The applicability of the Demirjian, Willems and Chaillet standards to age estimation of 5-15 year old Indian children

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KEYWORDS

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ABSTRACT

Background: Demirjian's method of age estimation has been reported to overestimate age and Willems' method to give consistently more accurate results. Not enough, however, is known about the applicability of Chaillet's standards.

Aim: The present study aimed to compare the accuracy of Demirjian's, Willems' and Chaillet's standards in age estimation of 5 to 15 year-old Indian children.

Design: In this cross-sectional observational study, three methods were compared for accuracy in estimating the age of 1200 Indian children aged 5-15 years.

Results: Demirjian's method overestimated age by +0.24 ± 0.80 years, +0.11 ± 0.81years and +0.19 ± 0.80 years in boys, girls and the total sample, respectively. With Willems' method, overestimations of +0.09 ± 0.80 years, +0.08 ± 0.80 years and +0.09 ± 0.80 years were obtained in boys, girls and the total sample, respectively. Chaillet's method underestimated age by -0.12 ± 0.69 years, -0.45 ± 0.88 years and -0.25 ± 0.83 years in boys, girls and the total sample, respectively. Statistically significant differences were observed between dental and chronological ages with all methods ($p < 0.001$). Significant sex-based differences were observed only with Demirjian's and Chaillet's methods ($p < 0.05$).

Conclusion: Willems' method was the most accurate in age estimation, followed by Demirjian's and Chaillet's methods. While Demirjian's method was more accurate than Chaillet's in females, Chaillet's method better predicted the age of males.

INTRODUCTION

First proposed more than four decades ago, the Demirjian method[1] has emerged as the most widely researched and applied technique in dental age (DA) estimation of children and adolescents. This is owing largely to the simplicity of the method, as well as the radiographic and schematic illustrations of tooth development and accompanying description, which the original[1] and subsequent works[2] provided. However, Demirjian's French-Canadian standards have been reported to consistently overestimate age in most populations, including a Belgian-Caucasian population studied by Willems and co-workers,[3] which highlighted the need for population-specific databases. In order to avoid this overestimation, these latter researchers adapted Demirjian's maturity scores using a weighted ANOVA and constructed new tables for boys and girls, from which a maturity score could be directly expressed

in years. The Willems method is increasingly recognized as a more accurate predictor of age in recent years. Chaillet and co-workers,[4] adapted Demirjian's scores for the same Belgian population using polynomial functions and constructed another set of tables which they observed to be more accurate for this population. The dental literature abounds with reports[4-18] on the applicability of the Demirjian method and its variations to non-Indian and Indian populations. Extensive research[7,8,11,14,16-20] has been carried out using the Willems method as well. However, previous research on Indian populations is limited by inadequate sample sizes, age structures, grouping and approaches to statistical analysis.[16-19] Tests of the application of the Chaillet standards to non-Indian populations are few,[4,5,21-23] and while one study[24] did test these standards in an Indian population, the sample size was relatively small, the age range was 9 to 20 years and the Demirjian 8-teeth method was used for dental staging. Hence, the present study proposed to evaluate and compare the validity of the Demirjian, Willems and Chaillet standards in determination of chronological age (CA) of a reasonably large sample of 1200 Indian children aged 5 to 15 years.

METHODOLOGY:

This study was designed as a cross-sectional observational study. Ethical clearance was obtained from the Ethical Committee, Pacific Dental College and Hospital, Udaipur, India. Parents/ guardians had signed an agreement with the dental institution that dental records and radiographs could be used only for research and educational purposes without the possibility of personal identification.

Sampling method: A convenience sampling method was employed, all radiographs being digital and made during the period from January 2012 to September 2015 of children aged between 5.0 and 15.9 years who had sought treatment at the Department of Paediatric Dentistry, Pacific Dental College and Hospital, Udaipur, Rajasthan, India, and required an orthopantomograph (OPG) as part of the investigation protocol.

Selection criteria: Both parents of all children were of Indian origin and nationality. Only patients with a documented date of birth and date of radiography in the oral health record were included to facilitate verification of the chronological age (in completed decimal years) for each subject. Orthopantomographs with image distortion due to improper position or movement of the patient during exposure, and incomplete image or lack of clarity resulting from an improper exposure technique were excluded. Also, radiographs were excluded from the study if the patient had any history of surgical/medical treatment or systemic illness with the potential to cause significantly delayed or early development, significant numbers of teeth other than third molars missing either congenitally or due to disease and trauma, or malformation of teeth or obvious dental pathology that could affect tooth development.

