Dentistry Section

Comparison of Nolla's Method, Cameriere's Indian-specific Method, and Acharya's Indian-specific Regression Formula for Estimation of Dental Age in Puducherry and Cuddalore Population, Southern India

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ABSTRACT

Introduction: Forensic dental age estimation plays a vital role in determining the identity of a deceased individual. There are numerous dental age estimation methods available to estimate dental age using radiographs based on tooth maturation.

Aim: To compare Nolla's method, Cameriere's Indian-specific method, and Acharya's Indian-specific regression formula in estimating dental age in the Puducherry and Cuddalore populations of South India.

Materials and Methods: This retrospective study was conducted in the Department of Oral Medicine and Radiology at the Indira Gandhi Institute of Dental Sciences, Puducherry, India, between January 2021 and October 2022. The study included 448 panoramic radiographs (202 males and 246 females) of individuals aged between six and 17 years. Chronological age was recorded based on the subject's date of birth. Dental age was estimated using Nolla's method, Acharya's Indian-specific regression formula, and Cameriere's Indian-specific method. Two qualified and experienced oral radiologists evaluated all the samples to assess their reliability. Data were analysed using descriptive statistics, the Pearson's correlation coefficient, and Student's t-test.

Results: Nolla's method (excluding the third molar) revealed a mean age of 13.52±3.15 years, while Nolla's method (including the third molar) revealed a mean age of 12.81±2.84 years. Acharya's Indian-specific method revealed a mean age of 15.08±2.92 years, and Cameriere's Indian-specific regression formula revealed a mean age of 11.51±2.19 years. The results showed that the age estimated by Nolla's method (including the third molar) had a p-value of 0.93 (>0.05), indicating no significant differences between the estimated dental age and chronological age. The r-values for Acharya's Indian-specific regression formula, Nolla's method (excluding the third molar), Nolla's method (including the third molar), and Cameriere's Indian-specific method were found to be 0.682, 0.885, 0.847, and 0.849, respectively, indicating a strong positive correlation among the age estimation methods.

Conclusion: Nolla's method (including the third molar) was found to be the most accurate method for dental age estimation when compared with the other three methods in the Puducherry and Cuddalore populations.

Keywords: Age estimation, Forensic odontology, Open apex, Panoramic radiograph, Tooth mineralisation

INTRODUCTION

Forensic odontology is an evolving field of forensic medicine that deals with the examination, handling, and presentation of dental evidence in a court of law [1]. Age estimation plays a vital role in forensic odontology. One of the periods of human existence is distinguished by involution, equilibrium, and physical evolution, e.g., infancy, childhood, adolescence, young adulthood, middle life, senescence, and senility are the seven ages of humankind [2]. Age assessment in the forensic field is a topic that has existed for as long as forensic anthropology itself. It has traditionally been linked to the biological profile estimation process used to analyse skeletonised human remains [3]. When unidentified deceased remains are discovered, forensic age estimation is a crucial method for establishing identity. Age determination of cadavers is carried out for victims of mass disasters such as fire accidents, homicides, feticides, crashes, and infanticides, etc. [4]. Since age assessment frequently involves estimating a person's age in various situations, it has a legal and humanitarian foundation.

There are numerous age estimation methods using hard and soft tissue analysis available, with varying levels of accuracy. However, as teeth are least damaged by the environment, methods that use hard tissues like bone and teeth are the most effective tools of identification

[5]. Dental age estimation provides a scientific, affordable, and reasonably quick method of determining age. Many methods are available for dental age estimation using orthopantomograms conducted on different populations. There is a dearth of literature to compare Nolla's method, Cameriere's Indian-specific method, and Acharya's Indian regression formula in determining dental age, and there is also no available literature to compare these three methods with chronological age. This paved the way for conducting the above-mentioned methods and determining the best-suited method for the Puducherry and Cuddalore population. Furthermore, to establish a definitive derivation of age, the present research was conducted on a large scale in the Puducherry and Cuddalore populations. In the present study, dental age was estimated using Nolla's method, Cameriere's Indian-specific method, and Acharya's Indian regression formula, and compared with the chronological age in the Puducherry and Cuddalore populations. The objective of the study was to evaluate which of the above-mentioned methods is better suited for the selected population.

