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Cameriere's Third Molar Index for Legal Age Estimation in Iran

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Abstract

Background and objectives: Age determination has various applications, including providing information for archaeology and identifying individuals in forensic medicine. Various methods have been recommended to date for determining age. One of these methods was presented in 2006 by Cameriere et al., which was based on the assessment of the root of only one tooth (the third molar). The aim of this study is to assess the accuracy of the third molar index in determining the legal age of the Iranian population aged 15-24 years old.

Materials and methods: In this cross- sectional study, 300 panoramic radiographs (184 Females and 116 Males) were used. Patients were aged 15-24 years old. the legal age was determined based on the Cameriere's method and compared with the actual age of the individuals. Data were analyzed using SPSS Ver. 20 with descriptive statistics and the ROC curve. The significance level was set at P-value < 0.05.

Results: After performing statistical analysis, the results were as follows: Sensitivity was 77% (95%, CI: 0.72 - 0.83), specificity was 93% (95%, CI: 0.87 - 0.99), the positive predictive value was 97% (95%, CI: 0.72 - 0.81), and the negative predictive value was 56% (95%, CI: 0.47 - 0.65).

Conclusion: This study found that Cameriere's third molar index is 91% accurate in distinguishing individuals above and below 18 years old. However, due to limitations like specific age ranges and non-randomized sampling, further research with larger, more diverse samples is needed. If validated, the index could be useful for forensic age estimation in the Iranian population.

Keywords: Molar; Third; Age Determination by Teeth; Radiography; Panoramic

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1. Introduction

In recent years, determining and estimating age have become increasingly important, and determining an individual's age has become a vital question in forensic medicine. Age estimation is done for various reasons, and it is mostly used in forensic medicine when evaluating whether an individual has reached the age of majority becomes important. In most countries, the legal age is 18 years, though this depends on the rules of each country (1). Age estimation is applicable for both living and deceased individuals. The clinical profile of an individual is used to identify and process deceased individuals, and for living individuals, it helps resolve certain social- legal problems, such as estimating the real age of orphans who want to be adopted or situations in which an individual refuses to disclose their real age for any reason (2-5). Various methods have been presented to date to determine and estimate age, including non-medical methods such as physical examination and radiographic assessment of the skeleton and teeth, or a combination of both (2, 6). In 1973, Demirjian developed a method to determine age (7). This study was conducted on children of French-Canadian origin. In this method, the development of the

seven left mandibular teeth is assessed using panoramic radiography, and classifications are based on a predetermined table with eight stages (8). However, this method also has some limitations, including the need for time and high accuracy to perform calculations, and reliance on tables and diagrams. Furthermore, research conducted in various countries has shown that this method tends to overestimate dental age. For example, a review article by Jayaraman et al. conducted in Germany demonstrated that the Demirjian method overestimates dental age (9).

In 2006, Cameriere et al. presented a new method to determine and estimate the age of individuals over 18 years old (legal age) in the Italian population. Due to the simplicity of this method, it was considered advantageous over other methods. This method is based on the relationship between age and the third molar index (I_{3M}), which assesses the extent of root openness of the third molar to determine the individual's age. Cameriere defined a cutoff value for I_{3M} based on his research, estimating individuals with $I_{3M} < 0.08$ as 18 years old or older. Cameriere demonstrated that $I_{3M} < 0.08$ is a more reliable criterion than Demirjian tables for distinguishing individuals aged 18 years or older from those under 18 years old (10).

Numerous studies have been conducted in various countries to assess the accuracy of the Cameriere equation, demonstrating that this method is effective in those countries (11), such as Sardinia (12), Turkey (13), Texas (14), Peru (15), Netherlands (16), Brazil (17), Hungary (18), Africa (19), Serbia (20), Albania (21). Although these articles indicated the accuracy of the Cameriere's method, they emphasized the need to customize this equation for each specific region (22). Our aim in this study was to assess the accuracy of the third molar index in determining legal age in the northern Iranian population aged 15-24 years old.

2. Materials and methods

Assuming that the sensitivity of the I_{3M} index is 86.6% (23), an analysis of 298 panoramic radiographs allows for estimating this accuracy with a 5% precision at a 95% two-sided confidence interval and a 20% loss of subjects. The sample size was calculated using WinPepi (PEPI for Windows) version 11.65.

