Original Article

Teeth as an Anatomical Modality for Age Estimation Using Radiographic Approach

Kusum Singal, Neelkamal Sharma, Permila Singh[1], Vikas Kumar

Department of Genetics, MDU, [1]Department of Statistics, GCW, Rohtak, Haryana, India

Abstract

Introduction: Age estimation of adult individuals represents an important part of forensic anthropology, forensic medicine, forensic osteology, and forensic dentistry. Teeth proved to be a perfect anatomical tool for age estimation. The study was performed with aim to evaluate the coronal pulp cavity index (CPCI) using radiographic approach and to correlate the CPCI with the real age, i.e. chronological age of the individuals. **Material and Methods:** CPCI was radiographically evaluated using radiovisiographs (RVGs) of 320 individuals (160 males and 160 females) having age range of 15–54 years. The sample comprised of 1280 RVGs of 4 teeth per individual (maxillary canine, maxillary second premolar, mandibular canine, and mandibular first premolar). Two radiographic measurements were performed on all radiographs. One is coronal pulp height and another one is height of crown (coronal height). CPCI for each radiograph was calculated and correlated with the chronological age of the study individuals using statistical software SPSS (Version 21). **Results:** Intra-observer agreement of CPCI measurements was almost perfect. The accuracy of regression models, when applied to different set of radiograph samples, was within acceptable range of differences in the forensic anthropology. **Discussion and Conclusions:** All the selected teeth showed a strong negative correlation with the chronological age. However, all selected teeth do not have equal applicability for age estimation suggesting that further evaluation on different samples for teeth specific regression models for age estimation.

Keywords: *Adults, age estimation, forensic anthropology, forensic dentistry, radiovisiographs*

Introduction

Age estimation is living as well as dead is one of the foremost queries to be resolve by the forensic scientists. Various parts of the human body can be utilized as a recognizable proof for this purpose. Alternate parts of the body such as skull, pelvic bones, and long bone ossification centers may can be utilized for age estimation. However, mass disasters such as serious crashes or flames, tsunami, earthquakes, or internment conditions make different parts unsatisfactory for use as an age indicator.[1] In such type of situations, teeth being least influenced by all the environmental conditions proved to be one of the best evidence available for estimation of age. Dynamic morphology of the teeth such as outer enamel in the crown area and cementum in root region make them highly resistant against any kind of damage. Dental age estimation in kids depends on formative stages and eruption sequence of teeth and is quiet basic and easy process while in adults, it is a bulky process.[2] With the end goal of dental age estimation, different techniques have been produced. These include exceptionally mind-boggling, tedious, and ruinous methods, for example, transparency of dentin, tooth cementum annulations, and aspartic acid racemization.[3-5] Deposition of secondary dentin is a one of the age-related changes that can be studied for the purpose of age estimation. Histological sectioning of teeth and radiographic method are the two ways described in literature for the assessment of secondary dentine.[6,7]

The radiographic method is a nondestructive procedure that can be used both in living and dead individual when contrasted with other tedious, costly, and dangerous techniques requiring extracted tooth that may emerge moral, religious, social, or logical issues.[8-10] In addition, strategies such as digitization of all radiographs and computer-assisted imaging software will reduce the subjective errors and thus enhance the reliability, accuracy, and precision of results.[11,12] The present study

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Address for correspondence:
Dr. Neelkamal Sharma, Department of Genetics, MDU, Rohtak, Haryana, India. E-mail: neelforensics@gmail.com

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was conducted with the aim of age estimation from teeth using nondestructive approach.

