ORIGINAL ARTICLE

Radiographic evaluation of dental age using Demirjian's eight-teeth method and its comparison with Indian formulas in South Indian population

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Abstract

Aim: The study was conducted to evaluate the applicability of Demirjian method and its comparison with Indian formulas for estimation of dental age in subjects attending a dental school in South India. **Materials and Methods:** A total of 250 individuals (130 males and 120 females) between 7 and 18 years, with orthopantamographs were included in the study. Chronological age was recorded based on subject's date of birth. Dental age was estimated using Demirjian's and Indian formulas. All the data obtained was entered into spreadsheet and subjected to statistical analysis. **Results:** The mean chronological age of the study sample was 12.39 ± 3.32 years; while the mean age obtained from Demirjian's method and Indian-specific regression formula were 11.56 ± 3.17 years and 14.20 ± 3.24 years, respectively. In the present study, the Demirjian's method under estimated dental age by 0.84 years in males and 0.83 years in females ($P < 0.05$). Indian-specific regression formulas overestimated dental age by 1.72 years in males and 1.91 years in females ($P < 0.05$). **Conclusion:** The published Demirjian's and Indian-specific regression formulas are not applicable to the present study group. Hence population-specific cubic regression formulas were developed for males and females in Bhimavaram town (South India).

Key words: Forensic science, panoramic radiography, regression analysis, tooth mineralization, tooth

Introduction

Age is defined as the length of time a person has lived or an object has existed. Chronological age of the individual or an object is defined as the amount of time that has elapsed since the person was born, or since the object was made. In cases where the actual age of the individual is not accessible, an estimate of age at the time of death can be made based on the biological maturity of the body. Taranger J considered biological maturation as a series of gradual transformations through time going on in the human body from conception to death as a part of life cycle of the organism.[1] Biological maturity can be measured in any of the four physiological divisions: Somatic, sexual, skeletal, and dental.

Dental age estimation in the living is mostly based upon non-invasive methods, which evaluate the timing and sequence of defined growth stages of the developing

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dentition and the sequence or modification of traits in the mature dentition and the surrounding tissues. One such method is Demirjian's method, which is based on 10 mineralization stages which span from no sign of tooth mineralization to apex closure for the eight permanent mandibular teeth.[2]

Several authors have tested the Demirjian's method against their population groups with varying success. However, results were less accurate if population of different ethnic origin were compared to Demirjian's standards. Hence they highlighted the necessity to create databases representative for each population. As a result Indian-specific regression formulae using the modified Demirjian's eight teeth method following the gender-specific French maturity scores were developed.[3] In this context there is a need to evaluate the applicability of Demirjian'smethod in age estimation and its comparison with Indian formulas when applied to the present population in south India.

Materials and Methods

A total of 250 individuals of age between 7 and 18 years (6.01-18.99 years) were included in the study who were advised orthopantomograph (OPG). They were categorized into males (130) and females (120). A specially designed proforma including the demographic details of the patient and consent form was duly filled at the time of examination.

Individuals between the age groups of 7 and 18 years who were advised orthopantomograph for various diagnostic and treatment purposes were included in the study. The technical reasons and patient factors for exclusion of radiograph include.

Image distortion due to either patient movement during exposure, or improper positioning of patient for exposure;

Incomplete image formation due to incorrect exposure technique;

Significant numbers of missing teeth due to disease or trauma;

History of chronic disease, illness or syndrome known to significantly affect dental development.

History of medical treatment known to significantly affect dental development.

For each individual an OPG was taken using Orthopantomograph machine (Orthoralix) and PSP sensors (Digora), under standard exposure conditions as recommended by the manufacturer. The final images were obtained by accompanying software (Digora for Windows 2.7.103.437 network client, copyright© 1993-2010 Sorodex) in Digital Imaging and Communications in Medicine (DICOM) format and were viewed using RadiAntDicom viewing software (32 bit) with magnification and measuring tools (ver. 1.0.4.4439, Copyright 2009-2012 Medixant) [Figure 1]. 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 taken, thus giving the chronological age of the patient at the time of the radiograph. Dental age was calculated by using Demirjian's and Indian formulas for males and females.

