A Digital Radiographic Study of Age Estimation Using Area-specific Formula in Odisha Population

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ABSTRACT

Aim: The aim of the article was to evaluate the feasibility of pulp/tooth area ratio in three mandibular teeth, namely left canine, left first premolar, and left second premolar (33, 34, and 35), as an indicator of age using digital panoramic radiograph and Kvaal's parameters. The study also aimed at computing an area-specific formula for age estimation in Odisha population.

Materials and methods: Observation and analysis of 50 digital orthopantomographs (OPGs) and clinical data of patients were made. These images were saved as high-resolution JPEG files. Using the Adobe Photoshop CS3 (extended) image editing software program (Adobe Systems Inc, San Jose, California, United States), the pulp/tooth area ratio of 33, 34, and 35 was analyzed. These ratios were substituted in Odisha population-specific formula, derived using principal component regression analysis.

Results: The mean chronological age was 33.24 years. Principal component regression analysis was used to derive multiple regression formulae for individual teeth as well as a combined formula. R^2 (coefficient of determination) for combined three mandibular teeth was highest (0.7769) with a standard error of 4.5969 years and thus was a better predictor of age in the population of Odisha. In terms of an individual tooth, comparison between chronological and predicted age revealed that left second mandibular premolar (35) had highest correlation to actual age. Karl Pearson's correlation coefficient showed correlation between age and the mean of ratios from combined three mandibular teeth was stronger than that of single tooth.

Conclusion: In the present study, second left mandibular premolar showed highest correlation to actual age when used alone. The use of three teeth in combination increased the correlation. This Odisha-specific formula showed promising results and can be used for forensic applications in this population.

Clinical significance: Using three different teeth for age estimation proved to be a better predictor of age in the Odisha population. Moreover, the obtained formula can act as a standard and be used for anthropological or forensic investigations in the said population.

Keywords: Age estimation, Mandibular canine, Mandibular premolars, Odisha population, Pulp/tooth area ratio.

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INTRODUCTION

Age estimation is a key aspect of forensic anthropology, which finds appositeness in both the living and dead. The estimation of age finds application in civil, criminal cases and is also an important determinant in identification and establishment of profile of a deceased individual, especially during mass disasters or in anthropological studies.[1] Different techniques of age estimation are available. Presence or absence of skeletal elements and the representation of general age are the factors determining the selection of the apt methodology.[2]

Postmortem environment tends to affect the remains, which may render the process of age estimation inaccurate. Tooth has been deemed most durable and the last to be affected by postmortem changes among the different parts of the body, thus making them valuable for age estimation.[3] Various morphological, biochemical, and histological techniques are available for dental age estimation, some of which include the analysis of cemental annulations, root transparency, determination of aspartic acid racemization, evaluation of attrition, secondary dentin deposition, periodontal attachment, cementum apposition, and root resorption.[4,5] The disadvantage with these techniques being that they are invasive, require extraction of teeth and preparation of histological sections, thus, not making them feasible for living individuals.[6]

Radiographic methods of age estimation are non-invasive, uncomplicated, simple techniques which can be used in both living and deceased individuals, in comparison to other cumbersome,

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exorbitant and precarious methods. In addition, procedures such as digitization of radiographs and computer-assisted image analysis avoid the observer bias in subjectivity; reduce radiation exposure; and also ameliorate reliability, accuracy, and precision manifold.[7,8]

Noninvasive radiographic techniques rely on determining the amount of secondary dentin deposition.[9] This is done by measuring the reduction of pulp chamber size, which is then correlated with

chronological age. Further, the regression analysis is carried out and equations are derived to estimate the age. Age-predicting regression equations using pulp/tooth area ratio in mandibular canines were formulated by Cameriere et al. in Italian population, with high levels of accuracy.[8] In the Indian population, better accuracy in age estimation was obtained by Saxena using modified Kvaal's method.[10] However, both these techniques use anterior teeth, which are not always present in older individuals and more prone to trauma in younger individuals.[11] Thus, taking all these facts into consideration, the present study was conducted to evaluate the feasibility of pulp/tooth area ratio in three mandibular teeth, namely left canine, left first premolar, and left second premolar (33, 34, and 35), as an indicator of age using digital panoramic radiograph and Kvaal's parameters. Moreover, the study also aimed at computing an area-specific formula for age estimation in Odisha population.

