Original Article

Comparison of Demirjian and Cameriere methods and development of modified Cameriere and Demirjian formula more efficient for North Indian population

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Abstract

Introduction: Accurate age estimation is of utmost importance in several branches of life, be it disaster victim identification (DVI), sports, fashion, education, and many more. Several studies/formulas have been proposed over the years from various parts of the world and amongst them, Cameriere's method of age estimation is now being accepted globally, and the related work is still one of the most thought about.

Aim: The aim of this study was to access the relationship between dental age (DA) and chronological age using Cameriere and Demirjian age estimation method in the north Indian population and develop a population-specific regression formula and validate it in the north Indian population.

Materials and Methods: Orthopantomograms (OPG) of 762 children of north India with age groups between 7 and 16 years were collected. Seven left permanent mandibular teeth were analyzed using both Cameriere and Demirjian's age estimation method. The resultant data were subjected to statistical analysis.

Results: The mean differences between CAge and DAge with age were 1.21 (males), 0.14 (males) and 1.72 (females), 0.28 (females) respectively, which shows significant disparity, wherein Demirjian follows overestimation and Cameriere follows the underestimation trend. Therefore, we modified these methods using the linear regression model.

Conclusion: The modified Demirjian and Cameriere formula after validation shows a better fit in the north Indian state of the Uttar Pradesh population.

Keywords: Age estimation, Cameriere method, forensic dentistry, orthopantomograms

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INTRODUCTION

In the community of forensics mainly in the field of dentistry, odontology, and medicine, age estimation is of important significance for dead and alive people to clarify civil and criminal lawsuits. It is one of the prime disciplines of forensic odontology that assists mainly in medico-legal cases.[1] Teeth, as well as the oral structure, play a vital role in determining the biological profile of an individual as it has low variability indicators than any other development feature.[2] In living cases, tooth sample

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is used in child labor, child abuse, and violence, refugees and military schools, and dead cases, it is basically used in personal identification.[3] The dental maturity shows a) mineralization stages in the tooth, b) formation of the crown, c) maturity of the root, d) tooth eruption, and e) root apex maturation, and the tooth is thoroughly analyzed for genetic and environmental influences.[4] There are four methods of dental age DA) estimation, which are employed during the assessment of teeth: morphological, histological, biochemical, and radiological. The above-mentioned methods are of great value to the forensic odontologist and helpful in determining the age in different age group samples such as prenatal period, infants, children, adolescents, and adults.[5] The age estimation in children and adolescents is based on the analysis of mineralization of permanent dentition and radiographic methods, but some studies have drawn that tooth formation is a more reliable indicator of dental maturity than any other indicators such as gingival emergence or eruption.[6] In children, the utilization of radiographic methods for age estimation proved as a practical, simple, and reliable method, especially in living, dead, or skeletal remains.[7] In adult dentition, age estimation techniques are limited to the assessment of the progression of wear and age changes in the teeth.[8]

The literature presented in Demirjian's methods has analyzed its accuracy, validity, and reliability in comparison to other methods in different populations. It has been regarded as the widely accepted method because, in each study or population, different age estimation methods were analyzed and compared.[9] However, Cameriere's age estimation method assessed the DA based on the relationship between the age and measurement of open apices in teeth. This method is mainly applicable to children and determines the chronological age and has developed a linear regression formula.[10] A comparison of Demirjian's and Cameriere's methods on different populations and different age groups such as in children and adults showed overestimation in Demirjian's case and underestimation in Cameriere's case and the same will follow vice-versa. Moreover, some studies showed that both the methods are strongly correlated with chronological and dental ages and have potential relevance to estimating age in the Indian population, where authors such as Acharya have developed the Indian formula that has proved effective in the evaluation of DA.[11,12]

The aim of the present study was to analyze the relationship between estimated DA and chronological age using Cameriere's open apices method and Demirjian's method between children aged 7 and 16 years in the north Indian population and also develop a population-specific regression formula in north Indian population and validate the regression formula in the sample population.

MATERIAL AND METHODS

A population (OPGs) of 762 ($N = 762$) individuals (where 433 were girls and 329 were boys) ranging in age from 7 to 16 years, with almost 57% of the studied population being girls, were considered randomly from the Department of Oral Medicine and Radiology of King George's Medical University, Lucknow.

The exclusive and particular patient's data comprised their personal information including date of birth, information of radiograph dataset with no objection certificate duly signed by their parents/guardians. We are very sure that their requisites were used only for academic, research, and developmental purposes. The dental records or computer images of orthopantomographs (OPGs), all were saved, and then later examined under scrutiny using the ImageJ software.

Inclusion criteria- OPGs- Left side mandibular teeth in the absence of any developmental anomalies and diseases were selected.

Exclusion criteria- OPGs Left side mandibular teeth with developmental anomalies and missing teeth were excluded from the study.

Radiographic evaluation

Cameriere's method

For teeth with two roots, Ai, i = 6, 7, the sum of the distances between the inner sides of the two open apices was evaluated. To take into account the effect of possible differences in magnification and angulation among radiographs, measurements were normalized by dividing by the tooth length (Li, i = 1.,7) shown in Figure 1.

