JOURNAL OF FORENSIC SCIENCES

J Forensic Sci, March 2012, Vol. 57, No. 2
doi: 10.1111/j.1556-4029.2011.02011.x
Available online at: onlinelibrary.wiley.com

TECHNICAL NOTE

ODONTOLOGY

Kenan Cantekin,[1] D.D.S., Ph.D.; Yucel Yilmaz,[2] D.D.S., Ph.D.; Tevfik Demirci,[1] D.D.S.; and Mevlut Celikoglu,[3] D.D.S., Ph.D.

Morphologic Analysis of Third-Molar Mineralization for Eastern Turkish Children and Youth

ABSTRACT: To date, there has been no chronological age estimation according to third-molar mineralization in eastern Turkish children and adolescents. The aim of this study was to analyze the development of the mandibular third molar and its relationship to chronological age in subjects aged 7–22 years according to Demirjian's stages. The final sample consisted of 1348 [622 males (mean age, 12.72 ± 3.14) and 726 females (mean age, 12.92 ± 2.89)] conventional orthopantomograms from eastern Turkish youths. An independent *t*-test was performed to evaluate the difference between sexes. Regression analysis was performed to obtain regression formulae for dental age calculation with chronological age. In males, there was a difference between males and females only at stage C ($p = 0.03$); females were advanced 0.37 years compared with males at the stage C. Third-molar development among eastern Turkish children and youths occurs at a more advanced age than other populations for almost all stages.

KEYWORDS: forensic science, dental age estimation, third-molar mineralization, Eastern Turkish, linear regression, Demirjian method

Economic globalization, European integration, and current armed conflicts have led to an increase in cross-border migration in Europe (1). Turkey is located within European borders and has been making efforts to become a member of the European Union (EU). There has been a continuous migration of Turkish citizens to EU countries, especially Germany. The Turkish population abroad increased from 600,000 in 1972 to 3,800,000 in 2004. Moreover, studies have predicted a continuing flow of 1.3–2.7 million migrants from Turkey to various countries, especially those within the EU, up to 2030 (2).

The eastern region of Turkey has one of the lowest socioeconomic statuses for Turkey and for Europe. Therefore, it is one of the areas most ripe for migration (3). Unfortunately, births are not recorded regularly in Turkey, especially in rural regions. However, identification of age is very important in identifying criminal and legal responsibility, and for many social events, such as beginning a job, joining the army, and marriage. Turkish law defines three legally relevant age limits: 12, 15, and 18 years (4), unlike the legally relevant age threshold in most European countries which range from 14 to 18 years old (5).

There are many skeletal indicators for forensic age estimation in children and adolescents, such as hand-wrist examination, diaphysis–epiphysis fusion, cervical vertebrae assessment, changes in secondary sex characteristics, fusion of cranial sutures—all of which have their advantages and disadvantages (6–9).

[1]Department of Pediatric Dentistry, Faculty of Dentistry, Ataturk University, Erzurum, Turkey.
[2]Pediatric Dentistry, Ataturk University, Erzurum, Turkey.
[3]Department of Orthodontics, Faculty of Dentistry, Karadeniz Technical University, Trabzon, Turkey.

Received 8 June 2010; and in revised form 3 Feb. 2011; accepted 1 Mar. 2011.

Dental development based on age estimation is one of the most reliable indicators of chronological age (10). Radiographic assessment of the degree of third-molar formation is an important method of forensic age estimation in adolescents and young adults, as all other permanent teeth have finished their development in this age group (11), and so third molars represent the only teeth still in development.

There have been limited studies concerning how ethnic origins can influence tooth mineralization (12,13). This, however, constitutes a restraint on the reliability of age estimation, and hence on the forensic value of information essential to legal security. After reviewing the literature, there have been some reports on the research of age estimation based on third-molar mineralization in the western region of Turkey (2,9,14); however, there has been no study for eastern Turkish children and youths. On the other hand, the Eastern Anatolia Region is the largest geographical region (21% of Turkey) (15) and has the lowest average temperature (−8°C in winter) of all Turkish regions. Additionally, socio-economical status of this region is lower than the other regions of Turkey (16). The aim of the present study was, therefore, to establish reference data on third-molar mineralization, evaluated according to the eight stages proposed by Demirjian et al. (17), for eastern Turkish children and youths.

