Accuracy of Demirjian's 8 teeth method for age prediction in South Indian children: A comparative study

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Abstract

Introduction: Demirjian's method of tooth development is most commonly used to assess age in individuals with emerging teeth. However, its application on numerous populations has resulted in wide variations in age estimates and consequent suggestions for the method's adaptation to the local sample. Original Demirjian's method utilized seven mandibular teeth, to which recently third molar is added so that the method can be applied on a wider age group. Furthermore, the revised method developed regression formulas for assessing age. In Indians, as these formulas resulted in underestimation, India-specific regression formulas were developed recently. The purpose of this cross-sectional study was to evaluate the accuracy and applicability of original regression formulas (Chaillet and Demirjian 2004) and India-specific regression formulas (Acharya 2010) using Demirjian's 8 teeth method in South Indian children of age groups 9–20 years. **Methods:** The present study consisted of 660 randomly selected subjects (330 males and 330 females) were in the aged ranging from 9 to 20 years divided into 11 groups according to their age. Demirjian's 8 teeth method was used for staging of teeth. **Results:** Demirjian's method underestimated the dental age (DA) by 1.66 years for boys and 1.55 years for girls and 1.61 years in total. Acharya's method over estimated DA by 0.21 years for boys and 0.85 years for girls and 0.53 years in total. The absolute accuracy was better for Acharya's method compared with Demirjian method. **Conclusion:** This study concluded that both the Demirjian and Indian regression formulas were reliable in assessing age making Demirjian's 8 teeth method applicable for South Indians.

Keywords: Age estimation, Demirjian method, dental development, forensic odontology, regression analysis, South Indians

Introduction

The application of forensic odontology is expanding as the science develops. Teeth and bones are most commonly used for identification of an unknown individual and for age determination.[1] Dental age (DA) is useful for evaluating a child's growth status and for assessing the ages of subjects in anthropological, forensic and medico-legal situations.

Dental age is a practical method of gauging a child's degree of maturity. Most commonly tooth formation used for assessing dental maturation because it is a continuous and progressive process that can be followed radiographically and most teeth can be evaluated at each examination, also considered as reliable indicators of maturation because they are less affected than other body tissues by endocrinopathies and environmental insults, exogenic factors such as malnutrition or disease.[2-4]

Dividing tooth formation in to discrete maturity events such as crown and root stages provides the opportunity to assess maturity from childhood to early adulthood. Demirjian *et al*. method[5] of age assessment utilizes seven mandibular teeth on left side, which has been widely used in all populations, but revealed variations in age estimates in Indians. As only seven teeth were included, it limits the use of this method in individuals above 16 years and also found to be inaccurate in some previous studies.[6-8]

To overcome this, Chaillet and Demirjian[9] added the third molar for an assessment of age in French children and derived regression formulas for age assessment. Another major modification made in this study was that two additional stages were included to staging of teeth for easier calculation and to develop cubic equations with good reliability.

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Radiographic analysis including third molar development expands the years of age estimation to 9–23 years as crown and root development can be studied independent of eruption. This revised method was tested by Acharya[10] on an Indian sample which showed recognizable differences and led to the development of India-specific formulas to accurately predict the age in Indians. As yet no studies have tested these Demirjian's and India-specific formulas on South Indians using Demirjian's 8 teeth method, this study purposes to evaluate the applicability and accuracy of Demirjian's and Acharya's formulas for age estimation on selected population.

Methods

Study consisted of 660 randomly selected subjects (330 males and 330 females) with age ranging from 9 to 20 years divided into 11 groups according to age [Table 1]. Informed consent was taken from all the individuals and the study was approved by the Ethical Committee of our institution, Visakhapatnam, and comprised of patients of same ethnic origin were included in the study. Patients with: (a) Serious medical illness. (b) History of extraction of permanent teeth. (c) History of trauma to face. (d) Impacted or ankylosed teeth or transposition of teeth. (e) Congenital absence of third molars was excluded from the study. Clinical examination of all 660 subjects was performed and name, sex, date of birth of each individual and date of X-ray was recorded. Six hundred and sixty digital orthopantomographs (OPG) were taken with a Planmeca digital machine (Planmeca OY, Asentajankatu 6, FIN-00880 Helsinki, Finland) in the Department of Oral Medicine and Radiology.

