Accuracy of age estimation in 6-21 year old South Indian population – A comparative analysis of clinical and radiographic methods

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The authors declare that they have no conflict of interest.

KEYWORDS

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ABSTRACT

Unavailability of chronological age brings to the forefront the importance of age estimation for human identification. Dental age is routinely assessed based on the calcification stages and/or the eruption of teeth, which exhibit wide variations amongst different ethnic groups. The current study aimed at estimating the dental ages in 384 South Indian subjects aged 6-21 years, using clinical and radiographic methods and comparing the predictive accuracy of these two dental age estimation methods. For the estimation of age by clinical method, Foti and co-workers' mathematical Model 2 was employed and for the radiographic method, Chaillet and Demirjian's method with Acharya's Indian formula was used. The clinical method yielded a mean error in the range of -3.16 to 4.07 years and -1.83 to 4.32 years among male and female subjects respectively whereas the radiographic method yielded an error of -9.52 to 1.96 years among males and an error of -10.72 to 2.66 years in females. The mean absolute error for the entire sample obtained by clinical method was 0.80 years and by radiographic method was 0.89 years. We found that the clinical method had a better accuracy in estimating dental age of children and adolescents when compared to the radiographic method in South Indian (Karnataka) population. However, the difference between the two is negligible implying that either of the methods can be employed in clinical practice

INTRODUCTION

Human identification is one of the most important, challenging and indispensable aspects of forensic science.[1] Its clinical applications are enormous both in situations requiring identification of a living or a deceased individual.[2] Various parameters are used to draw the identity of an individual, of which estimation of age plays a pivotal role. Requirement for age estimation has a wide role in situations of child adoption, child marriage, penal code, infanticide, rape, judicial punishment, commercial or sexual exploitation, domestic employment, requests for political asylum, issues of inheritance and pension claims of the elderly.[3,4] It is also important in the practice of medicine and dentistry for the evaluation of developmental progress, occasionally to achieve accurate diagnosis and in treatment planning.[4,5] Age of the individual mandates estimation when the chronological age is unknown[4,5] or unavailable.

Age estimation methods most frequently use the skeletal maturation and/or the teeth development, as these parameters have shown to correlate positively with the chronological age. Among the two, age estimation using teeth has demonstrated higher correlation[6,7] as teeth are minimally affected by environmental diversities like nutritional and endocrine disturbances and withstand post-mortem destruction.[7] Dental age estimation methods utilize numerous factors starting from the appearance of tooth germs to the post-eruption alterations of the teeth.[7] Age estimation of young and adolescent individuals on the basis of stages of tooth development and eruption pattern are the most reliable.[8]

Clinical observation of tooth eruption was the method chosen for dental age estimation before the advent of radiographic techniques and still remains a practical method in situations where other dental age estimations methods cannot be carried out. This method is non-invasive, technique insensitive and economical.[8,9] Foti and co-workers proposed Model Number 2 for age estimation in living individuals by clinical examination of the erupted teeth, specifically under conditions when radiographic evaluation is either not possible or not permissible.[10,11]

Tooth eruption is likely to be influenced by a multitude of factors such as premature loss of primary teeth and crowding.[12] However, development of teeth is not affected as such. As a result they show less variation during estimation of age.[12] Screening radiographs like panoramic radiographs allow for detailed evaluation of the developmental stages of all the teeth in a single view.[7,13] The most well-known radiographic method for ascertaining dental age is the Demirjian method. Although this method was considered reliable, several studies showed high dependence on the characteristics such as race, ethnicity of the specific population in question.[12] Acharya thus derived an Indian specific regression formula using Demirjian's 8-teeth method.[14]

With this, the present research aimed at evaluating the accuracy of Foti's clinical method and Chaillet & Demirjian's radiographic method (using Acharya's Indian formula) for age estimation in people of Karnataka, a state in southern India.

MATERIALS AND METHODS:

The study sample consisted of 384 South Indian subjects aged 6 to 21 years. The subjects were divided into 16 groups starting from 6 years to 21 years with a class interval of 1 year (e.g. Group I:- 6 – 6.9 years, Group II:- 7 – 7 .9 years..... Group XVI: - 21 – 21.9 years). Each age group consisted of 24 subjects with equal distribution of 12 subjects in both the genders. The rationale for this equal distribution was that the maturity scores for each tooth in radiographic method is gender specific. The review board of institutional ethical committee has given approval for this comparative study.

