



RESEARCH ARTICLE

ORTHOPANTOMOGRAM – AN EFFECTIVE TOOL FOR AGE ESTIMATION IN CHILDREN

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ABSTRACT

Objectives: The objective of this study was to assess the accuracy and applicability of modified Cameriere's European formula given by Rai B *et al* for dental age estimation in south Indian children.

Methods: The study comprised of a total of 600 subjects, who were divided into 10 groups, according to the chronological age. The first group consisted of subjects who are 5 years old, including subject's age ranging from 5.00 to 5.99. Next group included the subjects who were 6 years old, and so on. Digital form of the orthopantomogram obtained for diagnosis and treatment were collected. Chronologic age was noted and Dental age estimation was performed on the orthopantomogram using the formula described by Rai *et al*. $Age = 9.402 - 0.879 C + 0.663 N_0 - 0.711 s - 0.106s \times N_0$
Statistical analysis of data was done using paired t test. Pearson's correlation was used to measure the strength and direction of association between chronological and dental age.

Results: The results showed a mean difference of 0.31 between the chronologic and dental age in total sample, which is statistically insignificant. Pearson's correlation was used to measure the strength and direction of association between chronological and dental age and a value of 0.985 suggest a positive correlation between chronologic age and estimated dental age.

Conclusion: The results showed that modified Cameriere's formula given by Rai *et al* gave a statistically insignificant underestimation of 0.31 years, suggesting its suitability for age estimation in children in south Indian population.

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INTRODUCTION

One of the most important sub-disciplines of forensic sciences is age estimation and is very important in medico-legal issues. The broadening frontiers of dentistry have taken the dentist as an expert witness in legal room proceedings because of the field of forensic sciences. Age assessment is required in following circumstances like, asylum seekers of unknown age, young people accused of criminal activities, and convicted criminals whose age is claimed to be less than 18 years prior to sentencing, marriage of a minor and the laws concerning adoption of children as well as child labouring (Priyadarshini *et al.*, 2015). Developing teeth are used most reliably in age

estimation; teeth are the most indestructible part of the body and exhibit the least turnover of all the natural structure. The methods based on the stages of tooth formation as appreciated on radiographs seems to be more appropriate in the assessment of age than those based on skeletal development as the dental development and calcification is controlled more by genes than by environmental factors (Panchbhai, 2011).

Methods of age estimation

The first known attempt that used teeth as an indicator of age originated from England. Edwin Saunders, a dentist, was the first to publish information regarding dental implications in age assessment by presenting a pamphlet entitled "Teeth a Test of Age" to the English parliament in 1837 (Priyadarshini *et al.*, 2015). Literature describes several techniques that address age

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estimation in adults. The various methods are divided into three categories:

1. Morphological methods
2. Biochemical methods
3. Radiological methods

Morphological methods are based on assessment of teeth (ex-vivo). Hence, these methods require extracted teeth for microscopic preparation. However, these methods may not be acceptable due to ethical, religious, cultural, or scientific reasons. The biochemical methods are based on the racemization of amino acids. The racemization of amino acids is a reversible first-order reaction and is relatively rapid in living tissues in which metabolism is slow. Aspartic acid has been reported to have the highest racemization rate of all amino acids and to be stored during aging. In particular, L-aspartic acids are converted to D-aspartic acids and thus the levels of D-aspartic acid in human enamel, dentine, and cementum increase with age (Priyadarshini *et al.*, 2015). Radiographic assessment of age is a simple, non-invasive and reproducible method that can be employed both on living and unknown dead. The most frequently used method for age estimation in children is the study of radiographs of teeth and hand/wrist. Skeletal methods present some drawbacks in view of the important variability of bone maturation, which is influenced by environmental factors. An approach based on dental development was shown to be suitable for age determination in children because the calcification rate is controlled more by genes than by environmental factors, and this yields a lower variability (Cameriere *et al.*, 2006). Various odontological methods have also been carried out to estimate age, assessing eruption phases within acceptable error limits. The most common method for age estimation was published in 1973 by Demirjian, Goldstein and Tanner which estimated chronological age based on developments of seven teeth from the left side of the mandible (Demirjian *et al.*, 1973). In 2006, Cameriere *et al.* developed a method for assessing chronological age in children, based on the relationship between age and measurement of open apices in tooth roots (Cameriere *et al.*, 2006). In 2007, the technique was tested in a large sample of children from various European countries, providing a common formula useful for all these countries and it has been accepted that Cameriere's method is more accurate than other methods for estimating the age of children in age groups 6–15 years (Cameriere *et al.*, 2007). The same formula has been tried by Rai B *et al* in Indian population for age estimation and to increase the accuracy they have described a modification of the formula that is suitable for Indian conditions with different variable for north Indian and south Indian population (Rai *et al.*, 2010). With this background, the aim of our study was to assess the accuracy and applicability of modified Cameriere's European formula given by Rai *et al.* (2010) for dental age estimation in south Indian children.

