

The Less Known Anderson Method for Dental Age Estimation in Indian Scenario: A Pilot Study

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Abstract

Introduction: There are different dental age estimation methods for children and adolescents but Anderson method for dental age estimation in later childhood and early adolescence is less known in Indian scenario.

Objectives: The aim of study was to compare the efficacy of Anderson's method in Indian children (6-17 years) for dental age estimation.

Materials and methods: Digital Orthopantomogram of 104 subjects were collected for the assessment of maxillary teeth and mandibular teeth development using Moorrees method of staging and dental age was assessed using mean dental age given by Anderson method.

Results and discussion: Anderson's method was found to be more accurate with mean difference age overestimation of 0.04 years for mandibular arch, underestimation of 0.43 years for maxillary arch and 0.19 years for combining both maxillary and mandibular arches.

Conclusion: This study showed significant relation between dental age and chronological age for both the sexes.

Keywords: Anderson method; Children; Adolescent; Chronological age; Dental age estimation

Introduction

All teeth shows morphologically distinct stages of mineralization which can be identified radiographically and bilaterally symmetrical teeth achieve each stage at a similar age [1-5]. Ideally, age estimation in a specific population should be done by the usage of different methods provided by existing literature and practices, as well as the development of new methods to ensure the application of the most adequate technique [6].

In order to quantify continuous process from first traces of cusps mineralization until root apex closure, many authors suggested different number of radiographic stages. Nolla's study was one of the first to assess tooth formation longitudinally and quantify dental maturation. In this method, a sum of tooth scores against each year of age were given and which were used to predict age into 1 year age groups and also provides an age at each stage for each tooth. Even though, other methods have been used, the most widely used method for dental age estimation was described by Demirjian et al. [1] because of its simplicity. This method has been tested in various populations and has been mostly reported to overestimate the age of an individual [7-11].

Demirjian et al. [1] method in which tooth formation is divided into eight stages and criteria of these stages for each tooth were given separately. Each stage of the left mandibular seven teeth was allocated a score and the sum of the scores gave an evaluation of the subject's

dental maturity and the dental age was calculated using the sex specific tables. When applying this method, toward the end of dental maturation fewer stages contribute more, so that a single stage change can lead to a large jump in dental age.

The system developed by Moorrees et al. [4] described fourteen morphologically distinct staging through which each developing tooth passes. Each of these stages is identifiable radiographically. Anderson et al. [12] study described the mean ages of attainment (and standard deviation) of each of the fourteen stages of development described by Moorrees et al. [4] for every tooth in both dental arches (Tables 1-4). The mean ages of attainment (and standard deviation) for each stage, for each tooth was derived and the results recorded in tabular form, separated into male/female and mandibular/maxillary teeth. This table could then be used to estimate the chronological age of a subject based on the stages of development of the teeth of that subject.

The advantage of this system is that, being based on all deciduous and permanent teeth, it is far more versatile than many derived in the previous studies. This versatility lies in the fact that any teeth can be used in the assessment. This can be very useful from a clinical point of view in forensic cases when fragmentation, decomposition or predation of the remains may mean that not all teeth are actually recovered. The user may also use this versatility to their advantage by selecting teeth for analysis that have the least amount of variance about the mean, thus providing a more accurate age estimate. Specifically; clearly defined stages, high intra-observer, and applicability to both the deciduous and permanent dentition give this system a wide range of application [12].

As this method has not been tested in Indian children, for that reason, the aim of this study was to evaluate the applicability of Anderson method of dental age estimation in Indian children of 6-17 years age.

Staging	Incisors				Canine		Premolars				Molars					
	Central		Lateral		First		Second		First		Second		Third			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1									3.7	0.38			3.8	0.45	9.4	1.4
2									4	0.55			4.3	0.54	10.2	1.44
3									4.3	0.62			4.8	0.53	10.8	1.47
4					3.6	0.18	4.1	1.54	4.8	0.57	3.4	0.2	5.3	0.6	11.5	1.49
5			3.6	0.24	3.9	0.41	4.8	1.28	5.5	0.63	3.6	0.17	5.9	0.62	12.4	1.5
6	3.6	0.21	4	0.46	4.8	0.59	5.6	1.21	6.3	0.7	3.7	0.14	6.7	0.71	13.3	1.51
7	4	0.46	4.8	0.46	5.7	0.68	6.6	1.17	7.2	0.73	3.7	0.28	7.6	0.75	14.1	1.48
8	4.7	0.45	5.4	0.45	6.6	0.74	7.6	1.13	8.1	0.86	4.3	0.4	8.5	0.8	14.8	1.41
9	5	0.45	5.7	0.46	6.9	0.74	7.9	1.12	8.5	0.87	4.9	0.43	9.4	0.9	15.5	1.25
10	5.8	0.47	6.5	0.49	8.1	0.73	9	1.12	9.5	0.92	5.7	0.58	10.5	0.99	16.1	1.73
11	6.6	0.56	7.3	0.57	9.4	0.8	10.2	1.12	10.6	0.99	6.8	0.65	11.6	1.05	16.8	1.9
12	7.3	0.61	8.1	0.61	10.9	0.99	11.2	1.13	11.9	1.12	7.8	0.65	12.5	1.11	17.4	0.75
13	8.1	0.68	9	0.71	12.2	1	12.2	1.17	12.9	1.19	8.8	0.73	13.6	1.18	18.2	0.85
14	9.2	0.89	9.9	0.81	13.5	1.22	13.3	Jan-3 1	14	1.27	10	0.91	14.8	1.26	18.5	0.97