The radiographs were taken using the Caranex D system (Soredex, Finland) and belonged to patients aged between 15 and 24 years. They were obtained for diagnostic purposes upon request by dentists. Inclusion criteria were age between 15 and 24 years, presence of the left mandibular third molar, and absence of systemic disease or orofacial abnormalities. Unclear images and visual artifacts were excluded from the study. The age of each participant at the time of radiography was determined based on their birth date and subtracted from the date of radiography.

Then, their age was calculated based on the number of days and divided by 365. The radiographs were assessed by a student senior dental student who was trained by an orthodontics specialist. After gathering the required radiographs, the dental age of the patients was calculated using the Cameriere's method (10). In order to calculate intra-observer error, 50 cases were randomly selected with a 2-week interval, and the third molar index was reassessed by the same individual achieving a consensus coefficient of 99.6% (ICC). To determine dental age using the Cameriere's method, panoramic radiographs in the Romexis Viewer program were carefully evaluated. If the left mandibular third molar was fully erupted and the tooth apex completely closed, the third molar index was considered zero ($I_{3M}= 0$). If the tooth was not fully erupted and the root apices were not closed, the distance between the inner surfaces (A + B) was measured using the linear tool in the program (Figure. 1). This measurement was then divided by the tooth length, defined as the distance from the highest point of the crown to the lowest point of the apex.

If $I_{3M} < 0.08$, the individual is considered an adult (18 years old or older). Similarly, the third molar index was measured for all samples and the results were entered into Excel software.

The test's sensitivity (Se), defined as the proportion of participants aged 18 or older who tested positive, along with its specificity (Sp), defined as the proportion of individuals under 18 years who tested negative, were assessed (24). Additionally, we calculated the Positive Predictive Value (PPV), which measures how many individuals were correctly identified as positive, and the Negative Predictive Value (NPV), which measures how many individuals were correctly identified as negative. We also considered the likelihood ratio of a positive test (LR+) and the likelihood ratio of a negative test (LR-) for the cut-off value of $I_{3M} = 0.08$. The LR+ is the ratio of the true positive rate (sensitivity) to the false positive rate (1-specificity). Conversely, the LR- is the ratio of the false negative rate (1- sensitivity) to the true negative rate (specificity) (24, 25). An (LR+) greater than 1 increases the likelihood of being an adult, while an (LR+) less than 1 decreases this likelihood. In this study, the likelihood

ratios indicate how much more likely adults are to have an I_{3M} value below 0.08 compared to minors, and vice versa. Likelihood ratios above 10 for (LR+) and below 0.1 for (LR-) are considered strong evidence to accept or rule out the assessment in most cases. The Bayes post-test probability (p) of being 18 years or older, defined as the proportion of individuals 18 years or older with an I_{3M} value below 0.08, can help distinguish between those who are or are not 18 years or older. According to Bayes' theorem, p can be expressed as:

$$p = \frac{\text{Se} \times \text{p0}}{\text{Se} \times \text{p0} + (1 - \text{Sp}) \times (1 - \text{p0})}$$

