

Accuracy of Demirjian's, Willems, Nolla's and Modified Cameriere's Dental Age Estimation Methods in Young Western Indian Children- A Cross-sectional Study

ANSHULA DESHPANDE¹, NEHA PRADHAN², KINJAL PATEL³

ABSTRACT

Introduction: In forensic odontology, Dental Age (DA) assessment has gained popularity, since it is less variable than other indices and is less impacted by environmental variables. One of the methods used in estimating dental development is radiological method which is most practical and reliable.

Aim: To compare accuracy of Demirjian's, Willems, Nolla's and modified Cameriere's DA estimation methods in young western Indian children.

Materials and Methods: This cross-sectional observational study was conducted in the Department of Paediatric and Preventive Dentistry, KM Shah Dental College and Hospital, Sumandeep University, Vadodara, Gujarat, India, from May 2014 to May 2017. A total of 224 orthopantograms (OPGs) of children aged between 3-11 years having the anthropological roots in the western part of India, were analysed for the accuracy of the following age

estimation methods: 1) Demirjian's; 2) Willems; 3) Nolla's; and 4) Modified Cameriere's method in various age group ranges and in both the genders of the study population. To avoid observer bias, each digital OPG of an individual was coded with a numerical identity number. Results were analysed using unpaired t-test and Spearman's correlation test (p-value <0.05).

Results: An overestimation was observed in the Demirjian's and Willems DA estimation methods in all the age groups and both the genders, while modified Cameriere's method gave overestimation in the older age groups and approximation to the Chronological Age (CA) in younger age groups. Nolla's method proved to be the best method in study population.

Conclusion: Nolla's method of age estimation was more accurate than other methods for determining the age in 3-11 years old western Indian children.

Keywords: Adolescent, Age determination by teeth, Diagnostic imaging, Forensic dentistry, Odontogenesis, Panoramic radiography, Sex factors

INTRODUCTION

The CA of a person is considered as one of the main components of any individual's identity. It is important on the legal, medical and medicolegal front. For people, who have proper documentation of their date of birth, it is extremely easy to calculate their CA, but when there is no documentation or faulty and forged documentation, it becomes very difficult to establish a person's CA which can tamper with the concerned individual's identity. Also, other reasons like death due to natural calamity or criminal victim, there are chances of losing individual's identity. Thus, establishing the CA through means other than the date of birth becomes an essential tool. Due to this, CA estimation using morphological and radiological analysis on teeth has gained popularity in the fields of paediatric dentistry, orthodontics, forensic dentistry, human anthropology, bioarchaeology, psychometrics etc., [1,2].

Children with the same CA may show differences in the developmental stages of different biological systems. Thus, to bridge this gap between the actual CA and the developmental ages, several indices have been developed, like indices for sexual maturity, somatic maturity, skeletal age and DA [3,4].

The DA estimation has gained acceptance in forensic odontology because it is less variable when compared to other indices and less affected by environmental factors [5]. Many methods have been used in estimating dental development including anatomy, histology, tooth emergence dates and radiology. Among these, the radiographical methods are most practical and reliable [6].

Method of age assessment using Demirjian's method has been widely accepted, may be due to the maturity scoring system, that it

creates, is universal in application and the conversion to DA can be made with the use of relatively small local samples and can reach an equivalent DA by comparison for different populations [7].

Willems G et al., in 2001 tested the applicability of Demirjian's scores on Belgian Caucasian population and resulted in new tables for boys and girls with age scores directly expressed in years [8].

In 1960, Nolla CM realised the potential of measuring the calcification of developing teeth on radiographs to assess the DA. The radiographs included, extraoral right and left lateral jaws, intraoral maxillary and mandibular occlusals, intraoral right and left maxillary periapicals of posterior. The development of teeth was studied and divided into 10 stages. The stages described for the development of teeth are easy to understand and correlate, and appropriate additional decimals can be added if the tooth is found to be in between the stages [9].

A new method was published by Cameriere R et al., involving measurement of open apices of left mandibular permanent teeth in 2006 which was carried out on 455 white Italian children [10]. This was tested in 2010 on the Indian population by Rai R et al., and a population specific regression equation was derived, calling it as "modified Cameriere's technique" [11].

Very sparse data is available for accuracy of this DA estimation methods, so this led to aim of the study to check accuracy of Demirjian's, Willems, Nolla's and modified Cameriere's DA estimation methods in young western Indian children.

MATERIALS AND METHODS

This cross-sectional observational study was conducted in the Department of Paediatric and Preventive Dentistry, KM Shah Dental

College and Hospital, Sumandeep University, Vadodara, Gujarat, India, between May 2014-May 2017. The study was initiated after the approval from the University Ethical Committee (SVIEC/ON/DENT/BNP915D160010).

