ORIGINAL ARTICLE

Assessment of age of majority by measurement of open apices of the third molars using Cameriere's third molar maturity index

Preeti Sharma,
Vijay Wadhwan[1],
S. M. Ravi Prakash[2],
Pooja Aggarwal,
Neeraj Sharma[3]
Departments of Oral Pathology and Microbiology, [1]Oral Pathology and [2]Oral Medicine and Radiology, Subharti Dental College, Swami Vivekanand Subharti University, [3]Independent Dental Practitioner, KK Dental Care Centre, Meerut, Uttar Pradesh, India

Address for correspondence:
*Dr. Preeti Sharma,
BH-15, Pallavpuram, Phase-I,
Meerut - 250 110, Uttar Pradesh, India.
E-mail: neepreeti_121@yahoo.com*

Abstract

Aims and Objectives: Evaluation of biological age of a living subject around the legal cutoff age for adulthood has become a grave concern for forensic experts in India, mainly due to the consequences of criminal obligations in judicial proceedings. Thus, this study was planned to examine the open apices of third molars in discriminating between individuals who are aged 18 years or older and who are not 18 years or older and to assign a cutoff for estimation of the age of 18 years. **Materials and Methods:** Orthopantomographs of 1062 individuals (14 and 23 years) were assessed, to verify Cameriere's third molar maturity index (I_{3M}). The apical ends of the roots of the left mandibular third molar were analyzed. If the apical ends of the roots are completely closed, then I_{3M} is zero; otherwise, it is calculated as the sum of the distances between the inner sides of the two open apices divided by the tooth length. **Results and Conclusion:** The sensitivity of the test for 0.08 value was 74.7% for males and 66% for females. Specificity was 83.6% for males and 79.6% for females. The probability that an Indian individual with an I_{3M} <0.08 in 18 years or older is 78% for males and 70.3% for females. I_{3M} is efficacious to determine age in Indian population.

Key words: Age estimation, forensic anthropology population data, India, majority status, third molar maturity index

Introduction

Estimation of chronological age is extremely valuable in forensic dentistry, human anthropology, and bioarcheology, and it may be accomplished using morphological and radiological characteristics of teeth.[1]

It has been observed that the accuracy of dental aging is not consistent from birth to maturity. Assessment of age in younger population is more accurate because more teeth are forming and the intervals between morphologic stages are brief, and thus, more reliable.[2]

Access this article online	
Website: www.jfds.org	Quick Response Code
DOI: 10.4103/jfo.jfds_31_16	

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

How to cite this article: Sharma P, Wadhwan V, Ravi Prakash SM, Aggarwal P, Sharma N. Assessment of age of majority by measurement of open apices of the third molars using Cameriere's third molar maturity index. J Forensic Dent Sci 2017;9:96-101.

© 2017 Journal of Forensic Dental Sciences | Published by Wolters Kluwer - Medknow

One of the most intimidating challenges for the forensic scientists is that the suspect in the court of law is an adult or a minor. In India, age estimation of the legal adult age of 18 years is a fundamental question in forensic medicine, adult franchise, driving license, minimum age of government service employment, legally permissible marriageable age for females in India and in undocumented minors in child labor cases. When an individual reaches the age of legal majority, their treatment within the criminal and civil legal systems is changed dramatically in India. Forensic odontologists often assist government agencies in estimating the ages of persons who may or may not have reached that legally important age. In the age span of 15.7–23.3 years of age, the third molar represents the only tooth still in development and is thereby very important for age calculation. Third molars are in many respects the most variable teeth in the dentition. However, the only tooth usually visible from crypt appearance to apex completion on radiographs of children and young adults is the third permanent molar.[3] Mincer *et al*.[2] evaluated the radiographic reliability of the third molar as an age indicator by studying 823 American children; mineralization stages were estimated using Demirjian *et al*.'s tables.[4] Various research papers[5-8] have tested the accuracy and precision of third molar development as an estimator of chronological age. A new concept of analysis of chronological age in children by measuring the open apices in seven mandibular teeth on orthopantomographs (OPGs) of Italian children was proposed by Cameriere *et al*.[9] where regression analysis helped in arriving at a general formula.

Later, Cameriere *et al*., in 2008,[10] developed a method for assessing adult age based on the relationship between age and the third molar maturity index (I3M), according to measurement of the open apices of the third molar to identify a threshold (cutoff) which could be used to discriminate between individuals who are aged 18 years or older and who are not 18 years or older. There always has been acontemplation on the existence of population differences in tooth formation globally. Therefore, the main objectives of this study were to examine the open apices of third molars in discriminating between individuals who are aged 18 years or older and who are not 18 years or older, to verify the validity of Cameriere's cutoff value of I3M and to estimate its sensitivity, specificity, and accuracy in Indian population.

