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Radiographic evaluation of third-molar development in relation to the chronological age of Turkish children in the southwest eastern Anatolia region

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ABSTRACT

To study the chronological age of third-molar mineralisation of Turkish children from the southwest Eastern Anatolia region, the Demirjian staging method was used to determine the stage of the mineralisation of four third molars (18, 28, 38 and 48) and to compare third-molar development by sex and age with the results of previous studies. The study comprised 832 Turkish children from the southwest Eastern Anatolia region aged 6–16 years based on radiological evidence from digital orthopantomograms. The mean age of the 832 patients was 11.03 ± 1.98 years, with 424 males (mean age, 10.97 ± 1.97) and 408 females (mean age, 11.09 ± 2.00). The orthopantomograms were scored by two observers. The Wilcoxon matched-pairs signed-rank test used to assess intra- and inter-observer assessment revealed strong agreement between both observers' measurements. Statistical analysis of the association between sex and age was performed with the Mann–Whitney *U*-test and the Wilcoxon test. Regression analysis was performed to obtain regression formulae for calculating the dental and the chronological age. The statistical analysis showed a strong correlation between age and third-molar development in males ($R^2 = 0.61$) and females ($R^2 = 0.63$). New equations (age = 7.49 + 0.69, development stage (DS) 38 + 0.70, DS18) were derived for estimation of the chronological age. The results showed that there was no significant difference in mineralisation between 18 and 28 and 38 and 48 in males or females. For both sexes, the dental age was lower than the chronological age. Males reached the developmental stages earlier than females. In the whole population, the boys' and the girls' dental ages were 0.84 years and 0.16 years earlier, respectively, than their chronological ages. The use of third-molar teeth as a developmental marker is suitable, particularly when comparing the obtained standard deviation with other skeletal-age calculation techniques.

In recent years, the forensic age determination of living people has become increasingly important because of its application to unidentified cadavers and human remains, as well as remains lacking documentation of age. Many skeletal indicators for forensic age estimation of youth exist, including hand–wrist examination, diaphysis–epiphysis fusion, cervical vertebrae assessment, fusion of cranial sutures and changes in secondary sex characteristics. All these methods have advantages and disadvantages and are more or less inaccurate, especially during the early years of life [1,2].

Teeth provide helpful information for age estimation. For example, observing dentition stages in children yields highly accurate age assessments. However, this accuracy decreases as a child's dental development nears completion [3]. Two methods are used to estimate the age of juveniles: morphological examination of skeletal features and radiological examination of the development of the third molars [4]. The radiographic assessment of third-molar mineralisation serves as a particularly important method for forensic age estimation. Additionally, the third molar possesses a unique advantage over other teeth because its development tends to continue over a longer period and until a later age [2]. Although many studies have evaluated the usefulness of third-molar mineralisation as a reliable indicator of age estimation in different populations [2,5–19], the influence of geographic origin on the mineralisation rate has not been sufficiently analysed. Previous studies have shown that dental development varies slightly among dissimilar populations, making population-specific studies necessary, and studies of different ethnic populations have yielded varied age estimations [2,18–20].

A review of the literature revealed little research on age estimation in the Turkish population. At the start of this study, we hypothesised that Turkish children from the southwest Eastern

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Anatolia region might have a different pattern of third-molar maturation compared to children in the countries from which the standards were derived.

Therefore, this study assessed chronological-age estimates based on developmental stages of Turkish children from southwest Eastern Anatolia and compared them to estimates based on third-molar development by sex and age and to the results of previous studies on other ethnic populations [2].

1. Materials and methods

Orthopantomograms were performed on 832 Turkish children ranging from 6 to 16 years in southwest Eastern Anatolia. The mean age was 11.03 ± 1.98 years, including 424 males (mean age, 10.97 ± 1.97) and 408 females (mean age, 11.09 ± 2.00). All the orthopantomograms were taken with a digital orthopantomogram X-ray machine (PlanmecaProline XC 2009; Helsinki, Finland) at the Inonu University, Faculty of Dentistry and Department of Orthodontics in Malatya, Turkey. The radiological examinations were performed from January 2010 to June 2011. The patients' names, gender and birth dates were recorded for each radiograph.