Final sample: Of the 1303 radiographs collected, 103 did not meet the selection criteria owing to either congenital absence of several teeth (n = 22), lack of image clarity (n = 08) or inadequate information regarding the date of birth (n = 73). Thus, a final sample of 1200 OPGS of 699 male and 501 female Indian children aged 5 to 15 years was selected for the study. The distribution of radiographs by age and sex is presented in Table 1. Radiographs of patients aged 5.0 to 5.9 years were included in age group 5, of those aged 6.0 to 6.9 years in age group 6 and so on. Thus, age group 15 consisted of children aged 15.0 to 15.9 years.

Table 1: Distribution of the study sample by age and gender

Chronological age (years)		Females		Males		Total	
Age group	Age range	N	%	N	%	N	%
5	5.0 - 5.9	24	4.79	23	3.29	47	3.92
6	6.0 - 6.9	39	7.78	40	5.72	79	6.58
7	7.0 - 7.9	46	9.18	58	8.30	104	8.67
8	8.0 - 8.9	50	9.98	58	8.30	108	9.00
9	9.0 - 9.9	55	10.98	78	11.16	133	11.08
10	10.0 - 10.9	55	10.98	100	14.31	155	12.92
11	11.0 - 11.9	40	7.98	82	11.73	122	10.17

Calculation of chronological age: The dates of birth and of making the OPG were obtained from the hospital records. A function of Microsoft Excel was used to calculate the difference between the recorded date of birth and the date on which the OPG was made, to obtain the chronological age (CA) in decimal years.

Data collection: All digital radiographs meeting the selection criteria were saved as jpeg images and viewed on the same LCD monitor using Windows Photo Viewer and a magnifying glass for improved visualization. The examiners were allowed to use resources of image improvement such as brightness, contrast and zoom. Each OPG was coded with a numerical ID to avoid examiner bias. Age and sex of the subjects were thus unknown to the examiner. Nomenclature for teeth assessed was assigned according to the Fédération Dentaire Internationale (FDI) system. Seven mandibular teeth of the left side (excluding the third molar) were evaluated by the Demirjian's dental staging method.[1] Once the stage that most accurately described the stage of development of the tooth in question was identified, the corresponding alpha-numeric rating (0 to H) was assigned to that tooth. The alpha-numeric stages 0 to H were converted to the revised self-weighted gender-specific numerical scores of Demirjian and Goldstein.[2] The individual scores for were summed to obtain a total maturity score or dental score (DS), which was converted to a dental age (DA) using the Demirjian, Tanner and Goldstein tables.[1]

In Chaillet's method, the maturity scores provided by Chaillet et al.[4] were summed to obtain the total maturity score, which was converted to a dental age using the tables constructed by the same authors, while in the Willems method, the maturity scores provided by Willems et al.[3] for each tooth were summed to directly provide the dental age in years.

Reproducibility of measurements: Two well-trained examiners independently evaluated 100 radiographs using Demirjian's method of dental staging, after a period of mutual calibration without any knowledge of age or sex, in order to allow an analysis of inter-examiner agreement. Ultimately, a single examiner assessed all radiographs. Intra-examiner agreement was assessed by having one examiner re-evaluate the same 100 radiographs after a period of two months without any knowledge of sex or age or of the stages assigned in the first evaluation.

Data analysis: All statistical analyses and data management were performed using Statistical Package of Social Sciences 19.0 (SPSS Inc., Chicago, IL, USA) for Windows and MS-Excel (Microsoft Office 2010). Analyses were made for each sex and age group, and for the total sample. Kolmogorov-Smirnov and Shapiro-Wilk tests were performed to test the normality of the data. As the sample showed a non-normal distribution, non-parametric tests were applied. For all tests, a p value ≤ 0.05 was considered statistically significant.

The accuracy of each method of age estimation was determined by mean difference between estimated dental age and the chronological age (DA–CA) for each sex and age group, and the total sample. A positive result indicated an overestimation, and a negative result indicated an underestimation of age. Box-plot graphs are used to present the mean DA-CA of each sex and age group, and the total sample, with whiskers indicating the range. Absolute accuracy was determined by means of the absolute differences between DA and CA of girls and boys and the total sample for each method. The Wilcoxon signed rank test was applied to assess the significance of DA-CA for both methods for each sex and age group, for the total sample and between methods. Independent t-test was employed for comparisons of DA-CA between sexes. The correlation between DA and CA was analysed using Spearman's rank correlation coefficient for each sex and for the total study sample. Inter- and intra-examiner agreements are expressed as percentages. Cohen's kappa coefficient was used to calculate the degree of reliability of these agreements. Regression analyses were performed and gender-specific equations were derived for all three methods.

