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Radiographic evaluation of third molar development in relation to chronological age among Turkish children and youth

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Abstract

A sharp increase in forensic age estimation of living persons has been observed in recent years. However, ethnic populations residing in different countries have been insufficiently analyzed. According to 2004 data compiled by the Essen-based Turkey Research Center, there are 3.8 million Turkish people living abroad, and 3.2 million of them reside in European Union countries. Despite the high number of Turks living abroad, little is known about third-molar development for forensic application in this population. Hence, it was considered worthwhile to determine the developmental stages of the third molar in a group of Turkish population, to assess chronological age estimation based on the developmental stages, and to compare third molar development according to sex, age and location. Orthopantomograms of 1134 Turkish patients, ages 4–20 years were examined and third-molar developmental stages were evaluated based on Demirjian's classifications. Orthopantomograms were scored by two different observers, and Wilcoxon matched-pairs signed-ranks test used to test intra- and inter-observer reliability revealed a strong agreement between both intra- and inter-observer measurements. Linear regression analysis was performed to correlate third-molar development and chronological age, and further statistical analysis was performed to determine the relation between sex, age and location. Results showed a strong linear correlation between age and molar development (males: $r^2 = 0.57$; females: $r^2 = 0.56$). Mineralizations of left and right third molars were compared using Wilcoxon tests, and no statistical differences were found. No significant differences were found in third-molar development between males and females. Mandibular third molar crypt formation was observed in 2.4% of patients at age seven and maxillary third molar crypt formation was observed in 1.3% of patients at age seven. A strong correlation was found between third-molar development and chronological age. Among the Turkish population, third molar crypt formation is observable at as early as 7 years in both the mandible and maxilla. Agenesis can be determined conclusively if no radiolucent bud is present by age 14.

Keywords: Forensic odontology; Dental age; Tooth formation; Third molar; Dental age estimation

1. Introduction

Forensic age estimation is one of the key research areas in the field of forensic medicine [1–18]. In general, morphological and radiological examinations of third molars comprise part of orthodontic, pedodontic and oral surgical treatments, providing clinicians with valuable information [3,10,12,13,19]. From a forensic odontologistic perspective, sufficiently precise and reliable determination of age using third-molar mineralization is crucially important because it has been one of the parameters proposed to aid in determining the age of unidentified cadavers and human remains as well as the age of living persons for purposes of differentiation between juvenile and adult status in criminal law cases [2–7,11] to determine whether a suspect without valid identification documents has reached the age of criminal responsibility and whether general criminal law in force for adults is to be applied. In many European countries, the legally relevant age thresholds range from 14 to 18 years of age [20].

Since the early 1960s there has been a continuous migration of Turkish citizens to EU countries, especially Germany. In recent years, economic globalization and European integration have led to an increase in cross-border migration [21]. As a result, the Turkish population abroad increased from 600,000 in 1972 to 3,800,000 million in 2004 [22]. Moreover, studies have predicted a continuing flow

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Table 1
Distribution of age and sex in the study population

Age (years)	Male	Female	Total
4	24	15	39
5	21	15	36
6	19	21	40
7	41	29	70
8	35	39	74
9	45	45	90
10	57	51	108
11	33	43	76
12	46	53	99
13	37	57	94
14	43	52	95
15	40	31	71
16	23	45	68
17	13	30	43
18	7	21	28
19	13	22	35
20	27	41	68
Total	524	610	1134

of between 1.3 and 2.7 million migrants from Turkey to various countries, especially those within the EU, up until 2030 [23,24]. Despite the high number of Turks living abroad, little is known about third-molar development of the Turkish population that would have forensic application in aiding in the determination of maturity parameter variations applicable to this population. Hence, it was considered worthwhile to determine third-molar developmental stages in a Turkish sample population, to assess chronological age estimation based on developmental stages and to compare third-molar development by sex, age and location.

2. Material and methods

In this retrospective study, orthopantomograms of 1134 Turkish Caucasian individuals with known chronological age and gender were selected. Of these, 524 were male and 610 were female, and their ages ranged from 4 to 20 years. Both parents of all the subjects were of Turkish Caucasian origin and had Turkish nationality. The radiographs used were taken from patient files of the Faculty of Dentistry, Department of Oral Diagnosis and Radiology of the Ankara University, Ankara, Turkey for the period from 1996 to 2005. Table 1 shows the distribution of orthopantomograms by gender and age. The criteria for inclusion in the sample were the availability in their clinical records of an orthopantomography of adequate quality, and no history of medical or surgical disease that could affect the presence and development of third molars. Exclusion criteria were; image deformity affecting third molar visualization, orthopantomograms showing obvious dental pathology. Radiographs meeting these selection criteria were evaluated using the formation stages described by Demirjian et al. (from Stages "A" to "H") [18] with two modifications. Stage 0 was indicating the case of absence and Stage 1 was indicating the radiolucent bud, prior to calcification (Fig. 1). Radiographs of adequate quality were evaluated using a magnifying glass on a standard viewing box in a darkened room for improved visualization. The scores were determined by two observers (an oral and maxillofacial radiologist and a pediatric dentist) who had previously not established agreement concerning reference orthopantomographs on the classification of the teeth. Thus, individual differences in the examination were included intentionally in order to evaluate the variation between independent observers.