MATERIALS AND METHODS

A total of 50 digital Orthopantomographs (OPGs) and clinical data of 50 patients of Odisha who visited the Department of Oral Medicine and Radiology in our institution were retrieved from the archives as part of the retrospective study. Individuals ranging from 30–40 years of age were selected for the study as this age-group is less prone to trauma, accidents, or assaults unlike their younger counterparts and are free from the pathoses of old age, both of which could result in tooth loss. Moreover, since the study aimed at deducing a population-based formula, it was imperative that the subjects had a full set of dentitions. The teeth selected for the study were mandibular left canine, left first premolar, and left second premolar (33, 34, and 35), since these teeth are less likely to get damaged by traumatic forces and also less likely to undergo attritional wear in comparison with the molars. From postmortem aspect, these teeth are not easily lost in dry skull material as the molars. Above all, the analysis of these teeth is easier and more feasible since they are single-rooted with large pulpal area and have simpler morphology with less diversity.[12]

High-quality panoramic radiographs with fully erupted permanent left mandibular canine and premolars with complete root formation were included in the study. OPGs with developmental anomalies, any pathology which could alter the teeth's surface area like caries or periodontitis or periapical lesions, malaligned canine and premolars and teeth with fillings or any prosthetic fittings were excluded from the study. Patients undergoing or patients who had undergone fixed orthodontic treatment or endodontic treatment involving mandibular canine and premolars were also not included.

Digital OPGs were saved as high-resolution JPEG files on the desktop computer (AMD operating system, 32 bit, 14'' LCD screen) and transferred to the Adobe Photoshop CS3 (extended) image editing software program (Adobe Systems Incorporated, San Jose, California, United States). Eleven horizontal lines were marked on the teeth in the digital radiograph using Adobe Photoshop's inbuilt line tool to measure the morphological parameters. The lines were marked at the cusp tip, at the maximum curvature of crown on the mesial and distal aspect and at the cemento–enamel junction (CEJ). Lines were also marked apically from CEJ to the root apex at every one-eighth increment, with the exception of one-eighth increment immediately apical to the CEJ. All measurements were made by a single examiner who was unaware of the personal details of the subjects.

The following morphological measurements were made on the digital radiograph[9] (Fig. 1):

T—Tooth length

R—Root length

P—Pulp length

A—Pulp/root width at cementoenamel junction (CEJ)

B—Pulp/root width midway between A and C

C—Pulp/root width midway between apex and CEJ.

These measurements were made for all the three teeth in the selected OPGs, after which the following calculations were done:

M—Mean value of above all ratios (P/R, P/T, A, B, C)

W—Mean of pulp/root width at B and C calculated as B + C/2

L—Mean of ratios of all lengths calculated as (P/R + P/T)/2

W–L—Difference between width and length.

The values obtained were used in the regression equation for Kvaal's method according to the formula:

$$\text{Age} = 129.8 - (316.4 \times M)\,(6.8 \times [W - L])^{9}$$

Using principal component regression analysis, regression formulae were determined for age estimation in the Odisha population, separately for individual teeth as well as by taking the three teeth together. Comparison between original chronological age and predicted age in different teeth was done to ascertain the effectiveness of the study. Karl Pearson's correlation coefficients between original age and predicted age were also calculated. Statistical analysis was done using the SPSS v 20.0 (SPSS Inc, Chicago, Illinois, United States) statistical software package and $p < 0.05$ indicated a significant correlation.