Material and Methods

This investigation was performed on radiovisiographs (RVGs) gathered from individuals visiting to the Department of Oral Diagnosis Medicine and Radiology, Post Graduate Institute of Dental Sciences, Rohtak and PDM Dental College and Research Institute, Bahadurgarh, Haryana, India. These radiographs were taken as a part of the routine treatment that is being rendered to the patient. Gnatus radiographic imaging system with standard specifications (7–10 mA, 0.05 s exposure time, 70 kV voltage), Kodak sensor and XCP-CP sensor holder were used for taking RVGs of the study individuals. Radiographic images were taken using paralleling technique only after performing the oral clinical examination. To normalize the angulations and magnification errors among X-rays, grid was used and all measurements were taken in the form of ratios only. The radiographs were recorded in digital form. To overcome the magnification and angulations differences, grid was used while taking RVGs of each tooth. Protocol of the study was approved by Institutional Human Ethical Committee, MDU Rohtak (Ethical clearance dated July 4, 2017).

Inclusion criteria

- RVGs chosen were of the individuals matured in the vicinity of 15 and 54 years
- Teeth selected for the study were completely erupted into the oral cavity.

Exclusion criteria

- Teeth with any pathology, for example, caries or periodontitis and periapical sores
- Malaligned or pivoted teeth
- Teeth with any prosthetic fittings
- Individuals suffering from systemic disorders such as endocrine disorders, diabetes, and gastrointestinal were excluded from the study
- Pregnant and lactating mothers were also excluded from the study.

Radiographic pictures of the all teeth were handled utilizing computer-assisted imaging program ADOBE Photoshop version CS6. The sequential age of the patient was computed by substracting the date of radiograph from the date of birth of the patient. Two radiographic parameters were measured on each radiograph. One is coronal height (CH) and another one is coronal pulp cavity height (CPH) [Figure 1]. Coronal pulp cavity index (CPCI) was calculated after that using formula CPH/CH × 100. Morphological factors and the sequential age of all the study individuals were entered into Microsoft Excel spreadsheet. Relationship coefficient was assessed for each tooth as well as for males and females. The assessed age was then contrasted and the sequential age of the person.

Results

The study was conducted on 1280 RVGs obtained from 320 individuals (160 males and 160 females). The sample was divided into four age groups. Each study subset has equal number of observations [Table 1]. Data were tabulated into Microsoft excel sheet. Linear regression was done for each tooth utilizing statistical software SPSS (Version 21, IBM Co., Armonk, NY, USA). The outcomes were computed and related with the chronologic age for assessment. Descriptive statistics and Pearson correlation were done to link mean sequential age with mean evaluated age by CPCI strategy. The significance limit was set at 5%. To prevent or minimize intra-observer errors, all measurements were carried out twice after an interval of 2 weeks by the same observer. Intra-observer reproducibility and reliability (99.96%) of measurements was studied using the concordance correlation coefficient ($P < 0.05$). Intra-observer reliability of measurement for CPH, CH, and CPCI was 99.95%, 99.96%, and 99.96%, respectively. The regression analysis has been used to find the linear equations for predicting age using CPCI. Teeth-wise and gender-wise r^2 represented by scatter diagram [Figures 2 and 3]. Coefficient of determination (r^2) calculated ranges from 0.916 to 0.968. Descriptive Statistics was analyzed for all selected teeth and female and male study individuals separately [Tables 2 and 3]. Regression equations were developed for different study teeth in male and female study individuals.

For females;
- Maxillary canine Y = 71.934 − 1.70 × X
- Maxillary second premolar Y = 75.017 − 1.187 × X

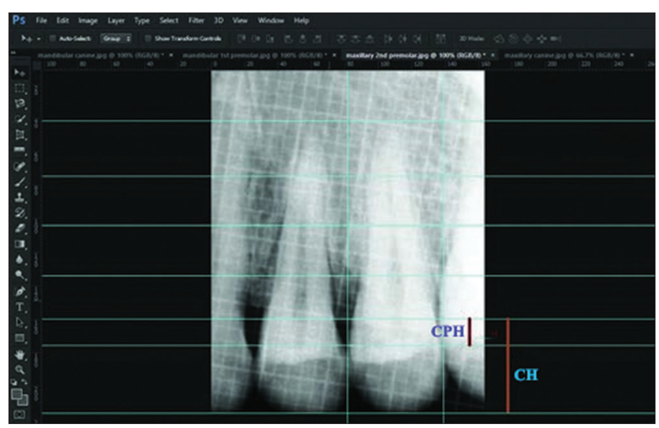

Figure 1: Parameters measured for maxillary second premolar (between two vertical lines). CPH: Coronal pulp height, CH: Crown height