Materials and Methods

Digitalized orthopantomographs (OPGs) of 1142 healthy living Indian individuals aged between 14 and 23 years were retrieved from the Department of Oral Medicine and Radiology, of which 1062 OPGs (597 boys, 465 girls) were selected for analysis of age estimation [Table 1]. Radiographs showing developmental abnormalities, any pathoses, severely rotated teeth, or those which were unclear were excluded from the analysis. Chronological age of the subject was calculated by subtracting the date of the X-ray from the date of birth. The Ethics Committee for Research involving Human Subjects of the Subharti University (India) had approved the required protocols to collect radiographs for human subjects.

All digitalized OPGs were recorded as computer files in JPG format, which were examined by the computer-aided drafting program (Adobe Photoshop® CS4, Adobe Systems Inc. San Jose, CA). Only the left permanent third lower molar, tooth No. 38, according to classification by Federation Dentaire Internationale, was evaluated [Figure 1]. Dental age estimation was completed according to the Cameriere *et al*.[10] method. The apical ends of the roots of the left lower third molar of each individual were analyzed and I_{3M} was defined as follows: $I_{3M} = 0$, if the root development of the third molar is complete, i.e., the apical ends of the roots are completely closed. Maturity index I_{3M} was calculated in a similar way to the ratio Ai to Li, when $i = 6$ or 7, as analyzed for the other two teeth with two roots in Cameriere *et al*.[9] Therefore, I_{3M} was evaluated as the sum of the widths of the inner margins of the two open apices than divided by tooth length.

Table 1: Sample of orthopantomographs in Indian population according to sex and age categories

Age	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

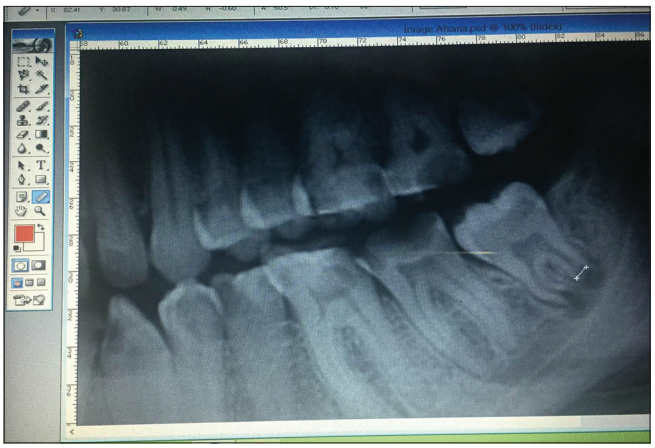

Figure 1: Measuring open apices of third molar

SPSS Statistics 17.0 for Windows (SPSS Inc., Chicago, IL, USA) and MS Excel 2003 (Microsoft Office 2003, Microsoft, Redmond, WA, USA) were used for all statistical analysis. The names of all individuals, gender, date of birth, and date of X-rays were recorded on the orthopantomogram. According to the results reported by Cameriere *et al*.[10] and De Luca *et al*.,[11] a cutoff value of 0.08 was used for consideration if a person was a minor of 18 years of age or older. This means that an individual is considered to be 18 years of age or older if the I_{3M} is lower than 0.08.

The sensitivity of the test, p_1 (i.e., proportion of individuals older than or equal to 18 years of age who have $I_{3M} < 0.08$) as well as the specificity, p_2 (i.e., proportion of individuals younger than 18 who have $I_{3M} \geq 0.08$), were evaluated. The efficacy and accuracy of the I_{3M} have proved helpful in discriminating between individuals who are aged 18 years and are not aged 18 years by the posttest probability of being 18 years of age or more (i.e., the proportion of individuals with I_{3M} <0.08 who are older than or equal to 18 years).

According to Bayes' theorem, posttest probability may be written as:

$$p = \frac{p_1 p_0}{p_1 p_0 + (1-p_2)(1-p_0)}$$

Where P is posttest probability and p_0 is the probability that the individual in questioning is 18 or older, presuming that individual is aged between 14 and 23 years, which represents the designated population. Probability p_0 was evaluated with the data retrieved from the statistical office of India (http://www. indiastat.com/).

Results

Real age gradually decreased as I_{3M} increased for both males and females [Figure 2]. The mean age for both genders varied across I_{3M} classes and the differences were statistically significant for the third age group [Table 2]. Noteworthily, the mean age of males was higher than that of females when I_{3M} was between 0.08 and 0.3 ($P < 0.001$). No significant difference was observed in the maturation of males and females.