Selection criteria for the patients included:

(1) Turkish child with a Turkish parent,
(2) well nourished and free from any known serious illness,
(3) normal growth and dental development, with no impactions, congenital absence or teeth transposition and
(4) having all third molars.

Exclusion criteria included:

(1) image deformity affecting the third molars, hypodontia or gross pathology and
(2) orthopantomogram showing obvious dental pathology, such as a dentigerous cyst associated with a third molar.

All the assessments of the orthopantomograms were performed on an ASUS VH222D medical liquid crystal display (LCD). The brightness of the LCD was 300 cd m^2. The evaluation and classification covered the development phase of four third molars: 18, 28, 38 and 48. Tooth mineralisation was evaluated according to the method described by Demirjian et al. [8]. The development and mineralisation of the third molars were classified into eight stages, labelled A–H (Table 1). The first four stages (A–D) showed crown calcification from the appearance of the cusp to the completion of the crown and the second four stages (E–H) showed root formations from initial radicular bifurcation to apical closing.

1.1. Statistical analyses

Descriptive statistics were obtained by calculating the means, standard deviations and range of the patients' chronological ages at six stages of dental development. Statistical analysis was performed with the Mann–Whitney *U*-test and the Wilcoxon test for gender and age. Regression analysis was performed to obtain regression formulae for dental-age calculation, with chronological age as the independent variable and third-molar development stages as the dependent variables. All the data were analysed using the SPSS software package (SPSS for Windows, version 10.0, Chicago, IL, USA). The statistical analyses were performed using the Student's *t*-test for independent samples of males and females.

The mineralisation stages were evaluated by two observers who did not have an established opinion about orthopantomograms. We tested the consistency of the assessments of the dental development stages by the two radiologists and the reproducibility of those results. Eight weeks after the first evaluation, 100 orthopantomograms were randomly selected. All 100 orthopantomograms were then evaluated by both observers. Four weeks after the first evaluation, these orthopantomograms were re-evaluated by the same observers.

Finally, the Wilcoxon matched-pairs signed-rank test was performed to analyse the evaluation results. $P < 0.05$ values were considered statistically significant.

Table 1
Stages of tooth calcification as described by Demirjian et al.

Stage A: Calcification of single occlusal points without fusion of different calcifications.
Stage B: Fusion of mineralisation points; the contour of the occlusal surface is recognisable.
Stage C: Enamel formation has been completed at the occlusal surface, and dentin formation has commenced. The pulp chamber is curved, and no pulp horns are visible.
Stage D: Crown formation has been completed to the level of the amelocemental junction. Root formation has commenced. The pulp horns are beginning to differentiate, but the walls of the pulp chamber remain curved.
Stage E: The root length remains shorter than the crown height. The walls of the pulp chamber are straight, and the pulp horns have become more differentiated than in the previous stage. In molars the radicular bifurcation has commenced to calcify.
Stage F: The walls of the pulp chamber now form an isosceles triangle, and the root length is equal to or greater than the crown height. In molars the bifurcation has developed sufficiently to give the roots a distinct form.
Stage G: The walls of the root canal are now parallel, but the apical end is partially open. In molars only the distal root is rated.
Stage H: The root apex is completely closed (distal root in molars). The periodontal membrane surrounding the root and apex is uniform in width throughout.

2. Results

Repeated scorings of the 100 orthopantomograms indicated significant intra- and inter-observer differences for 18 ($P < 0.05$) but no significant differences for 28, 38 and 48. Intra-observer consistency was rated at 94%, 96%, 93% and 96% for 18, 28, 38 and 48, respectively, whereas inter-observer agreement was 96%, 97%, 93% and 96% for 18, 28, 38 and 48, respectively. The agreement was evaluated using the Wilcoxon matched-pairs signed-rank tests.