Table 1: Age and gender distribution of study individual

Age groups (years)	Males (*n*)	Females (*n*)	Total
15-24	40	40	80
25-34	40	40	80
35-44	40	40	80
45-54	40	40	80

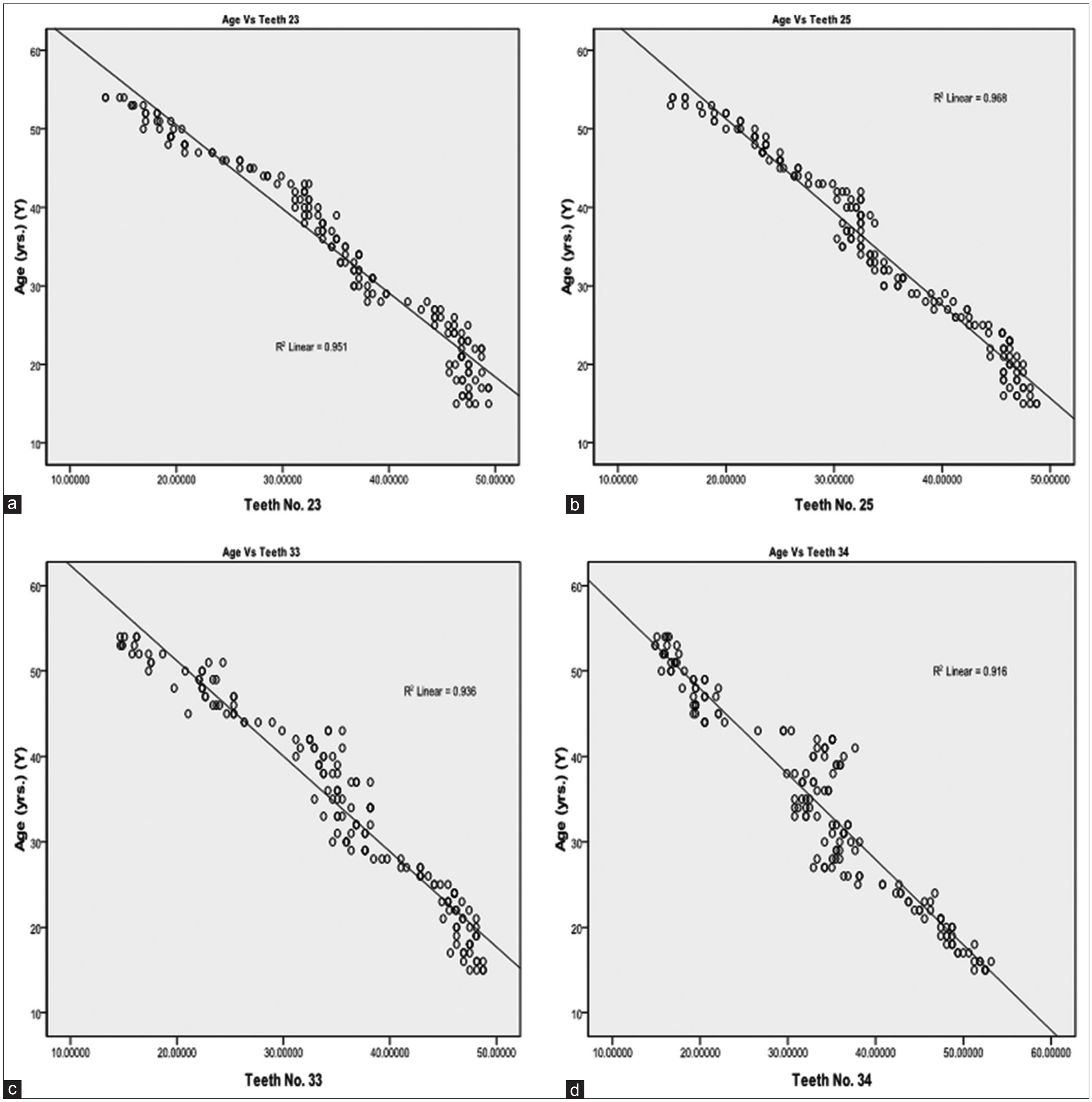

Figure 2: Scatter diagram and linear regression equations for different teeth. (a) 23 (maxillary canine) (b) 25 (maxillary second premolar) (c) 33 (mandibular canine) (d) 34 (mandibular first premolar) for whole Female study samples

- Mandibular canine Y = 73.511–1.116 × X
- Mandibular first premolar Y = 67.934 − 0.999 × X.

For males, regression equation;

- Maxillary canine Y = 74.182 − 1.129 × X
- Maxillary second premolar Y = 75.932 − 1.205 × X
- Mandibular canine Y = 72.725 − 1.10 × X
- Mandibular first premolar Y = 68.330 − 1.016 × X.

Where Y is the age to be estimated, and X is the CPCI of the teeth.

Inter-teeth correlations were assessed using Pearson test. The correlation between chronological age and CPCI of selected teeth was indicated by R^2. The high value of R^2 indicates the strong negative correlation. With increasing age value of CPCI goes on decreasing. R^2 value for each tooth has been generated for male individuals and female individuals [Tables 4 and 5].

