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Original Article

Age estimation based on the third molar development in a Turkish population: A radiographic study

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Abstract

Aim: The aim of this study was to determine the maturation levels of the third molar teeth of individuals aged between 7 and 25 years, to evaluate the relationship between dental maturation, chronological age and gender, and to test the reliability of this formula by developing regression formulas based on dental maturation data of the third molars for age estimation in a Turkish population.

Material and Methods: In this retrospective study, digital panoramic radiographs of a total of 630 patients including 380 females and 250 males, ages 7-25 years were used. The dental maturation of the third molars on the panoramic radiographs was evaluated with the modified Demirjian's classification system. The descriptive statistics, Cohen's Kappa, Kolmogorov-Smirnov, Kruskal Wallis, Chi-Square, Mann-Whitney U, Wilcoxon, Spearman Correlation and Linear regression tests were used for statistical analysis.

Results: The mean chronological age (CA) was 14.38±2.51 years, with a median age of 14.00 years. Mann-Whitney U test showed that there was no statistically significant difference between the mean CA for females and males (p = 0.968). The mean age difference between the estimated dental age (DA) and CA for females and males was 0.002 and -0.004 years, respectively. This was found not to be statistically significant according to Wilcoxon-signed ranks test (p=0.541).

Conclusion: According to the results of this study, the use of third molars as a developmental marker is appropriate. There were no significant differences in third molar development between genders.

Keywords: Age estimation; dental age; Demirjian; maturation; third molar.

INTRODUCTION

The forensic age determination is one of the most important identifying features not only for dead persons but also for living individuals to assess whether a child has attained the age of criminal responsibility, in scenarios involving rape, kidnapping or marriage, in premature births, adoption procedures, pediatric endocrine diseases and orthodontic malocclusion, as well as in circumstances in which the birth certificate is not available or the records are suspicion (1-3). Additionally, because of the fact that immigrants and refugees in some countries may not have valid identification documents, the need of age estimation is also rising (4).

Presently, many ways have been devised to estimate chronological age such as a physical examination, radiographs of the left hand, and dental assessment from panoramic radiographs (5). The combine of these ways gives the excellent result. Skeletal development is highly influenced by, whereas tooth development is more affected by genetic factors (6). In addition, teeth are the strongest structures in the human body which are protected by the soft and hard tissues of the face, and are highly resistant to external factors, such as decomposition processes and extreme temperatures (7). Dental development can give an accurate measure of infant and fetal age (8). Hence, teeth givemore reliable results compared to the skeletal development for age estimation (9). Dental maturity, stated as dental age (DA), is considered superior owing to its lower variability, the ease of the procedure, and especially when the availability of other evidence/remains is scarce.

Radiographic evaluation of the development of third molars serves as a particularly important method for the determination of age from a forensic point of view. In addition, the third molars have a unique advantage over

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other teeth because of their development tends to last for a longer period of time (9). Although many studies have evaluated the usefulness of third molar mineralization as a reliable indicator of age estimation in different populations (2,10,11), the effect of geographic origin on the mineralization rate has not been sufficiently analyzed. Previous studies have shown that tooth development varies in different populations and requires population-specific studies. Studies of different ethnic populations gave different age estimates (2,3,12). In this context, the aim of this study was to determine the maturation levels of the third molar teeth of individuals aged between 7 and 25 years, to evaluate the relationship between dental maturation, chronological age and gender, and to test the reliability of this formula by developing regression formulae based on dental maturation data of the third molars for age estimation in a Turkish population.

MATERIAL and METHODS

This study was approved by the Ethical Committee of the Faculty of Dentistry, Necmettin Erbakan University, Turkey. In this study, digital panoramic radiographs of a total of630 patients including 380 female and 250 male, ages 7-25 years were used. This study was a retrospective study of digital panoramic radiographs produced using the Morita Veraviewepocs 3D R100-P (J Morita MFG Corp., Kyoto, Japan) machines which operated at 65 kVp and 5 mA, 14.8 seconds rotation time. The selected radiographs were obtained from the patients' radiographic databases at the Faculty of Dentistry, Necmettin Erbakan University, Turkey. The patients' demographic data, including patients' names, sexes, dates of birth, and the dates of the radiographs, were recorded confidentially. Radiographs with any permanent tooth deficiency, dental development disorders, and any lesions in the third molar region were excluded from the study.

