Researches Ethics Board at Hacettepe University. The records of the patients in the age group of 2–16 years, who visited the Department of Dentomaxillofacial Radiology, Faculty of Dentistry, Hacettepe University between 2011 and 2012, were reviewed. Panoramic radiographs of the patients without any obvious developmental anomalies were selected from the patients' records. The radiographs that were unclear and that bilaterally showed teeth with gross pathology, root canal treatment, shape and position anomalies and bilateral absence of the teeth in the mandibula were excluded. The study sample comprised of digital panoramic radiographs from a total of 799 individuals (412 females, 387 males) aged 2.20–15.99 years.

The chronological age of each subject was calculated by subtracting the date of the panoramic examination from the date of birth in decimal system.

For all five methods (A: Demirjian's original method, B: Demirjian's revised method, C: Demirjian's four teeth method and D: Demirjian's alternate four teeth method, and E: Willems method), each of the seven left permanent teeth of the mandible was assessed, and maturity scores were determined according to developmental criteria (A–H) by two observers. The right permanent teeth were evaluated when the left side was unsuitable for the evaluation. Demirjian's sex-specific numerical scores assigned to each tooth, and they were summed up to obtain an overall maturity score, for four methods separately. These scores were subsequently converted into a dental age using published conversion tables for original method and maturity percentile curves at the 50th percentile for the other three methods. For Willems method, adapted maturity scores of seven teeth were summed up and directly obtained dental age.

Before analyzing data, inter and intra-observer agreement was evaluated via Cohen's Kappa statistic to ensure that there was no significant measurement error. To evaluate intra-observer reliability, 71 radiographs were randomly selected from the different age groups and re-examined six months after the initial scoring by two observers separately. Similarly, randomly selected 94 panoramic radiographs, seven teeth for each, were examined to evaluate inter-observer reliability. To compare dental methods among gender and age groups, a repeated measures ANOVA was performed on age differences, i.e. residuals, which is the magnitude of difference between estimated age and chronological age. The response variable was symmetrically distributed among comparison groups, however; statistical tests rejected normality as a result of large sample size [36,37]. Previous studies showed that ANOVA is robust to moderate departures from normality and can be used when sample size is large enough [38,39]. Pairwise comparisons between methods were also provided.

For each tooth, the amount of kappa was estimated above 0.7. The overall agreement, which was estimated from 658 different evaluations within 94 radiographs for each tooth, was obtained as 0.824. Intra-observer agreement values were 0.950 and 0.878. Table 1 shows that from both inter and intra-observer results, the agreement of measurements was found to be almost perfect according to the categorization of kappa statistic proposed by Fleiss [40]. Although the measuring bias was highly decreased, there still existed imbalanced structures within subgroups. As expected, the number of observations within younger subsets was extremely low. Therefore, age interval 2.99–5.99 was collected to a single group and introduced into ANOVA as <5.99.

## 3. Results

Gender and age distributions of sample are presented in Table 2. Table 3 gives descriptive statistics for age residuals of each method independent from age groups. Willems method (E) provided the best result for both males and females. This result can be graphically seen from Fig. 1.

All methods overestimated the chronological age and the amount of overestimation was slightly higher for females (Fig. 1). However, the performance of each method was found to be different for changing age groups according to ANOVA results given in Table 4.

The results of repeated measures ANOVA showed that higher order interactions were significant for both within and between subject effects. Hence, we can conclude that each method gave different results for each gender and age groups (Fig. 2). For patients aged below 5.99, each method gave almost similar results for females and males whereas there were differences among methods within gender.

We also demonstrated pairwise comparisons in Table 4. Since Willem's method was found to be more accurate than Demirjian's four methods, only the pairwise comparisons versus Willem's method with false discovery rate (FDR) adjusted $p$-values were given in Table 5.

For females, Willems method was significantly diverse from Demirjian's methods at all ages. However, for males, Demirjian's four teeth (C) and alternate four teeth methods (D) mostly gave similar results with Willem's method (E).

**Table 1**
Inter/intra-observer agreement values.

| Tooth No. | N | Inter-observer | | N | Intra-observer | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Observer 1 | | Observer 2 | |
| | | Kappa | $p$ | | Kappa | $p$ | Kappa | $p$ |
| $I_1$ | 94 | 0.890 | <0.001 | 71 | 0.965 | <0.001 | 0.888 | <0.001 |
| $I_2$ | | 0.915 | | | 0.862 | | 0.863 | |
| C | | 0.708 | | | 0.940 | | 0.856 | |
| $PM_1$ | | 0.761 | | | 0.926 | | 0.829 | |
| $PM_2$ | | 0.697 | | | 0.982 | | 0.847 | |
| $M_1$ | | 0.910 | | | 0.977 | | 0.896 | |
| $M_2$ | | 0.812 | | | 0.930 | | 0.915 | |
| Total | 658 | 0.824 | <0.001 | 497 | 0.950 | <0.001 | 0.878 | <0.001 |