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Original Article

Correlation between chronological age and third molar developmental stages in an Iranian population (Demirjian method)

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ABSTRACT

Background: Third molar development is the only available tool for estimating the age of individuals after puberty. Since this tooth has very high interethnic variability, formulas calculated to estimate the age from its development stages cannot be generalized to other populations and should be adjusted for each region. Therefore, this study was conducted to evaluate this method in a sample of Tehran individuals for the first time, and also to compare the development of third molars across sexes and arches, and to estimate cutoff developmental stages for legal minor/major identification.

Materials and Methods: A total of 150 dental patients aged between 15 and 25 years old were prospectively enrolled, and their Demirjian stages were recorded. The associations between chronological age and Demirjian stages were evaluated. Dental formation was compared between sexes and jaws. Cutoff stages were determined to identify legal minor/major cases (above or below 18 years old). Age estimation formula was found for this population.

Results: Of the 150 included patients, 56 were males. The difference between the ages of males and females at each given developmental stage was nonsignificant ($P > 0.05$), except for the H stage. Age difference between same stage teeth of the maxilla and mandible was nonsignificant. Each of the G and H stages was significantly above 18 years old ($P < 0.001$). Furthermore, E and F stages were below 18 years old ($P < 0.001$). All the correlations between Demirjian stages and age were above 90% (all $P < 0.001$). Third molar development was positively affected by the chronological age ($P = 0.000$) and being maxillary ($P = 0.000$) but not sex ($P = 0.113$). Regression formula for age estimation was: age = 6.52+ (0.64 × sex) + (0.32 × arch) + (1.86 × Demirjian stage).

Conclusion: Development of third molar might complete after the age 22. Iranian individuals with third molars at the G and H stages are likely above 18 while those at E and F are likely below 18. Pace of molar development differs for jaws, but intergender differences are open to further investigations.

Key Words: Age determination by teeth, forensic anthropology, forensic dentistry, growth and development, third molars

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INTRODUCTION

One of the most important factors utilized in establishing the identity of an individual is age estimation. Since teeth can preserve for a long time and endure many forms of extreme hazards such

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as burning, they are considered proper tools for forensic medicolegal purposes such as age and sex determination.[1,2] In forensic dentistry, there are instances when a person with unknown age needs to be legally examined. In these cases, biological signs of development such as skeletal maturation and dental maturation or eruption can be used to estimate the age.[1,2] Physical and clinical examinations might be used to roughly estimate the age of individuals not yet gone through puberty (mainly those under 14 years age); biochemical and histological methods which are expensive, invasive, and need complicated laboratory equipment, whereas radiologic technique is conservative and fast as it does not require either extraction or preparation of microscopic sections, is economic, and is usable for living and dead individuals (and hence is preferable).[1-3] Radiographic age estimation can be done either using skeletal indicators (such as cerebral vertebral radiography, epiphyseal unification of the anterior iliac crest, clavicle's medial extremity, fusion of diaphyses and epiphyses in long bones, and fusion of the occipital base with sphenoid) which are not the most accurate methods or using dental maturation stages and third molar maturation in the case of individuals at their postpubertal growth peak.[1-4] The validity of dental-based age estimation methods is higher than that of skeletal radiography (and other methods such as indicators of somatic, skeletal, or sexual maturity) since unlike bone formation, dental formation/calcification is more under genetic influence than climate, environmental, pathological, and hormonal factors.[2,3]

One of the most important aims of forensic dentistry is to examine that whether or not the age of a person or victim has passed the juvenile/adult threshold (being 18 years old or so depending on the country's legislations) for numerous legal purposes such as receiving social rights, marriage, and employment.[1] Permanent teeth excluding the third molars usually calcify and erupt before the pubertal growth peak. Many bones as well reach their maturation after puberty. Hence, after the ages 14 or 15, the options narrow down to using the mineralization of third molars and their root growth pattern (as the only quantitative biological variable available for age estimation) for individuals passed the puberty or in their early 20s.[1,2,4-9] Therefore, mineralization and development of third molars is one of the few age estimation tools when development is nearing its completion.[5,9-11] Moreover, third molars' long periods of crown and root developments make their radiographic usage favorable and practical in a very broad age range of 9–23 years.[2,5,9] Furthermore, third molars' relatively smaller vulnerability to environmental factors such as infection or mechanical effects during development (compared to their eruption) make their development stages more proper for age estimation.[12]