Discussion

Forensic Anthropology works for three major area gender

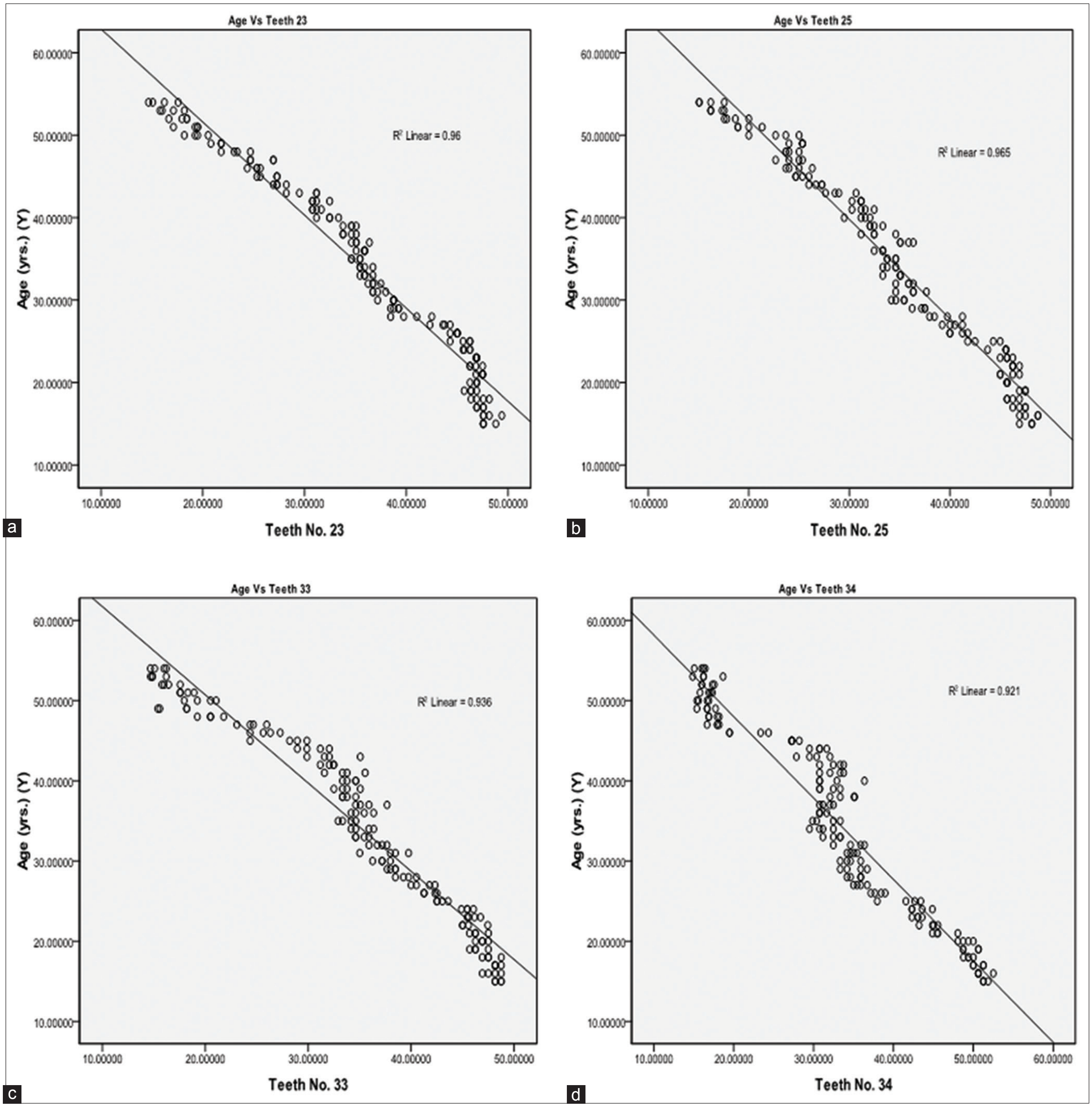

Figure 3: Scatter diagram and linear regression equations for different teeth. (a) 23 (maxillary canine) (b) 25 (maxillary second premolar) (c) 33 (mandibular canine) (d) 34 (mandibular first premolar) for whole male study samples

Table 2: Descriptive statistics for all selected teeth of female study individuals

	Mean	SD	*n*
Age (years)	34.50	11.580	160
Teeth number 23	34.9745874	10.55321036	160
Teeth number 25	34.1454761	9.59886308	160
Teeth number 33	34.9496280	10.03848848	160
Teeth number 34	33.4282292	11.09337871	160

SD: Standard deviation

Table 3: Descriptive statistics for all selected teeth of male study individuals

	Mean	SD	*n*
Age (years)	34.5000000	11.57963947	160
Teeth number 23	35.1409622	10.04799870	160
Teeth number 25	34.3961109	9.44335015	160
Teeth number 33	34.7458248	10.18498510	160
Teeth number 34	33.3115068	10.94533032	160

SD: Standard deviation

Table 4: Inter-teeth correlations of different teeth in whole female samples

	Age (years)	Teeth number 23	Teeth number 25	Teeth number 33	Teeth number 34
Age (years)					
Pearson correlation	1	−0.975**	−0.984**	−0.968**	−0.957**
Significant (two-tailed)		0.000	0.000	0.000	0.000