Table 1: Age (years) of attainment of mineralization stages of teeth of the male mandible.

Staging	Incisors				Canine		Premolars				Molars					
	Central		Lateral		First		Second		First		Second		Third			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1									4.2	0.7			3.7	0.37	9.4	1.55
2									3.8	0.57			4.1	0.52	10.1	1.57
3							3.4	0.09	4.3	0.59			4.6	0.51	10.6	1.49
4							3.7	0.28	4.7	0.6			5.1	0.56	11.3	1.58
5					3.6	0.13	4.3	0.48	5.2	0.65			5.7	0.57	11.9	1.56
6	3.6	0.2	3.7	0.28	4.1	0.49	5	0.54	5.9	0.74			6.3	0.66	12.8	1.63
7	3.7	0.29	4.3	0.45	4.8	0.52	5.8	0.63	6.7	0.76	3.6	0.27	7.2	0.74	13.7	1.66
8	4.3	0.41	5	0.5	5.6	0.58	6.6	0.67	7.5	0.82	4	0.45	8.1	0.74	14.5	1.52
9	4.6	0.4	5.2	0.5	5.9	0.6	7	0.68	7.8	0.83	4.6	0.45	9	0.79	15.4	1.56
10	5.3	0.44	5.9	0.53	6.9	0.68	7.9	0.76	8.6	0.91	5.3	0.55	10	0.86	16.3	1.4
11	6.1	0.52	6.7	0.6	8.1	0.79	8.9	0.81	9.6	1.02	6.3	0.6	11	0.93	17.3	1.41
12	6.7	0.53	7.3	0.69	9.2	0.8	9.9	0.86	10.6	1.06	7.2	0.65	11.8	0.91	17.7	1.44
13	7.3	0.65	8	0.74	10.3	0.85	10.9	0.93	11.6	1.12	8.2	0.71	12.6	0.98	18.2	1.62

14	8.1	0.77	8.8	0.78	11.4	0.92	11.9	1.03	12.8	1.25	9.3	0.75	13.8	1.28	18.3	2.23
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Table 2: Age (years) of attainment of mineralization stages of teeth of the female mandible.

Staging	Incisors				Canine		Premolars				Molars					
	Central		Lateral		First		Second		First		Second		Third			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1									3.6	0.31			3.8	0.44	9.5	1.45
2									3.8	0.42			4.2	0.53	10.2	1.45
3							3.8	1.88	4.2	0.5			4.8	0.53	10.8	1.46
4					3.6	0.16	4	1.17	4.8	0.48			5.3	0.58	11.5	1.51
5			3.7	0.23	3.9	0.43	4.9	1.03	5.5	0.56			5.9	0.62	12.4	1.59
6	3.7	0.28	4	0.48	4.9	0.53	5.8	1	6.3	0.65	3.8	0.3	6.7	0.72	13.3	1.58
7	4.1	0.49	5	0.54	5.8	0.61	6.9	1	7.2	0.7	3.7	0.28	7.6	0.78	14.2	1.54
8	5	0.52	6	0.61	6.6	0.66	7.8	1	8.3	0.83	4.3	0.4	8.5	0.8	14.8	1.44
9	5.3	0.53	6.3	0.62	7	0.67	8.1	0.98	8.6	0.84	4.9	0.43	9.5	0.85	15.5	1.25
10	6.3	0.66	7.2	0.7	8.2	0.76	9	0.96	9.6	0.91	5.8	0.57	10.6	0.92	16.2	1.21
11	7.4	0.75	8.2	0.74	9.6	0.82	10	1.01	10.6	0.98	6.8	0.64	11.5	1	17	1
12	8.3	0.79	9.1	0.76	11.1	0.95	11.1	1.01	11.6	1.07	7.8	0.71	12.4	1.07	17.4	0.81
13	9.4	0.9	10	0.79	12.3	1.06	12.2	1.08	12.5	1.11	8.9	0.88	13.4	1.2	18	0.93
14	10.6	1.05	11.1	0.91	13.7	1.28	13.5	1.26	13.8	1.27	10.01	1.02	14.6	1.28	18.2	0.93

Table 3: Age (years) of attainment of mineralization stages of teeth of the male maxilla.

