Original Article

Assessment of the mineralisation stages of third molars and validation of Mincer *et al.*'s age estimation method: A retrospective, cross-sectional study in Western India population

Jayasankar P. Pillai, Vaishali Dodia[1], Pooja Monpara[2], Khushali Shah[3], Sima Odedra

Department of Oral Pathology, Govt. Dental College and Hospital, Ahmedabad, Gujarat, [1]Associate Dentist, Shri Ramakrishna Ashrama Medical Center, Rajkot, Gujarat, [2]Dental Officer, Swadeep Foundation, Rajula, Gujarat, [3]Department of Oral Pathology, K.M. Shah Dental College and Hospital, Sumandeep University, Vadodara, Gujarat, India

Abstract

Context: Age estimation is one of the prime requisites in forensic human identification cases and the criminal justice system. There are several age estimation methods using dental parameters. A method proposed by Mincer *et al*. which uses the mineralization stages of third molars based on Demirjian's developmental stages is less tested in the Indian population.

Aim: The present study aimed to assess the developmental status of the third molars and to apply and validate Mincer *et al*.'s method on the Western India population.

Methods and Material: A total of 306 orthopantomograms (OPGs) from 128 males and 178 females with a mean age of 16.89 years ± 3.68 were analysed. Demirjian's A-H staging was applied to record the developmental stages of 1100 third molars. Mincer *et al*.'s mean age of attainment was applied based on the American Whites (Caucasian) population for males and females separately using stages of #18 and #38.

Results: There was a slight overestimation of the chronological age (CA) in both #18 and #38. The females showed more accurate estimated age (EA) than males.

Conclusions: Mincer *et al*.'s method is a convenient age estimation method using the third molar's developmental stage. The mean age of attainment mentioned in the original Mincer *et al*.'s study can be used in the Western Indian population, with a residual value ranging from 0.21 to 0.25 years.

Keywords: Age estimation, Demirjian's staging, Mincer *et al*.'s method, third molar

Address for correspondence: Dr. Jayasankar P. Pillai, Department of Oral Pathology, Govt. Dental College and Hospital, Ahmedabad - 380 016, Gujarat, India.
E-mail: jppillaigdch@gmail.com
Submitted: 30-Jun-2023, **Revised:** 09-Oct-2023, **Accepted:** 10-Oct-2023, **Published:** 20-Dec-2023

INTRODUCTION

The dental age estimation methods apply the radiological,[1,2] morphological,[3,4] histological[5-7] and biochemical[8,9] parameters of teeth to estimate the age. The radiological method involves the assessment of the mineralisation status of both the erupted and unerupted teeth.[10] Demirjian's method using the graded developmental stages of teeth is one of the most widely followed radiographic dental age

Access this article online

Quick Response Code:

Website: https://journals.lww.com/JPAT/

DOI: 10.4103/jomfp.jomfp_292_23

How to cite this article: Pillai JP, Dodia V, Monpara P, Shah K, Odedra S. Assessment of the mineralisation stages of third molars and validation of Mincer *et al*.'s age estimation method: A retrospective, cross-sectional study in Western India population. J Oral Maxillofac Pathol 2023;27:748-53.

estimation methods.[11] Several population-based studies have validated this method.[12-14] Chronologically, the third molar is the only tooth that is developing till the age of 25 years.[15] On average, the apex closure of the third molar occurs at the mean age of 21.96 years.[16] Thus, the developmental status of third molars becomes the prime importance during the age assessment process in legal cases determining the juvenility status.[17] Mincer *et al.* adopted Demirjian's original method of scoring the calcification stages from A to H [Figure 1] for all the third molars using orthopantomograms (OPGs).[18] This radiographic method has been applied on South Indian population to validate the method and derive an India-specific regression equation.[19] But there is hardly any validation study on Mincer *et al.*'s method in the Western Indian population. Hence, the present study was conducted to assess the mineralisation stages of third molars and validate Mincer *et al.*'s method using OPGs from the Western part of India.

