Original Article

Age determination in children by orthopantomograph and lateral cephalogram: A comparative digital study

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Abstract

Background and Aims: The assessment of age is useful in forensic medicine and forensic odontology and in treatment planning in various branch of dentistry. The aim of study is comparative evaluation and assessment of applicability of Demirjian's method, Willem's method of dental age (DA) estimation, and Maria de Paula Caldas's method of skeletal age estimation for children aged 9–16 years. **Materials and Methods:** A total of 140 individuals (70 females and 70 males) between the age group of 9–16 years were enrolled. These individuals were grouped by a difference of 1 year into 7 groups (each group comprising of 20 individuals: 10 males and 10 females)**.** Dental age estimation was performed from orthopantomograph images of mandibular teeth of left quadrant by both Demirjian's and Willem's methods. Skeletal age estimation was done from Lateral Cephalogram by Caldas Digital Method. The differences between the chronological age and the estimated dental and skeletal ages were statistically tested using paired *t*-test. **Results:** Demirjian's DA estimation overestimated males (0.4040 years) and females (0.1316 years). Willem's DA estimation method underestimated males (0.1386 years) and females (0.4210 years) and Caldas skeletal age estimation overestimated males (0.2982 years) and females (0.4259 years). **Conclusion:** The study concluded Willem's DA estimation method was the most accurate for male and Demirjian's method for female for Gujarati Population. Caldas's new computer-assisted method for skeletal age estimation used in the present study is easy to perform and less time-consuming and objective method and can be applied for Gujarati population.

Key words: Demirjian's method, dental age estimation, skeletal age estimation, Willem's method

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Introduction

Various modalities are available in the assessment of age of a person such as skeletal and dental changes. Chronological age (CA) refers to period that has elapsed beginning with an individual's birth and extending to

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any given point in time. Skeletal age is used to describe the maturation stages by using growth spurts. Based on radiographic examination of skeletal development of hand–wrist and cervical vertebrae, bone age is assessed and then compared with the CA. A discrepancy between these two values indicates abnormalities in skeletal development. Dental age (DA) refers the period that elapsed from formation of tooth buds and emergence of tooth up to the given period of time. It is the one of the few measures of physiological development that is uniformly applicable from infancy to late adolescence. After attaining maturity teeth continue to undergo changes, making age estimation possible among adults.[1,2]

Determination of maturation and subsequent evaluation of growth potential during preadolescence or adolescence is extremely important. CA is regarded as a poor indicator of the skeletal development due to significant individual variability. Assessing skeletal maturity require visual inspection of the developing bones– their initial appearance and their subsequent ossification-related changes in shape and size. Various areas of the skeleton have been used: foot, ankle, hip, elbow, hand–wrist, and the cervical vertebrae. It is well known that the lateral view of the cervical vertebral bodies' changes with growth.[3]

In recent years, evaluation of the cervical vertebrae has been increasingly used to determine skeletal maturation. Recognizing skeletal developmental stages from cephalometric radiographs is very useful to assess physiologic maturity without resorting to any special radiograph. Many authors found that cervical vertebrae could offer an alternative method for assessing maturity without the need of hand–wrist radiographs. However, cervical vertebrae have been used to evaluate growth in a subjective manner because they have used only a qualitative comparison between the patient images and those from atlases.[4]

The last physiologic measure is dental maturity, which can be determined by the stage of tooth eruption or the stage of tooth formation. The latter is proposed as a more reliable criterion for determining dental maturation.

Ogodescu *et al*., Urzel and Bruzek, Djukic *et al*., Ambarkova *et al*., Ye *et al*., Patel *et al*., and Gupta *et al*. (2015) concluded that there was overestimation of age in male and female by Demirjian's method.[5-10]

Willems *et al*., Franco *et al*., Mohammed *et al*., and Gupta *et al*. (2015)[10-13] concluded that there was underestimation of age in male and female by Willem's method.

Caldas Mde *et al*. (2010)[14] concluded that there was overestimation of age in male and female by new computer assisted cervical vertebrae maturation (CVM) method.

