Assessment of correlation between chronological age and modified Demirjian estimated dental age

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Original Article

Abstract

BACKGROUND AND AIM: This study was designed to assess the correlation between chronological age and modified Demirjian estimated dental age.

METHODS: Panoramic radiographs of 183 Patients between 13.5 and 20.5 years old were assessed for the developmental stage of lower right third molars. Student's t-test was used to measure the same hypothesis of the chronological age and estimated modified Demirjian dental age described above and Pearson's correlation coefficient was used to measure the linear correlation between them.

RESULTS: The result of the test at a significance level of 95% led to the hypothesis. There was no significant difference between chronological age and estimated dental age measured by modified Demirjian method (P = 0.81). Pearson correlation coefficient between dental age in modified Demirjian's method and chronological age was calculated 40%.

CONCLUSION: The mean dental age in both male and female, was calculated 0.33 years less than chronological age.

KEYWORDS: Chronological Age; Demirjian's Method; Dental Age; Mandibular Third Molar

Estimating children's age plays a critical role in forensic medicine, endocrinology, pediatrics and clinical dentistry. Dental age is of critical importance particularly in diagnosis and planning of pediatric and orthodontic treatment procedures. Dental age of children may be assessed based on development of teeth in radiographic images. Assessment of dental developmental stages is more valuable than dental formation because the formation time is short and begins as soon as teeth begin to appear inside the mouth and can change by factors that may be local, like lack of space or systematic, like nutrition status.[1-4]

Several methods are suggested to determine dental evolution in radiography.[5,6] Among methods using dental calcification to determine dental age, the most common method in the world is Demirjian's technique.[6] It is based on calcification of permanent teeth in panoramic radiographic images. The method however has some limitations and weaknesses, such as requiring much time and accuracy in calculations, and using curves and diagrams, and the fact that it was originally developed for people of Canadian decent.[6-11] Moreover, the method resulted in overestimation in research works undertaken in various countries. Since the

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publication of reports on dental age determination by the technique of Demirjian et al., other methods have been developed by Nolla,[12] Galic et al.,[13] Willems et al.,[14] and Cameriere et al.[15] The problem with dental age determination through Demirjian method emerges when nearly all roots of the patient's permanent teeth have already evolved and the technique has to focus on the patient's wisdom teeth (third molar). Based on previous studies, modified Demirjian's method has the best accuracy, reliability and inter- and intra-observer agreement.[16,17]

Modified Demirjian technique is a perfect technique to estimate dental age radiologically. Radiographic analysis of third molar development allows to estimate age in a range of 9-23 years, because crown and root development can be studied regardless of eruption. The third molar is of particular interest because (a) it is the last and most variable tooth to form and (b) it is the only tooth to be completely formed after puberty, which has made it attractive in forensic and legal circles as an estimator of adulthood.[18]

The modified Demirjian method was studied in various populations and its application resulted in differences between various races.[8,19,20] As similar studies were already undertaken in other countries, this study was focused on evolutional stages of modified Demirjian technique on third molar teeth.

Methods

Ethical approval of this study was granted by the Shahid Sadoughi University of Medical Sciences, Yazd, Iran (IR.SSU.REC.1395.81). The present study was a retrospective review of 284 panoramic radiographs of orthodontics patients referring to a state-run dentistry clinic (Khatam al-Anbia dental clinic, Yazd, in 2016). Radiographs showing developmental/evolutionary problems, lacking third molars or those with invisible third molars were totally eliminated from the study. Dental age was estimated by modified Demirjian method using right third molars.

Panoramic radiographs of acceptable quality and clarity which were showing at least the lower-right third molars were chosen. Estimation of dental age was also performed on all existing third molars of patients.

Chronological age of patients was collected from their medical files, taking into account their month of birth and by subtracting the radiography date from the birth date. Dental age was calculated by modified Demirjian method for lower-right third molars (Figure 1).[21]


Figure 1. Developmental stages of third molar roots based on modified Demirjian's method

SPSS (version 18, SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Kolmogorov-Smirnov test was used to verify data normality hypothesis. Average difference between dental and chronological ages was calculated for all ages. T-test was used for comparison between groups. A reliability level of 95% was considered for all of the tests used in this study.

To verify the repeatability of the analyses, 83 of the panoramic radiographs were

Table 1. Descriptive data on estimated dental age by modified Demirjian method and chronological age of studied population

	Number	Chronological age	Dental age	Chronological age	Dental age	Chronological age	Dental age
		Minimum		Maximum		Mean ± SD	
Total	183	13.5	13.75	20.58	19.5	17.21 ± 1.17	16.88 ±1.08
Female	126	13.5	13.75	20.58	19.5	17.20 ± 1.18	16.90 ± 1.14
Male	57	13.5	13.95	19.50	18.4	17.24 ± 1.13	16.80 ± 0.95

SD: Standard deviation

randomly chosen and examined 1 month later by oral and maxillofacial radiology experts. Kappa agreement coefficient was employed to test the agreement of old and new dental ages.

