ORIGINAL ARTICLE

Accuracy and Reliability of Age Estimation by Cameriere's Open Apex Method in the Population of Maharashtra: A Pilot Study

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ABSTRACT

Context: Age estimation is an integral part of investigations in legal and humanitarian scenarios, particularly when the relevant proof documents are unavailable or suspicious of being fraudulent. A radiological method for age estimation using open apices of teeth was suggested by Cameriere *et al.* in 2006. The present study aims to test the accuracy and reliability of Cameriere's method in the population of Maharashtra.

Materials and Methods: Orthopantomograms of 108 patients of age ranging from 6 to 15 years were analyzed using Image J software. Estimation of age was done by Cameriere's open apex method using the original European linear regression formula.

Results: There was an overall overestimation of age by a mean of 0.77 years. The mean overestimation in age for males was 0.88 years, and for females was 0.64 years. The two-tailed P value was found to be 0.2958, which indicated that there was no statistically significant difference between the discrepancies noted, respectively, in both the genders.

Conclusion: Cameriere's open apex method can be utilized to efficiently and accurately estimate age in a non-invasive manner. The slight discrepancies amongst various populations can be resolved by extensive studies using the method in these regions, compiling the data, and developing region-specific variables in the existing formula.

Keywords: Dental age, Forensic odontology, Open apices, Panoramic radiography.

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INTRODUCTION

Age estimation is an integral part of investigations in legal and humanitarian scenarios, particularly when the relevant documents of proof are unavailable or suspicious of being fraudulent. It finds applications in various legal cases involving children and juveniles for civil aspects like adoption, child labor, or other criminal proceedings such as rape, kidnapping, and illegal immigration.[1] An accurate and dependable method that can estimate age with high probability, can aid in narrowing down the list of possible victims or even play a decisive role in such cases.

The study group on forensic age diagnostics has suggested using a combination of physical examination, dental status, and radiographic examination to improve the accuracy of age estimation.[2] The teeth erupt in a definite chronological sequence, providing a fair indication of a person's age. Unlike other skeletal tissues, once formed, dental tissues do not undergo significant remodeling once their mineralization is completed and are only slightly affected by aging or hormone alteration.[3] Therefore, dental tissues are recommended as a tool for the assessment of age.

A multitude of methods and formulae have been developed over time, each aiming to accurately estimate the age of the subjects in question, living or dead, by analyzing the dentition-related factors. Most of these methods involve examination of histomorphological features of teeth such as incremental lines

of Retzius, cementum annulations, the translucency of dentin, racemization of collagen in dentin, or regressive alterations in teeth.[4] However, these methods warrant extraction of the tooth followed by tedious preparatory procedures, which is not possible in many legal cases.

A relatively non-invasive radiological method for age estimation was suggested by Cameriere *et al.* in 2006. It involved radiological evaluation of proportional measurements of formative crowns to the open apices of teeth in children and adolescents.[5] They utilized a linear regression formula that could estimate age significantly accurately.

The formula was tested amongst the populations of various regions of India, and naturally, owing to geographic,

dietary, and ethnic influences, a certain discrepancy was observed from the original European formula.[6] However, India is a climatically and culturally diversified country and shows variations even amongst different states. Consequently, modifications such as the addition of a dummy variable were proposed in the original formula, specific for populations of Central, North, and South Indian populations.[6-9]

The present study was conducted to determine the accuracy of Cameriere's open apex method for age determination as well as to confirm the applicability of the original formula provided by Cameriere *et al*. in the population of Maharashtra a state in the western part of India.

Materials and Methods

The institutional ethical board approved the protocol of the present study. The study was conducted for two years (from Oct 2019 to Oct 2021), during which orthopantomograms (OPGs) were obtained from the institutional department of Oral Radiology based on convenience sampling. Only patients with mixed dentition advised to obtain an OPG for their routine treatment were included in the study; none of the patients was exposed to radiation specifically for the sake of the study.