SUBJECTS AND METHODS

The development of the third molars was assessed using data from digital OPGs collected as part of the principal author's ongoing comparative age estimate study. The procedures followed both the ethical norms of the responsible committee on human experimentation and the principles of the 1975 Helsinki Declaration, and were approved by the institutional ethics committee [No. IEC GDCH/S.3/2021 dated 24/03/2021]. The study subjects were provided a document detailing the objectives of the investigation and their roles in the study, in the local language and their written consents were obtained. The sample size was determined using the Fisher's formula.[20] A total of 350 OPGs were collected for this study. Out of which only 306 OPGs showed clear visibility of third molars in one or more quadrant and that had records of the actual date of birth (DoB) and date of radiographs (DoX) which were considered for further evaluation. If all the 306 OPGs third molars in all the four quadrants were considered, then there would be 1224 third molars for evaluation. But there were 124 OPGs where the third molar was missing in at least one quadrant. Hence only 1110 third molars were considered for the evaluation of their development stages [Figure 2]. The maturation stages of the third molars were noted based on the Demirjian's stages given in 1973.[11] For estimating the age, the upper right third molar (#18) and lower left third molar (#38) were selected. Those third molars having stage D and above

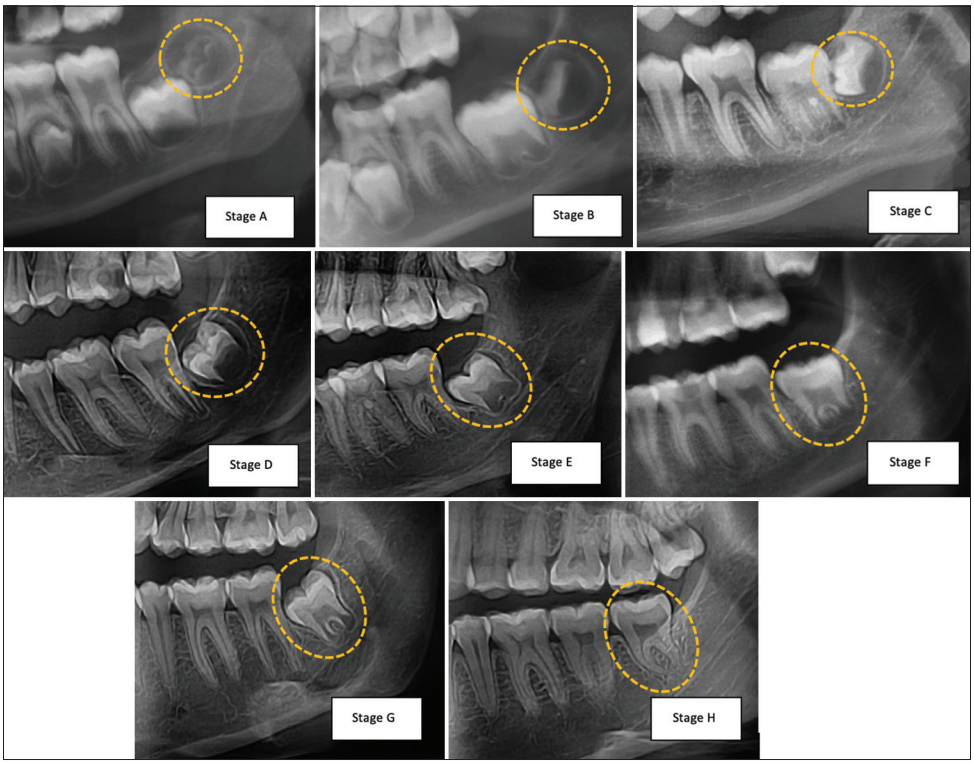

Figure 1: The figure showing the stages of third molar development according to Demirjian's A-H staging. (Stage A- Cusp tips have mineralised but not yet coalesced; Stage B- Mineralized cusp tips are united so the mature coronal morphology is well-defined; Stage C- Crown is ½ formed, the pulp chamber is evident and dentinal deposition is occurring; Stage D- Crown formation is complete to the dentino-enamel junction. The pulp chamber has a trapezoidal form; Stage E- Formation of the inter-radicular bifurcation has begun. Root length is less than the crown length; Stage F- Root length is at least as great as crown length. Roots have funnel-shaped endings; Stage G- Root walls are parallel, but apices remain open; Stage H-Apical ends of the roots are completely closed, and the periodontal membrane has a uniform width around the root.)

were considered for estimating the age. The mean age of attainment of these third molar's crown-root maturity stage was noted down from table given in Mincer *et al.*'s original study.[18]

Statistical analysis

The computer program JASP Version 0.16.1 (JASP Team 2022, University of Amsterdam, Netherlands) was used to carry out the statistical analysis. Third molar development between sides and between arches was correlated using the nonparametric Spearmen's correlation coefficient. Third molar development stages were compared using the Mann-Whitney U test, and mean estimated ages (EAs) between sexes were compared using the unpaired *t*-test. The paired test was used to compare #18 and #38's chronological age (CA) and EA. The significance threshold was kept at 5% ($P < 0.05$).

