Contents lists available at ScienceDirect

Journal of Oral Biology and Craniofacial Research

Comparative evaluation of Willems and Cameriere methods of dental age estimation among 6–14 year old Bengali children[☆,☆☆]

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ARTICLE INFO

ABSTRACT

Background: The knowledge of dental age estimation is essential to assess growth and development which aids in designing a treatment plan. Willems and Cameriere methods are the two most widely used approaches of dental age estimation.
Aim: The primary objective of this study was to evaluate the reliability and applicability of the two methods, among 6–14 year old children of Bengal populace. The secondary objective was to compare the efficacy of Sante DICOM Viewer and CorelDRAW Graphic Suite in assessing dental age by Cameriere method.
Materials and methods: The study sample encompassed 411 digital panoramic radiographs. Dental age was estimated using Willems and Cameriere methods. CorelDRAW Graphic Suite and Sante DICOM Viewer software were used for dental age estimation by Cameriere method. Paired *t*-test was applied for the inter group comparison. Pearson correlation coefficient was also used to measure the regression among all the groups.
Results: Dental age was overestimated by 0.286 years using Willems method (p = 0.001). However, there was no significant difference between dental ages estimated by Cameriere method using both software (p = 0.130).
Conclusion: Both the methods were equally applicable for age estimation in the targeted population. Cameriere method can be performed with equivalent accuracy using both software.

1. Introduction

Dental age estimation in pediatric dentistry finds its relevance in determining milestones of growth and in calculating the chronological age, in understanding various anomalies like oligodontia and anodontia. In interceptive orthodontics, knowledge of the time of each stage of tooth development may enable clinicians to formulate treatment.[1,2] Six to fourteen years is the most crucial time for assessing the development needed for orthodontic therapy.[3] It has emerged as a major tool in the field of forensic dentistry.[4]

Radiomorphological method and radiometric method are generally used for calculating the dental age. Radiomorphological method is performed by analysing different stages of morphological development of teeth through radiographs e.g Nolla's method, Demirijan's method, Willems method while radiometric method relies on mathematical values measured using computer software e.g. Cameriere method.[5] Nolla in 1960 formulated a method to assess dental age by evaluating the developmental stages of teeth.[6] However, it was found that Nolla's Method underestimated the age in numerous studies.[7–9] Demirijan in 1970 also studied the developmental stages of the permanent teeth of the lower left quadrant to estimate the dental age.[10] Hostiuc et al., in 2021.[11] found that this method significantly overestimated the age in both genders in some studies.[7,12,13] Therefore, Willems et al. revised the traditional method by modifying the scoring table.[14] However, any

radiomorphological method is always subjected to observation bias[15] and hence Cameriere et al., in 2006[5] designed a radiometric approach which has shown a very strong correlation with chronological age.[4,15,16] Cameriere's method can be performed either with a graphic software which evaluates Joint Photographic Experts Group (JPEG) images or using a Digital Imaging and Communications in Medicine (DICOM) software to evaluate images in DICOM format.

The growth of the person relates to physiological and biological age, which possibly is not always dependable along with calendar-chronological ages. The disparity between chronological age and physiological age increases with growth. Hormonal, racial, environmental, and host factors contribute to this discrepancy.[4] Wide variations in dental age were seen across ethnicities.[15–18] A lacuna in the literature exists that compares the accuracy of the radiomorphological method (Willems method) and the radiometric method (Cameriere method) in evaluating dental age among children of Bengal. Hence, the primary objective of this study was to compare and evaluate the accuracy of Willems and Cameriere methods of age estimation among 6–14 year old children of Bengal ethnicity. A comparative assessment of the efficacy of Sante DICOM viewer and CorelDRAW graphic suite in performing Cameriere method was the secondary objective.

2. Materials and Methods

2.1. IEC approval

The approval for this cross sectional study was obtained from the Institutional Ethical Committee (IEC) of two institutions with codes (IGIDSIEC2022NRP16PGMKPPD) and (GNIDSR/IEC/22–23/15)

2.2. Selection criteria

Digital Diagnostic Panoramic radiographs of healthy 6–14 year old children of Bengali origin where all permanent teeth of the third quadrant were present were included. Children with systemic diseases or congenital anomalies like oligodontia, anodontia, or those with a history of therapeutic dental treatment, traumatic injuries, jaw surgeries, or cysts or tumours of the jaws were excluded. Panoramic radiographs with artefacts or distorted images were not considered.