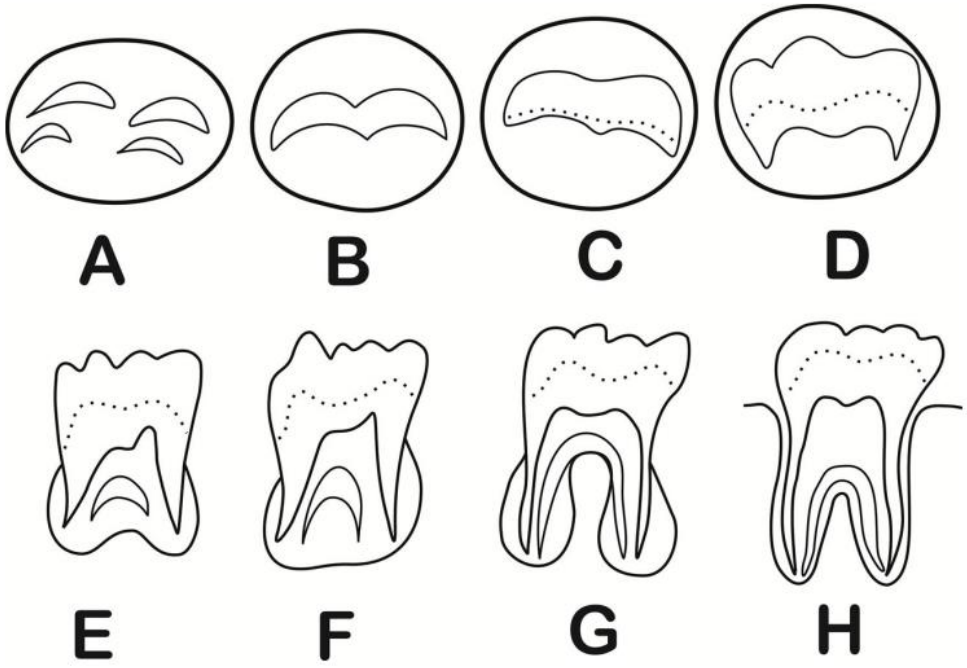

Figure 1. Tooth mineralization stages as defined by Demirjian et al. (1973) are as follows: Stage A: Calcification begins on the occlusal surface without any fusion. Stage B: The occlusal surface forms through the fusion of mineralization points. Stage C: Enamel formation is complete, dentin formation begins, and the pulp chamber lacks pulp horns. Stage D: The crown is fully formed up to the cementoenamel junction, and root formation starts. Stage E: The roots are shorter than the crown height, with calcification at the radicular bifurcation. Stage F: The roots are equal to or longer than the crown height. Stage G: The root canal walls are parallel, with open apical endsStage H: The root apexes are fully closed. (Source: Trakinienėa et al, 2018 (27))

To assess the internal consistency of the observers, the intraclass correlation coefficient (ICC) was used. Data were then entered into the SPSS Ver. 20 software, and descriptive statistics including mean, standard deviation, minimum, maximum, median, first and third quartiles, as well as sensitivity and specificity indices, positive and negative predictive values, were statistically analyzed. The significance level was set at P-value < 0.05, with a 95% confidence interval.

3. Results

In this research, 299 panoramic radiographs were assessed, including 183 men and 116 women. The study participants were aged between 15 and 24 years, with a mean age of 20.1 years and a standard deviation of 2.78. All participants had a third molar tooth in the left mandible.

Table 1 presents descriptive statistics including the mean, standard deviation, minimum value, maximum value, median, and chronological age of individuals grouped by I_{3M} index. According to the results, the highest mean age was observed in the I_{3M} index range of 0-0.08, while the lowest mean age was observed in the range of 0.09-1.3 (Figure 2). Additionally, the table demonstrated that as the I_{3M} index increased, the mean age decreased.

Table 2 presents descriptive statistics including the mean, standard deviation, minimum value, maximum value, median and chronological age of individuals grouped by I_{3M} index, categorized by gender. According to the results

