Olze *et al*. stages of radiographic visibility of root pulp and cameriere's third molar maturity index to estimate legal adult age in Hyderabad population

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Abstract

Context: Predicting one's attainment of age of majority is a controversial issue and considered as important aspect in medicolegal cases. In India, individuals older than 18 years of age have full capacity regarding civil conduct and are tried as adults for criminal charges. **Aims and Objective:** To compare the accuracy of Olze *et al.*, stages of radiographic visibility of root pulp, and Cameriere's third molar maturity index ($I_{3M} < 0.08$) to estimate the age of majority. **Materials and Methods:** A total of 615 digital orthopantomographs of children aged between 15 and 22 years. The lower left third molars were evaluated using ImageJ computer software. The effectiveness of both methods was evaluated using sensitivity, specificity, positive likelihood ratios (LR+), and LR negative (LR−). **Results:** For $I_{3M} < 0.08$, the sensitivity, specificity, LR+, LR− were 0.76, 0.72, 2.79, 0.32 and 0.67, 0.76, 2.83, 0.43 in males and females respectively. For Stage 0, the sensitivity, specificity, LR+, LR− were 0.68, 0.86, 5.18, 0.36 and 0.72, 0.91, 8.63, 0.31, respectively. **Conclusion:** Stage 0 of Olze's radiographic root pulp visibility showed to be more accurate than cutoff value of $I_{3M} < 0.08$ in discriminating adults and minors of Hyderabad sample when a test of high sensitivity and specificity is required.

Key words: Age of majority, Hyderabad, orthopantomograph, radiographic root pulp visibility, third molar maturity index

Introduction

Estimation of age of individuals needs a multidisciplinary effort, and finding of the age of majority has an important role in medicolegal cases. The age of majority is delineated as the age at which the law judges an individual that he or she has attained adulthood and asserted to be a full legal citizen. It also states that the individual does not

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need any supervision of a parent or guardian furthermore in making decisions.[1-3]

Assessing biological age in late adolescent and early adult individuals, about the legal cutoff age of 18 years is always a challenge for forensic experts. Comprehensive age estimation includes many methods and the most frequently used method is assessing the development of third molars. These methods are supplemented by assessing various skeletal indicators. The assessment of dental and skeletal parameters assessment is helpful in estimation of the age of unknown individual within probable confidence interval (CI).[3,4]

Virtually every age has got medicolegal importance and no age is immune from medicolegal scrutiny, which age estimation becomes crucial in forensic practice. One of the daunting tasks for forensic odontologists is to assess whether the individual in dispute with law and justice has attained age of majority (>/<18 years), i.e. major or a minor.[5,6]

A major problem worldwide now is increase in number of asylum seekers due to terrorism and internal conflicts. According to the UN Child Convention act, children of <18 years have special rights and should not be sent back to their native countries. Many asylum seekers are misusing this act, and hence local authorities are taking expert views in confirming the age of such individuals. Apart from this, age of 18 is considered an important cutoff age in many countries in criminal proceedings. This cutoff age determines whether to apply juvenile or adult penal law, which have different considerations and punishments. Legal authorities ask experts for scientific proof whether the examined individual is under or over 18 years. Different methods used for age estimation are based on orthopantomographs (OPGs), intraoral periapical radiographs, and hand–wrist radiographs. Study Group on Forensic Age Diagnostics of the German Society of Legal Medicine gave an organized proposal for examinations.[5-7]

It is still not easy to prove beyond reasonable doubt that a person is over 18 years of age, and it is even more intricate to establish that the person is over 21 years of age.[4,8] Researchers have therefore been concentrating on the tooth development process and the third molars in particular. It would be of great advantage to find a dental method to be applied after the complete root formation of the third molars.[9,10] Therefore, we carried out this study to compare the accuracy of Cameriere's third molar maturity index (I_{3M} < 0.08) and Olze *et al.*, stages of radiographic visibility of root pulp to estimate age of majority.