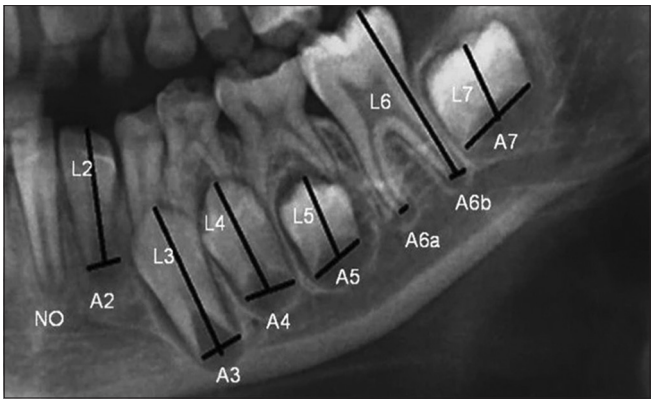

Figure 1: A radiographic image illustrating the apical width and tooth length measurement described in Cameriere's method

Lastly, dental maturity was evaluated with the normalized measurements of seven permanent left mandibular teeth (xi = Ai/Li, i = 1.,7), the sum of normalized open apices s¼ x 1 x 2 x 3 x 4 x 5ð x 6 x 7, and the number (N0) of teeth with root development complete.[13]

Demirjian method

The stages of dental development were evaluated on seven permanent teeth from the left side of the mandible, except third molars, according to Demirjian *et al*., 1973.[14] The dental development of permanent teeth was divided into eight mineralization stages (A to H), from cone-shaped calcifications of the upper portion of the crypt or stage A to fully closed apices or stage H. Subsequently, they were staged according to the Demirjian (1973) maturity chart and tooth description that are shown in Figures 2 and 3.[15]

Based on developmental stages, each tooth was given an appropriate score. The score assigned for each of the seven teeth is added and a total maturity score (S) was obtained as shown in Figure 4.

To obtain age as a function of the maturity score, we calculated a cubic function between the real age and the maturity score for the seven mandibular teeth (Y = aX3 + bX2 + cX + d, with Y as age and X as maturity score).[14]

Statistical analysis

The data obtained were subjected to statistical analysis using the SPSS version 25 software for comparing the accuracy of the above-mentioned two methods by paired *t*-test. The Demirjian (DAge) and Cameriere (CAge) accuracy were calculated by the difference between the chronological age and the estimated age for all groups. The positive values indicate over-estimation, and the negative values indicated under-estimation of age. The Pearson correlation coefficient and paired *t*-test were used for calculating the accuracy of DAge and CAge. *P* value < 0.05 was considered to be statistically significant.

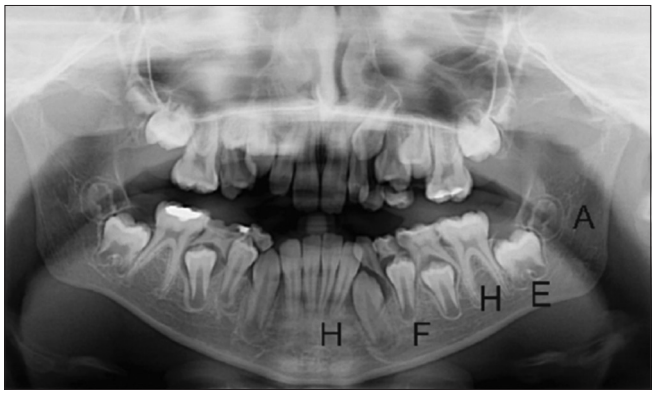

Figure 2: Demonstration of mineralization A, E, F, and H stages by Demirjian's method

RESULTS

The mean ± SD of observers inter and intra-agreement were 0.897 ± 0.020 and 0.961 ± 0.014 for Demirjian's method and 0.975 ± 0.007 and 0.951 ± 0.071 for Cameriere's method, respectively.

Table 1 shows the age and sex distribution of the sample population. Tables 2 and 3 show the correlation of chronological age with Cameriere's and Demirjian's using Pearson's method.

Also, Tables 2 and 3 represent the comparison of DAge and CAge with age. The mean differences between CAge and DAge with age were 1.21 (males), 0.14 (males) and 1.72 (females), 0.28 (females) respectively (*P* < 0.05).