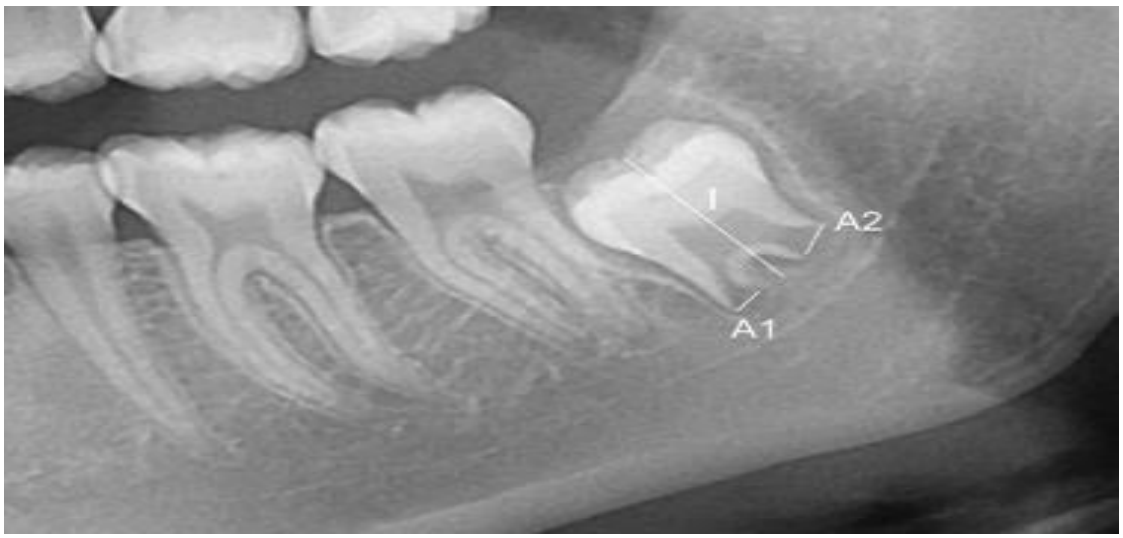

Figure 2. The way of measuring third molar index I_{3M} = (A1 + A2) / I , for example, if: A + B = 4 mm (distance between inner surfaes of roots) and C = 20 mm (length of the tooth), then the I_{3M} would be: I_{3M}= 20 mm / 4 mm = 0.2.

Table 1. Presenting the assessment of descriptive indices (mean, median, standard deviation, range) of the calendar age of individuals, categorized according to the I_{3M} (third molar maturity index) classification.

I_{3M}	Numbers	Mean	SD*	Min$^{\theta}$	Max$^{£}$	Median
0 - 0.08	181	21.62	2.00	15	24	22.00
0.08 - 0.3	70	18.63	1.99	15	24	18.00
0.3 - 0.5	22	16.95	1.94	15	22	16.50
0.5 - 0.7	10	15.90	0.88	15	17	16.00
0.7 - 0.9	7	16.57	1.51	15	19	16.00
0.9 - 1.3	8	15.75	0.71	15	17	16.00
Total	298	20.11	2.79	15	24	21.00

* Standard Deviation
$^{\theta}$ Minimum
$^{£}$ Maximum

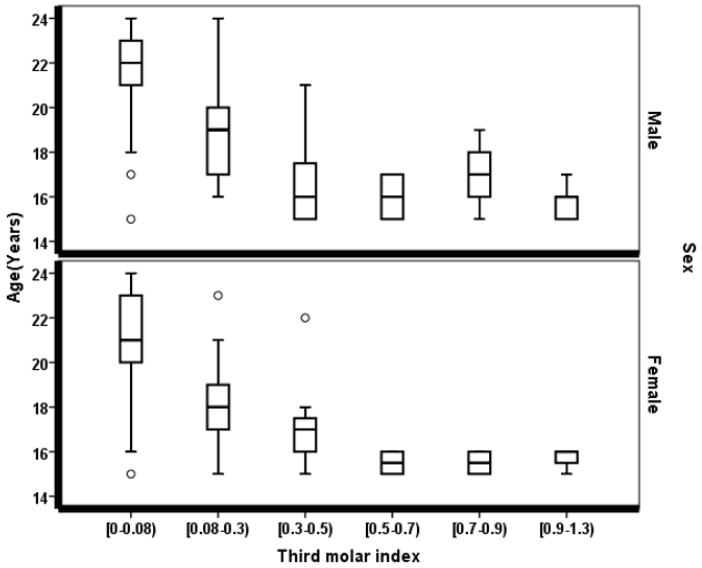

Figure 3. A box plot showing the association between age (in years) and the third molar maturity index (I_{3M}) for males and females. It highlights the median and interquartile ranges, with whiskers representing the minimum and maximum ages, excluding outliers.

in men, the highest mean age was observed in the I_{3M} Index range of 0-0.08, while the lowest mean age was observed in the range of 0.09-1.3. Additionally, the table showed that as the I_{3M} index increased, the mean age tended to decrease. Similarly, in women, the highest mean age was observed in the I_{3M} index range of 0-0.08, while the lowest mean age was observed in the range of 0.09-1.3. The table also indicated that an increase in the I_{3M} index corresponded with a decrease in mean age.

The internal consistency coefficient of the observer (ICC) was measured by re-measuring the third molar index of 50 randomly selected panoramic radiographs, yielding a value of 0.99 with a 95% confidence interval of 0.993-0.998, indicating excellent and significant reliability ($P < 0.001$, where values above 0.7 are considered excellent).