Dental age determination using Demirjian's 8 teeth method

Chronological age (CA) of an individual was calculated by subtracting the birth date from the date on which the radiographs were exposed for that particular individual. Decimal age was taken for simplicity of statistical calculation and ages were estimated on a yearly basis, e.g. 9 years 9 months as 9.75 years and it was considered in 9 years age group. To avoid observer bias, each digital OPG of an individual was coded with a numerical identity number (1–660) to ensure that the examiner was blind to sex, name and age of subjects. Evaluators were given written instructions for staging, including drawings and written descriptions of the ten stages of tooth development of Demirjian's 8 teeth method that supplements the graphic representations with archetypical radiographs for each stage. Each tooth was Staged 0–9, depending on the stage of calcification. Each stage of the mandibular eight teeth (central incisor to third molar) was allocated a score and the sum of the scores gave a total maturity score (S), which was then substituted in the regression formulas given by Chaillet and Demirjian (2004) and Acharya (2010) to estimate age of an individual.

Table 1: Distribution of sample according to age and sex

Age	Males	Females	Total
9-9 years. 11 months	30	30	60
10-10 years. 11 months	30	30	60
11-11 years. 11 months	30	30	60
12-12 years. 11 months	30	30	60
13-13 years. 11 months	30	30	60
14-14 years. 11 months	30	30	60
15-15 years. 11 months	30	30	60
16-16 years. 11 months	30	30	60
17-17 years. 11 months	30	30	60
18-18 years. 11 months	30	30	60
19-20 years	30	30	60
Total	330	330	660

Method 1: Chaillet and Demirjian's regression formulas based on tooth development of French children (original method)

1. For males, age $= (0.000055 \times S^3) - (0.0095 \times S^2) + (0.6479 \times S) - 8.4583$
2. For females, age $= (0.0000615 \times S^3) - (0.0106 \times S^2) + (0.6997 \times S) - 9.3178$

Method 2: Acharya's Indian formulas for age estimation (Indian method)

1. For males, age $= 27.4351 - (0.0097 \times S^2) + (0.000089 \times S^3)$
2. For females, age $= 23.7288 - (0.0088 \times S^2) - (0.000085 \times S^3)$

Statistical analyses

All statistical analyses were performed using the Statistical Package for Social Sciences Computer software (SPSS version 20.0. SPSS Inc., Chicago, IL, USA). Before starting the study, in pursuit of training and calibration for methods, 50 randomly selected radiographs were re-evaluated by the two observers. The inter- and intra-observer agreements were determined using the intraclass correlation coefficient. The differences between the estimated DA and the CA were compared based on the age and gender with paired t-test and Wilcoxon signed rank test. Both parametric and nonparametric tests were used, in all the tests $P < 0.05$ was considered as statistically significant. Spearman rank correlation test was performed to assess the relation between the estimated DA according to two methods and the CA, and the accuracy of the two methods was obtained.

Accuracy refers to how close DA is to CA, that is the mean difference between DA and known age will be zero or close to zero. In recent studies, mean absolute difference (AD), which is the difference between DA and known age proportionally aged to within an age interval or to within a proportion of known age, considered as a measure to quantify a method's accuracy.[11-13] Hence, in this study, the effectiveness of the two methods was compared in terms of AD between the estimated and actual age, and the number of age estimates that were either <±1 year (between 1.2 and 2 years, considered as accurate) or >±2 years (considered as inaccurate) from actual age.[9,14,15]

Results

The comparison of the dental age using Demirjian method and the chronological age

Table 2 for both gender compare the DA derived from original regression formulas and the CA depending on age groups. For both boys and girls, except for the 11–11.99 year age groups, in all the age groups statistically significant differences were observed and the DA was underestimated in comparison to the CA.

The comparison of the dental age using Acharya method and the chronological age

Table 3 for both gender compare the DA derived from India-specific regression formulas and the CA depending on age groups. For boys, except for 9–9.99, 10–10.99, 12–12.99, 13–13.99, 18–18.99 and 19–20 years age groups, in all age groups significant differences were observed and the DA was over estimated in all age groups except for 12–12.99, 13–13.99, 14–14.99 and 19–20 years. For girls, except for 10–10.99, 11–11.99 and 13–13.99 years age groups, statistically significant differences were found in other age groups and the DA was over estimated in comparison to CA in all age groups.