Staging	Incisors				Canine		Premolars				Molars					
	Central		Lateral		First		Second		First		Second		Third			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1									4	0.56			3.7	0.41	9.2	1.38
2									3.8	0.48			4.2	0.54	9.9	1.36
3							3.4	0.1	4.3	0.57			4.6	0.52	10.5	1.37
4							3.7	0.26	4.7	0.6			5.1	0.57	11.1	1.42
5			3.6	0.15	3.6	0.13	4.4	0.46	5.3	0.68			5.6	0.58	11.8	1.43
6	3.6	0.14	3.8	0.4	4.1	0.49	5.1	0.56	5.9	0.65			6.3	0.66	12.7	1.49
7	3.8	0.38	4.5	0.51	4.9	0.57	5.8	0.59	6.8	0.72	3.6	0.27	7.1	0.74	13.6	1.57
8	4.6	0.41	5.2	0.56	5.6	0.61	6.6	0.66	7.7	0.81	4	0.44	8.1	0.76	14.4	1.55
9	4.9	0.41	5.5	0.57	5.9	0.63	6.9	0.67	8	0.81	4.6	0.44	9	0.81	15.1	1.38
10	5.7	0.49	6.3	0.61	7	0.72	7.8	0.73	8.8	0.8	5.4	0.56	10	0.85	16.1	1.39
11	6.6	0.62	7.3	0.7	8.2	0.76	8.7	0.8	9.7	0.86	6.3	0.62	11	0.93	16.9	1.24
12	7.4	0.76	8.1	0.73	9.4	0.81	9.7	0.9	10.6	0.9	7.2	0.67	11.8	1.02	17.7	1.07

13	8.2	0.78	8.8	0.77	10.6	0.86	10.6	0.9	11.5	1.01	8.2	0.68	12.6	1.11	18.4	1
14	9.3	0.8	9.7	0.83	11.9	1.04	11.8	0.96	12.6	1.1	9.2	0.74	13.6	1.27	18.8	0.7

Table 4: Age (years) of attainment of mineralization stages of teeth of the female maxilla.

Materials and Methods

The study sample consisted of 104 randomly selected OPGs (50 males and 54 females) of age ranging from 6 to 17 years with known date of birth (of Indian descent and parents of each subject having same ethnicity) divided into eleven groups according to age (Table 5). Initial screening was done to satisfy the inclusion criteria namely: children of age between 6-17 years with known date of birth, children free of developmental anomalies, OPGs without any distortions. Radiographs with, developmental anomalies, bilaterally missing teeth in maxilla and mandible were excluded from the study. All the radiographs were collected from the archive of Department Oral Medicine and Radiology, JSS Dental College and Hospital, JSS Academy of Higher Education and research, Mysore, Karnataka, India which were taken with PROMAX digital Planmeca Machine (Planmeca OY, Asentajankatu 6, FIN-00880 Helsinki, Finland).

Assessment of dental age using Anderson method

Chronological age (actual age) of an individual was calculated by subtracting the birth date from the date on which the radiographs were exposed for that particular individual. Digital panoramic radiographs (Orthopantomograms {OPGs}) of all children were used to assess the status of maturation on the basis of calcification of the permanent teeth on the left side of maxillary and mandibular arches, from central incisor to the third molar. To avoid observer bias, each digital OPG of an individual was coded with a numerical identity number (1-104) to ensure blinding to age of the subjects. Staging were given according to Moorrees method of 14 staging system in which the labeling nomenclature were changed by Anderson from Ci, Cco, Coc,...Ac etc.

to numbering system from stages “1” through “14” and criteria for each of those staging for each tooth were given separately (Table 6). 40 radiographs were selected randomly for self-training purpose and to provide proper staging system by repeating the observations at one week interval for four weeks.