RESULTS

The data of 306 OPGs from 128 males (41.8%) and 178 females (58.2%) with a mean age of 16.89 years ± 3.68 was used in this study. The development stages of only 1100 third molars were considered in the study. The stage-wise distribution of the third molars in all the quadrants is shown in Table 1. In nearly 61% of the overall sample, the third molars were demonstrating the root formation stages (stages E-H) and out of which the root apex closure completed in 43.4% of cases. The Mann-Whitney U test revealed a significant sex difference in the stages for upper and lower third molars in the study sample [Table 2]. The comparisons of the stages of third molar development between sides and between arches revealed a significant correlation and an insignificant difference in all possible pairs of third molars [Table 3]. There were 208 and 223 OPGs which showed stage D

Table 1: The table showing the stage-wise distribution of third molars in the study samples

Dev. stage	#18*		#28*		#38*		#48*		Total	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
A	2	0.65	0	0.00	11	3.60	10	3.27	23	2.09
B	19	6.21	20	6.54	12	3.92	11	3.60	62	5.64
C	21	6.86	24	7.84	48	15.69	53	17.32	146	13.27
D	60	19.61	68	22.22	38	12.42	33	10.78	199	18.09
E	13	4.25	16	5.23	40	13.07	42	13.73	111	10.09
F	26	8.50	25	8.17	23	7.52	22	7.19	96	8.73
G	39	12.75	39	12.75	46	15.03	48	15.69	172	15.64
H	70	22.88	70	22.88	76	24.84	75	24.51	291	26.45

*Tooth numbering in FDI system

Table 2: The table showing the stage-wise distribution of all four third molars in male and female subjects. (*n*=306)

Stage	#18				#28			
	Male		Female		Male		Female	
	n	%	*n*	%	*n*	%	*n*	%
A	2	1.56	0	0.00	0	0.00	0	0.00
B	13	10.16	6	3.37	16	12.50	4	2.25
C	12	9.38	9	5.06	13	10.16	11	6.18
D	29	22.66	31	17.42	28	21.88	40	22.47
E	3	2.34	10	5.62	7	5.47	9	5.06
F	6	4.69	20	11.24	6	4.69	19	10.67
G	17	13.28	22	12.36	14	10.94	25	14.05
H	27	21.09	43	24.16	30	23.44	40	22.47
Missing	19	14.84	37	20.79	14	10.94	30	16.85
Total	128	100.00	178	100.00	128	100.00	178	100.00
Sig.*	0.013				0.033			
	#48				#38			
Stage	Male		Female		Male		Female	
	n	%	*n*	%	*n*	%	*n*	%
A	3	2.34	7	3.93	3	2.34	8	4.49
B	7	5.47	4	2.25	6	4.69	6	3.37
C	28	21.88	25	14.05	26	20.31	22	12.36
D	16	12.50	17	9.55	19	14.84	19	10.67
E	14	10.94	28	15.73	13	10.16	27	15.17
F	11	8.59	11	6.18	8	6.25	15	8.43
G	16	12.50	32	17.98	19	14.84	27	15.17
H	31	24.22	44	24.72	30	23.44	46	25.84
Missing	2	1.56	10	5.62	4	3.13	8	4.49
Total	128	100.00	178	100.00	128	100.00	178	100.00
Sig.*	0.160				0.241			

