Original Article

Third-Molar Development in Relation to Chronologic Age in Turkish Children and Young Adults

Yildiray Sisman[a]; Tancan Uysal[b]; Fatih Yagmur[c]; Sabri Ilhan Ramoglu[d]

ABSTRACT

Objective: To assess estimation of chronologic age based on the stages of third-molar development following the eight stages (A–H) method of Demirjian et al and to compare third-molar development by sex and age with results of previous studies.

Materials and Methods: The final sample consisted of 900 orthopantomograms from young Turkish subjects of known chronologic age (range, 8–25 years; mean age, 15.18 ± 4.81 years) and sex (380 males with a mean age of 14.51 ± 4.55; 520 females with a mean age of 15.67 ± 4.94). Statistical analysis was performed using the Mann-Whitney *U*-test and the Wilcoxon test between sex and age. Regression analysis was performed to obtain regression formulas for dental age calculation with the chronologic age

Results: Statistically significant differences ($P < .05$) in third-molar development between males and females were revealed regarding the calcification stages D and G. Third-molar genesis was attained earlier in males than in females. Statistical analysis showed a strong correlation between age and third-molar development for males ($r^2 = .65$) and for females ($r^2 = .61$). New equations (Age = 8.92 + 1.50 Development stage) were derived for estimating chronologic age.

Conclusion: The use of third molars as a developmental marker is appropriate, especially when comparing the obtained standard deviation with other skeletal age calculation techniques.

KEY WORDS: Third molar; Chronological age; Turkish; Age estimation

INTRODUCTION

In the past decade the number of unidentified cadavers and human remains as well as the number of remains lacking age documentation and therefore requiring age determination has increased.[1,2] This requires age calculation, not only for differentiating the juvenile from the adult status in criminal law cases, but especially when determining the age of a crime victim and also for estimating chronologic age in relation to school attendance, social benefits, employment, and marriage.[1,2]

Determining chronologic age in persons within the range of 15.5–23.5 years remains a problem. Skeletal indicators, such as diaphysis–epiphysis fusion, hand–wrist examination, cervical vertebrae assessment, amino acid racemization, sternoclavicular bones, changes in the pubic symphysis, fusion of cranial sutures, or changes in secondary sex characteristics, all have their advantages and disadvantages and, especially during these years, are more or less indecisive.[3–7]

Teeth represent useful material for age estimation. In childhood, for example, observing dentition stages results in highly accurate age assessments. However, this accuracy decreases as a person's dental development is completed.[8] Two methods of age evaluation are available for juveniles: the morphologic examination of skeletal features and radiologic examination of the development of third molars.[1]

The third molar offers a unique advantage over other teeth because its development tends to continue over a long period and until a later age. But third mo-

[a] Assistant Professor and Department Chair, Department of Oral Diagnosis and Radiology, Faculty of Dentistry, Erciyes University, Kayseri, Turkey.

[b] Associate Professor and Department Chair, Department of Orthodontics, Faculty of Dentistry, Erciyes University, Kayseri, Turkey.

[c] Assistant Professor, Department of Forensic Sciences, Faculty of Medicine, Erciyes University, Kayseri, Turkey.

[d] Research Fellow, Department of Orthodontics, Faculty of Dentistry, Selcuk University, Konya, Turkey.

Corresponding author: Dr Tancan Uysal, Erciyes Üniversitesi Dişhekimliği Fakültesi, Ortodonti A.D. Melikgazi, Kampüs Kayseri, 38039 Turkey
(e-mail: tancanuysal@yahoo.com)

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Table 1. Stages of tooth calcification as described by Demirjian et al[11]

Stage A: Calcification of single occlusal points without fusion of different calcifications.
Stage B: Fusion of mineralization points; the contour of the occlusal surface is recognizable.
Stage C: Enamel formation has been completed at the occlusal surface, and dentine 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.

lars are the most inconstant of all teeth.[9] However, evaluation of third-molar maturity seems to be an adequate method for estimating the age of undocumented juvenile suspects or asylum seekers when used in conjunction with the other skeletal maturity indicators.

