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Assessing the accuracy of Cameriere's Indian-specific formula for age estimation on right and left sides of orthopantomogram

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Abstract

Background: Age estimation is of prime importance in forensic science and clinical dentistry. In children, age estimation can be done by skeletal maturity indicators like hand-wrist radiographs and dental age estimation. Skeletal maturity indicators compared with dental age estimation is limited as they are influenced by various environmental parameters, whereas calcification of teeth depends on genes rather than environmental factors. Many of the dental age estimation methods use extracted teeth, which are quite invasive, whereas Cameriere's method is a recently introduced radiographic method first in European population; where in age estimation is done using open apices of teeth by orthopantomogram (OPG). Indian-specific formula was introduced later using permanent mandibular teeth on left side of jaw. The present study aimed to estimate the age and also to determine the accuracy of Cameriere's method using Indian-specific formula on both right and left sides of mandible in Khammam population of South India and also to determine the side which can be efficient in determining age.

Methodology: The present study comprised radiographs of 50 subjects (25 boys and 25 girls) ranging from 5 to 15 years. The soft copies of the radiographs of selected subjects were retrieved from the computer attached to the digital orthopantomogram machine (Orthophos XG5; Sirona Dental Systems). The 7 left and right permanent mandibular teeth were assessed in OPGs. The number of teeth with closed apical and with open apical ends of roots was examined and measured. The values were tabulated based on the Cameriere method of age estimation using Indian-specific formula. Statistical analysis was done using paired *t* test and Karl Pearson's correlation coefficient test.

Results: Comparison of dental age with chronological age in males showed non-significant results on both left and right sides of the OPG with a *p* value of 0.3765 and 0.3045, respectively. Likewise in females, *p* values of 0.2167 and 0.8089 were noted. When males and females were compared, non-significant results were obtained with a *p* value of 0.1613 in the age estimated on the left side of the OPG and a *p* value of 0.4322 on the right side of the OPG. Correlation test showed that left side of the OPG showed better results in determining age than the right side of the OPG with an *r* value of 0.9982 and 0.9485 in males and females, respectively.

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Conclusion: Cameriere's method of age estimation using Indian-specific formula proves to be an accurate and a reliable method which can be used to assess the chronological age of individuals. There is also a good correlation found between the chronological age and dental age of younger age group individuals.

Keywords: Forensic age estimation, Open apices, Forensic dentistry, Panoramic radiography

Introduction

Forensic odontology is a branch of dentistry which deals with the proper handling and examination of dental evidence (Shamim et al. 2006). Age estimation is an integral component of forensic odontology. In children, age estimation is a point of interest for various reasons which include medico-legal issues, orthodontic treatment, criminal liability, pediatric endocrinology, adoption and illegal immigration (De Luca et al. 2012).

Several methods of age estimation exist like skeletal, odontological, anthropological, radiological and psychological methods (Cameriere et al. 2006). Though skeletal methods are used for age estimation, bone maturation is thought to be influenced by various environmental factors. However, dental age estimation methods show low variability as the calcification and maturation of tooth are less controlled by environmental factors and more often by genes (Nolla 1960). In addition, tooth formation is less influenced by endocrinopathies, malnutrition and thus can be a reliable indicator for age estimation (Shrestha et al. 2015).

Dental age estimation methods include Gustafson's technique, incremental lines of Retzius, perikymata, prenatal and postnatal line formation, racemization of collagen in dentin, cemental incremental lines, translucency of dentin and DNA material of teeth. All these methods are based on histological and morphological changes of the teeth and majority of these require the extraction or crushing of the teeth which is a major disadvantage (Shamim 2011).

One of the first radiographic methods of age estimation was given by Demirjian, Goldsteiner and Tanner who considered calcification of tooth for age estimation and developed a scoring system (Demirjian et al. 1973).

A non-destructive radiographic method was later introduced by Cameriere et al. 2006 which determines age based on the measurement of the open apices in the permanent mandibular developing roots of the teeth (Cameriere et al. 2006). Many studies have been performed using this technique and hence proved this to be an accurate and reliable method in determining the age in children of age group 5–13 years (De Luca et al. 2012).