*Mann-Whitney *U* test, Significant at $P<0.05$

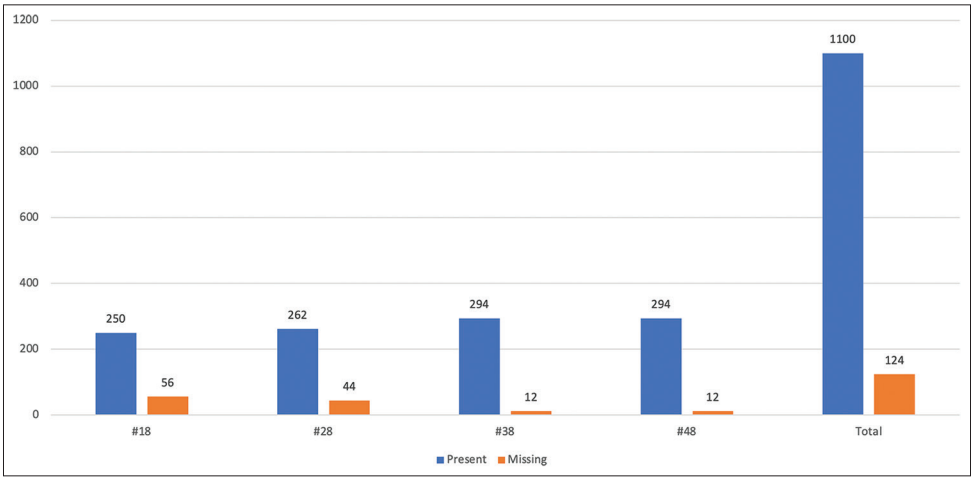

Figure 2: The graph showing the frequency distribution of third molars in all the quadrants in the study sample

and above in #18 and #38, respectively. On application of Mincer *et al.*'s mean value in #18 and #38, it was observed that the overall mean difference between CA and EA was 0.21 years ± 2.08 and 0.25 years ± 1.84 using the #18 [Figure 3] and #38 [Figure 4], respectively. There was a slight overestimation of the CA in both the teeth, but the difference was significant only in #38 [Table 4]. There were 191 OPGs with both #18 and #38 in their developing status in stage D and above. In this sample, only the overall sample using #38 was showing a significant difference between CA and EA [Table 5]. There was symmetry in the stages between #18 and #38 in 59.2% of 191 cases.

DISCUSSION

The present study assessed the third molar development stages and the precision of Mincer *et al.*'s approach in age estimation. A sample of 306 patients was supposed to have 1224 third molars; however, 124 OPGs (10.1%) showed missing of at least one third molar. Hence, the data from the remaining 1100 third molars were evaluated. The quadrant-wise quantification of the third molars in all 306 OPGs showed the presence of third molars in one or more quadrants in 233 (76.14%) cases. While stages D and above were taken into account in Mincer *et al.*'s original study, the data for stages A–C were not taken into account in the present study. The estimation of age was done using the stages of #18 and #38 and by applying the mean age of attainment as given by Mincer *et al.*'s original study. By applying Mincer *et al.*'s method to both teeth, it was shown that the CA was overstated. A comparable overestimation of CA using Demirjian's approach in the Indian population has also been documented in research.[21] A meta-analysis of published articles on Demirjian's method has reported an overestimation of ages in either sex.[22]

The staging in #18 and #38 in the present study considerably varied between males and females. The crown formation is more advanced in males, and the root formation is advanced in females. However, another study in the South Indian population reported a significant difference at calcification stages F and G in maxillary third molars and stage F in mandibular third molars ($P < 0.05$) between male and female subjects.[12] In Hispanic males, the developmental stages in third molars are faster than in Hispanic females, and maxillary third molars reach developmental stages faster than mandibular third molars in both sexes.[21] The present study did not report the stage-wise difference between males and females.

In the present study, the maxillary third molars are advanced in stages when compared to the mandibular molars. In a

Table 3: Table showing the results of pair-wise comparison of developmental stages of third molars in the same and opposite arches

Pair (FDI system)	*n*	Spearman's Correlation		Wilcoxon Signed-rank test	
		Coefficient	Sig.	*Z*	Sig*.
#18 - #28	244	0.96	<.001	0.213	0.823
#18 - #38	244	0.887	<.001	-0.827	0.379
#18 - #48	245	0.905	<.001	-1.293	0.164
#28 - #38	256	0.909	<.001	-0.997	0.282
#28 - #48	256	0.917	<.001	-1.457	0.111
#38 - #48	284	0.975	<.001	-0.957	0.310

*Significant at $P<0.05$

Table 4: Table showing the results of the descriptive statistics of chronological age and estimated age using #18 and #38 in both sexes