2.3. Sample size calculation

With sensitivity of the Cameriere's method being at 95 %, significance at 5 %, and precision at 5 % the minimum sample size was estimated at 384. Originally 600 OPGs were collected from March 2022 to November 2023 of which 178 did not satisfy the inclusion criteria. Seven percent greater than the sample size were used to account for the loss of the radiographs for which age estimation could not be done. Hence the study was done with 411 panoramic radiographs.

2.4. Procedure

The digital OPGs were divided into 8 age groups: Group 1 (6–6.99 years), Group 2 (7–7.99 years), Group 3 (8–8.99 years), Group 4 (9–9.99 years), Group 5 (10–10.99 years), Group 6 (11–11.99 years), Group 7 (12–12.99 years), and Group 8 (13–13.99 years). The analysis is more accurate when teeth are grouped according to their usual maturation patterns based on specific age range.

Vatech, PaX- Primo OPG machine was used for imaging. All the anatomical landmarks were maintained while positioning the head to ensure the standardization of the radiographs. All the potentially identifying information of the patient was concealed, and radiographs were reversibly coded. The data were noted on a customised Excel sheet by RP who was not involved in the scoring of radiographs to avoid bias. Two other investigators, MK and AS performed a pilot study of 40 radiographs to assess inter-observer agreements, which were evaluated using

Kappa statistics and found to be 0.8. Since high inter-observer agreement was obtained, the remaining radiographs were evaluated by a single investigator, MK.

2.5. Chronological age

The chronological age for each subject was obtained by calculating the difference between the date on which the radiograph was taken and the date of birth.

2.6. Willems Method

Eight developmental stages given by Demirijan et al., in 1970 were used to assess each tooth of the lower left quadrant on OPG, and they were assigned a stage from A to H accordingly. 10 Each stage was scored according to the scoring tables given by Willems et al..[14] All the values thus obtained were added to obtain the maturity score, which indicated the dental age of that particular patient.

2.7. Cameriere Method

Permanent teeth of the third quadrant (except for the third molar) were numbered from 1 to 7 from central incisor to second molar. The number of teeth with closed apices (N0) was calculated. The length of all the teeth with open apex was estimated and denoted as Li (where i = 1, …, 7). The distance between the inner walls of the roots of teeth with open apices was measured. In a single-rooted tooth with an open apex, the distance between the inner walls was denoted as Ai (where i = 1, …,5). In a multirooted tooth, the distance between the inner walls of each root with an open apex was measured, and then these values were summed up to obtain Ai (where i = 6, 7). The length of each tooth was measured from the cuspal tip till the open apex for a single-rooted tooth. In the case of multirooted teeth, the length was measured by drawing a line from the middle of the occlusal aspect to a point that lies approximately in the middle of an imaginary line that joins the apices of the roots (Fig. 1). The probable effects of variation in magnification and angulation among the OPGs were taken into consideration, and hence, the measurements were optimised by dividing Ai with Li, which yielded the value Xi (where i = 1,2, …7). Sante DICOM Viewer and CorelDRAW Graphic Suite were used to analyse the data.[16]

The formula used for calculating dental age was given below.

$$\text{Dental age} = 8.971 + (0.375 * g) + (1.631 * X5)$$
$$+ (0.674 * N0) - (1.034 * s) - (0.176 * s * N0)$$

The variable 'g' is 1 for boys and 0 for girls; 's' is the sum of all the normalised values (s = Σ Xi).[5]

Chronological age and dental age obtained using both methods were tabulated. All the measured values and calculated data were entered into a customised Microsoft Excel sheet.

2.8. Statistical analysis

SPSS software version 16 was used for statistical analysis. Paired t-test was used for statistically analysing the difference between chronological age and dental age calculated by each of the age estimation methods. The Pearson correlation coefficient was used to measure regression among all the groups. The level of significance was set at 0.05 ($p < 0.05$).

