Age Estimation in Mixed-dentition Children, Using Cameriere's European Formula and Demirjian's Method: A Comparative Pilot Study

Rathna Valluri[1], Yash Jain[2], Chintala Lalitha[3], Parappa Sajjan[4], Kranti Kiran Reddy Ealla[5], Raghunath Dantu[6]

Abstract

Aim: The objective of the present investigation is to compare the accuracy of two methods of age estimation, Cameriere's European formula and Demirjian's method, in estimating the age of mixed-dentition children in Telangana.

Materials and methods: Digital orthopantomographs (OPGs) of 36 children between the age of 7 years and 12 years were subject to analysis. All the OPGs were analyzed for dental age using both Cameriere's and Demirjian's methods for mixed dentition. Chronological age was calculated by subtracting the date of births from the date on which the OPGs were taken. Statistical analysis: descriptive analysis was performed. The accuracies of both the methods (Cameriere's and Demirjian's) were evaluated by calculating the mean prediction error. Wilcoxon signed-rank test was performed for both methods of dental age estimation with chronological age and for boys and girls. Significance threshold was set at 5%.

Results: Cameriere method resulted in a mean prediction error of 0.579 for girls and 0.483 for boys. Demirjian's method resulted in a mean prediction error of 2.228 for girls and 2.046 for boys.

Conclusion: In conclusion, as far as accuracy is concerned, Cameriere's European formula proved to be more accurate, according to the current investigation.

Significance: The significance of age estimation is reflected in various fields such as pediatric endocrinology, orthodontics, law, anthropology, archeology, and forensics where identification of unascertained human bodies is required (crime investigations, mass disasters). Demirjian's method is commonly employed for dental age estimation in pediatric dentistry, orthodontics, and forensic dentistry. Cameriere's method may serve as a more accurate and reliable method for dental age estimation.

Keywords: Age estimation, Cameriere's European formula, Demirjian's method, Dental age, Forensic dentistry, Orthopantomograph, Radiographic age estimation.

Key message: Cameriere's European formula proved to be better, in terms of accuracy, in determining the chronological age of mixed-dentition children in the region of Telangana, according to the current investigation.

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Introduction

Age estimation from dental radiographs using morphological parameters of teeth is considered to be the most convenient in terms of cost/benefit ratio.[1] Many authors defined various developmental stages in the 4–15-year age range. Nolla described 11 stages; Moorrees et al., 13–14 stages; Haavikko, 12 stages; Liliequist and Lundberg, 8 stages; Demirjian et al., 8 stages; Anderson et al., 13–14 stages; and Willems et al., 8 stages.[2–9] These stages are dependent on predescribed stages of tooth mineralization during a tooth's development, and age estimation through these requires minimal resources. But these methods lead to variable results that depend on the examiner's interpretation. In contrast, age estimation methods using measures (ratios) from radiographs employ regression formulae rather than radiographic developmental stages and show lesser variation with changing examiners; hence, these are more reliable.[10]

Cameriere's European Formula for Dental Age Estimation

In 2006, a formula was introduced by Cameriere et al. for age estimation in children utilizing radiographs of teeth. The formula uses specific normalized measurements of the teeth (measured on a computer screen using an image processing software) and a regression formula for calculating age.

[1,2]Department of Dentistry, Malla Reddy Institute of Dental Sciences, Hyderabad, Telangana, India

[3,6]Department of Oral Medicine and Radiology, Malla Reddy Institute of Dental Sciences, Hyderabad, Telangana, India

[4]Department of Public Health Dentistry, Malla Reddy Institute of Dental Sciences, Hyderabad, Telangana, India

[5]Department of Oral Pathology, Malla Reddy Institute of Dental Sciences, Hyderabad, Telangana, India

Corresponding Author: Rathna Valluri, Department of Dentistry, Malla Reddy Institute of Dental Sciences, Hyderabad, Telangana, India, Phone: +91 9177174051, e-mail: rathnavalluri@gmail.com

Need for the Current Study

While the commonly utilized Demirjian's method is dependent upon predescribed stages of tooth mineralization, Cameriere's method applies regression formula that reduces the variation in results caused by interexaminer variability. Even though Cameriere's

method of age estimation, in mixed dentition, has been proven to be more accurate than Demirjian's method internationally, only a limited amount of literature exists in the Indian context. Hence, this study was conducted to analyze the prospective usefulness of Cameriere's method for dental age estimation in mixed-dentition children in the Indian population.