Age (Yrs.)	#18			#38		
	Male (*n*=82)	Female (*n*=126)	Total (*n*=208)	Male (*n*=89)	Female (*n*=134)	Total (*n*=223)
	Mean (SD)					
Chronological age (CA)	17.75 (3.11)	18.25 (3.00)	18.05 (3.05)	17.82 (3.08)	18.53 (2.83)	18.25 (2.95)
Estimated age (EA)	17.99 (1.77)	18.45 (1.82)	18.27 (1.81)	18.23 (1.88)	18.68 (1.88)	18.5 (1.89)
Difference (EA-CA)	0.24 (2.03)	0.19 (2.12)	0.21 (2.08)	0.4 (1.86)	0.15 (1.84)	0.25 (1.85)
Sig*.	0.291	0.308	0.145	0.044	0.362	0.046
Correlation (*r*)	0.789	0.715	0.746	0.825	0.768	0.794

*significant at $P<0.05$; SD=Standard Deviation

Table 5: Table showing the results of the descriptive statistics of chronological age and estimated age from 191 OPGs with both #18 and #38

Age (Yrs.)	#18			#38		
	Male (*n*=76)	Female (*n*=115)	Total (*n*=191)	Male (*n*=76)	Female (*n*=115)	Total (*n*=191)
	Mean (SD)					
Chronological age	17.96 (3.08)	18.48 (2.86)	18.27 (2.95)	17.96 (3.08)	18.48 (2.86)	18.27 (2.95)
Estimated age (EA)	18.13 (1.75)	18.57 (1.78)	18.39 (1.78)	18.32 (1.83)	18.75 (1.86)	18.58 (1.85)
Difference	0.18 (2.02)	0.09 (2.12)	0.12 (2.08)	0.36 (1.9)	0.27 (1.85)	0.3 (1.87)
Sig*.	0.451	0.658	0.415	0.104	0.126	0.026
Correlation (*r*)	0.786	0.672	0.72	0.816	0.771	0.791

*significant at $P<0.05$; SD=Standard Deviation

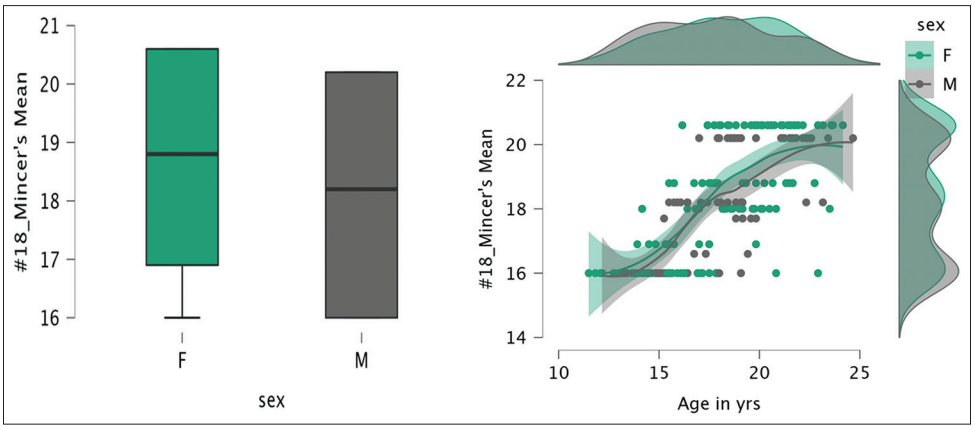

Figure 3: The box plate and scatter plot images of the mean chronologic age and mean estimated age using Mincer et al's method in upper right third molar (#18)