Racial variations in the relationships have been suggested therefore the objective of this study is to investigate the relationships between the stages of calcification of various teeth and skeletal maturity stages among children in dental OPD.

Materials and Methods

A study was undertaken in the department of OMR, GDCH during 2016–2018. This study was approved by the institutional Ethics Committee of GDCH (ethical approval no IEC GDCH/OMR.3/2017) and is in accordance with its later amendments or comparable ethical standards. A total of 140 individuals (70 girls and 70 boys) between the age group of 9–16 years were enrolled. These individuals were grouped by a difference of 1 year into 7 groups (each group comprising of 20 individuals: 10 males and 10 females).

The inclusion criteria were a full complement of mandibular permanent teeth (erupted or unerupted), nonsyndromic children, patients with normal growth and development, cephalometric and panoramic radiographs with high clarity and good contrast. The exclusion criteria were history of trauma or injury to face, head and neck, congenital anomalies, dental abnormalities, history of mandibular left permanent teeth extractions, gross dental pathology affecting mandibular dentition, any local or systemic disorder affecting the development and eruptive pattern of permanent dentition, patients already treated or taking treatment from Orthodontics department.

Chronological age

CA was calculated by subtracting the date of the birth (taken from valid government document) from the date of the panoramic radiograph after having converted both to a decimal age.

For every individual included in the study, a panoramic radiograph (orthopantomograph [OPG]) and lateral cephalogram were taken with standard parameters and adequate protective measures. The interpretation of the panoramic radiographs was done. The OPGs were analyzed for the developmental stages of teeth according to the criteria given by both the Demirjian's method and the Willem's method. All cephalometric radiographs were traced by using Planmeca software (LANMECA PROLINE XC, Finland).

Age estimation

All assessments were performed by one investigator in a darkened room with a radiographic illuminator to ensure contrast enhancement of the tooth images. To avoid the examiner bias at the time of collecting data, CA was first recorded on a data collection sheet and the DA scores were tabulated later on a separate sheet.

Dental age (Demirjian's Method)[15]

The development of each left permanent mandibular tooth, except the third molar, was rated on an 8-stage scale from A to H, and the criteria for the stages were given for each tooth separately. Each stage of the seven teeth was allocated a score, and the sum of the scores gave an evaluation of the individual's dental maturity, measured on a scale from 0 to 100. The dental maturity score of each individual was then converted to DA by using standard tables and/or percentile curves which were given for each gender, separately [Figure 1].

Dental age (Willem's Method)[11]

The development of each left permanent mandibular tooth, except the third molar, was rated on an 8-stage scale from A to H, and the criteria for the stages were given for each tooth separately using Demirjian *et al*. After noting all stages of teeth from central incisor to the second molar by the examiners, the developmental status of a particular tooth was calculated in years on the basis of tables given by Willems *et al*. All the values from central incisor to the second molar thus obtained were summed to obtain an overall maturity score, which will indicate the DA of that particular patient [Figure 1].

Skeletal Age (Caldas Mde *et al*. method)[14]

All cephalometric radiographs were traced using Planmeca software by the same operator. On the digital lateral cephalograms, anatomical landmarks were marked on the third and fourth cervical vertebrae given by Caldas Mde *et al*. [Figures 2 and 3].

Image improvement resources such as brightness control, inversion, pseudocoloring, and zoom could be used to make it easier to find each point. With the aid of these landmarks, the following measurements were automatically obtained:

- Anterior vertebral body height (AH)
- Vertebral body height (H)
- Posterior vertebral body height (PH)
- Anteroposterior vertebral body height (AP).

Cervical vertebral bone age was automatically calculated using the formulas developed by Caldas Mde *et al*. (2007).[4]

- Female cervical vertebral bone age = 1.3523 + 6.7691 × AH3/AP3 + 8.6408 × AH4/AP4
- Male cervical vertebral bone age = 1.4892 + 11.3736 AH3/AP3 + 4.8726 × H4/AP4.