Sum of squares and cross-products	21,320.000	−18,953.085	−17,383.652	−17,884.702	−19,552.825
Covariance	134.088	−119.202	−109.331	−112.482	−122.974
	160	160	160	160	160
Teeth number 23					
Pearson correlation	−0.975**	1	0.985**	0.985**	0.947**
Significant (two-tailed)	0.000		0.000	0.000	0.000
Sum of squares and cross-products	−18,953.085	17,707.870	15,861.557	16,587.736	17,632.522
Covariance	−119.202	111.370	99.758	104.325	110.896
n	160	160	160	160	160
Teeth number 25					
Pearson correlation	−0.984**	0.985**	1	0.980**	0.960**
Significant (two-tailed)	0.000	0.000		0.000	0.000
Sum of squares and cross-products	−17,383.652	15,861.557	14,649.969	15,017.599	16,252.360
Covariance	−109.331	99.758	92.138	94.450	102.216
n	160	160	160	160	160
Teeth number 33					
Pearson correlation	−0.968**	0.985**	0.980**	1	0.958**
Significant (two-tailed)	0.000	0.000	0.000		0.000
Sum of squares and cross-products	−17,884.702	16,587.736	15,017.599	16,022.629	16,968.111
Covariance	−112.482	104.325	94.450	100.771	106.718
n	160	160	160	160	160
Teeth number 34					
Pearson correlation	−0.957**	0.947**	0.960**	0.958**	1
Significant (two-tailed)	0.000	0.000	0.000	0.000	
Sum of squares and cross-products	−19,552.825	17,632.522	16,252.360	16,968.111	19,567.025
Covariance	−122.974	110.896	102.216	106.718	123.063
n	160	160	160	160	160