Results

A number of 183 panoramic radiographs belonging to legible Iranian young adults met the inclusion criteria. Kappa agreement coefficient of this study was 0.82 showing a good level. In other words, reliability of the first round of estimation was confirmed by the second analysis of the samples.

Distribution of sex and mean/minimum/maximum chronological age of studied patients and dental age by modified Demirjian method are presented in table 1.

Mean estimated dental age by modified Demirjian method was 0.33 year (about 4 months) less than the chronological age. Table 2 presents data on difference of chronological and estimated dental age by modified Demirjian method.

T-tests were used to examine the significant difference between chronological age and estimated dental age by modified Demirjian method. T-tests were also used to study the effect of sex on age estimation, and no difference was observed between the two sexes in estimated dental ages, showing that sex did not affect age estimation by modified Demirjian method (P = 0.95).

Pearson's correlation coefficient test was used to look for a linear correlation between estimated dental age by modified Demirjian method on lower and upper third molars and the chronological age of the patients. The calculated value was 40%. The ratio between estimated dental age and chronological age was 29% for male and 32% for female patients. Figure 2 provides a comparison between chronological and estimated dental age by modified Demirjian method based on sex of patients.

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Table 2. Difference of mean, minimum and maximum of chronological and estimated dental age by modified Demirjian method

	Number	Minimum	Maximum	Mean ± SD	P
Difference of chronological and dental age	183	-0.25	1.08	0.33 ± 1.7	0.81

SD: Standard deviation

Table 3. Pearson correlation coefficients between 4 studied teeth

	LR	LL	UL	UR
LR Pearson correlation (n = 183)	1	0.880[*]	0.753[*]	0.706[*]
N	183			176
P	< 0.001	< 0.001	< 0.001	< 0.001
LL Pearson correlation	0.880*	1	0.760[*]	0.750[*]
N	178	178	171	173
P	< 0.001	< 0.001	< 0.001	< 0.001
UL Pearson correlation	0.753[*]	0.760[*]	1	0.909[*]
N	174	171	175	174
P	< 0.001	< 0.001	< 0.001	< 0.001
UR Pearson correlation	0.706[*]	0.750[*]	0.909[*]	1
N	176	173	174	177
P	< 0.001	< 0.001	< 0.001	< 0.001

LR: Lower-right; LL: Lower-left; UL: Upper-left; UR: Upper-right
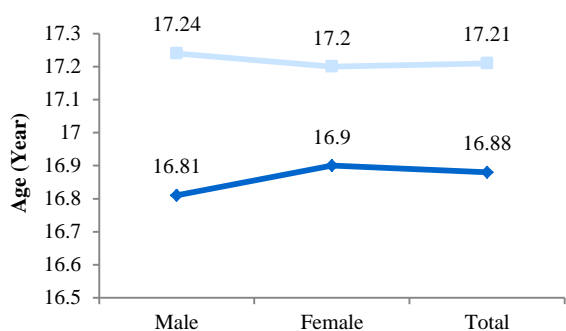[*]Correlation is significant at the 0.01 level (2-tailed)

Figure 2. Sex-based comparison between chronological and modified Demirjian method estimated dental age

Figure 2 shows that the modified Demirjian estimated dental age provided a lower age average in comparison to chronological age.

Correlation coefficient of estimated dental age for lower-left (LL), lower-right (LR), upper-left (UL), and upper-right (UR) third molars are provided in table 3. Maximum correlation was reported for upper-left and upper-right third molars. Minimum value was calculated for upper-right and lower-right third molars, which was 0.706. Value of P for all variables in table 3 was < 0.001 at a significance level of 90%, indicating an acceptable correlation assumptions between the two variables.

Based on the present study using linear regression, the formula for calculating chronological age from estimated dental age is as follows:

Table 4 is regression model for Sex-Free.

Sex-free linear regression model: y = 10.384 + 0.39x

Table 5 is Regression model for female.

Female linear regression model: y = 9.611 + 0.433x

Table 6 is Regression model for male.

Male linear regression model: y = 8.033 + 0.53x

Using regression models to predict the exact chronological age, we can use this model to predict Dmirjian method based on the estimated age.