3. Results

A total of 411 digital OPGs were collected for the study, of which 207 were OPGs of females (50.4 %) and 204 were those of males (49.6 %). The distribution of samples was depicted in Supplementary Table I. The mean chronological age for the overall samples was found to be 9.9 ±
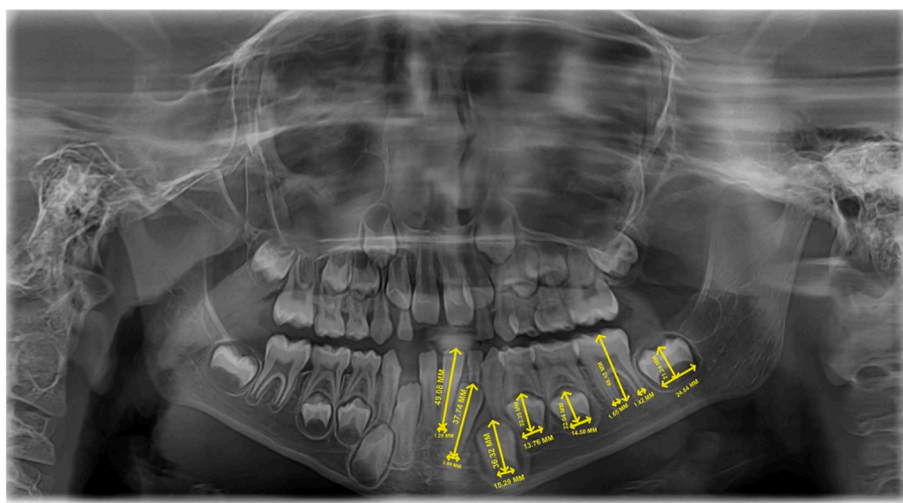
Fig. 1. Cameriere method of dental age estimation.

2.19 years, while the mean dental age estimated by Willems method was found to be 10.18 ± 2.34 years. The mean dental age calculated by Cameriere method using CorelDRAW Graphic Suite software (Cameriere CD) was 9.75 ± 2.12 years. Dental age estimated by Cameriere method using Sante DICOM software (Cameriere SD) yielded a mean value of 9.8 ± 2.10 years.

Group 1: The estimated mean difference between dental age by Willems method and chronological age was −0.08 years, which was statistically insignificant (p = 0.906). Dental age by Cameriere SD method was found to be overestimating the chronological age by 0.309 years and was significant (p = 0.007). Similarly, a significant mean difference (p = 0.036) of 0.269 years was observed between dental ages by Cameriere method using both software.

Group 2: The mean difference between chronological age and dental age by Willems method was found to be −0.269 years, which was statistically significant (p = 0.000). Dental age calculated by Cameriere SD method was found to overestimate the dental age by 0.127 years but was statistically insignificant. Similarly, no significant difference (p = 1.000) was found between dental age estimated by Cameriere CD method and Cameriere SD method.

Group 3: A mean difference of −0.256 years was found between chronological age and dental age calculated by Willems method, which was statistically significant (p = 0.000). Dental age by Cameriere SD method was found to overestimate the age by 0.062 years, although it was of no statistical significance. Similarly, no significant mean age difference (p = 1.000) was observed between dental ages estimated by Cameriere CD method and Cameriere SD method.

Group 4: The mean difference was −0.131 years between dental age estimated by Willems method and chronological age (p = 0.056). Cameriere SD overestimated the dental age by 0.023 years but was statistically insignificant (p = 1.000). Similarly, there was no statistical significance in the difference observed between dental age estimated by Cameriere CD method using Cameriere SD method (p = 1.000).

Group 5: Estimated mean difference between dental age by Willems method and chronological age was −0.228 years, which has statistical significance (p = 0.001). A significant difference of 0.182 years (p = 0.02) was found between chronological age and dental age, estimated by Cameriere CD method. There was an insignificant difference observed between dental ages by Cameriere method using both software, where p was 1.

Group 6: Significant difference of 0.226 years was found between the former and dental age evaluated by Cameriere CD method (p = 0.029). Dental age performed by Cameriere SD method yielded an over-estimation of 0.239 years, which had no statistical significance (p =

0.231). There was no significance in the difference observed between dental age by Cameriere method using both software, where the p value was 1.

