Reliability of determining the age of majority: a comparison between measurement of open apices of third molars and Demirjian stages.

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ABSTRACT

Aim: This study examines the open apices of third molars in discriminating between individuals who are or are not 18 years of age or older and to assign a cut-off for estimation of the age of 18 years. Furthermore, this method was compared to those based on Demirjian's stages 8 and 9.

Methodology: Orthopantomographs (OPGs) of 1062 individuals (14 and 23 years) were assessed, to verify Cameriere's third molar maturity index (I3M). The apical ends of the roots of the left mandibular third molar were analysed. Mineralization of the third molar was also evaluated.

Results: A cut-off value of I3M =0.08 was taken. The sensitivity of this test was 70.76% and specificity was 82%. The results of the test showed a better specificity for Stage 9 and better sensitivity for stage 8 for adult age. Accuracy was 74.58% for third molar maturity index as compared to 72.41% for stage 9.

INTRODUCTION

Forensic age estimation of living individuals is one of the most intimidating challenges for the forensic community. However, it has been extremely advantageous in helping authorities in searching for unknown victims, determining eligibility for social benefits and assisting immigration services in the processing of undocumented immigrants. Human dentition has been proved to be one of the most reliable estimators of chronological age.[1,2] Various morphological methods can be used during human skeletal growth and development. The last tooth to initiate and complete development is the third molar and thus, is the last available dental morphological predictor of age.[3] After reaching the age of legal majority, the treatment of an individual changes dramatically within the criminal and civil legal courts in India. In these scenarios, forensic odontologists are often consulted by government agencies in estimating the ages of adolescents or juveniles who may or may not have reached that legally crucial age. Eighteen years of age is the threshold at which an individual is legally considered to have attained adulthood and, consequently, the legal system considers the person's activities, differently.

The Indian Juvenile Justice (Care and Protection of Children) Act, 2000, states that an individual who has not attained the age of 18 years is considered as a juvenile. While, as per the Juvenile Justice (Care and Protection of Children) Amendment Bill, 2006, a "juvenile in conflict with law", i.e. a juvenile affirmed to have committed an offence, cannot be sentenced to

death or life imprisonment or committed to prison. On the contrary, such young offenders are counselled by Juvenile Justice Boards and remanded to a special home, usually for 3 years or until the time he/she attains majority status.[4] In India, according to Section 87 of the Indian Penal Code or IPC, eighteen years is also the legally acceptable age for giving/obtaining consent; while the Child Marriage Restraint Act, 1978 accepts it as the legally permissible age for marriage of females. Furthermore, it is the minimum age to enter government service in India.[5] Therefore, estimating whether an individual has (or has not) reached the age of majority can be very detrimental in India in a number of legal cases when the age is not confirmed or under dispute.

In particular, the third molar, whose development commences much later than other teeth, is usually the only tooth that is still undergoing calcification at this stage. Hence, although its development may be erratic and the tooth itself has a relatively high incidence of agenesis, the third molar has been the subject of immense interest as a predictor of 18 years of age and status of majority.[6,7,8]

In 1973, Demrjian et al[9] published a new classification of stages of tooth mineralization. In 1993, commissioned by the American Board Forensic Odontology, Mincer et al[3] studied 823 American children, prevalently Caucasians, aged between 14 and 24 years, to evaluate the radiographic reliability of the third molar as an age indicator and used Demirjian's tables to determine the mineralization stages. Using the revised grading system,[10] where alphabetical grading (A to H) was replaced with a numerical scale (Stages 0-9) on the mandibular (left) third molar, Acharya et al[11] determined majority/minority status applying three statistical approaches, i.e. traditional regression analysis, logistic regression analysis and Bayesian prediction.

The high number of subjects over 18 years of age with the third molar still not mature remains an important problem. The third molar has been used to evaluate age in late adolescence by various researchers from different countries like USA, South Africa, Japan, Austria, Turkey and Spain.[12-17] All these studies emphasized the dilemma of using the third molar as a determinator of age particularly for the age of majority i.e. 18 years. Actually, average age at the end of mineralization, i.e. Demirjian's stage 9, is usually reported to be more than 20 years and therefore classifying an individual as being over 18 only if the third molars which are in phase according to Demirjian yield a large number of errors (false non-adult).