Sample size calculation [1]: Intra-class correlation between DA (Cameriere) and CA=0.971

Intra-class correlation between DA (Nolla) and CA=0.94

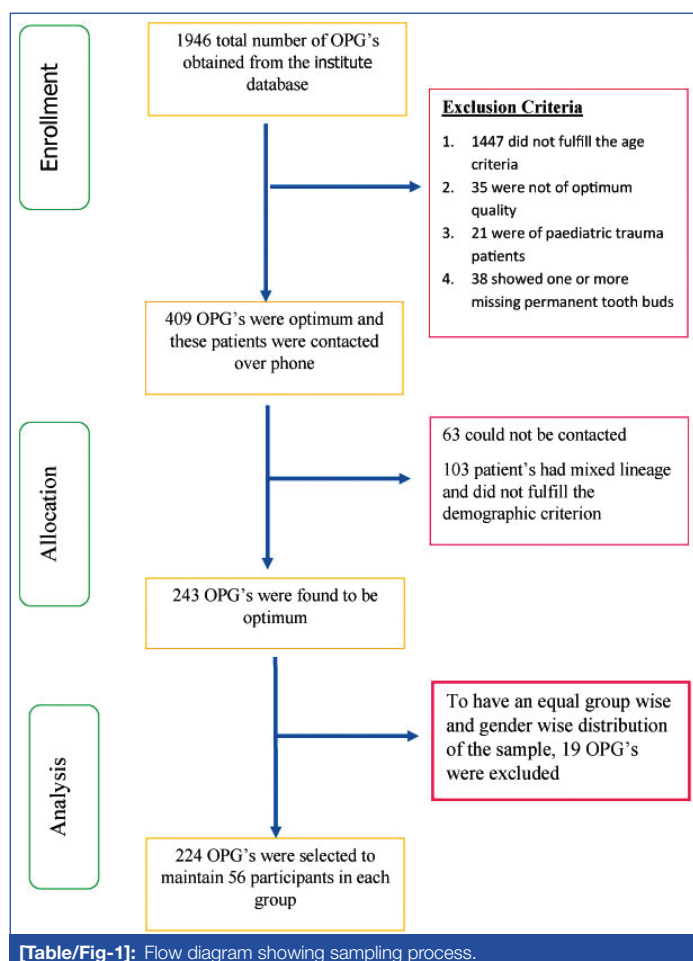
Power (%)=90

Alpha Error (%)=1

Sided=2

Required sample size=224

Enrollment, allocation and analysis of sample size is enlisted in [Table/Fig-1]. Study population consisted of 224 OPGs of children aged 3-11 years, where equivalent number of boys and girls were tried to maintain in each group. Demographic details and written consent were obtained from parents.



[Table/Fig-1]: Flow diagram showing sampling process.

Inclusion criteria: Children of age group 3-11 years who were advised orthopantomograms for various purposes and children with a western Indian lineage (western Indian: population belonging to the states of Maharashtra, Gujarat, Rajasthan) were included in the study.

Exclusion criteria: Children having serious medical conditions like psychiatric problems, congenital deformities, trauma to the orofacial region, extensive caries, permanent tooth buds/teeth extracted for various reasons, permanent teeth missing, mixed lineage and parents not willing to give informed written consent were excluded from the study.

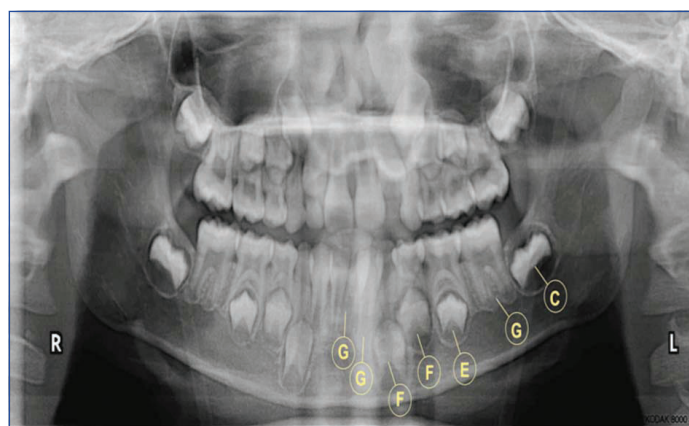
Study Procedure

Based on age 224 OPG's were divided into four groups: 3-5 years (Group 1), >5-7 years (Group 2), >7-9 years (Group 3), >9-11 years (Group 4) with 56 number of OPG's in each group. Initially, all the demographic details were collected and entered in the proforma. Before starting the study, intra-examiner reliability/reproducibility

was measured by Cohen's kappa statistics. As the value was above 0.75, the intra-examiner reproducibility was found to be optimum and further examinations were carried out. To avoid observer bias, each digital OPG of an individual was coded with a numerical identity number (1-224) to ensure that the observer is blind to name and age of subjects corresponding decoding details were filled on the proforma sheets. Blinding was done by the co-investigator.