Group 7: The estimated mean difference between dental age by Willems method and chronological age was statistically significant (p = 0.00). A significant difference of 0.268 years (p = 0.001) was found between the former and dental age evaluated by Cameriere CD method. Difference observed between dental ages estimated by Cameriere method using both the software was statistically insignificant.

Group 8: A mean difference of −0.464 years was found between chronological age and dental age calculated using Willems method which was statistically significant (p = 0.000). Significant difference of 0.348 years was found between the dental evaluated by Cameriere SD method and chronological age (p = 0.001). Dental age calculated using Cameriere SD method overestimated the age by 0.361 years which was statistically significant (p = 0.006). There was insignificant difference observed between dental age estimated by Cameriere method using both the software (p = 1.000). The above data is depicted in Table 1.

3.1. Overall comparison among chronologoical age and dental ages by Willems and cameriere methods

An overestimation of dental age by 0.286 years was found with Willems method, which was statistically significant (p = 0.001). Cameriere CD method was found to underestimate the dental age by 0.139 years, which was also statistically significant (p = 0.001). Similarly, Cameriere SD method underestimated dental age by 0.1 years, which was significant (p = 0.017). However, no statistical difference was found between dental ages estimated by Cameriere method using both software (p = 0.130). The results were depicted in Table 2. The Pearson Correlation Coefficient test (r = $\sqrt{R2}$) revealed a high correlation between the chronological age and dental age (Willems method), and a value of r = 0.979 was graphically illustrated below in Fig. 2a. This test (r) also revealed a high correlation between the chronological age and Cameriere CD method, where the value of r was 0.979, which was represented in Fig. 2b. It also exhibited a strong correlation between the chronological age and Cameriere SD method where the value of r was 0.949 Fig. 2c. Cameriere method using both software revealed a high correlation (r = 0.97) Fig. 2d.

4. Discussion

The primary objective of this research is to compare and evaluate the accuracy of dental age estimation between Willems and Cameriere

Table 1

Mean ages of all groups and groupwise comparison among Chronological Age and Dental Ages by Willems and Cameriere methods.

AGE (IN YEARS)	MEAN (IN YEARS)				COMPARISON							
					1 VS 2		1 VS 3		1 VS 4		3 VS 4	
	1	2	3	4	MD	p VALUE	MD	p VALUE	MD	p VALUE	MD	p VALUE
6–6.99	6.9 ± 0.33	6.59 ± 0.47	6.62 ± 0.40	6.81 ± 0.60	−0.08	0.906	−0.117	0.207	−0.309	0.007*	−0.192	0.036*
7–7.99	7.44 ± 0.32	7.71 ± 0.42	7.41 ± 0.47	7.57 ± 0.96	−0.269	0.000*	0.033	1.000	−0.127	1.000	−0.159	1.000
8–8.99	8.35 ± 0.27	8.61 ± 0.45	8.24 ± 0.58	8.29 ± 0.66	−0.256	0.000*	0.108	0.471	0.062	1.000	−0.046	1.000
9–9.99	9.45 ± 0.28	9.59 ± 0.44	9.40 ± 0.52	9.43 ± 0.63	−0.131	0.056	0.055	1.000	0.023	1.000	−0.032	1.000
10–10.99	10.44 ± 0.28	10.67 ± 0.47	10.26 ± 0.57	10.28 ± 0.70	−0.228	0.001*	0.182	0.020*	0.16	0.329	−0.022	1.000
11–11.99	11.5 ± 0.26	11.84 ± 0.53	11.27 ± 0.54	11.26 ± 0.77	−0.345	0.000*	0.226	0.029*	0.239	0.231	0.013	1.000
12–12.99	12.4 ± 0.30	12.94 ± 0.48	12.13 ± 0.52	12.21 ± 0.73	−0.542	0.000*	0.268	0.001*	0.192	0.371	−0.076	1.000
13–13.99	13.42 ± 0.29	13.89 ± 0.80	13.07 ± 0.58	13.06 ± 0.72	0.348	0.001*	0.348	0.001*	0.361	0.006*	0.13	1.000

1- Chronological Age; 2- Dental Age (Willems Method); 3- Cameriere CD; 4- Cameriere SD; MD- Mean Difference in years; (*)- Statically significant.