Since the growth of the child is influenced by numerous factors, it is stated that the various methods of age

estimation based on teeth do not provide a common formula for the whole world (Liversidge et al. 1999). Rai et al. in their study stated that Cameriere's European formula yielding correct value for the European sample could not be applied to the Indian one and a new formula was given for the Indian sample taking into account the differences between Central, North and South Indian population (Rai et al. 2010). The literature search revealed that most of the studies involving Cameriere's method have used permanent mandibular teeth on the left side of the orthopantomogram (OPG) to determine the age. The present study is a pilot study, which is one of its kinds and is designed to use both right and left permanent mandibular teeth on OPGs of subjects in Khammam population. The current study was also designed to estimate the age and to determine the accuracy of the Cameriere method using Indian-specific formula by measuring open apices of teeth on both right and left sides of mandible in Khammam population.

Materials and methods

The present pilot study included 50 individuals of Khammam district of Telangana, aged between 5 and 15 years. Among the 50 subjects, 25 were males and 25 were females. The inclusion criteria were absence of systemic diseases, dental anomalies, premature birth, nutritional and endocrine problems. The exclusion criteria were lack of one or more left and right permanent mandibular teeth and low-quality radiographs. Institutional ethical clearance was obtained and a written consent from each of these subjects also was taken. Patients who required digital radiography were selected for the purpose of this study and orthopantomograms [Orthophos XG5, Sirona Germany] were obtained which were later digitalised in the SIDEXIS XG software. The obtained OPGs were taken from patients who are attending or willing for an orthodontic treatment. These OPGs along with their demographic parameters were used in the present study. The OPGs were not specially taken for the purpose of study, with due consideration with the age of the individuals and the effects of radiation exposure. The obtained OPGs were analysed for the variables.

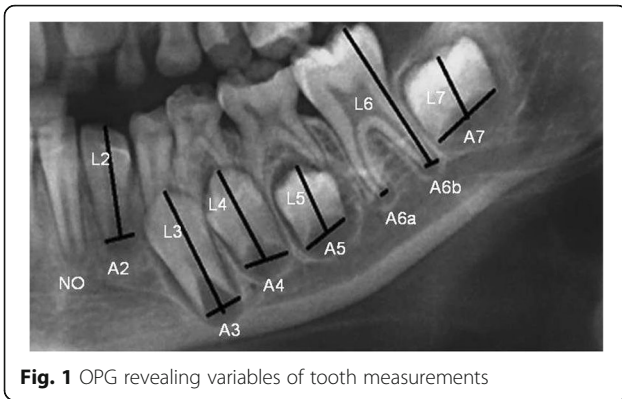


Fig. 1 OPG revealing variables of tooth measurements

Methodology of the study in detail

Chronological age of each child was calculated by subtracting the date of birth from the date of radiograph taken. The seven left and right permanent mandibular teeth were assessed after obtaining the OPGs. The number of teeth with complete root development or closed apical ends of the root was calculated as (N_0). The teeth with incomplete root development or open apices were considered and the distance between the inner sides of the open apex was measured as A_i (where $i = 1, \dots, 7$ the number of the tooth). In the case of teeth with multiple roots, the sum of the distances between the inner sides of the two open apices was evaluated (e.g. $A_6 = A_{6a} + A_{6b}$). To avoid magnification and angulation errors, measurements were normalised by dividing the tooth length (L_i , where $i = 1, \dots, 7$) [Fig. 1]. Finally, the dental maturity score for each tooth was obtained by calculating the X_i where ($X_i = A_i/L_i$, where $i = 1, \dots, 7$). The sum of all the normalised open apices is represented as ‘S’ where ($S = X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7$). Further all these values were substituted in the Indian-specific formula given by Cameriere et al. which is:

[age = $9.402 - 0.879c + 0.663N_0 - 0.711s - 0.106SN_0$] where ‘c’ is a dummy variable which denotes ‘1’ for South Indian population and ‘0’ for North and central Indian population. The obtained data was analysed using

the SPSS software using paired t test, unpaired t test and Karl Pearson correlation coefficient.

The present analysis was analysed by two observers independently to prevent inter-observer bias. This bias was calculated using intra class coefficient analysis which was 0.94, implying a good agreement between two observers.