RESULTS

The mean age (± SD) of the entire sample was 10.75 ± 2.72 years, those of girls and boys being 10.68 ± 2.87 and 10.81 ± 2.60, respectively. Inter- and intra-examiner agreements were 86% and 93% respectively, with Kappa values of 0.81 and 0.90 indicating almost perfect agreement.

In the present study, the mean chronological and Demirjian dental ages for girls were 10.68 ± 2.87 and 10.79 ± 2.86 years, respectively, while for boys the values were 10.81 ± 2.60 and 11.05 ± 2.71 years, respectively. The mean differences between dental and chronological ages for boys, girls and the total sample (+0.24 ± 0.80, +0.11 ± 0.81 and

+0.19 ± 0.80 years, respectively) were statistically significant ($p < 0.01$). Significant differences between mean dental and chronological ages were observed in age groups 6, 8, 9, 12, 14 and 15 for girls and 6, 7, 8, 10, 11, 14 and 15 for boys ($p \leq 0.05$). In girls, Demirjian's method overestimated age by +0.06 to +0.54 years in all age groups, with the exception of groups 8 and 14, for which underestimations of -0.21 and -0.37 years, respectively, were obtained. In boys, overestimations ranged from +0.15 to + 0.59 years in most age groups, with underestimations of -0.13 and -0.02 years for groups 5 and 12, respectively (Table 2).

Table 2: Comparison of chronological age (CA) and Demirjian dental age (DA) by gender and age group

Gender	Age group (years)	N	CA	DA	DA-CA	p value*	p value#
			Mean ± SD (years)				
GIRLS	5	24	5.46 ± 0.33	5.53 ± 0.58	+ 0.07 ± 0.43	0.543	0.846
	6	39	6.57 ± 0.32	7.11 ± 0.58	+ 0.54 ± 0.38	**< 0.001**	**< 0.001**
	7	46	7.52 ± 0.26	7.65 ± 0.67	+ 0.13 ± 0.47	0.097	0.167
	8	50	8.51 ± 0.31	8.30 ± 0.73	- 0.21 ± 0.44	**0.049**	**0.048**
	9	55	9.48 ± 0.30	9.84 ± 0.77	+ 0.36 ± 0.43	**0.001**	**0.001**
	10	55	10.55 ± 0.32	10.72 ± 0.85	+ 0.17 ± 0.52	0.173	0.101
	11	40	11.44 ± 0.32	11.58 ± 0.84	+ 0.14 ± 0.54	0.352	0.357
	12	55	12.49 ± 0.32	12.75 ± 0.87	+ 0.26 ± 0.53	**0.048**	**0.049**
	13	57	13.46 ± 0.30	13.52 ± 0.83	+ 0.06 ± 0.50	0.607	0.502
	14	59	14.48 ± 0.28	14.11 ± 0.62	- 0.37 ± 0.39	**< 0.001**	**< 0.001**
	15	21	15.48 ± 0.27	15.73 ± 0.51	+ 0.25 ± 0.26	**0.024**	**0.023**
	Total	501	10.68 ± 2.87	10.79 ± 2.86	+ 0.11 ± 0.81	**0.003**	**0.002**
BOYS	5	23	5.56 ± 0.29	5.43 ± 0.98	- 0.13 ± 0.42	0.551	0.503
	6	40	6.52 ± 0.31	7.05 ± 0.78	+ 0.53 ± 0.44	**< 0.001**	**< 0.001**
	7	58	7.48 ± 0.29	7.72 ± 0.67	+ 0.24 ± 0.46	**0.015**	**0.004**
	8	58	8.47 ± 0.29	8.89 ± 0.61	+ 0.42 ± 0.97	**< 0.001**	**< 0.001**
	9	78	9.46 ± 0.28	9.61 ± 0.82	+ 0.15 ± 0.45	0.111	0.069
	10	100	10.45 ± 0.29	10.76 ± 0.84	+ 0.31 ± 0.47	**< 0.001**	**< 0.000**
	11	82	11.51 ± 0.30	11.66 ± 0.70	+ 0.15 ± 0.37	**0.035**	**< 0.001**
	12	91	12.44 ± 0.30	12.42 ± 0.74	- 0.02 ± 0.45	0.705	0.541
	13	82	13.41 ± 0.31	13.56 ± 0.78	+ 0.15 ± 0.36	0.088	0.106
	14	58	14.47 ± 0.31	15.06 ± 0.58	+ 0.59 ± 0.46	**< 0.001**	**< 0.001**
	15	29	15.24 ± 0.25	15.80 ± 0.40	+ 0.56 ± 0.35	**< 0.001**	**< 0.001**
	Total	699	10.81 ± 2.60	11.05 ± 2.71	+ 0.24 ± 0.80	**< 0.001**	**< 0.001**
Total sample		1200	10.75 ± 2.72	10.94 ± 2.78	+ 0.19 ± 0.80	**< 0.001**	**< 0.001**