RESULTS

A correlation study was undertaken to evaluate the feasibility of pulp/tooth area ratio in three mandibular teeth, namely left canine, left first premolar, and left second premolar (33, 34, and 35), as an indicator of age using 50 digital OPGs.

The mean chronological age was 33.24 years. The correlation coefficients between chronological age and calculated ratios for
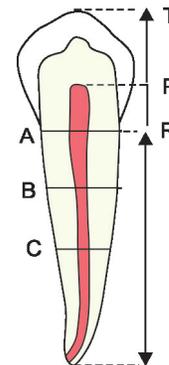
Fig. 1: Pictorial representation of morphological parameters measured on orthopantomographs

each tooth are shown in Table 1. Principal component regression analysis was used to derive multiple regression formulae for individual teeth as well as a combined formula. R^2 (coefficient of determination) for combined three mandibular teeth was highest (0.7769) with a standard error of 4.5969 years and thus was a better predictor of age in the population of Odisha (Table 2, Fig. 2).

In terms of an individual tooth, comparison between chronological and predicted age revealed that left second mandibular premolar (35) had highest correlation to actual age ($r = 0.8525; t = 11.1801$). Karl Pearson's correlation coefficient showed correlation between age and the mean of ratios from combined three mandibular teeth was stronger than that of single tooth ($r = 0.8784; t = 12.6012$); $p = 0.0001$ (Tables 3 and 4).

DISCUSSION

Age estimation forms one of the most crucial aspects of forensic odontology and finds application in various medicolegal, mass disaster, administrative, and ethical scenarios.[13] Tooth of an individual can be used to assess their age by measuring the regressive changes in the dental hard tissues like attrition, secondary dentin deposition, cementum apposition, and root dentin translucency. However, changes brought about by attrition and cementum apposition are unreliable as these are highly influenced by environmental factors and lifestyle of an individual.[14]

Assessment of age by secondary dentin apposition is one of the most effective and feasible methods for age estimation since it is a noninvasive radiographic technique which relies on the fact that the size of dental pulp decreases with increasing age due to apposition of secondary dentin, thus making it a reliable tool in individuals above the age of 25 years.[15,16] Secondary dentin is a narrow band of dentin deposited hemming the pulpal chamber after root formation is complete. This genesis process is continuous

but slower and occurs by a cellular process independent of external factors, thus making it a more reliable tool for age estimation.[14,17]

Histological or radiographic techniques can be employed to estimate age by assessing the secondary dentin apposition. In the current study, panoramic radiographs have been used due to factors like high reproducibility, possibility of digitization, less time consumption, no necessity of extraction of teeth, and no requirement of any specialized equipment.[7] Several studies have been done using single tooth, but ours combine the results of three different teeth to provide more accuracy. An area-specific formula for age estimation has also been formulated, which may have useful, practical, convenient, and prove to be utilitarian for forensic applications in the studied population. According to the findings of our study, the coefficient of determination for combined three mandibular teeth
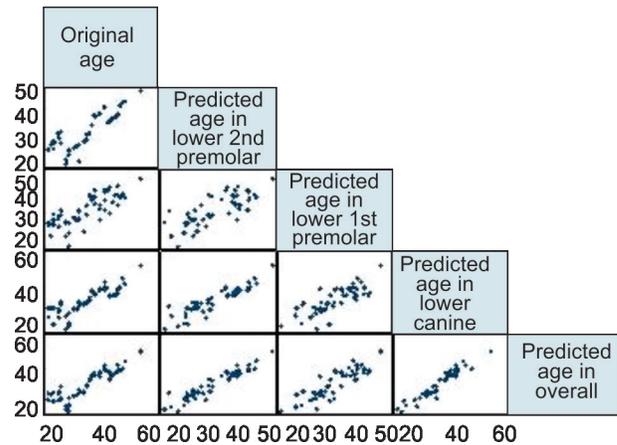

Fig. 2: Scatter diagram of chronological age against predicted age using regression model

Table 1: Correlation coefficients between chronological age and calculated ratios for each tooth