**Correlation is significant at the 0.01 level (two-tailed)

Table 5: Inter-teeth correlations of different teeth in whole male samples

	Age (years)	Teeth number 23	Teeth number 25	Teeth number 33	Teeth number 34
Age (years)					
Pearson correlation	1	−0.980**	−0.982**	−0.968**	−0.960**
Significant (two-tailed)		0.000	0.000	0.000	0.000
n	160	160	160	160	160
Teeth number 23					
Pearson correlation	−0.980**	1	0.986**	0.985**	0.952**
Significant (two-tailed)	0.000		0.000	0.000	0.000
n	160	160	160	160	160
Teeth number 25					
Pearson correlation	−0.982**	0.986**	1	0.974**	0.957**
Significant (two-tailed)	0.000	0.000		0.000	0.000
n	160	160	160	160	160
Teeth number 33					
Pearson correlation	−0.968**	0.985**	0.974**	1	0.967**
Significant (two-tailed)	0.000	0.000	0.000		0.000
n	160	160	160	160	160
Teeth number 34					
Pearson correlation	−0.960**	0.952**	0.957**	0.967**	1
Significant (two-tailed)	0.000	0.000	0.000	0.000	
n	160	160	160	160	160

**Correlation is significant at the 0.01 level (two-tailed) determination, age estimation, and stature estimation. Besides gender, age is another most important biological parameter of identification. Bones as well other skeletal remains play a very important role in age estimation. Although a lot of age estimation methods are available in the literature.

The present study was conducted with the aim to correlate the dimensions of coronal pulp with the chronological age of the study individuals. The study data consist of 1280 RVGs of maxillary canine, maxillary second premolar, mandibular canine, and mandibular first premolar tooth collected from 320 individuals having age range of 15–54 years. In the present study, the accurate age estimation percentage was higher in the male population as compared to female individuals [Figures 2 and 3]. This may be an expression of size of the pulp cavity is larger in males as males tend to have larger teeth. Premolar teeth were showing less standard deviation as compared to other teeth. The value of standard deviation ranges from 9.44 (in males) to 9.59 (in females) [Tables 2 and 3]. The results of present suggest that CPCI of all the selected teeth showed a negative correlation with chronological age which is in accordance with previous studies conducted by Drusini *et al*., Ikeda *et al*., Igbigbi and Nyirenda.[13-15] The correlation was observed to be high for premolars in contrast to other teeth included in the study in both males and females [Tables 4 and 5]. This could be attributed to physiological wear and masticatory forces thus compromising crown height measurements and increasing deposition of secondary dentin. As compared to studies conducted by Igbigbi and Nyirenda in Malawian populations and Zadzinska *et al*. in Caucasian, we have observed a higher degree of accuracy using CPCI method in the present study that highlights the importance of population-specific regression equations.[14,16]

Conclusion

The investigation could be concluded that among all teeth, maxillary second premolar was observed to be the best pointer for age estimation in the two sexual orientations. This demonstrates the importance of teeth specific regression formulas. An exceedingly critical relationship of age with CPCI was accounted in Haryana population. In spite of the fact that a considerable measure of research had been done in the region of age estimation; however, these investigations were directed in various populations, hampering examinations of their precision. To accomplish more exact age estimation, there is a requirement for verifying population-specific studies with bigger sample size and considering diverse natural factors, for example, dietary propensities, hereditary foundation and history of any disease that can influence the exactness of results. Advancement of these gender-specific and population-specific age estimation models may prove useful to forensic odontologists and anthropologists in various criminal and civil cases.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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