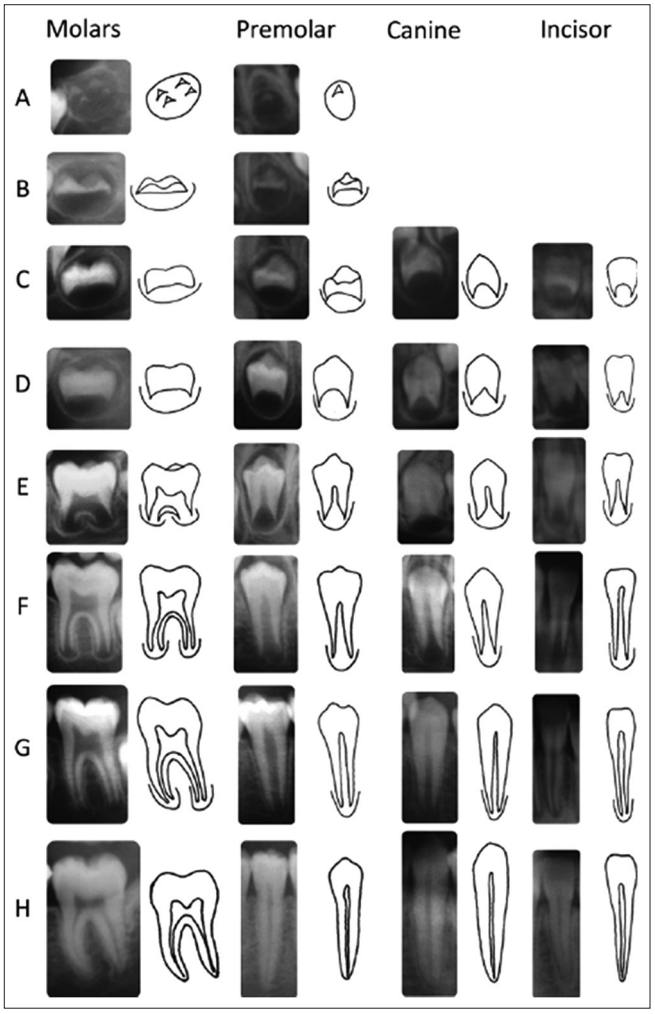

Figure 3: Developmental stages in Demirjian's method[15]

Table 2 (Appendix)

Self-Weighted Scores for Dental Stages
7 Teeth (Mandibular Left Side)

Boys

Tooth	Stage 0	A	B	C	D	E	F	G	H
M_2	0.0	2.1	3.5	5.9	10.1	12.5	13.2	13.6	15.4
M_1				0.0	8.0	9.6	12.3	17.0	19.3
PM_2	0.0	1.7	3.1	5.4	9.7	12.0	12.8	13.2	14.4
PM_1			0.0	3.4	7.0	11.0	12.3	12.7	13.5
C				0.0	3.5	7.9	10.0	11.0	11.9
I_2				0.0	3.2	5.2	7.8	11.7	13.7
I_1					0.0	1.9	4.1	8.2	11.8

Girls

Tooth	Stage 0	A	B	C	D	E	F	G	H
M_2	0.0	2.7	3.9	6.9	11.1	13.5	14.2	14.5	15.6
M_1				0.0	4.5	6.2	9.0	14.0	16.2
PM_2	0.0	1.8	3.4	6.5	10.6	12.7	13.5	13.8	14.6
PM_1			0.0	3.7	7.5	11.8	13.1	13.4	14.1
C				0.0	3.8	7.3	10.3	11.6	12.4
I_2				0.0	3.2	5.6	8.0	12.2	14.2
I_1					0.0	2.4	5.1	9.3	12.9

NB: Stage 0 is no calcification

Figure 4: Scores for dental stages[14]

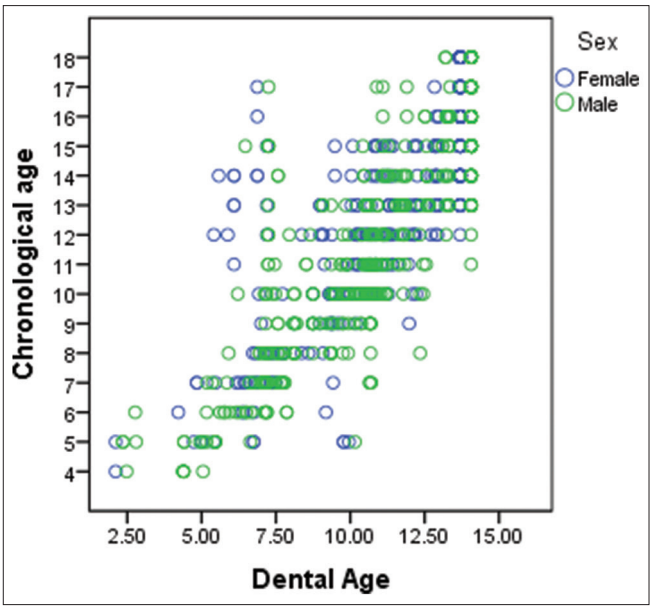

Figure 5: Scatterplot diagram showing the relation between the chronological age and dental age (Cameriere's method) in boys and girls

Table 1: Age and sex distribution of the sample

Age group	Sex	
	Female	Male
4 years	1	6
5 years	9	13
6 years	5	17
7 years	17	24
8 years	12	28
9 years	12	25
10 years	26	44
11 years	18	37
12 years	37	27
13 years	34	43
14 years	41	38
15 years	35	37
16 years	31	29
17 years	16	36
18 years	33	31
Total	327	435

As seen in Tables 4 and 5, DA was underestimated by Cameriere and whereas in Demirjian's method, there was an overestimation, and the difference was higher in the Cameriere method.

Figure 5 present the scatter P diagram, which shows the correlation of DA using Cameriere's method with chronological age. Figures 6 and 7 present the boxplots depicting the relationship between chronological age and Cameriere's age, whereas Figure 8 again represents the scatter P diagram showing correlation of DA using Demirjian's method with chronological age in boys and girls. Figures 9 and 10 represent boxplots depicting the relationship between chronological age and Demirjian's age.