Table 2. Providing an assessment of the descriptive indices of calendar age, stratified by I_{3M} index classification and sex.

Sex	I_{3M}	Numbers	Mean	SD	Min	Max	Median
Male	0 - 0.08	107	21.81	1.87	15	24	22.00
	0.08 - 0.3	47	18.79	2.04	16	24	19.00
	0.3 - 0.5	11	16.82	2.09	15	21	16.00
	0.5 - 0.7	8	16.00	0.93	15	17	16.00
	0.7 - 0.9	5	17.00	1.58	15	19	17.00
	0.9 - 1.3	5	15.80	0.84	15	17	16.00
	Total	183	20.19	2.78	15	24	21.00
Female	0 - 0.08	74	21.35	2.17	15	24	21.00
	0.08 - 0.3	24	18.17	1.97	15	23	18.00
	0.3 - 0.5	11	17.09	1.87	15	22	17.00
	0.5 - 0.7	2	15.50	0.71	15	16	15.50
	0.7 - 0.9	2	15.50	0.71	15	16	15.50
	0.9 - 1.3	3	15.67	0.58	15	16	16.00
	Total	116	19.94	2.82	15	24	20.00

Table 3 presents the number of samples for whom age estimation through the Cameriere's method was correct and incorrect, categorized by age groups (< 18 years old and ≥ 18 years old). This table demonstrates the association between individual age and the accuracy of the Cameriere's method.

Table 3. Evaluation the consistency of individuals' ages using a cutoff point of 0.08, providing a detailed analysis of age distribution and classification accuracy within the specified threshold.

1_{3M} cut-off	≥ 18	< 18	total
1_{3M} < 0.08	176	5	181
1_{3M} ≥ 0.08	52	56	117
Total	228	70	298

Table 4 presents the number of samples for whom age estimation through the Cameriere's method was correct and incorrect, categorized by age groups (< 18 years old and ≥ 18 years old), and further divided by gender. This table illustrates the association among individual age, gender, and the accuracy of the Cameriere's method.

Table 4. Assessment of Age Consistency Based on a Cut-off Point of 0.08, Stratified by Gender.

1_{3M} cut-off	Male		Female		Sensitivity	Specifity
	≥ 18	< 18	≥ 18	< 18		
1_{3M} < 0.08	105	2	71	3	77	93
1_{3M} ≥ 0.08	34	42	18	24		

After performing statistical analysis, the results are as follows: test sensitivity was 77% (CI: 0.72 - 0.83), specificity of the test was 93% (CI: 0.87 - 0.99), positive predictive value of the test was 97% (CI: 0.72 - 0.81), negative predictive value of the test was 56% (CI: 0.47 - 0.65), likelihood ratio +10.81 (CI: 4.63 - 25.22), and likelihood ratio -0.25 (CI: 0.19 - 0.31).

When separated by sex:
1) In females: test sensitivity was 80% (CI: 0.71 - 0.88), specificity of the test was 89% (CI: 0.77 - 1.00), positive predictive value of the test was 96% (CI: 0.91 - 1.00), negative predictive value of the test was 57% (CI: 0.42 - 0.72), likelihood ratio +18.7 (CI: 4.63 - 25.22), and likelihood ratio -0.23 (CI: 0.15 - 0.35).
2) In males: test sensitivity was 76% (CI: 0.68 - 0.83), specificity of the test was 95% (CI: 0.89 - 1.00), positive predictive value of the test was 98% (CI: 0.96 - 1.00), negative predictive value of the test was 55% (CI: 0.44 - 0.66), likelihood ratio +62.16 (CI: 4.28 - 64.58), and likelihood ratio -0.26 (CI: 0.19 - 0.35).