Subjects residing in South India for at least the past two generations who underwent clinical and radiographic examination for reasons other than that of the present study were included in the study after obtaining informed written consent. Further, only those subjects who were devoid of congenital anomalies or syndromes, metabolic disorders, dental disorders, malignancies and/or treatment for the same and those who provided proof for their date of birth were included in the study.

To eliminate observer bias, an identification number between 1 and 384 was randomly allocated to each subject by an individual who was not a part of the study. The date of birth of the subject was then documented against their allocated identification number.

Chronological age estimation

The chronological age of the subject was calculated by subtracting his or her date of birth from the date of examination. For the convenience of statistical analysis, the resultant age was converted into a decimal value (e.g. 6 years 3 months 25 days was recorded as 6.3 years and was included in the 6 - 6.9 year age group).

Dental age estimation by clinical method

A detailed intraoral examination was completed for each subject by using diagnostic instruments under adequate illumination. The eruption of maxillary incisors and molars of the deciduous dentition; maxillary canines and molars and mandibular premolars, 2nd molars and 3rd molars of the permanent dentition were recorded in a proforma sheet. A tooth was considered to be erupted if at least a portion of the tooth pierced the alveolar ridge mucosa and was visible in the oral cavity.

Dental age estimation by clinical method was calculated using the formula derived by Foti and co-workers' Mathematical Model 2.[10] The equation is as follows: Estimated age = 13.652 - (0.514 x number of erupted deciduous upper incisors) - (0.236 x number of erupted deciduous upper molars) + (0.314 x number of erupted permanent upper canines) - (1.748 x number of erupted permanent upper 1st molars) + (1.012 x number of erupted permanent upper 2nd molars) + (0.944 x number of erupted upper 3rd molars) + (0.252 x number of erupted lower premolars) + (0.285 x number of erupted permanent lower 2nd molars) + (1.537 x number of erupted lower 3rd molars).

Dental age estimation by radiographic method

Digital panoramic radiographs were obtained following the clinical examination as was indicated for the diagnosis. Patient's data pertaining to his/her identification number, name, age and gender was registered in the Sidexis XG software. Images obtained following the exposure were stored in the computer with an identification number unique to the subject to facilitate blinding.

In the chosen panoramic images, the calcification stage of all eight permanent teeth on the left (3rd) quadrant were assessed and graded from 0 to 9 based on the Chaillet & Demirjian's method[8,15] by the observer. In the absence of any tooth on the 3rd quadrant, the corresponding tooth on the 4th quadrant was considered for assessment.

Following assessment the grades of the developmental stages of calcification of all 8 teeth were recorded in the proforma. A gender specific maturity score was given to each grade using Demirjian's individual maturity score table.[5,15]

The resultant maturity scores of all 8 teeth were then summed to obtain the total maturity score (S). This value was substituted in Acharya's Indian formula[14] as given below

Age (Males) = 27.4351- (0.0097 x S^2) + (0.000089 x S^3)

Age (Females) = 23.7288- (0.0088 x S^2) + (0.000085 x S^3)

STATISTICS

The data obtained was subjected to statistical analysis using the SPSS (Statistical Package for Social Sciences) version 15.0 software. Student's unpaired t-test was used to compare the chronological age with the dental age as estimated by Foti's clinical method as well as Chaillet & Demirjian's radiographic method (using Acharya's formula). Comparison was done separately for males and females. Level of significance was set at p = 0.05 and 95% confidence intervals (CI). The values were represented as Mean ± SD and standard errors. Multiple linear logistic regressions were used to evaluate the relationship between the chronological age and estimated dental age by both the methods.

The mean of estimated dental age by both the methods were compared with the mean chronological age of the corresponding age group.

RESULTS

Results of statistical comparison between Foti's clinical age estimation method and chronological age

The mean age estimated by the clinical method for the entire male sample was 13.04 years and for the entire female sample was 12.99 years (Table 1).

observed in the group XV (20-20.9 years) and for females in the group VII (12-12.9 years). The minimum difference for males was seen in the group IX (14-14.9 years) and for females in the group X (15-15.9 years).

In the age groups of VI (11-11.9 years) and XIV (19-19.9 years), there was a statistically significant ($p < 0.05$) difference observed in the mean estimated age between males and females implying that in these age groups there is a necessity to apply formulae for both males and females separately (Table 2).