The CA of the individual was calculated by subtracting the birth date from the date on which the radiographs were exposed for that particular subject. The CA that was recorded in years and months was converted into years and appropriate decimal digits. Assessment of DA was done by comparing the orthopantomograms by all the following methods:

Method 1: Demirjian's method [7]: In this method, tooth formation was divided into eight stages and criteria of these stages for each tooth were given separately. Each stage of the left mandibular seven teeth is allocated a score from a preformed table of scores as observed on OPG [Table/Fig-2]. The sum of the scores gives an evaluation of the subject's dental maturity and the DA was then calculated using the sex specific tables.



[Table/Fig-2]: Radiograph (OPG) of a 7-year-old female evaluated by Demirjian's method; G- Wall of root canal are parallel but apical end is partially open. in molar distal root is rated; F- Wall of pulp chamber form an isosceles triangle and root length is equal to or greater than crown height; E- Root length shorter than crown length. Wall of pulp chamber are straight and pulp horns becomes more differentiate; C- Enamel formation has been completed at occlusal surface and dentine formation has commenced. No pulp horns are visible.

Method 2: Willems method [8]: The DA was also calculated using Willems et al., adjusted scores using tooth stages of Demirjian which constituted our second method.

Method 3: Nolla's method [9]: In this method each tooth of left mandibular quadrant, excluding third molar, was assigned a stage of between 1 and 10 by matching the radiographs with the comparison figures given. If the tooth was between stages an appropriate fraction (0.2, 0.5 or 0.7) was added as recommended by Nolla CM. The sum of the scores was then compared to the chart of average sum given for boys and girls and DA was calculated.

Method 4: Modified Cameriere's method [11]: The fourth method of assessment was DA estimation by using Cameriere's seven tooth method with Indian specific formula:

$$\text{Age} = 9.402 - 0.879c + 0.663No - 0.711s - 0.106sNo$$

Where,

c=variable (for boys it is 1 and for girls it is 0)

No=teeth with apical ends of the roots completely closed.

s=sum of Ai/Li ratio for every tooth at open apex

Ai=radiographic distance between inner sides of the open apex.

For teeth with multiple roots, Ai=average value of all roots

Li=radiographic tooth length

For teeth with multiple roots, Li=average length of all the roots

Once all the measurements and variables are recorded, they are substituted in the equation to get the final age.

STATISTICAL ANALYSIS

The statistical software namely Statistical Package for Social Sciences (SPSS) version 20.0 was used to calculate descriptive data and to perform unpaired t-test for the analysis of data. The analysis was performed assuming unequal variances. Based on the data gathered, comparisons were made between the CA and DA amongst various groups and also amongst the gender intra-groups. As the data was found to be normally distributed, unpaired t-test and Spearman's correlation test were performed.

RESULTS

The relationship between CA and Dental Age Estimate (DAE) was evaluated by each method, gender and age groups, as well as in the total population by analysis of means and standard deviation. Spearman's correlation test was used to check correlation between all four methods used in the study [Table/Fig-3]. Out of the 224 OPG's assessed for age estimation, 109 were of male children and 115 were of female children.

Methods		Male	Female	Both
Age by Demirjian's method	Correlation coefficient	0.962**	0.960**	0.960**
	Sig. (2-tailed)	0.001	0.001	0.001
Age by Willems method	Correlation coefficient	0.963**	0.945**	0.953**
	Sig. (2-tailed)	0.001	0.001	0.001
Age by Nolla's method	Correlation coefficient	0.976**	0.967**	0.969**
	Sig. (2-tailed)	0.001	0.001	0.001
Age by modified Cameriere's method	Correlation coefficient	0.933**	0.931**	0.928**
	Sig. (2-tailed)	0.001	0.001	0.001

[Table/Fig-3]: Spearman's correlation between Demirjian's method, Willems method, Nolla's method and modified Cameriere's method. Spearman's correlation ($p < 0.05$)

On applying Demirjian's method on all age groups, there was a constant overestimation of DA observed. Most favourable results were shown by males in the age group of >7-9 years whereas >5-7 years males and >9-11 years females age group showed least favourable results [Table/Fig-4].

