Comparative analysis of estimated age by pulp-to-tooth area ratio using CBCT in three different teeth on a subset of the Hyderabad population: A preliminary study

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KEYWORDS

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ABSTRACT

Objectives: The study aims to evaluate the pulp-to-tooth area ratio in permanent maxillary central incisors, lateral incisors, and canines for age estimation using three-dimensional cone beam computed tomography images.

Methods: Hundred cone-beam computed tomography (CBCT) images of patients aged between 12-70 years were retrospectively studied using NNT Viewer software version 13. Pulpal and teeth area were evaluated with the "area tool" in the acquired images in all three planes, and the pulp-to-tooth area ratio (PTR) was calculated with the measurements obtained. The reproducibility of intra-observer bias using paired t-tests was calculated.

Results: The coefficient of correlation (r) values of maxillary central incisors with age are -0.54, -0.623, and -0.50 in the axial, sagittal, and coronal planes respectively. The r values of maxillary lateral incisors are -0.05, -0.52, and -0.25 in the axial, sagittal, and coronal planes. The coefficient of correlation values (r) of maxillary canine with the age is -0.53, -0.62, and -0.49 in the axial, sagittal, and coronal planes. A strong correlation between chronological age and PTR in multiple sections of the maxillary incisors and canines (p-value < 0.05) was observed.

Conclusion: The permanent maxillary central incisor and canine yielded promising results in predicting age. The predicted age derived by mid-sagittal sections was closer to the chronological age than the axial sections, which had the least predictability.

INTRODUCTION

The hardest material in the body is human teeth, which makes them incredibly durable and helpful in situations where the body's soft tissue structures are destroyed by fire or other natural disasters.[1] Post-mortem dental records are acquired using radiographs, visual examinations, and dental charting in combination. Forensic radiology is the practice, interpretation, and reporting of radiographic examinations and procedures necessary for law enforcement or legal processes. For identification, age determination, and diagnosing the cause of death, radiological techniques are commonly used.[2] Unlike dental charts or written records, which may contain genuine errors or falsifications, dental radiography offers an impartial anatomical overview. Forensic dental identification requires radiology as a crucial component.[3] The least invasive radiologic method for estimating age is using panoramic X-rays, which only need a single image to capture the entire dentition. In addition, bone structures including the jaw, nasal fossa, and vertebrae are also visible for further evaluation.[4] When estimating an adult's age, several authors concentrated on changes associated with aging that can be seen by radiography. Three approaches can be recognized in this context.

A few researchers investigated estimating age using specific ratios or metrics. For instance, by evaluating the tooth pulp radiopacity, Kvaal et al. suggested an indirect method of measuring dentin apposition.[5] Using linear ratios, investigators correlated the multiple linear measurements they took of the pulp and the tooth. Analogously, Cameriere et al. suggested area assessments in place of linear measurements.[6] Another illustration of this type of measure is the Tooth Coronal Index (TCI), a height ratio at the crown level between the pulp cavity and the crown that was investigated by Ikeda et al.[7] Two-dimensional imaging systems are inadequate due to their generation of dimensional fluctuations, mesiodistal dimension limitation, and analytical hindrance caused by superpositions and malpositions. For precise forensic identification, 3D images are therefore necessary. The use of 3D measuring techniques to infer age from secondary dentin deposition was pioneered by Vanderwoort et al.[8] Using micro-CT, CT, or CBCT, subsequent studies have analyzed linear measurements, areas, and volumes.[8]

Dental growth, particularly in children, is a key factor in radiographic age estimation. In adults, however, a reduction in pulp area indicates the continuing deposition of secondary dentin throughout life.[9] The interrelationship between pulp width and aging was established with a metric analysis of the pulpal dimensions introduced by Kvaal et al. in 1995, which is based on the deposition of secondary dentin.[10] Cone-beam computed tomography (CBCT) has made it possible to view teeth in three dimensions (3D) and to take more precise measurements.[11] The present study aimed to analyze the pulp-to-tooth area ratio in three different teeth for age estimation using three-dimensional cone beam computed tomography images.