Comparison of the Chaillet and Demirjian's method with Acharya's method

Tables 4 and 5 shows the mean differences between the DAs and the CAs and mean values of absolute differences for boys and girls and in total according to the methods. Demirjian's method underestimated the DA by 1.66 years for boys and 1.55 years for girls and 1.61 years in total. ADs were 1.87 years for boys and 1.73 years for girls, with statistically significant differences between the gender ($P < 0.001$). Acharya's method overestimated DA by 0.21 years for boys and 0.85 years for girls and 0.53 years in total. ADs were 1.2 years for boys and 0.85 years for girls, with statistically significant differences between the genders ($P < 0.001$). The absolute accuracy was better for Acharya's method compared to Chaillet and Demirjian method. Figures 1 and 2 shows the accuracy of

Table 2: Comparison between DA using the Demirjian formula (original method) and CA (in years)

Sex	Age group (years)	*n*	Mean (SD)			95% CI of DA-CA	*t*-test (df)†	*P* value†	*P* value‡
			CA	DA	DA-CA				
Boys	9.00-9.99	30	9.39 (0.12)	8.54 (0.84)	−0.85 (0.82)	−1.16, −0.54	5.648 (29)	<0.001	<0.001
	10.00-10.99	30	10.44 (0.32)	8.62 (0.69)	−1.81 (0.70)	−2.07, −1.55	14.11 (29)	0.90	<0.001
	11.00-11.99	30	11.42 (0.24)	11.37 (1.80)	−0.04 (1.87)	−0.74, 0.65	0.12 (29)	<0.001	0.829
	12.00-12.99	30	12.41 (1.89)	10.80 (1.66)	−1.60 (1.66)	−2.22, −0.98	5.27 (29)	<0.001	<0.001
	13.00-13.99	30	13.28 (0.14)	11.68 (1.45)	−1.6 (1.5)	−2.16, −1.04	5.86 (29)	<0.001	<0.001
	14.00-14.99	30	14.39 (0.19)	13.08 (1.64)	−1.31 (1.62)	−1.92, −0.7	4.41 (29)	<0.001	<0.001
	15.00-15.99	30	15.46 (0.23)	13.80 (1.84)	−1.65 (1.86)	−2.35, −0.96	4.87 (29)	<0.001	<0.001
	16.00-16.99	30	16.41 (0.22)	14.73 (0.75)	−1.68 (0.78)	−1.97, −1.38	11.7 (29)	<0.001	<0.001
	17.00-17.99	30	17.33 (0.23)	15.28 (0.70)	−2.05 (0.8)	−2.35, −1.75	14.11 (29)	<0.001	<0.001
	18.00-18.99	30	18.45 (0.17)	15.96 (0.26)	−2.5 (0.26)	−2.6, −2.4	51.89 (29)	<0.001	<0.001
	19.00 or more	30	19.29 (0.25)	16.12 (0.24)	−3.17 (0.36)	−3.3, −3.03	48.48 (29)	<0.001	<0.001
	Total	330	14.39 (3.16)	12.72 (2.87)	−1.66 (1.45)	−1.8, −1.50	20.70 (329)	<0.001	<0.001
Girls	9.00-9.99	30	9.26 (0.19)	8.48 (0.58)	−0.78 (0.62)	−1.01, −0.55	6.92 (29)	<0.001	<0.001
	10.00-10.99	30	10.31 (0.25)	9.63 (0.98)	−0.68 (0.92)	−1.02, −0.33	4.029 (29)	<0.001	0.001
	11.00-11.99	30	11.27 (0.23)	10.99 (1.41)	−0.27 (1.44)	−0.81, 0.26	1.03 (29)	0.30	0.339
	12.00-12.99	30	12.43 (0.15)	11.83 (0.93)	−0.6 (0.87)	−0.9, −0.27	3.74 (29)	0.001	0.001
	13.00-13.99	30	13.39 (0.21)	12.33 (1.34)	−1.05 (1.3)	−1.54, −0.56	4.42 (29)	<0.001	0.001
	14.00-14.99	30	14.49 (0.22)	13.42 (1.16)	−1.06 (1.09)	−1.47, −0.65	5.31 (29)	<0.001	<0.001
	15.00-15.99	30	15.41 (0.18)	14.15 (0.83)	−1.25 (0.85)	−1.57, −0.94	8.09 (29)	<0.001	<0.001
	16.00-16.99	30	16.37 (0.28)	14.53 (0.5)	−1.84 (0.61)	−2.07, −1.61	16.39 (29)	<0.001	<0.001
	17.00-17.99	30	17.34 (0.22)	14.58 (0.83)	−2.75 (0.82)	−3.06, −2.45	18.3 (29)	<0.001	<0.001
	18.00-18.99	30	18.41 (0.20)	15.31 (0.54)	−3.09 (0.58)	−3.31, −2.87	28.9 (29)	<0.001	<0.001
	19.00 or more	30	19.38 (0.21)	15.72 (0.58)	−3.65 (0.65)	−3.9, −3.41	30.56 (29)	<0.001	<0.001
	Total	330	14.37 (3.20)	12.82 (2.44)	−1.55 (1.41)	−1.7, −1.4	19.87 (329)	<0.001	<0.001