OPGs of patients with mixed dentition between the age range of 6-15 years were selected for the study. Patients who have systemic conditions that could influence the formative or mineralization process of the teeth or those not having all the mandibular teeth present at least on one side were excluded. Patients undergoing orthodontic treatment were also excluded from the study.

The coordinating investigators (S. Su and O.K.) assigned a randomly generated code to each OPG and noted down the demographic details of the patient. The patient's chronological age (CA) was obtained by subtracting the date of obtaining the OPG from the patient's birth date. The investigator, tasked with estimating the age, was blinded regarding all the aspects of the patients, including name, chronological age, gender, religion, and socioeconomic status. The image of the coded OPG was provided to the investigator and was analyzed using "Image J" software. The software has the advantages of being easily available and free to use, making the study design quite feasible.

Seven left permanent mandibular teeth were considered, excluding the third molar. The number of teeth with closed apical ends (N) was determined. For teeth with open apices, the distance between the inner sides of the open apex was measured (A_i, i being the number of the element). For those teeth with two roots (i = 6 and 7), the sum of the distances between the inner sides of both apices was calculated. To avoid distortions by possible differences in magnification or angulation, the measure A_i was divided by the tooth length (L_i) so that $x_i = A_i/L_i$.

The measures obtained were used to estimate age according to the original formula provided by Cameriere *et al*.[5]:

$$\text{Dental Age} = 8.971 + 0.375g + 1.631 \cdot x_5 + 0.674 \cdot N - 1.034 \cdot S - 0.176S \cdot N_0$$

where g is a variable-1 for boys, and 0 for girls; $x_5 = A_5/L_5$; N = number of teeth with closed apical end; and S = sum of normalized open apices ($S = x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7$).

Two independent observers (SS and YA) analyzed the radiographs to minimize bias in image analysis and interpretation.

Results

A total of 108 samples were included in the study, comprising OPGs from 56 males and 52 females. The CA of the entire study population ranged from 7 to 14 years, with a mean of 10.314 years (S.D. = $\pm$ 1.768). The mean DA of the study population was found to be 11.080 years (S.D. = $\pm$ 1.272).

The mean overestimation in age for males was 0.88 years, and for females was 0.64 years. The two-tailed p value was found to be 0.2958, which indicated that there was no statistically significant difference between the discrepancies noted, respectively, in both the genders.

A co-efficient value of 0.92 was obtained using intra-class co-efficient analysis, which implied a good agreement between the two observers.

Discussion

Teeth are highly resistant to adverse conditions such as heat, trauma, and pressure generated during natural disasters such as fires, floods, and earthquakes.[10] Consequently, they are
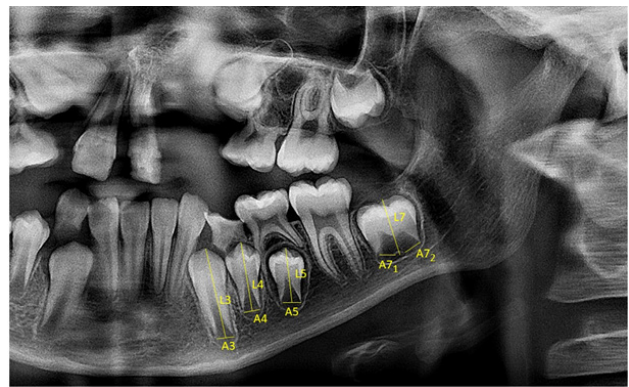

Figure 1: An example of analysis of the seven mandibular left teeth. 'A' represents the width of the open apex; 'L' represents the vertical length of the tooth. The number of teeth with closed apices is noted.

Table 1: Gender-specific characteristics of chronological age of the study population and its dental age calculated by Cameriere's method.