*Paired t test, #Wilcoxon Signed Rank test: $p \leq 0.05$ = significant

The mean chronological and Willems' dental ages for girls were 10.68 ± 2.87 and 10.76 ± 3.04 years, respectively, while for boys the values were 10.81 ± 2.60 and 10.90 ± 2.66 years, respectively. The mean differences between dental and chronological ages for boys, girls and the total sample (+0.09 ± 0.80, +0.08 ± 0.80 and +0.09 ± 0.80 years, respectively) were statistically significant ($p < 0.05$). Significant differences between mean dental and chronological ages were observed in age groups 6, 11, 13 and 14 for girls and 8, 10, and 15 for boys ($p \leq 0.05$). In girls, Willems' method overestimated age by +0.01 to +0.61 years in most age groups, while underestimating age by -0.02 to -0.25 years, in groups 7, 8, 10 and 13. In boys, overestimations ranged from +0.01 to +0.35 years in all age groups, with the exception of age group 12 for which an underestimation of -0.10 years was obtained (Table 3).

Table 3: Comparison of chronological age (CA) and Willems' dental age (DA) by gender and age group

Gender	Age group	N	Mean age ± SD (years)		Mean DA-CA (years)	p value#
			CA	DA		
GIRLS	5	24	5.46 ± 0.33	5.47 ± 0.86	+ 0.01 ± 0.84	0.964
	6	39	6.57 ± 0.32	6.81 ± 0.70	+ 0.24 ± 0.64	**0.033**
	7	46	7.52 ± 0.26	7.39 ± 0.78	- 0.13 ± 0.75	0.191
	8	50	8.51 ± 0.31	8.46 ± 0.73	- 0.05 ± 0.63	0.765
	9	55	9.48 ± 0.30	9.52 ± 0.78	+ 0.04 ± 0.79	0.811
	10	55	10.55 ± 0.32	10.53 ± 0.81	- 0.02 ± 0.85	0.694
	11	40	11.44 ± 0.32	11.73 ± 0.89	+ 0.29 ± 0.84	**0.032**
	12	55	12.49 ± 0.32	12.53 ± 0.83	+ 0.04 ± 0.88	0.744
	13	57	13.46 ± 0.30	13.21 ± 0.71	- 0.25 ± 0.70	**0.018**
	14	59	14.48 ± 0.28	15.09 ± 0.93	+ 0.61 ± 0.93	**< 0.001**
	15	21	15.48 ± 0.27	15.63 ± 0.37	+ 0.15 ± 0.42	0.126
	Total	501	10.68 ± 2.87	10.76 ± 3.04	+ 0.08 ± 0.80	**0.049**
BOYS	5	23	5.56 ± 0.29	5.74 ± 0.73	+ 0.18 ± 0.73	0.301
	6	40	6.52 ± 0.31	6.62 ± 0.77	+ 0.10 ± 0.84	0.183
	7	58	7.48 ± 0.29	7.62 ± 0.78	+ 0.14 ± 0.73	0.153
	8	58	8.47 ± 0.29	8.69 ± 0.69	+ 0.22 ± 0.76	**0.043**
	9	78	9.46 ± 0.28	9.56 ± 0.88	+ 0.10 ± 0.90	0.410
	10	100	10.45 ± 0.29	10.65 ±0.82	+ 0.20 ± 0.80	**0.015**
	11	82	11.51 ± 0.30	11.53 ± 0.75	+ 0.02 ± 0.75	0.705
	12	91	12.44 ± 0.30	12.34 ± 0.70	- 0.10 ± 0.67	0.145
	13	82	13.41 ± 0.31	13.42 ± 0.76	+ 0.01 ± 0.81	0.891
	14	58	14.47 ± 0.31	14.54 ±0.68	+ 0.07 ± 0.75	0.553
	15	29	15.24 ± 0.25	15.59 ±0.76	+ 0.35 ± 0.82	**0.048**
	Total	699	10.81 ± 2.60	10.90 ± 2.66	+ 0.09 ± 0.80	**0.002**
Total sample		120	10.75 ± 2.72	10.84 ± 2.83	+ 0.09 ± 0.80	**< 0.001**

#Wilcoxon Signed Rank test: $p \leq 0.05$ = significant

The mean chronological and Chaillet's dental ages for girls were 10.68 ± 2.87 and 10.23 ± 2.83 years, respectively, while for boys the values were 10.81 ± 2.60 and 10.69 ± 2.68 years, respectively. The mean differences between dental and chronological ages for boys, girls and the total sample (-0.45 ± 0.88, -0.12 ± 0.69 and -0.25 ± 0.83 years, respectively) were statistically significant ($p < 0.001$). Significant differences between mean dental and chronological ages were observed in age groups 8, 10, 11 and 12 for girls and 5, 6, 8 and 14 for boys ($p < 0.05$). In girls, the Chaillet method underestimated age by -0.04 to -0.93 years in all age groups, except group 5 for which an overestimation of +0.20 years was obtained. In boys, underestimations ranged from -0.01 to -0.36 years in all age groups, while overestimating age by +0.06 to +0.29 years in group 5, 8 and 14 (Table 4).