Table 1: Mean age values of Clinical method and Radiographic method

	Gender	N	Mean (In Years)
Chronological age	Male	192	13.99
	Female	192	13.91
Clinical method	Male	192	13.04
	Female	192	12.99
Radiographic method	Male	192	14.81
	Female	192	15.07

Table 2: Comparison of estimated mean dental age by Clinical method and Radiographic method to chronological age for both genders

		Clinical method				Radiographic method			
Age groups	**Gende**	**Mean**	**SD**	**S.E**	**P-Value**	**Mea**	**SD**	**S.E**	**P-Value**
I (6-6.9 years)	M	9.58	1.62	0.47	0.08	15.94	2.28	0.66	0.17
	F	8.39	1.60	0.46		17.28	2.37	0.68	
II (7-7.9 years)	M	9.38	1.27	0.37	0.14	12.37	1.86	0.54	<0.001*
	F	8.42	1.76	0.51		16.27	2.00	0.58	
III (8-8.9 years)	M	8.97	0.70	0.20	0.24	10.69	0.75	0.22	0.004*
	F	8.54	1.00	0.29		12.61	1.93	0.56	
IV (9-9.9 years)	M	9.33	0.43	0.12	0.63	10.30	0.53	0.15	0.04*
	F	9.40	0.36	0.10		10.67	0.28	0.08	
V (10-10.9years)	M	10.59	1.72	0.50	0.42	10.39	0.95	0.27	0.19
	F	10.08	1.22	0.35		10.91	0.93	0.27	
VI (11-11.9 years)	M	12.19	1.89	0.55	0.01*	11.19	1.52	0.44	0.62
	F	10.39	1.37	0.40		10.94	0.80	0.23	
VII (12-12.9 years)	M	13.03	1.78	0.51	0.86	11.31	1.82	0.53	0.43
	F	12.89	2.15	0.62		11.97	2.17	0.63	
VIII (13-13.9 years)	M	13.57	1.64	0.47	0.42	14.14	1.68	0.48	0.72
	F	14.01	0.85	0.25		13.84	2.31	0.67	
IX (14-14.9 years)	M	14.34	0.10	0.03	0.48	15.45	1.32	0.38	0.14
	F	14.22	0.58	0.17		14.42	1.92	0.55	
X (15-15.9 years)	M	14.65	1.50	0.43	0.55	16.23	2.05	0.59	0.07
	F	14.39	0.00	0.00		14.51	2.43	0.70	
XI (16-16.9 years)	M	15.32	1.96	0.56	0.67	16.60	1.74	0.50	0.54
	F	15.01	1.54	0.45		16.10	2.07	0.60	
XII (17-17.9 years)	M	14.52	0.56	0.16	0.25	17.10	1.63	0.47	0.70
	F	14.96	1.17	0.34		17.34	1.43	0.41	
XIII (18-18.9 years)	M	15.51	1.67	0.48	0.12	18.12	1.19	0.34	0.86
	F	14.67	0.67	0.19		18.04	0.97	0.28	
XIV (19-19.9 years)	M	16.69	2.16	0.62	0.03*	19.07	1.34	0.39	0.45
	F	18.62	1.76	0.51		18.62	1.49	0.43	
XV (20-20.9 years)	M	16.50	2.28	0.66	0.98	18.61	2.45	0.71	0.91
	F	16.48	2.02	0.58		18.70	0.99	0.29	
XVI (21-21.9 years)	M	17.49	2.12	0.61	0.84	19.52	0.96	0.28	0.11
	F	17.31	2.13	0.61		18.97	0.66	0.19	

* Statistically significant

Table 3: Mean error and M.A.E (Mean Absolute Error) in years for Clinical method and Radiographic methods of age estimation in all age groups