Areas of cervical vertebral bodies measured on digital cephalometric radiographs. Lower lines are tangent to front and back of lower parts of cervical vertebral bodies. AH3, AH4, Distance from top of front part to tangent of lower part; H3, H4, distance from top of middle part to tangent of lower part; PH 3, PH 4, distance from top of back part to tangent of lower part; AP3, AP4: Anteroposterior distance at middle of cervical vertebral body.[4]

Intraobserver error was calculated according to Dahlberg's formula using 20 cephalometric radiographs and 20 OPG (10 males and 10 females) selected randomly from groups; these were traced and measured, and the same radiographs were measured again 10 days later.

Figure 1: Radiographic analysis using orthopantomograph dental calcification stages (Demirjian 1973) 31 = H, 32 = H, 33 = G, 34 = G, 35 = G, 36 = H, 37 = G

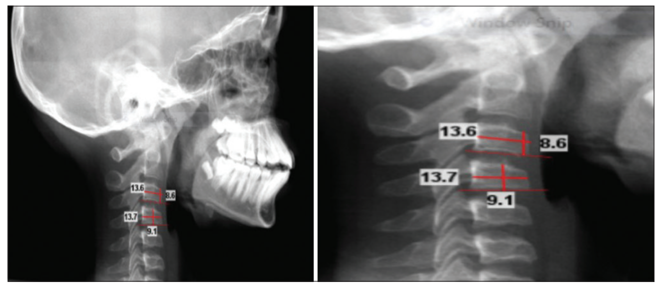

Figure 2: Radiographic analysis using lateral Cephalogram in male; AH3 = 8.6, AP3 = 13.6, H4 = 9.1, AP4 = 13.7

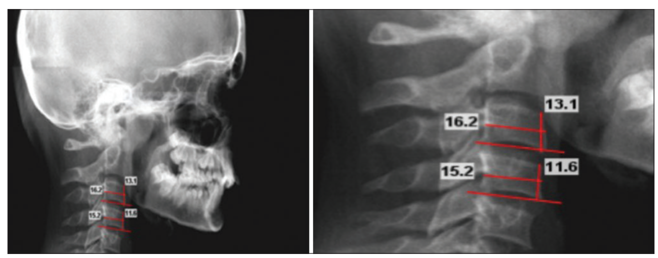

Figure 3: Radiographic analysis using Lateral Cephalogram in Female; AH3 = 13.1, AP3 = 16.2, AH4 = 11.6, AP4 = 15.2

Statistical analysis

Statistical Package for Social Sciences 20.0 (International Business Machines Corporation (IBM), Armonk, New York) was used for all analysis. The differences between the CA and the estimated dental and skeletal ages were statistically tested using paired *t*-test. In all these tests, $P > 0.05$ indicated no statistical difference between the age estimations and $P \leq 0.05$ indicated statistically significant difference between the age estimations under consideration. The correlation between CA, dental and skeletal age estimation methods was confirmed statistically by Pearson's correlation. In all these tests, *r* value closest to 1 was considered to indicate the strongest relation between the comparisons. The interobserver variability was tested using the Spearman Correlation Coefficient. The relation was considered strongest between the pair whose value was closest to 1.

The reproducibility of the estimations was statistically tested using the Pearson's Chi-square test. $P > 0.05$ indicated no statistically significant difference between the earlier and later estimations by the observers. Reliability of digital mode of DA and skeletal age estimation regression equation was also applied.

Results

Demirjian's method of DA estimation overestimated the age of male groups in all except in 9–9.99 year age group. Demirjian's method of DA estimation overestimated the age of female groups in all except in 10–10.99 and 14–15.99 year age groups [Table 1].

Willem's method of DA estimation underestimated the age of male in all age groups except in 10–11.99 and 15–15.99 year age groups. Willem's method of DA estimation underestimated the age of female in all age groups except in 11–11.99 year age group [Table 2].

Caldas's method of skeletal age estimation overestimated the age of male in all age groups except in 11–13.99 and 15–15.99 year age groups. Caldas's method of skeletal age estimation overestimated the age of female in all age groups except in 14–15.99 year age groups [Table 3].