Discussion

The highest level of reliability in dental age determination will be achieved when the evolving teeth are used for the process. Teeth

Table 4. Sex-free linear regression model

Coefficients[*]					
Model		Unstandardized coefficients		Standardized coefficients	t	P
		B	Standard error	Beta		
1	Constant	10.384	1.696	-	6.124	< 0.001
	Mean	0.391	0.100	0.395	3.891	< 0.001

[*]Dependent variable: age

Table 5. Female linear regression model

Coefficients[*]					
Model	Unstandardized coefficients		Standardized coefficients	t	P
	B	Standard error	Beta		
1 Constant	9.611	1.979	-	4.857	< 0.001
Mean	0.433	0.117	0.445	3.714	< 0.001

[*]Dependent variable: age

are the most resistant parts of human body with the lowest turn-over rate. Also, teeth are less sensitive to nutritional, hormonal and pathological factors.[22] In comparison to other teeth, third molars are the most used ones in forensic dentistry because they evolve slower and at later ages.[23] In terms of dental maturity, third molars are the only teeth that allow accurate dental determination after the age of 16 years.[24] On the other hand, panoramic radiography is one of the best tools for evaluation of dental calcification due to its potential in showing a wide range of facial and dental bones.[25] Thus, this paper is focused on determining chronological age and dental evolution phases of third molars by modified Demirjian technique on panoramic radiography images.

We found a significant linear correlation between chronological age and dental age of all four third molar teeth (based on Demirjian), a finding that is in line with other studies.[26-33]

In our study, the highest correlation coefficient was between UR and UL and also between LR and LL with rates of 91 and 88 percent. The correlation coefficient for UL/UR was 98% for men and the same for LL/LR in women was 85.8%.

Based on different studies, the highest correlation coefficient between dental and chronological age was reported between UR/UL and LR/LL.[29,34-36]

Moreover, in the work of Bagherpour et al.

on an Iranian population using Gleiser and Hunt method modified by Kohler, dental age of UR/UL showed the highest correlation, similar to the present study.[37] But studies of Rai et al. with modified Demirjian method on an Iranian population of 10-27 years found the highest correlation between LL/UL teeth which was 94%.[26] The difference may be related to the differences in the age range of the studied population, as in the present study a range of 13-21 years was used.

In our study, the highest correlation between dental and chronological age was found for UR, LR, LL and UL teeth at rates of 40.2, 39.2, 37.3 and 35.2 percent. In the study by Ezoddini et al. the highest rate of correlation between dental and chronological age was found for LR, LL and UR at rates of 23.9, 24.5 and 39.4 percent, similar to ours.[38] But in the study by Monirifard et al. the highest correlation between dental and chronological age was in LL for men and LR for women.[25]

We found a significant linear correlation between ages of left and right third molars which means that the ages estimated separately by these teeth were approximately the same.

In the works of Lopez et al.,[39] Orhan et al.,[29] Meinl et al.,[35] and Darji et al.,[33] there was no significant difference in the age of linear correlation between the third molars of both jaws. The coefficient was acceptable although not so large (32.9%).

Table 6. Male linear regression model

Coefficients[*]					
Model	Unstandardized coefficients		Standardized coefficients	t	P
	B	Standard error	Beta		
1 Constant	8.033	3.514	-	2.286	< 0.032
Mean	0.530	0.208	0.476	2.540	< 0.019

[*]Dependent variable: age

According to Olze et al.[40] and Li et al.,[41] there was no significant difference in the evolution of higher and lower third molars, but according to Gunst et al.[36] and Darji et al.,[33] maxillary third molar evolved a little quicker than the mandibular.

In the present study, the average estimated age by Demirjian method was underestimated compared to the average chronological age by a factor of 0.33 years, which is in line with several other studies,[24,30,38,42] while some other studies reported overestimation of age by Demirjian method.[1,43,44] The differences may be related to racial diversities among studied populations.

According to the present study using Demirjian method, no significant difference was observed in age estimation of the two sexes, a finding in line with that of several other studies.[27,29,33,44,45] However, there are many studies reporting significant differences in evolution of third molars between the two sexes.[23,32,35,36,38,39,46]

Effectiveness of age estimation is usually measured with mean absolute error (MAE), calculated by deducting the chronological age from the dental age. A positive result indicates overestimation, while a negative result points to underestimation.[28] In this study, the average MAE was -0.33 for all participants: -0.43 for men, and -0.3 for women. In the study by Khorate et al.,[28] the average MAEs for all participants, men and women by Demirjian method were 2.32, 2.25 and 2.29 respectively. His works also reported the lowest MAE for women. The difference in MAE between the present study and that of Khorate et al. may be due to differences in race and age range of studied population in the latter study (4-22 years).[28]

Conclusion

There was a significant linear correlation between the chronological age and dental age of all four third molar teeth, and also between ages of left and right third molars in our study.