To assess reliability, 100 randomly selected radiographs were re-examined 2 months after the initial examination by the same observers, and inter- and intra-observer agreement was determined using the Wilcoxon matched-pairs signed-ranks test. Statistical analysis was performed using the Mann–Whitney *U*-test and Wilcoxon test between gender, location and age. Multiple regression analysis was performed to determine the relation between tooth development and chronological age. Statistical analysis was performed using the SPSS 11.0 package (SPSS Inc., Chicago, IL) for Windows.

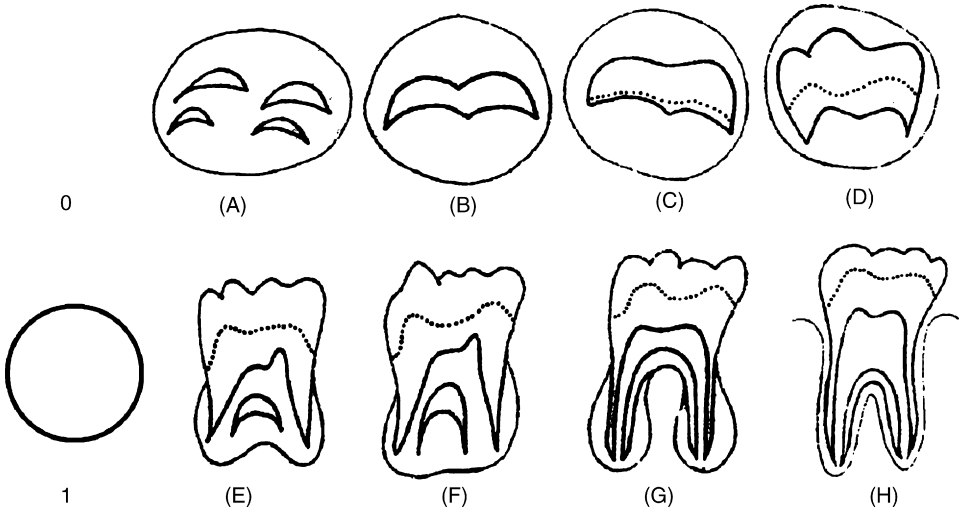

Fig. 1. Schematic drawings of the developmental stages of third molars (modified from Demirjian et al. [34]).

Table 2
Distribution of examined third molars in both jaws including all developmental stages

	Tooth				
	Number	18	28	38	48
Male	524 (100%)	356 (67.9%)	369 (70.4%)	398 (76.0%)	399 (76.1%)
Female	610 (100%)	397 (65.1%)	434 (70.1%)	451 (74.0%)	456 (74.6%)
Total	1134 (100%)	753 (66.4%)	803 (70.8%)	849 (74.8%)	855 (75.3%)

3. Results

Repeated scorings of a sub-sample of 100 radiographs indicated no significant intra- or inter-observer differences ($p > 0.05$). Intra-observer consistency was rated at 95%, whereas inter-observer agreement was 92%. Out of a total sample population of 1134 patients, 46.21% ($n = 524$) were male and 53.79% ($n = 610$) were female, the mean age was 11.3 ± 2.8 years and the age range from between 4 to 20 years. Table 2 shows the distribution of the different numbers of third molars detected in the sample. In most cases, either all of the third molars were radiologically evident or none of them were radiologically evident. Patients with all third molars comprised 739 (65.2%) of 1134 patients. 161 (14.2%) of the patients showed no signs of any third molar. Both mandibular third molars were observed in 839 (74.0%) patients, whereas both maxillary third molars were recorded in 625 patients (55.1%). Missing upper or lower third molars on both sides were found in 389 patients (34.3%) and 339 patients (29.9%), respectively. Table 3 shows the mean values and S.D. for each of the Demirjian stages of mineralization in relation to age and sex (Stages "0", "1", "A", and "B" were found to be insignificant).

Overall, no significant differences were found in third-molar development between males and females ($p > 0.05$), although there were slight differences at ages 8, 12 and 14. At age 8, the mandibular molars were more advanced in males than in females ($p = 0.04$). At age 12, the maxillary right molar was more advanced in females than in males ($p = 0.02$). At age 14, the left mandibular third molar was more advanced in males than in females ($p = 0.02$). No statistical differences were found between mineralization of right and left third molars when compared using Wilcoxon tests ($p > 0.05$).