All panoramic radiographs were obtained at 300 DPI (dots per inch) resolutionsusing a charged coupled device direct radiography system. For each patient, an evaluation page recorded age and gender. Panoramic images were exported in tagged image file format (TIFF) and coding was performed so that gender and age could not be determined by observers during the assessment. All radiographs were examined twice with one month interval by the same observer with eight years of experience (G.M.) in a dark room and in the same computer (Intel® Xeon® i5, 2.5 GHz; NVIDIA quadro 2000; 1366 x 768 pixels screen resolution, 4 GB memory, Microsoft Windows 7 operating system).The second observer (S.O.) was evaluated the 60 radiographs for inter-observer reliability.

Each patient's age was determined on the basis of the difference between the date of birth and the date of the X-ray. The dental maturation of the third molars on the panoramic radiographs was evaluated with the modified Demirjian's classification system (12), as shown in Figure 1. The third molar was scored"1"to"9,"depending on the stage of calcification. For statistical computations, stages were assigned a numeric value where stage 0 = 1, stage A = 2, stage B = 3, stage C = 4, stage D = 5, stage E = 6, stage F = 7, stage G = 8 and stage H = 9. These categories are based on the amount of crown and root formation as follows:

1. Cyrpt outline visible. No calcification (Stage 0)
2. Beginning of crown formation until it's completion up to cement enamel junction (Stage A, B, C),
3. Beginning of root formation until root length is equal to crown height (Stage D, E),
4. Root length longer than crown height until completion of root formation, apical foramen still open (Stage F, G),
5. Apical foramen is closed (stage H).

Examination and classification covered the development phase of the third left mandibular molar and, when not present, the contralateral molar was considered.

Statistical Analysis

The overall analysis was conducted with the SPSS statistical software, version 21.0 (SPSS Inc, Chicago, IL, USA) at the 5% level of significance. The descriptive statistics, Cohen's Kappa, Kolmogorov-Smirnov, Kruskal Wallis, Chi-Square, Mann-Whitney U, Wilcoxon, Spearman Correlation and Linear regression tests were used for statistical analysis.

RESULTS

The intra-observer and inter-observer agreements were excellent, with Kappa values equal to 0.91 and 0.93, respectively. A total of 628 panoramic radiographs were analyzed, made up of 378 (60.2%) females and 250 males (39.8%). The mean chronological age (CA) was 14.38 ±2.51 years, with a median age of 14.00 years. The mean age for females and males was 14.39±2.51 and 14.36±2.51 years, respectively. Mann-Whitney U test showed that there was no statistically significant difference between the mean CA for females and males (p = 0.968).

Our results show that the mean values of the CA in the initial cusp formation stage (score 2) were 9 years old in females (Table 1) and 10 years old in males (Table 2). The mean values of the CA in the completed crown formation stage (score 5) were 8 years old in both genders (Table 1 and 2). Moreover, the mean values of the CA in the apical foramen is closed stage (score 9) were 19.71 years old in females and 20.00 years old in males (Table 3). The most frequently observed stages for the third molar for both genders were stage 4 and 5 (Table 1 and 2).

A statistically significant difference between CA and dental maturation levels was observed ($p < 0.01$) for both genders (Table 1 and 2). There was no statistically significant difference in dental maturation levels according to sex ($p > 0.05$ Table 4). Linear regression coefficients are provided to assess the correlation of third-molar development and CA. Statistical analysis showed a strong correlation between age and third-molar development for males ($r^2 = .73$ $p < 0.01$) and for females ($r^2 = .74$ $p < 0.01$). Regression formulas for whole sample and males and females separately, based on the number of third-molar teeth present, were estimated. The following are new

equations derived in the current study:

Whole Sample: Age = 10.00±0.906 (Dental maturation level)

Females: Age = 09.59±0.989 (Dental maturation level)

Males: Age = 10.50±0.802 (Dental maturation level)

In order to test the reliability of our results, we determined the DA from this formula which we obtained by using dental maturation levels. For finding the accuracies, the mean absolute error of residuals (MAE) was calculated by subtracting the CA from the DA. The positive results indicate an overestimation and negative results indicate an underestimation. The mean overall DA was found to be 14.43±1.89 years. The overall median of the estimated DA was 14.49 years, while the minimum and maximum DA was 10.58 years and 18.40 years, respectively. The means of the estimated DA for females and males were14.48±1.81 and 14.36±2.00 years, respectively. Mann- Whitney U test revealed that the difference between the mean DA for females and males was not statistically significant (p=0.417). Median DA for both genders was found to be 14.49 years. The minimum and maximum of the estimated DA was 10.58 years and 18.40 years for both genders. The mean age difference between the estimated DA and CA for females and males was 0.002 and -0.004 years, respectively (Table 5). This was found not to be statistically significant according to Wilcoxon-signed ranks test (p=0.541)