Radiographic assessment of third molars reveals numerous diagnostic and treatment planning-relevant information such as the tooth's morphology, potential shape anomalies or missings, degree and location of calcification, timing and direction of eruption, and its adverse effects on the position and health of anterior teeth.[2,11,13,14] Numerous radiographic techniques are available for this purpose, among which panoramic or lateral cephalometric dental radiographs are the most commonly used techniques.[5,15] Various techniques have been proposed for the examination of mineralization and development stages, with Demirjian *et al*.'s 8-stage classification being one of the most clear, simple, accurate, and therefore as one of commonly used methods.[2,15]

However, third molars are associated with a high variability in morphology, anomalies, development, calcification, and eruption.[5,16] Furthermore, it has been recently observed that ethnicity can affect third molar calcification and eruption, which might usually revolve around the age range 17–21 years in Western countries.[5,8,10,13,17] The inherent and ethnic-dependent sources of variability call for improving the accuracy of third molar-based age estimation and also securing a reference for its use within each ethnic group.[2] Another concern might be retrospective nature of almost all previous studies, which this reduces the accuracy and reliability of chronological ages reported by patients when attending for radiographic examination. Therefore, this study was conducted to assess prospectively the accuracy of the Demirjian *et al*.[15] method in estimation of chronological age in a group of Tehran citizens and also to provide a mathematical formula to estimate the age for Iranians (or Caucasians worldwide from Iranian ancestry). Null hypotheses were (1) lack of correlations between Demirjian stages and chronological age, (2) lack of difference between chronological age of women and men at the same Demirjian stage, (2A) hypothesis #2 for mandible only, (2B) the same for maxilla only, (3) lack of difference between chronological age of

participants with mandibular and maxillary teeth at the same Demirjian stage, (3A) hypothesis #3 for men only, (3B) hypothesis #3 for women only, (4) lack of difference between chronological age of participants at stages E–H of Demirjian with the chronological age "18 years," and (5) lack of difference between dental stages of left and right sides.

MATERIALS AND METHODS

This cross-sectional study was performed on 600 third molars visible on digital panoramic radiographs of 150 Tehran citizens attending the Department of Radiology as well as a Tehran radiology center, for radiographic examination prescribed by their dentists (and for the sake of research purposes only). Patients were prospectively evaluated according to the following criteria until reaching the desired sample size. As the inclusion criteria, each patient had to have all four third molars present (not missing or extracted), had to be 15–25 years old, be systemically healthy, without any history of diseases known to be associated with dental malformation or anomalies, and without any radiographic sign indicating any pathology. The exclusion criteria were any history of surgical procedures in the posterior jaws, any craniomaxillofacial anomaly such as cleft palates and histories of orthodontic treatments.[5] The ethics of study were approved by the research committee of the university (approved thesis number: 23764). Participants signed written consents, after being explained that their data would be anonymized and no personal information would be used or published.

To determine patients' chronological age, their birth dates were directly asked from them. The stage of dental development was estimated by examining the digital panoramic radiographs by a single observer using the digital features of the image viewer.[2] Dental calcification was rated according to the approach proposed by Demirjian *et al*.: the first four stages of which (A–D) exhibit crown formation and the rest sort stages of root formations: (A) calcification of cusp tip; (B) connection of calcified cusps; (C) end of enamel formation and begin of dentin deposition; (D) completion of dentine formation up to the cementoenamel junction; (E) the pulp chamber walls are straight lines, the root is shorter than crown, and the furcation is visible; (F) root length is equal to or greater than the length of the crown, and the apex is cone-shaped; (G) the root canal walls are parallel to each other, and the apex is open; and (H) The apex is closed, and the periodontal ligament has a uniform width around the roots.[5,15]

Statistical analysis

Descriptive statistics were calculated for patients' chronological ages in different stages of dental development, per arch and sex. Independent-samples *t*-test was used to compare jaws and sexes, in terms of chronological ages of teeth being at the same dental stage. One-sample *t*-test was used to compare the chronological age of patients with third molars at E, F, G, and H stages with the age 18 years old as the legal threshold for minor/major discrimination. Spearman correlation coefficient was used to measure the dental developmental stages and chronological age. Multiple regression analyses were adopted to evaluate the possibility of dental age prediction from third molar calcification stages. Furthermore, regression formulas for age estimation based on dental stages were computed and provided. Statistical software in use was SPSS version 20.0 (IBM, Armonk, New York, USA). The level of significance was predetermined as 0.05.