The collected data was entered in a spreadsheet (Excel 2007, Microsoft office) and was analyzed using, statistical analysis software (SPSS version 16.01, SPSS.inc, Chicago, 1989-2007). χ^2 test and *t*-test were used to determine any significant differences between the groups. Significance was set at 0.05 level ($P < 0.05$). In order to assess the reproducibility of our analysis, a subset of 30 panoramicradiographs were randomly chosen to be reviewed by the same observer within a period of 2 weeks. The percentages of intra-observer agreement regarding the separate scores for each tooth and Cohen's Kappa coefficient were determined.

Results

A digital radiographic study was conducted on 250 children aged between 7 and 18 years who attended a dental institution in South India seeking various Orthodontic and Pedodontic treatments. Fifty-two percent ($n = 130$) of them were males and 48% ($n = 120$) were females. Table 1 gives the age and sex distribution of the study sample.

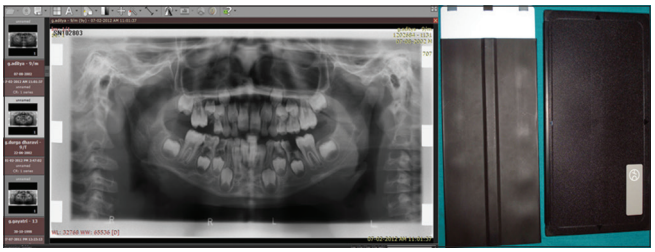

Figure 1: Radiant DICOM viewer with photostimulable phosphor sensors

Table 1: Demographic details of the study

Chronological age	Gender (%)		Total (%)
	Male	Female	
6.01-8.00	8 (3.2)	16 (6.4)	24 (9.6)
8.01-10.00	26 (10.4)	15 (6.0)	41 (16.4)
10.01-12.00	32 (12.8)	28 (11.2)	60 (24.0)
12.01-14.00	17 (6.8)	25 (10.0)	42 (16.8)
14.01-16.00	26 (10.4)	16 (6.4)	42 (16.8)
16.01-18.00	11 (4.4)	9 (3.6)	20 (8.0)
18.01-18.99	10 (4.0)	11 (4.4)	21 (8.4)
Total	130 (52.0)	120 (48.0)	250 (100)

Intra-observer analysis revealed kappa values for each tooth ranging from 0.457 to 0.842 and 0.682 to 1.000 in males and females, respectively. Most Kappa values were interpreted to represent from substantial agreement to almost perfect agreement [Table 2].

The mean chronological age in males was 12.42 ± 3.25 years; while the mean age obtained from Demirjian's method and Indian specific regression formula were 11.58 ± 3.28 years and 14.14 ± 3.14 years [Table 3]. Significant differences between mean chronological age and Demirjian's age were obtained in all age groups except 14-16 year age group indicating a greater applicability of Demirjian's method of age estimation in this age group. Similarly significant differences were obtained between chronological age and dental age obtained from Indian formulas in all age groups except 10-14 and 18-18.99-year age groups indicating a greater applicability of this method in these age groups. Graphical presentation of mean chronological age in various age intervals and its comparison with mean age obtained from Demirjian's and Indian formulas are present in Figure 2.

The mean chronological age in females is 12.36 ± 3.41 years, while the mean age obtained from Demirjian's and India- specific regression formulas are 11.53 ± 3.05 years and 14.27 ± 3.36 years, respectively [Table 4]. Significant differences between mean chronological age and Demirjian's age were obtained in all age groups except 10-14 year age group indicating a greater applicability of Demirjian's method of age estimation in this age group. Similarly significant differences were obtained between chronological age and dental age obtained from Indian formulas in all age groups except 18-18.99-year age group indicating a greater applicability of this method in these age groups. Graphical presentation of mean chronological age in various age intervals and its comparison with mean age obtained from Demirjian's method and Indian method are present in Figure 3.