	Correlation coefficients between age								
	Lower second premolar (35)			*Lower first premolar (34)*			*Lower canine (33)*		
Variables	*r value*	*t value*	*p value*	*r value*	*t value*	*p value*	*r value*	*t value*	*p value*
P	−0.7805	−8.5592	0.0001[*]	−0.8233	−9.9453	0.0001[*]	−0.7239	−7.1929	0.0001[*]
T	−0.6364	−5.6559	0.0001[*]	−0.7576	−7.9570	0.0001[*]	−0.5826	−4.9140	0.0001[*]
R	−0.7119	−6.9492	0.0001[*]	−0.7990	−9.1099	0.0001[*]	−0.4855	−3.8075	0.0004[*]
A	−0.6822	−6.3973	0.0001[*]	−0.4999	−3.9569	0.0003[*]	−0.3386	−2.4669	0.0173[*]
B	−0.2908	−2.0840	0.0426[*]	−0.3482	−2.5466	0.0142[*]	−0.7503	−7.7802	0.0001[*]
C	−0.3019	−2.1712	0.0350[*]	−0.2097	−1.4700	0.1482	−0.0809	−0.5563	0.5806
M	−0.8135	−9.5915	0.0001[*]	−0.2193	−1.5411	0.1300	−0.6830	−6.4114	0.0001[*]
W	−0.5016	−3.9751	0.0002[*]	−0.1724	−1.2002	0.2361	−0.7516	−7.8120	0.0001[*]
L	−0.4532	−3.4855	0.0011[*]	−0.6149	−5.3453	0.0001[*]	−0.6818	−6.3893	0.0001[*]
W–L	−0.4095	−3.0769	0.0035[*]	−0.7960	−9.0150	0.0001[*]	−0.5933	−5.0522	0.0001[*]

[*]$p < 0.05$ indicates significant correlation

Table 2: Regression formulae for age estimation in years based on digital OPGs from three teeth

Tooth	*Multiple regression formulae*	*R*	R^2	*SE*
Lower second premolar (35)	Age = 113.5218 − 36.1453 (M) − 22.2633 (W) + 7.7167 (W–L)	0.8347	0.6967	5.3601
Lower first premolar (34)	Age = 128.6294 − 6.6225 (M) − 58.5600 (W) + 54.4252 (W–L)	0.7658	0.5865	6.2586
Lower canine (33)	Age = 114.9419 − 40.6746 (M) − 27.8754 (W) + 19.5053 (W–L)	0.8558	0.7324	5.0346
Overall	Age = 129.0212 − 22.4435 (M) − 47.0612 (W) + 39.4414 (W–L)	0.8814	0.7769	4.5969

Table 3: Comparison between chronological age and predicted age in different teeth

Tooth	Age	Mean	SD	Paired t	p value
Lower second premolar (35)	Original age	33.24	9.42	0.1126	0.9108
	Predicted age	33.16	7.93		
Lower first premolar (34)	Original age	33.24	9.42	0.1171	0.9073
	Predicted age	33.14	7.08		
Lower canine (33)	Original age	33.24	9.42	0.1449	0.8854
	Predicted age	33.14	7.91		
Overall	Original age	33.24	9.42	0.0952	0.9246
	Predicted age	33.18	8.23		

Table 4: Correlation between chronological age and predicted age by Karl Pearson's correlation coefficient

	Correlation between original age and predicted age in		
Tooth	r value	t value	p value
Lower second premolar (35)	0.8525	11.1801	0.0001[*]
Lower first premolar (34)	0.7622	8.0712	0.0001[*]
Lower canine (33)	0.8425	10.7238	0.0001[*]
Overall	0.8784	12.6012	0.0001[*]

[*]$p < 0.05$

was very high and thus proved to be a better predictor of age in the Odisha population. In terms of an individual tooth, comparison between chronological and predicted age revealed that left second mandibular premolar (35) had highest correlation to actual age. Karl Pearson's correlation coefficient showed correlation between age and the mean of ratios from three mandibular teeth taken together was stronger than that of a single tooth.