Thus, this study was planned to examine the open apices of third molars in discriminating between individuals who are or are not 18 years of age or older and to fix a cut off for evaluation of the age of 18 for forensic purposes. Secondly, we aimed to compare sensitivity and specificity of this method with stages 8 and 9 of Demirjian.

MATERIALS AND METHODS:

Subjects and materials

Digitalized orthopantomographs (OPGs) of 1062 individuals aged between 14 and 23 years were retrieved from the Department of Oral Medicine and Radiology (Table 1). We evaluated the third molar maturity index by analysing the apical ends of the roots of the left mandibular third molar from the OPGs, to distinguish between individuals above and below 18 years of age. The third molar maturity index has been defined as: when the apical ends of the roots are completely closed, the inference is that the third molar has completed its root development i.e. I3M = 0. While, if the apical ends of the roots are open, then I3M is evaluated as the sum of the distances between the inner sides of the two open apices divided by the tooth length (Fig 1). Therefore, the maturity index, I3M, is calculated in a similar way to the ratios Ai to Li, I = 6,7 as is reported for the other two molars with two roots as in the studies carried out by Cameriere et al.[18,19]

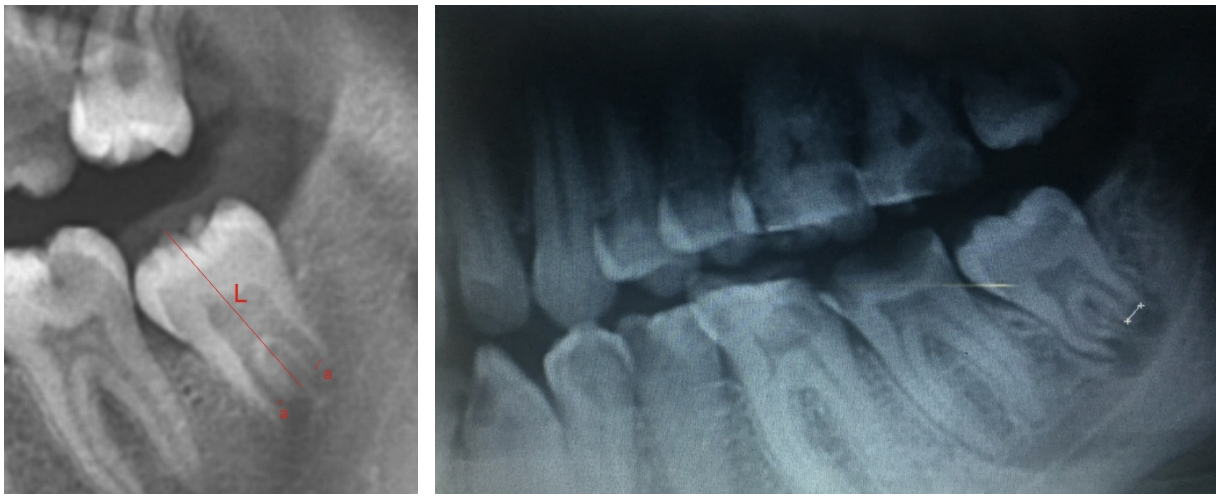
Statistical analysis

To evaluate inter-observer reliability, all measurements were carried out by two observers. The two observers made repeated observations of 30 OPGs at an interval of 2 weeks. The inter-observer reproducibility of the third molar maturity index, I3M, was studied with the concordance correlation coefficient and k (kappa) statistics were used to measure the inter-observer reproducibility of the Demirjian stages. Analysis of variance (ANOVA) was performed to compare age distributions among Demirjian stages and gender. With individual age as a dichotomous response, variable (E=1 if an individual is at least 18 years of age, E=0 otherwise) and gender and the third molar maturity index, I3M, as predictor variables, a generalized linear model was formulated to predict whether an individual is more than (E=1) or less than (E=0) than 18 years

Table 1: Sample of Orthopantomographs according to sex and age categories.