MATERIALS AND METHODS

This retrospective study included 3D CBCT scans of 100 patients with ages ranging from 12 to 70 years from the Department of Oral Medicine and Radiology at Army College of Dental Sciences (ACDS), Hyderabad, Telangana. Approval from the Institutional Ethics Committee (IEC) was sought for the same (ACDS/IEC/111/2022). The study included three-dimensional (3D) CBCT scans of the patients with fully formed roots of permanent maxillary central incisor, lateral incisor, and maxillary canine. CBCT scans were obtained using the NewTom GO Complete Vision machine (Cefla SC, Italy). NNT Viewer software version 13 (Cefla SC, Italy) was used to assess the pulp and tooth area of the maxillary central incisors, maxillary lateral incisors, and maxillary canines with fully formed roots using the area tool. The principal investigator (S B), an oral and maxillofacial radiologist with subject expertise used FOVs of 8X6 cm, 10X6 cm, and 10X10 cm to study the scans. The CBCT radiographic images used in this study were generated for diagnosis and standard dental care under the following exposure parameters: tube current 4.94 mA, tube voltage 90 kV, and exposure time 27.68 mAS. Patients with edentulous maxillary central incisors, lateral incisors, or canines, as well as those with root resorption (internal or external), teeth anomalies including but not limited to deformities, variations in tooth size or shape, or patients with any conditions affecting the pulp-to-tooth area, such as cysts or tumors in the region of interest, were excluded from the study. Additionally, radiographic images of patients with endodontic involvement in the selected teeth were excluded. Images for measurements were acquired using a multiplanar tool where the maxillary central incisors, lateral incisors, and canines were studied in all three planes, i.e., the axial at the level of CEJ, the mid-sagittal plane, and the mid-coronal plane (Figure 1). Pulpal and tooth areas were measured using the “area tool” in the acquired images in all three planes, and the pulp-to-tooth area ratio (PTR) was calculated from the measurements obtained (Figure 2). An image slice thickness of 0.15 mm was selected. A random sample of 70 radiographs was used for metric reiteration of the pulp-to-tooth area after two weeks by the same investigator S B, who was blinded to the chronological age of the subjects, to test the reproducibility of intra-observer bias using a paired t-test. A descriptive analysis was performed to obtain the mean age of the study sample and the mean pulp-to-tooth area ratio of the maxillary central incisors, lateral incisors, and canines in multiplanar sections (viz., axial at the level of CEJ, mid sagittal, and mid coronal sections), as depicted in (Tables 1 and 2). Pearson correlation coefficient between age and PTR based on tooth type, and the section type was calculated (Table 3). Linear regression analysis for age (dependent variable y) and the PTR of the three planes for the three tooth types (SEE= Std error of estimate) was calculated (Table 4). A multiple regression model with all the planes combined for each tooth was developed (Table 5).

Figure 1. Multiplanar selection of teeth to measure the pulp and tooth areas in axial, coronal, and sagittal sections.