Comparison of various methods with chronological age	Gender	Age group	N	Mean CA (SD)	Mean DA (SD)	Mean DA-Mean CA	Confidence interval		p-value
							Upper	Lower	
CA with Demirjian's method	Male	1 (3-5 years)	27	4.40 (0.60)	5.45 (1.34)	1.05	1.63	0.47	0.001*
		2 (>5-7 years)	25	6.24 (0.52)	7.58 (0.67)	1.34	1.68	0.99	<0.001**
		3 (>7-9 years)	29	8.24 (0.55)	9.04 (0.61)	0.80	1.10	0.49	<0.001**
		4 (>9-11 years)	28	9.83 (0.37)	11.11 (1.10)	1.28	1.69	0.86	<0.001**
	Female	1 (3-5 years)	29	4.32 (0.63)	5.64 (1.25)	1.31	1.83	0.79	<0.001**
		2 (>5-7 years)	31	6.45 (0.41)	7.88 (0.63)	1.42	1.69	1.15	<0.001**
		3 (>7-9 years)	27	8.50 (0.48)	9.67 (0.91)	1.17	1.57	0.77	<0.001**
		4 (>9-11 years)	28	9.93 (0.57)	11.48 (0.68)	1.55	1.87	1.22	<0.001**

[Table/Fig-4]: Intra-group comparison of CA with Demirjian's method age estimation in all the four groups. Unpaired t-test, * $p < 0.05$ - Significant, ** $p < 0.001$ - Highly significant

Comparison of various methods with chronological age	Gender	Age group	N	Mean CA (SD)	Mean DA (SD)	Mean DA-Mean CA	Confidence interval		p-value
							Upper	Lower	
CA with Willems method	Male	1 (3-5 years)	27	4.40 (0.60)	4.77 (1.17)	0.37	0.89	0.14	<0.001**
		2 (>5-7 years)	25	6.24 (0.52)	7.35 (1.16)	1.11	1.62	0.60	<0.001**
		3 (>7-9 years)	29	8.24 (0.55)	9.22 (0.70)	0.97	1.30	0.65	<0.001**
		4 (>9-11 years)	28	9.83 (0.37)	11.17 (0.81)	1.33	1.65	1.01	<0.001**
	Female	1 (3-5 years)	29	4.32 (0.63)	4.96 (1.02)	0.63	1.08	0.18	0.006*
		2 (>5-7 years)	31	6.45 (0.41)	7.62 (1.04)	1.16	1.56	0.76	<0.001**
		3 (>7-9 years)	27	8.50 (0.48)	9.66 (0.72)	1.16	1.49	0.82	<0.001**
		4 (>9-11 years)	28	9.93 (0.57)	10.76 (0.42)	0.82	1.08	0.56	<0.001**

[Table/Fig-5]: Intra-group comparison of CA with Willems method of age estimation in all the four groups. Unpaired t-test, * $p < 0.05$ - Significant, ** $p < 0.001$ - Highly significant

On application of Willems method on all the age groups, a consistent overestimation was observed for this method too. Amongst these, the least overestimation was seen in children of 3-5 years age group, rest all the groups showed similar results [Table/Fig-5].

Nolla's method proved to be the best method to be employed for the age estimation in the given population in all the age groups and genders showing near accurate results which were statistically non significant except in females of 4th (>9-11 years) age group [Table/Fig-6].

On modified Cameriere's method on all age groups, overestimation was observed in children aged >5-11 years. The youngest age group of 3-5 years showed age closer to CA but with greater confidence interval [Table/Fig-7].

On removing the age stratification of the entire data, the total number of males was 109 and the total number of females was 115 [Table/Fig-8]. Gender wise distribution of mean DA-CA seen in [Table/Fig-9]. The order of accuracy shown by the age estimation methods on removing age stratification and comparing four methods amongst male and female genders based on mean DA-CA were as follows: Nolla's method > Modified Cameriere's method > Willems method > Demirjian's method. The difference in mean CA and mean DA provides this inference as lower mean difference value suggests better accuracy in judging the age.

DISCUSSION

There is now complete agreement in the literature that techniques of DAE based on the examination of the mineralisation and development stage of the teeth are mostly unaffected by local and systemic influences, but is dependent on genetics since ethnic diversity exists [1,6,11]. Thus, it becomes essential to check for the variability seen in various ethnic groups. The population selected in the present study-western Indian, has not been evaluated for the chosen methods together in literature.

The majority of DA estimation studies, particularly those involving the dentition up to the second molar and the 14-year threshold, have focused on the methods or comparisons of methods, with little regard for the accuracy of estimation in cohorts of this age and in classifying individuals in relation to the threshold [12,13].

