Assessing the probability of having attained 16 years of age in juveniles using third molar development in a sample of South Indian population

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The authors declare that they have no conflict of interest.

KEYWORDS

Dental age estimation, Third molar mineralization, Demirjian's stages; Probability; 16 years.

J Forensic Odontostomatol
2021. Apr;(39): 1-16:23
ISSN :2219-6749

ABSTRACT

Juvenile crime or delinquency has been increasing at an alarming rate in recent times. In many countries, including India, the minimum age for criminal responsibility is 16 years. The present study aimed to estimate the probability of a south Indian adolescent either being or being older than the legally relevant age of 16 years using Demirjian's tooth formation stages. Orthopantomograms (OPG) of 640 south Indian adolescents (320 boys and 320 girls) aged between 12 and 20 years were retrospectively analyzed. In each OPG, Demirjian's formation stage of the mandibular left third molar was recorded and the data was subjected to statistical analysis. Descriptive and Pearsons correlation statistics were performed. The empirical probabilities were provided relative to the medico-legal question of predicting 16 years of age. The distribution of age throughout the 10th, 25th, 50th, 75th and 90th percentile follows a logical distribution pattern horizontally and vertically. Pearson's correlation statistics showed a strong positive correlation between the Demirjian's stages and age for both sexes. Therefore, it can be concluded that stage "F" can be used to predict the attainment of age equal to or older than 16 years with a probability of 93.9% for boys and 96.6% for girls.

INTRODUCTION

Age disputes arise when a child or a person fails to prove their age by providing documentary evidence which is legally accepted by a court of law. The question of age usually arises in civil and criminal proceedings. Forensic experts are often confronted with the conceptually simple medico-legal question, to determine whether an individual has attained legal age threshold or not.[1] According to Indian law and the Juvenile justice act, there are three different age thresholds to consider i.e., 14, 16 and 18 years. Similar to many countries, 18 years of age is one threshold with important ramifications in India. The minimum age for criminal responsibility is 16 years. According to the amendment bill of Indian juvenile justice act, 2015, juvenile offenders aged between 16 and 18 years will be treated as an adult if they are accused of committing a heinous crime.[2] Any such crimes involving individuals between 16 and 18 years of age must then be established using different criteria.

The physiology of human age estimation can be evaluated by the degree of maturation of the different tissue systems.[3] Age assessment using skeletal and dental anthropological methods is useful mainly in children and adolescents because of the development of several teeth and bones in parallel during childhood.[4] Dental maturation in particular is a helpful indicator due to its high reliability, less affected by variation in nutritional and endocrine status.[5,6] Several dental age assessment methods based on radiographs have been described in the literature. One of the most widely applied methods is the maturity standards proposed by Demirjian et al. in 1973 which was based on a sample of French-Canadian children.[7] Theoretically, it is based on eight developmental stages (A to H), ranging from crown initiation, root formation until the apex closure of the seven left permanent mandibular teeth.

Late in adolescence i.e., after the formation of the second molars, third molars are the only tooth that continues to form. It is a well known fact that third molars are far from ideal developmental markers of age, as they are considered the most variable tooth in the dentition. However, they still remain of prime medico-legal interest due to the unavailability of alternative reliable biological indicators. Mincer et al.[1] first studied the discriminatory ability of Demirjian's grading of third molar development with a view to predicting the attainment of 18 years. Later many researchers have tested the accuracy and precision of Demirjian's stages and reported varying probabilities for predicting the age of 18 years.[8-12] However, the effectiveness of these stages in predicting the attainment of 16 years, i.e., age of criminal responsibility was never tested within a south Indian sample. Therefore, the present study was aimed at determining the accuracy of Demirjian's classification of lower third molar in predicting the attainment of the age threshold of 16 years in a south Indian population.

MATERIAL AND METHODS

Sample

A sample of 640 orthopantomograms (OPG) were collected retrospectively from the archives of the radiology department, Panineeya Institute of Dental Sciences, Hyderabad, India and from private dental clinics. Of these, 320 were boys (50%) and 320 were girls (50%) of south Indian origin, aged from 12 to 19.9 years. Table 1 shows the age and gender distribution of the sample. All the radiographs were coded with unique identification to ensure that the observers were blinded to the demographic details of the subjects. A prior approval from the institutional research and ethics committee was obtained (PMVIDS&RC/IEC/OP/PR/0352-19). The need for obtaining informed consent was waived due to the retrospective nature of the study.