MATERIALS AND METHODS

Prior to conducting the study, the synopsis of the study was presented to the Ethical Committee of the Institute and clearance was achieved (Reg. No. ECR/828/Inst/AP/2016 dated: 19.01.2016).

Sample

Digital orthopantomographs (OPGs) of 36 children between the ages of 7 and 12 (inclusive) years were randomly selected (simple random selection) for analysis. The machine used for taking OPGs was Planmeca ProMax 2D S3 (Planmeca Oy Asentajankatu 6, FIN-00880 Helsinki, Finland). Figure 1 demonstrates the setup in which the OPGs were taken and the child's position. Six OPGs were chosen for each of the single-year age-groups. The distribution of the children according to their age in years and sex is shown in Table 1. The OPGs were segregated into single-year age-groups and each of the six age-groups contained six OPGs.

Inclusion criteria included clear, readable radiographs showing all of the first seven permanent mandibular teeth at various maturation stages. Only those subjects whose date of births were available in the institute's archives were included in the study.

Exclusion criteria included blurred or distorted radiographs, those missing (agenesis or extractions) any of the first seven permanent mandibular teeth, those showing dental abnormalities (dilaceration, supernumerary teeth, impactions), and radiographs of the patients with developmental disorders (cleft lip, palate) or history of orthodontic therapy. Those subjects with incomplete medical or dental history were excluded.

Methods

All the selected radiographs were subjected to dental age estimation using both the Cameriere's open apices' (2006) and Demirjian's (1973) methods for mixed dentition. For Cameriere's method of dental age estimation, a public domain image processing program, ImageJ (Rasband, W.S., ImageJ, U. S. National Institutes of Health, Bethesda, Maryland, USA), was used to procure measurements

and the linear regression formula derived by Cameriere et al. was utilized for estimating age.[1] For dental age estimation using Demirjian's method, the written and pictorial criteria laid down by Demirjian et al. were utilized. All measurements were recorded by a single observer.[7]

Radiographic Evaluation

Cameriere's Method of Age Estimation

For the application of Cameriere's technique (2006), a public domain image processing program, ImageJ, was used to procure measurements.[1] To measure, the images were magnified to at least 150% on a 23-inch high-resolution monitor. The first seven permanent mandibular teeth of the left side were considered. The number of teeth with completed root development, with closed apices, was noted as "$N0$" value. The next parameter recorded was "Ai"—the distance (for single-rooted teeth) or the sum of the distance (for double-rooted teeth) between the inner sides of the open apex ($i = 1, 2, 3, 4, 5$) or apices ($i = 6, 7$). These values were then divided by their corresponding tooth lengths ("Li", where $i = 1,…,7$) to normalize the effect of possible discrepancies in magnifications and angulations observed in the X-rays. Hence, the normalized measurements (xi) of the first seven mandibular molars were derived from the formula: $xi = Ai/Li$, where $i = 1,…,7$. Figure 2 shows Cameriere's method of measuring. Dental age was finally calculated using the following formula (where g is a variable equal to 1 for boys and 0 for girls, s is the sum of the normalized open apices, and $N0$ is the number of teeth with root development complete).

$$Age = 8.971 + 0.375g + 1.631 \times 5 + 0.674N0 - 1.034s - 0.176s \cdot N0$$

Table 1: Distribution of children ($n = 36$) according to their age and sex

Age (in years)	Boys (f*; %† of total sample)	Girls (f; % of total sample)	Total (f; % of total sample)
7 (6.6–7.5)	2; 5.56	4; 11.11	6; 16.67
8 (7.6–8.5)	3; 8.33	3; 8.33	6; 16.67
9 (8.6–9.5)	2; 5.56	4; 11.11	6; 16.67
10 (9.6–10.5)	2; 5.56	4; 11.11	6; 16.67
11 (10.6–11.5)	3; 8.33	3; 8.33	6; 16.67
12 (11.6–12.5)	3; 8.33	3; 8.33	6; 16.67
Total	15; 41.67	21; 58.33	36; 100