Comparison of various methods with chronological age	Gender	Age group	N	Mean CA (SD)	Mean DA (SD)	Mean DA-Mean CA	Confidence interval		p-value
							Upper	Lower	
CA with Nolla's method	Male	1 (3-5 years)	27	4.40 (0.60)	4.46 (0.04)	0.06	0.41	0.28	0.72
		2 (>5-7 years)	25	6.24 (0.52)	6.40 (0.50)	0.15	0.44	0.13	0.28
		3 (>7-9 years)	29	8.24 (0.55)	8.46 (0.57)	0.22	0.51	0.06	0.12
		4 (>9-11 years)	28	9.83 (0.37)	9.70 (0.46)	0.12	0.08	0.34	0.23
	Female	1 (3-5 years)	29	4.32 (0.63)	4.44 (0.68)	0.12	0.46	-0.22	0.48
		2 (>5-7 years)	31	6.45 (0.41)	6.59 (0.49)	0.13	0.36	-0.9	0.23
		3 (>7-9 years)	27	8.50 (0.48)	8.44 (0.57)	-0.05	0.23	-0.34	0.70
		4 (>9-11 years)	28	9.93 (0.57)	9.38 (0.61)	-0.54	-0.24	-0.85	0.001*

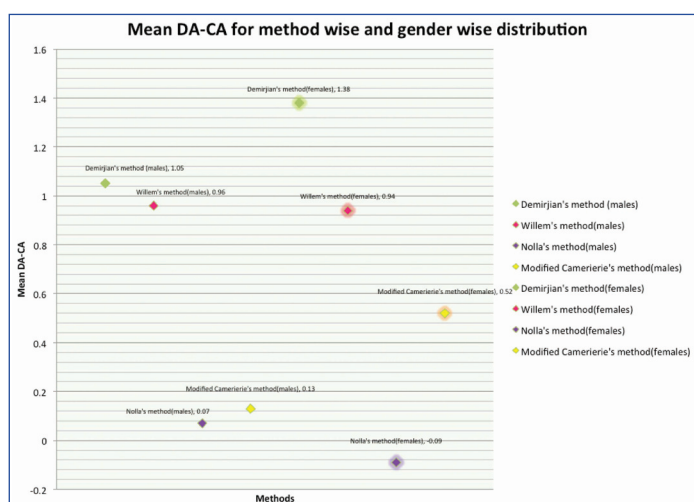
[Table/Fig-6]: Intra-group comparison of CA with Nolla's method of age estimation in all the four groups. Unpaired t-test, *p>0.05 - not significant

Comparison of various methods with chronological age	Gender	Age group	N	Mean CA (SD)	Mean DA (SD)	Mean DA-Mean CA	Confidence interval		p-value
							Upper	Lower	
CA with Modified Cameriere's method	Male	1 (3-5 years)	27	4.40 (0.60)	3.97 (2.75)	-0.42	0.68	-1.54	0.44
		2 (>5-7 years)	25	6.24 (0.52)	6.59 (1.23)	0.34	0.88	-0.19	0.20
		3 (>7-9 years)	29	8.24 (0.55)	8.44 (0.89)	0.19	0.58	-0.18	0.31
		4 (>9-11 years)	28	9.83 (0.37)	10.20 (0.59)	0.36	0.62	0.11	0.005*
	Female	1 (3-5 years)	29	4.32 (0.63)	4.60 (2.52)	0.27	1.24	-0.68	0.56
		2 (>5-7 years)	31	6.45 (0.41)	7.09 (0.99)	0.64	1.02	0.25	0.001*
		3 (>7-9 years)	27	8.50 (0.48)	9.30 (0.79)	0.80	1.16	0.44	<0.001**
		4 (>9-11 years)	28	9.93 (0.57)	10.30 (0.44)	0.37	0.63	0.11	0.006*

[Table/Fig-7]: Intra-group comparison of CA with Modified Cameriere's method of age estimation in all the four groups: Unpaired t-test, *p<0.05 - Significant, **p<0.001 - Highly significant

Gender	Method	N	Mean CA (SD)	Mean DA (SD)	Mean DA-CA	p-value*
Male	1 (Demirjian's method)	109	7.35 (2.13)	8.45 (2.30)	1.05	<0.001**
	2 (Willem's method)	109	7.35 (2.13)	8.31 (2.56)	0.96	0.002*
	3 (Nolla's method)	109	7.35 (2.13)	7.42 (2.09)	0.07	0.795
	4 (modified Cameriere's method)	109	7.35 (2.13)	7.48 (2.78)	0.13	0.690
Female	1 (Demirjian's method)	115	7.31 (2.19)	8.69 (2.35)	1.38	<0.001**
	2 (Willem's method)	115	7.31 (2.19)	8.25 (2.37)	0.94	0.002*
	3 (Nolla's method)	115	7.31 (2.19)	7.22 (1.98)	-0.09	0.742
	4 (modified Cameriere's method)	115	7.31 (2.19)	7.83 (2.60)	0.52	0.096

[Table/Fig-8]: Intermethod comparison of mean CA with mean dental age using Demirjian's method, Willem's method, Nolla's method and modified Cameriere's method of age estimation without age stratification.