So, we can observe that the Cameriere and Demirjian methods that are both derived from the European Caucasian population, and needed correction/modification. Hence, we used a regression model to correct the formula. The resultant regression formulas are shown in Tables 4 and 5 for both Cameriere's and Demirjian's methods, respectively. Here is the presented modified formula to calculate Cameriere's age, that is,

Dental age*= 9.152- (0.466×sum) +(0.935×N0) where * means it is for both males and females

Sum means the sum of normalized open apices For example,

Sum $=X_1+X_2+X_3$-----X_i where $X_i=A_i/L_i$ measurement of the ratio between the length of the projection of the open apices and the length of the tooth axis major.

ie

$X_i=A_1/L_1+A_2/L_2$+----A_i/L_i

A = distance between the projection of the open apices

L = length of the tooth axis

N0 = number of teeth with root development complete.

For example: If three teeth have completed their root development in that scenario,

$N0 = N_1 + N_2 + N_3$-----N_i, so in this example here N0 = 3.

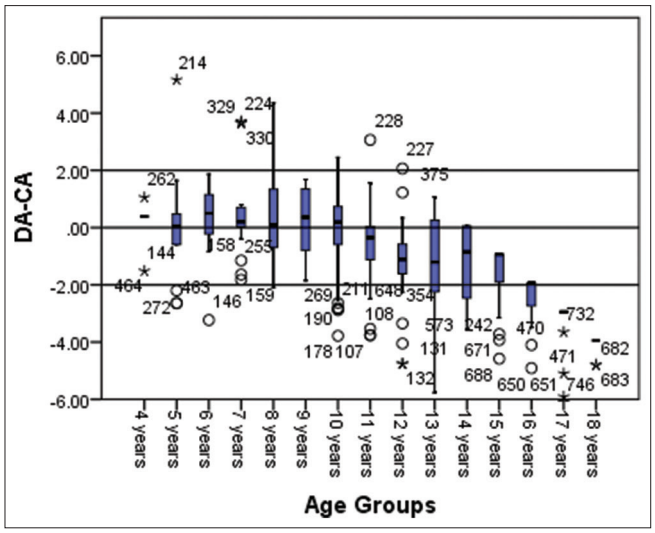

Figure 6: Boxplot of differences between real and estimated ages by Cameriere's method in boys. Horizontal lines inside boxes are located at the median of data; the height of boxes gives interquartile range (IQR); whiskers indicate the range

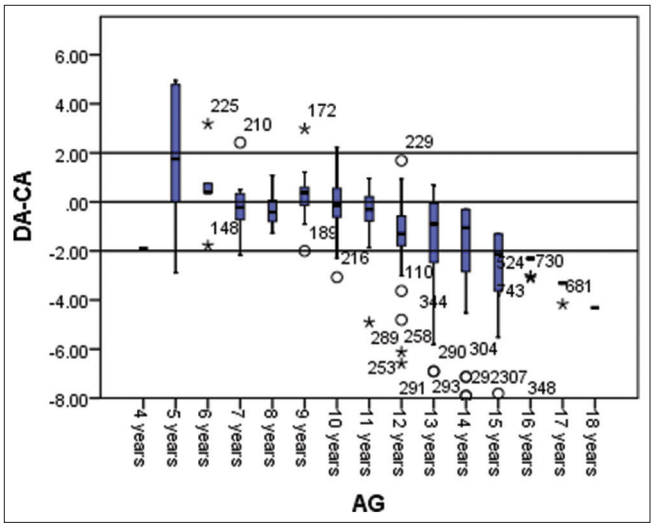

Figure 7: Boxplot of differences between real and estimated ages by Cameriere's method in girls. Horizontal lines inside boxes are located at the median of data; the height of boxes gives interquartile range (IQR); whiskers indicate the range

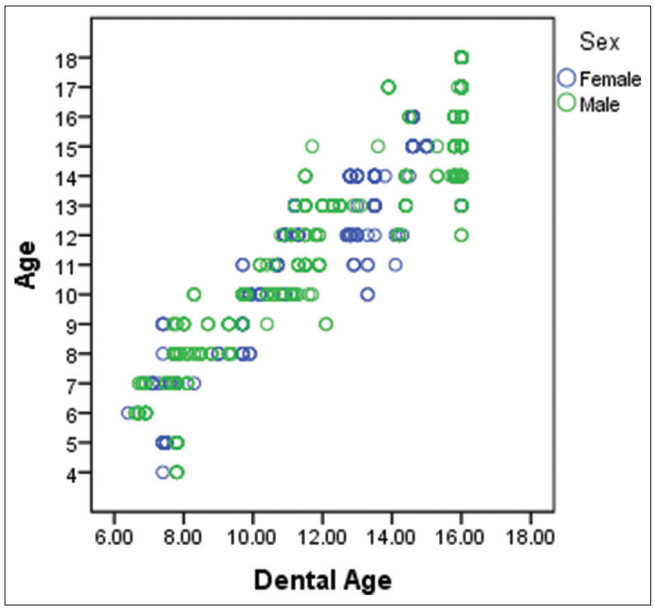

Figure 8: Scatterplot diagram showing the relation between the chronological age and dental age (Demirjian's method) in boys and girls