*f, frequency; †rounded off to nearest hundredths

Figs 1A and B: Position of the subject while taking an OPG: (A) Profile view; (B) Frontal view
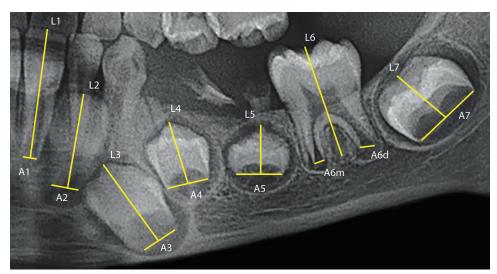
Fig. 2: Method for procuring tooth measurements for Cameriere's method using ImageJ software (L*i* represents the lengths of the teeth measured and A*i* represents the measurements of the open apices, where $i = 1,...,7$)

Table 2: Chronological ages' and estimated dental ages' descriptive statistics for girls, boys, and total sample

		n	Mean (in years)	Median (in years)	Minimum (in years)	Maximum (in years)	Standard deviation
Chronological age	Girls	21	9.658	9.49	6.83	12.37	1.705
	Boys	15	9.842	10.27	6.55	12.44	1.941
	Total	36	9.734	9.86	6.55	12.44	1.782
Cameriere's European formula	Girls	21	9.52	9.74	6.44	12.83	1.891
	Boys	15	9.698	10.1	7.01	12.46	1.608
	Total	36	9.594	9.91	6.44	12.83	1.756
Demirjian's method	Girls	21	11.861	11.59	9.76	15.34	1.917
	Boys	15	11.61	11.05	10.42	16.98	1.803
	Total	36	11.756	11.1	9.76	16.98	1.848

Demirjian's Method of Age Estimation

For age estimation using Demirjian's method, seven permanent teeth on the left side of the mandible were investigated. In 1973, Demirjian, Goldstein, and Tanner introduced a method for dental age estimation by describing eight stages of dental maturation that were denoted using letters (A to H).[7] The specific maturation stage of each of the first seven permanent teeth was identified by using Demirjian's maturation stage charts, and each stage was then converted into a score by using the table "self-weighted scores for dental stages" given by Demirjian et al. (separate values for boys and girls). The scores of all seven teeth were added and a dental maturity score was calculated, which is denoted by "*S*". Dental age was then calculated using Acharya's formula (with specific formulae for males and females):

$$\text{Males : Age} = 27.4351 - \left(0.0097 \times S^2\right) + \left(0.000089 \times S^3\right);$$

$$\text{Females : Age} = 23.7288 - \left(0.0088 \times S^2\right) + \left(0.000085 \times S^3\right).$$

Chronological Age Determination

The date of birth of the selected subjects was retrieved from the institute archives. To determine the chronological age, for each subject, the date of birth was subtracted from the date on which the radiograph was taken (chronological age = date on which OPG was taken – date of birth). Thus, the chronological age was calculated in decimal form (years).

Reproducibility

All measurements were performed by a single observer. For intraobserver reproducibility calculation, a random sample of five OPGs was remeasured after 10 days. Cohen's kappa statistic was used to calculate the intraobserver agreement for Demirjian's method and concordance correlation coefficient was used to calculate the intraobserver agreement for Cameriere's method.

Statistical Analysis

A spreadsheet from an open-source productivity suite, LibreOffice (Version: 6.3.0.4, Developed by: The Document Foundation), was used to perform the initial and descriptive statistics (Table 2). Age residuals: chronological age–estimated dental age (CA–EDA) were calculated for girls, boys, and the total sample for both Cameriere and Demirjian methods. Descriptive statistics for age residuals are given in Table 3.