In statistics, the Mean absolute error (MAE) is a quantity used to measure how close predictions are to the eventual outcomes. It is the mean error irrespective of positive or negative sign. The effectiveness of two methods (Demirjian's and Indian) were compared in terms of mean absolute error that were either <±1 year or >±2 years. The Demirjian's formulas revealed better age prediction (MAE = 0.83 years) compared to Indian formulas (MAE = 1.81). Most of the observations in Demirjian's method were present with in

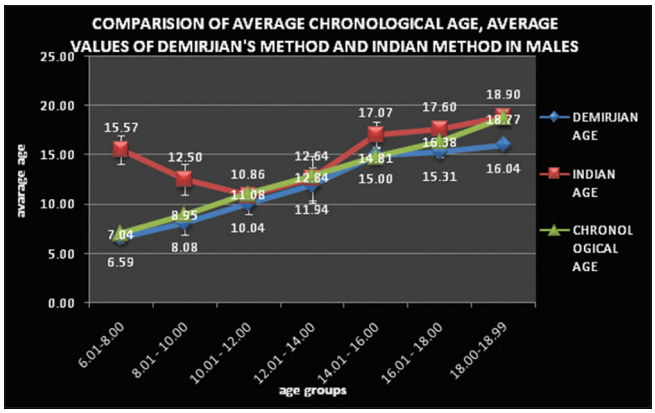

Figure 2: Graphical representation of differences in dental ages obtained from different methods, compared to chronological age of study sample in males

Table 2: Kappa statistics of the intra-observer agreement in males and females

Intra-observer variation	Teeth	Central	Lateral	Canine	Premolar 1	Premolar 2	Molar 1	Molar 2	Molar 3	Total
Males	Kappa value	0.656	0.457	0.538	0.874	0.791	0.842	0.789	0.741	0.711
	Percentage	87.09	77.41	64.52	90.32	83.87	93.55	83.87	77.42	82.26
	Reliability	S	M	M	S	S	AP	S	S	S
Females	Kappa value`	0.843	0.746	0.847	1.000	0.682	0.890	0.918	0.851	0.847
	Percentage	96.77	90.32	90.32	100	80.64	96.77	93.54	87.10	91.94
	Reliability	AP	S	AP	AP	S	AP	AP	AP	AP

S: Substantial; M: Moderate; AP: Almost perfect

Table 3: Comparison between chronological age (CA), Demirjian's age (DA) and Indian age (IA) in males

Age	*N*	Chronological age		Demirjian age		*t*-test for CA-DA		Indian age		*t*-test for CA-IA	
		Mean	Std. deviation	Mean	Std. deviation	*t*-value	Sig	Mean	Std. deviation	*t*-value	Sig
6.01-8.00	8	7.04	0.64	6.59	0.53	3.41	0.011*	15.57	1.42	12.19	0.000*
8.01-10.00	26	8.95	0.64	8.08	1.14	4.15	0.000*	12.50	1.55	-9.55	0.000*
10.01-12.00	32	11.08	0.54	10.04	0.99	6.59	0.000*	10.86	0.57	1.50	0.144
12.01-14.00	17	12.84	0.40	11.94	1.76	2.34	0.032*	12.64	2.28	0.39	0.699
14.01-16.00	26	14.81	0.49	15.00	0.79	-1.40	0.172	17.07	1.33	-9.92	0.000*
16.01-18.00	11	16.38	0.28	15.31	0.47	7.12	0.000*	17.60	0.82	-4.92	0.001*
18.01-18.99	10	18.77	0.28	16.04	0.25	31.00	0.000*	18.90	0.46	-1.02	0.332
Total	130	12.42	3.25	11.58	3.28	8.18	0.000*	14.14	3.14	-7.30	0.000*

*Statistically significant value $P<0.05$, (CA: Chronological age; DA: Demirjian's age; IA: Indian age)

<±1 year (54.4%), than Indian method (30.4%). Hence in the study group of 7-18 years more accurate age estimations were obtained from Demirjian's formulas than Indian formulas [Table 5].