[Table/Fig-9]: Mean DA-CA for method wise and gender wise distribution.

Studies have demonstrated that dental calcification evaluated on OPG provides reliable evidence to estimate the age of children and youths. Also, the OPG's give complete visualisation of the entire dentition in its entirety. They also reduce the radiation exposure of the children in comparison to taking the radiographic survey of the entire mouth. Thus, the popularity of the radiographic methods using OPG'S is due to their ease of availability and usability [5,6].

The sample size chosen, was based on the article and was found to be representative of the population under study [1]. The inclusion criteria chosen was children of age group 3-11 years of the western Indian ethnic group, as no data is available in the aforementioned population regarding the applicability of the DA estimation methods. Younger age group is preferred for radiographic assessment of DA as the best precision and accuracy for age estimation is achieved when individual growth is rapid and many teeth are under development [14,15].

Children with systemic problems like endocrinopathies were not excluded as endocrinal imbalances do not affect the maturation of the teeth. Also, children having gross malocclusion, periodontal conditions, ankylosed or impacted teeth, children who had premature extraction of deciduous teeth were included in the study as these local factors have also not reported to hinder in the process of tooth maturation [6]. Syndromic children and children with congenital deformities were excluded from the study due to the genetic or congenital effect on teeth maturation [16]. So were children who had reported with orofacial trauma, especially in the mandibular region, and unsatisfactory visualisation of all the teeth. The OPG's showing missing permanent tooth buds in the left mandibular region were excluded as the presence of all the teeth is a pre-requisite for correct calculations in all the methods.

Extensive caries of the primary dentition of the left side of mandible leading to dentoalveolar abscess involving the permanent tooth bud were also excluded as the infective agent directly affects the growth and development of the tooth bud [17].

Stratification was made based on the various age ranges and genders. Children grow differently at different times in their lives, the maturation process can be faster or slower at a particular period, and hence, age estimation done by various methods can differ in different age groups. Also, some methods may not be applicable in a particular age group [18].

Due to insufficient calcification of the 2nd premolar and 2nd molar teeth in the current investigation, Demirjian's approach and the modified Cameriere's approach could not be used on children less than three years of age. So, in this present study children more than three years of age included. It is also a known fact, that, girls mature faster and earlier than boys, hence, it was necessary to assess if the DA obtained through all the four methods showed in variability in the genders [19].

Even when using the same method of DA calculation, several factors might possibly alter age estimation and explain some discrepancies in findings between research. The suitability of the statistical methodology, the operator's effect, and the true relevance of ethnicity or environmental variables are all critical considerations [20]. Out of all these, the influence of the operator taking the readings is of prime importance. To avoid this bias,

single operator was used in this study, and intra-operator variability was tested using Cohen's kappa statistics before all the readings were recorded.

Dental maturity also provides useful information for diagnosis and treatment planning, especially for pedodontists and orthodontists [21,22]. The DA is not affected much by the environmental factors so it becomes an invaluable tool in assessing the CA of children for whom CA cannot be established through his or her birthday [2].

Amongst all these, Demirjian's method is one of the simpler and widely employed methods to predict age and maturation, as it comprises of clearly defined changes in shape that do not require speculative estimation. Also, as the stages are clearly defined it becomes easy to score the teeth. Multiple studies have been carried out using this technique in various populations and age groups but inconsistency has been observed in the results [1,7,23-29]. Hence, its applicability on the present population was necessary for us to know of its validity in the present ethnic population.

In all the four age groups that were studied in the present study, consistent overestimated was found which were statistically significant for Demirjian's methods. Various researches have tested the applicability of single age estimation method in various populations tabulated in [Table/Fig-10] [1,8,11,23-51].