The r value representative of Pearson correlation coefficient between CA and skeletal age by Caldas's method was 0.473 for male and 0.685 for female. The r value between CA and AH3, AP3, and AP4, H4 variables were 0.508, 0.329, 0.344 and 0.635, respectively, for male. The r value between CA and AH3, AP3, AH4 and AP4 Variables were 0.666, 0.391, 0.696 and 0.284 respectively for female [Table 4].

The r value between CA and DA by Demirjian's method (DAD) was 0.902 for male and 0.884 for female. In Willem's method (DAW) was 0.903 for male and 0.885 for female.

Table 5 demonstrates interobserver and intraobserver variability among observers A, B, and C regarding estimated values of DAD, DAW, and Caldas's method. The spearman rank Correlation coefficient of all three methods was close to 1. The r value for the Pearson's Chi-square test employed to evaluate intraobserver variability was 0.175 (>0.05).

A stepwise multiple regression analysis was developed to determine the formulas to obtain cervical vertebrae age of male and female sample using skeletal age as dependent variable AH3/AP3, AH4/AP4, H4/AP4 were independent variables.

Table 6 demonstrates reliability of digital mode of DA and skeletal age estimation Regression equation was calculated. For female, cervical vertebral bone age = 1.863 + 7.043 (AH3/AP3) +7.732 (AH4/AP4) and for male cervical vertebral bone age = 6.018 + 11.778 (AH3/AP3) +0.315 (H4/AP4) [Table 6].

Table 1: Comparison between chronologic age and dental age (Demirjian's method) in male and female (age in years)

Age groups	*n*	CA, mean (SD)		Demirjian's method, mean (SD)		*P*	
		Male	Female	Male	Female	Male	Female
9-9.99	20	9.3081 (0.1653)	9.503 (0.3612)	9.27 (0.857)	9.774 (1.033)	0.888	0.342
10-10.99	20	10.4892 (0.3594)	10.2872 (0.2351)	11.28 (1.16)	10.16 (0.948)	0.029	0.635
11-11.99	20	11.4661 (0.2706)	11.5331 (0.2776)	12.3 (1.051)	12.74 (0.847)	0.021	0.001
12-12.99	20	12.3307 (0.3346)	12.5905 (0.2303)	12.65 (0.899)	12.677 (1.081)	0.312	0.812
13-13.99	20	13.506 (0.3454)	13.6281 (0.2219)	13.83 (1.003)	13.87 (0.908)	0.323	0.476
14-14.99	20	14.5993 (0.3508)	14.5993 (0.3508)	14.86 (1.082)	13.88 (0.379)	0.508	0
15-15.99	20	15.3418 (0.2472)	15.5408 (0.3201)	15.68 (0.674)	15.26 (1.001)	0.25	0.433
Total	140	12.4344 (2.0632)	12.4913 (2.0598)	12.838 (2.239)	12.623 (2.068)	0.001	0.271

SD: Standard deviation, CA: Chronological age

Table 2: Comparison between chronologic age and dental age (Willem's method) in male and female (age in years)

Age groups	*n*	CA, mean (SD)		Willem's method, mean (SD)		*P*	
		Male	Female	Male	Female	Male	Female
9-9.99	20	9.3081 (0.1653)	9.503 (0.3612)	8.785 (0.707)	9.27 (0.817)	0.04	0.272
10-10.99	20	10.4892 (0.3594)	10.2872 (0.2351)	10.701 (1.265)	9.376 (1.319)	0.545	0.037
11-11.99	20	11.4661 (0.2706)	11.5331 (0.2776)	11.704 (1.207)	11.89 (1.11)	0.516	0.326
12-12.99	20	12.3307 (0.3346)	12.5905 (0.2303)	11.93 (1.06)	12.329 (0.849)	0.298	0.397
13-13.99	20	13.506 (0.3454)	13.6281 (0.2219)	13.071 (0.916)	13.337 (0.791)	0.152	0.344
14-14.99	20	14.5993 (0.3508)	14.5993 (0.3508)	13.932 (0.972)	13.272 (0.404)	0.078	0.001
15-15.99	20	15.3418 (0.2472)	15.5408 (0.3201)	15.948 (0.172)	15.018 (1.295)	0.001	0.26
Total	140	12.4344 (2.0632)	12.4913 (2.0598)	12.295 (2.341)	12.07 (2.189)	0.253	0.001