The distribution of age and gender in the study is described in Table 2. The mean mineralisation ages and standard deviations for the Demirjian stages of the third molars are described in Tables 3–6. Differences in the chronological age among 18 and 28 and 38 and 48 were tested. No significant differences were found among any of these teeth for either males or females. The independent samples *t*-test was used to determine the difference between males and females.

Males reached the various stages of development earlier than females. In the whole population sample, the dental age of the boys was 0.84 years earlier than their chronological age, whereas the dental age of the girls was 0.16 years earlier than their chronological age.

Differences in the age at which molar mineralisation occurred were also compared between genders. At stages A, B, C, D and E, mineralisation of 18 in females occurred 0.26, 0.15, 0.03, 0.34 and 0.56 years earlier, respectively, than mineralisation of 18 in males at the same stages. At stages A, B, C, D and E, mineralisation of 28 in females was 0.16, 0.10, 0.02, 0.31 and 0.95 years earlier, respectively, than mineralisation of 28 in males at the same stages. At stages B, D and E, mineralisation of 38 in females was 0.09, 0.62 and 0.10 years earlier, respectively, than mineralisation of 38 in males at the same stages. However, at stages A and C, mineralisation of 38 in males was 0.33 and 0.03 years earlier, respectively, than mineralisation of 38 in females at the same stages. Mineralisation of 48 in females at stages A, B, C, D and E was 0.17, 0.15, 0.02, 0.20 and 0.12 years earlier than mineralisation of 48 in males at the same stages.

Finally, linear regression coefficients were used to assess the correlation of third-molar development with chronological age. The statistical analysis revealed a powerful correlation between age and third-molar development for males ($R^2 = 0.61$) and for

Table 2
Distribution of age and gender in the study population.

Age (years)	Male	Female	Total
6–6.9	4	2	6
7–7.9	19	22	41
8–8.9	39	41	80
9–9.9	72	57	129
10–10.9	91	68	159
11–11.9	59	68	127
12–12.9	63	67	130
13–13.9	39	50	89
14–14.9	25	21	46
15–15.9	13	12	25
Total	424	408	832

Table 3
Statistic data of chronological mineralisation age of 18.

Stage	Female					Male					*P* value
	Number	Mean	SD	Min	Max	Number	Mean	SD	Min	Max	
A	91	8.95	1.36	6	12.8	72	8.69	1.36	6	13.3	0.23
B	128	10.31	1.22	7.7	13.8	96	10.16	1.28	7.2	14.4	0.39
C	115	11.56	1.26	8.1	15	120	11.52	1.29	8.1	13.9	0.82
D	78	13.02	1.46	6.8	15	104	12.68	1.35	7.7	15	0.10
E	10	14.37	0.76	13	15	13	13.81	1.54	9.7	15	0.30
F	2	15	0	14.2	15	3	15	0	15	15	–

Table 4
Statistic data of chronological mineralisation age of 28.

Stage	Female					Male					*P* value
	Number	Mean	SD	Min	Max	Number	Mean	SD	Min	Max	
A	98	9.02	1.33	6.8	12.8	86	8.86	1.40	6	13.3	0.42
B	124	10.38	1.28	6	13.8	85	10.28	1.27	7.2	14.4	0.58
C	116	11.57	1.29	8.1	15	119	11.55	1.31	8.1	13.9	0.87
D	76	13.01	1.47	6.8	15	101	12.70	1.34	7.7	15	0.14
E	9	14.49	0.69	13	15	14	13.54	1.80	9.7	15	0.14
F	2	15	0	15	15	3	15	0	15	15	–

females (R^2 = 0.63). Regression formulae for the whole sample and for males and females separately based on the third molar were estimated. The following new equations were formulated:

Whole sample:

$$\text{Age} = 7.49 + 0.69 \times \text{Development stage(DS)} \quad 38 + 0.70 \times \text{DS18}$$

Males:

$$\text{Age} = 7.51 + 0.83 \times \text{DS18} + 0.59 \times \text{DS38}$$

In the multiple linear regression model, DS38, the constant, and the DS18 variables were statistically significant ($P < 0.001$). The R^2 coefficient was 0.61.

$$\text{Females: Age} = 7.41 + 1.23 \times \text{DS38} + 0.61 \times \text{DS18} - 0.45 \times \text{DS48}$$

DS38, DS18 ($P < 0.001$), the constant, and DS48 ($P < 0.047$) were statistically significant variables in the regression model. The R^2 coefficient was 0.63.