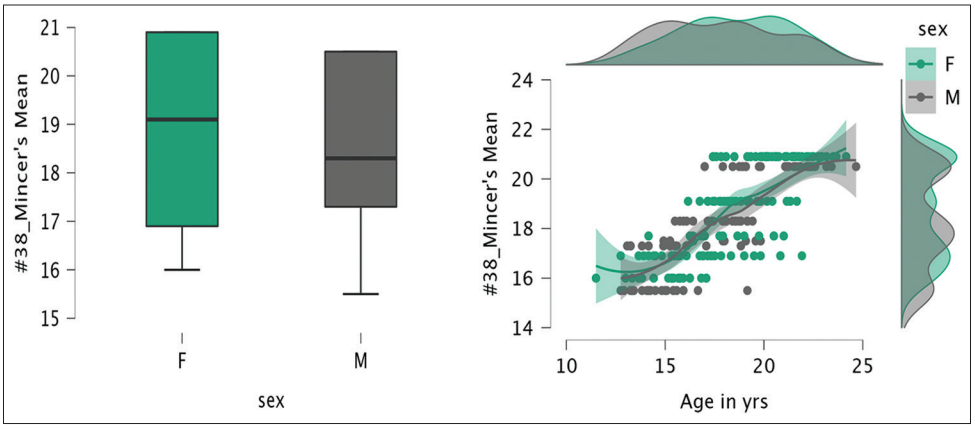

Figure 4: The box plate and scatter plot images of the mean chronologic age and mean estimated age using Mincer et al.'s method in lower left third molar (#38)

Chilean study also, the maxillary third molars reached all the stages of development much earlier than the mandibular third molar.[23] This result is in accordance with a study of the Danish population. But the Danish study scored the developmental stages of the third molar according to the Köhler modification of the 10-stage method of Gleiser and Hunt. They also observed that the mesial root of the third molar develops faster than the distal one in the same tooth.[24] According to a study on the South Indian population, the probability that an individual is older than 18 years is 94.12% and 100% for males and females, respectively, when all the third molars have attained stage H.[25]

It is also recommended to consider the impaction status of the third molars while estimating the age.[26] Though the third molars are potential candidates for age estimation, especially in juveniles, the effect of impaction may sometimes result in delayed maturation and put the EA process in jeopardy.[27] A delay of 0.14–0.44 years was observed in the mineralization of third molar roots at stage H in impacted third molars.[28]

Based on Mincer *et al.*'s study, the age of attainment and the standard deviation were recorded as per the developmental stage of third molars. The standard deviations of the EAs in both #18 and #38 were 1.78 and 1.85, respectively. This value is less than the mean standard deviation of 1.98 and 1.93 in Mincer *et al.*'s original study for the upper and lower third molars, respectively. It was observed that the EA did not differ significantly from the CA in female subjects for both #18 and #38. However, in males, there was a significant difference in #38 but not in #18. An advantage of using this method is that there is no use of mathematical calculations of scores based on the developmental stages while estimating the age. Further, it was also reported that the developmental stages of teeth as a parameter provided more accurate age estimation than the tooth measurements and ratio parameters.[29] However, in handling real-life cases, it is recommended that all the applicable methods of age estimation pertaining to the case exhibit have to be applied.

Limitations and future prospects

The present study did not consider the impaction status of the third molar, and it did not consider third molars from all four quadrants for age estimation. Only the developmental stages of #18 and #28 were used for estimating the age. These may be considered a limitation of the study. Moreover, the present study used the age of attainment mentioned in Mincer *et al.*'s original study, which was based on the data of the American Whites (Caucasian) population. There is also a need for large-scale data generation and validation of this method on different populations. Moreover, studies applying the developmental stages of third molars in all the quadrants need to be conducted with an aim of developing the Indian standards in the age of attainment of third molars.

CONCLUSION

With the limitations of the present study, it may be concluded that Mincer *et al.*'s method may be accurately used to estimate the age of the Western India population, especially females. Any one third molar in each arch can be considered for this method as there was no significant difference in the developmental stage between the antimeres.