†Paired *t*-test; ‡Wilcoxon signed-rank test. CI: Confidence interval; SD: Standard deviation; DA: Dental age; CA: Chronological age

Table 3: Comparison between DA using the Indian formula (Acharya) method and CA (in years)

Sex	Age group (years)	*n*	Mean (SD)			95% CI of DA-CA	*t*-test (df)†	*P* value†	*P* value‡
			CA	DA	DA-CA				
Boys	9.00-9.99	30	9.39 (0.12)	11.46 (0.82)	+2.06 (0.82)	1.75, 2.37	−13.7 (29)	<0.001	<0.001
	10.00-10.99	30	10.44 (0.32)	11.21 (0.86)	+0.78 (0.98)	0.41, 1.15	−4.37 (29)	<0.001	<0.001
	11.00−11.99	30	11.42 (0.24)	12.23 (1.8)	+0.81 (1.9)	0.10, 1.52	−2.34 (29)	0.026	0.12
	12.00-12.99	30	12.41 (1.89)	11.69 (1.35)	−0.72 (1.41)	−1.24,−0.19	2.79 (29)	0.009	0.01
	13.00-13.99	30	13.28 (0.14)	12.29 (1.5)	−0.98 (1.54)	−1.56,−0.4	3.5 (29)	0.002	0.003
	14.00-14.99	30	14.39 (0.19)	14.23 (1.9)	−0.16 (1.91)	−0.88, 0.55	0.47 (29)	0.64	0.75
	15.00-15.99	30	15.46 (0.23)	15.48 (1.92)	+0.01 (1.96)	−0.72, 0.74	−0.02 (29)	0.968	0.61
	16.00-16.99	30	16.41 (0.22)	16.61 (1.29)	+0.19 (1.31)	−0.29, 0.68	−0.81 (29)	0.42	0.95
	17.00-17.99	30	17.23 (0.23)	17.55 (1.23)	+0.22 (1.31)	−0.27, 0.71	−0.9 (29)	0.37	0.33
	18.00-18.99	30	18.45 (0.17)	18.75 (0.48)	+0.3 (0.45)	0.13, 0.47	−3.7 (29)	0.001	0.01
	19.00 or more	30	19.29 (0.25)	19.05 (0.4)	−0.23 (0.51)	−0.43,−0.04	2.5 (29)	0.018	0.02
	Total	330	14.39 (3.16)	14.59 (3.17)	0.20 (1.57)	0.03, 0.37	2.4 (329)	0.01	<0.001
Girls	9.00-9.99	30	9.26 (0.19)	10.01 (0.28)	+0.75 (0.35)	0.61, 0.88	−11.7 (29)	<0.001	<0.001
	10.00-10.99	30	10.31 (0.25)	10.45 (1.11)	+0.13 (1.06)	−0.26, 0.53	−0.7 (29)	0.49	0.47
	11.00−11.99	30	11.27 (0.23)	12.08 (2.02)	+0.81 (2.05)	0.04, 1.57	−2.15 (29)	0.03	0.22
	12.00-12.99	30	12.43 (0.15)	13.2 (1.37)	+0.76 (1.33)	0.27,1.25	−3.21 (29)	0.003	0.006
	13.00-13.99	30	13.39 (0.21)	14.03 (2.19)	+0.64 (2.15)	−0.16, 1.14	−1.63 (29)	0.114	0.19
	14.00-14.99	30	14.49 (0.22)	15.85 (1.86)	+1.36 (1.78)	0.69, 2.03	−4.18 (29)	<0.001	<0.001
	15.00-15.99	30	15.41 (0.18)	17.1 (1.46)	+1.68 (1.47)	1.13, 2.23	−6.2 (29)	<0.001	<0.001
	16.00-16.99	30	16.37 (0.28)	17.75 (0.9)	+1.38 (0.99)	1.01, 1.75	−7.65 (29)	<0.001	<0.001
	17.00-17.99	30	17.34 (0.22)	17.85 (1.5)	+0.51 (1.48)	−0.03, 1.07	−1.9 (29)	0.06	0.039
	18.00-18.99	30	18.41 (0.20)	19.18 (0.99)	+0.78 (1.02)	0.39, 1.16	−4.17 (29)	<0.001	<0.001
	19.00 or more	30	19.38 (0.21)	19.94 (1.07)	+0.56 (1.13)	0.13, 0.98	−2.71 (29)	0.01	0.006
	Total	330	14.37 (3.20)	15.22 (3.60)	0.85 (1.47)	0.7, 1.01	10.5 (329)	<0.001	<0.001