Materials and Methods

A sample of 615 digital OPGs were collected and third molars were analyzed using Cameriere's third molar maturity index and pulp space visibility stages by Olze *et al.*[1,11] The duration of the study was from January 1, 2017 to December 31, 2018 and the sample consisted of the patients who came for dental treatments to a referral hospital. Ethical clearance was obtained from the institution and informed consent from all the patients. All the analyses were performed using a blind approach with the readers not aware of age of the patients.

Inclusion criteria
1. Participants between 15 and 22 years
2. Participants whose date of birth was known
3. Participants with good-quality radiographs and
4. Participants without systemic diseases which can affect growth like hypothyroidism.

Exclusion criteria
1. Participants with unknown birth dates
2. Participants with missing third molars, severe caries, fillings in third molar
3. Participants with developmental anomalies
4. Chronological age (CA) of the individuals was considered as the difference between the dates on which radiograph was taken and date of birth of the individual subject.

Cameriere's third molar maturity index
Digital OPGs were analyzed using ImageJ analysis software. Lower left permanent third molars (38) were evaluated. Height from the cusp tip to root tip was measured along with width of apices of teeth with open apices. If third molar root development is complete with closed apical ends, 3rd molar maturity index (I_{3M}) was considered as zero. If not, I_{3M} was calculated as the total of the distances between the inner sides of the two open apices divided by the entire tooth length [Figure 1]. A cutoff value of I_{3M} < 0.08 (Cameriere *et al.*) was applied for validation.[1]

Radiographic visibility of root pulp (Olze *et al.*)
The digital OPGs were also classified using pulp space visibility given by Olze *et al.*[11] They categorized root pulp visibility of the lower third molars with apical closure indicating completed root formation into four stages (*n* = 352): Stage 0 = visible lumen of all root canals up to root apex. Stage 1 = the lumen of one root canal is not entirely discernible up to the root apex; Stage 2 = two root canals with incompletely visible lumen to the apex, or one canal might be virtually not visible in entire length; And Stage 3 = the lumen of two root canals are virtually not visible in entire length.

Statistical analysis
The obtained data were entered into Microsoft Excel sheets and statistically analyzed. For each case, variables such as name, gender, patient identification number, date of birth, date of exposure of radiograph, and Olze *et al.* stage visibility

Figure 1: Cameriere's third molar maturity index.jpg

Figure 2: Scatter plot between third molar maturity index and chronological age.jpg

of the root pulp were recorded. Analysis was done by SPSS Version 20 (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0., Armonk, NY: USA, IBM Corp). The CA was calculated by subtraction of date of birth date from the date of radiograph exposure and recorded as years and 1/10 of years. For each stage, a minimum and a maximum were noted and a median with upper and lower quartiles and also mean and standard deviation were calculated.

Sensitivity and specificity values were calculated. And also, the positive likelihood ratios (LR+) and LR negative (LR−) were also calculated to express how many times more or less likely a test result is to be found in (>18 years) compared to (<18 years) individuals.

Results

Table 1 showed age and gender distribution of the total sample. A total of 615 OPGs were analyzed to verify discriminating ability of third molar maturity index value ($I_{3M} < 0.08$). On the other hand, performance of Olze *et al*., stages were verified in a sample of 352 (151 males and 201 females) belonged to age groups of 16–21.9 years. Maximum number of cases was in between age groups 19 and 19.9 years and least between 21 and 21.9 years. Table 2 shows descriptive statistics and [Figure 2] shows the scatter plot indicating that with increase in age, there is decrease in third molar maturity index (TMM) value in both males and females. Median values among males above 19 years were 0.00, indicating closed apices. Similarly, females above 20 years of age showed a median I_{3M} value of 0.00. Standard deviation was similar among both the genders, but as the age progressed, the deviation was decreasing in males (0.03) in comparison to females (0.05).