Using modified Demirjian method, we did not observe any significant difference in age estimation of the two sexes. The average estimated age by modified Demirjian method was underestimated compared to the average chronological age by a factor of 0.33 years.

Conflict of Interests

Authors have no conflict of interest.

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References

1. Koshy S, Tandon S. Dental age assessment: the applicability of Demirjian's method in south Indian children. Forensic Sci Int 1998; 94(1-2): 73-85.
2. Eid RM, Simi R, Friggi MN, Fisberg M. Assessment of dental maturity of Brazilian children aged 6 to 14 years using Demirjian's method. Int J Paediatr Dent 2002; 12(6): 423-8.
3. Moorrees Cf, Fanning Ea, Hunt EE Jr. Age variation of formation stages for ten permanent teeth. J Dent Res 1963; 42: 1490-502.
4. Infante PF, Owen GM. Relation of chronology of deciduous tooth emergence to height, weight and head circumference in children. Arch Oral Biol 1973; 18(11): 1411-7.
5. McGregor IA, Thomson AM, Billewicz WZ. The development of primary teeth in children from a group of Gambian villages, and critical examination of its use for estimating age. Br J Nutr 1968; 22(2): 307-14.
6. Demirjian A, Goldstein H, Tanner JM. A new system of dental age assessment. Hum Biol 1973; 45(2): 211-27.
7. Liversidge HM, Speechly T, Hector MP. Dental maturation in British children: Are Demirjian's standards applicable? Int J Paediatr Dent 1999; 9(4): 263-9.
8. Mornstad H, Reventlid M, Teivens A. The validity of four methods for age determination by teeth in Swedish children: a multicentre study. Swed Dent J 1995; 19(4): 121-30.
9. Mani SA, Naing L, John J, Samsudin AR. Comparison of two methods of dental age estimation in 7-15-year-old Malays. Int J Paediatr Dent 2008; 18(5): 380-8.
10. Nykanen R, Espeland L, Kvaal SI, Krogstad O. Validity of the Demirjian method for dental age estimation when applied to Norwegian children. Acta Odontol Scand 1998; 56(4): 238-44.