According to study results, amongst the Turkish population, the first appearance of third molars bud occurs in the mandibula. Maxillary and mandibular third molar crypt formation was not observed at 6 years. Mandibular third molar crypt formation was observed in 2.4% of the patients at age 7 years, while maxillary third molar crypt formation was observed 1.3% of the patients at age 7 years. Mandibular and maxillary third molars were generally found at similar stages of development. However, when the formations were different, the maxillary third molar was commonly more advanced than the mandibular one even though there is no statistical difference between their formations. It was also seen that third molars were reached complete crown calcification at around the age of 14 in both maxilla and mandibula.

Finally, multiple regression coefficients are provided to assess the correlation of third molar development and chronological age. Statistical analysis showed a strong correlation between age and third molar development for males ($r^2 = 0.57$) and for females ($r^2 = 0.56$).

4. Discussion

Age estimation for medico-legal purposes (such as age at death, establishment of adult status, application in criminal law and other legal matters) represents a fundamental problem for which various methods have been established [10]. According to the recommendations of the international and interdisciplinary study group on forensic age estimation established for the most part by the Berlin Study Group chaired by Prof.

Table 3
Mean and standard deviation for the mineralization stages in relation to age and sex in the study population

	Male				Female			
	Tooth 18	Tooth 28	Tooth 38	Tooth 48	Tooth 18	Tooth 28	Tooth 38	Tooth 48
Stage C	13.4	14.0	13.9	13.8	14.2	14.4	14.2	14.2
	0.6	0.9	0.9	0.9	1.4	1.1	1.2	1.2
Stage D	14.8	14.8	14.5	14.5	15.2	15.4	15.2	15.1
	2.8	2.7	2.7	2.8	2.8	2.6	2.7	2.7
Stage E	15.5	15.5	15.6	16.2	16.5	16.4	16.1	16.2
	2.8	2.8	2.8	2.9	2.3	2.3	2.4	2.3
Stage F	16.8	16.7	16.9	16.8	17.2	17.4	17.0	17.0
	2.8	2.8	2.7	2.8	2.5	2.5	2.5	2.5
Stage G	17.8	17.9	17.9	17.9	18.0	17.9	17.9	18.0
	2.4	2.4	2.2	2.4	2.2	2.2	2.3	2.3
Stage H	20.2	20.1	20.1	20.0	20.1	20.0	20.0	20.0
	1.8	1.8	2.0	2.0	1.9	1.9	1.9	1.9

Gunther Geserick in 2000, every expert opinion should comprise three independent evaluations by forensic experts in the relevant disciplines, namely, a physical examination by a medical doctor, an X-ray examination of the left hand by a radiologist and a dental examination comprised of a registration of dentition status and evaluation of an orthopantomogram by a dentist [2,4,5,9,11,25]. For purposes of the latter, the eruption and mineralization of third molars represents one of the main criteria for dental age estimation.

Various methods of determining chronological and radiographical stages have been used for dental age estimation [18,26–42]. However, the results achieved on the basis of these classifications cannot be compared directly. Moreover, a distinction is made, for example, between 1/4, 1/3, 1/2 and 2/3 of the estimated future root length; this results in a rather subjective evaluation [2,4,5]. For example, age estimates based on current root length development as a percent of total expected root length are extremely subjective. Demirjian's eight-stage method [35], or a variant thereof, is one of the principal methods used to quantify the degree of maturity. Certain numerical methods, like the technique proposed by Kullman et al. [17], are also common. Demirjian's method is one of the most simple, practical, and widely employed methods [11,43], as it is comprised of clearly defined changes in shape that do not require speculative estimation. A number of scientific papers have reported on the forensic application of Demirjian's system for the establishment of degree of third-molar maturation. Recent studies have verified that Demirjian's classification system performs well in terms of both observer agreement and correlation between estimated and true age [2–5,9–11]. Thus, Demirjian's classification system was selected as the most suitable one for this study.