Table 4: Comparison of chronological age (CA) and Chaillet dental age (DA) by gender and age grou

Gender	Age group (years)	N	CA	DA	DA-CA	p value#
			Mean ± SD (years)			
GIRLS	5	24	5.46 ± 0.33	5.66 ± 0.84	0.20 ± 0.64	0.308
	6	39	6.57 ± 0.32	6.53 ± 0.67	- 0.04 ± 0.30	0.613
	7	46	7.52 ± 0.26	7.12 ± 0.94	- 0.40 ± 0.67	0.062
	8	50	8.51 ± 0.31	8.00 ± 1.04	- 0.51 ± 0.60	**0.005**
	9	55	9.48 ± 0.30	9.17 ± 0.66	- 0.31 ± 0.53	0.384
	10	55	10.55 ± 0.32	10.11 ± 0.73	- 0.44 ± 0.63	**0.002**
	11	40	11.44 ± 0.32	10.88 ± 0.63	- 0.56 ± 0.73	**0.004**
	12	55	12.49 ± 0.32	11.56 ± 0.69	- 0.93 ± 0.91	**0.001**
	13	57	13.46 ± 0.30	12.64 ± 0.96	- 0.82 ± 1.17	0.893
	14	59	14.48 ± 0.28	14.35 ± 0.99	- 0.13 ± 1.06	0.150
	15	21	15.48 ± 0.27	14.69 ± 0.70	- 0.79 ± 0.90	0.476
	Total	501	10.68 ± 2.87	10.23 ± 2.83	- 0.45 ± 0.34	**0.005**
BOYS	5	23	5.56 ± 0.29	5.85 ± 0.62	0.29 ± 0.71	**0.001**
	6	40	6.52 ± 0.31	6.48 ± 0.88	- 0.04 ± 0.59	0.097
	7	58	7.48 ± 0.29	7.47 ± 0.86	- 0.01 ± 0.25	0.614
	8	58	8.47 ± 0.29	8.53 ± 0.80	0.06 ± 0.37	**0.008**
	9	78	9.46 ± 0.28	9.32 ± 0.95	- 0.14 ± 0.58	0.801
	10	100	10.45 ± 0.29	10.22 ± 0.89	- 0.23 ± 0.62	0.182
	11	82	11.51 ± 0.30	11.38 ± 0.79	- 0.13 ± 0.65	0.504
	12	91	12.44 ± 0.30	12.17 ± 0.84	- 0.27 ± 0.77	0.832
	13	82	13.41 ± 0.31	13.05 ± 0.91	- 0.36 ± 0.86	0.825
	14	58	14.47 ± 0.31	14.71 ± 0.92	0.24 ± 0.92	**0.007**
	15	29	15.24 ± 0.25	15.18 ± 0.69	- 0.06 ± 0.91	0.795
	Total	699	10.81 ± 2.60	10.69 ± 2.68	- 0.12 ± 0.20	**< 0.001**
Total sample		1200	10.75 ± 2.72	10.50 ± 2.75	- 0.25 ± 0.32	**< 0.001**

#Wilcoxon Signed Rank test: $p \leq 0.05$ = significant

The lowest mean DA-CA was obtained with the Willems method, followed by the Demirjian and Chaillet method. Significant sex-based differences were observed in mean DA-CA with the Demirjian and the Chaillet methods ($p = 0.005$ and $p < 0.0001$, respectively) but not the Willems method ($p > 0.05$). With the Demirjian method the mean DA-CA was significantly lower in girls than in boys, whereas, the reverse was true with the Chaillet's method (Table 5).

When the Spearman correlation coefficient test was performed for girls, boys and the total sample, strong linear correlations were observed between CA and DA for all methods, r values ranging from 0.875 to 0.966 and p values < 0.001 (Table 6). An inter-method comparison of mean DA-CA values revealed statistically significant ($p < 0.05$) differences in girls, boys and the total sample (Table 7).