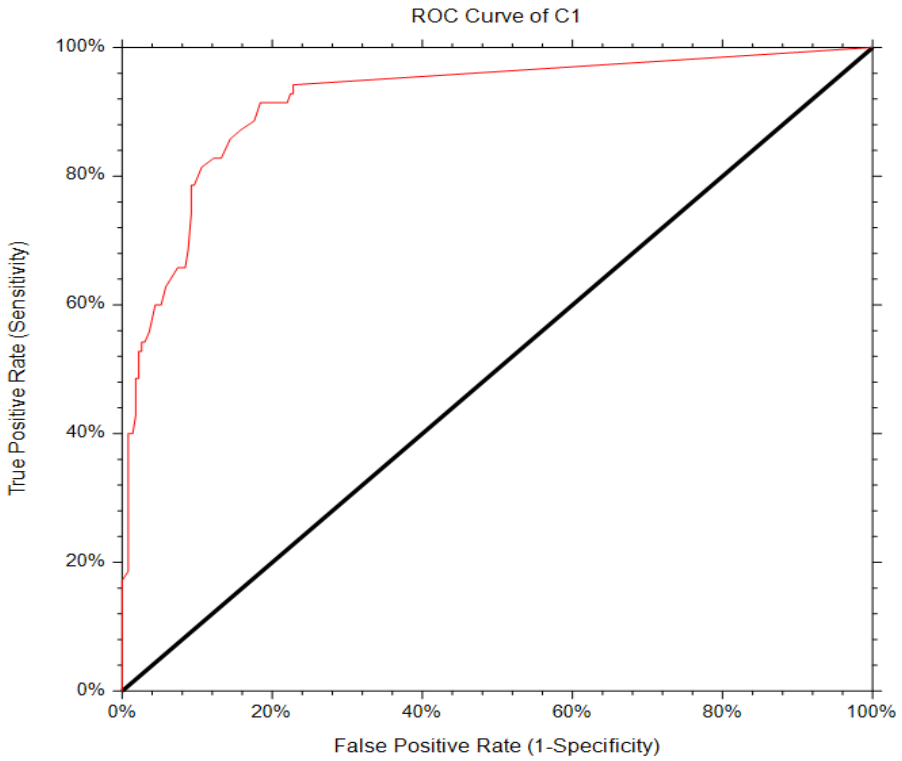

Figure 4. ROC curve to show legal age based on third muler index in sample of Iranian population. The diagram shows that the area under its curve is 91%, indicating that the test has high accuracy.

4. Discussion

The primary goal of this study was to evaluate the efficacy of Cameriere's Third Molar Index (I_{3M}) as a tool for determining the legal age of the Iranian population aged 15-24 years. Given the importance of accurate age determination in legal, forensic, and social contexts, particularly in a diverse population like Iran, the utility of I_{3M} offers a promising avenue (28). By assessing the developmental stage of third molars through radiographic analysis, this research aimed to contribute valuable insights into the reliability and applicability of I_{3M} in this specific demographic. Such an evaluation is crucial for enhancing the accuracy of age estimation methods used in legal proceedings, forensic investigations, and social welfare contexts, thereby addressing pertinent challenges related to age verification in Iran.

X-rays of wisdom teeth are commonly used to assess age in older children, typically those aged 16-22 years. This is because, in this age range, most teeth have fully developed, with only the third molars occasionally having undeveloped roots (2, 29, 30). The time range for the growth of the third molar is from mid-adolescence to the early twenties. The complete closure of the tooth apex of the third molar typically indicates an age of over 18 years, thereby classifying the individual as an adult (31, 32). Regarding methods based on tooth development, the widely accepted method for this purpose in various countries is the Demirjian method (26). The Demirjian method sums the developmental stages of the mandibular left teeth (excluding the wisdom tooth), and the resulting

number correlates with the individual's age as indicated in a reference table (33, 34). One limitation of this method is its reliance on the presence of all teeth; in 1976, Demirjian addressed this limitation by modifying the method to allow for age determination across a wider age range (35), The variation in dental growth patterns among different populations underscores the need for specific standard methods tailored to each population. To address this, researchers worldwide have tested the Demirjian method on their respective populations and developed specific equations (36). Based on the majority of studies conducted in this field, most results indicate that the Demirjian method is not universally applicable across all populations (36, 37). However, there is an exception; Willems et al. (7), discussed the accuracy of the Demirjian method in a population from Bulgaria and found it to be over-estimated in both genders. They subsequently modified the Demirjian method to directly convert it into dental age. The Willem's method has been tested by researchers in Bangladesh, England, and Canada, who found it to be more accurate in various populations compared to the Demirjian method (38). One of the newest studies in this regard was conducted by Cameriere (10). He designed a method in which the legal age of individuals is determined using the third molar index (I_{3M}), derived from the distance of the apex of the third molar roots (10).