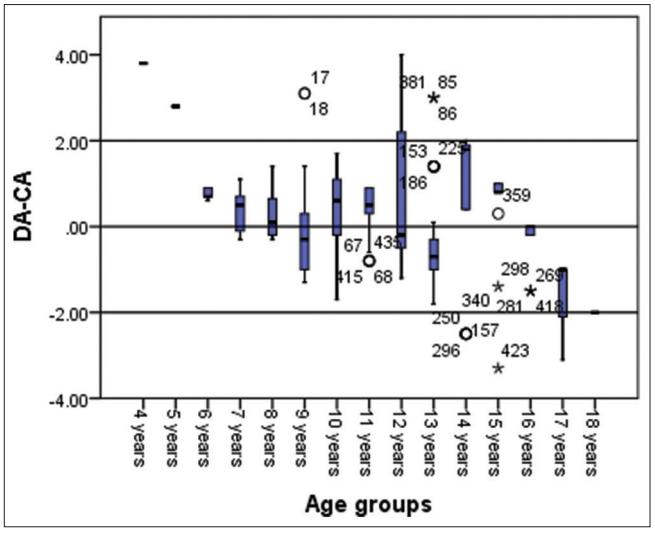

Figure 9: Boxplot of differences between real and estimated ages by Demirjian's method in boys. Horizontal lines inside boxes are located at the median of data; the height of boxes gives the interquartile range (IQR); whiskers indicate the range

The presented modified formula to calculate Demirijian's age, that is

Dental age = -6.552+ (0.303 × sex) +(0.208 × TMS)

Sex; 0 = Female; 1 = Male, TMS = Total Maturity Score obtained by the sum of self-weighted scores of all seven teeth, from which the dental age was calculated using an age conversion table.

It was seen that there was no significant disparity between age and calculated age using the modified Demirjian and modified Cameriere method. Therefore, after comparing the ICC of DAge, CAge, modified Cameriere, and modified Demirjian methods, it can be concluded that modified formulas of Demirjian and Cameriere methods have better reliability with age.

DISCUSSION

In various ethnicities, teeth have been used for determining age in numerous studies. However, it remains unclear how accurate and reliable these methods are.[16] The objective of this study was to correlate the chronological age of the north Indian population located in Lucknow and the surrounding

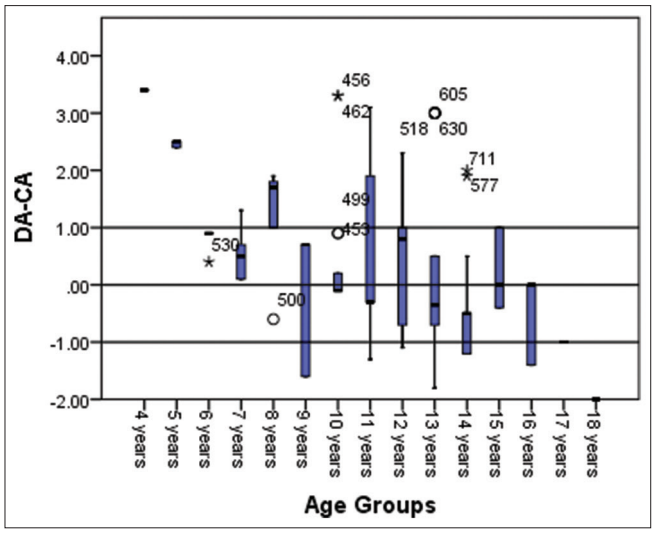

Figure 10: Boxplot of differences between real and estimated ages by Demirjian's method in girls. Horizontal lines inside boxes are located at the median of data; the height of boxes gives the interquartile range (IQR); whiskers indicate the range

region with their estimated DA using the Demirjian *et al*.[14] and Cameriere *et al*.[13] methods. Meanwhile, this study was designed to create an area-modified Cameriere and Demirjian formula for the Lucknow residing sample in the sample population of 7–16 years of age.

In this study, both Demirjian and Cameriere methods were observed to have a high intra-observer agreement, wherein the value for the Demirjian technique was greater than that for the Cameriere method. As stated by Dhanjal *et al*.,[17] this high value was seen in intra-observer agreement, which can be attributed to the obvious evolutionary nature of radiographies and their absence of intermediate stages. Comparing the Demirjian, Moorrees, and London Atlas methods, Alkandiri *et al*.[18] reported that the Demirjian method was simpler and clearer in interpreting the developmental changes involved in tooth eruption in the oral cavity. Both the Cameriere and Demirjian methods have been developed on European populations as using radiographic techniques to estimate the age, as these are simpler and non-destructive methods. However, unlike the studies done by Mazzilli and Guo *et al*., this study had fewer samples in the younger age group, that is, 7–16 years due to the lower demand for panoramic radiography in younger age groups.[19,20]

There were inconsistencies in both the Demrijian and Cameriere methods. The Demirjian method overestimated the DA in both male and female samples up to 15 years of age, and then there was a downward trend that showed underestimation when they reached 16–18 years, whereas the Cameriere method showed underestimation, which conflicts with Pinchi *et al*.[21] findings.