MATERIALS AND METHODS

Subjects reporting to the Department of Oral Medicine and Radiology, A.E.C.S. Maaruti College of Dental Sciences and Research Centre, within the age group of 5 to 15 years who were advised orthopantomograms during the course of diagnosis and treatment were recruited in the study. Subjects with all the teeth present in the lower left quadrant, with no systemic diseases, congenital abnormalities, developmental dental anomalies and severe malocclusion were included in the study. Informed consent was obtained from the parent/

guardian. A total of 600 subjects were included in the study and the subjects were divided into 10 groups according to their chronological age. The first group consisted of subjects who are 5 years old, including subject's age ranging from 5.00 to 5.99. Next group included the subjects who were 6 years old, and so on. Subject's identification number, gender, date of birth and the date orthopantomogram was recorded were noted. Digital form of the radiographs obtained for diagnosis and treatment were collected. Panoramic Radiograph machine-Carestream CS 8000C, equipped with standard positioning device, at 71 kV, 10 mA and constant exposure time of 13.2 seconds was used. Images were stored on computer file and processed by a computer-aided drafting program - Adobe Photoshop. Radiographs of the left permanent developing mandibular teeth, except wisdom teeth, were evaluated. Mandibular teeth were chosen because they can be easily visualized on panoramic radiographs. The chronologic age of an individual was calculated by subtracting the birth date from the date on which the radiographs were exposed for that particular individual after converting both to a decimal age. Decimal age was taken for simplicity of statistical calculation and age was estimated on a yearly basis, for example, 12 years 9 months as 12.75 years and was considered in the 12 years age group.

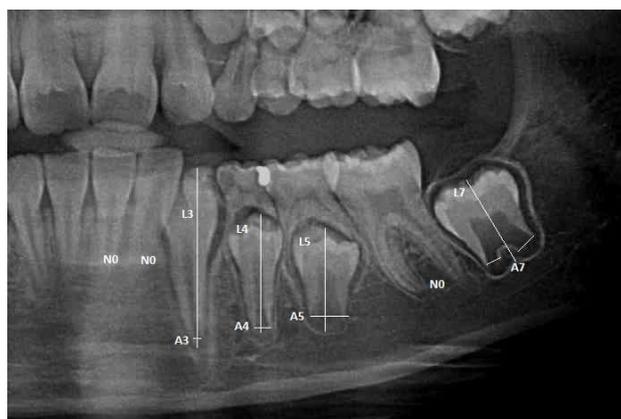


Fig. 1. An example of tooth measurement: N0, teeth with apical ends completely closed; A_i , $i=1, \dots, 5$ (teeth with one root), is the distance between the inner sides of the open apex; A_i , $i=6, 7$ (teeth with two roots), is the sum of the distances between the inner sides of the two open apices; and L_i , $i=1, \dots, 7$, is the length of the seven teeth

Dental age estimation was performed according to the method described by Rai *et al.* (2010) (Fig 1).

1. The number of teeth with complete root development, i.e., apical ends of the roots completely closed (N0), were counted.
2. Teeth with incomplete root development, i.e., with open apices, were examined and the distance (A_i , $i = 1, \dots, 7$) between the inner side of the open apex was measured.
3. In order to take into account the effect of possible differences among radiographs in magnification and angulations, measurements were normalized by dividing by the tooth length (L_i , $i = 1, \dots, 7$).
4. Dental maturity was evaluated according to the normalized measurements of the seven left permanent developing mandibular teeth ($x_i = A_i/L_i$, $i = 1, \dots, 7$), the sum of the normalized open apices (s) and the number (N0) of teeth with complete root development.
5. Lastly, age was calculated with the formula:

$$\text{Age} = 9.402 - 0.879 C + 0.663 N_0 - 0.711 s - 0.106 s \times N_0$$

Where "c" is a variable, 1 for south Indian population and 0 for central and north Indian population.

Statistical analysis

Data was entered into Microsoft® Excel & was analyzed using Predictive analysis Software version 18.0 (PASW Statistics). Data were summarized as Mean & Standard Deviation (SD). Paired t test was used to test the difference between

Chronological age & Estimated dental age among different age groups. Pearson's correlation was used to measure the strength and direction of association between Chronological & Estimated dental age among different age groups. P value less than 0.05 was considered significant for all the statistical tests.