MATERIALS AND METHODS

This retrospective study was conducted in the Department of Oral Medicine and Radiology at Indira Gandhi Institute of Dental

Sciences, Puducherry, India, between January 2021 and October 2022. The present study received approval from the Institutional Ethical Committee (IGIDSIEC2021NRP11PGPROMR). The study included panoramic radiographs retrieved from the archives of the ORTHOPHOS XG- Dentsply Sirona Orthopantomogram (OPG) Machine, Model no. D3352, taken between January 2013 and December 2020, in the age group of 6 to 17 years.

Inclusion criteria: Diagnostic panoramic radiographs belonging to subjects in the population of Puducherry and Cuddalore were included in the present study. Subjects with complete case records related to the date of birth and the date of the orthopantomogram radiograph were included.

Exclusion criteria: Panoramic radiographs with distortion and lack of contrast were excluded from this study. Radiographs with orthodontic appliances, impacted teeth, periapical lesions, endodontically treated teeth, radiopaque crowns, edentulous spaces, fixed prosthesis, and dental anomalies were excluded.

Study Procedure

A total of 660 panoramic radiographs were taken from the records. Based on the inclusion and exclusion criteria, 212 samples were eliminated, and 448 OPGs were selected for the present study. Informed consent was obtained from the records. The panoramic radiographs used for the study were exposures made as part of diagnostic and treatment planning requirements. There was no exposure made exclusively for the present study. Chronological age was calculated by deducting the date of birth from the date on which the OPG was imaged. Dental age was estimated using the Acharya's Indian regression formula, Nolla's method (excluding the third molar), Nolla's method (including the third molar), and Cameriere's Indian-specific method. The samples were independently evaluated by two equally qualified and experienced Oral Radiologists who were blinded to the chronological age.

Acharya's Indian-specific method: According to this method, the teeth in the left lower quadrant, including the third molar, were used to evaluate the ten stages of tooth mineralisation (stage 0 to stage 9). If any teeth were missing, the corresponding teeth in the right lower quadrant were used for the evaluations. The evaluated stages of tooth mineralisation were entered into a Microsoft Excel sheet that was prepared with the maturity score index and the dental age maturity formula for calculating dental age using Acharya's Indian-specific method. As the stages were entered, the dental age was calculated by substituting the formula: Males=27.4351-(0.0097×S^2) ((0.000089×S^3); Females=(23.7288-(0.0088×S^2) (0.000085×S^3), where S is the sum of scores of all the teeth in the third quadrant [6].

Nolla's method: This method assessed the 10 phases of tooth mineralisation using teeth in the left upper and lower quadrants. The obtained stages of tooth mineralisation were entered into a Microsoft Excel sheet, and the scoring was based on the 10 stages. To determine the development of a particular tooth, the radiograph was closely matched with the comparative figure. For example, an observation would receive a score of 3.0 if one-third of the crown was completed, and a score of 7.0 if one-third of the root was completed. A value of 0.5 was assigned when the radiographic reading was between two grades. A value of 0.2 was added when the radiograph displayed a reading that was slightly higher than the shown grade but not quite halfway between that stage and the next. A value of 0.7 was added if the development was slightly below what the grade suggested. Both maxillary and mandibular dentition scores were added up and compared with Nolla's chart to estimate dental age by Nolla's method [7]. In Nolla's method (excluding the third molar), only seven teeth in both the left maxillary and mandibular dentition were considered for staging and scoring. However, in Nolla's method 2 (including the third molar), all eight teeth in both the left maxillary and mandibular dentition were

considered. Separate scoring charts were available, and comparison was performed accordingly to estimate dental age.