When performance of Cameriere's TMM value was verified, it was observed that in males, the sensitivity was 0.76 (95% CI 0.68–0.83) and specificity was 0.72 (95% CI 0.64–0.79). The LR + and LR − were 2.79 (95% CI 2.08–3.75) and 0.32 (95%
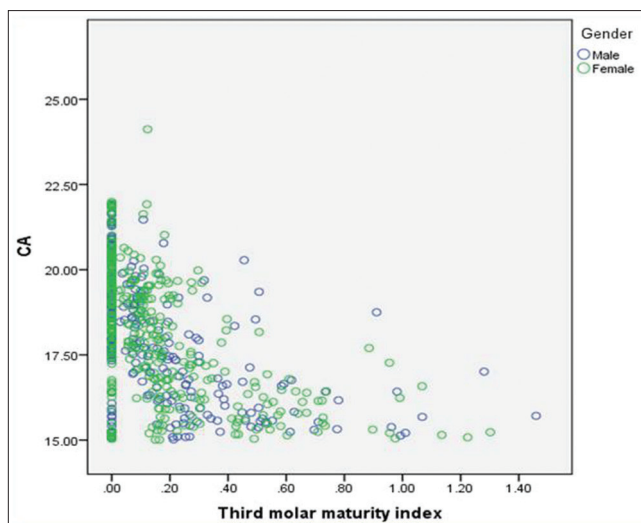
Table 1: Age and gender distribution of the sample; the numbers in parenthesis indicates the sample evaluated to verify the performance of root pulp visibility stages by Olze *et al*.

Age groups	Males	Females	Grand total
15-15.9	52	63	115
16-16.9	36 (16)	53 (16)	89 (32)
17-17.9	47 (37)	53 (37)	100 (74)
18-18.9	41 (34)	59 (49)	100 (83)
19-19.9	50 (44)	73 (63)	123 (107)
20-20.9	23 (20)	37 (36)	60 (56)
21-21.9	11	17	28
Grand total	260 (151)	355 (201)	615 (352)

Table 2: Summary statistics of third molar maturity index <0.08 according to age groups

Age groups	Males						Females					
	n	Mean	SD	Min	Med	Max	n	Mean	SD	Min	Med	Max
15-15.9	52	0.36	0.3	0.00	0.28	1.46	63	0.37	0.3	0.00	0.31	1.3
16-16.9	36	0.31	0.2	0.00	0.24	0.98	53	0.31	0.2	0.00	0.22	1.07
17-17.9	47	0.12	0.2	0.00	0.08	1.28	53	0.16	0.1	0.00	0.11	0.96
18-18.9	41	0.11	0.1	0.00	0.06	0.91	59	0.07	0.1	0.00	0.05	0.51
19-19.9	50	0.05	0.1	0.00	0.00	0.51	73	0.08	0.08	0.00	0.06	0.31
20-20.9	23	0.03	0.1	0.00	0.00	0.46	37	0.01	0.04	0.00	0.00	0.17
21-21.9	11	0.009	0.03	0.00	0.00	0.11	17	0.03	0.05	0.00	0.00	0.18

Min: Minimum age, Max: Maximum age, SD: Standard deviation

CI 0.23–0.45). In females, the sensitivity was 0.67 (95% CI 0.6–0.73) and specificity was 0.76 (95% CI 0.68–0.82). The LR + and LR − were 2.83 (95% CI 2.11–3.8) and 0.43 (95% CI 0.35–0.54), respectively [Tables 3 and 4].