Table 1. Age and gender distribution of the total sample

Age groups	Boys	Girls	Total
12-12.9	40	40	80
13-13.9	40	40	80
14-14.9	40	40	80
15-15.9	40	40	80
16-16.9	40	40	80
17-17.9	40	40	80
18-18.9	40	40	80
19-19.9	40	40	80
Total	**320**	**320**	**640**

Radiographs of the individuals who were healthy, with no apparent history of disease or developmental anomalies were included. Radiographs exhibiting obvious pathology, deformities affecting appearance of third molars and showing major variations in tooth eruption or tooth morphology were excluded. All the radiographs evaluated were pre-treatment in nature. Chronological age of each individual was calculated by the difference between the date of birth and the date on which the radiographic examination was carried out.

Method

Developmental stage of each mandibular third molar was rated according to the grading system described by Demirjian et al.[7] The observers scored the stage of third molar development by comparing the radiographs with representative sketches of each stage. All OPGs were analysed by a single examiner, a forensic odontologist (SBB), who had six years of experience in evaluating radiographic images and in age estimation analysis. The second examiner was a dentist with a master's degree. In case of disparities while allotting stages to the same tooth by the two observers, the earliest formation stage was chosen. Intra- and inter-observer reliability was tested by evaluation of 100 orthopantomograms selected randomly after an interval of two months.

Statistical analysis

Statistical analysis was performed using the SPSS 20.0 statistical package (IBM SPSS Inc, New York, USA). The level of significance was set at 5% ($p<0.05$).

Cohen's kappa statistics were performed to calculate intra- and inter-observer reliability. For statistical analysis, the letter stages of Demirjian et al.[7] were converted to numerical values as follows: A=1, B=2, C=3, D=4, E=5, F=6, G=7 and H=8. Descriptive statistics and percentile distribution for each stage of tooth development for both genders were calculated. Pearson's correlation statistics were performed to test the correlation between the age and the Demirjian stages of tooth development.

Chi-square analysis was conducted to test the association between the developmental stage and age. For this purpose, the chronological age is dichotomized as < 16 or ≥ 16 years, instead of being continuous and open-ended. The performance of the stages was tested by 2×2 contingency table. The output of contingency table displays the number of true positives, true negatives, false positives and false negatives.[13] The performance was assessed using accurate classification, sensitivity or true positive rate (refers to the measure that correctly detect individuals who are above 16 years), specificity or true negative rate (measure the ability to correctly detect individuals who are below 16 years), positive (LR+) and negative (LR-) likelihood ratios. Likelihood ratios combine the sensitivity and specificity into a single value that indicates which cut-off is best in discriminating the age threshold. Values of LR+ >1 increase the likelihood of the subject being older than 16 years, while values of LR- <0.1 decrease the likelihood of age being above 16 years.[14]

The Bayes posterior probability (Bayes PTP) of being 16 years or older may help to discriminate between those who are or are not aged 16 years or more.[15] Briefly, it refers to the conditional probability of a hypothesis being correct given the value of the observed information.[16] According to Bayes' theorem, post-test probability may be written as[17]

$$\text{Post-test probability} = \frac{\text{Pre-test probability} \times \text{sensitivity}}{(\text{Pre-test probability} \times \text{sensitivity}) + (1 - \text{Pre-test probability}) \times (1 - \text{specificity})}$$

Pre-test probability is the probability that the subject in question is 16 years old or older, given that he or she is aged between 12 and 20 years, which represent the target population. It was calculated as the proportion of subjects between 16 and 20 years of age who live in the Andhra Pradesh and Telangana according to demographic data from the 2011 census (http://www.censusindia.gov.in/2011census/C-series/C-13.html) and those between 12 and 20 years which was evaluated from data from the same website source. This proportion was considered to be 51.3% for boys and 51.9% for girls.

RESULTS

Cohen's kappa statistics revealed values of 0.891 for intra-observer and 0.863 for inter-observer, indicating almost perfect agreements. The results of repeated scoring of 100 radiographs did not reveal statistically significant intra- or inter-observer differences ($p>0.05$), indicating substantial consistency of evaluation. The final sample analysed consisted of 609 orthopantomograms, 310 (48.4%) were boys and 299 were (46.7%) girls. Of the total sample, 4.8% subjects were excluded from analysis since they presented with no mandibular third molars. The mean ages of 320 boys and 320 girls were 15.99 ± 2.33 years and 15.99 ± 2.34 years, respectively ($p=0.742$). Prior to the evaluation of the main sample, mineralization of the lower wisdom teeth was compared between the right and left sides using Wilcoxon test. No difference in terms of the mineralization between the sides was observed ($p=0.639$). Pearson's correlation statistics showed a strong positive correlation between the Demirjian's stages and age for both sexes i.e., 0.785 ($p<0.05$) and 0.733 ($p<0.05$) for boys and girls, respectively.