†Paired *t*-test; ‡Wilcoxon signed-rank test. CI: Confidence interval; SD: Standard deviation; DA: Dental age; CA: Chronological age

Table 4: Summary of mean differences in years (DA-CA) between the DA and the CA and AD for each radiographic method for girls and boys

Sex	Method	*n*	CA (SD)	DA (SD)	DA-CA (SD)	95% CI of DA-CA	DA-CA[a]	AD	AD[a]	*t*-statistic[b] (df)	*P*[b]	*P*[c]
Girls	Demirijian	330	14.37 (3.2)	12.82 (2.44)	−1.55 (1.41)	−1.70, −1.39	−1.376	1.737 (1.18)	1.495	19.87 (329)	<0.001	<0.001
	Acharya	330	14.37 (3.2)	15.22 (3.6)	0.85 (1.47)	0.69, 1.01	0.858	1.346 (1.05)	1.187	10.5 (329)	<0.001	<0.001
Boys	Demirjjian	330	14.39 (3.16)	12.72 (2.87)	−1.66 (1.45)	−1.82, −1.50	−1.602	1.878 (1.16)	1.678	20.7 (329)	<0.001	<0.001
	Acharaya	330	14.39 (3.16)	14.59 (3.17)	0.21 (1.57)	0.038, 0.38	0.174	1.205 (1.04)	0.935	2.4 (329)	0.01	<0.001
Total	Demirjian	660	14.38 (3.18)	12.77 (2.67)	−1.61 (1.44)	−1.72, −1.50	−1.503	1.807 (1.17)	1.564	28.72 (659)	<0.001	<0.001
	Acharya	660	14.38 (3.18)	14.91 (3.41)	0.53 (1.56)	0.41, 0.65	0.536	1.276 (1.04)	1.026	8.75 (659)	<0.001	<0.001

[a]Median; [b]Paired samples *t*-test; [c]Wilcoxon signed-rank test, [a]AD: Median absolute difference. AD: Absolute difference; SD: Standard deviation; DA: Dental age; CA: Chronological age; CI: Confidence interval

Demirjian method for boys and girls, respectively. Figures 3 and 4 shows the accuracy of Indian method for boys and girls, respectively. Figure 5 shows the distribution of results for males and females and compares the accuracy of both the methods.

Correlation between dental and chronological ages depending on gender and two methods

Table 6 shows the correlation between DAs and CAs depending on gender and methods. Spearmen rank correlation test showed significant relation between DA and CA for both boys ($r = 0.90$ for Demirjian's method, $r = 0.85$ for Acharya's method: $P < 0.001$) and girls ($r = 0.91$ for Demirjian's method, $r = 0.90$ for Acharya's method: $P < 0.001$).

The assessment of the inter- and intra-observer agreements

Intraclass correlation coefficient values for the inter- and intra-observer agreements were found to be 0.95 and 0.94, respectively [Tables 7 and 8]. There was no statistically significant difference and the values were thought to be considerably high and reliable representing an excellent agreement among the observers for both the methods.

Table 5: Mean accuracy (in years) for each method for children aged 9.00-20.00 years

Author	Sex	*n*	Mean	SE	SD
Demirjian	Boys	330	−1.663	0.080	1.456
	Girls	330	−1.551	0.078	1.418
	Total	660	−1.607	0.056	1.437
Acharya (Indian formula)	Boys	330	0.209	0.087	1.576
	Girls	330	0.854	0.081	1.478
	Total	660	0.532	0.061	1.560

SE: Standard error; SD: Standard deviation

Discussion

Since years Demirjian's method has been widely applied for many populations for age estimation of children and adolescents because of the simplicity of the method, as well as radiographic and schematic illustrations of tooth development with descriptions provided in all works.[5,9,16] However, previous studies,[6,15,17] resulted in relatively wide variations between estimated and actual age, prompting several authors to suggest the use of population specific standards.