Saxena and Juneja et al. estimated the chronological age of the Indian population by measuring the pulp/tooth area ratio and other morphological variables of maxillary canine teeth using digital radiographs. The former did not observe any significant correlation while the latter reported a significant correlation between age and morphological variables.[10,18] Saxena observed a linear relationship of pulp/tooth area ratio of the right maxillary canine with chronological age in the Indian population. However, in our study, in terms of individual tooth, left second mandibular premolar showed the highest correlation to actual age.

Jagannathan et al. assessed the suitability of pulp/tooth volume ratio of mandibular canines for age prediction in the Indian population using cone beam computed tomography (CBCT). The equation derived yielded mean absolute error of 8.54 years when applied in their control group.[19] However, in our study with lower canines, standard error of 5.0346 was observed.

Kumar and Choudhary performed a similar study on the North Indian population using maxillary canines. Their formula [age = 96.795 − 513.561 × (p/t area ratio)] gave good results in the concerned population.[20] Similar effective results with the same formula were also obtained by Jeevan et al. in the South Indian population using maxillary canines.[21] Dehghani et al. estimated the chronological age in the Iranian population by calculating the pulp/tooth area ratio of upper and lower canines in digital panoramic radiographs and concluded that the ratio of upper canine showed better correlation with chronological age than that of lower canine.[22] On the contrary, in the present study, mandibular canines

were used, and the best results were obtained when the findings of mandibular canine and premolars were combined.

On comparison between the standard error with respect to the formula derived for mandibular first premolar, our study showed an error of 6.2586 years of chronological age in contrast to Ravipati et al.'s 8.586 years. Moreover, correlation between age and PTR was statistically significant with a p value of <0.001 and R^2 value of 0.635 in the results of Ravipati et al.,[23] whereas, in our study, the value was 0.7622 with a p value of 0.0001 which was highly significant. However, in our study, all the three teeth taken together gave more precise results.

Chandan et al. estimated age by Kvaal's method in the North Indian population using digital panoramic radiography and a total of six teeth, i.e., maxillary central incisor, maxillary lateral incisor, maxillary second bicuspid, mandibular lateral incisor, mandibular canine, and mandibular first bicuspid on either the left or the right side. They reported that mandibular canines were better for age estimation, followed by maxillary second premolar and maxillary three teeth taken together.[24] On the contrary, in our study, coefficient of determination for combined three mandibular teeth was very high, thus a better predictor of age in the population of Odisha. In terms of individual tooth, the comparison between chronological and predicted age revealed that left second mandibular premolar had the highest correlation to actual age.

The findings of our study were not in concordance with the study of Singal et al. who evaluated age by Kvaal's modified measurements using computer-aided imaging software and digitized parameters using four teeth per subject, namely maxillary canine, maxillary second premolar, mandibular canine, and mandibular first premolar, and found a significant negative correlation between chronological age and variables, and maxillary second premolar showing the most promising results.[25]

Gulsahi et al. investigated the relation between chronological age and ratio of pulp volume to tooth volume measurements using CBCT images of single-rooted teeth. Their study revealed that the ratio

was not gender dependent and the strongest correlation was found between the age and ratio measured on maxillary central incisors followed by maxillary lateral incisors, mandibular second premolars, mandibular canines, mandibular first premolars, and maxillary canines, respectively.[26] Our results were not in accordance with this study.

Salemi et al. used Kvaal's method to estimate the chronological age of individuals based on the correlation of age with morphological variables of the maxillary canine teeth using CBCT. They reported that their suggested fitted regression model could estimate the age of individuals with acceptable accuracy and mean absolute error of less than 5 years. Our study using the mean values of three teeth showed more precise results.[27]

Timme et al. investigated the suitability of ultrahigh field 9.4T ultrashort echo time (UTE) magnetic resonance imaging (MRI) for evaluation of pulp cavity volume in relation to the total tooth volume and concluded that this technology is a precocious, radiation-free procedure that allows the volume of the dental pulp to be determined at high spatial resolution.[17] This technology may prove to be a potentially valuable instrument for age assessment of living individuals and pave the future for further research in this field.