CA: Chronological age, SD: Standard deviation

Table 3: Comparison between chronologic age and skeletal age (Caldas's method) in male & female (age in years)

Age groups	*n*	CA, mean (SD)		Caldas method, mean (SD)		*P*	
		Male	Female	Male	Female	Male	Female
9-9.99	20	9.3081 (0.1653)	9.503 (0.3612)	11.7484 (0.7639)	11.4736 (0.9168)	0	0
10-10.99	20	10.4892 (0.3594)	10.2872 (0.2351)	12.7438 (2.6427)	11.8182 (0.5018)	0.019	0
11-11.99	20	11.4661 (0.2706)	11.5331 (0.2776)	11.135 (1.7076)	12.1366 (1.4142)	0.547	0.22
12-12.99	20	12.3307 (0.3346)	12.5905 (0.2303)	11.6442 (1.3559)	13.232 (1.4811)	0.153	0.192
13-13.99	20	13.506 (0.3454)	13.6281 (0.2219)	12.8704 (1.1471)	13.781 (0.8983)	0.109	0.596
14-14.99	20	14.5993 (0.3508)	14.5993 (0.3508)	15.1245 (2.4578)	13.458 (1.8087)	0.492	0.165
15-15.99	20	15.3418 (0.2472)	15.5408 (0.3201)	13.8626 (1.4096)	14.5213 (0.7913)	0.007	0.002
Total	140	12.4344 (2.0632)	12.4913 (2.0598)	12.7327 (2.1272)	12.9172 (1.5512)	0.25	0.026

CA: Chronological age, SD: Standard deviation

Table 4: Comparison of dental ages estimated by Demirjian's and Willem's methods and skeletal age estimated by Caldas's method with the standard of chronologic age of male and female

Variables	Pearson correlation in male		Pearson correlation in female	
CA	Correlation value	*P*	Correlation value	*P*
SA	0.473	≤0.05 (significant)	0.658	≤0.05 (significant)
AH3	0.508	≤0.05 (significant)	0.666	≤0.05 (significant)
AP3	0.329	≤0.05 (significant)	0.391	≤0.05 (significant)
AP4	0.344	≤0.05 (significant)	0.696	≤0.05 (significant)
H4	0.635	≤0.05 (significant)	0.284	≤0.05 (significant)
Dental age Demirjian	0.902	≤0.05 (significant)	0.884	≤0.05 (significant)
Dental age Willems	0.903	≤0.05 (significant)	0.885	≤0.05 (significant)

CA: Chronological age, SA: Skeletal age, H: Vertebral body height, AH: Anterior vertebral body height, AP: Anteroposterior vertebral body height

Table 5: Inter and intra observer variability in estimation of dental and skeletal ages

Variables	Spearman's rank correlation coefficient for observer		
	A versus B	A versus C	B versus C
SA (Caldas's method)	0.984	0.980	0.987
Dental age (Demirjian's method)	0.980	0.981	0.991
Dental age (Willem's method)	0.987	0.989	0.978
Intra observer variability (*r*)		0.175	

SA: Skeletal age

Discussion

In the present study, DA estimation was conducted on seven teeth of left quadrant of mandible on individuals ranging in age from 9 to 16 years. From several investigations, the tooth calcification of homologous teeth was found to be symmetrical; therefore, only left mandibular teeth were examined. Further, the seven left mandibular teeth represented the age range of commencement to completion of root calcification close to the age range of the patients selected for the study.

The maxillary posterior teeth were omitted from the study because superimposition of calcified structures in this area resulted in inaccurate assessment of the stage of development of these teeth.