Table 2

Overall Comparison among Chronological Age and Dental Ages by Willems and Cameriere methods.

Comparison		Mean Difference	p value
Chronological age	Dental Age (Willems method)	−0.286	0.001*
Chronological age	Dental Age (Cameriere CD method)	0.139	0.001*
Chronological age	Dental Age (Cameriere SD method)	0.1	0.011*
Dental Age (Cameriere CD method)	Dental Age (Cameriere SD method)	0.597	0.130

(*)- statically significant.

methods with respect to chronological age, using two software programs: CorelDRAW Graphic Suite and Sante DICOM. In 6 and 9 year old children, Willems method determined the dental age with good accuracy. Studies conducted in South India[18,19] were in concordance with our result for the 6 year old group. Results of studies done in France[20] and China[21] were similar to the present findings for the 9 year old children but studies done on South India,[19] and Cadenas[22] populace contradicted our finding. The result revealed an overestimation of age with this method in age groups of 7, 8, 10, 11, 12 and 13 year old children. Findings of studies by authors[22,25] were in agreement with our result for 7 year old age group. However, Nemsi et al.[23] underestimated dental age for this group on Tunisian populace which contradicted our finding. Studies done in Turkey[4,8] and Kenya[22] were similar to our findings in 8 year old children while study by Kumar et al.[18] revealed disagreement. The present findings for 10 year old group were aligned

with the findings of studies by authors.[15,16] Results found in literature[8,15,17,21] confirmed our findings for 12 year old children while studies done in China[21] contradicted current results for the same group. Findings of some studies[7,8,21] were similar to our results for 13 year old children. However, studies by other authors[18,19] showed accuracy with Willems method in estimating dental age for the same group, which contrasted our findings. The disparity in the outcomes may be attributed to the observer bias involved in the method since in Willems method interpretation of each stage is highly dependent on the observer's knowledge and perception.[15,23] Cameriere CD method showed accuracy in determination of the dental age of children in 6, 7, 8, and 9 year old groups, while it underestimated the ages of children belonging to 10, 11, 12, and 13 year old groups. Findings by authors[15,24,25] were in agreement with the outcome of our study for the 6 year old group. Some authors[17,25] revealed overestimation in the 8 year old group, which contradicted our result. Studies conducted in Bosnia[16] and Croatia[24] also exhibited disagreement with the present finding for the 9 year old group. The present result for the 10 year age group was aligned with the findings of studies conducted in Egypt[17] and Croatia[24] but was in contrast with the results of the studies by author.[25] Galic et al. [16] confirmed the findings for the 11 year old group. Ozveren et al.[15] and Brkić et al.[24] was in concordance with the findings of the present study for the 12 year old group. However, study done in Turkey[8] showed disagreement with our result. Some studies[15,17,25] revealed an underestimation of age which was similar to our finding for the 13 year old group. Cameriere SD method revealed overestimation and underestimation for age groups of 6 and 13 years, respectively.

The disparities can be attributed to factors such as nutrition, genetic diversity among individuals,[14] incorrect documentation of birth date, usage of different statistical analyses, and variation in sample size across
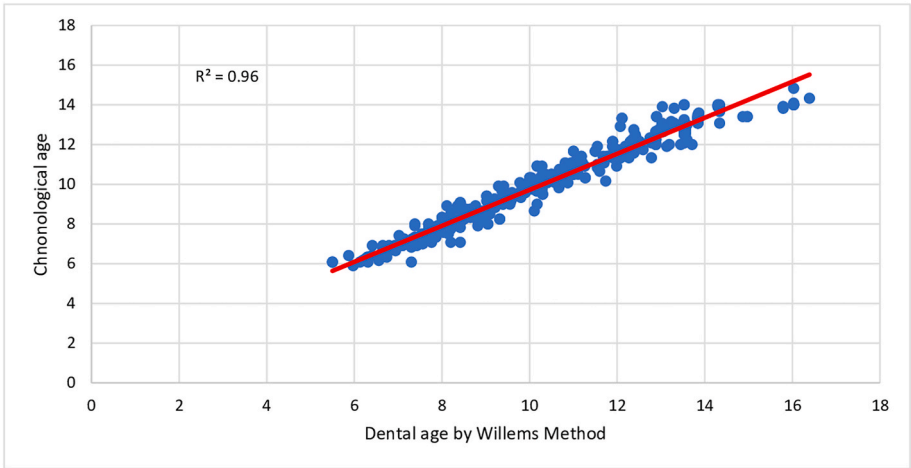