Age (years)	Male	Female	Total
14	18	13	31
15	44	18	62
16	77	54	131
17	75	62	137
18	78	24	102
19	35	55	90
20	84	83	167
21	80	82	162
22	57	54	111
23	49	20	69
Total	**597**	**465**	**1062**

Figure 1: Measurement of the length and width of the root apices in mandibular third molar.



of age by using a logistical model such as link function. The predictive accuracy of the model was assessed by the determination of the characteristic receiver operating curve (ROC) [Fig 2]. Receiver operating characteristic curve was used as a linear scale to determine the different levels of predicted probability that an individual is of age 18 years or older.

All significant variables were used to examine the medico-legal question as to whether an individual is older or younger than 18 years of age. The test was carried out to ascertain a threshold (cut-off) that could be used to assign an individual to the population of those younger (T=0) or older (T=1) than 18. The sensitivity p_1 of the test (i.e. the proportion of children for or older than 18 years of age, which verifies event T=1) was determined and also its specificity, p_2 ((i.e. the proportion of children younger than 18 years of age, who verify the event T=0).

Open apices in teeth can prove to be extremely crucial to distinguish between individuals who are

or are not aged 18 years or more, by the post-test probability of being 18 years of age or more (i.e. the proportion of individuals aged 18 or over in whom event E= 1 is verified).
The observations were entered in Microsoft excel file and the statistical analysis as well as the related graphs were completed with the SPSS 17.0 version statistical programme and the Microsoft Excel® programme. The significance level was set at 5%.

RESULTS

Representation of Demirjian stages was done by observing any disagreement between two measurements made by different observers, k=1.
The inter-observer representation of Demirjian stages was very good with Cohen's kappa statistic (±standard deviation) at k= 0.830±0.09, indicating substantial homogeneity of evaluation between operators. In the case of the reproducibility of the third molar maturity index, I3M, the estimated concordance correlation coefficient (±standard deviation) for inter-observer variability was pc = 0.999±0.001, when the measures of both observers were compared. Our results showed very good reliability between the two observers.
We distinguished the individual age in the sample using the Demirjian stages of third molars and gender [Table 2].
We applied ANOVA to ascertain the differences in age distributions among Demirjian stages and gender; it exhibited that gender had no influence on the mean value of the age distributions (p= 0.620) [Table 3].

Figure 2: Receiver operating characteristic curve for assessment of the sensitivity and specificity of age of majority. Diagonal segment are produced by ties