Results

In the present study, the chronological mean age for 25 male subjects was 8.42 years, estimated mean age based on left side of the OPG was 8.44 and estimated mean age based on right side of the OPG was 8.58 which on comparison showed non-significant results with a p value of 0.3765 and 0.3045, respectively Table 1.

The chronological mean age for 25 female subjects was 9.24 years, estimated mean age based on left side of the OPG was 9.46 and estimated mean age based on right side of the OPG was 9.17 which on comparison showed non-significant results with a p value of 0.2167 and 0.8089, respectively Table 2.

When males and females were compared, non-significant results were obtained with a p value of 0.1613 in the age estimated on the left side of the OPG and a p value of 0.4322 on the right side of the OPG Table 3.

Upon performing Karl Pearson correlation analysis in male subjects, age estimation on left side of the OPG showed better results than the right side of the OPG with an r value of 0.9982 Table 4. Likewise in female subjects, age estimation on left side of the OPG showed better results than the right side of the OPG with an r value of 0.9485 Table 5.

Discussion

Age estimation plays an imperative role in pediatric endocrinology, clinical dentistry, medico-legal cases, forensic medicine, illegal immigration, terrorism and prejudiced birth certificate. In children, skeletal and sexual maturity index was always used to assess age, but dental

Table 1 Comparison of chronological age and estimated age based on left and right sides in males by paired t test

Methods	Mean	Std. Dv.	Mean Diff.	SD Diff.	% of Diff.	Paired t	p value
Chronological age	8.42	2.25					
Estimated age Cameriere’s method left side	8.44	2.24	-0.02	0.13	-0.29	-0.9011	0.3765, NS
Chronological age	8.42	2.25					
Cameriere’s method right side	8.58	2.41	-0.16	0.78	-1.95	-1.0493	0.3045, NS
Cameriere’s method left side	8.44	2.24					
Cameriere’s method right side	8.58	2.41	-0.14	0.78	-1.66	-0.9018	0.3761, NS

* $p < 0.05$ and NS non-significant

Table 2 Comparison of chronological age and estimated age based on left and right sides in females by paired *t* test

Methods	Mean	Std. Dev.	Mean Diff.	SD Diff.	% of Diff.	Paired <i>t</i>	<i>p</i> value
Chronological age	9.24	2.68					
Cameriere's method left side	9.46	2.78	- 0.22	0.88	- 2.43	- 1.2686	0.2167, NS
Chronological age	9.24	2.68					
Cameriere's method right side	9.17	2.80	0.07	1.37	0.72	0.2445	0.8089, NS
Cameriere's method left side	9.46	2.78					
Cameriere's method right side	9.17	2.80	0.29	1.07	3.07	1.3573	0.1873, NS

**p* < 0.05 and NS non-significant

age estimation methods have recently gained popularity because they are less variable or less influenced as maturity indicators (Bagh et al. 2014; Deepak et al. 2015). A non-destructive method for age estimation in Italian population was proposed by Cameriere et al. wherein the 'gender', '× 5' (second premolar), 'N₀' and 's' played a major role as variables in the formula specific for European population (Cameriere et al. 2006). In a country as large as India, ethnic, social and nutritional causes tend to influence the child's growth differently. The same European formula could not be applied to the Indian population because of wide ethnic variation and thus the emphasis was made on the region of the country denoted as 'c' in the Indian formula to have significant correlation with age estimation. Hence, in the Indian formula 'c', 'N₀' and 's' were used as important variables in the formula derived for Indian population for age estimation (Bagh et al. 2014).

In the present study, when the chronological age was compared with the estimated age in males, non-significant results were obtained with a *p* value of 0.3765 and 0.3045 for left and right sides of the OPG, respectively. Similarly, when the chronological age was compared with the estimated age in females, non-significant results were obtained with a *p* value of 0.2167 and 0.8089 for left and right sides of the OPG, respectively. This was in accordance with the studies conducted by Rai et al. and Bagh et al. who also found non-significant results while comparing

dental age with the chronological age using Indian-specific formula (Rai et al. 2010; Bagh et al. 2014). On the other hand, our results are in contrast to the study conducted by Pratyusha et al. where significant results were obtained when comparing dental age with the chronological age using Indian-specific formula (Pratyusha et al. 2017).