11. Demirjian A, Goldstein H. New systems for dental maturity based on seven and four teeth. Ann Hum Biol 1976; 3(5): 411-21.
12. Nolla CM. The development of permanent teeth. J Dent Child 1960; 27(4): 254-66.
13. Galic I, Vodanovic M, Cameriere R, Nakas E, Galic E, Selimovic E, et al. Accuracy of cameriere, haavikko, and willems radiographic methods on age estimation on Bosnian-Herzegovian children age groups 6-13. Int J Legal Med 2011; 125(2): 315-21.
14. Willems G, Van Olmen A, Spiessens B, Carels C. Dental age estimation in Belgian children: Demirjian's technique revisited. J Forensic Sci 2001; 46(4): 893-5.
15. Cameriere R, Ferrante L, Cingolani M. Age estimation in children by measurement of open apices in teeth. Int J Legal Med 2006; 120(1): 49-52.
16. Chaillet N, Demirjian A. Dental maturity in South France: A comparison between Demirjian's method and polynomial functions. J Forensic Sci 2004; 49(5): 1059-66.
17. Leurs IH, Wattel E, Aartman IH, Etty E, Prahl-Andersen B. Dental age in Dutch children. Eur J Orthod 2005; 27(3): 309-14.
18. Thevissen PW, Pittayapat P, Fieuws S, Willems G. Estimating age of majority on third molars developmental stages in young adults from Thailand using a modified scoring technique. J Forensic Sci 2009; 54(2): 428-32.
19. Nystrom M, Haataja J, Kataja M, Evalahti M, Peck L, Kleemola-Kujala E. Dental maturity in Finnish children, estimated from the development of seven permanent mandibular teeth. Acta Odontol Scand 1986; 44(4): 193-8.
20. Davis PJ, Hagg U. The accuracy and precision of the "Demirjian system" when used for age determination in Chinese children. Swed Dent J 1994; 18(3): 113-6.
21. Liversidge HM, Marsden PH. Estimating age and the likelihood of having attained 18 years of age using mandibular third molars. Br Dent J 2010; 209(8): E13.
22. Panchbhai AS. Dental radiographic indicators, a key to age estimation. Dentomaxillofac Radiol 2011; 40(4): 199-212.
23. 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.
24. Gandhi N, Jain S, Kumar M, Rupakar P, Choyal K, Prajapati S. Reliability of third molar development for age estimation in Gujarati population: A comparative study. J Forensic Dent Sci 2015; 7(2): 107-13.
25. Monirifard M, Yaraghi N, Vali A, Vali A, Vali A. Radiographic assessment of third molars development and it's relation to dental and chronological age in an Iranian population. Dent Res J (Isfahan) 2015; 12(1): 64-70.
26. Rai B, Kaur J, Jafarzadeh H. Dental age estimation from the developmental stage of the third molars in Iranian population. J Forensic Leg Med 2010; 17(6): 309-11.
27. Kedarisetty SG, Rao GV, Rayapudi N, Korlepara R. Evaluation of skeletal and dental age using third molar calcification, condylar height and length of the mandibular body. J Forensic Dent Sci 2015; 7(2): 121-5.
28. Khorate MM, Dinkar AD, Ahmed J. Accuracy of age estimation methods from orthopantomograph in forensic odontology: a comparative study. Forensic Sci Int 2014; 234: 184-8.
29. 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.
30. Mohammed RB, Koganti R, Kalyan SV, Tircouveluri S, Singh JR, Srinivasulu E. Digital radiographic evaluation of mandibular third molar for age estimation in young adults and adolescents of South Indian population using modified Demirjian's method. J Forensic Dent Sci 2014; 6(3): 191-6.
31. Ajmal M, Assiri KI, Al-Ameer KY, Assiri AM, Luqman M. Age estimation using third molar teeth: A study on southern Saudi population. J Forensic Dent Sci 2012; 4(2): 63-5.
32. Naik SB, Patil SN, Kamble SD, Mowade T, Motghare P. Reliability of Third Molar Development for Age Estimation by Radiographic Examination (Demirjian's Method). J Clin Diagn Res 2014; 8(5): ZC25-ZC28.
33. Darji J, Govekar G, Kalele S, Hariyani H. Age estimation from third molar development a radiological study. J Indian Acad Forensic Med 2011; 33: 130-4.
34. Mohtavipour ST, Mohtavipour SS, Refahi M. Radiographic evaluation of third molar development in relation to chronological age in Gilani children and adolescents. J Isfahan Dent Sch 2011; 7(1): 14-23. [In Persian].
35. Meinl A, Tangl S, Huber C, Maurer B, Watzek G. The chronology of third molar mineralization in the Austrian population-a contribution to forensic age estimation. Forensic Sci Int 2007; 169(2-3): 161-7.
36. 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.
37. Bagherpour A, Anbiaee N, Partovi P, Golestani S, Afzalinasab S. Dental age assessment of young Iranian adults using third molars: A multivariate regression study. J Forensic Leg Med 2012; 19(7): 407-12.
38. Ezoddini Ardakani F, Navab Aazam A, Bashardoost N, Mansoorian H, Ahmadieh MH, Sadat Hosseni SA. Correlation between chronological, skeletal, and dental age on panoramic radiography in patients referred to Yazd dental clinics on 2004-05. J Dent Sch Shahid Beheshti Univ Med Sci 2006; 24(4): 474-84. [In Persian].

39. Lopez TT, Arruda CP, Rocha M, Rosin AS, Michel-Crosato E, Biazevic MG. Estimating ages by third molars: stages of development in Brazilian young adults. J Forensic Leg Med 2013; 20(5): 412-8.
40. 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.
41. Li G, Ren J, Zhao S, Liu Y, Li N, Wu W, et al. Dental age estimation from the developmental stage of the third molars in western Chinese population. Forensic Sci Int 2012; 219(1-3): 158-64.
42. Rai B, Anand SC. Tooth developments: an accuracy of age estimation of radiographic methods. World Journal of Medical Sciences 2006; 1(2): 130-2.
43. Hegde RJ, Sood PB. Dental maturity as an indicator of chronological age: radiographic evaluation of dental age in 6 to 13 years children of Belgaum using Demirjian methods. J Indian Soc Pedod Prev Dent 2002; 20(4): 132-8.
44. Prabhakar AR, Panda AK, Raju OS. Applicability of demirjian's method of age assessment in children of davangere. J Indian Soc Pedod Prev Dent 2002; 20(2): 54-62.
45. Lewis AJ, Boaz K, Nagesh KR, Srikant N, Gupta N, Nandita KP, et al. Demirjian's method in the estimation of age: A study on human third molars. J Forensic Dent Sci 2015; 7(2): 153-7.
46. Kanmani R, Srinivasan SV, Jonathan DM. Mandibular third molar development as an indicator of chronological age for a pondicherry population of southern India. J Dent 2012; 2(2): 153-8.