Conclusion

It can be concluded from the current study that the regression formula obtained using the present technique showed quite accurate results. The coefficient of determination for combined three mandibular teeth proved to be a better predictor of age in the population of Odisha. Further studies should be conducted with a larger sample size and taking into consideration high variability in the formation of teeth in individuals, genetic, and ethnic factors.

Clinical Significance

Using three different teeth for age estimation proved to be a better predictor of age in the Odisha population. Moreover, the obtained formula can act as a standard and be used for anthropological or forensic investigations in the said population.

References

1. Mathew DG, Rajesh S, Koshi E, et al. Adult forensic age estimation using mandibular first molar radiographs: a novel technique. J Forensic Dent Sci 2013;5(1):56–59. DOI: 10.4103/0975-1475.114552.
2. Ubelaker DH, Khosrowshahi H. Estimation of age in forensic anthropology: historical perspective and recent methodological advances. Forensic Sci Res 2019;4(1):1–9. DOI: 10.1080/20961790.2018.1549711.
3. Behura SS, Mukherjee S, Nishat R, et al. Assessment of the awareness of knowledge of dental records in forensic dentistry among undergraduate dental students. Indian J Forensic Med Toxicol 2020;14(1):123–129. DOI: 10.37506/v14/i1/2020/ijfmt/192879.
4. Chaudhary RK, Doggalli N. Commonly used different dental age estimation methods in children and adolescents. Int J Forensic Odontol 2018;3(2):50–54. DOI: 10.4103/ijfo.ijfo_18_18.
5. Alkass K, Buchholz BA, Ohtani S, et al. Age estimation in forensic sciences: application of combined aspartic acid racemization and radiocarbon analysis. Mol Cell Proteomics 2010;9(5):1022–1030. DOI: 10.1074/mcp.M900525-MCP200.
6. Babshet M, Acharya AB, Naikmasur VG. Age estimation in Indians from pulp/tooth ratio of mandibular canines. Forensic Sci Int 2010;197(1–3):125.e1–125.e4. DOI: 10.1016/j.forsciint.2009.12.065.
7. Panchbhai AS. Dental radiographic indicators: a key to age estimation. Dentomaxillofac Radiol 2011;40(4):199–212. DOI: 10.1259/dmfr/19478385.
8. Cameriere R, Ferrante L, Belcastro MG, et al. Age estimation by pulp/tooth ratio in canines by peri-apical X-rays. J Forensic Sci 2007;52(1):166–170. DOI: 10.1111/j.1556-4029.2006.00336.x.
9. Kvaal SI, Kolltveit KM, Thomsen IO, et al. Age estimation of adults from dental radiographs. Forensic Sci Int 1995;74(3):175–185. DOI: 10.1016/0379-0738(95)01760-g.
10. Saxena S. Age estimation of Indian adults from orthopantomographs. Braz Oral Res 2011;25(3):225–229. DOI: 10.1590/s1806-83242011005000009.
11. Bosmans N, Ann P, Aly M, et al. The application of Kvaal's dental age calculation technique on panoramic dental radiographs. Forensic Sci Int 2005;153(2–3):208–212. DOI: 10.1016/j.forsciint.2004.08.017.
12. Aboshi H, Takahashi T, Komuro T. Age estimation using microfocus x-ray computed tomography of lower premolars. Forensic Sci Int 2010;200(1–3):35–40. DOI: 10.1016/j.forsciint.2010.03.024.
13. Acharya AB. Age estimation in Indians using Demirjian's 8-teeth method. J Forensic Sci 2011;56(1):124–127. DOI: 10.1111/j.1556-4029.2010.01566.x.