3. Discussion

The Study Group on Forensic Age Diagnostics [21] recommends that researchers should use a combination of several examinations to increase the accuracy of age estimations in living individuals and to improve identification of age-relevant developmental disorders. These include physical examinations, X-ray examinations of the left hand and dental examinations, including determination of the dental status and an X-ray of the dentition. Skeletal-age determination and dental-age estimation are very important methods for age estimation. The TW2 and TW3 methods developed by Tanner and Whitehouse are the clinically prevalent skeletal-age-determination methods for forensic age estimation in living individuals [22].

Table 5
Statistic data of chronological mineralisation age of 38.

Stage	Female					Male					*P* value
	Number	Mean	SD	Min	Max	Number	Mean	SD	Min	Max	
A	124	9.30	1.46	6	13.4	108	8.97	1.31	6	13.9	0.73
B	130	10.57	1.31	7.7	13.8	93	10.66	1.31	7.2	14.9	0.64
C	97	11.78	1.28	8.1	15	108	11.75	1.21	7.7	14.4	0.85
D	62	13.27	1.36	6.8	15	86	12.89	1.28	9.7	15	0.93
E	9	14.29	0.78	13	15	10	14.39	0.55	13.4	15	0.76
F	2	15	0	15	15	3	15	0	15	15	–

Table 6
Statistic data of chronological mineralisation age of 48.

Stage	Female					Male					*P* value
	Number	Mean	SD	Min	Max	Number	Mean	SD	Min	Max	
A	129	9.31	1.43	6	13.2	117	9.14	1.42	6	13.9	0.36
B	132	10.69	1.34	7.7	13.8	90	10.77	1.39	7.2	14.9	0.66
C	93	11.88	1.32	8.1	15	102	11.68	1.26	7.7	15	0.27
D	59	13.17	1.45	6.8	15	85	12.86	1.26	9.7	15	0.18
E	9	14.29	0.78	13	15	11	14.37	0.52	13.4	15	0.78
F	2	15	0	15	15	3	15	0	15	15	–

Another important method for forensic age diagnosis is dental-age estimation by assessing tooth development stages. Tooth development is an accurate measure of dental age that seems to be independent of exogenic factors such as malnutrition or disease [3,6,21,23,25].

In the literature, Kullman et al. [10] Gleiser and Hunt [26], Moorrees et al. [27], Kvaal et al. [28], Köhler et al. [29] and Paewinsky et al. [30] discuss a range of available methods for dental-age estimation based on evaluations of the chronological age of tooth mineralisation. However, studies report varied results using these methods, and some results were evaluated too subjectively to make direct comparisons possible [18]. Landa et al. [31] assessed the reproducibility and application of the regression formulae developed by Kvaal et al. [28] and Paewinsky et al. [30]. They found that the method used by Kvaal et al. cannot be applied directly to digital orthopantomograms. The differences in the age estimations obtained using the regression formulae to analyse the digital images were so great compared with the real ages that this method must be discouraged as a reliable means of estimating age based on a direct digital orthopantomogram sample.

Demirjian et al. [8] presented a different classification method, which differentiates among eight stages of root and crown development (stages A–H). Stages A, B, C and D represent crown development, whereas stages E, F, G and H represent root development. The stages proposed by Demirjian et al. [8] are defined by changes in the shape or proportions and are independent of speculative estimations of length; no metric estimations are defined. Therefore, this classification is simple and objective. Dhanjal et al. [32] assessed the validity of the common classification systems defined by Demirjian et al. [8], Kullman et al. [10], Gleiser and Hunt [26], Gustafson and Koch [33] and Harris and Nortje [34]. They found that the most accurate results were obtained with the staging system of Demirjian et al. Therefore, we selected this method for the present study.