RESULTS

The difference between chronological age and dental age among different age and gender subgroups were tested using Paired t test. Table 1 illustrate the mean and standard deviation

Table 1. Comparison of mean chronological age & dental age

Age	N	Mean	SD	Paired difference		Paired t test	
				Mean	SD	t	p value
Chronological age	600	11.37	2.34	0.31	0.41	18.504	0.08
Dental age	600	11.07	2.37				

P ≤ 0.05, N – Number of subjects, SD – Standard deviation

Table 2. Comparison of mean chronological age & dental age in different age groups

Age Groups	Age	N	Mean	SD	Paired difference		Paired t test	
					Mean	SD	t	p value
5.0-5.9	Chronological age	11	5.47	0.22	0.16	0.10	5.41	0.086
	Dental age	11	5.31	0.25				
6.0-6.9	Chronological age	17	6.47	0.22	0.27	0.24	4.51	0.081
	Dental age	17	6.20	0.35				
7.0-7.9	Chronological age	29	7.49	0.27	0.26	0.08	18.282	0.0560
	Dental age	29	7.22	0.26				
8.0-8.9	Chronological age	39	8.50	0.24	0.29	0.05	36.428	0.093
	Dental age	39	8.21	0.24				
9.0-9.9	Chronological age	68	9.46	0.25	0.34	0.48	5.837	0.089
	Dental age	68	9.12	0.53				
10.0-10.9	Chronological age	77	10.46	0.27	0.40	1.02	3.415	0.065
	Dental age	77	10.07	1.09				
11.0-11.9	Chronological age	95	11.49	0.24	0.27	0.06	44.584	0.068
	Dental age	95	11.22	0.24				
12.0-12.9	Chronological age	87	12.52	0.23	0.29	0.04	72.55	0.074
	Dental age	87	12.22	0.23				
13.0-13.9	Chronological age	87	13.47	0.26	0.29	0.04	75.044	0.077
	Dental age	87	13.17	0.26				
14.0-15.0	Chronological age	90	14.50	0.27	0.31	0.05	61.041	0.098
	Dental age	90	14.18	0.27				

P ≤ 0.05, N – Number of subjects, SD – Standard deviation

Table 3. Mean difference between chronological age & dental age in different age groups

Age Groups	Mean difference
5.0-5.9	0.16
6.0-6.9	0.27
7.0-7.9	0.26
8.0-8.9	0.29
9.0-9.9	0.34
10.0-10.9	0.40
11.0-11.9	0.27
12.0-12.9	0.29
13.0-13.9	0.29
14.0-15.0	0.31
Total	0.31

Table 4. Correlation between chronological and dental age in different age groups

Age group	N	Correlation Coefficient (R)	R ²	P value
5.0-5.9 Years	11	0.917	0.841	<0.001
6.0-6.9 Years	17	0.739	0.546	0.001
7.0-7.9 Years	29	0.956	0.914	<0.001
8.0-8.9 Years	39	0.979	0.958	<0.001
9.0-9.9 Years	68	0.407	0.166	0.001
10.0-10.9 Years	77	0.376	0.141	0.001
11.0-11.9 Years	95	0.971	0.943	<0.001
12.0-12.9 Years	87	0.987	0.974	<0.001
13.0-13.9 Years	87	0.99	0.980	<0.001
14.1-15 Years	90	0.984	0.968	<0.001
Total	600	0.985	0.970	<0.002

P ≤ 0.05, N – Number of subjects, R² – Coefficient of variance

of chronological and dental age of the total sample. On applying paired t test, a p value of 0.08 was obtained which indicate that there is no statistically significant difference between chronological and dental age. Table 2 illustrate the comparison of mean chronological age & dental age in different age groups. Mean and standard deviation was calculated for each group and on applying paired t test, p value > 0.05 was obtained for all the groups indicating that the estimated dental age does not vary statistically significantly from the chronological age. Table 3 represent the mean difference between chronological age & dental age in different age groups and a mean difference of 0.31 was observed. Pearson's correlation was used to measure the strength and direction of association between chronological and dental age among different age and gender subgroups. A positive value of correlation coefficient ($R=0.985$) and coefficient of variance ($R^2=0.970$), which are close to 1, indicates a positive correlation between chronologic age and dental age in different age groups which is depicted in Tables 4.