Table 2: Pearson's correlation between the chronological age and Cameriere's dental age

Overall sample		
	Age	**DA**
Age		
Pearson's correlation	1	0.531**
Sig. (2-tailed)		0.000
n	762	762
Males		
Age		
Pearson's correlation	1	0.929**
Sig. (2-tailed)		0.000
n	435	435
Females		
Age		
Pearson's correlation	1	0.353**
Sig. (2-tailed)		0.000
n	327	327

**Correlation is significant at the 0.01 level (2-tailed)

Table 3: Pearson's correlation between the chronological age and Demirjian's dental age

Overall sample		
	Age	**DA**
Age		
Pearson's correlation	1	0.824**
Sig. (2-tailed)		0.000
n	762	762
Males		
Age		
Pearson's correlation	1	0.852**
Sig. (2-tailed)		0.000
n	435	435
Females		
Age		
Pearson's correlation	1	0.780**
Sig. (2-tailed)		0.000
n	327	327

**Correlation is significant at the 0.01 level (2-tailed)

Chaudhry *et al*.[22] reports overestimation using the Demirjian method, whereas Haavikko and Willems methods showed underestimation. In the study by Javadinejad *et al*.[16] the mean value of estimated DA by the Demirjian method was 0.85, whereas using the Cameriere method resulted in an underestimation of the mean value of DA as 0.19 years with significant disparity from the chronological age. Moreover, Abesi *et al*.[23] stated that the overestimated DA by 0.38 years occurred in the Demirjian method. Similarly, the study conducted by Wolf *et al*.[24] showed that the Demirjian method had an overestimation trending estimating DA for both boys and girls by an average of 0.6 and 0.18, whereas the Cameriere method had a slight underestimation pattern for average age in boys of 0.07 and girls of 0.08 respectively. There was a greater disparity, however, in the chronological age and DAge in the present study than in CAge, which could have been because the subjects were of different races. As in this current study, the dissimilarity between

Table 4: Comparison between the chronological age and dental age estimated using Cameriere's formulae in boys and girls

Age groups	Mean (SD)			95% CI	*t* (df)	*P*
	CA	DA	DA- CA (SE)			
Boys						
4 years	4 (0)	4.18 (0.87)	-0.18 (0.35)	-1.09 to 0.73	-0.509 (5)	0.632
5 years	5 (0)	4.97 (2.03)	0.024 (0.56)	-1.20 to 1.25	0.044 (12)	0.966
6 years	6 (0)	6.32 (1.19)	-0.324 (0.29)	-0.93 to 0.29	-1.116 (16)	0.281
7 years	7 (0)	7.48 (1.41)	-0.488 (0.28)	-1.08 to 0.11	-1.695 (23)	0.104
8 years	8 (0)	8.27 (1.34)	-0.276 (0.25)	-0.79 to 0.24	-1.085 (27)	0.288
9 years	9 (0)	9.26 (1.12)	-0.266 (24)	-0.73 to 0.19	-1.187 (24)	0.247
10 years	10 (0)	9.85 (1.43)	0.142 (0.21)	-0.29 to 0.57	0.656 (43)	0.515
11 years	11 (0)	10.46 (1.39)	0.537 (0.22)	0.07 to 1.01	2.351 (36)	0.024*
12 years	12 (0)	10.71 (1.55)	1.284 (0.30)	0.66 to 1.90	4.278 (26)	0.000*
13 years	13 (0)	11.90 (1.62)	1.098 (0.24)	0.59 to 1.59	4.434 (42)	0.000*
14 years	14 (0)	12.57 (1.70)	1.420 (0.27)	0.86 to 1.98	5.140 (37)	0.000*
15 years	15 (0)	12.83 (2.24)	2.164 (0.36)	1.41 to 2.91	5.856 (36)	0.000*
16 years	16 (0)	13.55 (0.75)	2.441 (0.14)	2.15 to 2.72	17.39 (28)	0.000*
17 years	17 (0)	13.62 (1.34)	3.379 (0.22)	2.92 to 3.83	15.05 (35)	0.000*
18 years	18 (0)	14.01 (0.21)	3.995 (0.03)	3.91 to 4.07	103.5 (30)	0.000*
Overall	12.09 (3.75)	10.88 (2.89)	1.209 (0.09)	1.02 to 1.39	12.68 (434)	0.000*
Girls						
4 years	4 (0)	2.11 (0)	–	–	–	–
5 years	5 (0)	6.69 (2.71)	-1.696 (0.91)	-3.78 to 0.39	-1.874 (8)	0.098
6 years	6 (0)	6.58 (1.76)	-0.584 (0.78)	-2.77 to 1.60	-0.741 (4)	0.500
7 years	7 (0)	6.69 (1.08)	0.302 (0.26)	-0.25 to 0.85	1.152 (16)	0.266
8 years	8 (0)	7.66 (0.71)	0.335 (0.20)	-0.11 to 0.78	1.633 (11)	0.131
9 years	9 (0)	9.30 (1.18)	-0.302 (0.34)	-1.05 to 0.44	-0.886 (11)	0.395
10 years	10 (0)	9.91 (1.13)	0.087 (0.22)	-0.37 to 0.54	0.394 (25)	0.697
11 years	11 (0)	10.43 (1.26)	0.561 (0.29)	-0.06 to 1.19	1.877 (17)	0.078
12 years	12 (0)	10.56 (1.78)	1.432 (0.29)	0.83 to 2.02	4.886 (36)	0.000*
13 years	13 (0)	11.52 (2.09)	1.477 (0.35)	0.74 to 2.21	4.109 (33)	0.000*
14 years	14 (0)	12.03 (2.45)	1.964 (0.38)	1.18 to 2.74	5.114 (40)	0.000*
15 years	15 (0)	12.41 (1.51)	2.581 (0.25)	2.06 to 3.10	10.07 (34)	0.000*
16 years	16 (0)	13.39 (1.23)	2.602 (0.22)	2.15 to 3.05	11.76 (30)	0.000*
17 years	17 (0)	13.21 (1.70)	3.790 (0.42)	2.88 to 4.69	8.896 (15)	0.000*
18 years	18 (0)	13.69 (0)	–	–	–	0.000*
Overall	12.87 (3.45)	11.15 (2.66)	1.71 (0.11)	1.47 to 1.94	14.33 (326)	0.000*