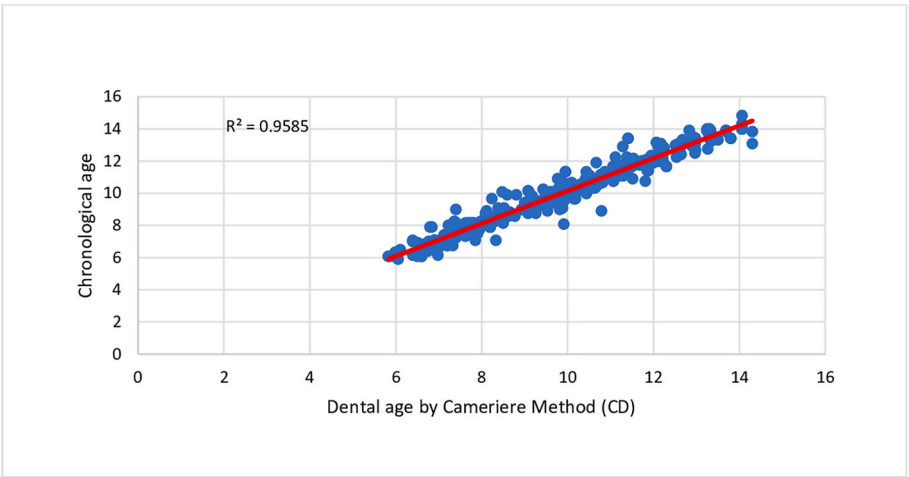**Fig. 2a.** Correlation between Chronological age and Dental age by Willems Method.

Fig. 2b. Correlation between Chronological age and Dental age by Cameriere CD Method.
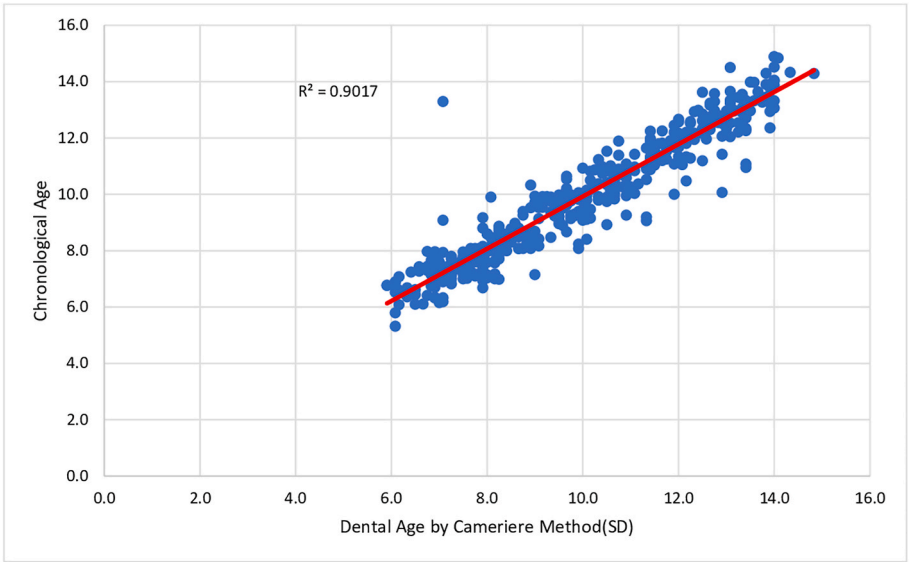