A study of the chronology of third-molar mineralization conducted in 2004 by Olze et al. [5] used Demirjian's classification system to examine orthopantomograms of 929 Japanese females and 686 Japanese males between the ages of 12 and 30 years. No statistical differences were found in mineralization levels based on sex or location (maxilla-mandible or left-right molars). Bolanos et al. [6] evaluated third-molar development in 786 young people between 4 and 20 years of age. According to their findings, there were no statistical differences in terms of the presence or absence of third molars by sex when comparisons were made between subjects of the same age. Moreover, crown calcification was observed to be complete at around the age of 14 and root formation complete at an average age of 18.5 years. Gunst et al. [7] evaluated 2513 orthopantomograms of patients of Belgian Caucasian origin between the ages of 15.7 and 23.3 years in an attempt to correlate chronological age and third-molar mineralization. They found that the mean age at each development stage was lower for males than for females, and that maxillary development reached completion slightly earlier than mandibular development. They also reported that the likelihood that an individual of Belgian Caucasian origin whose tooth development was complete was over the age of 18 was 96.3% for males and 95.1% for females. Prieto et al. [9] also carried out a cross-sectional study of 1054 orthopantomograms that assessed chronological age estimation based on Demirjian's stages of third-molar development. They observed no differences between left- and right-side development, but slight variations regarding age was found in their study.

In addition to the above-mentioned studies, a few comparative studies have also been conducted on third-molar mineralization. Mincer et al. [43] studied 823 U.S. citizens (80% white, 19% black) between the ages of 14.1 and 24.9 years. No significant differences were observed with regard to the chronology of third-molar mineralization by race. However, when Gorgani et al. [44] examined 229 black and 221 white U.S. citizens aged 6–14 years, they determined that third-molar crown mineralization was completed about 1 year earlier in black Americans than in white Americans. In a study with a total population of 3031, Olze et al. [4] compared the orthopantomograms of 1597 Japanese and 1434 Germans between the ages of 12 and 26 years. Significant differences between Japanese and German subjects were observed, namely, German men and women reached Stages D–F approximately 2–3 years earlier than Japanese men and women. In another recent study [2] a comparison of third-molar mineralization was conducted on German, Japanese and South African sample populations using Demirjian's classification system. Findings from this study indicated that the Japanese subjects reached Stages D–F an average of 1–2 years later than the German subjects, whereas the South African subjects reached Stages D–G an average of 1–2 years earlier than the Germans subjects.

To the best of our knowledge, there are only two reports available in the literature on the Turkish population [1,13]. In a study by Willershausen et al. [1] of 1202 orthopantomograms, 72% were from subjects of central and southern European origin, whereas the remaining 28% were from subjects of Turkish or other, unspecified backgrounds. This study utilized Kullman's classification to determine third-molar mineralization stages [17]. According to their findings, there were no statistical differences in third-molar mineralization stages between the left and right jaw segments, but root development stages generally occurred earlier in upper third molars than in lower third molars and among girls than among boys. Accordingly, the Turkish population was found to reach the ''Ac'' stage at a mean age of 20.6 years [1]. Our study determined that the Turkish population reached Stage H (complete root development according to Demirjian's stages, comparable to Kullman's ''Ac'' stage) at a mean age of 20.1 years. No statistical differences were found between right and left sides. Maxillary third-molar development was commonly more advanced than mandibular third-molar development, although these differences were not statistically significant. However, statistically significant differences were found in the development of third molars between Turkish male and females. This is consistent with other studies in which third-molar development was found to be more advanced in males than in females [7,9,10,17].

Uzamis et al. [13] examined 400 panoramic radiographs of Turkish children and adolescents (188 female, 212 male). They reported that in their study, the mandibular third molars

began to calcify between ages 7 and 9 years. These findings were similar to the findings of our study. They also stated that in males, third-molar crypt formation occurred earlier in the mandibular arch than in the maxillary arch, whereas this was reversed in females. Specifically, they reported that third-molar crypt formation can be observed at as early as 7 years in the mandible and 8 years in the maxilla. In contrast to this finding, our study found third-molar crypt formation to be observable at as early as 7 years in both mandible and maxilla. This difference may be due to the smaller size of their study sample (400 subjects) in comparison to ours (1134 subjects). Our study found almost no bud formation occurring after age 10 in males and age 11 in females. It should be noted that, as mentioned in earlier reports, lack of bud formation by age 11 may be a sign of agenesis, which can be confirmed if no bud is observed to have formed by around age 14 [6,12,13,45]. Results about the probability of an individual being less than 18 years old (Stages D and E) or older than 18 years old (Stage H) are in accordance with the previous studies [9,43,46]. When our findings are compared with those of other studies, third-molar development among the Turkish Caucasian population is found to occur at an earlier age than among the Japanese [4,10,47] and American populations [43] but at a similar age to the Spanish [9] and German [4] populations.

5. Conclusions

The data described above may provide a reference for the forensic application of third-molar examinations of the Turkish population. However, additional studies with a larger study population must be conducted to meet the need for population-based information on third-molar development. An unquestionable increase in the number of criminal cases in which third-molar examinations are relied upon supports the necessity of a larger, more comprehensive survey. The assessment of age amongst the Turkish population may provide a valuable forensic tool not only within Turkey, but also in other countries with different definitions of the age of majority in regard to legal prosecution.

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