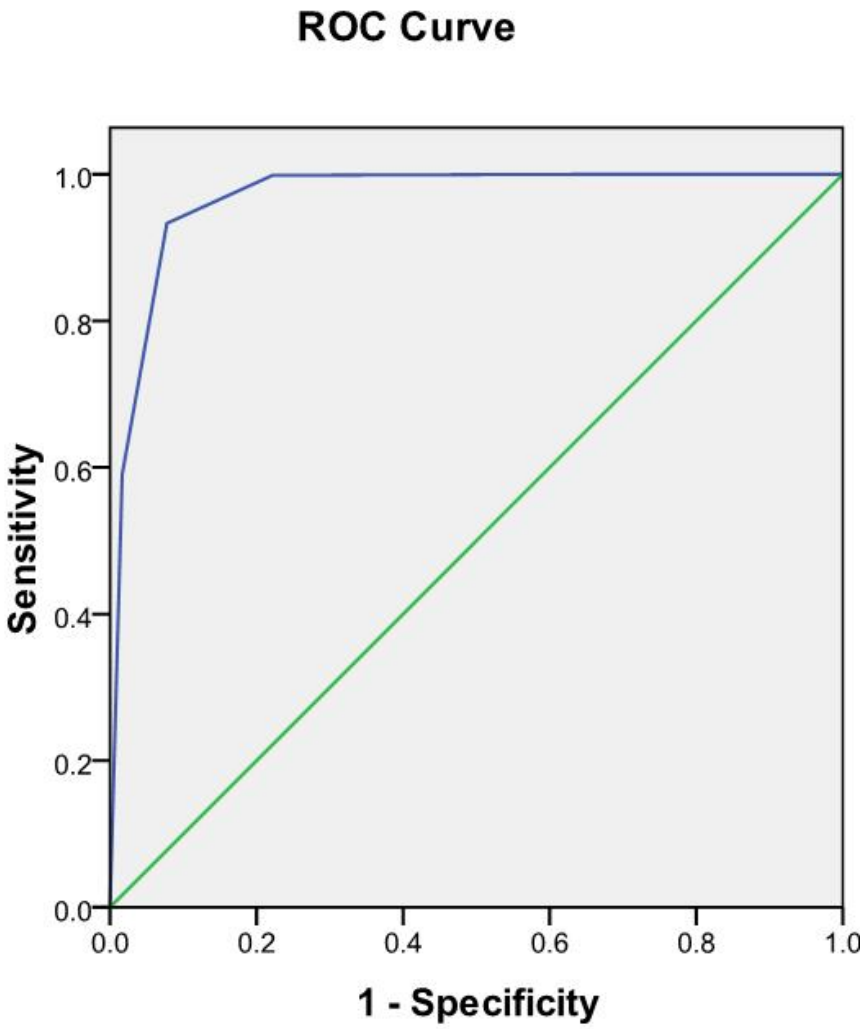


Table2: Mean and standard deviations for mineralization stages in relation to age and gender in study population

	Male Mean (SD)	**Female Mean (SD)**
Stage 4	14.13 (0.35)	14.00 (0.00)
Stage 5	15.32 (0.70)	15.33 (0.77)
Stage 6	16.39 (0.76)	16.49 (0.69)
Stage 7	17.39 (0.76)	17.54 (1.26)
Stage 8	19.38 (1.51)	19.65 (1.29)
Stage 9	21.02 (1.54)	20.93 (1.36)

Table 3: Percentage of individuals at least 18 years old or older by stage and gender

	Male N (%)	**Female N (%)**
Stage 4	0	0
Stage 5	0	0
Stage 6	1 (1.2)	0
Stage 7	31 (50.8)	15 (40.5)
Stage 8	117 (91.4)	123 (91.8)
Stage 9	234 (98.3)	180 (98.9)

Table 4 affirmed the frequency distribution by gender and stages of individuals older than or at least 18 years old. From this table, the inference drawn is that only Stage 9 can be used dependably to test adult age. We observed 98.3% of males 99% of females in Stage 9 to be adults.

When we used the third molar maturity index, I3M, we found a cut-off value of I3M for adult age which maximized the post-test probability and, at the same time, minimized the frequency of false negatives (i.e. the proportion of individuals of 18 years of age or older who were wrongly classified to the sub-adult population).

Setting p = P (E=1) as the probability that an individual was at least 18 years old, the probability on I3M and gender was formulated with a linear logistic model:

Logit (p) = b_1+ b_0 I_{3M}

In sum, the probability that an individual is 18 years or older depends on the degree of maturity of the third molar I3M, but it does not significantly depend on gender.

The maximum likelihood estimates of parameters of the logistical model used to estimate the probability that an individual was 18 years of age or older, p, given the values of the factor I3M, are listed in Table 5.

Table 6 revealed the discrimination performance of the test i.e. to ascertain the crucial question authorized by law whether an individual is older or younger than 18. This helped in assigning an individual to the population of those younger than 18 if the test resulted negative (T = 0) and to the older age group if the test resulted positive (T=1).

In forensic investigations, where age estimation is the main point of consideration, it becomes highly significant and detrimental in the Court of law that the test reveals a low proportion of individuals younger than 18 whose test is positive (T=1) and so it was more appropriate to pay more attention to the chance of a false positive than to that of a false negative.

Based on these assumptions, we affirmed that an individual is considered to be 18 years of age or older (the test is positive, T=1) if I3M is lower than the cut-off value of 0.08; otherwise, an individual is considered to be under 18 (the test is negative, T=0). In our study, 496 individuals were classified as 18 or greater than 18 years.

The sensitivity of this test (the proportion of individuals being 18 years of age or older whose test is positive) was 70.76% and its specificity (the proportion of individuals younger than 18 whose test is negative) was 82%. The proportion of correctly classified individuals was 88.41%. The accuracy was 74.58%. Hence, the probability that a subject positive on the test (T=1) was 18 years of age or older was 74.58% (Table 7).