Material and Methods

Samples

In this retrospective study, a total of 1423 conventional orthopantomograms (OPTs) taken by the faculty of dentistry at Ataturk University, Erzurum were assessed. The patients' names, sex, and birth dates were recorded for each radiograph. Table 1 shows the age and sex distribution of the sample sets.

TABLE 1—*Distribution of age and sex of the sample.*

Age (years)	Male	Female	Total
7	28	38	66
8	29	36	65
9	42	47	89
10	33	48	81
11	65	83	148
12	61	71	132
13	72	79	151
14	53	63	116
15	46	49	95
16	25	33	58
17	28	32	61
18	26	25	51
19	18	21	39
20	25	24	49
21	33	34	67
22	38	43	81
Total	622	726	1348

All data were obtained from the patients records including medical, social, and dental anamnesis and radiographs (OPTs and bitewings). Selection criteria included the following: (i) eastern Turkish children and youths aged between seven and 22 years; (ii) born after a normal gestation period and healthy; and (iii) having normal growth, development, and dental conditions. Exclusion criteria included the following: (i) image deformities affecting third molars and (ii) OPTs showing obvious dental anomalies/pathologies of third molars. Nineteen films were excluded for poor radiographic quality, and 56 films were excluded for agenesis of lower wisdom teeth. The final samples, therefore, consisted of 1348.

Examination

The mineralization status of the third molars was assessed using the formation stages described by Demirjian et al. (17) (Fig. 1), based on eight stages of tooth formation. All assessments were carried out by two well-trained investigators, in a darkened room with a radiographic illuminator.

Reproducibility

Dental and skeletal maturation assessments were performed independently by two investigators (one researcher in orthodontics, the other in pediatric dentistry) without any knowledge of the children's chronological ages. To assess reliability, 120 randomly selected radiographs were reexamined 30 days after the initial examination by the same observers, and inter- and intra-observer agreement was determined using the paired *t*-test.

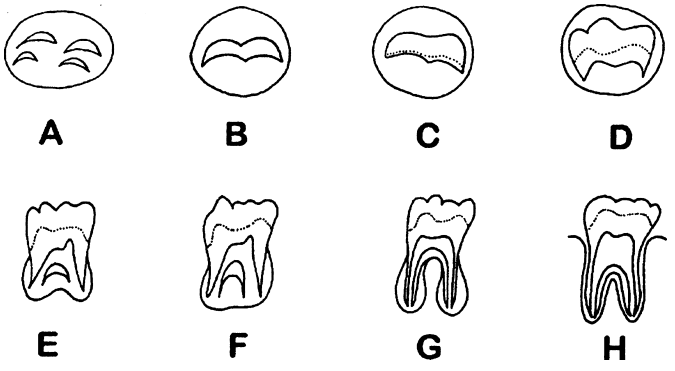

FIG. 1—*Mineralization status of the third molars based on eight stages of tooth formation.*

Statistical Analysis

The Kolmogorov–Smirnov test was used to test the normality of distribution of the developmental stages of both mandibular third molars in each sex and age group. An independent *t*-test was performed for sex and age to determine the relationship between tooth developments. Linear regression analysis was performed to obtain regression formulae for dental age calculation with chronological age and to determine the coefficient of determination (r^2) for each sex. Statistical analysis was performed using the SPSS 15.0 package (SPSS Inc., Chicago, IL) for Windows.

Results

Repeated scorings of a subsample of 120 radiographs indicated no significant intra- and inter-observer differences ($p > 0.05$). Intra- and inter-observer consistencies were rated at 93% and 91%, respectively.

The mean age was 12.83 ± 3.01 years, made up of 622 males (mean age, 12.72 ± 3.14) and 726 females (mean age, 12.92 ± 2.89).

The mean mineralization ages and standard deviations for the Demirjian stages of third molars are shown in Table 2. There was a difference between males and females for stage C ($p = 0.03$). Females were advanced by 0.47 years more than the males at stage C. In addition, a slight delay was observed in females for stage A ($p = 0.06$).

Third-molar crypt formation was observed in 3.8% of patients aged 7 years. It was also seen that third molars had reached complete crown calcification at age 13 years, ranging from 10.4 to 15.9 years (Table 2).