Up to now several studies have been undertaken in different populations to explore the usefulness of the third molar as a reliable age indicator.[8,10–24] These studies show that dental development varies slightly between different populations, making population-specific studies necessary. Recently, for different ethnic groups, numerous reports have been published on the evaluation of third-molar development,[8,10–15,17–24] and further studies were warranted for Hispanic populations.[16] At the start of this study, we hypothesized that Turkish children might have a different rhythm of third-molar maturation than that of children in the countries from which the standards were derived. Hence, it was considered worthwhile to determine third-molar developmental stages in a sample of young Turkish people, to assess chronologic age estimates based on developmental stages, to compare third-molar development by sex and age, and to compare these data with the results of previous studies.

MATERIALS AND METHODS

In this cross-sectional study, orthopantomograms of 1114 white Turkish subjects with known chronologic age and sex were selected. Selection criteria included the following:

- Turkish and white;
- Well nourished and free of any known serious illness; and
- Normal growth and development and dental conditions, for example, no impactions, congenital absence, or transposition of teeth.

Exclusion criteria excluded the following:

- Image deformity affecting third molars; and
- Orthopantomogram showing obvious dental pathology.

Thirty-two films were excluded for poor radiographic quality, and 182 films were excluded for agenesis of the third molars. The final sample consisted of 900 orthopantomograms from Turkish individuals of known chronologic age and sex. Mean age of the 900 patients in the series was 15.18 $\pm$ 4.81 years (range, 8 to 25 years); 380 were male (mean age, 14.51 $\pm$ 4.55) and 520 were female (mean age, 15.67 $\pm$ 4.94).

All assessments were performed in a darkened room with a radiographic illuminator to ensure contrast enhancement of the tooth images. Examination and classification covered the development phase of the third right mandibular molar and, when not present, the contralateral molar was considered.

Tooth calcification was rated according to the method described by Demirjian et al[11] in which one of eight stages of calcification, A to H, was assigned to the third-molar tooth (Table 1). The first four stages (A–D) show crown formation from the beginning of cusp calcification to completed crown, and the second four (E–H) root formations from initial radicular bifurcation to apical closing.

Descriptive statistics were obtained by calculating the means, standard deviations, and range of the chronologic ages for the eight stages of dental development. Statistical analyses were performed using the Mann-Whitney *U*-test and Wilcoxon test between sex and age. Regression analysis was performed to obtain regression formulas for dental age calculation with chronologic age as the independent variable and third-molar developmental stages as dependent variables. All statistical analyses were performed using the SPSS software package (SPSS for Windows 98, version 10.0, SPSS, Chicago, Ill).

To test the reproducibility of the assessments of dental development stage, two investigators reevaluated randomly selected panoramic radiographs from 10% of the same male and female subjects 8 weeks

Table 2. Descriptive values and statistical comparisons of Demirjian stages in both sexes[a]

Demirjian Stage	Male					Female					Test *P* Value
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	
Stage A	72.00	11.53	3.44	8.00	24.00	101.00	12.64	4.48	8.00	25.00	NS
Stage B	70.00	11.60	1.52	9.00	18.00	68.00	11.44	1.69	7.00	18.00	NS
Stage C	58.00	12.22	1.85	8.00	16.00	56.00	12.46	1.83	8.00	16.00	NS
Stage D	40.00	12.90	1.50	10.00	17.00	75.00	13.60	2.24	8.00	22.00	*
Stage E	31.00	14.42	1.69	10.00	18.00	36.00	15.42	2.40	10.00	18.00	NS
Stage F	20.00	16.90	1.50	12.00	22.00	32.00	16.84	2.10	14.00	24.00	NS
Stage G	26.00	18.08	2.38	10.00	22.00	48.00	19.29	2.32	14.00	24.00	*
Stage H	63.00	22.10	2.87	10.00	25.00	104.00	22.66	2.18	15.00	25.00	NS

[a] SD indicates standard deviation; Min, minimum; Max, maximum; and NS, not significant; * $P < .05$.

after the first evaluation. Inter- and intraobserver agreements were determined using the Wilcoxon matched-pairs signed-rank test.