Table 4: Summary table of ANOVA

	df	SSQ	MSSQ	F	Pr(F)
Gender	1	0.210	0.210	0.134	0.714
Stage	5	4633.43	926.68	592.188	<0.001**
Gender x Stage	5	5.51	1.103	0.705	0.620
Residuals	1050	1643.10	1.565		

**p<0.001; Highly significant

Table 5: Para estimates for logistical model

Parameter	Value	Std. Error	p value
b0	2.400	0.160	<0.001
b1	-2.767	0.225	<0.001

Table 6: Classification table describing discrimination performance of the test

	Age		Total
	<18	≥18	
T =0	296	205	501
T =1	65	496	561
Total	361	701	1062

Table 7: Percentage of sensitivity, specificity, correct classification, and post-test probability (95% confidence interval) of test of adult age when stages 8 and 9 and I_{3M} index <0.08 are used to discriminate between individuals who are or are not aged 18 years or more

	Phase 8	Phase 9	I_{3M}<0.08
Sensitivity	93.30	59.06	70.76
Specificity	92.24	98.34	81.99
PPV	95.89	98.57	88.41
NPV	87.63	55.30	59.08
Accuracy	92.94	72.41	74.58

PPV: Positive predictive value; NPV: Negative predictive value.

DISCUSSION

In view of global rise of incidence of crime rates by juveniles in India, it has become increasingly important to determine the age of majority with precision. Various research studies have focused on wisdom tooth eruption and later on its mineralization to assess the age of 18 years.[12-17,20] Mincer et al earlier[3] suggested the method of degree of third molar development to estimate ages in the living; however, it was subsequently concluded to be a less precise method in identifying the adult individuals. However, they also emphasized that in dire situations, third molar formation is the only usable datum for age estimation. The timing of mandibular third formation was documented for two groups of children in England and South Africa and it was found that children from London and Cape Town were significantly delayed in the mean age of initiation and almost all subsequent formation stage of the permanent mandibular third molar compared to black South African children.[21]

Our results revealed that, if the root apices of the third molar are closed (i.e. the third molar is at terminal grade 9), then there is a high probability that the subject is at least 18 years of age. However, in terminal stage 9, only 59% of individuals were there, and the homogeneity between "at or over 18 years or under 18 years" and belonging to Stage 9 or not was 98%. Stage 8 shows a greater sensitivity as compared to stage 9, however, it decreases the specificity and the positive predictive value.

Hence, if stage 8 is selected as a predictor of adult age, it improves test sensitivity with respect to Stage 9, but, it markedly increases the false positive individuals, which is considered an ethically unacceptable error in the judiciary system. If Cameriere et al's[22] I3M method with a cut-off of 0.08 is used to estimate the legal adult age of 18 years, it significantly increases test sensitivity with respect to Stage 9. Furthermore, it minimises the number of false positive individuals. From a forensic point of view, it is significant that the percentage of false positives is small, since it is a graver error to consider a subject younger than 18 as a criminal in the Court of law than the judgement which does not consider a subject older than 18 as chargeable.

In forensic science, the judges are most inclined to ascertain whether the individuals in question have reached the threshold of the age of majority; it becomes a cumbersome decision for them to make in borderline cases. There are two unacceptable errors in the Courts of judgement, technically unacceptable and ethically unacceptable errors. In the first category falls the errors of judgement due to forensic age estimation indicating that a subject actually over 18 is in fact a juvenile or minor. However, if a minor who is under the age of majority is declared as an adult in the Court, it is considered an ethically unacceptable error, as it implies the direct violation of minors' rights. If they are judged to be under 18, they will be treated as juveniles, with the advantages of child care in reform homes; a child wrongly judged to be over 18 may be at risk of exploitation if placed with adults.

Thus, we must minimise false positives and in our study third molar maturity index achieved the lesser number of false positives similar to Cameriere's results in Italian population.[22] Study on Albanian sample[23] showed substantial success of suggested value for I3M, with the 87.4% and 92.5% correctly classified females and males, respectively. Similarly, high accuracy was obtained using third molar maturity index as a determinant of the age of majority in the Croatia.[24]

CONCLUSION

Our research compared the efficacy of third molar maturity index and Demirjian stages in estimating 18 years of age in Indian population. The accuracy of forensic age estimation in living subjects can be increased by evaluating population-specific results. The present study conducted on Indian adolescent sample proved that the I3M method is fairly accurate and reasonably reliable, therefore, it can also be recommended to be used for assessment of age of majority in a forensic context.

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