RESULTS

Of the 150 included patients, 56 were males with an average age of 20.09 years, and 94 were females with an average age of 19.17 years. No "A or B" stages were observed in the whole population [Table 1]. The difference between the ages of males and females at each given developmental stage was nonsignificant (independent-samples *t*-test's $P > 0.05$), except for the last stage (the completion) where females were significantly younger at the H stage compared to men at their H stage (independent-samples *t*-test's $P = 0.0003$, third molar completion was seen in males aging 23.2 years old and in females at 22.4 years) [Table 1]. When evaluating maxilla only, there was no difference between mean ages of males and females at each of developmental stages ($P > 0.05$), except in the H stage in which males were older ($P = 0.040$). When evaluating mandible only, again there was no difference between mean ages of males and females at each of developmental stages ($P > 0.05$), except in the H stage in which males were older ($P = 0.040$).

The difference between chronological ages at which maxilla and mandible were at the same dental stages was not significantly different for all the developmental stages D–H (independent-samples

Table 1: Age distribution of patients according to the stage of third molar development, sex, and arch

Sex	Jaw	Stage	*n*	Mean	SD	95% CI	Minimum	Maximum
Male	Maxilla	D	19	15.26	0.45	15.0-15.5	15	16
		E	7	16.00	0.00	16.0-16.0	16	16
		F	12	17.17	0.39	16.9-17.4	17	18
		G	16	19.13	1.59	18.3-20.0	18	23
		H	58	23.03	1.96	22.5-23.5	19	25
	Mandible	C	2	15.00	0.00	15.0-15.0	15	15
		D	22	15.55	0.67	15.2-15.8	15	17
		E	8	16.50	0.53	16.1-16.9	16	17
		F	8	17.50	0.53	17.1-17.9	17	18
		G	18	19.00	0.69	18.7-19.3	18	20
		H	54	23.41	1.63	23.0-23.9	20	25
Female	Maxilla	D	32	15.25	0.44	15.1-15.4	15	16
		E	18	15.89	0.32	15.7-16.0	15	16
		F	14	17.00	0.55	16.7-17.3	16	18
		G	48	18.58	0.96	18.3-18.9	17	21
		H	76	22.37	1.72	22.0-22.8	19	25
	Mandible	C	1	15.00	-	-	-	-
		D	37	15.32	0.47	15.2-15.5	15	16
		E	26	16.54	0.65	16.3-16.8	16	18
		F	10	17.60	0.52	17.2-18.0	17	18
		G	40	18.85	0.86	18.6-19.1	18	21
		H	74	22.46	1.65	22.1-22.8	20	25

SD: Standard deviation; CI: Confidence interval; *n*: Number of third molar teeth per table row

t-test's $P > 0.05$). When evaluating men only, there was no difference between maxilla and mandible in terms of average chronological ages of maxillary versus mandibular teeth at each of the developmental stages ($P > 0.05$). When evaluating women only, there was no difference between maxilla and mandible in terms of average chronological ages of maxillary versus mandibular teeth at each of the D, G, and H developmental stage ($P > 0.05$). However, mandibular and maxillary teeth had significantly different ages in women in the E and F stages: the average age of mandibular teeth at the E stage was greater than the average of maxillary teeth at the E stage ($P = 0.000$) and F stage [$P = 0.013$, Table 1].

No significant difference was observed between left and right sides (independent-samples *t*-test's $P > 0.05$).