Panoramic radiographs were used because they are easier to make than intraoral radiographs in young or nervous children; they give less radiation for a full mouth radiograph (MacDonald 1969) and the picture of the mandibular region they produce is little distorted. Although there is 3%–10% enlargement on the left side of mandible (Demirjian A, *et al*. 1971), this is not a serious drawback because our rating system is based on shape criteria and relative values rather than on absolute lengths.[15]

The skeletal age was estimated using Lateral Cephalogram according to new computer-assisted method and formula for cervical vertebra given by Caldas Mde *et al*. in 2010[14] which is quick and relatively easy to learn and perform, less time-consuming in practice and shows greater reproducibility between observers and no need of special radiograph to assess skeletal maturity and allows skeletal age to be calculated in an objective manner as other CVM methods evaluate growth in a subjective manner because these methods uses only a qualitative comparison between the patient's images and those of an atlas.[4,14] In the Indian population, there is no established norm on computer-assisted CVM method for skeletal age estimation; hence, Caldas Mde *et al*. 2010[14] method was taken as a method of comparison in this study.

The *r* value representative of Pearson correlation coefficient was close to 1 for all the pairs such as chronologic age and DA by Demirjian's method, chronologic age and DA by Willem's method but in chronologic age and skeletal age by Caldas method for male and female individuals, it was 0.473 and 0.658. This signified that there was a strongly positive correlation between the age estimation methods of Demirjian's and Willems methods pairs and less strong positive correlation

Table 6: Reliability of digital mode of dental age and skeletal age estimation regression equation

Sex	Age	*n*	Regression equation	R^2	SEE	Significant
Female	CA	70	2.884+3.352 (AH3/AP3)+9.529 (AH4/AP4)	0.450	1.549	0.000
	SA	70	1.863+7.043 (AH3/AP3)+7.732 (AP4/AH4)	0.957	0.325	0.000
Male	CA	70	9.641+5.026 (AH3/AP3)+0.155 (H4/AP4)	0.209	1.862	0.000
	SA	70	6.018+11.778 (AH3/AP3)+0.315 (H4/AP4)	0.994	0.168	0.000

*CA: For female: Dependent variable=CA; Independent variables=AH3/AP3; AH4/AP4, For male: Dependent variable=CA; Independent variables=AH3/AP3; H4/AP4, *For SA: For female: Dependent variable=SA; Independent variables=AH3/AP3; AH4/AP4, For male: Dependent variable=SA; Independent variables=AH3/AP3; H4/AP4. SA: Skeletal age, CA: Chronological age, H: Vertebral body height, AH: Anterior vertebral body height, AP: Anteroposterior vertebral body height, SEE: Standard error of estimate

in Caldas method for males as compared to females. Hence, all three methods under the study were applicable for age estimation for the population under study. This supported the findings of El-Bakary and Patel *et al*.[16,17] Hence, the three methods under study can be applied as representatives of chronologic age for the population under study.

There was consistent overestimation of age by Demirjian's DA estimation method among male and female in all age groups except 9–9.99 years age in male and among female 10–10.99 and 14–15.99 years age This finding was consistent with findings of Hegde and Sood[18] for underestimated male age group and Mani *et al*.[19] for underestimated female age group who stated that varying degree of underestimation in male and female age group indicates that dental growth is not a steady and uniform process, but associated with parapubertal speed fluctuations.[19]

Ogodescu *et al*.,[5] Urzel and Bruzek,[6] Ambarkova *et al*.,[8] Ye *et al*.,[9] Patel *et al*.,[16] and Gupta *et al*.[10] also concluded that there was overestimation of age in male and female by Demirjian's method.