Previous studies[6-8] have shown overestimation of age in Indians, however all of them evaluated Demirjian's 7 teeth method and did not consider the third molar. A drawback of the Demirjian 7 teeth method was it excluded the third molar

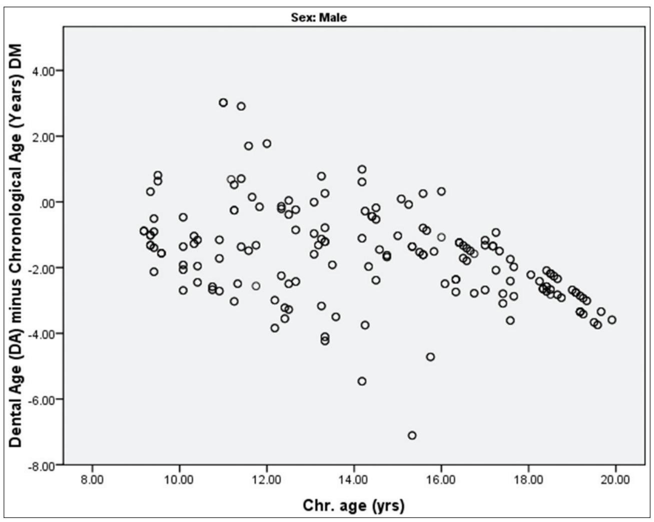

Figure 1: Accuracy of Demirjian method (95% confidence limits of mean accuracy in years) for boys with ages 9.00–20.00 years (DM: Demirjian method)

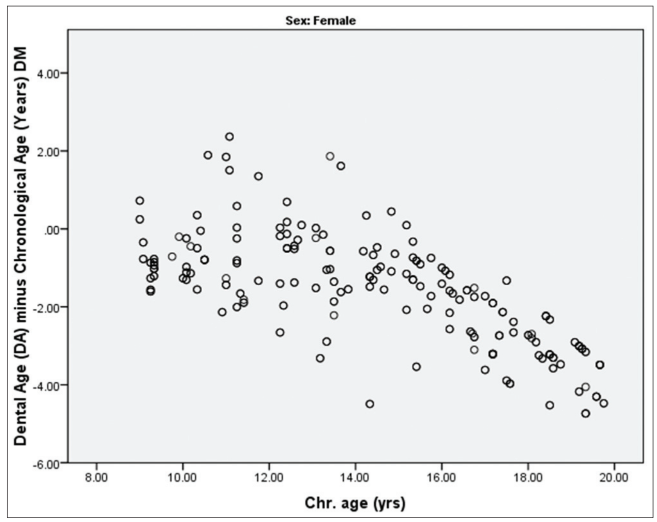

Figure 2: Accuracy of Demirjian method (95% confidence limits of mean accuracy in years) for girls with ages 9.00–20.00 years (DM: Demirjian method)

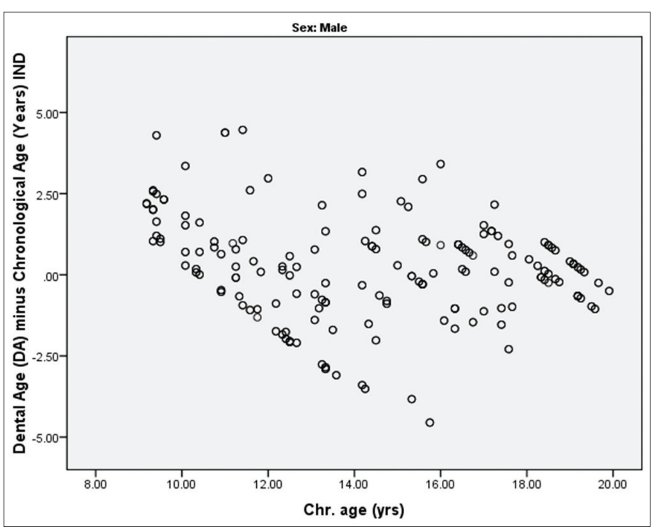

Figure 3: Accuracy of Indian method (95% confidence limits of mean accuracy in years) for males with ages 9.00–20.00 years (IND: Indian method)