Table 1. The distribution of dental maturity stages according to age in females

		Demirjian's dental maturation										
		0	1	2	3	4	5	6	7	8	Total	p value
Age	7.00	1	0	0	0	0	0	0	0	0		0.000
	8.00	1	0	0	0	0	1	0	0	0	2	
	9.00	4	2	0	0	0	0	0	0	0	6	
	10.00	3	3	1	2	0	0	0	0	0	9	
	11.00	2	4	1	6	4	0	0	0	0	17	
	12.00	2	5	5	21	18	1	1	0	0	53	
	13.00	6	4	1	22	25	3	0	0	0	61	
	14.00	3	4	0	10	24	7	2	0	0	50	
	15.00	2	1	4	2	24	17	7	0	0	57	
	16.00	1	0	0	1	15	13	12	4	0	46	
	17.00	0	0	0	0	8	12	9	8	1	38	
	18.00	0	0	0	0	2	6	7	5	1	21	
	19.00	0	0	0	0	0	0	1	5	1	7	
	20.00	0	0	0	0	0	0	0	2	2	4	
	21.00	0	0	0	0	0	1	1	1	1	4	
	23.00	0	0	0	0	0	0	1	0	1	2	
Total		25	23	12	64	121	60	41	25	7	378	

Table 2. The distribution of dental maturity stages according to age in males

		Demirjian's dental maturation										
		0	1	2	3	4	5	6	7	8	Total	p value
Age	8.00	1	0	0	0	1	0	0	0	0	2	0.000
	9.00	1	1	1	0	0	0	0	0	0	3	
	10.00	4	4	1	2	1	0	0	0	0	12	
	11.00	3	2	1	5	2	0	0	0	0	13	
	12.00	3	3	3	13	1	0	0	0	0	23	
	13.00	3	1	5	15	9	5	0	0	0	38	
	14.00	4	2	2	12	16	10	2	0	0	48	
	15.00	2	0	1	6	8	8	2	0	0	27	
	16.00	2	0	0	0	6	10	7	3	1	29	
	17.00	1	0	0	1	2	8	12	11	1	36	
	18.00	0	0	0	0	2	3	3	3	0	11	
	19.00	0	0	0	0	0	0	0	3	2	5	
	21.00	0	0	0	0	0	0	0	0	1	1	
	23.00	0	0	0	0	0	0	0	0	1	1	
	25.00	0	0	0	0	0	0	0	0	1	1	
Total		24	13	14	54	48	44	26	20	7	250	

Table 2. The distribution of dental maturity stages according to age in males										
	Female					Male				
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max
Stage 0	**25**	11.72	2.42	7.00	16.00	24	12.50	2.40	8.00	17.00
Stage A	23	11.96	1.69	9.00	15.00	13	11.38	1.61	9.00	14.00
Stage B	12	12.83	1.75	10.00	15.00	14	12.43	1.60	9.00	15.00
Stage C	64	12.66	1.14	10.00	16.00	54	12.98	1.39	10.00	17.00
Stage D	121	14.06	1.72	8.00	18.00	48	14.15	1.87	8.00	18.00
Stage E	60	15.75	1.57	12.00	21.00	44	15.34	1.48	13.00	18.00
Stage F	41	16.56	1.86	12.00	23.00	26	16.46	1.07	14.00	18.00
Stage G	25	17.84	1.37	16.00	21.00	20	17.30	0.92	16.00	19.00
Stage H	7	19.71	1.98	17.00	23.00	7	20.00	3.21	16.00	25.00

*SD indicates standard deviation; Min, minimum; Max, maximum; and NS, not significant; *P .05

Table 3 The distribution of dental maturity stages according to gender					
		Gender		Total	p value
		Female	Male		
Modified Demirjian	Stage 0	25	24	49	0.053
	Stage A	23	13	36	
	Stage B	12	14	26	
	Stage C	64	54	118	
	Stage D	121	48	169	
	Stage E	60	44	104	
	Stage F	41	26	67	
	Stage G	25	20	45	
	Stage H	7	7	14	
Total		**378**	**250**	**628**	

Table 4 Mean difference values between the dental age and the chronological age using the new age prediction model in both sexes			
Gender	**n**	**Mean**	**SEP**
Female	378	0.002	0.093
Male	250	-0.004	0.098

n: number of samples, mean: mean difference value between the dental and the chronological ages, SEP: standard error of prediction

DISCUSSION

Previous studies have shown that the mineralization of third molar teeth is a process specific to the population and has not been shown to occur at the same age in each ethnic group (13-15). Therefore, it is very important to obtain population-specific reference data. Due to the lack of other reliable biomarkers in the late adolescent period, CA should be estimated from the third molar formation phase (16). In this context, this study aims to assess the DA obtained from dental maturation levels in a Turkish population and evaluate this method's accuracy in that group.