The one-sample *t*-test, comparing each of the G and H stages with the age 18 years old, showed that all the molars at their G stages were significantly greater than 18 years old, either in maxilla of each sex, or in mandible of each sex, or in both jaws of each sex (maxilla and mandible combined), or in each jaw (both sexes combined), or in the whole sample (all P values < 0.001). Similar results were obtained for the H stage, all being significantly above the age 18 years old (all P values < 0.001). Few cases of the G stage had chronological ages of 17. However, no Iranian individual with ages below 18 was seen in the molar H stage in each jaw or sex group. In a similar fashion, the E and F stages were all significantly below the minor/major threshold of 18 years old (all P values < 0.001).

According to the Spearman correlation coefficient, excellent positive correlations existed between the third molar calcification/development stages and chronological age in each of the sexes or jaws or in all of them combined [Table 2].

The regression analysis showed that third molar development can be positively affected by the chronological age ($P = 0.000$) and being developed in the maxilla ($P = 0.000$) but not sex ($P = 0.113$). According to the regression analysis, developmental stage of third molars can be used to estimate the chronological age, based on the following formula [Table 3]:

Chronological age (year) = 6.52 + 0.64 × sex (0 for female, 1 for male) + 0.32 × jaw (1 for maxilla, 2 for mandible) + 1.86 × third molar calcification/development stage (3–8 instead of C to H).

DISCUSSION

According to the findings of this study, Demirjian stages and chronological age were correlated. Molars

Table 2: Spearman correlations between dental development stage and chronological age

Sex	Jaw	ρ	*P*
Male	Maxilla	0.907	0.000
	Mandible	0.931	0.000
Female	Maxilla	0.939	0.000
	Mandible	0.946	0.000
Male	Both	0.918	0.000
Female	Both	0.941	0.000
Both	Maxilla	0.928	0.000
Both	Mandible	0.941	0.000
Both	Both	0.934	0.000

ρ: Spearman coefficient

Table 3: The results of regression analysis

Variable	*B*	SE	β	*P*
Constant	6.52	0.34	-	0.000
Sex	0.64	0.13	0.09	0.000
Jaw	0.32	0.13	0.05	0.011
Stage	1.86	0.04	0.88	0.000

B: Regression coefficient; SE: Standard error; β: Standardized regression coefficient

developed in both genders similarly throughout the whole development span except that at the end of development period, development accelerated in women who reached the last Demirjian stage faster (at a younger age about 1 year) than men. There was no considerable difference between the speed of molar development in the mandible and maxilla. Molars at G and H stages (especially H) would highly suggest chronological ages above 18 years old. On the other hand, molars at E and F stage are suggestive of ages below 18 years old. Our results regarding the strong association found between the chronological age and developmental stage of third molars were similar to many other studies showing such strong correlations.[2,18,19] In this study, the D stage was found in patients at their 15, which was consistent with other studies reporting that the D developmental stage has been seen in individuals aged about 12.5–15 years old (with ethnic-dependent variations), while it was in contrast to other studies which found older ages being at the D stage (such as about 18 years old in Japanese and about 16 years old in Germans).[2,19-21] Moreover, in this study, sex did not play a direct role in dental formation pace which was in line with some previous studies[2,18,20] and in contrast to other studies which found sex-dependent trends in third molar development.[19,22] Our results in terms of the age of completion of third molars were consistent with other studies reporting ages about 21.5 in Indian men and 23.3 in Indian women[5] or around 22 in Korean men and 24 in Korean women[23] or about 22.1 years in Turkish men and 22.6 years in Turkish women.[9] The order of root development can begin sooner in the maxilla or mandible of individuals of different ethnicities; some studies reported the eruption of third molar to happen first in the maxilla and then in the mandible[24-26] while Priyadharshini *et al*.[5] reported the opposite. In this study, there was not much difference between timing of dental stages seen in the maxilla and mandible. These differences might root in ethnic differences as well as methodological limitations, such as the minimum or maximum ages accepted as the inclusion criteria. Furthermore, the nutritional status which might be poorer in some countries and usually better in Western countries can play a role in development pace and calcification timings.[5,27]