Table 5 showed descriptive statistics of stagewise of CA of both males and females. In males, the mean CA of the participants with Stage 0 was 16.08 years, Stage 1 was 17.01 years, and Stage 2 was 17.42 years. In females, the mean CA was 16.22 years, 16.76 years, and 18.14 years for

stages 0, 1, and 2, respectively. It was also observed that the corresponding stages of root pulp visibility appeared earlier in females compared to males. When the discriminating ability of Stage 0 was tested to find major/minor status of the participants, our results showed that in males, sensitivity was 0.68 (95% CI 0.55–0.79) and specificity was 0.86 (95% CI 0.78–0.93). The LR+ and LR− were 5.18 (95% CI 2.98–9.02) and 0.36 (95% CI 0.25–0.53). In females, the sensitivity was 0.71 (95% CI 0.58–0.83) and specificity was 0.91 (95% CI 0.85–0.95). The LR+ and LR− were 8.63 (95% CI 4.9–15.2) and 0.31 (95% CI 0.2–0.47), respectively [Tables 6 and 7].

Discussion

Predicting major/minor status of individuals who were in dispute with court of law is a frequent encounter in medicolegal practice. The age of majority is applicable in India for various purposes such as issue of driving license, basic age of entry to government service employment, and marriageable age for females. Forensic odontologists regularly help government agencies in age assessments. After 14 years of age, third molars are the only available teeth, still in developing stage, and therefore, many dental age estimation methods rely on this tooth. During age groups of 15–23 years, they are the only teeth usually visible from crypt appearance to apex completion on radiographs.[9-11] Mincer *et al.* (1993) studied radiographic reliability of the third molars as age indicators in 823 American children, they concluded that even though third molars are the most variable teeth they are the only usable datum for age estimation.[12]

Cameriere *et al.* introduced third molar maturity index (I_{3M}), based on the measurement of the tooth length and width of apices of teeth with open apices and given a cutoff value of 0.08 that would discriminate individuals above 18 years or not. It was thought that there will be difference in cutoff values and results in different populations.[13]

Literature suggests that the mean age of complete apical closure of third molars is between 20 and 23 years. Even though the presence of fully formed roots of third molars under the age of 18 years is very low, but this cannot be ruled out. Cameriere *et al.* demonstrated better performance of $I_{3M} < 0.08$ in differentiating adults or juveniles when compared to the Demirjian staging system. Later, many studies have been carried out testing the validity and performance of Cameriere's $I_{3M} < 0.08$.[3,14-16]

Deliberate falsification of age for different purposes is usually done, and it is one of the primary reasons, for which forensic expert opinion is sought. Many methods for age estimation are based on the skeletal parameters and dental development. However, these methods were found to be accurate when applied to the individuals of the same population from whom the formulae and standards were derived. This is the main challenge for the forensic experts. Hence, age estimation has to be performed after deriving population-specific standards.[17-19] Acharya was the first to use Demirjian system in India and concluded that one in four cases resulted in "incorrect classification."[18]

To the best of our knowledge, after thorough search of the literature, our study is the first one that compared third molar maturity index value (0.08) and Olze *et al.*, stages of pulp space visibility for discrimination of individuals around 18 years. According to Cameriere *et al.*, a person is considered to be of 18 years of age or older if $I_{3M} < 0.08$. The reason for using the cutoff value by Cameriere *et al.* was that mineralization stages of the Demirjian method significantly affect the specificity and sensitivity of the test to distinguish subjects between adults or minor.[13]

When Cameriere's cutoff value was tested in the studied population, the sensitivity values were 76% and 77% in males and females, respectively, while specificity values were 82% and 86%. On the contrary to our findings, Sharma *et al.*, in their study, found that both sensitivity and specificity were better in males than females.[6] De Luca *et al.* carried a study on Italian sample (397 patients), aged between 13 and 22, stressed the usefulness of I_{3M} in estimating the age of majority, but suggested to use Cameriere's method along with other methods in order to improve the accuracy.[15]

Galic I *et al.* evaluated the applicability of Cameriere's I_{3M} value of 0.08 in Croatian sample. They found that the CA

Table 3: Contingency table describing the discrimination performance between above (≥18 years) and below (<18 years) of cutoff value of third molar maturity index value for males and females