The percentage of absolute CA–EDA values within ±0.25, ±0.50, ±0.75, ±1.00, ±1.25, ±1.75, ±2.00 and above two was calculated for both methods of dental age estimation (Tables 4 and 5) to find the accuracy percentage. Then the accuracies of both the methods

Table 3: Mean, minimum, and maximum values of the difference (residuals) between the chronological age and estimated dental age (CA–EDA) using Cameriere's and Demirjian's methods, and their respective p values

	CA–EDA:C			95% confidence interval			CA–EDA:D			95% confidence interval		
	Mean (SD)	Min.	Max.	Lower	Upper	p	Mean (SD)	Min.	Max.	Lower	Upper	p
Girls	0.138 (0.734)	−1.657	1.398	−0.196425	0.471482	0.322 (NS)	−2.204 (2.424)	−8.511	0.257	−3.307009	−1.10003	0.000 (NS)
Boys	0.144 (0.589)	−1.463	0.912	−0.182159	0.469652	0.156 (NS)	−1.768 (2.881)	−10.43	1.6702	−3.363363	−0.172463	0.008 (NS)
Total	0.140 (0.668)	−1.657	1.398	−0.085871	0.36611	0.087 (NS)	−2.002 (2.593)	−10.43	1.6702	−2.899496	−1.144537	0.000 (NS)

CA, chronological age; EDA:C, estimated dental age: Cameriere's; EDA:D, estimated dental age: Demirjian's; SD, standard deviation; p value as determined from Wilcoxon signed-rank test

(Cameriere and Demirjian) were evaluated by calculating the mean prediction error for both the methods. Mean prediction error is equal to the average of all the absolute residual errors (CA–EDA) of a given method of dental age estimation. It is calculated from the following formula:

$$\text{ME} = \frac{1}{n}\sum_{1}^{n}\left|\text{Age}_i - \text{Age}_{\text{est},i}\right| = \frac{1}{n}\sum_{1}^{n}E_i$$

where Age_i is the chronological age and $\text{Age}_{\text{est},i}$ is the estimated age.

Wilcoxon signed-rank test was performed for both the methods of dental age estimation with chronological age. Statistical analysis was performed using IBM SPSS Statistics 23 (IBM SPSS Statistics for Windows, Version 23.0; IBM Corp., Armonk, NY). Significance threshold was set at 5%.

To compare the absolute accuracy of the two dental age estimation methods in boys and girls, independent sample—Mann–Whitney U test was performed for each of the methods.

RESULTS

Intraobserver difference was not statistically significant between the two sets of measurements carried out on remeasured OPGs.

The distribution of chronological age is the same among boys and girls (independent samples—Mann–Whitney U test, $p = 0.680$).

Descriptive Statistics of the Sampled Ages

The mean age (CA or chronological age) of the total sample ($n = 36$) was 9.734 (min. = 6.55 and max. = 12.44). Gender-specific mean age was 9.658 (min. = 6.83 and max. = 12.37) and 9.842 (min. = 6.55 and max. = 12.44) for girls and boys, respectively. The descriptive statistics [mean, median, minimum, maximum, and standard deviation (SD) in years] of the CA and EDA of the girls, boys, and the total sample are given in Table 2.

Descriptive Statistics of Age Residuals (Table 3)

Cameriere's Method

The mean for CA–EDA: Cameriere values was 0.138 years (with SD 0.734) for girls, 0.144 years (with SD 0.589) for boys, and 0.140 years (with SD 0.668) for the total sample.

Demirjian's Method

The mean for CA–EDA: Demirjian was −2.204 years (with SD of 2.424) for girls, −1.768 years (with SD of 2.881) for boys, and −2.002 years (with SD of 2.593) for the total sample.

Percentage of Accuracy

The percentage of accuracy for Cameriere's method within 1 year was found to be 80.95% and 93.33% for girls and boys, respectively. The percentage of accuracy for Demirjian's method within 1 year was 42.86% and 46.67% for girls and boys, respectively (Table 4).

Median of Residuals

The median of the residuals for Cameriere's method was 0.188 years (interquartile range, IQR = 0.751) for the total sample, 0.096 years (IQR = 0.893) for girls, and 0.205 years (IQR = 0.573) for boys (Table 5). The median of residuals for Demirjian's method was −1.163 (IQR = 1.982) for the total sample, −1.256 (IQR = 2.451) for girls, and −0.961 (IQR = 1.714) for boys (Table 5).