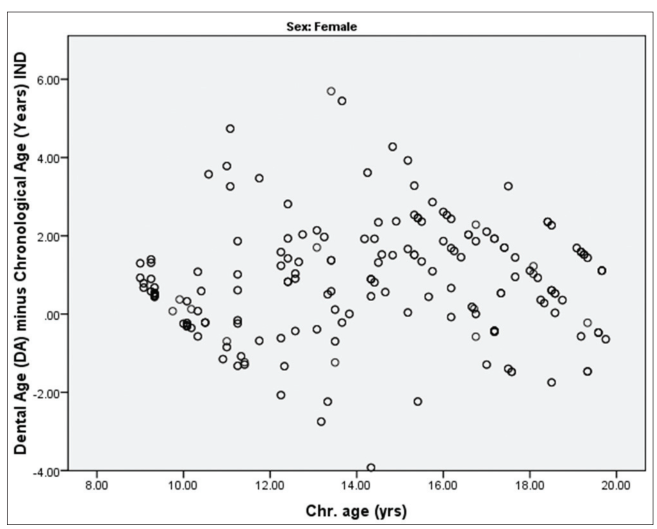

Figure 4: Accuracy of Indian method (95% confidence limits of mean accuracy in years) for females with ages 9.00–20.00 years (IND: Indian method)

owing to its variability in regard to size, shape and likelihood of congenital absence and also because of wide variation in its development.[5] Nevertheless, this tooth is one of the few predictors available for the assessment of age in individuals of 16–23 years age group. Chaillet and Demirjian[9] method utilized third molar and developed new maturity scores for age estimation in French children and regression formulas derived in this study were used by Acharya[10] in Indians, as resulted in discrepancies in estimated age, led to development of India-specific regression formulas to predict age. This study purposed to test the repeatability and accuracy of both the methods for South Indian children by determining mean difference for each gender and age cohort separately.

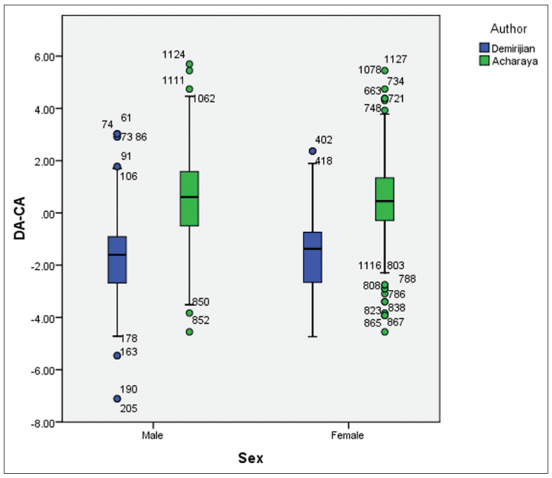

Figure 5: Boxplot of the difference between the dental age and the chronological age for girls and boys according to the Demirjian and Acharya method. Boxplots shows median and interquartile range, whiskers indicate the range

Table 6: Spearman correlation between CA and DA for two methods for boys and girls separately and whole sample

	r-value		
	Boys	Girls	Both
Demirjian	0.903*	0.914*	0.906*
Acharya	0.853*	0.909*	0.887*

**P*<0.0001: Very high significant. CA: Chronological age; DA: Dental age

Acharya[10] tested the Chaillet and Demirjian's formulas on 295 radiographs of individuals aged 7–16 years and compared in terms of the number of age estimates that fell outside the 95%, 97% and 99% confidence intervals. Furthermore, developed Indian specific formulas from 355 individuals aged 7–18 years and also tested the Indian and Demirjian's cubic equations on 70 individuals of age 9 to 18 years and concluded that Indian formulas predicted age better than Demirjian' formulas. Kumar and Gopal[18] tested Demirjian's 8 teeth method using India-specific formulas on a sample of 121 individuals of South India and showed that in 57.9% of cases the error rate was within ±1 year with accuracy of 1.18 years and also found that the addition of third molar increased the error rates in the older individuals.

In the present study, for boys, the mean (standard deviation [SD]) CA was 14.39 years (3.16 years). The mean DA was 12.72 years (2.87 years) with a mean difference of −1.66 years according to the Demirjian method and the mean DA was 14.59 years (3.17 years) with a mean accuracy of 0.2 years according to the Indian method. For girls, the mean (SD) CA was 14.37 years (3.2 years). The mean DA was 12.82 years (2.44 years) with a mean accuracy of −1.55 years according to the Demirjian method and the mean DA was 15.22 years (3.6 years) with a mean accuracy of 0.85 years according to the Indian method [Tables 4 and 5]. The present study resulted in better age prediction in girls compared to boys according to Demirjian's formulas, whereas according to Indian formulas age was accurately predicted in boys similar to previous study.[10] However, in contrast to present study, females were accurately predicted in other study, where only Indian formulas were used.[18] The present study also showed that Indian formulas were more accurate (0.53 years) in predicting age compared to Demirjian (1.6 years) formulas similar to previous study.[10] Significant correlation was found between the estimated DA, according to Demirjian formulas ($r = 0.9$) and Indian formulas ($r = 0.88$), and CA [Table 6].