		Clinical method				Radiographic method			
Age	**Gender**	**Mean**	**SD**	**M.A.E**	**P-Value**	**Mean**	**SD**	**M.A.E**	**P-Value**
I (6-6.9 years)	M	-3.16	1.83	0.53	0.09	-9.52	2.24	0.65	0.24
	F	-1.83	1.79	0.52		-10.72	2.58	0.75	
II (7-7.9 years)	M	-1.85	1.27	0.37	0.13	-4.83	1.98	0.57	<0.001*
	F	-0.86	1.73	0.50		-8.71	2.02	0.58	
III (8-8.9 years)	M	-0.46	0.61	0.18	0.30	-2.19	0.92	0.27	0.004*
	F	-0.07	1.12	0.32		-4.14	1.88	0.54	
IV (9-9.9 years)	M	0.26	0.51	0.15	0.85	-0.72	0.52	0.15	0.10
	F	0.22	0.37	0.11		-1.05	0.40	0.12	
V (10-10.9 years)	M	0.04	1.75	0.51	0.49	0.24	1.01	0.29	0.15
	F	0.47	1.18	0.34		-0.35	0.92	0.27	
VI (11-11.9 years)	M	-0.61	1.81	0.52	0.02*	0.39	1.51	0.44	0.68
	F	1.15	1.44	0.42		0.60	0.90	0.26	
VII (12-12.9 years)	M	-0.50	1.76	0.51	0.85	1.23	1.78	0.51	0.41
	F	-0.36	1.87	0.54		0.57	2.04	0.59	
VIII (13-13.9 years)	M	-0.08	1.66	0.48	0.58	-0.64	1.71	0.49	0.61
	F	-0.39	0.92	0.27		-0.21	2.30	0.66	
IX (14-14.9 years)	M	0.09	0.27	0.08	0.24	-1.02	1.36	0.39	0.11
	F	0.30	0.56	0.16		0.10	1.93	0.56	
X (15-15.9 years)	M	0.85	1.52	0.44	0.50	-0.73	1.95	0.56	0.07
	F	1.16	0.28	0.08		1.04	2.50	0.72	
XI (16-16.9 years)	M	1.21	1.98	0.57	0.89	-0.07	1.71	0.49	0.72
	F	1.31	1.49	0.43		0.21	2.06	0.59	
XII (17-17.9 years)	M	2.97	0.54	0.16	0.47	0.39	1.80	0.52	0.90
	F	2.68	1.24	0.36		0.30	1.50	0.43	
XIII (18-18.9 years)	M	3.04	1.53	0.44	0.26	0.43	1.07	0.31	0.66
	F	3.61	0.74	0.21		0.24	0.96	0.28	
XIV (19-19.9 years)	M	2.90	2.26	0.65	0.04*	0.52	1.42	0.41	0.39
	F	1.06	1.82	0.53		1.05	1.54	0.44	
XV (20-20.9 years)	M	4.07	2.35	0.68	0.89	1.96	2.56	0.74	0.77
	F	3.93	2.07	0.60		1.72	0.98	0.28	
XVI (21-21.9 years)	M	3.99	2.10	0.61	0.71	1.96	0.85	0.24	0.03*
	F	4.32	2.18	0.63		2.66	0.57	0.17	
		CLINICAL METHOD ---- MAE for whole sample = 0.80 years				RADIOGRAPHIC METHOD ---- MAE of Entire sample = 0.89 years			
		CLINICAL METHOD ---- MAE for male sample = 0.76 years				RADIOGRAPHIC METHOD ---- MAE for male sample = 0.88 years			
		CLINICAL METHOD ---- MAE for female sample = 0.84 years				RADIOGRAPHIC METHOD ---- MAE for female sample = 0.90 years			

* Statistically significant ; SD = Standard Deviation ; MAE = Mean Absolute Error

Accuracy of the Clinically Estimated Dental Age
The clinical method yielded a mean error in the range of -3.16 to 4.07 years among male subjects and -1.83 to 4.32 years in females subjects. The positive result indicates an over-estimation and negative result indicates an under-estimation. The estimated age was considered accurate if it was <±1 year from the chronological age "CA" and was considered inaccurate if it was >±2 years (Table 3).
Accuracy refers to how close the estimated dental age (EDA) is to the chronological age. Theoretically, the difference between the EDA and the chronological age must be zero or close to zero. In recent studies, the statistical tool that has been used to quantify accuracy is Mean Absolute Error (MAE). MAE is the average of all absolute errors. The main objective of MAE is to consider all the observations in the group and make the values unaffected by the extremes. It tells us how large an error we can expect from the predicted values. For example, MAE of 0.80 means that during the clinical application of age estimation the value obtained is likely to have an error up to +/- 0.80 years. At present, MAE is considered to be the best parameter to express the accuracy of any age estimation method.
The mean absolute error for the entire sample by the clinical method obtained was 0.80 years, for male sample was 0.76 years and for female sample was 0.84 years (Table 3).