RESULTS

Repeated scorings of a subsample of 90 radiographs indicated no significant intra- or interobserver differences ($P > .05$). Intraobserver consistency was rated at 98%, whereas interobserver agreement was 95%.

The third-molar formation process was examined in both sexes, and the mean ages and standard deviations for the Demirjian stages are described in Table 2 and illustrated in Figure 1. Statistically significant differences ($P < .05$) were revealed in third-molar development between males and females regarding the calcification stage D and stage G. These differences indicated that third-molar genesis attained the Demirjian formation stages earlier in males than in females. In addition, a slight (not significant) delay was recognized in males only for the stages B and F.

Meaningful landmarks in tooth formation, such as crown completion (stage D), root-length completion (stage G), and apical closure (stage H) were defined for a Turkish population. Percentile distributions of the patients by age with these formation stages are indicated in Figures 2 through 4. According to our data for stage D, around 75% of the females and 90% of the males were ≤15 years old. For stage G, approximately 70% of the males and 60% of the females were between 17 and 20 years old. For stage H, around 70% of the male and 80% of the female patients were >21 years old. Formation of third-molar teeth was completed before the age of 18 years in only seven subjects (four females and three males).

Finally, linear regression coefficients are provided to assess the correlation of third-molar development and chronologic age. Statistical analysis showed a strong correlation between age and third-molar development for males ($r^2 = .65$) and for females ($r^2 = .61$). 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 = 8.92 + 1.50 Development stage

Males: Age = 8.63 + 1.48 Development stage

Females: Age = 9.20 + 1.50 Development stage

DISCUSSION

Chronologic age estimation by tooth development has been used over a long period. Tooth development is an accurate measure of chronologic age that seems to be independent of exogenic factors such as malnutrition or disease.[7,8,25] The third-molar calcification

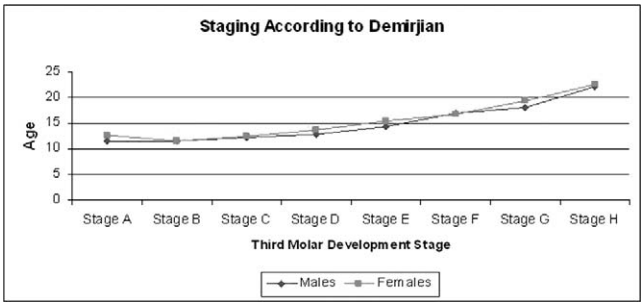

Figure 1. Illustrations of mean ages and standard deviations for Demirjian stages in both sexes.

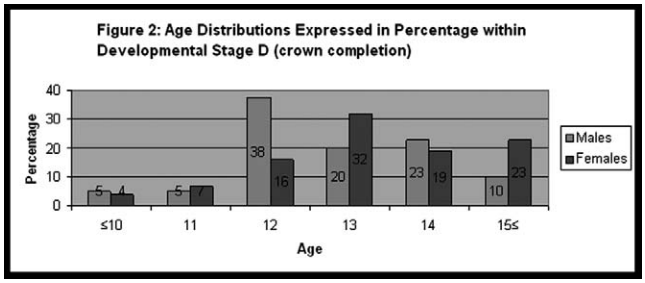

Figure 2. Age distributions expressed in percentage within developmental stage D (crown completion).

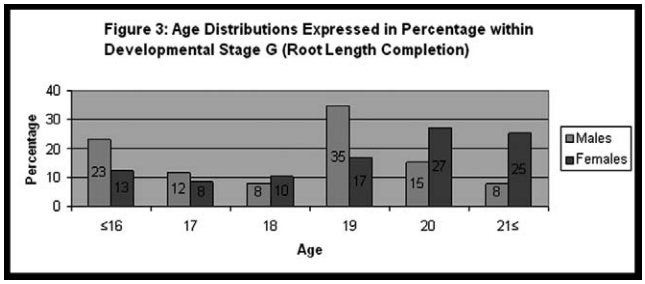

Figure 3. Age distributions expressed in percentage within developmental stage G (root-length completion).