Sl no.	Author's name and year	Place of study	Sample size	Method of dental age estimation used	Conclusion
Demirjian's method					
1	Present study			Demirjian's method	Consistent overestimated was found which were statistically significant.
2	Koshy S and Tandon S, in 1998 [23]	South Indian children	184 OPGs	Demirjian's method	Overestimation of the age
3	Willems G et al., in 2001 [8]	Belgain Caucasian children	2523 OPGs	Demirjian's method	Overestimation of age
4	Eid RM et al., in 2002 [24]	Brazilian children	689 OPGs	Demirjian's method	Overestimation of the age
5	Hegde RJ and Sood PB, in 2002 [25]	south Indian children from Belgaum district	197 OPGs	Demirjian's method	Overestimation of the age
6	Al-Emran S, in 2008 [26]	Saudi children	490 OPGs	Demirjian's method	Overestimation of the age
7	Malik P et al., in 2012 [27]	North Indian girls,	100 OPGs	Demirjian's scores	Demirjian's system was found to give accurate results
8	Gandhi N et al., in 2015 [28]	Indian adolescents from Gujarat.	30 OPGs	Demirjian's method	Underestimation the age
9	Mohammed RB et al., in 2015 [1]	South Indian children	660 OPGs	Demirjian's method	Overestimation of the age
10	Rath H et al., in 2017 [29]	Eastern Indian population of children and youngadults from Orissa.	106 OPGs	Demirjian's scores	Found the results to be accurate on an Eastern Indian
Willems method					
11	Present study			Willems method	Willems method also showed significant overestimation, showed better results than Demirjian's method.
12	Grover S et al., in 2011 [30]	North Indian population	215 OPGs	Willems method	Overestimation of dental age
13	Ramanan N et al., in 2012 [31]	Japanese children and young adults	1877 OPGs	Willems method	Comparable results were obtained using
14	Mohammed RB et al., in 2014 [32]	South Indian population	332 OPGs	Willems method	Constant underestimation in both the genders was observed.
15	Wang J et al., in 2017 [33]	Systemic Review	11 articles	Willems method	Willems method gives inaccurate results.
16	Willems G et al., in 2017 [34]	African Black children	986 OPGs	Willems method	Overestimation of dental age
17	Yusof M MYP et al., in 2017 [35]	Systemic Review	19 article	Willems method	Willems method gives accurate results.
18	Cherian JM et al., in 2020 [36]	North Indian Children	390 OPGs	Willems method	Accurate age estimation in both the genders was observed.
Nolla's method					
19	Present study			Nolla's method	Nolla's method gave accurate results in all the 4 age groups and also in both the genders the exception being girls in the age group of 9-11 years, where this method showed statistically significant underestimation.
20	Green LJ, in 1961 [37]	American caucasian children	56 OPGs	Nolla's method	It has shown overestimation
21	Briffa K et al., in 2005 [38]	Maltese children	120 OPGs	Nolla's method	Underestimation

22	Kurita LM et al., in 2007 [39]	Brazilian children	360 OPGs	Nolla's method	Underestimation
23	Abou El-Yazeed M et al., in 2008 [40]	Egyptian children	378 OPGs	Nolla's method	Accurate results with choose approximate value obtained from nearest possible whole number.
24	Butti AC et al., in 2009 [41]	Italian children	500 children	Nolla's method	Significant difference in one gender found in the studies done
25	Miloglu O et al., in 2011 [42]	Turkish children	719 children	Nolla's method	Significant difference in one gender found in the studies done
26	Sachan K et al., in 2013 [43]	North Indian children from Lucknow	90 children	Nolla's method	Accurate results with choose approximate value obtained from nearest possible whole number.
27	Nandlal B et al., in 2014 [44]	South Indian children from Mysore district		Nolla's method	Underestimation
28	Chalkoo AH et al., in 2016 [45]	North Indian children from Kashmir	120 children	Nolla's method	Significant difference in one gender found in the studies done
Cameriere's method of age estimation					
29	Present study			Modification of Cameriere's method	Overestimation was observed in children aged >5-11 years. The youngest age group of 3-5 years showed age closer to CA but with greater confidence interval
30	Prabhakar AR et al., in 2002 [46]	South Indian populations	151 children	Modification of Cameriere's method	Comparable and statistically insignificant readings in younger children of both the genders whereas it showed statistically significant overestimated readings in older children of both the genders
31	Rai R et al., in 2010 [11]	Indian Children	480 OPGs	-	Gave an Indian formula for the application of Cameriere's method on the local population
32	Thomas D et al., in 2014 [47]	South Indian children from Mangalore.	25 subjects	Cameriere's method of age estimation	Inconsistency in the Indian population
33	Pratyusha K et al., in 2017 [48]	South Indian populations	60 OPGs	Modification of Cameriere's method	Comparable and statistically insignificant readings in younger children of both the genders whereas it showed statistically significant overestimated readings in older children of both the genders
Comparative studies					
34	Present study				Nolla's method showed the least mean DA- CA out of the four methods where as Demirjian's method showed the maximum mean DA-CA out of the four methods.
35	Mohammed RB et al., in 2015 [1]	South Indian children	660 OPGs	South Indian children	660 OPGs
36	Prasad H and Kala N, in 2019 [49]	Systemic review	20 Studies	Demirjian's and Willems' methods in the Indian population.	Willems method produced more accurate age which was very close to the CA, both in boys and girls.
37	Ashraf S et al., in 2020 [50]	Saudi Arabian population	350 subjects	Demirjian's, Willems and the London Atlas Method	Demirjian's method on Saudi population is most accurate among the methods tested
38	Cortés MM in 2020 [51]	Spanish children	604 OPGs	Compared Willems, Demirjian and Nolla methods	Willems method is more appropriate due to its greater precision in estimating dental age.