We investigated the accuracy of Cameriere's method using a sample of 300 individuals aged between 15 and 24 years old. Firstly, we assessed the reliability and validity of the observer using statistical tests (ICC), and the internal reliability and validity were reported at a significantly excellent level (ICC = 0.9), indicating the correct technique execution by the observer. Among our findings, the sensitivity of this method was higher in women (80%, CI: 0.71 - 0.88) compared to men (76%, CI: 0.68 - 0.83), while the specificity was lower in women (89%, CI: 0.77 - 1.00) compared to men (95%, CI: 0.89 - 1.00). The variation in accuracy between genders can be attributed to the faster development of the third molar in males (39). The positive predictive value of the test was lower in women (96%) than in men (98%), whereas the negative predictive value was higher in women (57%) compared to men (55%). In summary, our results indicate that the analysis of the third molar index is more accurate in men. Our study findings are consistent with a study by Zelic et al. conducted in 2016 in Serbia (20). Although their study had a larger sample size (598 participants), their results indicate that the third molar index is more accurate in men [sensitivity = 96% (95%, CI: 0.93 - 0.98), specificity = 94% (95%, CI: 0.90 - 0.98)] compared to women [sensitivity = 86% (95%, CI: 0.83 - 0.87), specificity = 98% (95%, CI: 0.94 – 0.99)]. In the study conducted by De Lucaet al., with 397 subjects, the specificity was 95.7% (95%, CI: 0.92 - 0.98) and the sensitivity was 86.6% (95%, CI: 0.80 - 0.91) (23).

Additionally, in men aged over 23 years, all samples had mature apexes, whereas in women, some samples showed open apexes. In our study, the number of men aged over 18 years with a third molar index greater than 0.08 (indicating open tooth apex) was nearly half that of women. In Zelic et al. study, it was found that as men age, the rate of increase in the third molar index tends to be higher and faster compared to women (20). The results of the current study were consistent with studies conducted by Solari et al. (39) and Olze et al. (40) on white population. In contrast, the study of Liversidge (33) was conducted on both white and black populations, and found that the results in blacks were opposite to those in whites. This difference may be due to variations in growth patterns among different ethnicities.

Other studies recommend investigating current methods within a specific population and utilizing modified, population-specific methods for age determination (41, 42). For instance, De Luca et al. evaluated the accuracy of the third molar index and concluded that there is no difference between the two genders (23);

While this method had an inverse effect on the Croatian population, a significant difference was observed between the two genders (43). This difference was observed in the Albanian population. In our study, the classification of the third molar for both genders were identical, but this method is more accurate in men.

5. Limitations

Our study has several limitations. Firstly, this study is limited to a specific age range, which may affect the generalizability of the results. Future research should seek to include a broader age range to enhance the applicability of the findings across different age groups. Secondly, our study used non-randomized sampling methods. This was due to the absence of an appropriate sampling frame that would allow for random selection of participants. While we mitigated bias through convenient sampling, the lack of randomization may limit the generalizability of our findings to the broader population. Future studies should consider employing more rigorous sampling techniques to enhance the reliability and validity of results.

6. Conclusion

The present study demonstrated that Camieriere's third molar index exhibited promising accuracy (91%) in differentiating between individuals above and below 18 years old. However, limitations such as specific age range and non-randomized sampling necessitate further investigation with larger and more diverse samples to confirm these findings. If these results are corroborated, Camieriere's third molar index could potentially be a valuable tool in forensic age estimation for the Iranian population.

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Ethics

The study protocol was approved by the ethics committee of Babol University of Medical Sciences (IR.MUBABOL.HRI.REC.1398.375).

Author contributions

Parisa Alizadeh Nili: Investigation, Writing – Original draft

Sedighe Sheikhzadeh: Conceptualization, Project administration, Writing – Review & editing

Maryam Johari: Conceptualization, Project administration, Writing – Review & editing

Conflict of interest

The authors declare no conflict of interest.

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