Table 5: Intra-method comparison between genders of mean dental and chronological ages (DA-CA)

Gender	N	Demirjian		Chaillet		Willems	
		Mean DA-CA ± SD (years)	p value	Mean DA-CA ± SD (years)	p value	Mean DA-CA ± SD (years)	p value
Girls	501	+ 0.11 ± 0.81	**0.005**	- 0.45 ± 0.34	**<0.001**	0.08 ± 0.80	0.830
Boys	699	+ 0.24 ± 0.80		- 0.12 ± 0.20		0.09 ± 0.80	

Independent t-test; p≤ 0.05 = significant

Table 6: Correlation between chronological and dental ages by method

Method	r / p values	Females	Males	Total sample
Demirjian	r value	0.957	0.962	0.961
	p value	**< 0.001**	**< 0.001**	**< 0.001**
Chaillet	r value	0.837	0.877	0.841
	p value	**< 0.001**	**< 0.001**	**< 0.001**
Willems	r value	0.966	0.959	0.962
	p value	**< 0.001**	**< 0.001**	**< 0.001**

Spearman's rank correlation coefficient: r = Spearman's rho, p = significant

Table 7: Inter-method comparison of mean dental and chronological ages (DA-CA) by gender and age group

	Method with mean DA-CA		Difference in mean DA-CA	95% CI of DA-CA	Absolute difference	p value#
	(years ± SD)			Years		
Females (N = 501)	Demirjian	Willems	-0.03 ± 0.80	0.05 to 0.16	0.61	**< 0.001**
		Chaillet	-0.56 ± 0.85	0.48 to 0.62	0.62	**< 0.001**
	Willems	Chaillet	0.53 ± 0.84	-0.53 to -0.40	0.65	**< 0.001**
Males (N = 699)	Demirjian	Willems	-0.15 ± 0.80	0.09 to 0.16	0.56	**< 0.001**
		Chaillet	-0.36 ± 0.75	0.05 to 0.14	0.58	**0.012**
	Willems	Chaillet	0.21 ± 0.75	-0.16 to 0.44	0.56	**< 0.001**
Total (N = 1200)	Demirjian	Willems	-0.10 ± 0.80	0.03 to 0.26	0.58	**< 0.001**
		Chaillet	-0.44 ± 0.83	-0.20 to 0.54	0.60	**< 0.001**
	Willems	Chaillet	-0.34 ± 0.82	-0.34 to -0.19	0.62	**< 0.001**

#Wilcoxon Signed Rank test: p ≤ 0.05 = significant

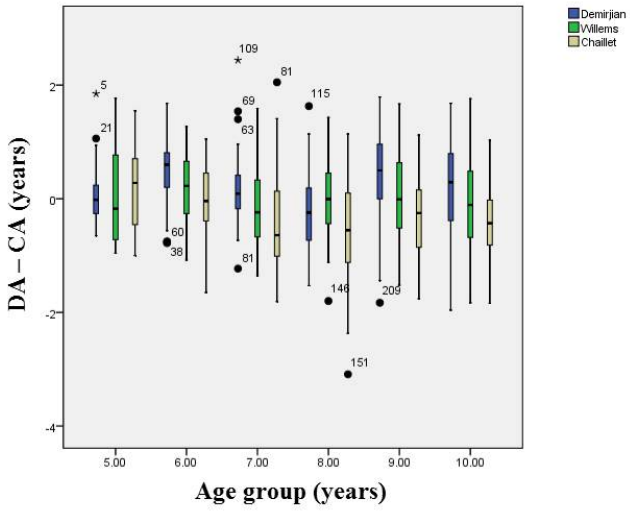
Box-plot graphs 1-5 present the mean DA-CA of each sex and age group, and the total sample,with whiskers indicating the range.Regression analyses were performed and the following equations were derived:

For the Demirjian method:
Males: CA = 0.914 + 0.883 × DA
Females: CA = 0.316 + 0.961 × DA

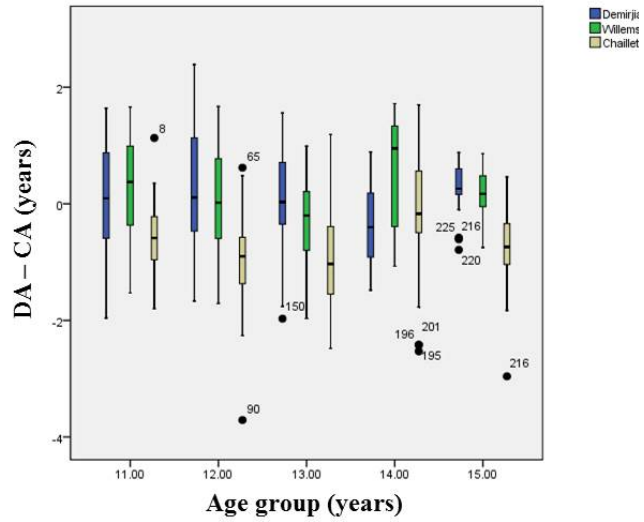
For the Willems method:
Males: CA = 0.622 + 0.934 × DA
Females: CA = 0.894 + 0.909 × DA