The contingency tables for males [Table 3] and females [Table 4] reveal the numbers of individuals with $I_{3M} \geq 0.08$, i.e., who are older than 18 years and those who have $I_{3M} \geq 0.08$ and are younger than 18 years; those with I_{3M} <0.08 who are older than 18 years and the individuals with I_{3M} <0.08 who are younger than 18 years.

Tables 3 and 4 reveal the close association between adult age and positivity on the test, i.e., I_{3M} <0.08 both in males and females. Majority of male subjects (89.1%) were accurately classified. These results demonstrate that the test for sensitivity (p_1) for males, the percentage of individuals being 18 years of age or older whose test was positive, was 74.7% and test for specificity (p_2), the percentage of subjects younger than 18 years whose test was negative, was 83.6%. The estimated accuracy (p), that a subject positive on the test (i.e., $I_{3M} < 0.08$) was 18 years of age or older, was 77.9%.

The results of Table 4 show that the test for sensitivity (p_1) for females was 66% and the test for specificity was 79.6%, while 87.5% individuals were correctly classified. The estimated accuracy or posttest probability was 70.3%.

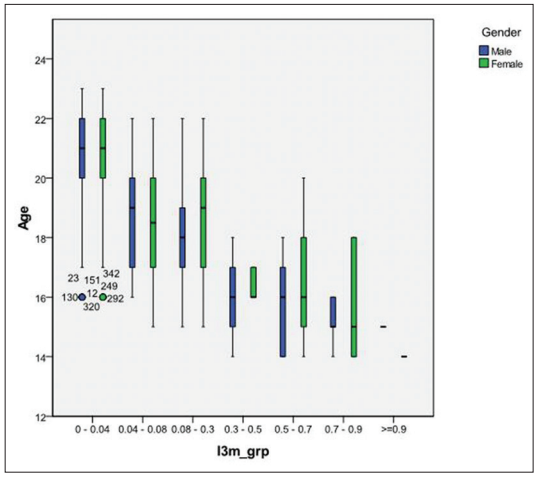

Figure 2: Boxplot of relationship between chronological age and Cameriere's third molar index of open apices of mandibular left third molar in females and males. Boxplot shows median and inter-quartile ranges while whiskers are lines extending from box to maximum and minimum ages, excluding outliers

Table 2: Summary statistics of chronological age according to gender and third molar maturity index: Number of individuals, mean, standard deviation, minimum value, 1st quartile, median, 3rd quartile and maximum value of age distribution for each third molar maturity index class

I_{3M}	Male							Female							*P*
	n	Mean±SD	Minimum	Q1	Median	Q3	Maximum	*n*	Mean±SD	Minimum	Q1	Median	Q3	Maximum	
0-0.04	248	20.83±1.71	16.00	20.00	21.00	22.00	23.00	194	20.75±1.64	16.00	20.00	21.00	22.00	23.00	0.587
0.04-0.08	73	18.66±1.73	16.00	17.00	19.00	20.00	22.00	46	18.28±1.83	15.00	17.00	18.50	20.00	22.00	0.262
0.08-0.30	146	18.08±1.93	15.00	16.75	18.00	19.25	22.00	141	18.65±1.81	15.00	17.00	19.00	20.00	22.00	0.009*
0.30-0.50	74	16.23±1.36	14.00	15.00	16.00	17.00	18.00	23	16.35±0.49	16.00	16.00	16.00	17.00	17.00	0.685
0.50-0.70	11	15.82±1.66	14.00	14.00	16.00	18.00	18.00	52	16.73±2.10	14.00	15.00	16.00	18.00	20.00	0.181
0.70-0.90	32	15.34±0.55	14.00	15.00	15.00	16.00	16.00	5	15.80±2.05	14.00	14.00	15.00	18.00	18.00	0.279
≥0.90	13	15.00±0.00	15.00	15.00	15.00	15.00	15.00	4	14.00±0.00	14.00	14.00	14.00	14.00	14.00	-

*$P < 0.05$; significant. I_{3M}: Third molar maturity index, Q1: 1st quartile, Q3: 3rd quartile, SD: Standard deviation

Table 3: Contingency table describing discrimination performance of the test for males

Test	Age			Total
	≥18		<18	
I_{3M}				
<0.08	286		35	321
≥0.08	97		179	276
Total	383		214	597
Sensitivity (%)	**Specificity (%)**	**Positive predictive value (%)**	**Negative predictive value (%)**	**Accuracy (%)**
74.67	83.64	89.10	64.86	77.89

I_{3M}: Third molar maturity index

Table 4: Contingency table describing discrimination performance of the test for females