Uzamis et al. [35] studied 400 panoramic radiographs of Turkish children and adolescents (188 female and 212 male subjects). They reported that the mandibular third molars start to calcify between the age of 7 and 8 years and the maxillary third molars start to calcify around the age of 8 years. In addition, Orhan et al. [24] and Uysal et al. [2] obtained similar findings in a Turkish population. In accordance with these findings, this study used the same minimum age.

As previous studies that investigated sex differences yielded varied results, we studied the mean ages of each dental stage for male and female patients in a Turkish population. We did not find statistically significant differences in third-molar development between the male and female subjects, but the differences indicated that third-molar genesis was attained 8.16 months earlier in males than in females. This finding is consistent with previous studies, which reported that the mean age at some development stages was lower in males than in females in the following populations: Belgian whites [36], Hispanics [13], Swedes [3] and Spaniards [14].

A review of the literature revealed only a few studies that have been carried out on Turkish populations. Willershausen et al. [38] examined 1202 orthopantomograms of 602 female and 600 male probands of central and southern European origin from Turkey and other unspecified countries. This study analysed the mineralisation stages of third molars using the Kullman [3] method and found no reliable information on possible ethnic differences because the sample of patients was too small.

Orhan et al. [24] determined that members of the Turkish population reach stage D at a mean age of 14.9 years. Our findings indicate that Turkish people reach stage D at a mean age of 13.1 years for males and 12.8 years for females, consistent with the results of studies of other Turkish samples [2]. Sisman et al. [2] studied third molar development in 900 Turkish subjects and found that third-molar genesis was attained earlier in males than in females. Statistical analysis showed a strong correlation between age and third-molar development in both males and females in the present study.

Olze et al. [19] evaluated the chronological age of third-molar mineralisation in 1615 Japanese subjects. They observed no statistically significant difference in the chronology of third-molar mineralisation between the maxilla and the mandible and between the left and right sides. A comparison of the two genders also did not yield a significant difference.

Prieto et al. [14] studied third molar mineralisation in 1054 Spaniards aged 14–21 years. They found that the development of the third molars in males took place earlier than in females. They also found no difference between the left and right sides. In addition, they reported that third-molar maturity takes place earlier in Spanish populations than in French-Canadian, Scandinavian, American, German, Japanese and South African populations. The root development in this Spanish population was similar to that of American Hispanics. This present study found similar results.

The result showing the probability of an individual being younger than 18 years at stages A, B, C, D and E is consistent with previous studies [11,13,14,38]. When our results are compared to those of other studies, all stages of third-molar development among the white Turkish population are found to occur at an earlier age than in Japanese [19,25,39], South African [12], German [18] and Spanish [7,14] populations [2].

In this study, regardless of gender, the chronological age of third-molar mineralisation in Turkish children from southwest Eastern Anatolia was the same on both the left and right sides of the mouth. No difference was found between the two sides in the same-gender group. This result is similar to that found by other researchers in studies of different ethnic populations [14].

The mean absolute difference between the dental age and the chronological age showed the highest precision. The development stage of the third molar showed a nearly linear relation to the age of the subjects, whether male or female. The latter develops a little later, as previously stated [36–39]. The statistical analysis revealed a stronger correlation for males ($R^2 = 0.61$) than for females ($R^2 = 0.63$). These results are in agreement with studies of other ethnic groups [7,12,14,18,19].

In summary, the chronological age of third molar mineralisation warrants further study to determine and analyse the real difference among different geographic groups to enable more accurate age estimations.

4. Conclusions

(1) Nearly all stages of third-molar development among Turkish children from the southwest Eastern Anatolia region occur at an earlier age than in other populations.
(2) In single-gender groups of Turkish children from this region, the mineralisation ages between the two sides in the upper and lower jaw are similar.
(3) The chronology of the mean age and the complete time to third-molar mineralisation were earlier in females than in males.
(4) The use of third molars as a developmental marker is appropriate, especially when comparing the obtained standard deviation with other skeletal-age-calculation techniques based, for example, on hand–wrist examinations or examinations of long bones.

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