Table 2 displays the output of descriptive statistics, i.e., mean, standard deviation, median, minimum and maximum ages of left mandibular third molar crown- root formation for the eight stages of tooth development. The sample sizes for stage "A" were too small to consider, and therefore, not included in the analysis. The mean ages at each developmental stage showed that the third molar genesis in boys attained the formation stages "C", "D" and "E" earlier than in girls. However, approximately a six month delay was recognised in boys for the formation stages "F" and "G" except the stage "H". Table 3 shows the percentile distribution at each developmental stage for both genders. This illustrates the variation of each stage in the age span. The distribution of ages throughout the 10th, 25th, 50th, 75th and 90th percentile follows a logical distribution pattern horizontally and vertically.

Table 2. Age distribution by sex and Demirjian stage for tooth 38

Stage	Sex	N	Mean (SD)	Median	Minimum	Maximum
B	Boys	5	12.45 (0.3)	12.39	12.08	12.8
	Girls	4	12.47 (0.2)	12.51	12.19	12.68
C	Boys	34	12.81 (0.9)	12.56	12	15.71
	Girls	25	12.78 (0.7)	12.3	12.01	14.44
D	Boys	67	14.25 (1.2)	14.16	12.01	19.03
	Girls	80	14.01 (1.1)	14.13	12.1	18.17
E	Boys	56	15.51 (1.5)	15.49	12.73	19.35
	Girls	46	15.26 (1.3)	15.33	13.1	19.39
F	Boys	53	16.63 (0.9)	16.61	13.82	18.48
	Girls	59	17.07 (1.1)	16.88	14.38	19.98
G	Boys	28	17.81 (1.1)	17.83	13.77	19.86
	Girls	28	18.23 (0.9)	18.08	16.23	19.67
H	Boys	67	18.96 (0.6)	18.99	17.33	19.91
	Girls	56	18.83 (0.7)	18.75	17.41	19.96

SD Standard deviation

Table 3. Age distribution in percentile by stage and sex

Percentiles						
Stage		10th	25th	50th	75th	90th
B	Boys	12.08	12.13	12.39	12.8	-
	Girls	12.19	12.23	12.51	12.67	-
C	Boys	12.06	12.19	12.56	12.84	14.47
	Girls	12.09	12.15	12.3	13.26	13.91
D	Boys	13.08	13.3	14.16	14.72	15.4
	Girls	12.39	13.13	14.13	14.78	15.2
E	Boys	13.45	14.57	15.49	16.31	17.49
	Girls	13.42	14.44	15.33	15.96	16.58
F	Boys	15.4	16.19	16.61	17.35	17.72
	Girls	16.12	16.27	16.88	17.58	19.01
G	Boys	16.72	17.39	17.83	18.43	19.31
	Girls	17.07	17.57	18.08	19.11	19.53
H	Boys	17.98	18.52	18.99	19.43	19.79
	Girls	18.01	18.34	18.75	19.47	19.87

Table 4 displays a cross-tabulation of the data undertaken on the basis of the age group (whether < 16 or ≥ 16 years) and developmental stage. The chi-square test showed that the relationship between the age and stage attainment is statistically significant for both sexes ($p<0.05$). According to our data, 100% of the subjects, both boys and girls, who were marked stages "B" and "C" were found in the age group under 16 years. A total of 95.5% boys and 98.8% girls who were rated as stage "E" were below 16 years of age. For stage "F," approximately 84.9% boys and 91.5% girls were in the age group above 16 years. 100% subjects, who were categorized stages "G" and "H" were older than 16 years of age.