14. Arora J, Talwar I, Sahni D, et al. Secondary dentine as a sole parameter for age estimation: Comparison and reliability of qualitative and quantitative methods among North Western adult Indians. Egyptian J Forensic Sci 2016;6(2):170–178. DOI: 10.1016/j.ejfs.2016.05.006.
15. Pinchi V, Pradella F, Buti J, et al. A new age estimation procedure based on the 3D CBCT study of the pulp cavity and hard tissues of the teeth for forensic purposes: a pilot study. J Forensic Leg Med 2015;36:150–157. DOI: 10.1016/j.jflm.2015.09.015.
16. Marroquin Penaloza TY, Karkhanis S, Kvaal SI, et al. Application of the Kvaal method for adult dental age estimation using cone beam computed tomography (CBCT). J Forensic Leg Med 2016;44:178–182. DOI: 10.1016/j.jflm.2016.10.013.
17. Timme M, Borker J, Nagelmann N, et al. Evaluation of secondary dentin formation for forensic age assessment by means of semi-automatic segmented ultrahigh field 9.4 T UTE MRI datasets. Int J Legal Med 2020;134(6):2283–2288. DOI: 10.1007/s00414-020-02425-7.
18. Juneja M, Devi YB, Rakesh N, et al. Age estimation using pulp/tooth area ratio in maxillary canines: a digital image analysis. J Forensic Dent Sci 2014;6(3):160–165. DOI: 10.4103/0975-1475.137047.
19. Jagannathan N, Neelakantan P, Thiruvengadam C, et al. Age estimation in an Indian population using pulp/tooth volume ratio of mandibular canines obtained from cone beam computed tomography. J Forensic Odontostomatol 2011;29(1):1–6. PMID: 21841263; PMCID: PMC5734837.
20. Kumar M, Choudhary S. Age estimation using pulp tooth area ratio in North Indian population. J Indian Acad Oral Med Radiol 2019;31(4):359–362. DOI: 10.4103/jiaomr.jiaomr_148_19.
21. Jeevan MB, Kale AD, Angadi PV, et al. Age estimation by pulp/tooth area ratio in canines: Cameriere's method assessed in an Indian sample using radiovisiography. Forensic Sci Int 2011;204(1–3):209.e1–209.e5. DOI: 10.1016/j.forsciint.2010.08.017.
22. Dehghani M, Shadkam E, Ahrari F, et al. Age estimation by canines' pulp/tooth ratio in an Iranian population using digital panoramic radiography. Forensic Sci Int 2018;285:44–49. DOI: 10.1016/j.forsciint.2018.01.016.
23. Ravipati S, Guttikonda VR. Age estimation using pulp/tooth area ratio of permanent mandibular first premolar. J NTR Univ Health Sci 2019;8(3):192–197. DOI: 10.4103/JDRNTRUHS.JDRNTRUHS_51_19.
24. Chandan PK, Arora KS, Das M, et al. Assessment of validity and reliability of Kvaal's method for age estimation among a population sample – a retrospective study. Indian J Dent Res 2020;31(2):186–190. DOI: 10.4103/ijdr.IJDR_209_18.
25. Singal K, Sharma N, Narula SC, et al. Evaluation of age by Kvaal's modified measurements (KMM) using computer-aided imaging software and digitized parameters. Forensic Sci Int Rep 2019;1:100020. DOI: 10.1016/j.fsir.2019.100020.
26. Gulsahi A, Kulah CK, Bakirarar B, et al. Age estimation based on pulp/tooth volume ratio measured on cone-beam CT images. Dentomaxillofac Radiol 2018;47(1):20170239. DOI: 10.1259/dmfr.20170239.
27. Salemi F, Farhadian M, Sabzkouhi BA, et al. Age estimation by pulp to tooth area ratio in canine teeth using cone-beam computed tomography. Egypt J Forensic Sci 2020;10(2). DOI: 10.1186/s41935-019-0176-9.