Test	Age			Total
	≥18		<18	
I_{3M}				
<0.08	210		30	240
≥0.08	108		117	225
Total	318		147	465
Sensitivity (%)	**Specificity (%)**	**Positive predictive value (%)**	**Negative predictive value (%)**	**Accuracy (%)**
66.04	79.59	87.50	52.00	70.32

I_{3M}: Third molar maturity index

Discussion

Numerous body changes accompany the adolescent period, many of which may be used as age indicators, for example, signs of sexual maturation, anthropometric data, and mineralization of bones. In case of bone mineralization, the growth of several parts of the body, the appearance of ossification centers, their morphology, size, and fusion can also be used for age assessment.[12]

Schmeling *et al*.[13] emphasized that to increase the diagnostic accuracy, a physical examination, radiographic examination of the left hand as well as a thorough dental examination including the determination of the dental status and an orthopantomographic examination of the dentition should be performed in each case. Ascertainment of dental age using tooth mineralization stages to appraise a subject's degree of maturity is also one of the methods for judging physiologic development.[2,13,14] The third molar is the most inconsistent tooth of the human dentition, in terms of its time of formation and eruption, size, being congenitally absent frequently, malformed, or impacted. Therefore, the association between chronological age and formation of the third molar is considered to be moderate.[2] Still, third molars are sometimes used to judge the juvenile versus adult status of subjects who lack age documentation.

The need for effective and reliable scientific methods to determine age, particularly adult and over age of 18-year-old, within a specific population has become increasingly important in resolving court cases. We used Cameriere's cutoff value of I_{3M}[10] to assess the age in young Indian population.

Our study observed the similar maturation of third molars in males when compared with females. Males were slightly more accurately classified (89.1%) than females (87.5%) into adults or minors. Specificity was better for males (83.6%) compared to females (79.6%). Sensitivity was also better for males (74.7%) than females (66%). Both results were reasonably good in estimating the accuracy which was found to be 77.9% in males and 70.3% in females. These are important findings because the method was verified on a larger population of Indian origin than for previously tested population samples from Italy.[10] For the medicolegal purposes, it is important to minimize the proportion of false negative results, i.e., individuals who are >18 years of age but identified as minors.

Previous studies have observed no significant gender difference in average timing of maturation of permanent third molar[15] though not a consistent finding, most studies have observed mean age earlier in boys compared to girls for all or most mineralization stages.[16,17]

Thevissen *et al*.[18] found that no important differences existed in the degree of third molar development among the 14 examined countries implying that ethnical variations in third molar development are of clinically minor validity. Liversidge[3] showed that the third molars in South African children mature earlier when compared to sample of Caucasian and Bangladeshi children from London.

A review of the population-specific third molar studies conducted on the United States population to estimate age in relation to whether an individual has reached the legal age of majority was done. This study suggested that ancestral population specificity plays a significant role in accurate and reliable age estimation.[19] However, larger population-specific data from the Asian population is scarce.

There is increased need of forensic experts to use all available methods for age estimation for different purposes, especially forensic and medicolegal. Several age limits are applied for penal and criminal responsibility, where 18 years of age is the most common. It was emphasized by De Luca *et al*.[11] that some people could deliberately remove third molars to prevent their assessment of age. Noteworthily, there are other reliable indicators for assessing skeletal age with applicable confidence intervals. Cameriere *et al*.[20] applied the ratio between the total area of carpal bones and epiphyses of the ulna and radius and carpals as age indicators in Italian population and later in Slovenian sample[12] and found the method acceptable as age estimator.

Most studies[2,21,22] have used Demirjian staging system (DSS)[4] where dental development of the tooth was divided into eight specific stages of mineralization. Acharya[22] applied Demirjian's grading to the third mandibular molar in an Indian sample and observed that this tooth correctly predicted juvenile/adult status in 73.2% of cases. However, Mincer *et al*.[2] showed the low accuracy of DSS approach. They pointed that a small number of the developmental stages, which cover a specific age range of target population, are not distributed uniformly.

Cameriere *et al*.[10] showed that small numbers of mineralization stages of DSS considerably effect on the sensitivity and specificity of the test to discriminate subjects between adults or minor. The same study showed that specific cutoff value 0.08 for I_{3M} for both genders better discriminated subjects between adults and minor when compared to DSS approach. Later, in 2014, Cameriere *et al*.[23] tested the accuracy of cutoff value of the I_{3M} on the Albanian sample and found the method reliable in discriminating between Albanian adults and juveniles, with 87.5% correctly classified females and 92.5% correctly classified males and recommended it for determining the adult age in individuals from other populations.