Cameriere's Indian-specific method: Dental age estimation was performed using Cameriere's Indian-specific formula. Seven mandibular teeth, excluding the third molar, were evaluated for dental age estimation. Dental age estimation was done using the following formula:

$$Age=9.402- 0.879c+0.663No-0.711s-0.106sNo$$

where No represents the number of teeth with apical end closed, s represents the sum of A/L ratio for every tooth at open apex, and c represents the variable for girls (0) and boys (1). Ai represents the radiographic distance between the inner sides of the open apex, and Li represents the radiographic tooth length (Li, i=1...7) [4].

STATISTICAL ANALYSIS

The statistical analysis was carried out using SPSS software version 16.0. Descriptive statistics, including mean and standard deviation, were calculated. Student's t-test was performed to compare the chronological age and the estimated dental ages, with a p-value of 0.05 used as the significance level. Pearson's correlation coefficient and the Intraclass correlation coefficient test were also conducted.

RESULTS

The study included 448 OPGs, with 202 males and 246 females [Table/Fig-1]. Descriptive statistics, including mean and standard deviation, were calculated for chronological age and estimated dental age according to gender [Table/Fig-2]. Nolla's method (excluding the third molar) showed a mean age of 13.52±3.15 years, with an overestimation of chronological age by 0.7 years in both sexes. Nolla's method (including the third molar) revealed a mean age of 12.81±2.84 years, with an overestimation of chronological age by 0.7 years in females and 0.3 years in males. The samples were divided into 11 subgroups based on age. The distribution of samples, along with their mean, standard deviation, and p-value for all age estimation methods, is presented in [Table/Fig-3]. A significant difference (p<0.01) was found between the Acharya's years method and chronological age for all age groups.

Gender	Frequency (n)	Percentage (%)
Males	202	45.1
Females	246	54.9
Total	448	100

[Table/Fig-1]: Distribution of samples based on gender.

Comparison groups	Males		Females	
	N	Mean±SD	n	Mean±SD
Chronological age	202	12.43±3.16	246	13.10±2.98
Acharya's Indian-specific method	202	14.65±2.80	246	15.44±2.98
Nolla's method (excluding the third molar)	202	13.17±3.32	246	13.80±2.98
Nolla's method (including the third molar)	202	12.73±3.05	246	13.87±2.66
Cameriere's Indian-specific regression formula	202	11.05±2.40	246	11.88±1.93

[Table/Fig-2]: Mean and standard deviation for chronological age (in years) and various dental age estimation methods (for males and females).

Overall mean and standard deviation for chronological age and the three methods were estimated [Table/Fig-4]. The age estimated by Nolla's method (including the 3rd molar) had a p-value of 0.93 (>0.05), indicating statistical insignificance compared to the chronological age. This method was found to be the best predictor of dental age. The dental age estimation by the other three methods showed a p-value of 0.001 (<0.05), indicating statistical significance as there was a considerable difference between the dental predicted age and the chronological age.