Key messages

The application of Mincer *et al.*'s method in the present study overestimated the chronological age. There is a need for large-scale validation of this method on different populations in India.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Chaillet N, Demirjian A. Dental maturity in South France: A comparison between Demirjian's method and polynomial functions. J Forensic Sci 2004;49:1059-66.
2. Kvaal SI, Kolltveit KM, Thomsen IO, Solheim T. Age estimation of adults from dental radiographs. Forensic Sci Int 1995;74:175-85.
3. Gustafson G. Age determinations on teeth. J Am dent Assoc 1950;41:45-54.
4. Li C, Ji G. Age estimation from the permanent molar in northeast China by the method of average stage of attrition. Forensic Sci Int 1995;75:189-96.
5. Maples WR. An improved technique using dental histology for estimation of adult age. J Forensic Sci 1978;23:764-70.
6. Stott GG, Sis RF, Levy BM. Cemental annulation as an age criterion in forensic dentistry. J Dent Res 1982;61:814-7.
7. Acharya AB. Forensic dental age estimation by measuring root dentin translucency area using a new digital technique. J Forensic Sci 2014;59:763-8.
8. Ohtani S. Estimation of age from dentin by using the racemization reaction of aspartic acid. Am J Forensic Med Pathol 1995;16:158-61.
9. Spalding KL, Buchholz BA, Bergman LE, Druid H, Frisén J. Forensics: Age written in teeth by nuclear tests. Nature 2005;437:333-4.
10. Panchbhai AS. Dental radiographic indicators, a key to age estimation. Dentomaxillofac Radiol 2011;40:199-212.
11. Demirjian A, Goldstein H, Tanner JM. A new system of dental age assessment. Hum Biol 1973;45:211-27.
12. Acharya AB. Age estimation in Indians using Demirjian's 8-teeth method. J Forensic Sci 2011;56:124-7.
13. Akhil S, Joseph TI, Girish KL, Sathyan P. Accuracy of Demirjian's and Indian-specific formulae in age estimation using eight-teeth method in Kanyakumari population. Indian J Dent Res 2019;30:352.
14. Bijjaragi SC, Sangle VA, Saraswathi FK, Patil VS, Rani SA, Bapure SK. Age estimation by modified Demirjian's method and its applicability in Tibetan young adults: A digital panoramic study. J Oral Maxillofac Pathol 2015;19:100.
15. Nelson SJ. Wheeler's Dental Anatomy, Physiology and Occlusion. 11th ed. St. Louis, Missouri: Elsevier; 2020.
16. Jung YH, Cho BH. Radiographic evaluation of third molar development in 6-to 24-year-olds. Imaging Sci Dent 2014;44:185-91.
17. Balla SB, Chinni SS, Galic I, Alwala AM, Machani P, Cameriere R. A cut-off value of third molar maturity index for indicating a minimum age of criminal responsibility: Older or younger than 16 years? J Forensic Leg Med 2019;65:108-12.
18. Mincer HH, Harris EF, Berryman HE. The A.B.F.O. study of third molar development and its use as an estimator of chronological age. J Forensic Sci 1993;38:379–90.
19. Arumugam V, Doggalli N, Patil K. Age estimation of third molar in South Indian population by ABFO recommended Mincer method-an Indian specific formula. J Forensic Med Toxicol 2019;36:1-8.
20. Charan J, Biswas T. How to calculate sample size for different study designs in medical research? Indian J Psychol Med 2013;35:121-6.
21. Patel PS, Chaudhary AR, Dudhia BB, Bhatia PV, Soni NC, Jani YV. Accuracy of two dental and one skeletal age estimation methods in 6–16 year old Gujarati children. J Forensic Dent Sci 2015;7:18–27.
22. Esan TA, Yengopal V, Schepartz LA. The Demirjian versus the Willems method for dental age estimation in different populations: A meta-analysis of published studies PLoS One 2017;12:e0186682.
23. Pinares Toledo J, Retamal Yermani R, Ortega Pinto A, Villanueva Conejeros R. Development of the third molar in Chileans: A radiographic study on chronological age. Forensic Sci Int Rep 2021;3:100177.
24. Arge S, Boldsen JL, Wenzel A, Holmstrup P, Jensen ND, Lynnerup N. Third molar development in a contemporary Danish 13–25 year old population. Forensic Sci Int 2018;289:12-7.
25. 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;7:153-7.
26. Guo YC, Yan CX, Lin XW, Zhang WT, Zhou H, Pan F, *et al.* The influence of impaction to the third molar mineralization in northwestern Chinese population. Int J Legal Med 2014;128:659-65.
27. Pilloud MA, Heim K. A test of age estimation methods on impacted third molars in males. J Forensic Sci 2019;64:196-200.
28. Meghana RV, Mallempalli P, Kondakamalli S, Boringi M, Vaddeswarapu RM, Kairamkonda CR, *et al.* A test to study the influence of impaction on mandibular third molar development and forensic age estimation in a sample of south Indian children and young adults. Leg Med (Tokyo) 2022;54:101998.
29. Thevissen PW, Fieuws S, Willems G. Third molar development: Measurements versus scores as age predictor Arch Oral Biol 2011;56:1035-40.