Results of statistical comparison between Demirjian's radiographic method and chronological age
The mean age estimated by the clinical method for the entire male sample was 14.81 years and for the entire female sample was 15.07 years (Table 1).
The maximum mean age difference for males was observed in group XV (20-20.9 years) and for females in group I (6-6.9 years). The minimum difference for both males and females was seen in the group IV (9-9.9 years). In the age groups II - IV (7-9.9 years), a statistically significant ($p < 0.05$) difference were observed in the mean estimated age between males and females (Table 2).

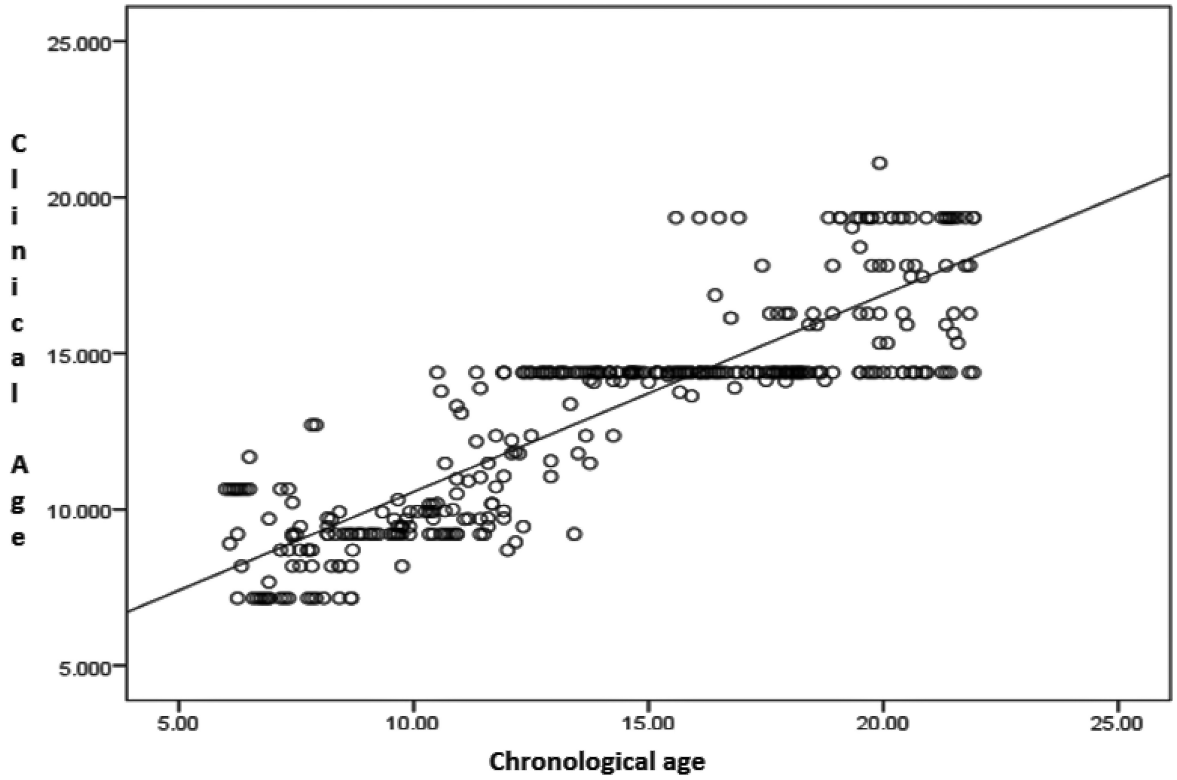
Accuracy of the Radiographically Estimated Dental Age
The radiographic method yielded a mean error in the range of -9.52 to 1.96 years among the male subjects and -10.72 to 2.66 years in female subjects.
The mean absolute error for the entire sample obtained was 0.89 years, for male sample was 0.88 years and for female sample was 0.90 years (Table 3).

Comparison of clinical and radiographic methods
An error of $\leq \pm$ 1year was observed in 39.6% of the subjects for whom EDA was predicted by clinical method and in 32.8% of the subjects for whom EDA was predicted by radiographic method indicating that the clinical method a better predictor of age than radiographic method. Even though the clinical method is performing better, in 46.6% of the subjects the EDA is falling within $\pm$ 3 years when estimated by radiographic method suggesting radiographic method is efficient in estimating the DA within 3 years (Table 4).
The ages estimated by both the methods were correlated with the chronological age for the entire study population using Pearson's correlation. The p value was set at 0.001.
Clinical method correlated positively with chronological age ($r < +1$) for the entire study group and was highly significant ($p < 0.001$). The correlation coefficient was 0.87. The values being greater than 0.80 indicated a strong correlation (Graphs 1).
Similarly, the radiographic method also positively correlated with chronological age ($r < +1$) for entire subjects and was highly significant ($p < 0.001$). However the correlation coefficient was 0.64 for the entire study group. Values were ranging from 0.50 to 0.80 indicating a moderate correlation (Graphs 2).