Age groups	Comparison groups	N	Mean	SD	t	p-value
>6-7 years	Chronological age	35	6.00	0.00	-	-
	Acharya's Indian-specific method	35	15.11	2.27	-15.55	<0.01*
	Nolla's method (excluding third molar)	35	6.37	0.97	-1.46	0.2
	Nolla's method (including third molar)	35	7.17	0.40	-11.07	<0.01*
	Cameriere's Indian-specific method	35	6.04	1.44	-0.10	0.92
>7-8 years	Chronological age	35	7.00	0.00	-	-
	Acharya's Indian-specific method	35	12.67	1.73	-14.66	<0.01*
	Nolla's method (Excluding third molar)	35	7.38	0.79	-2.12	0.05*
	Nolla's method (Including third molar)	35	7.42	0.47	-4.07	<0.01*
	Cameriere's Indian-specific method	35	7.26	1.08	-1.08	0.29
>8-9 years	Chronological age	35	8.00	0.00	-	-
	Acharya's Indian-specific method	35	11.46	1.65	-8.89	<0.01*
	Nolla's method (Excluding third molar)	35	7.89	1.05	-0.45	0.66
	Nolla's method (Including third molar)	35	7.94	0.94	-0.25	0.81
	Cameriere's Indian-specific method	35	7.85	1.22	0.53	0.60
>9-10 years	Chronological age	35	9.00	0.00	-	-
	Acharya's Indian-specific method	35	10.88	0.96	-0.86	<0.01*
	Nolla's method (Excluding third molar)	35	9.53	1.44	-1.60	0.13
	Nolla's method (Including third molar)	35	9.34	1.26	-1.12	0.25
	Cameriere's Indian-specific method	35	8.96	1.34	-0.13	0.90
>10-11 years	Chronological age	44	10.00	0.00	-	-
	Acharya's Indian-specific method	44	12.03	1.62	-7.00	<0.01*
	Nolla's method (Excluding third molar)	44	11.15	1.59	-4.00	<0.01*
	Nolla's method (Including third molar)	44	10.95	1.26	-4.20	<0.01*
	Cameriere's Indian-specific method	44	10.21	1.46	-0.32	0.42
>11-12 years	Chronological age	44	11.00	0.00	-	-
	Acharya's Indian-specific method	44	12.58	1.82	-5.14	<0.01*
	Nolla's method (Excluding third molar)	44	12.44	1.75	-4.88	<0.01*
	Nolla's method (Including third molar)	44	11.93	1.40	-3.93	<0.01*
	Cameriere's Indian-specific method	44	10.80	1.07	1.10	0.28
>12-13 years	Chronological age	44	12.00	0.00	-	-
	Acharya's Indian-specific method	44	14.37	2.15	-8.04	<0.01*
	Nolla's method (Excluding third molar)	44	13.83	1.68	-7.94	<0.01*
	Nolla's method (Including third molar)	44	13.02	1.41	-5.25	<0.01*
	Cameriere's Indian-specific method	44	11.88	1.14	0.74	0.46
>13-14 years	Chronological age	44	13.00	0.00	-	-
	Acharya's Indian-specific method	44	14.50	1.95	-5.40	<0.01*
	Nolla's method (Excluding third molar)	44	14.23	1.47	-5.91	<0.01*
	Nolla's method (Including third molar)	44	13.07	1.40	-0.35	0.73
	Cameriere's Indian-specific method	44	12.07	1.08	6.05	<0.01*
>14-15 years	Chronological age	44	11	0.00	-	-
	Acharya's Indian-specific method	44	15.86	2.20	-6.15	<0.01*
	Nolla's method (Excluding third molar)	44	15.15	1.36	-6.16	<0.01*
	Nolla's method (Including third molar)	44	14.08	1.59	-0.35	0.73
	Cameriere's Indian-specific method	44	12.46	1.29	8.70	<0.01*
>15-16 years	Chronological age	44	15.00	0.00	-	-
	Acharya's Indian-specific method	44	17.15	1.70	-9.34	<0.01*
	Nolla's method (Excluding third molar)	44	15.81	0.92	-6.45	<0.01*
	Nolla's method (Including third molar)	44	14.75	1.52	1.21	0.23
	Cameriere's Indian-specific method	44	13.07	0.36	38.96	<0.01*
>16-17 years	Chronological age	44	16.00	0.00	-	-
	Acharya's Indian-specific method	44	17.52	1.74	-5.78	<0.01*
	Nolla's method (Excluding third molar)	44	15.93	0.80	0.57	0.57
	Nolla's method (Including third molar)	44	14.65	1.78	5.04	<0.01*
	Cameriere's Indian-specific method	44	13.10	0.26	73.46	<0.01*

[Table/Fig-3]: Comparison of estimated dental ages with the chronological age amongst specific age groups.
(*denotes level of significance, p-value <0.05, which was statistically significant and revealed a significant difference between the predicted dental age and the chronological age)

Comparison groups	N	Mean±SD	Mean difference	SD difference	p-value
Chronological age	448	12.80±3.07	-	-	-
Acharya's Indian-specific method	448	15.08±2.92	-2.28	2.40	<0.01*
Nolla's method (excluding the third molar)	448	13.52±3.15	-0.72	1.50	<0.01*
Nolla's method (including the third molar)	448	12.81±2.84	-0.01	1.65	0.93
Cameriere's India regression formula	448	11.51±2.19	1.29	1.68	<0.01*