Discussion

The pattern of tooth development was reasonably consistent with minor variations between population of different ethnic origin and it was the rate of development that varied from region to region. For this reason Demirjian's method has been widely used throughout the world, and has been shown to provide an accurate estimate of age when modified to the local population. Most of these modifications have involved either changing the values of the self-weighted maturity scores and/or constructing regression models based on local samples. One such modification was done by Dr. Ashith B. Acharya in 2010. He tested Demirjian's 8teeth method using 547 Indians (348 females and 199 males) aged between 7 and 25 years and developed Indian-specific regression formulas.

The kappa statistics for the present study indicated the level of intra-observer agreement to be 'substantial' in males and 'almost perfect' in females. In absolute terms

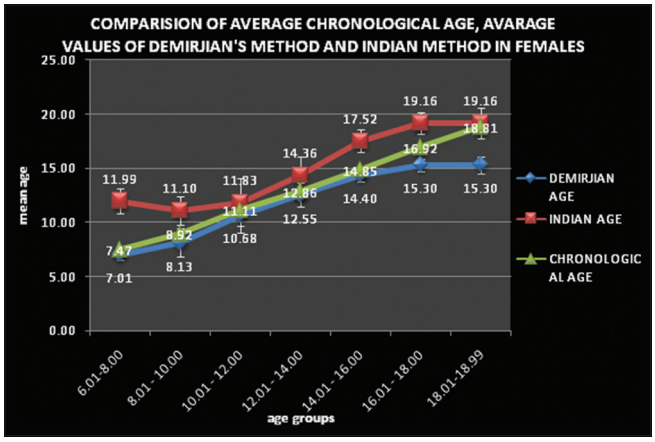

Figure 3: Graphical representation of differences in dental ages obtained from different methods, compared to chronological age of study sample in females

the study reported an intra-observer agreement of 82.26% in males and 91.94% in females. Maia NCG *et al.*, reported a mean intra-observer and inter-observer agreement of 86.6% (kappa value – 0.67) in his study using Demirjian's method.[4]

The predictive maturity scores and cubic regression formulas of this study are population specific. While they may work well on cases of French-Canadian origin they found to over- or under-estimate predicted age in population of a genetically different heritage. In the present study, the Demirjian's method under estimated dental age by 0.84 years in males and 0.83 years in females which were found to be statistically significant at $P < 0.05$ level (except in 14-16-year males and 10-14-year females).

The mean underestimation of age by Demirjian's method in the present study was 0.83 years. The magnitude of mean underestimation of age varied between age groups. It was as high as 2.73 years in males and 3.52 years in females in 18-18.99-year age group.Greater difference in dental age when compared to chronological age was observed between 9 and 10 years of boys and girls of Belgian Caucasian population.[5] Rózyło-Kalinowska *et al.*, reported significant difference between chronological and dental age using Demirjian's method in girls aged 11 and 12 years, as well as in 13-year-old boys.[6] Al. Emranfounda statistically significant advancement in dental age in boys and girls of age group 9-14.[7] Bagherpour *et al.*, found highest mean difference or mean error (ME) between chronological age and dental age in older age group in boys and 6-8 year old girls. He suggested that Demirjian method is appropriate for estimating the dental age of patients, especially those belonging to the 9-13-year-old age group.[8] Al-Tuwirqi *et al.*, found largest difference between chronological and dental ages (1.10 ± 0.80 years, $P < 0.001$) in 11-12-year-old Saudi Arabian girls, and the smallest difference (0.33 ± 1.19 years, $P < 0.01$) in 11-12-year-old Australian boys.[9]

Our results suggest a delay in French-Canadian children in dental age over south Indian children. But other studies showed variations in age estimations, when Demirjian's method was applied to different population groups in

Table 4: Comparison among chronological age (CA), Demirjian's age (DA) and Indian age (IA) in females