Mean Prediction Errors

Cameriere method resulted in a mean prediction error of 0.579 for girls and 0.483 for boys (Table 6). However, Demirjian method

Table 4: The percentage of accuracies for estimated dental ages

	Cameriere's method		Demirjian's method	
	Girls % (n = 21)	Boys % (n = 15)	Girls % (n = 21)	Boys % (n = 15)
±0.25	47.62	33.33	4.76	13.33
±0.50	52.38	66.67	23.81	26.67
±0.75	66.67	86.67	33.33	33.33
±1.00	80.95	93.33	42.86	46.67
±1.25	90.48	93.33	47.62	53.33
±1.50	95.24	100	52.38	53.33
±1.75	100	100	61.9	60
±2.00	100	100	66.67	73.33
>±2.00	100	100	33.33	26.67

Table 5: Median of residuals (in years)

Method	Gender	Median	Q1	Q3	IQR
Cameriere	Girls	0.096	−0.169	0.724	0.893
	Boys	0.205	−0.058	0.515	0.573
	Total sample	0.188	−0.17	0.581	0.751
Demirjian	Girls	−1.256	−3.061	−0.61	2.451
	Boys	−0.961	−2.008	−0.294	1.714
	Total sample	−1.163	−2.371	−0.389	1.982

Q1, first quartile; Q3, third quartile; IQR, interquartile range

Table 6: Mean prediction error (years) for each method for children aged 7–12 years

			Mean of absolute		95% confidence interval	
Method	Gender	n	residuals	SE	Lower	Upper
Cameriere	Girls	21	0.579	0.105	0.333185	0.77513
	Boys	15	0.483	0.089	0.292979	0.673714
	Total sample	36	0.525	0.071	0.379839	0.669467
Demirjian	Girls	21	2.228	0.524	1.135223	3.320729
	Boys	15	2.046	0.691	0.56352	3.52812
	Total sample	36	2.152	0.414	1.311814	2.992342

SE, standard error

resulted in a mean prediction error of 2.228 for girls and 2.046 for boys.

Wilcoxon signed-rank Test

It resulted in statistically insignificant difference ($p = 0.087$) for estimated Cameriere's age and CA, while it resulted in statistically significant difference ($p = 0.000$) for CA and Demirjian's age (the significance level was set at 0.05).

Mann–Whitney *U* Test

This test was applied to the absolute residuals of Cameriere's and Demirjian's methods for boys and girls, and it resulted in a *p* value of 0.885 and 0.773, respectively.

Discussion

The current study aims at comparing the accuracy of two methods in determining the true age of mixed-dentition children, one of which uses developmental stages of teeth (Demirjian's) and another measures (ratios) from radiographs (Cameriere's).

After analysis of the median of residuals of both the methods, Cameriere's method showed an underestimation of the true age of the children with a median residual of 0.188 years (IQR = 0.751) for the total sample, 0.096 years (IQR = 0.893) for girls, and 0.205 years (IQR = 0.573) for boys. The positive values of the residuals denote an underestimation of the true age by Cameriere's method. Demirjian's method showed an overestimation of the true age for the total sample, girls, and boys with median residuals as −1.163 (IQR = 1.982), −1.256 (IQR = 2.451), and −0.961 (IQR = 1.714), respectively. The negative values of the residuals denote an overestimation of the true age by Demirjian's technique.

Better percentage of accuracy was observed within 1 year (±1 year) for Cameriere's method with 80.95% for girls and 93.33% for boys (compared to the Demirjian's method which had values of 42.86% and 46.67% for girls and boys, respectively).

The Cameriere method resulted in a mean prediction error of 0.579 for girls and 0.483 for boys (Table 6). This shows the accuracy is better for boys than for girls. However, this is not statistically significant ($p \geq 0.005$). Demirjian method resulted in a mean

prediction error (ME) of 2.228 for girls, which is greater than that of boys (ME = 2.046), but this difference is not statistically significant ($p \geq 0.005$).

Wilcoxon signed-rank test resulted in statistically insignificant difference ($p = 0.087$) for estimated Cameriere's age (the median of differences between CA and EDA: C is zero) and CA, while it resulted in statistically significant difference ($p = 0.000$) for CA and Demirjian's age (the median of differences between CA and EDA: C is not zero). The significance level was set at 0.05.