[Table/Fig-4]: Overall comparative analysis between the mean chronological age and various dental age estimation methods.
(*denotes the level of significance, p-value <0.05, which was statistically significant and revealed a significant difference between the predicted dental age and the chronological age)

Pearson's correlation coefficient (r-value) revealed the correlation between chronological age and Acharya's India specific method, Nolla's method (excluding 3rd molar), Nolla's method (including 3rd molar), and Cameriere's Indian regression formula. All the methods used in the study showed a significantly positive correlation with chronological age. The highest correlation was observed with Nolla's method (excluding the third molar) [Table/Fig-5].

The Intraclass Correlation Coefficient test (ICC) was used to analyse the interobserver reliability between the two observers for all three age estimation methods. The highest agreement between the observers was obtained with Cameriere's India regression formula, which was 93% [Table/Fig-6].

The regression model summary indicated that all three dental age estimation methods predicted chronological age by 79.3%.

Variable		Chronological age	Acharya's India-specific method	Nolla's method (excluding the third molar)	Nolla's method (including the third molar)	Cameriere India regression formula
Chronological age	Pearson correlation Sig. (1-tailed)	1	0.682	0.885	0.847	0.849
		-	<0.01	<0.01	<0.01	<0.01
	N	448	448	448	448	448

[Table/Fig-5]: Correlation between chronological age and various age estimation methods.
(r=0- No correlation between two variables; r >0- Positive correlation; r<0- Negative correlation)

Age estimation methods	Interobserver reliability
Acharya's Indian-specific method	80%
Nolla's method (excluding the third molar)	90%
Nolla's method (including the third molar)	91%
Cameriere's India regression formula	93%

[Table/Fig-6]: Intraclass Correlation Coefficient (ICC) between two observers in estimating dental age.

Based on chronological age as the gold standard, the observations from this study suggest that Nolla's method (including the third molar) is more accurate compared to Acharya's India's specific method, Nolla's method (excluding the third molar), and Cameriere's India regression formula for estimating dental age in the populations of Puducherry and Cuddalore.

DISCUSSION

In the present study, Nolla's method (excluding the third molar) revealed a mean age of 13.52±3.15 years, with an overestimation of chronological age by 0.7 years in both sexes. Nolla's method (including the third molar) revealed a mean age of 12.81±2.84 years, with an overestimation of chronological age by 0.7 years in females and 0.3 years in males, resulting in an overall discrepancy of 0.01 years of overestimation. This indicates that Nolla's method is the best method for the study population.

Cortes MM et al., and Duruk G et al., applied Nolla's method in the Spanish and Turkish populations, respectively, and observed a marginal discrepancy in estimating dental age compared to chronological age in these two studies [7,8]. These two studies showed only a marginal variation from the present study. Noaman BR and Abdullah AO observed that Nolla's method slightly overestimated chronological age between four and nine years of age and underestimated chronological age between nine and thirteen years of age in the Kurdish Iraqi population, which was not in accordance with the present study [9]. However, a study by Thomson D observed a significant interclass correlation with the average chronological age being 10.213±2.33 and the estimate with Nolla's method was 10.04±2.25 in the South Indian population [10]. The observations of the studies conducted by Thomas D and Mohammad RB et al., in the South Indian population are in concurrence with the present study [10,11]. Nolla's method has been tested in varied populations globally and consistently indicates near-perfect estimation of dental age in all the tested populations. A possible explanation for its ability to estimate dental age accurately is its robust staging and sub-staging methods, which document sufficient data correlating to the development of tooth structure over time.

In the present study, the Acharya's Indian-specific method revealed a mean age of 15.08±2.92 years, with an overestimation of chronological age by 2.22 years in males and 2.34 years in females, resulting in an overall discrepancy of 2.28 years. Age-specific p-values were calculated and found to be <0.05 (statistically significant) for all age groups, indicating a significant difference between the estimated dental age and chronological age in all age groups. As a general acceptance, an error of up to 12 months is universally agreed upon for dental age estimation [12]. Hence, this method does not satisfy the general error acceptance criteria.