Linear regression coefficients were used to assess the correlation between 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 females ($r^2 = 0.56$). The new equations were the following:

Males: Age = 9.54 + 1.08 Development stage

Females: Age = 10.01 + 0.93 Development stage

Discussion

Dental age estimation is an important method in forensic age diagnosis (18). From a forensic odontology perspective, sufficiently precise and reliable determination of age using third-molar mineralization is crucially important because it has been one of the parameters proposed for aiding in determining the age of unidentified cadavers and human remains; moreover, third-molar mineralization can also determine the age of living persons for purposes of differentiation between juvenile and adult status in criminal law cases 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. Additionally, it is also useful for estimating chronological age in relation to school attendance, social benefits, employment, and marriage (1,9,13). There are various methods for dental age estimation through evaluating the chronological age of tooth mineralization. These methods were presented by Moorrees et al. (19), Kvaal et al. (20), Gleiser and Hunt (21), Kullman et al. (22), and Paewinsky et al. (23). However, different results were found using these methods, partly

TABLE 2—*Statistic data of chronological mineralization age of 38.*

	Male				Female				
Stage	Mean	SD	Min	Max	Mean	SD	Min	Max	*p*-Value
A	9.22	1.72	7.3	14.5	9.61	1.56	7.3	13.9	0.06
B	10.87	1.63	8.2	13.8	10.68	1.43	8.9	14.1	0.37
C	12.09	1.34	9.5	14.2	11.62	1.27	9.9	15.0	0.03*
D	13.23	1.17	10.7	15.9	13.30	1.36	10.4	15.9	0.62
E	14.19	0.84	12.7	15.5	14.18	0.99	12.5	15.9	0.93
F	15.66	0.95	12.8	20.1	15.65	0.85	13.0	21.2	0.94
G	17.22	0.97	15.3	21.5	17.20	0.92	15.1	18.0	0.90
H	20.43	0.87	18.0	22.4	20.47	0.84	18.2	22.5	0.72

*$p < 0.05$.

because some results were too subjectively evaluated to be compared directly (24).

Demirjian et al. (17) presented a classification distinguishing four stages of crown development (stages A–D) and four stages of root development (stages E–H). Olze et al. (25) and Dhanjal et al. (26), assessed 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. reported the most accurate results. Because of the fact that all other permanent teeth have finished their development in this age group (11), especially during adolescence, the left third molar is the sole variable dental indicator (27), the present study was based on third-molar mineralization proposed by Demirjian.

So far, several studies have been carried out in the Turkish population to define chronological age using the third-molar mineralization method proposed by Demirjian (2,9,14). Orhan et al. (2) studied 839 mandible molars and 625 molars of western Turkish people. They reported that there was statistically no difference between males and females. On the contrary, we found statistical differences between males and females at stage C ($p = 0.03$) for eastern Turkish people. According to their findings, the western Turkish population reached stage H (complete root development, according to Demirjian's stages) at a mean age of 20.10 years for males and at a mean age of 20.00 years for females (2). We observed that the eastern Turkish population reached stage H at a mean age of 20.43 years for males and at a mean age of 20.43 years for females. The dental mineralization age of eastern Turkish youths was advanced at stages D–G, but delayed at stage H compared with western Turkish youths. Uzamis et al. (14) examined 400 panoramic radiographs of western Turkish children and adolescents (188 females, 212 males). They reported that the mandibular third molars began to calcify between ages seven and nine. Sisman et al. (9) noticed the third molar begin to calcify at aged eight. However, we found third-molar crypt formation to be observable at as early an age as seven in both males and females. This diversity could be explained by differences in the selected region.

Different results were obtained by different authors studying the chronological age of different ethnic groups using the classification method proposed by Demirjian. Willershausen et al. (28) assessed 1202 OPTs for three ethnic groups (Central European, South-East European, Turkish), and additionally one undefined ethnic group, and reported that there were no significant growth rate differences in various ethnic groups. However, Olze et al. (13) examined a total of 3652 OPTs from Germans (1430), Japanese (1597), and South Africans (584) and reported that there were significant differences between Germans and Japanese at stages D–G for females and at stages D–F for males. Additionally, they found significant differences between South Africans and Germans at stages E and G for females and at stages D and E for males.