Table 5 shows the output of contingency table for Demirjian stages "D", "E" and "F". Table 6 displays the performance measures. Among the tested stages, Stage "F" showed better performance. For boys, the values of sensitivity, specificity LR+, LR-, accuracy and Bayes PTP 88.2%, 93.9%, 14.52, 0.12, 90.9% and 93.9%. For girls, they were 92.3%, 96.5%, 26.4, 0.08, 94.3% and 96.6% respectively. LR+ values of 14.52 and 26.4 in boys and girls indicate that when Demirjian stage "F" was attained, then a boy is almost 14.52 times and a girl is 26.4 times more likely to be above 16 than under 16 years. LR- values of 0.12 and 0.08 in boys and girls indicate that when Demirjian stage "F" was not attained, then a boy is almost 8 times and a girl is 20 times more likely to be below 16 than above 16 years.

Table 4. Distribution of the sample (percentage), by sex and age group, according to the stage of mineralization

Sex	**Age groups**	**Formation stages**						
		B	**C**	**D**	**E**	**F**	**G**	**H**
Boys	**<16 years**	5 (100)	34 (100)	64 (95.5)	40 (71.4)	8 (15.1)	1 (3.6)	0 (0)
	≥16 years	0 (0)	0 (0)	3 (4.5)	16 (28.6)	45 (84.9)	27 (96.4)	67 (100)
Girls	**<16 years**	4 (100)	25 (100)	79 (98.8)	35 (76.1)	5 (8.5)	0 (0)	0 (0)
	≥16 years	0 (0)	0 (0)	1 (1.2)	11 (23.9)	54 (91.5)	28 (100)	56 (100)

Table 5. Criterion validity (chronological age ≥ 16 years) according to tooth staging for boys and girls

Stage	**Sex**	**TP**	**TN**	**FP**	**FN**
D	**Boys**	39	158	113	0
	Girls	30	150	119	0
E	**Boys**	103	155	49	3
	Girls	109	149	40	1
F	**Boys**	143	139	9	19
	Girls	144	138	5	12

TP True positive; TN True negative; FP False positive; FN False negative

Table 6. Performance measures of Demirjian's stages for legal age threshold over 16 years

Measures	Boys	Girls
Stage D		
Sensitivity	100 (90.9- 100)	100 (88.4- 100)
Specificity	58.3 (52.1- 64.2)	55.7 (49.6- 61.7)
LR+	2.4 (2.08- 2.76)	2.26 (1.98- 2.59)
LR-	0.00	0.00
Accuracy	63.5 (57.9- 68.9)	60.2 (54.4- 65.7)
Bayes PTP	71.7 (68.7- 74.4)	70.9 (68.1- 73.6)
Stage E		
Sensitivity	97.1 (91.9- 99.4)	99.09 (95.04- 99.9)
Specificity	75.9 (69.5- 81.6)	78.8 (72.3- 84.4)
LR+	4.05 (3.16- 5.17)	4.68 (3.55- 6.17)
LR-	0.04 (0.01- 0.11)	0.01 (0.00- 0.08)
Accuracy	83.2 (78.5- 87.2)	86.2 (81.8- 89.9)
Bayes PTP	81 (76.9- 84.5)	83.5 (79.3- 86.9)
Stage F		
Sensitivity	88.2 (82.2- 92.7)	92.3 (86.9- 95.9)
Specificity	93.9 (88.7- 97.1)	96.5 (92.03- 98.8)
LR+	14.52 (7.69- 27.41)	26.4 (11.15- 62.53)
LR-	0.12 (0.08- 0.19)	0.08 (0.05- 0.14)
Accuracy	90.9 (87.2- 93.9)	94.3 (91.05- 96.6)
Bayes PTP	93.9 (89- 96.7)	96.6 (92.3- 98.5)

LR Likelihood ratio; PTP Post-test probability

DISCUSSION

It is a well known and widely accepted fact that the third molars are by far the most variable teeth in the dentition. However, their protracted formation in adolescence and into early adulthood with completion often beyond the second decade of life made them the subject of interest in many studies.[18] In the present study, we set out to determine the accuracy of Demirjian's classification of the lower third molar in discriminating between individuals of 16 years of age threshold in a south Indian population. We observed bilateral agenesis in 4.8% cases of total sample, with no significant differences between genders.

When analysing the probability of an individual being under 16 years of age based on Demirjian's stages of third molar mineralization, the accuracy is higher in earlier stages (B & C). More than 95% of subjects who were classified as stage "D" are under 16 years of age. Subsequent to stage "E", there is a sharp decline in the proportion of times that chronological age is estimated to be less than 16 years of age.