Age groups	Males (N)	Females (N)	Total (N)
6-6.99	5	5	10
7-7.99	4	5	9
8-8.99	5	5	10
9-9.99	3	5	8
10-10.99	4	6	10
11-11.99	4	6	10
12-12.99	7	2	9
13-13.99	3	7	10
14-14.99	5	5	10
15-15.99	5	4	9
16-16.99	5	4	9
Total	50	54	104

Table 5: Distribution of entire sample according to age and sex.

Single rooted teeth stages			Descriptors	Multirooted teeth stages		
	Ci	1	Initial cusp formation: Mineralization of cusp tips has begun	Ci	1	
	Cco	2	Coalescence of cusps: Mineralization centers are beginning to unite	Cco	2	
	Coc	3	Mineralized cusp outline is complete	Coc	3	
	Cr ½	4	½ of estimated crown mineralization is complete	Cr ½	4	

	Cr ¼	5	¼ of estimated crown mineralization is complete	Cr ¼	5	
	Crc	6	Crown mineralization complete; but, root formation has not begun	Crc	6	
	Ri	7	Initial root formation	Ri	7	
-	-	-	Initial cleft formation: Mineralization visible in inter-radicular area	Cli	8	
	R ¼	8	¼ of estimated root formation is complete	R ¼	9	
	R ½	9	½ of estimated crown mineralization is complete	R ½	10	
	R ¾	10	¾ of estimated crown mineralization is complete	R ¾	11	
	Rc	11	Root length complete: Apex remains funnel shaped	Rc	12	
	A ½	12	Apex is ½ closed: Root walls are parallel	A ½	13	

	Ac	13	Apical closure is complete	Ac	14	
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Table 6: Developmental staging descriptors.

After noting all mineralization stages of each tooth from central incisor to the third molar on left side of maxillary and mandibular arches, the mean age were given in year for each staging of teeth from sex specific table of Anderson method [12]. All the mean dental age values from central incisor to third molar of maxillary arch and mandibular arch thus obtained were summed and average was taken to obtain an overall mean age separately for maxillary and mandibular arch but the tooth with staging 14 were omitted from determination of dental age taking into consideration that staging 14 denotes fully matured and calcified tooth which can decelerate the dental age and plays no role for age estimation.

After getting dental age for maxillary and mandibular arches separately, again the average mean age were taken combining both maxillary and mandibular arches as it is given in equation;

$$\text{Age} = \frac{\text{Sum of mean ages of each tooth}}{\text{Total number of teeth assessed}}$$

In this way dental age of the cases were obtained for maxillary arch, mandibular arch and for combining both maxillary and mandibular arches. To test inter-examiner variability, 22 OPG images one from each age group for male and female separately were re-evaluated by my guide after one month from which, good acceptable variability were found.

Data were analyzed by Statistical Package for the Social Sciences Computer Software (SPSS, version 20.0, SPSS Inc., Chicago, IL, USA) using Pearson's Chi-square test, $p < 0.05$ was considered to be significant.

The differences between dental age (estimated age) and chronological age (actual age) of maxillary, mandibular, both maxillary and mandibular arches for all age group together and in different age groups in both sexes were tabulated using descriptive statistics keeping the confidence interval limits at 95%, with the minimum marginal error to 1% (to estimate the difference of at least 1 year between the chronological age and the dental age), the difference were compared using ANOVA test and stepwise multiple regression was applied to find out which of the tooth best predicts.

Results

Comparison of the dental age applying the Anderson method, the chronological age (actual age) and differences between dental age (estimated age) and chronological age of maxillary arch, mandibular arch and both maxillary and mandibular arches along with both genders and age groups are presented in Tables 7-11.

Arches	N	CA		DA		CA-DA		95% CI CA-DA		t value	p value	r value
		Mean	SD	Mean	SD	Mean	SD	Lower	Upper			
Maxillary	50	11.51	3.21	11.12	3.25	0.39	0.86	0.14	0.63	3.18	0.01*	0.964
Mandibular	50	11.51	3.21	11.51	3.3	-0.01	0.87	-0.25	0.24	-0.03	0.97	0.964
Max and Mand	50	11.51	3.21	11.32	3.27	0.19	0.84	-0.04	0.43	1.62	0.11	0.967

Table 7: Paired t test between chronological age and dental age of maxillary, mandibular, maxillary and mandibular arches according to Anderson's method for South Indian males with the mean difference between both (* $p < 0.05$ is statistically significant. N: Number; CA: Chronological age; DA: Dental age; CI: Confidence interval; SD: Standard deviation).