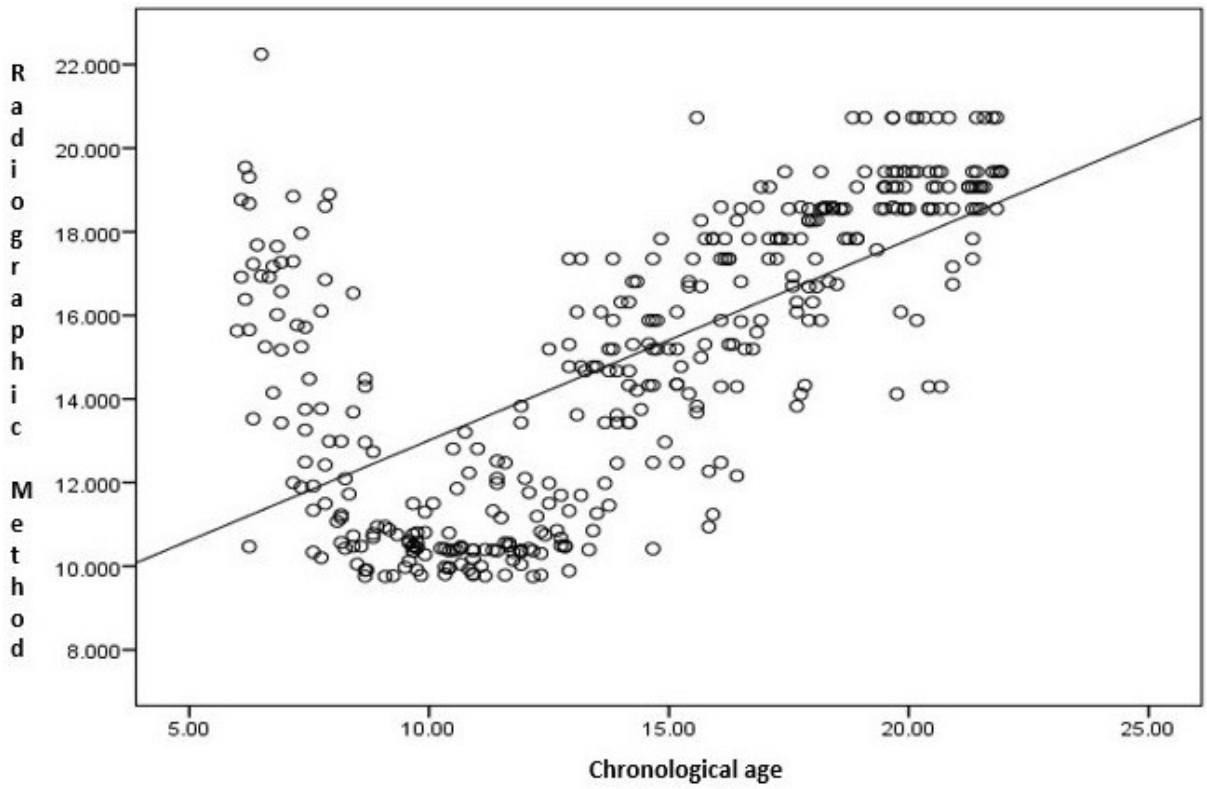
Table 4: Frequency distribution of total sample as per error range for Clinical and Radiographic methods

Error distribution	**$\leq \pm$ 1year**	**± 1.01 to ± 3 years**	**$\geq \pm$ 3.01 years**
Clinical Method	152	143	89
	39.6%	37.2%	23.2%
Radiographic Method	126	179	79
	32.8%	46.6%	20.4%

Graph 1: Scatterplot depicting the relationship btw CA and EDA by clinical method for entire study group



Graph 2: Scatterplot depicting the relationship btw CA and EDA by radiographic method for entire study group



DISCUSSION

Dental age estimation plays a crucial role in the identification of living and dead subjects.[3] Various physical, chemical and histological methods have evolved over the years to estimate age using the teeth.[16] However, the majority of them result in the loss of physical evidence.