DISCUSSION

Age determination of individuals using the available scientific methods is a common part of forensic practice. Tooth formation has been more widely used than tooth eruption for assessing dental maturation because it is a continuous and progressive process that can be followed radiographically and clinically at each examination (Shrestha *et al.*, 2014). Studies have shown that morphological measurements can be reliably made in panoramic radiography, provided some corrections are made to take into account the individual variability of tooth size and the differences in magnification of radiographs and angulations between x-ray beam and film (Cameriere *et al.*, 2006). Dental x-ray methods have proved to be most accurate in childhood until the teeth have erupted and root development is completed (with the exception of wisdom teeth). However, in adolescence the validity of skeletal methods improves considerably (Shrestha *et al.*, 2014). So the use of dental x-ray as method of choice in the present study validates its reliability. Panoramic radiographs are ideal screening tools as they are inexpensive, readily available, provide an unobstructed view of the entire dental arch and have less radiation exposure. The panoramic radiograph is considered the best tool for age estimation in children because intraoral radiography is difficult to obtain in children without image distortion (Jatti *et al.*, 2013). Wood *et al.* (2006) argued that the panoramic radiograph being a tomograph could result in overlapping of teeth, especially those tilted in a buccolingual direction, falling out of the focal trough, resulting in misestimation of age. To overcome this disadvantage, all cases were screened for severe malocclusion and tilting of teeth. The age range from 5-15 years remains most critical with regard to estimating a child's dental age and this age group is commonly accepted for dental age estimation in children as teeth development passes through various stages during this age group (Bagh *et al.*, 2014). The present study aimed to assess the accuracy and applicability of modified Cameriere's European formula given by Rai B *et al.* (Rai *et al.*, 2010) for dental age estimation in south Indian children by evaluating the open apices and number of teeth with complete root formation on orthopantomograms. A study was done by Cameriere *et al.* (2006) on Italian population of children aged between 5-15 years. Study was based on seven mandibular left healthy permanent teeth for assessing dental age by measurement of open apices in teeth. Pearson's correlation coefficients between age and the variables (gender,

open apices, number of teeth with closed apices) showed that the correlations between age and the open apices in teeth were significant and negative. Gender and the number of teeth with the apical end of the root canals completely closed (N0) showed a significant correlation with chronological age. With the aid of a stepwise multiple regression model, a linear relationship between open apices, N0, and age was shown and a formula was given. The same author Cameriere *et al.* (2007) have done a study in a large sample of children from various European states, providing a common formula. The results showed that the median of the absolute value of residual errors were 0.035 years. A similar study was conducted by Shrestha *et al.* (Bagh *et al.*, 2014) using Cameriere's formula for age estimation in south Indian population. The results showed that the formula resulted in under estimation of age by 0.18 years which was statistically insignificant, suggesting the applicability of this formula in Indian population.

But contradictory results were obtained in the study conducted by Rai *et al.* (2010) who aimed to evaluate an Indian sample by using Cameriere's European formula; and if this formula turns out to be unsuitable, to study a specific formula for Indian children. Subjects were recruited from north, central and southern part of India to check if there is any influence of region. According to the authors, the European formula was not suitable for age estimation in Indian children and they derived a new linear regression formula for Indian population. When region was considered, a significant difference was noted between north and south regions. So this was included as a variable in the formula. According to the authors various factors like ethnicity, nutrition and regional variability might have played a key role for the difference in age estimation in Indian population using the European formula. In our study of evaluating 600 orthopantomograms and calculating the dental age, a mean difference of 0.31 was noted between the chronological and dental age and the difference was not statistically significant (p value 0.08). When each age group was analyzed separately, there was no statistically significant difference between the chronologic age and estimated dental age (p value > 0.05 was noted). These findings suggest that the dental age calculated using modified Cameriere's formula given by Rai *et al.* was reliable and formula is accurate for south Indian population. Pearson's correlation was used to measure the strength and direction of association between chronological and dental age. The value of correlation coefficient (R) obtained was 0.985 indicating a positive correlation between chronologic age and dental age in different age groups. The value of coefficient of variance; $R^2 = 0.970$ which is close to the value obtained in the study by Rai *et al.* where the $R^2 = 0.897$. The mean difference between chronological age and dental age in our study was 0.31 which suggest that there is an underestimation of age by 0.31 years, but the difference is statistically insignificant.

Conclusion

The modified Cameriere's formula given by Rai *et al.* for age estimation in children showed a mean difference of 0.31 between chronological age and dental age and the difference between the mean chronologic age and dental age was not statistically significant. Even though there was an underestimation of 0.31 years, as the difference is not statistically significant, we can conclude that, the modified Cameriere's formula given by Rai *et al.* is suitable for age estimation in children in south Indian population. Further

studies are warranted including larger samples from more number of states of India to truly call it an Indian formula for age estimation.

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