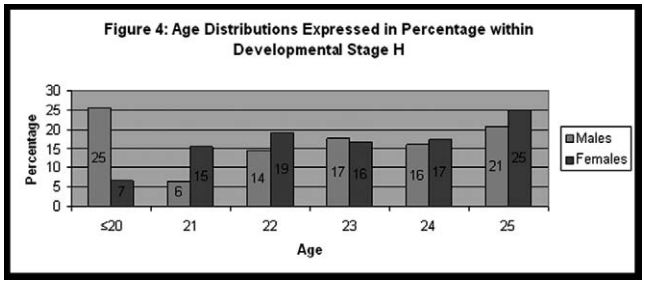

Figure 4. Age distributions expressed in percentage within developmental stage H (apical closure).

stage is one of the few tools that can be used to assess age when development is nearing completion.[5] However, age estimates based on dental methods have shortcomings, especially during adolescence when the third molar is the only remaining variable dental indicator. Indeed, a great variation in position, morphology, and time of formation exists.

The differences between populations, the different methodology, and the dissimilarity among observers are other important shortcomings. In the present study, to overcome some of these shortcomings, all selected subjects were of white Turkish origin, and all 1114 orthopantomograms were evaluated by two well-trained observers using eight stages according to the method of Demirjian et al.[11]

In the literature, a range of different classifications for evaluating tooth mineralization is available. In the past, different classifications were presented by Gleiser and Hunt,[26] Moorrees et al,[27] Kullman et al,[8] and Kohler et al.[28] However, some of these classifications identify a large number of stages that are hard to delimit from each other. Demirjian et al[11] presented a classification distinguishing four stages of crown development (stages A–D) and four stages of root development (stages E–H). The system avoids any numeric identification of stages so as not to suggest that the different stages represent processes of the same duration. The stages proposed by Demirjian et al[11] are defined by changes of shape, independent of speculative estimations of length. Dhanjal et al[29] investigated the reproducibility of different radiographic stage assessment of third molars and concluded that the method of stage assessment of third molars developed by Demirjian et al[11] performed best not only for intra- and interexaminer agreement, but also for the correlation between estimated and true age. Therefore, this classification seemed to be the most appropriate for our study.

Uzamis et al[30] examined 400 panoramic radiographs of Turkish children and adolescents (188 female, 212 male subjects). They reported that the mandibular third molars start to calcify between the ages of 7 and 9 years. Orhan et al[24] showed similar findings in a Turkish population. In accordance with these findings, in the present study the minimum age limit was selected as 8 years old for third-molar crypt formation. This was possible because the crypt was visible as early as 8 years in the mandibular arch.

Because previous studies that investigated sex differences showed rather diverse results, we examined the mean ages of each stage for male and female patients for a Turkish population. Statistically significant differences ($P < .05$) in third-molar development between male and female subjects were revealed regarding calcification stages D and G. These significant differences indicated that third-molar genesis in males attained these Demirjian formation stages 8 to 12 months earlier than in females. This observation was consistent with previous studies, which report that the mean age at some of the development stages was lower for males than for females in the following populations: Belgian whites,[31] Hispanics,[16] Swedes,[8] or people of Spanish origin.[17] However, other researchers have demonstrated similar mean age values and distributions for both sexes.[10,23,32]

In addition to the aforementioned studies, a few comparative studies have also been conducted on third-molar mineralization. Gorgani et al[33] examined 229 black and 221 white US citizens aged 6–14 years. Among the black subjects crown mineralization of the third molars was completed 1 year earlier than in the white subjects. Harris and McKee[34] studied 655 white and 335 black US citizens aged 3.5–13 years. Whereas the black subjects reached the earlier stages of wisdom tooth mineralization about 1 year earlier, the gap appeared to narrow for later stages. This trend is confirmed by the work of Mincer et al.[14] They examined 823 US citizens (80% white, 19% black; aged 14–25 years) but did not establish any significant differences in the time frame for wisdom tooth mineralization. Daito et al[35] addressed wisdom tooth mineralization in 9111 Japanese children aged 7–16 years and compared their data with the values provided by Gravely,[36] Rantanen,[37] and Haavikko[38] for white populations. No significant differences were discovered.