*Statistically significant ($P < 0.05$)

Linear Regression: Model Summary[b]				
Model	R	R square	Adjusted R square	Std. error of the estimate
1	0.825[a]	0.681	0.680	2.063

[a.]Predictors: (constant), N0, sum. [b.]Dependent variable: age

Coefficients[a]							
Model	Unstandardized coefficients		Standardized coefficients Beta	*t*	Sig.	95.0% Confidence interval for B	
	B	Std. Error				Lower Bound	Upper Bound
1							
(Constant)	9.152	0.247		37.043	0.000	8.667	9.637
Sum	-0.466	0.070	-0.207	-6.650	0.000	-0.604	-0.329
N0	0.935	0.044	0.659	21.191	0.000	0.848	1.021

[a.]Dependent Variable: Age. Formulae: Dental age* = 9.152- (0.466×sum) + (0.935×N0), *For both males and females

chronological age and CAge and DAge was significant, as Cameriere and Demirjian *et al*.[13,14] formulas were designed for various communities in Europe. Therefore, there is a need to modify these formulas for the better fit in our studied population. The linear regression formula included gender and morphological variables, such as the calculated sum of the numbers of teeth with open apices, the number of teeth with root apexification completed, and their interactions. Demirjian *et al*.[14] have assigned a score for each stage of tooth maturation [Figure 4]; these are then added to calculate the subject's total dental maturity, followed by converting this value to DAge using available tables, whereas our area-specific regression formula would directly convert the dental maturity score to DA. AlShahrani *et al*.[25] stated that entered number of teeth with closed root apices and standardized values were

Table 5: Comparison between the chronological age and dental age estimated using Demirjian's 7- teeth method in boys and girls