Estimation of age by assessing the stages of tooth development has often been the preferred method as it closely coincides with the chronological age and it can be evaluated using radiographs.

Age estimation by analysing the dental development was done using radiographs. Demirjian's method[8] is one of the oldest and most widely used radiographic method for ascertaining dental age due to its simplicity, pre-set criteria for evaluating tooth maturity, schematic illustrations and gender specific maturity scores. Nevertheless, it has demonstrated significant differences between the predicted and the true age in non-Canadian population. Several authors[5,17] therefore have developed an Indian-specific formula for accurate age prediction in an Indian population. As our study was on an Indian population, we used Demirjian's radiographic method in combination with Acharya's formula for the radiographic method of age estimation.

Next best and non-invasive means of dental age estimation is perhaps the clinical method as proposed by Foti and co-workers wherein the age is estimated by assessing the pattern of teeth eruption. We applied their regression model 2.

Accuracy of Foti's Clinical Method

In our study, Foti's clinical method yielded age estimates for the ages 7 – 15 years with a difference within ± 1 year between estimated and true age (Table 4), which was in concordance with the study by Dinakar et al in a Goan population.[5] But, a negligibly higher error of 1.16 years was observed among female subjects of 11-12 years and 15 -16 years. This over-estimation can be attributed to the early pubertal changes observed in females compared to males.

The error of more than 1 year observed in our study in the subjects younger than 7 years old is comparable with the results observed by Foti et al.[10] When Foti and co-workers[10] validated all of their 4 models on French population aged 6 – 21 years, their DAE using model 2 in the subjects below 10.5 years showed a significant error of >1 year; this could be due to inherent limitation in Foti's Model 2 regression formula, as it does not consider deciduous canines, mandibular incisors, molars and permanent 1st molars, teeth commonly present in a 6 year old child.

Similarly, Foti's clinical method failed to make precise estimates for the age group of 16 – 22 years. An error of 1.06 – 4.32 years in EDA was bound to occur in these age groups (Table 3) as 3rd molars show a diverse eruption pattern in the population of the present generation, most often, remaining occult.

The mean error of 0.92 $\pm$ 1.39 (S.D) years obtained for the entire study sample is comparable with Foti and co-workers' [10] achieved mean error of - 0.47 $\pm$ 1.85 years in their study group.

We found a statistically significant difference ($p<0.05$) in the mean estimated ages between males and females in the age group of 11-11.9 years and 19-19.9 years (Table 2). This difference may be due to the absence of gender specific formulae thus imploring a need to derive gender specific regression formulae.

Accordingly, in our study Foti's method estimated a mean absolute error of 0.80 years for the entire study sample (Table 3). This implies that age estimated by clinical method using Foti's Model 2 regression formula is likely to estimate the chronological age within 1 year difference. Dinakar et al[5] observed a MAE of 2.33 years in a Goan population.[5] The MAE of as low as 0.80 years achieved in our study suggests that Foti's method can predict the age of South Indian (Karnataka) population with greater accuracy and hence can be effectively used during forensic age estimation.

Accuracy of modified Demirjian's method

For the radiographic method of DAE, we chose to use Chaillet and Demirjian's 8-teeth[15] method as our study subjects aged between 6-21 years. It is based on the assessment of calcification stages of mandibular left permanent teeth including 3rd molars using panoramic radiographs. It provides a gender specific dental maturity scoring system and tables for conversion of them to dental ages.[8,15]

As Demirjian's 7-teeth method over-estimated the dental age by 1.2 – 3 years in South Indian population,[18,19] Acharya[14] used Chaillet and Demirjian's 8-teeth method on 547 panoramic radiographs of South Indian population and

derived new regression formulae for them. We applied Acharya's regression formulae in our study as the subjects are from Karnataka, South India.