The difference in accuracy of Cameriere's and Demirjian's methods for boys and girls was not statistically significant ($p = 0.885$ and $p = 0.773$, respectively).

In a study by Cameriere et al. that had OPG samples from 401 girls and 355 boys (age range of 5–15 years) from different nationalities of Italy, Spain, and Croatia aimed at evaluating the accuracy of Cameriere's method for estimating true age and comparing it with that of Demirjian's and Willems methods, the results showed that Cameriere's method underestimated the true age of children slightly (similar to the current study) with median residuals for girls and boys as 0.081 and 0.036, respectively.[11] Similar to the current study, it also showed that Demirjian's method overestimated the true age with median residuals of −0.750 and −0.611 for girls and boys, respectively. In the study, it was concluded that more than 90% of the absolute values of residual errors obtained from Cameriere's methods was less than 1 year (in the current study, approximately 86% of the absolute values was less than 1 year).

Galić et al., in a study comprising analysis of OPGs of 591 girls and 498 boys [Bosnian–Herzegovinian (BH) children, with age range of 6 to 13 years], reported an overestimation of true age by Cameriere's method for girls (statistically significant) and underestimation for boys (statistically insignificant).[12] After comparing the accuracies of the three methods of age estimation (Cameriere, Haavikko, and Willems), it was concluded that Cameriere's method proved to be the most accurate (followed by Haavikko) of the three, for determination of the true age.

In a study by Javadinejad et al., where four methods of age estimation were compared, it was concluded that Cameriere's method was the second most accurate method, preceded by Smith's method, and followed by Willems and Demirjian methods.[13]

Wolf et al., in a study including 479 OPGs of German children (age range of 6–14 years), reported that Demirjian's method was more accurate and appropriate for the investigated German population.[14]

In another study by Ozveren et al. where the applicability of Willems' and Cameriere's methods for Turkish children was assessed, it was highlighted that there was better percentage of accuracy within 1 year for Cameriere's method than for Willems' method (modified Demirjian's method) for that population.[15] It was also suggested that population subgroups require further specific research to spot correction factors for more accurate age estimation.

Lan et al., in a study of 480 OPG samples (of children in age range of 8–16 years), reported that both the methods underestimated the true age, and Demirjian's method was more accurate than the Cameriere's method for the Hunan Han nationality.[16]

Studies in the Indian Context

A study by Pratyusha et al., consisting 60 OPG samples of children in the age range of 9–12 years, reported that of the three methods of dental age estimation, Cameriere's population-specific regression formula showed the closest approximation to the true age while the difference was more with Demirjian's method, followed by Cameriere's European formula.[17]

However, in the current study, Cameriere's European formula proved to be more accurate than Demirjian's method. Nair et al., in a similar study with 10 subjects (age range of 7–12 years) from rural population of Kerala, also showed that Cameriere's method mostly underestimated the true age and Demirjian's method mostly overestimated true age and these findings were in sync with the findings of the current study.[18]

Limitations of the Current Study

Due to the small sample size, analysis of the residuals of individual age-groups has not been done. Further studies should be conducted with larger sample size. In this study, Cameriere's European formula has been used which is not specific to the Indian population. Regression analysis studies must be done specific to the Indian population.

CONCLUSION

According to the current investigation, Cameriere's European formula was found to underestimate (not significantly) the ages of the mixed-dentition children (both boys and girls) in the region of Telangana, and Demirjian's method was found to overestimate (significantly) their ages (both boys and girls). Analysis of mean prediction errors for both the methods revealed Cameriere's European formula to be more accurate than Demirjian's method. In conclusion, Cameriere's European formula proved to be better for the region of Telangana, India, according to the current investigation.

Scope for the Future

With an increase in the digitalization of dentistry, the need for relying on older methods of age estimation (that use charts of predefined stages of tooth mineralization) reduces. Digitally measuring the morphological traits of teeth and applying regression formulae is more convenient now, and it is likely to replace the older techniques if their accuracy is established.

ETHICS STATEMENT

Patients' privacy was maintained. All patients were informed about the study and their consent was taken to use their records for the study.

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