Age groups	Mean (SD)			95% CI	*t* (df)	*P*
	CA	DA	DA- CA (SE)			
Boys						
4 years	4 (0)	7.8 (0)	–	–	–	–
5 years	5 (0)	7.8 (0)	–	–	–	–
6 years	6 (0)	6.77 (0.11)	-0.77 (0.02)	-0.83 to -0.7	-27.39 (16)	0.000*
7 years	7 (0)	7.42 (0.47)	-0.42 (0.09)	-0.63 to -0.22	-4.384 (23)	0.000*
8 years	8 (0)	8.28 (0.56)	-0.28 (0.11)	-0.49 to -0.06	-2.664 (27)	0.013*
9 years	9 (0)	8.91 (1.22)	0.08 (0.24)	-0.42 to 0.58	0.343 (24)	0.735
10 years	10 (0)	10.41 (0.81)	-0.41 (0.12)	-0.65 to -0.16	-3.335 (43)	0.002*
11 years	11 (0)	11.38 (0.53)	-0.38 (0.08)	-0.56 to -0.21	-4.386 (36)	0.000*
12 years	12 (0)	12.63 (1.59)	-0.63 (0.31)	-1.26 to -0.01	-2.065 (26)	0.049*
13 years	13 (0)	12.70 (1.28)	0.29 (0.19)	-0.09 to 0.69	1.524 (42)	0.135
14 years	14 (0)	14.90 (1.58)	-0.90 (0.25)	-1.42 to -0.38	-3.506 (37)	0.001*
15 years	15 (0)	15.70 (0.78)	-0.71 (0.12)	-0.97 to -0.44	-5.477 (36)	0.000*
16 years	16 (0)	15.77 (0.45)	0.22 (0.08)	0.05 to 0.39	2.677 (28)	0.012*
17 years	17 (0)	15.47 (0.92)	1.52 (0.15)	1.21 to 1.83	9.956 (35)	0.000*
18 years	18 (0)	16 (0)	–	–	–	–
Overall	12.09 (3.75)	12.23 (3.25)	-0.14 (0.06)	-0.27 to -0.01	-2.112 (434)	0.035*
Girls						
4 years	4 (0)	7.4 (0)	–	–	–	–
5 years	5 (0)	7.45 (0.05)	-2.45 (0.01)	-2.49 to -2.41	-139.7 (8)	0.000*
6 years	6 (0)	6.80 (0.22)	-0.80 (0.10)	-1.07 to -0.52	-8.000 (4)	0.001*
7 years	7 (0)	7.5 (0.33)	-0.50 (0.08)	-0.67 to -0.32	-6.112 (16)	0.000*
8 years	8 (0)	9.38 (0.71)	-1.38 (0.21)	-1.83 to -0.92	-6.671 (11)	0.000*
9 years	9 (0)	8.93 (1.13)	0.06 (0.32)	-0.65 to 0.78	0.204 (11)	0.842
10 years	10 (0)	10.29 (0.92)	-0.29 (0.18)	-0.67 to 0.07	-1.629 (25)	0.116
11 years	11 (0)	11.43 (1.37)	-0.43 (0.32)	-1.11 to 0.24	-1.342 (17)	0.197
12 years	12 (0)	12.38 (1.01)	-0.38 (0.16)	-0.71 to -0.04	-2.292 (36)	0.028*
13 years	13 (0)	12.99 (1.53)	0.01 (0.26)	-0.53 to 0.54	0.022 (33)	0.982
14 years	14 (0)	13.34 (0.70)	0.65 (0.11)	0.42 to 0.87	5.891 (40)	0.000*
15 years	15 (0)	15.31 (0.62)	-0.31 (0.11)	-0.52 to -0.11	-2.991 (34)	0.005*
16 years	16 (0)	15.59 (0.64)	0.40 (0.11)	0.16 to 0.64	3.503 (30)	0.001*
17 years	17 (0)	16 (0)	–	–	–	–
18 years	18 (0)	16 (0)	–	–	–	–
Overall	12.87 (3.45)	13.15 (7.34)	-0.28 (0.38)	-1.04 to 0.46	-0.754 (326)	0.451

*Statistically significant ($P < 0.05$)

Linear Regression: Model Summary[b]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.810[a]	0.656	0.655	2.143

[a]Predictors: (Constant), TMS, Sex. [b]Dependent Variable: Age

Coefficients[a]							
Model	Unstandardized Coefficients		Standardized Coefficients Beta	*t*	Sig.	95.0% Confidence Interval for B	
	B	Std. Error				Lower Bound	Upper Bound
1							
(Constant)	-6.552	0.529		-12.394	0.000	-7.589	-5.514
Sex	0.303	0.159	0.041	1.901	0.058	-0.010	0.616
TMS	0.208	0.006	0.816	37.691	0.000	0.197	0.219

[a]Dependent Variable: Age. Formulae: Dental age = -6.552+ (0.303×sex) + (0.208×TMS), Sex; 0 = Female; 1 = Male

not clearly defined for a few teeth. So, it seemed better to choose standardized values as an input variable. In a study conducted by Rai *et al*.[10] in the Indian population, there was no significant difference between the two genders in estimating the DA, so they did not include gender as a factor in their model and simply included race in the formula. However, we eliminated race as a factor in our analysis similar to Cugati *et al.,*[26] wherein race did not have a significant effect on regression model output in the Malaysian study population.

In our analysis, the estimated mean DA using the modified Cameriere formula and the modified Demirjian formula was very subtly different from the chronological age, comparable to the findings of Al Shahrani *et al*.[25] and Gilbert *et al*.[27] This difference in the modified Cameriere

approach is consistent with Guo *et al.'s*[20] investigation. According to Gilbert *et al*.[27] direct application of Demirjian's method for age estimation is not suitable; therefore, they used the modified Demirjian formula, applicable to both male and female populations, which has negligible difference when compared to chronological age.

The modified Cameriere age and modified Demirjian formula gave DA, which was found to be more suitable for the population of Uttar Pradesh in northern India. Because around 13 years of age, the teeth complete their root apexification. Therefore, the Cameriere and Demirjian methods, which are based on measuring the distance between both the ends of the teeth apices and stages allocated to individual teeth, do not have good accuracy and are subjective to bias. In our population, subjects belonged to various age ranges, and the modified Cameriere and modified Demirjian methods had good accuracy. However, these modified formulas do not seem to have an acceptable accuracy in some age ranges in girls and boys due to the uneven distribution of subject numbers in different age ranges.

CONCLUSION

There were statistically significant differences between chronological age and DA calculated and estimated using the Demirjian and Cameriere methods. However, both the Demirjian and Cameriere methods need modification to better fit the north Indian state of the Uttar Pradesh population. After modification, both the modified Cameriere and Demirjian methods have a very high accuracy in comparison to the Demirjian and Cameriere methods. Therefore, modified formulas have better clinical applicability in estimating the age of children and adolescents.

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Abbreviations used

1. DAge- Demirjian age
2. CAge- Cameriere age
3. ICC- Intra Class Comparison
4. OPGs- Orthopantomographs

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Conflicts of interest

There are no conflicts of interest.

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