Arches	N	CA		DA		CA-DA		95% CI CA-DA		t value	p value	r value
		Mean	SD	Mean	SD	Mean	SD	Lower	Upper			
Maxillary	54	11.15	3.07	10.67	3.11	0.47	1.04	0.19	0.76	3.36	0.01*	0.943
Mandibular	54	11.15	3.07	11.23	3.24	-0.08	0.88	-0.32	0.15	-0.73	0.46	0.962

Max and Mand	54	11.15	3.07	10.95	3.15	0.19	0.86	-0.04	0.43	1.66	0.1	0.962
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Table 8: Paired t test between chronological age and dental age of maxillary, mandibular, maxillary and mandibular arches according to Anderson's method for South Indian females with the mean difference between both (*p<0.05 is statistically significant. N: Number; CA: Chronological age; DA: Dental age; CI: Confidence interval; SD: Standard deviation).

Age group	Sex	N	CA		DA		CA-DA		95% CI CA-DA		t value	p value
			Mean	SD	Mean	SD	Mean	SD	Lower	Upper		
6-6.99	M	5	6.46	0.36	5.95	1.05	0.51	0.77	-0.45	1.47	1.46	0.21
	F		6.28	0.21	6.4	0.87	-1.2	0.87	-1.2	0.96	-0.308	0.77
		5										
7-7.99	M	4	7.37	0.3	7.28	1.07	0.08	1.2	-1.83	2	0.14	0.89
	F		7.26	0.24	7.32	1.03	-0.05	0.92	-1.21	1.09	-0.14	0.89
		5										
8-8.99	M	5	8.42	0.36	8.48	0.79	-0.06	0.94	-1.23	1.11	-0.14	0.89
	F		8.52	0.35	7.94	0.56	0.57	0.72	-0.33	1.47	1.75	0.15
		5										
9-9.99	M	3	9.5	0.26	8.75	0.48	0.74	0.22	0.19	1.29	5.83	0.02*
	F		9.34	0.27	9.08	0.59	0.25	0.4	-0.25	0.75	1.39	0.23
		5										
10-10.99	M	4	10.35	0.4	9.94	1.01	0.4	1.25	-1.58	2.39	0.65	0.56
	F		10.5	0.28	9.41	0.26	1.08	0.33	0.73	1.42	8.03	0.00*
		6										
11-11.99	M	4	11.7	0.23	10.78	0.4	0.91	0.26	0.49	1.33	6.95	0.00*
	F		11.36	0.27	10.41	0.36	0.95	0.48	0.44	1.46	4.82	0.00*
		6										
12-12.99	M	7	12.18	0.18	12.12	0.4	0.05	0.34	-0.26	0.37	0.44	0.67
	F		12.3	0.28	12.58	0.72	-0.28	1	-9.34	8.76	-0.4	0.75
		2										
13-13.99	M	3	13.1	0.1	12.6	0.29	0.49	0.23	-0.09	1.08	3.62	0.06
	F		13.2	0.31	12.35	0.31	0.84	0.47	0.4	1.28	4.7	0.00*
		7										
14-14.99	M	5	14.38	0.34	13.56	0.59	0.81	0.35	0.37	1.25	5.17	0.00*
	F		14.1	0.1	13.19	0.57	0.9	0.61	0.14	1.66	3.3	0.03*
		5										
15-15.99	M	5	15.52	0.35	15.17	1.62	0.34	1.53	-1.56	2.24	0.49	0.64
	F		15.2	0.11	15.62	1.59	-0.42	1.63	-3.01	2.17	-0.51	0.64
		4										

16-16.99	M	5	16.2	0.29	15.85	0.99	0.35	1.24	-1.19	1.89	0.63	0.56
	F		16.4	0.34	15.83	2.83	0.56	2.7	-3.74	4.87	0.41	0.7
		4										

Table 9: Paired t test on different age groups between chronological age and dental age of maxillary arch according to Anderson's method for South Indian males and females with the mean difference between both (*p < 0.05 is statistically significant. N: Number; CA: chronological age; DA: dental age; CI: confidence interval; SD: standard deviation).