In the present study, radiographic method accurately estimated dental age of 9-19.9 year old subjects with an error less than ± 1 year (Table 3). Similar results were achieved by Mohammed RB et al[20] and Sonali et al.[13]

Although the radiographic method estimated DA accurately in 9-19.9 years old subjects, large variations were observed in estimated dental ages of 6-8.9 year old subjects (Table 3) which is probably due to two reasons: a) The Indian formula that we used was derived from individuals aged 7-25 years and thus the formula is not accurate/applicable for the younger age groups b) The second and most likely reason is perhaps dependent on the assessment of tooth development stage (TDS) during age assessment. Under-estimation of DA is directly related to the lower scoring of the TDS. As per the criteria laid down by Demirjian for TDS, a lower score has to be assigned to the calcification stage when in doubt.[8] In individuals of 6-9 years, the mandibular anterior teeth will be in different stages of calcification. Further, the use of panoramic radiographs will have variable degree of cervical spine shadow superimposition over the mandibular anterior region. These inherent limitations may result in under-scoring thus influencing TDS and calculated age.

In the age group of 20-21 years, we observed an over-estimation of DA in both genders with an error of 1.72 – 2.66 years (Table 3). This may be because of genetically influenced early maturation of 3rd molars leading to score 9 or the interplay of environmental effects such as nutrition and diet. Acharya in his study also observed over-estimation in this age group.[14]

In the age groups of 7-8.9 years and 21-21.9 years, we observed a significant difference ($p<0.05$) in the estimated ages of males and females (Table 3). Though the formulae that we used for radiographic age assessment are gender specific, they have been derived by applying the French weighted maturity scores. This necessitates the calculation of maturity scores specifically for an Indian population.

Our study estimated the MAE to be 0.89 years for the entire sample (Table 3) which implies that in any clinical situation during forensic investigation, the age estimated for a South Indian population by Chaillet and Demirjian method using Acharya's formula is likely to estimate the chronological age within 1 year difference. Our results are in concordance with the results of Acharya[14] and Sonali[13] et al on a South Indian population and significantly lower when compared to the MAE in a Goan population. Their higher MAE of 2.33 could be due to the variation in the sample population and the age groups of the subjects included in their study.

Comparison of the Foti's clinical method and Modified Demirjian's radiographic method

The clinical method was able to accurately assess dental age in 39.6% of the population when compared to 32.85% by radiographic method. By considering the error rate of ± 1 year as accurate, this comparison suggests that the clinical method is a better predictor of dental age than the radiographic method (Table 4).

To the best of our knowledge, ours is the first study to compare the accuracy of clinical and radiographic methods in age assessment of a South Indian population.

The clinical method was accurate in DA assessment of subjects in the age range of 7-15 years. The radiographic method accurately assessed the DA of 10-20 years old subjects (Tables 3).

In a study on a Goan population,[5] DA estimated by using Foti's regression model 2 as well as Acharya's formula was accurate in 44% of their population. Although in our study, the clinical method was a better predictor of age than the radiographic method, the accuracy achieved among our population is less when compared to Goan subjects. This variation reflects the racial differences in the tooth maturation and emphasises the necessity to derive population specific regression formulae. This difference could also be the result of using radiographs to estimate DA by Foti's regression model[5] 2 since it seems inappropriate to predict the duration required for the eruption process by radiographs.

When Pearson's correlation statistical test was applied to our study population, the DA estimated by clinical method showed strongly positive association with true age and this correlation was highly significant ($p<0.001$) with correlation coefficient of 0.87 years (Graph 1). These results are at parity with the correlation coefficient of 0.86 achieved by Dinakar et al.[5]

Our values are also comparable with the correlation coefficient of 0.78 observed by Foti & co-workers' [10] in their study on a French population. Assessment of association between the radiographic method of DAE with the CA also indicated a highly significant ($p<0.001$) positive correlation (Graph 2). However, with a coefficient of 0.64 the values expressed a moderate correlation between the two.

The results of our study imply that clinical method of age estimation (Foti's method and formula) provides an age estimate that is on average more accurate (MAE = 0.76 years for males and 0.84 for females) than the radiographic method (Demirjian grades and scores assessed using Acharya's Indian Formula) (MAE = 0.88 years for males and 0.9 years for females) in the population of Karnataka, India.

CONCLUSION

Clinical method is a better predictor of age than the radiographic method. But the difference between the two may be considered as practically small implying that either of the methods can be employed in clinical practice. However, one must be judicious while extrapolating the observations made from the current study to the entire South Indian population as there exists an enormous amount of genetic admixture and cultural diversities which necessitates population and sub-population specific studies.

In future, there is a need to derive gender-specific regression model 2 for an effective application of Foti's clinical method in age assessments. Further, the maturity scores specific for an Indian population need to be studied and regression formulae derived in order to improve the predictive accuracy of the radiographic method.

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