Overestimation of age was observed in males by 0.02 years and 0.16 years when using left and right sides of the OPG, respectively. Whereas in females, overestimation of age by 0.22 years was noted on using left side of the OPG and underestimation of age by 0.07 years was observed on using right side of the OPG. Rai et al. studied Cameriere's method in Haryana population and found overestimation of age by 0.60 years in girls and by 0.70 years in boys (Rai et al. 2009). Javadinejad et al. in a study compared the accuracy of four age estimation methods and found the method to underestimate age by 0.11 years in girls and 0.27 years in boys (Javadinejad et al. 2015).

When the accuracy of this method was tested for males and females, non-significant results were obtained with a *p* value of 0.1613 on the left side of the OPG and a *p* value of 0.4322 on the right side of the OPG respectively. Similar results were obtained by Bagh et al. and Attiguppe et al. (Bagh et al. 2014; and Attiguppe et al. 2016). Non-significant results prove that gender does not influence age estimation. However, it is very likely that the maturation of girls and

Table 3 Comparison of male and females with respect to chronological age, estimated age Cameriere's method left side and estimated age Cameriere's method right side by independent *t* test

Variable	Gender	Mean	SD	SE	<i>t</i> value	<i>p</i> value
Chronological age	Male	8.42	2.25	0.45	- 1.1653	0.2497
	Female	9.24	2.68	0.54		NS
Estimated age Cameriere's method left side	Male	8.44	2.24	0.45	- 1.4225	0.1613
	Female	9.46	2.78	0.56		NS
Estimated age Cameriere's method right side	Male	8.58	2.41	0.48	- 0.7922	0.4322
	Female	9.17	2.80	0.56		NS

**p* < 0.05 and NS non-significant

Table 4 Correlation between estimated age based on left and right sides in males by Karl Pearson’s correlation coefficient method

Methods	Correlation between chronological age with		
	r value	t value	p value
Estimated age based on Cameriere’s method left side	0.9982	80.8408	0.0001*
Estimated age based on Cameriere’s method right side	0.9459	13.9749	0.0001*

*p < 0.05

boys in India may occur at about the same time because the early maturation of girls may be offset by malnutrition and greater amount of physical work required for them (Rai et al. 2010).

When both right and left sides of the OPG were compared in the subjects, estimated age on left side of the OPG showed better results when compared with the right side in males and females with an r value of 0.9982 and 0.9485, respectively. The accuracy on the left side of the OPG could be due to two reasons:

1. Left side of the mandible is longer by the age of 6 years in both the genders. On the other hand, the right side of the mandible is longer only by 12 years in girls and by 16 years in boys which means that the rate of growth of mandible is faster on the left side when compared with right (Melnik 1992).
2. Regressive evolution pattern is observed on the right side of the mandible and thus the superior age estimation on the left side of the OPG (Paliwal et al. 2010).

Conclusion

In the present study, a very good correlation was found between the chronological age and estimated age in the studied sample. Comparison between males and females showed non-significant results and left side of the OPG showed superior results when compared with the right side for age estimation. Thus, Cameriere’s method of age

Table 5 Correlation between estimated age based on left side and right sides in females by Karl Pearson’s correlation coefficient method

Methods	Correlation between chronological age with		
	r value	t value	p value
Estimated age based on Cameriere’s method left side	0.9485	14.3561	0.0001*
Estimated age based on Cameriere’s method right side	0.8769	8.7496	0.0001*

*p < 0.05

estimation using Indian-specific formula proves to be an accurate and a reliable and can be used to assess the age of the individuals.

Abbreviations

OPG: Orthopantamogram

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Nil

Authors’ contributions

PV, RS and GV contributed to the study conception and design. GD, SN and CAK contributed to the acquisition of samples. PV, RS, GV, GD, SN and CAK contributed to the analysis and interpretation of the data. PV, RS and GD contributed to the drafting of the manuscript. PV, RS, GV, GD, SN and CAK contributed to the critical revision of the manuscript. All authors have read and approved the final manuscript.

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Availability of data and materials

The data was obtained from patients who visited the outpatient department of Mamata Dental College, Khammam.

Ethics approval and consent to participate

Institutional ethical committee clearance was obtained for the study.

Consent for publication

Given by all authors.

Competing interests

The authors declare that they have no competing interests.

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