Age group	Sex	N	CA		DA		CA-DA		95% CI CA-DA		t value	p value
			Mean	SD	Mean	SD	Mean	SD	Lower	Upper		
6-6.99	M	5	6.46	0.36	6.39	0.74	0.06	0.45	-0.5	0.63	0.33	0.75
	F		6.28	0.21	6.78	0.45	-0.5	0.45	-1.07	0.07	-2.42	0.07
		5										
7-7.99	M	4	7.37	0.3	7.79	1.19	-0.41	1.36	-2.58	1.75	-0.6	0.58
	F		7.26	0.24	7.55	1.01	-0.29	0.89	-1.41	0.82	-0.73	0.5
		5										
8-8.99	M	5	8.42	0.36	8.63	0.8	-0.21	0.88	-1.31	0.88	-0.53	0.62
	F		8.52	0.35	8.36	0.77	0.15	0.88	-0.93	1.25	0.4	0.7
		5										
9-9.99	M	3	9.5	0.26	9.14	0.46	0.35	0.29	-0.37	1.09	2.09	0.17
	F		9.34	0.27	9.9	0.42	-0.56	0.23	-0.86	-0.27	-5.3	0.01*
		5										
10-10.99	M	4	10.35	0.4	9.95	1.07	0.39	1.33	-1.73	2.52	0.59	0.59
	F		10.5	0.28	9.83	0.36	0.66	0.44	0.19	1.13	3.67	0.01*
		6										
11-11.99	M	4	11.7	0.23	11.55	0.8	0.14	0.66	-0.91	1.19	0.42	0.69
	F		11.36	0.27	11.13	0.47	0.23	0.6	-0.39	0.87	0.96	0.37
		6										
12-12.99	M	7	12.18	0.18	12.4	0.66	-0.21	0.6	-0.77	0.34	-0.93	0.38
	F		12.3	0.28	12.85	0.42	-0.55	0.7	-6.9	5.8	-1.1	0.47
		2										
13-13.99	M	3	13.1	0.1	12.88	0.06	0.22	0.05	0.09	0.34	7.33	0.02*
	F		13.2	0.31	12.63	0.35	0.56	0.5	0.1	1.03	2.97	0.02*
		7										
14-14.99	M	5	14.38	0.34	13.56	0.59	0.81	0.35	0.37	1.25	5.17	0.00*
	F		14.1	0.1	13.91	0.55	0.19	0.59	-0.54	0.92	0.72	0.51
		5										
15-15.99	M	5	15.52	0.35	15.73	1.21	0.21	1.07	-1.54	1.12	-0.43	0.68

	F		15.2	0.11	16.1	1.72	-0.89	1.74	-3.67	1.88	-1.08	0.38
		4										
16-16.99	M	5	16.2	0.29	16.33	1.35	-0.13	1.6	-2.12	1.86	-0.18	0.86
	F		16.4	0.34	17.5	0.9	-1.1	0.7	-2.22	0.02	-3.11	0.05
		4										

Table 10: Paired t test on different age groups between chronological age and dental age of mandibular arch according to Anderson's method for South Indian males and females with the mean difference between both (*p<0.05 is statistically significant. N: Number; CA: chronological age; DA: dental age; CI: confidence interval; SD: standard deviation).

Age group	Sex	N	CA		DA		CA-DA		95% CI CA-DA		t value	p value
			Mean	SD	Mean	SD	Mean	SD	Lower	Upper		
6-6.99	M	5	6.46	0.36	6.17	0.89	0.28	0.60	-0.46	1.04	1.06	0.34
	F	5	6.28	0.21	6.59	0.60	-0.31	0.61	-1.07	0.45	-1.13	0.32
7-7.99	M	4	7.37	0.30	7.53	1.13	-0.16	1.28	-2.20	1.87	-0.25	0.81
	F	5	7.26	0.24	7.55	1.01	-0.29	0.89	-1.41	0.82	-0.73	0.50
8-8.99	M	5	8.42	0.36	8.55	0.77	-0.13	0.90	-1.25	0.98	-0.34	0.75
	F	5	8.52	0.35	8.15	0.64	0.36	0.77	-0.60	1.33	1.04	0.35
9-9.99	M	3	9.50	0.26	8.94	0.44	0.55	0.20	0.03	1.06	4.61	0.04*
	F	5	9.34	0.27	9.49	0.47	-0.15	0.26	-0.48	0.16	-1.35	0.24
10-10.99	M	4	10.35	0.40	9.95	1.03	0.40	1.28	-1.64	2.44	0.62	0.57
	F	6	10.50	0.28	9.62	0.30	0.87	0.37	0.47	1.26	5.69	0.00*
11-11.99	M	4	11.70	0.23	11.17	0.57	0.52	0.42	-0.14	1.20	2.50	0.08
	F	6	11.36	0.27	10.77	0.40	0.59	0.53	0.03	1.16	2.71	0.04*
12-12.99	M	7	12.18	0.18	12.26	0.50	-0.07	0.43	-0.48	0.32	-0.47	0.65
	F	2	12.30	0.28	12.71	0.57	-0.41	0.85	-8.12	7.28	-0.69	0.61
13-13.99	M	3	13.10	0.10	12.74	0.17	0.35	0.12	0.04	0.66	4.97	0.03*
	F	7	13.20	0.31	12.49	0.26	0.70	0.44	0.29	1.11	4.18	0.00*
14-14.99	M	5	14.38	0.34	13.82	0.40	0.55	0.23	0.26	0.85	5.28	0.01*
	F	5	14.10	0.10	13.55	0.55	0.54	0.59	-0.19	1.28	2.06	0.10
15-15.99	M	5	15.52	0.35	15.45	1.39	0.06	1.28	-1.52	1.65	0.11	0.91
	F	4	15.20	0.11	15.86	1.65	-0.66	1.68	-3.34	2.02	-0.78	0.49
16-16.99	M	5	16.20	0.29	16.09	1.16	0.11	1.41	-1.64	1.86	0.17	0.87
	F	4	16.40	0.34	16.66	1.43	-0.26	1.24	-2.24	1.71	-0.43	0.69