Males				Females			
Test	<18	≥18	Total	Test	<18	≥18	Total
≥0.08	99TP	30FN	129	≥0.08	131TP	64FN	195
<0.08	36FP	95TN	131	<0.08	38FP	122TN	160
Total	135	125	260	Total	169	186	355

TP: True positive, FP: False positive, TN: True negative, FN: False negative

Table 4: Test of diagnostic accuracy of third molar maturity index <0.08 for age at least 18 for overall sample, males and females separately

Test (I_{3M} <0.08)	Diagnosis				95% CI			
	TP	FP	TN	FN	Sensitivity	Specificity	LR+	LR−
Males	99	36	95	30	0.76 (0.68-0.83)	0.72 (0.64-0.79)	2.79 (2.08-3.75)	0.32 (0.23-0.45)
Females	131	38	122	64	0.67 (0.60-0.73)	0.76 (0.68-0.82)	2.83 (2.11-3.8)	0.43 (0.35-0.54)

TP: True positive, FP: False positive, TN: True negative, FN: False negative, LR+/−: Positive/negative likelihood ratio, CI: Confidence interval, I_{3M}: Third molar maturity index

gradually decreased as I_{3M} increased in both genders. The sensitivity was 84.3% for females and 91.2% for males. Specificity was 95.4% and 91.9% for females and males respectively. The proportions of accurately classified males were 88.8%, and for females, it was 91.5%. They concluded that I_{3M} can be used as a determinant of the age of majority in the Croatian sample.[1]

Angelakopoulos *et al.* retrospectively evaluated the cutoff value of I_{3M} = 0.08 for discriminating South African minors from adults, and its relationship with CA. They found that I_{3M} decreased as the real age gradually increased in both sexes with an overall accuracy of 90%, sensitivity of 80%, specificity of 95%, predictive positive value of 96% and the negative predictive value of 76% and concluded that I_{3M} is a valuable method to distinguish participants who are around legal adult age in South Africa.[2]

Similarly, Rózylo-Kalinowska *et al.* assessed Cameriere's I_{3M} in a sample of Polish individuals. The specificity and sensitivity for males was 91.2% and 86.2%, respectively, and for females, it was 93% and 82.6%, respectively. The probabilities of correctly classified individuals were 87.6% and 85.3% in males and females, respectively. They concluded that the specific cutoff point of $I_{3M} < 0.08$ may be a useful tool for discriminating adults from minors in Poland.[3]

Table 5: Statistical data on the age (years) of the stages of root pulp visibility of 38, by stage in females and males (*n*=352)

Gender	Stage	Number	Min	Max	LQ	Median	UQ	Mean	SD
Females	0	57	16.22	20.43	16.92	17.58	18.15	17.69	1.1
	1	118	16.76	20.81	18.4	19.15	19.7	19.11	0.8
	2	26	18.14	20.99	19.59	19.87	20.44	19.91	0.7
Males	0	60	16.08	20.91	16.99	17.62	18.85	17.86	1.2
	1	69	17.01	20.69	18.47	19.06	19.64	18.98	0.8
	2	22	17.42	20.95	19.29	19.73	20.29	19.73	0.8

Min: Minimum age, Max: Maximum age, SD: Standard deviation, LQ: Lower quartile; UQ: Upper quartile

Table 6: Contingency tables describing discrimination performance between above (≥18 years) and below (<18 years) of root pulp visibility staging (Stage 0) for males and females, respectively

	Males				**Females**		
Test (years)	Stage 0	> Stage 0	Total	Test (years)	Stage 0	> Stage 0	Total
<18	41TP	12FP	53	<18	41TP	12FP	53
≥18	19FN	79TN	98	≥18	16FN	132TN	148
Total	60	91	151	Total	57	144	201