For the Chaillet method:
Males: CA = 2.104 + 0.791 × DA
Females: CA = 0.768 + 0.969 × DA

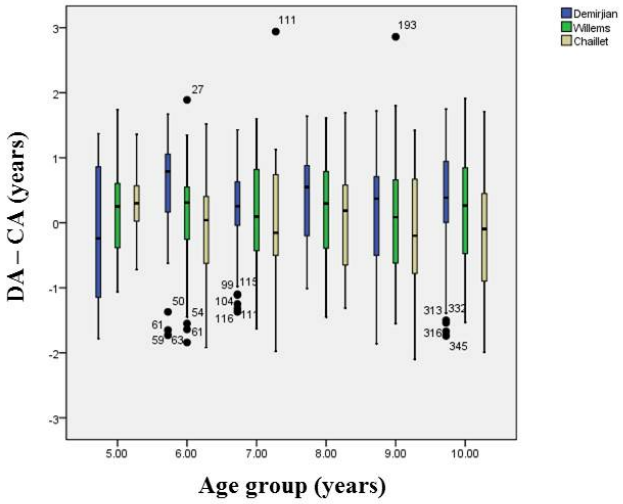
Graph 1: Box plot of mean DA-CA of females aged 5-10 years



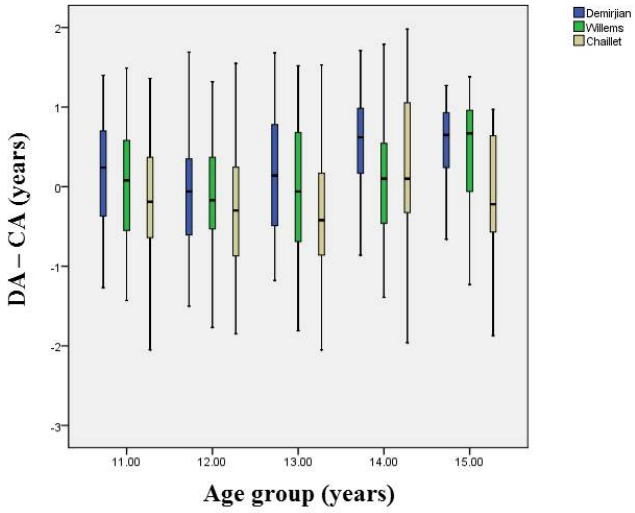
Graph 2: Box plot of mean DA-CA of females aged 11-15 years



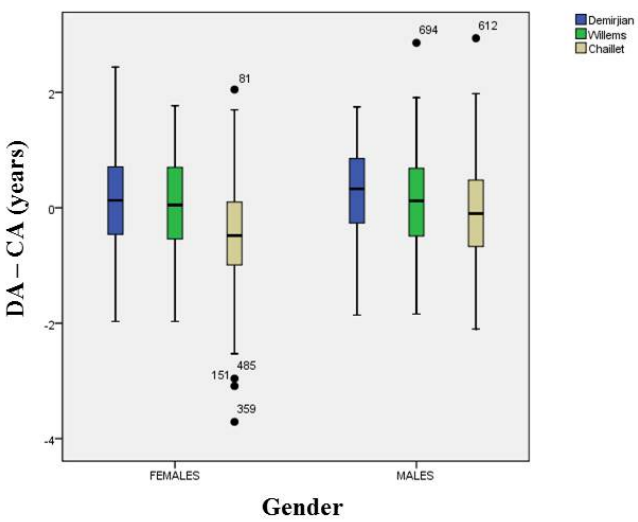
Graph 3: Box plot of mean DA-CA of males aged 5-10 years



Graph 4: Box plot of mean DA-CA of males aged 11-15 years



Graph 5: Box plot of mean DA-CA by gender for the total sample



DISCUSSION

Owing to the consistent overestimations of age reported with Demirjian's French-Canadian standards in most populations, Willems and his co-workers[3] and Chaillet et al.,[4] developed new dental maturity standards using weighted ANOVA and polynomial functions, respectively, for the same Belgian population. While the Demirjian and Willems methods have been widely tested, the Chaillet standards have not, especially on Indian populations. Therefore, the present study compared the Demirjian, Willems and Chaillet methods on a sample of orthopantomographs of Indian children aged 5 to 15 years, obtained by a convenience sampling method. This method is preferred by most researchers because it is fast, inexpensive and easy and the subjects are conveniently accessible.