In the literature, only a few studies are available that

Table 3. Mean age and standard deviation in years in different populations, based on Demirjian's method

Demirjian Stage	Gender	Japanese (Olze et al [15])		German (Olze et al [15])		Spanish (Prieto et al [17])		South African (Olze et al [15])		Turkish (Present Study)	
		Mean	SD[a]	Mean	SD	Mean	SD	Mean	SD	Mean	SD
D	Male	18.20	3.30	16.30	3.10	15.08	1.04	15.08	1.04	12.90	1.50
	Female	18.00	2.80	15.50	2.60	15.11	1.00	15.11	1.00	13.60	2.24
E	Male	18.50	2.70	16.70	2.30	15.22	1.03	15.20	2.40	14.42	1.69
	Female	18.60	2.30	16.80	2.30	16.00	1.43	15.90	2.30	15.42	2.40
F	Male	20.40	2.40	18.30	2.20	16.42	1.34	18.70	2.30	16.90	1.50
	Female	20.50	2.20	19.10	2.50	16.83	1.56	21.30	2.50	16.84	2.10
G	Male	21.80	2.50	20.60	2.40	17.92	1.50	20.80	2.20	18.08	2.38
	Female	21.80	2.00	21.70	2.10	18.41	1.44	19.80	2.30	19.29	2.32
H	Male	22.70	2.00	22.70	1.90	19.74	1.09	22.60	1.90	22.10	2.87
	Female	22.40	2.10	23.00	1.80	19.66	0.98	22.40	1.90	22.66	2.18

[a] SD indicates standard deviation.

were carried out on Turkish populations. Willershausen et al[32] studied a total of 1202 orthopantomograms of 602 female and 600 male probands of central and southern European origin, from Turkey and other unspecified countries. This study determined the mineralization stages of third molars using the method of Kullman.[8] According to the author, no reliable information could be given with respect to possible ethnic differences, because the number of cases was too small for that purpose. A sufficient number of cases could only be presented for the Ac stage (which is comparable to Demirjian's stage H), which describes the completion of root development.

Orhan et al[24] determined that the Turkish population reaches stage H at a mean age of 20.1 years. Our findings indicate that the Turkish population reaches stage H at a mean age of 22.1 years in males and 22.6 years in females. This is not consistent with the results of other Turkish sample studies. The diversity could be explained by the differences in the selected age range of the study populations.

Results reporting the probability of an individual being younger than 18 years (at stages D and E) or older than 18 years (at stage H) are in accordance with previous studies.[14,16,17,33] When our findings are compared with those of other studies (Table 3), third-molar development among the white Turkish population is found to occur at an earlier age than in Japanese,[21,23,35] South African,[15] and German[21] populations for all stages. It is only for stages F, G, and H that third-molar development takes place earlier in the Spanish[10,17] than in the Turkish population.

Mean absolute difference between dental age and chronologic age showed the highest precision. The stage of development of the third molar has a practically linear relation to the age of the subjects, whether male or female; the latter develops a little later as stated.[31,39] Statistical analysis shows a stronger correlation for male ($r^2 = .65$) than for female ($r^2 = .61$) subjects. These results also agree with studies on other populations.[17]

CONCLUSIONS

- Third-molar development among the Turkish white population occurs at an earlier age than in other populations for almost all stages. Only in stages F, G, and H does third-molar development take place earlier in Spanish[17] than in Turkish individuals.
- To increase the accuracy of age determination, indications of sexual maturity and ossification should also be evaluated in addition to third-molar mineralization.
- 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 on hand-wrist or long bones, for example.

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