In this study, both the G and H stages could indicate with at least 95% degree of confidence that the person might be above 18 years old. The only stage that had a minimum chronological age at 18 or above it (the minor/major cutoff) was the H stage. Therefore, this developmental stage in Iranians might be used at a much higher degree of confidence for verification of the threshold of 18 years for minor/major legal rights. However, this should not be generalized to other populations. For example, Knell *et al*.[22] showed that in Swedish population and Sisman *et al*.[9] in Turkey, the H stage can be seen in younger teenagers as well. Furthermore, it is claimed that about a quarter of Indians requiring identification as minor/major might be incorrectly categorized.[1,7] This might be related to the high variations seen in the development of third molars.[5,16] Furthermore, methodological limitations might be the case as the Demirjian and Goldstein[16] method or other classifications[6,26] might be difficult at some points because of defining numerous stages that are hard to distinguish from each other. The method proposed by Demirjian and Goldstein[16] avoids any numeric identification of stages to eliminate the illusion of these stages being of the same duration.[5,9,11] This might make it superior compared to other proposed approaches.[5,9] Furthermore, this method has been shown to have a high reproducibility and capable of correct age estimation in various ethnicities.[2,8,14,15,17] Still, age determination based on third molars remains a challenge: third molars are highly variable in terms of numerous characteristics such as development, eruption pattern, shape and contour, size, and relative positions and have an

unusual 10-year period of development.[1,5,8,9,27-29] Their development begins usually when the child is 8 or 9 years old (sometimes even at 5 or 6) while its mineralization might begin sometimes between the ages 7 and 16 years old. Their enamel becomes completely mineralized sometime between the ages 12–18 years old, their roots complete sometimes between the ages 18–25 years, and they might erupt into the oral cavity sometimes between the ages 12 and 22 years.[5,16] Owing to these variations, their usage is challenging, and the only major reason for their usage in age estimation is that they are almost the only option after puberty.[1,5,8,9,27-29] Age estimation based on dental development is most accurate when there are many teeth developing (which is not the case after the age of 14 or higher, when all other permanent teeth are already erupted).[2] Hence, whenever possible, multifactorial methods for age determination might be advantageous over this method.[1,30]

In the present study, females reached certain third molar calcification stages (only the H stage) sooner than males. This was in contrast to results in Indians, Japanese, or Turkish individuals, in which third molar development was found to occur sooner in few stages in Indian males compared to females.[5,9] On the other hand, another Indian research accorded with the current study, showing that third molar development was attained earlier in women than in men.[30] Moreover, yet in another Indian study, no statistically significant differences were observed between pace of dental calcification in women and men.[1]

The Demirjian method of age estimation is advantageous over many other methods because of its objective, clear, and standardized criteria explaining stages of dental development, especially the subjective methods and those using dental eruption only.[15,31] On the other hand, it is not necessarily reliable perfectly in populations other than the population of the origin of this system (French-Canadian), leading to the introduction of modifications such as that introduced by Willems *et al*.[31,32] There are other objective methods with more stages.[31,33] Each of these methods has its own limitations; for example, more stages allow a more accurate estimation while at the same time might become more difficult to conduct and less clear. The Demirjian method is widely accepted in part because of its rather high reliability and ease of use.[5,8,10,13,15]

This study was limited by some factors. A larger sample would improve the reliability of findings. Furthermore, a sample collected from different cities would better represent an Iranian population. Furthermore, it was better to determine Demirjian stages twice or more (e.g., by two observers), to reach a more accurate estimate, and to understand the level of estimation reliability.

CONCLUSION

It was concluded that Demirjian third molar development in either maxilla or mandible is almost perfectly correlated with the chronological age of Iranians (from Tehran) and therefore might be used to estimate their chronological age. Development of third molar might complete after the age 22. Iranian individuals with third molars at the G stage and especially the H stage of development are extremely likely to be above the minor/major threshold of 18 years old. Those at F and especially E stages are very likely to be under 18. Third molar calcification and development was influenced by chronological age and the jaw (maxillary third molars might complete sooner compared to mandibular teeth) but not sex, the role of which was inconclusive and hence needing future larger studies to assess it. The following formula might be used to estimate the chronological age of an individual from the Iranian ancestry (from Tehran region, in particular): chronological age (year) = 6.52 + 0.64 × sex (0: female, 1: male) + 0.32 × jaw (1: maxilla, 2: mandible) + 1.86 × third molar calcification stage (3: C, 8: H).

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Conflicts of interest
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