Prieto et al. (29) analyzed 1054 OPTs of a Spanish population between 14 and 21 years of age. In comparison with this study, in stages C–G, the eastern Turkish sample was 1.18–3.37 years earlier for females and 0.70–2.87 years earlier for males. However, these developmental advances of eastern Turkish subjects continuously diminish in the following stages. At stage H (apex closure), Spanish females and males complete wisdom teeth mineralization 0.81 and 0.69 years earlier than the eastern Turkish sample, respectively. This difference may be attributed to their study sample being limited to 21 years of age compared to our sample (limited to 22 years of age). When our findings are compared with previous studies (Table 3), eastern Turkish male individuals were 2.27–3.38 years earlier in stages D–H than German samples, and eastern Turkish female individuals were 2.20–4.5 years earlier in stages D–H than German samples (13). Eastern Turkish females and males were 1.93–4.85 years and 2.27–4.95 years earlier than their Japanese

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

		German, Olze et al. (13)	Japanese, Olze et al. (13)	South African, Olze et al. (13)	Western Turkish, Orhan et al. (2)	Eastern Turkish, Our study
Stage	Gender	Mean	Mean	Mean	Mean	Mean
D	Male	16.30	18.20	15.08	14.50	13.23
	Female	15.50	18.00	15.11	15.20	13.30
E	Male	16.70	18.50	15.20	15.60	14.19
	Female	16.80	18.60	15.90	16.10	14.18
F	Male	18.30	20.40	18.70	16.90	15.66
	Female	19.10	20.50	21.30	17.00	15.65
G	Male	20.60	21.80	20.80	17.90	17.22
	Female	21.70	21.80	19.80	17.90	17.20
H	Male	22.70	22.70	22.60	20.10	20.43
	Female	23.00	22.40	22.40	20.00	20.47

counterparts, respectively (13). Eastern Turkish samples were 1.01–5.65 years earlier than the South African samples.

We observed a faster development of third molars in eastern Turkish males only at stages A, C, and D as described by Demirjian et al. (17). In contrast, some previous studies (11,27,29,30) reported faster development of third molars in males than females for all stages. Arany et al. (30) reported that males entered the stages earlier than females; a significant sex difference was observed in stages D, E, and G in the Japanese population. Prieto et al. (29) found a significant sexual dimorphism in stages E–G, with males reaching the stages earlier. Levesque and Tanguay (31) reported that Franco-Canadian males reach Demirjian's stages earlier than girls in stages F–H.

Statistical analysis shows almost the same correlation for males ($r^2 = 0.57$) and females ($r^2 = 0.56$). In agreement with our data, Liversidge (32) found that the mean age for most stages between Bangladeshi boys and girls was similar, except for crypt. On the other hand, Prieto et al. (29) and Sisman et al. (9) found stronger correlations for males ($r^2 = 0.54$; $r^2 = 0.65$, respectively) than for females ($r^2 = 0.45$; $r^2 = 0.61$, respectively). This diversity could be explained by the differences in the selected age range of the study populations. Additionally, a newly prepared equation for eastern Turkish children and adolescences using linear regression, proposed by Demirjian, will be very useful for forensic age determination through third-molar mineralization.