One of the measures to test the ability of the model to discriminate the subjects 16 years of age or older is through finding the percentage of correct classifications i.e., sensitivity and specificity. According to Cardoso et al.[6] the model has good predictive capabilities if sensitivity and specificity are greater than or equal to 80%. The capacity of the model is called reasonable, if the values are between 50% and 80%, and is called mediocre model when they are below 50%. From a legal point of view, it is important to enable a subject to be judged as accurately as possible to confirm if they are of legal age. Therefore, methods that have better sensitivity and specificity should be used, with errors kept to a minimum. When the performance of stage "D" as a cut-off value for predicting 16 years was tested, sensitivity of 100% in both sexes and specificity of 58.3% and 55.7% in boys and girls was observed. This difference between the sensitivity and specificity for stage "D" could be due to the fact that the authors tested attainment of stage "D" for predicting age over 16 years. However, the distribution data according to stage of mineralization (Table 4) showed that more than 95% of subjects who were classified as stage "D" are under 16 years of age. Specificity values will be improved when attainment of stage "D" is tested to predict age under 16 years.

The sensitivity and specificity percentages for stage "E" were 97.1% and 75.9%, 99.09% and 78.8% for boys and girls respectively. A total of 24% and 21.2% of false positives, 2.8% and 0.9% false negatives were seen in boys and girls. In the criminal context, the issue of specificity is of special importance as it represents the number of false positive attributions.[19] Only methods or cut-off values with high specificity index can fulfil the legal requirements. In the present study, when stage "F" was tested as a cut-off value, a sensitivity percentage of 88.2%, 92.3% and specificity percentage of 93.9% and 96.5%, indicating only 6.1% and 3.5% false positive attributions for boys and girls, respectively. Similar to our findings, Caldas et al.[20] also reported better specificity values for stage "F" then stages "D" and "E". However, their sensitivity values were much less.

Mincer et al.[1] believed that third molar development may provide better accuracy for prediction of attainment of adulthood, instead of estimation of exact chronological age. So far, most authors chose to determine the likelihood of attainment of 18 years using Demirjian stages of tooth development.[21,22] According to their results, Demirjian's developmental stage "H" could be a reliable developmental marker for indicating age over 18 years. Comparatively, stage "H" is easily recognizable, fully mineralized tooth with apex. Therefore, the probability of a subject being 18 years or older can be easily determined. However, in the present study we chose 16 years age for assessment, as it is also an age with legal relevance in India. In our opinion, the diagnosis of age equal to older than 16 years can be made with accuracy using stage "F" of the radiological development of the third molars, with an accuracy of 90.9% for boys and 94.3% for girls. Few authors have reported lower accuracy between stages "F" and "G" (due to a span of 3-3.5 years) particularly while representing 16 year cut-off.[23] They believed that fewer Demirjian's root stages might affect the accuracy of age estimation. Harris[18] recommended that finer gradations would be an advantage especially in root stages where differences of a fraction of a year can have considerable medico-legal consequences. Solari and Abramovitch[8] modified Demirjian's method and introduced two extra root stages at "F" and "G" to improve the precision of this method. Future studies might require to adopt these extra stages to improve the accuracy of age estimation especially in the 16 year cut-off in the studied population.

Probabilistic assessments are crucial in a forensic setting because they provide a measure of uncertainty about the correlation between the real age and dental maturation.[24] Although, our study findings offer a probabilistic approach using Demirjian's tooth developmental stages, one should bear in mind that this approach may perhaps be seen as more representative of dental maturation and, thus, may not perform accurately in all populations. One of the main concerns is the representativeness of the sample which is comprised of healthy south Indian children. However, age estimation in forensic and legal settings does not typically involve such children, but children who grow under impoverished environments. In particular, dental and skeletal maturation tend to be delayed in malnourished children, and they may appear younger than they really are.[6] Therefore, proper care must be taken while using these models in malnourished children as it is more likely that false negatives may increase. Finally, we believe that the described data may provide south Indian references for third molar examination for the purpose of forensic investigation, especially in 16 year olds.

CONCLUSIONS

To the best of the present investigators' knowledge, this is the first study to address the issue of the minimum age of criminal responsibility, i.e., 16 years from third molars using Demirjian's tooth developmental stages in south Indian children. Our findings concluded that stage "F" can be used to predict the attainment of age equal to or older than 16 years with probability of 93.9% for boys and 96.6% for girls. These determined probabilities might be valuable in future forensic practice for the prediction of age over 16 years in the studied population. However, additional studies with larger samples should be conducted concerning the larger number of crimes by juveniles of 16 to 18 years.

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