[Table/Fig-10]: Applicability of all four age estimation technique in various population [1,8,11,23-51].

Willems method also showed significant overestimation in study population in all the age groups, but showed better results than Demirjian's method. Even in this method there was no difference seen between the two genders of a group. Various study conducted to estimate age using Willems method tabulated in [Table/Fig-10] [30-36]. A systematic review done by Yusof M MYP et al., found that Willems method gives accurate results [35], and another systematic review done by Wang J et al., found that it was inaccurate [Table/Fig-10] [33].

Nolla's method has been one of the first and most widely used method of evaluating the developmental stage of the developing teeth [9].

In the present study, we found that Nolla's method gave accurate results in all the four age groups and also in both the genders the exception being girls in the age group of 9-11 years, where this method showed statistically significant underestimation. Though, this method showed almost consistent results in the present study. Various study related to age estimation of Nolla's method tabulated in [Table/Fig-10] [37-45].

The inconsistency in the results can be due to the non availability of the decimal system to record the conversion of maturity score to DA, which forces the examiner to approximate the value obtained to the nearest possible whole number, which may not be representative

enough [44,45]. Similarly, Cameriere's method of age estimation has shown inconsistency in the Indian population, where researcher gave an Indian formula for the application of this method on the local population [11]. This method was on south Indian populations and they found comparable results which is inconsistent with our findings, as in this study also this method showed comparable and statistically insignificant readings in younger children of both the genders whereas it showed statistically significant overestimated readings in older children of both the genders. Various studies related to age estimation of Cameriere's method is tabulated in [Table/Fig-10] [11,46-48].

There are very few studies in literature that compared these four methods of age estimation in a single population in various age groups [1,49-51]. Such studies give us the insight about which method to resort to in times of need for a particular population of a given age. As gender did not seem to pose a challenge, all the methods can be applied in either of the genders to know the DA. Also, the correct age can be calculated if the gender of the child is known in cases of age disputes and/or when knowing the CA for legal/medical/medicolegal purposes is not possible.

Limitation(s)

Even though the sample size was statistically representative of the population, but better results can be obtained with larger

sample size. To obtain more specific application based on population, more specific population can be studied although in present study, western Indian population comprising of patients having the lineage from Gujarat, Maharashtra and Rajasthan were evaluated. Another aspect which can be adopted is, more than one examiner examines all the data, so the chances of errors can be lessened.

CONCLUSION(S)

The order of accuracy based on mean DA-CA on removing age stratification and comparing four methods of age estimation amongst male and female genders were as follows: In Group 1 (3-5 years) the order of preference was Nolla's>Willems>Modified Cameriere's>Demirjian's, without any gender preference. In Group 2, 3 and 4 the order of preference were Nolla's>Modified Cameriere's>Willems>Demirjian's, without any gender preference.

Thus, it can be concluded that, all the four DA estimation methods selected viz., Demirjian's, Willems, Nolla's and Modified Cameriere's method are not equally accurate in correlating the DA and CA in young Western Indian children. Nolla's method showed the least mean DA-CA out of the four methods where as Demirjian's method showed the maximum mean DA-CA out of the four methods. Further research on this population is required for affirming the results of the present study.

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PARTICULARS OF CONTRIBUTORS:

1. Professor, Department of Paediatric and Preventive Dentistry, K.M Shah Dental College and Hospital, Vadodara, Gujarat, India.
2. Former Postgraduate Student, Department of Paediatric and Preventive Dentistry, K.M Shah Dental College and Hospital, Vadodara, Gujarat, India.
3. Former Postgraduate Student, Department of Paediatric and Preventive Dentistry, K.M Shah Dental College and Hospital, Vadodara, Gujarat, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:

Dr. Anshula Deshpande,
Professor, Department of Paediatric and Preventive Dentistry, K.M Shah Dental College and Hospital, Sumandeep Vidyapeeth, Piparia, Waghodia-391760, Vadodara, India.
E-mail: fobeng37@yahoo.com

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