TP: True positive, FP: False positive, TN: True negative, FN: False negative

The mean age of participants increased with Olze *et al.* pulp visibility stages. When discriminating ability of Olze *et al.*, Stage 0 was tested, it was observed that the sensitivity and specificity values in males were 68% and 87%, while in females, they were 72%, 92%, respectively. It was observed that low sensitivity and high specificity indicates that a positive test is in itself is very good at confirming the age <18. However, a negative test is not very helpful because sensitivity is low. The reason for this phenomenon is that after the formation of the tooth has been completed, the secondary dentine formation is a lifelong process which gradually narrows the lumen of the pulp canal.[17,18] Therefore, Olze *et al.*[11] analyzed and concluded that this technique can be useful for determining age 21 more likely attained.

Results from the study of Olze *et al.*, revealed that Stage 0 was first noticed at 17.6 and 17.2 years in males and females, Stage 1 for either of sex was between 21 and 22.4 years, stage 2 by males between 22.3 and 22.7 years, by females between 23.4 and 24.7 years, respectively.[11] Similar values were reported from by Timme *et al.* and Guo *et al.*,[20,21] but in the present study, we observed that our values are minimal when compared to those of other studies.[11,20,21] Similar findings compared to our values were reported by Akkaya *et al.*, where Stage 0 was first noticed at 16.61 and 16.43 years for males and females, Stage 1 at 17.91 and 16.93 year, and Stage 2 at 18.13 and 18.14 years, respectively. Such differences among studies might be attributed to differences in study design, sample age ranges, statistical approaches, population differences, and interobserver variations. Akkaya *et al.* highlighted that image quality is important as low resolution increases subjectivity and observer error.[22]

Daniel Pérez-Mongiovi *et al.* carried a study to determine the usefulness of the visibility of the dental pulp in lower-third molars in forensic age estimation. They could successfully predict age over 21 in 96.2% of females and 96.9% of males. On the other hand, in individuals younger than 21 years, they could accurately predict in only 19.6% and 27.0% for females and males, respectively.[10]

For any given method, it is always important to verify errors which are associated with it. In forensic age estimation, those errors are classified as technically (Type I) and ethically unacceptable (Type II) errors.[21] It is always important to keep number of ethically unacceptable errors to minimum or to be eliminated as they wrongly classify

Table 7: Tests of diagnostic accuracy for at least 18 years of age (*n*=352)

Test	**Diagnosis**				**95% CI**			
	TP	FP	TN	FN	Sensitivity	Specificity	LR+	LR−
Performance of stage 0 (males)	41	12	79	19	0.68 (0.55-0.8)	0.86 (0.78-0.93)	5.18 (2.98-9.02)	0.36 (0.25-0.53)
Performance of stage 0 (females)	41	12	132	16	0.72 (0.58-0.83)	0.91 (0.86-0.95)	8.63 (4.9-15.2)	0.31 (0.2-0.47)

TP: True positive, FP: False positive, TN: True negative, FN: False negative, LR+/−: Positive/negative likelihood ratio, CI: Confidence interval

minors as majors, leading to violation of minor's rights. In our study, Stage 0 has produced 22.6% Type II errors in either of sex, while Cameriere's cutoff value has produced 24.3% of Type II errors for overall sample, which indicates that both methods have derived near equal number of Type II errors.

When both the methods were compared Cameriere's cutoff value had more sensitivity than stage 0 of Olze *et al*., stages in males and females. On the contrary, higher specificity values were exhibited by Stage 0 of Olze *et al*., for both genders.

Conclusion

When values of sensitivity, specificity, LR+, and LR− of both tests were taken into account both performed similarly without much variation in their results. When Type II errors of each test considered, Stage 0 of Olze *et al*., produced lesser percentage of errors. Therefore, we may recommend the stage 0 of radiographic visibility of root pulp as useful to discriminate adults and minors in Hyderabad population. It is also important to keep in mind that the use of combination of methods is essential to improve the accuracy of estimating age of majority.

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Conflicts of interest
There are no conflicts of interest.

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