References

1. Olze A, Taniguchi M, Schmeling A, Zhu BL, Yamada Y, Maeda H, et al. Studies on the chronology of third molar mineralization in a Japanese population. Leg Med (Tokyo) 2004;6(2):73–9.
2. Orhan K, Ozer L, Orhan AI, Dogan S, Paksoy CS. Radiographic evaluation of third molar development in relation to chronological age among Turkish children and youth. Forensic Sci Int 2007;165(1):46–51.
3. Dekkers AJ, Noordam R. Less immigrants and more emigrants in 1988. Maandstat Bevolking 1989;37(9):23–8.
4. Buken B, Safak AA, Yazici B, Buken E, Mayda AS. Is the assessment of bone age by the Greulich-Pyle method reliable at forensic age estimation for Turkish children? Forensic Sci Int 2007;173(2–3):146–53.
5. Schmeling A, Olze A, Reisinger W, Geserick G. Age estimation of living people undergoing criminal proceedings Lancet 2001;10(9293): 1644–5.
6. Kreitner KF, Schweden FJ, Riepert T, Nafe B, Thelen M. Bone age determination based on the study of the medial extremity of the clavicle. Eur Radiol 1998;8(7):1116–22.
7. Tanner JM, Whitehouse RH, Marshall WA, Carter BS. Prediction of adult height from height, bone age, and occurrence of menarche, at ages 4 to 16 with allowance for midparent height. Arch Dis Child 1975;50(1):14–26.
8. Mornstad H, Pfeiffer H, Teivens A. Estimation of dental age using HPLC-technique to determine the degree of aspartic acid racemization. J Forensic Sci 1994;39(6):1425–31.
9. Sisman Y, Uysal T, Yagmur F, Ramoglu SI. Third-molar development in relation to chronologic age in Turkish children and young adults. Angle Orthod 2007;77(6):1040–5.
10. Reventlid M, Mornstad H, Teivens AA. Intra- and inter-examiner variations in four dental methods for age estimation of children. Swed Dent J 1996;20(4):133–9.
11. Thorson J, Hagg U. The accuracy and precision of the third mandibular molar as an indicator of chronological age. Swed Dent J 1991;15(1):15–22.
12. Harris EF. Mineralization of the mandibular third molar: a study of American blacks and whites. Am J Phys Anthropol 2007;132(1):98–109.
13. Olze A, Schmeling A, Taniguchi M, Maeda H, van Niekerk P, Wernecke KD, et al. Forensic age estimation in living subjects: the ethnic factor in wisdom tooth mineralization. Int J Legal Med 2004;118(3):170–3.
14. Uzamis M, Kansu O, Taner TU, Alpar R. Radiographic evaluation of third-molar development in a group of Turkish children. ASDC J Dent Child 2000;67(2):136–41.
15. http://www.allaboutturkey.com/eastern-anatolia.htm.
16. Celikoglu M, Cantekin K, Ceylan I. Dental age assessment: the applicability of Demirjian method in eastern Turkish children. J Forensic Sci 2011;56(Suppl. 1):S220–2.
17. Demirjian A, Goldstein H, Tanner JM. A new system of dental age assessment. Hum Biol 1973;45(2):211–27.
18. Schmeling A, Grundmann C, Fuhrmann A, Kaatsch HJ, Knell B, Ramsthaler F, et al. Criteria for age estimation in living individuals. Int J Legal Med 2008;122(6):457–60.
19. Moorrees CF, Fanning EA, Hunt EE Jr. Age variation of formation stages for ten permanent teeth. J Dent Res 1963;42:1490–502.
20. Kvaal SI, Kolltveit KM, Thomsen IO, Solheim T. Age estimation of adults from dental radiographs. Forensic Sci Int 1995;74(3):175–85.
21. Gleiser I, Hunt EE Jr. The permanent mandibular first molar: its calcification, eruption and decay. Am J Phys Anthropol 1955;13(2):253–83.
22. Kullman L, Johanson G, Akesson L. Root development of the lower third molar and its relation to chronological age. Swed Dent J 1992; 16(4):161–7.
23. Paewinsky E, Pfeiffer H, Brinkmann B. Quantification of secondary dentine formation from orthopantomograms—a contribution to forensic age estimation methods in adults. Int J Legal Med 2005;119(1):27–30.
24. Olze A, Taniguchi M, Schmeling A, Zhu BL, Yamada Y, Maeda H, et al. Comparative study on the chronology of third molar mineralization in a Japanese and a German population. Leg Med (Tokyo) 2003;5(Suppl. 1):S256–60.
25. Olze A, Mahlow A, Schmidt S, Wernecke KD, Geserick G, Schmeling A. Combined determination of selected radiological and morphological variables relevant for dental age estimation of young adults. Homo 2005;56(2):133–40.
26. Dhanjal KS, Bhardwaj MK, Liversidge HM. Reproducibility of radiographic stage assessment of third molars. Forensic Sci Int 2006;159 (Suppl. 1):S74–7.
27. Gunst K, Mesotten K, Carbonez A, Willems G. Third molar root development in relation to chronological age: a large sample sized retrospective study. Forensic Sci Int 2003;136(1–3):52–7.
28. Willershausen B, Loffler N, Schulze R. Analysis of 1202 orthopantograms to evaluate the potential of forensic age determination based on third molar developmental stages. Eur J Med Res 2001;6(9):377–84.
29. Prieto JL, Barberia E, Ortega R, Magana C. Evaluation of chronological age based on third molar development in the Spanish population. Int J Legal Med 2005;119(6):349–54.
30. Arany S, Iino M, Yoshioka N. Radiographic survey of third molar development in relation to chronological age among Japanese juveniles. J Forensic Sci 2004;49(3):534–8.
31. Levesque GY, Tanguay R. Sexual dimorphism in the development, emergence, and agenesis of the mandibular third molar. J Dent Res 1981;60:1735–41.
32. Liversidge HM. Timing of human mandibular third molar formation. Ann Hum Biol 2008;35(3):294–321.

Additional information and reprint requests:
Kenan Cantekin, D.D.S.
Department of Pediatric Dentistry
Faculty of Dentistry
Ataturk University
Erzurum
Turkey
E-mail: k_cantekin@hotmail.com