Table 7: ICC between two examiners for two methods among boys and girls

	A1 age versus A2 age (ICC (95% of CI))			B1 age versus B2 age (ICC (95% of CI))		
	Boys	Girls	Both	Boys	Girls	Both
Demirjian	0.934 (0.883-0.962)	0.973 (0.952-0.985)	0.951 (0.928-0.967)	0.918 (0.871-0.947)	0.933 (0.897-0.956)	0.925 (0.898-0.944)
Acharya	0.892 (0.809-0.938)	0.976 (0.958-0.986)	0.943 (0.916−0.962)	0.839 (0.749-0.897)	0.936 (0.902-0.958)	0.905 (0.873-0.930)

A, B: Two observers; A1, B1: First reading; A2, B2: Second reading after 1 month; ICC: Intraclass correlation coefficient; CI: Confidence interval

Table 8: ICC between two examiners for two methods among boys and girls

	A1 age versus B1 age			A2 age versus B2 age		
	Boys	Girls	Both	Boys	Girls	Both
Demirjian	0.974 (0.968-0.979)	0.953 (0.941-0.962)	0.965 (0.959-0.970)	0.960 (0.930-0.977)	0.957 (0.925-0.976)	0.959 (0.939-0.972)
Acharya	0.951 (0.939-0.960)	0.950 (0.938-0.960)	0.950 (0.942-0.958)	0.863 (0.759-0.922)	0.969 (0.945-0.982)	0.927 (0.892-0.951)

A, B: Two observers; A1, B1: First reading; A2, B2: Second reading after 1 month; ICC: Intraclass correlation coefficient

Better method demonstrates the accuracy or smaller difference between DA and the CA and the extent to which estimated ages remain consistent over repeated measurements of the same individual. The present study showed no significant observer errors for both the methods similar to original studies.[9,10] Acharya compared the Indian as well as Chaillet and Demirjian's cubic equations on a 9–18 years age group of 70 Indian individuals. The test of the Indian regression formulas revealed better age prediction compared to Demirjian's formulas in terms of mean absolute error (MAE), similar to present study. The Indian formulas resulted in an MAE of 0.87 years (0.7 years in males, 0.99 years in females) and Demirjian formulas deduced an MAE of 1.29 years (0.94 in males and 1.55 in females). In the present study, Indian formulas resulted in an MAE of 1.27 years (1.2 years in boys and 1.34 years in girls) and Demirjian formulas resulted in an MAE of 1.8 years (1.87 years in boys, 1.73 years in girls). However, Acharya[10] also tested the Indian regression equations on a sample of 461 Indian individuals aged between 7 and 25 years and resulted in an MAE of 1.43 years (1.17 years for males and 1.6 years for females) relatively close to present study. Kumar and Gopal[18] utilized only Indian regression formulas for age estimation in 7–23 rear age individuals, resulted in an MAE of 1.18 years for the total sample.

In the present study, Demirjian's cubic equations showed an underestimation of age in agreement with the previous study.[10] This can be attributed to the addition of the third molar, which may have resulted in an underestimation of age in all age groups. This may imply that the third molar contributes to an overall slowing down of dental development in Indians. On the other hand, in the present study, use of Indian specific formulas tends to slightly over estimate the age. Overall, the average age of the total sample was 14.38 years, whereas the mean of the estimated age using the Indian formulas was 14.91 years. In this study, the test of the India-specific cubic functions and the original formulas revealed better ability of the former to predict age accurately in South Indians in agreement with previous study.[10]

In contrast to previous research in Indians,[10,18] the sample used in the present study is larger with relatively well-distributed cases across all age groups and gender. Moreover, this study utilized digital OPG for the analysis. Future studies should be directed to develop the maturity scores representative of the population being studied to improve the age prediction, as French weighted scores were used to perform regression analysis in Indians.

Conclusion

Age estimation methods including third molar plays an essential role in forensic field. In this study, Demirjian's regression equations resulted in underestimation of age and Indian specific cubic equations resulted in mild overestimation of age. However, both the methods tested using Demirjian's 8 teeth method were found to be reliable in assessing age, with Indian method as the most accurate for predicting age of South Indian children of 9–20 year age groups.

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