Only the mandibular teeth were evaluated in the present study because, unlike the developing maxillary permanent teeth whose radiographic views are often obstructed by bony structures of the maxilla, the teeth of the mandible are quite clearly visible in an OPG. Further, a very high degree of symmetry is known to exist between the teeth of the left and right sides, only the seven mandibular teeth of the left quadrant were assessed. Third molar germs were excluded from assessment because of the high degree of variability observed in third molar genesis and development.

While assessing dental age, it is important not only to consider the proximity of the estimated age to the actual or chronological age, but also the reproducibility of the age estimation method. In the present study, agreements between and within examiners for Demirjian's method of dental staging were obtained in percentages and measured by Cohen's kappa coefficient. This coefficient is a more robust measure than simple percent agreement calculation, taking into account the agreement occurring by chance. Inter- and intra-examiner agreements for Demirjian's dental staging were observed to be 91% and 90%, respectively, with a kappa coefficient of 0.83. The difference in mean DA-CA was not significant between examiners or between two assessments by the first examiner. Other studies have reported kappa values ranging from 0.68 to 0.92 for inter-examiner agreements[9,10] and from 0.67 to 0.96 for intra-examiner agreements.[11,12]

The Demirjian method has been found to consistently overestimate age in various populations, with a majority of studies reporting overestimations of up to +1.23 years in males and +1.20 years in females.[13] The Willems method has, in recent years, been accepted as a more accurate method of age estimation with reports of overestimations of up to +0.55 in males and +0.53 years in females.[14] Reports of underestimations of age with both these methods, although available, are few. In the present study, overestimations of age by +0.24 and +0.09 years for males and by +0.11 and +0.08 years for females, were obtained using the Demirjian and the Willems methods respectively. Studies testing the Chaillet's multi-ethnic international maturity standards[21] have reported overestimations of +0.28 and +0.37 years in males and +0.09 and +0.21 years in females of Bosnian-Herzegovinian[22] and Spanish Caucasian populations,[23] respectively. Underestimations have been reported of -0.48 and -0.18 years in males and -0.61 and -0.59 years in females of Venezuelan[23] and French[8] populations, respectively. In the present study, underestimations were obtained of -0.12 years in males and -0.45 years in females, with Chaillet's original standards for Belgian children.

Significant sex-based differences were observed with the Demirjian and Chaillet methods in the present study but not with the Willems method. This sex difference has been attributed to the faster biological and dental maturation in girls, which leads to a higher dental compared to chronological age.[15] However, some other studies[12,16] have reported a higher dental age compared to chronological age in boys than in girls.

The accuracy or precision of an age estimating method may be affected by the quality of the reference material (sample), reliability of the method and biological variability in dental development.[25,26] Hence, it is important to accept that no age estimation method can predict the exact age of every individual. In the present study, significant correlations were observed between the chronological and estimated dental ages with all the three methods tested. The Willems method was the most accurate in age estimation, followed by the Demirjian and the Chaillet methods. While the Demirjian method was more accurate than the Chaillet method in females, the Chaillet method better predicted the age of males compared to the Demirjian method.

Most studies on non-Indian[7,27] and Indian[16,17] populations have found the Willems method to be more accurate than the Demirjian method, while one Indian study[18] reports the reverse.

The mean prediction errors obtained with all three methods for the sample ranged from 1.08 to 3.0 months. Although smaller intervals are desirable, differences between chronological and estimated ages of up to 12 months can be considered to be within normal standards.[28] While the low mean prediction errors suggest that the published standards of the age estimation methods tested could be suitable, gender-specific formulae were derived in the present study, which could increase the accuracy of these methods when applied to Indian populations.

The main limitation of this study would be the use of a convenience sample, which may be subject to sampling bias and may not be representative of the entire population.[29] However, obtaining a random sample was not practical. Further, exposing children to X-radiation for obtaining orthopantomographs when not indicated for diagnosis or treatment may raise ethical concerns. With the use of convenience sampling, we could prevent unnecessary exposure to radiation. By including a large sample of varied age and of both sexes, we have attempted to reduce the sampling bias of a convenience sampling.

CONCLUSIONS

From the results of this study, it was concluded that the Willems and Demirjian methods overestimated age, while the Chaillet method underestimated age. The Willems method most accurately predicted the age (mean prediction error = 1.08 months for both sexes) of the study sample, followed by the Demirjian and Chaillet methods. The Demirjian method was significantly more accurate in girls compared to boys while the reverse was true for the Chaillet method. The Willems method was equally accurate in both sexes. Significant differences between estimated dental age and chronological age were observed with each of the methods. The gender-specific formulae derived in the present study could increase the accuracy of these methods when applied to Indian populations.

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