In this study, the third molars were selected for evaluation because they matched with maxillary growth and showed individual development (17). In addition, knowledge of the correlation between chronological and skeletal age and development is of great importance, since it can become the target of an impulse or initiate pathological processes during its formation (17,18). Some authors have suggested that third molar development can be used in age prediction without other biological parameters (19-21).

Various radiographic methods have been used in the literature for dental age estimation (12,13, 22-31). However, as many of these methods are based on subjective evaluations, it is not right to make a direct comparison (32, 33). In some studies, the reproducibility and applicability of these methods were found to be low (34). In many studies, Demirjian's method was used in the literature. This method has been reported to be simple, practical and objective (16). Recent studies have confirmed that the modified Demirjian's classification system performs well in terms of both the observer agreement and the correlation between the predicted and actual age (32, 33). For this reason, modified Demirjian's method was used in this study.

Studies conducted in Turkish populations indicated that start to the calcifying time of the mandibular third molar teeth was around seven and eight years of age (9,13,14). Therefore, the seven years old was selected as the minimum age limit for this study.

Consistent with our results, the literature indicates a strong correlation between the maturation stages of Demirjian and CA (10,13,19). Orhan et al.(13) examined 1134 panoramic radiographs of Turkish children and adolescents between ages 4 to 20 years (524 male, 610 male subjects). They reported that third molars reached complete crown calcification at around the age of 14 in the mandible. In another study conducted for the same population (10), it was stated that at the stage D, calcification was completed before 15 years old. These results are similar to our results. Our study ranged

from 7 to 25 years of age, so we were able to examine at what age the mandibular third molar root maturation was completed. Based on the stages of the third molar formation, individuals in stage 0, A, B, C, D, E are likely to be under 18 years of age, while an individual in stage H is more likely to be older than 18 years of age. These results indicate that the Demirjian's method can be used for age determination in judicial investigations.

In the literature, it was stated that the maturation phases of the third molar did not show a statistically significant difference according to gender (10,13,35). In our study also, no significant difference was found between the genders although third molar development occurs earlier in males than in females. This shows that gender has no effect on root-crown development. In addition, it should also be noted that the result obtained is valid for our sample.

Statistical analysis showed a strong correlation between age and third-molar development for males (r^2 =0.73 p <0.01) and for females (r^2 =0.74 p <0.01). These results are in accordance with the other studies (10,15,19,34). Orhan et al.(13) found that there was strong correlation for males (r^2 =0.57) and for females (r^2 =0.56) between age and third molar development in a Turkish population. In another study from same Turkish population, Cantekin et al.(35) analyzed 1423 panoramic radiographs between 7 and 22 years of age. They found also the same results (for males r^2 =0.57, and for females r^2 0.56) as Orhan et al.(13). Our results were stronger than theirs. These differences may be due to differences in the number and age distribution of the sample.

It has been proposed to use certain population standards to increase the accuracy of age estimates (32). Several studies used the original (1973) and modified Demirjian's methods in different populations (1976). The results varied between populations and even between gender and age groups in the same population (35-37). Olze et al.(32) stated that Japanese and South Africans were 1 or 2 years older than the Germans.

In this study, one third molar method was tested. Our results indicated that the new age prediction model provided the accurate method for age estimation in both genders with no significant differences between the CA and the DA. The MAE values were nearest to zero for both genders. This is consistent with Pavlovic et al. (37,38). This result indicated that the third molar can be used for age estimation in Turkish population. Liversidge et al.(39) stated that the MAE value was an important parameter for the accuracy of age estimation methods.

CONCLUSION

The present investigation provides representative data on mandibular third molar mineralization in the Turkish population. According to the results of this study, the use of third molars as a developmental marker is appropriate. An individual in stage H is more likely to be older than 18 years of age. There were no significant differences in third molar development between genders. There is a need for future studies will be included additional maturity indicators as an indicator in diagnosis and treatment planning in orthodontic patients and in other dental fields in order to clarify the reliability of dental maturation.

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