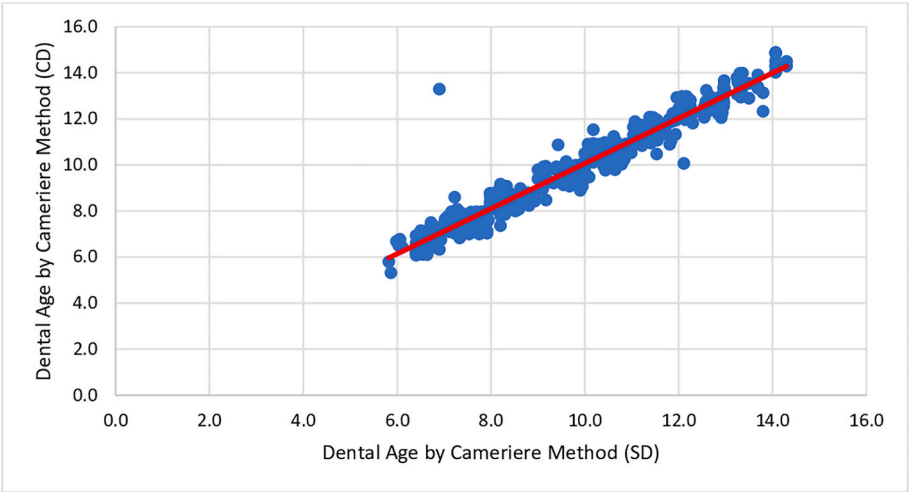**Fig. 2c.** Correlation between Chronological age And Dental Age by Cameriere SD Method.

Fig. 2d. Correlation between Dental age Estimated by Cameriere CD Method and Cameriere SD Method.

studies. In 10 and 11 year old groups, differences in findings may occur due to pre-pubertal hormonal fluctuation, which might alter the rate of dental maturation.[8,24] A contributing factor to the underestimation of age by Cameriere CD method in 11–13 year old children is the difficulty encountered during the assessment of the narrow apex opening, which is nearly closed or closed in older cohorts.[15] The discrepancy could also be due to the fact that the original studies were done with samples of the European population.[4,5,14–16,22–24] Hence, if studies are conducted among different ethnicities, it will help us to understand their applicability across countries. However, both Willems and Cameriere methods exhibited a high positive correlation with chronological age for the total sample size; thereby, it can be inferred that both methods can be recommended to calculate the age.

The strengths of the study are that it was the first one done on the population of Bengal, and it was also the first study done to evaluate the accuracy of two software programs in estimating dental age using Cameriere method. The study has used two methods, which are based on standards of current day population. It has also correlated both methods by analysing their mean differences across all age groups, thereby contributing to its distinctive attribute.

However, the limitations are the sample size was unevenly distributed among all age groups, and the probable incorrect reporting of date of birth and the effect of other environmental factors like nutrition were not considered, which could have possibly reflected in the results. Further studies can be conducted to develop new modifications in the methods of age estimation by taking into consideration various other parameters, like genetic, nutritional, and hormonal factors, pertaining to this population, which can yield better accuracy.

5. Conclusion

It can be inferred that both Willems and Cameriere method are equally reliable in estimating the dental age in the population of West Bengal. Cameriere method can be performed with equivalent accuracy using both software.

Patient/Guradian consent

Not Applicable.

Ethics statement

Study approved by the Institutional Ethical Committee of IGIDS and GNIDSR with IEC approval code of IGIDSIEC2022NRP14PGRRPPD and GNIDSR/IEC/22–23/15 respectively.

Authors contributions

Mehuli Kar: Conceptualisation, Methodology, Investigation, Resources, Data Curation, Formal Analysis, Writing original draft, Review and editing the manuscript, Funding acquisition.

Aruna Sharma: Conceptualisation, Methodology, Investigation, Review and Editing the manuscript, Project administration, Supervision.

Kaushik Dutta: Conceptualisation, Methodology, Investigation, Review and editing the manuscript, Formal Analysis, Project Administration, Supervision.

Rekha Puttanavar: Quality control.

Sanguida A: Conceptualisation.

Ezhumalai Govindasamy: Methodology, Data Curation, Formal Analysis, Software, Review and Editing the manuscript.

Ethical clearance

Study does not involve any intervention on patients.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jobcr.2025.02.006.

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