Age	*N*	Chronological age		Demirjian age		*t*-test CA-DA		Indian age		*t*-test for CA-IA	
		Mean	Std. deviation	Mean	Std. deviation	*t*-value	Sig	Mean	Std. deviation	*t*-value	Sig
6.01-8.00	16	7.47	0.51	7.01	0.53	5.23	0.000*	11.99	1.18	−11.24	0.000*
8.01-10.00	15	8.92	0.56	8.13	1.30	2.79	0.014*	11.10	1.35	−4.93	0.000*
10.01-12.00	28	11.11	0.55	10.68	1.68	1.71	0.099	11.83	2.21	−2.07	0.048*
12.01-14.00	25	12.86	0.59	12.55	1.10	1.45	0.16	14.36	1.70	−4.71	0.000*
14.01-16.00	16	14.85	0.40	14.40	0.59	3.27	0.005*	17.52	1.05	−11.19	0.000*
16.01-18.00	9	16.92	0.39	15.30	0.56	6.61	0.000*	19.16	1.03	−5.78	0.000*
18.01-18.99	11	18.81	0.09	15.30	0.76	16.84	0.000*	19.16	1.40	−0.85	0.41
Total	120	12.36	3.41	11.53	3.05	6.87	0.000*	14.27	3.36	−10.58	0.000

*Statistically significant value $P<0.05$, (CA: Chronological age; DA: Demirjian's age; IA: Indian age)

Table 5: Mean absolute error obtained in Demirjian's and Indian methods

Method	Mean absolute error			Error (%)	
	Total	Males	Females	<±1 year (accurate)	>±2 years (inaccurate)
Demirjian's	0.83	0.84	0.83	136/250 (54.4)	50/250 (20)
Indian	1.81	1.72	1.91	76/250 (30.4)	111/250 (44.4)

the world. Overestimated dental age was observed in Chinese population by 11 months in boys and 7 months in girls.[10] Similar results were observed in Davangere children where Demirjian's method overestimated age by 1.20+/- 1.02 years and 0.90+/- 0.87 years in males and females, respectively.[11] Hedge *et al*., reported over estimation of dental age using Demirjian's method by 0.14 years in boys and 0.04 years in females in Belgaum population.[12]

In the present study, the Indian-specific regression formulas over estimated dental age by 1.72 years in males and 1.91 years in females. It was as high as 8.53 years in males and 4.52 years in females in younger age group (6-8 years). These overestimates were found to be statistically significant at $P < 0.05$ level. Kumar *et al*., reported the mean absolute error using Indian method in male between 7 and 16 years as 1.2 years and between 16.1 and 23 years as 1.3 years. In females with age groups 7-16 years and 16.1-23 years, the mean absolute error was 0.95 and 1.16 years, respectively. These variations can be hypothesised to the inclusion of third molar which increased the error rates in the older individuals within the sample.[13]

Although population-specific curves proposed by Demirjian were more accurate in the prediction of age, a considerable variation within each population still existed. These results advocate construction of new population specific curves for each region. Many authors prefer polynomial functions than percentile method (age-maturity score charts), as they are highly reliable.[14,15] Hence in forensic point of view polynomial functions are more useful for dental health clinicians for age estimation. Hence new regression formulas for males and females were developed and maturity score charts for age between 7 and 17 years were developed.

Males: $AGE = (7.584933012) + (0.000*S) + (-0.000395087*S^2) + (1.30357E\text{-}05*S^3)$.

Females: $AGE = (9.8053) + (0.000*S) + (-0.0022*S^2) + (2.940E\text{-}05*S^3)$.

Where "S" is the total maturity score obtained by the sum of self-weighted scores of all eight teeth.

Despite the lack of applicability of the standards of Demirjian system to the present sample, the underlying system of defined stages of tooth calcification proved sound. The observed levels of intra-observer agreements were high in our study. As both Demirjian's and Indian formulas failed to accurately estimate age in Bhimavaram population (South India), specific cubic regression formulas for males and females were developed.

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