The study by Kiran CS et al., observed a mean age of 14.20±3.24 years, with an overestimation of chronological age by 1.72 years in males and 1.91 years in females when Acharya's Indian-specific regression formulas were used in the South Indian population, which was similar to the results of the present study [13]. The observations of the study by Tandon A et al., presented similar findings in a study carried out on the North Indian population [6]. On the contrary, Mohammed RB et al., observed a difference of 0.21 years in males and 0.85 years in females (within 1 year), and Shivakumar B et al., observed a very strong correlation between chronological age and dental age estimated by Acharya's Indian-specific method [11,14]. Both studies conducted by Mohammed RB et al., and Shivakumar B et al., concluded that Acharya's Indian-specific method was a reliable method for assessing dental age in the South Indian population, which contrasted with the present study [11,14]. However, Jain S et al., observed an underestimation of 0.04 years in males and an overestimation of 0.74 years in females in the Central Indian population, which is contrary to the present study [15].

In the present study, Cameriere's India Regression formula revealed a mean age of 11.51±2.19 years, with an underestimation of chronological age by 1.38 years in males and 1.22 years in females, resulting in an overall discrepancy of 1.29 years of underestimation. This method also does not satisfy the general error acceptance criteria (within 12 months) [12]. From 6 to 13 years of age, the p-value for Cameriere's India regression formula was >0.05, indicating a statistically insignificant difference between dental age and chronological age. However, between the age group of 13 and 17 years, a significant difference was observed between the estimated dental age and chronological age. This indicates that it is an effective method of age estimation between six and 13 years of age, but a significant decrease in accuracy was observed in the age group of 13 to 17 years.

The observations of the study by Babu E et al., presented similar results of underestimation of chronological age as the present study, as both studies involved the Puducherry population [16]. Pratyusha K et al., observed that Cameriere's Indian-specific method is a reliable method of age estimation in the Andhra Pradesh population, with p-values of 0.48 and 0.49 among males and females, respectively [17]. Vadla P et al., observed p-values of 0.38 and 0.22 (>0.05-no significant difference) in males and females in the Telangana population [18]. The observations of the studies conducted by Pratyusha K et al., and Vadla P et al., were in conflict with the present study due to a noticeable discrepancy in sample size [17,18]. The present study utilised 448 OPGs compared to a much smaller sample size utilised by the other studies, and the population involved in their study does not include the Dravidian population as in the present study.

Limitation(s)

A panoramic radiograph is a two-dimensional radiographic technique that captures an image of the entire dentition and jaws. However, it is important to note that panoramic radiographs have inherent limitations, including image magnification and distortional errors. These errors can affect the interpretation process, particularly during the staging of dental development.

Interpreting the anterior teeth on a panoramic radiograph can be challenging due to the superimposition of the cervical spine, which can obscure the roots of these teeth. This is an inherent error in panoramic radiography. Additionally, interpreting the completion of maxillary posterior roots can be complicated by the superimposition

of anatomical structures such as the maxillary sinus, maxillary tuberosity, and floor of the nasal fossa, which overlap with the roots of the maxillary teeth. These structures can make it difficult to accurately determine the stages of dental development in the maxillary arch.

Other factors that can further complicate interpretation include the presence of anatomical structures like the mental foramen, variations in tooth root morphology such as bifid roots, and the presence of pathologies like condensing osteitis or hamartomas like odontomas. These factors add to the challenge of accurately assessing dental development stages on panoramic radiographs.

CONCLUSION(S)

The observations of the present study indicate that Nolla's method (including the third molar) is the most reliable for estimating dental age compared to Nolla's method (excluding the third molar), Acharya's Indian-specific method, and Cameriere's Indian regression formula. However, further studies with larger sample sizes are needed to improve the accuracy of dental age estimation. In addition to these three methods, other age estimation methods such as the Schour and Massler method, Morress method, and Gustafson method can also be used in the same population to estimate dental age.

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