The overestimation of the DA observed in certain age groups could probably be due to the prepubertal or pubertal growth changes pertinent during this age period.[16] Varying results in different populations may also arise due to the ethnic differences in different population groups.[6] There was overestimation in older age groups in female individuals in contrast to underestimation in male individuals indicating that adolescent females have a tendency towards early dental development than males which was in agreement with findings of Demirjian and Levesque.[20]

There was consistent underestimation of age by Willems DA estimation method among male and female in all age groups except 10–11.99 and 15–15.99 years age in male and among female in 11–11.99 years' age. However, these differences of chronologic and DA by Willem's method were consistently smaller than differences between chronologic age and DA by Demirjian's method for male. This was suggestive of the fact that Willem's DA estimation method is more accurate than the Demirjian's DA estimation method for the male group under study. This was same for Demirjian's method for female age group. This suggestive of Demirjian's method is more accurate than Willem's for female group under study. Urzel V *et al*. (2001),[6] Franco *et al*.,[12] Mohammed *et al*.,[13] and Gupta *et al*. (2015)[10] also concluded that there was underestimation of age in male and female by Willem's method.

There was consistent overestimation of age by Caldas New Computer assisted method of skeletal age estimation in all age groups except 11–13.99 and 15–15.99-year age groups of male and 14–15.99-year age groups of females. This finding supported those of Caldas Mde *et al*. (2010)[14] Furthermore, the differences between chronologic age and skeletal age were greater among female than male in all age groups except 9–10.99 year age in male. This indicated that females belonging to population under study were advanced in skeletal age than males of same age group. This supported the findings of Serene Koshy and Tandon.[21]

An additional explanation for the differences in certain age groups may be that present sample was relatively small study. Other probable causes may be the biological variation in individual children, Cultural and geographic difference between populations, age range, sample size, age distribution of sample, and statistical approach, time gap between two studies, environmental factors such as socioeconomic status, nutrition, and dietary habits that vary in different population groups.[6,22]

The comparison of mean chronologic age with mean DA s by Demirjian's and Willem's methods and mean skeletal age by Caldas method for male and female individuals indicated that Demirjian method and Caldas method overestimated while Willem's method underestimated the age of all individuals. The Willem's method of DA estimation for male and Demirjian's method of DA estimation for female resulted in accurate age estimation which was closest to chronologic age.

The *r* value for all three age estimation methods between observers A and B, A and C, and B and C was close to 1. This indicated that there was a strong agreement among the ratings of all observers. The *P* value for intraobserver variability was > 0.05 indicating that there was no statistically significant difference between the estimated stages of same patients by each of the observers at two different points of time. Hence, the reproducibility of the findings of any patient by any of the observers involved in the study was high and can be relied over.

The completion of crown calcification and root formation of all mandibular teeth (excluding third molars) occurs around

9 years and 16 years of age, respectively. The 9–16 year age group was selected for this study based on other maturation studies and the fact that orthodontic treatment is frequently performed at this age group which critically requires skeletal age assessment.[16] Hence, one can estimate skeletal age and DA without resorting to any special radiograph in Indian population and unwanted radiation can be minimized.

In the Indian population there is no established norm on Computer assisted CVM method for skeletal age estimation, hence Caldas Mde *et al*. 2010[14] method was taken as a method of comparison in this study.[4,14] Caldas's new computer-assisted method for skeletal age estimation used in the present study is easy to perform and less time-consuming and objective method. The measurements obtained using this method are more precise and thus help in more accurate and automatically calculate cervical vertebra bone age. Considering these benefits, the present study recommends the use of digital method to assess skeletal age estimation without resorting to any special radiograph in Indian population.

Panoramic radiographs were used because they are easier to make than intraoral radiographs in young or nervous children; they give less radiation for a full mouth radiograph (MacDonald 1969) and the picture of the mandibular region they produce is little distorted. Although there is 3%–10% enlargement on the left side of the mandible (Demirjian A, *et al*. 1971), this is not a serious drawback because our rating system is based on shape criteria and relative values rather than on absolute lengths.[15] A limitation of this study needs larger sample size in various population.

Conclusion

Willem's DA estimation method was the most accurate and consistent for male and Demirjian's method for female. Caldas's new computer-assisted method for skeletal age estimation used in the present study is easy to perform and less time consuming and objective method. The measurements obtained using this method are more precise and thus help in more accurate and automatically calculate cervical vertebra bone age. Considering these benefits, the present study recommends the use of digital method to assess skeletal age estimation without resorting to any special radiograph in the Indian population.

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Conflicts of interest
There are no conflicts of interest.

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