	Males (n=56)		Females (n=52)	
	Chronological age	Dental age	Chronological age	Dental age
Mean	10.07143	10.95857	10.57692	11.21192
Max	14	14.3	13	12.34
Min	7	7.34	8	8.8
S.D.	1.943354	1.413948	1.432756	0.908744

preserved over long periods while other parts of the body deteriorate. Therefore, utilizing teeth is highly recommended for forensic and paleontological investigations.

Continuous deposition of dentin occurs, which results in the narrowing of apices during the process of root formation.[11] It occurs systematically, at different chronological ages for different teeth. Cameriere's age estimation method effectively employs this phenomenon for age estimation.

The major advantage of Cameriere's method for age estimation is that it is relatively non-invasive and does not require the extraction of teeth, as compared to other histomorphological analytical methods. Since a vertical to horizontal ratio is obtained in the method, discrepancy due to radiographic image distortion is also minimized. Although distortion may vary along the horizontal and vertical axes, it is generally not significant under normal conditions and would affect the ratio only in extreme values.[12] These qualities of Cameriere's method make it a preferable choice for efficient and accurate age estimation.

The applicability of Cameriere's open apex method of age estimation is not only limited to forensic odontology but can extend to other branches of dentistry as well. Two individuals of the same age may show variation in the chronological development of teeth, owing to the differences in their upbringing, nutritional status, and ethnic differences.[13] This may constitute a drawback of age estimation using this method when legal aspects are considered but can be beneficial in another way. Most of the treatment procedures in interceptive orthodontics and pedodontics are based on the developmental stages of teeth. Using these developmental stages to calculate the dental age would be more apt for treatment planning than using the chronological age, which may or may not accurately depict the developmental status of the patient.

Similar studies in other parts of India have found varied and contrasting results.[6,7,9] The results of our study indicated that there was an overestimation of age with a mean difference of 0.88 years in males and 0.64 years in females. A similar overestimation of age by 0.70 years in boys and 0.60 years in girls was found by Rai *et al*. in the population of Haryana (North India).[6] Vadala *et al*. found a relatively lower overestimation of 0.02 years in males and 0.22 years in females in the Khammam population (South India).[7] On the contrary, Ganepalli *et al*. found an underestimation with a mean difference of 1.50 years in males and 1.54 years in females (South India).[9]

The discrepancies amongst various studies may be a result of a combination of various factors: (i) There would be an obvious difference in the chronological closure of root apices amongst different populations,[14] (ii) The near-closed apices of roots in patients of older age group make analysis difficult and subject it to errors,[15] and (iii) radiographic causes wherein distortion along one axis significantly exceeds the other.[12] While a part of these discrepancies may be solved by introducing dummy variables for specific populations, those attributable to errors in methods or samples are relatively more difficult to deal with.

These errors may create a barrier in stating the probability of estimated age in the court of law. Wrongful conviction due to erroneous methodology in age estimation would be the worst possible outcome. Therefore, population-specific data from different regions of various countries concerning the validity and reliability of methods used for age estimation must be generated regularly and on a large scale.

The findings from our pilot study need to be reinforced by conducting further studies with a larger sample size on the population of Maharashtra. A calculated sample size concerning the population of Maharashtra would provide statistically more reliable and valid information concerning the applicability of Cameriere's method for age estimation.

Any population-specific modifications required in the formula could also be incorporated. Furthermore, such studies would also reveal the impact, if any, of radiographic distortion in age estimation using Cameriere's open apex method. Nevertheless, the method enabled an efficient and fairly accurate estimation of age except for slight overestimation. Our findings highlight the potential reliability of Cameriere's open apex method for age estimation after sufficient scientific validation is carried out.

Conclusion

Cameriere's open apex method can be satisfactorily utilized to efficiently and accurately estimate age in a non-invasive manner. The slight discrepancies existing amongst various populations can be resolved by extensive studies using the method in these regions, compiling the data, and developing region-specific variables in the existing formula. Therefore, more such studies are recommended to generate data that would help improve the accuracy and reliability of the estimated age produced by this method, which our study could save as a pretext.

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