A study by De Luca *et al*.[11] on another Italian sample of 397 subjects, aged between 13 and 22, emphasized the usefulness of I_{3M} in assessing 18 years of age, nevertheless, cautioned that using a combination of all available methods will improve the accuracy of age estimates.

Another study highlighted the efficacy of I_{3M} in estimating 18 years cutoff age in Croatian population and revealed 91.5% females and 88.8% males as accurately classified.[24]

Up-to-date, insufficient knowledge has been obtained about how and does really ethnic origin can influence on tooth mineralization. However, this constitutes a limitation on the reliability of the age estimation method on third molars and hence on the value of the specific information of estimated age stated by a forensic expert.

Conclusion

Population-specific standards would enhance the accuracy of forensic age estimates based on wisdom tooth mineralization in living subjects. In conclusion, the results of this paper encourage us also to test the cutoff value of I_{3M} = 0.08 on other Indian subjects and to investigate any possible ethnic variability. In the forensic field, as what intrigues judges is whether the individuals in question have reached a specific threshold age of majority, to give reliable judgement in the Court of law.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

References

1. Liversidge HM. Crown formation times of human permanent anterior teeth. Arch Oral Biol 2000;45:713-21.
2. 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.
3. Liversidge HM. Timing of human mandibular third molar formation. Ann Hum Biol 2008;35:294-321.
4. Demirjian A, Goldstein H, Tanner JM. A new system of dental age assessment. Hum Biol 1973;45:211-27.
5. Solari AC, Abramovitch K. The accuracy and precision of third molar development as an indicator of chronological age in Hispanics. J Forensic Sci 2002;47:531-5.
6. 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;118:170-3.
7. 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;169:161-7.
8. 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;165:46-51.
9. Cameriere R, Ferrante L, Cingolani M. Age estimation in children by measurement of open apices in teeth. Int J Legal Med 2006;120:49-52.
10. Cameriere R, Ferrante L, De Angelis D, Scarpino F, Galli F. The comparison between measurement of open apices of third molars and Demirjian stages to test chronological age of over 18 year olds in living subjects. Int J Legal Med 2008;122:493-7.
11. De Luca S, Biagi R, Begnoni G, Farronato G, Cingolani M, Merelli V, *et al.* Accuracy of Cameriere's cut-off value for third molar in assessing 18 years of age. Forensic Sci Int 2014;235:102.e1-6.
12. Cameriere R, Ferrante L, Ermenc B, Mirtella D, Strus K. Age estimation using carpals: Study of a Slovenian sample to test Cameriere's method. Forensic Sci Int 2008;174:178-81.
13. 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;122:457-60.
14. Willems G. A review of the most commonly used dental age estimation techniques. J Forensic Odontostomatol 2001;19:9-17.
15. Garn SM, Lewis AB, Bonne B. Third molar formation and its developmental course. Angle Orthod 1962;32:270-9.
16. Moorrees CF, Fanning EA, Hunt EE Jr. Age variation of formation stages for ten permanent teeth. J Dent Res 1963;42:1490-502.
17. Nyström ME, Ranta HM, Peltola JS, Kataja JM. Timing of developmental stages in permanent mandibular teeth of Finns from birth to age 25. Acta Odontol Scand 2007;65:36-43.
18. Thevissen PW, Fieuws S, Willems G. Third molar development: Evaluation of nine tooth development registration techniques for age estimations. J Forensic Sci 2013;58:393-7.
19. Lewis JM, Senn DR. Dental age estimation utilizing third molar development: A review of principles, methods, and population studies used in the United States. Forensic Sci Int 2010;201:79-83.
20. Cameriere R, Ferrante L, Mirtella D, Cingolani M. Carpals and epiphyses of radius and ulna as age indicators. Int J Legal Med 2006;120:143-6.

21. Knell B, Ruhstaller P, Prieels F, Schmeling A. Dental age diagnostics by means of radiographical evaluation of the growth stages of lower wisdom teeth. Int J Legal Med 2009;123:465-9.
22. Acharya AB. Accuracy of predicting 18 years of age from mandibular third molar development in an Indian sample using Demirjian's ten-stage criteria. Int J Legal Med 2011;125:227-33.
23. Cameriere R, Santoro V, Roca R, Lozito P, Introna F, Cingolani M, *et al.* Assessment of legal adult age of 18 by measurement of open apices of the third molars: Study on the Albanian sample. Forensic Sci Int 2014;245:205.e1-5.
24. Galic I, Lauc T, Brkic H, Vodanovic M, Galic E, Biazevic MG, *et al.* Cameriere's third molar maturity index in assessing age of majority. Forensic Sci Int 2015;252:191.e1-5.