Table 11: Paired t test on different age groups between chronological age and dental age of maxillary and mandibular arch according to Anderson's method for South Indian males and females with the mean difference between both (*p<0.05 is statistically significant. N: Number; CA: chronological age; DA: dental age; CI: confidence interval; SD: standard deviation).

The present study showed a significant correlation between chronological age (actual age) and dental age (estimated age) in both males (maxillary arch: r=0.964; mandibular arch: r=0.964; maxillary and mandibular arch: r=0.967) and females (maxillary arch: r=0.943; mandibular arch: r=0.962; maxillary and mandibular arch: r=0.962).

The independent samples test results indicated that the mean chronological age (actual age) was 11.33 years for maxillary arch, mandibular arch, both maxillary and mandibular arches and the mean dental age (estimated age) was 10.89 years for maxillary arch, 11.37 years for mandibular arch, 11.13 years for both maxillary and mandibular arches. These means indicated an under aging of the entire sample for maxillary arch by 0.43 years, for combining both maxillary and mandibular arches by 0.19 years but in case of mandibular arch for entire sample the mean dental age was found near to Anderson method (i.e., 0.04 years) (Figure 1).

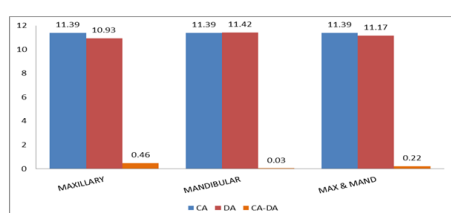


Figure 1: Mean difference (CA-DA) between mean chronological age (CA) and dental age (DA) of maxillary, mandibular, maxillary and mandibular arches according to Anderson's method for entire sample.

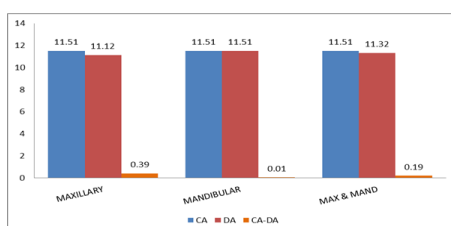


Figure 2: Mean difference (CA-DA) between mean chronological age (CA) and dental age (DA) of maxillary, mandibular, maxillary and mandibular arches according to Anderson's method for Males.

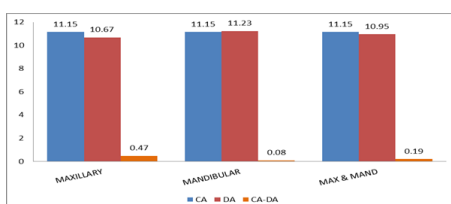


Figure 3: Mean difference (CA-DA) between mean chronological age (CA) and dental age (DA) of maxillary, mandibular, maxillary and mandibular arches according to Anderson's method for females.

The mean age difference between dental age (estimated age) determined using the Anderson method (from the Burlington, Canada, Caucasian population) and the chronological age (actual age) of this Indian population was 0.39 ± 0.86 years for maxillary arch, 0.01 ± 0.87 years for mandibular arch, 0.19 ± 0.84 years combining both maxillary and mandibular arches in case of males and 0.47 ± 1.04 years for maxillary arch, 0.08 ± 0.88 years for mandibular arch, 0.19 ± 0.86

years combining both maxillary and mandibular arches in case of females (Figures 2 and 3).

Independent t-test showed that the differences of maxillary arches were statistically significant ($p < 0.05$) and the differences of mandibular arches and combining both maxillary and mandibular arches were statistically not significant ($p > 0.05$) (for both males and females).

In males, the greatest underestimation for maxillary arch was found in 15-16 year old age group followed by 10-11, 16-17 and 7-8 year age groups; for mandibular arch was found in 10-11 year of age group; for both maxillary and mandibular arches was found in 16-17 year old age group followed by 10-11 and 15-16 year age groups and the greatest overestimation for mandibular arch was found in 16-17 followed by 7-8 year old age group; for both maxillary and mandibular arches was found only in 7-8 year of old age group but in case of maxillary arch such overestimation was not found. In females, the greatest underestimation was found only in 16-17 year of age group of maxillary arch whereas in case of mandibular arch and combining both maxillary and mandibular arches such underestimation was not found and the greatest overestimation for all three parameters was found in age group of 15-16 year (Tables 9-11).

Discussion

Although the mineralization stages of the teeth indicate physiologic development [13,14] more than chronological age, the dental mineralization stages are closely related to chronological age. Dental mineralization is a better measure of chronological age than is skeletal mineralization because tooth formation is modified much less by malnutrition and hormone imbalance [15-17]. OPGs are the most suitable radiographic technique for the evaluation of mineralization of teeth to access age in children because a single radiograph gives the complete developmental status of dentition in children and also for the comparison of antemortem and post-mortem data in case of unidentified body.

There are different dental age estimation methods for children and adolescents like Demirjian method, Nolla method, Shour and Massler method, Moorrees method, Willems method etc. and as the time of need those dental age estimation methods were modified for population specific data. But till date no studies were found on Anderson method which was published in 1976. While doing age estimation of any cases either living or dead, the first one thing comes to our mind is accuracy, whether the method we are applying can give us good age estimation with less standard deviation or error. By our study we felt that we are really missing the age estimation method which can give us good accuracy for dental age estimation of children and adolescents i.e., Anderson method. The investigator must use more number of different methods and must perform repetitive practicing of staging system and calculations so as to improve the accuracy of age estimation.

When comparison among genders is done, females mature earlier than males, however in the present study Anderson method was better applied for both sexes. In the present study it was observed that between the children (6 to 18 years) of India and the town of Burlington, Canada, the difference in tooth maturation was not much.

When stepwise multiple regressions were applied to find out which of the tooth best predicts the chronological age (actual age), following results were obtained. Out of 16 teeth the first teeth to predict chronological age was mandibular left third molar with contribution of

62.3%, the second tooth along with the first tooth to predict chronological age was maxillary left second premolar with the combined contribution of 69.9% and at third step along with previous two teeth, the third tooth to enter into equation was mandibular left first molar with combined contribution of 73.3%. The fourth tooth to enter into the equation was mandibular left second molar along with previous three teeth within the total contribution of 74.8%.

It should be clear that omission of fully developed or matured tooth i.e., stage 14 and taking averages of mean ages of maxillary and mandibular arches teeth was applied in this study only but not in Anderson's original study, only they have given as mean ages for each tooth according to staging of each tooth. As Anderson et al. has used Moorrees et al. fourteen staging system, the study shows much more good accuracy because of fourteen staging system which give minute details of teeth development or maturation. Compared to other staging system for dental age estimation methods like Nolla et al. used ten developmental staging and Demirjian et al. used eight developmental staging which shows that minute details of tooth development may not be recorded which are affecting the accuracy for age estimation. And also Anderson et al. study is the first study that has included all the maxillary and mandibular teeth along with third molars for age estimation.

In case if the tooth was not present on the left side of jaw, the tooth present on the right side was assessed taking into consideration that bilaterally symmetrical teeth achieve each stage at a similar age [1-5]. For staging the development of maxillary teeth was found quite difficult due to the superimposition of teeth which made the accuracy quite compromised compare to mandibular arch. Staging of maxillary third molars should be graded carefully as the fusion of two roots may be present. Moreover, it is equally important to realize that no age estimation will accurately determine the exact age for every individual since development naturally varies between individuals. Most important aspect of dental age estimation is to remember that one should not restrict to only one age estimation technique, but to apply different techniques available and perform repetitive practicing of staging system and calculations.

Conclusion

Anderson method was found much more reliable method of dental age estimation in children and adolescents of Indian population which showed significant relation between dental age and chronological age. As this method defines the teeth development in 14 stages and all 8 teeth are included of each arch, the more accuracy was observed. This method can be implicated for living individuals (e.g., crime investigation, marriage, child labor) as well as for dead individuals (dental age estimation). As no published data is available regarding the application of Anderson method in selected population, this paper provides an insight in using Anderson method in Indians for estimating dental age. This is second study in whole world till date as we were not able to find such similar study in any literature. So it can be one of the

major dental age estimation method in children and adolescents in upcoming days.

Declarations of Interest

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