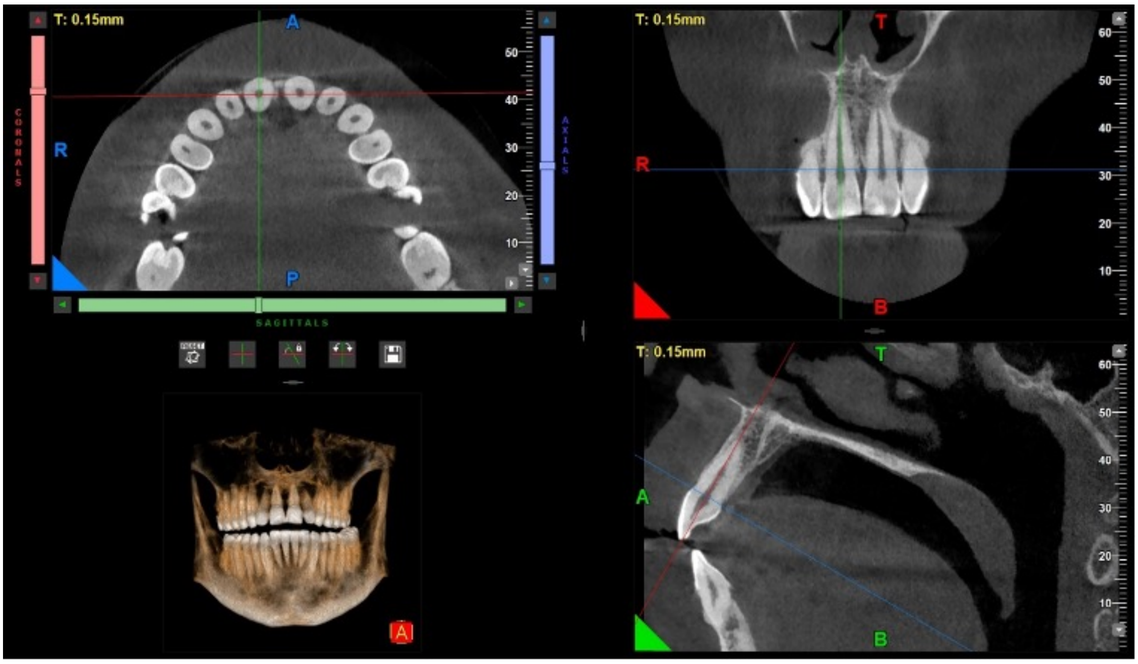
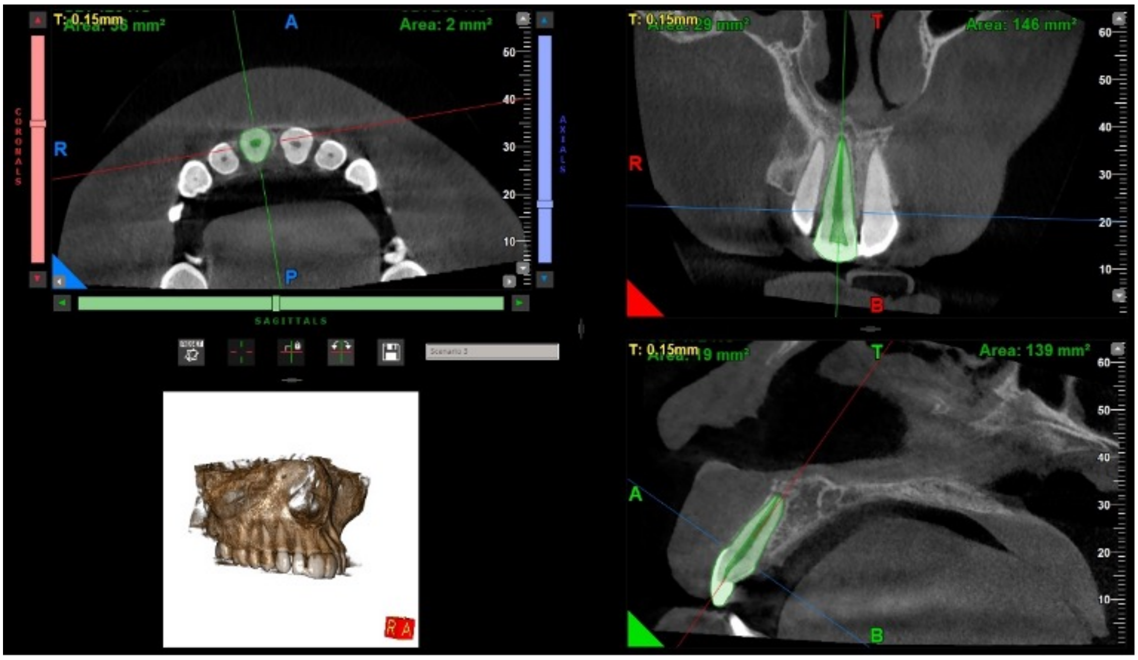


Figure 2. Tooth and pulp area measurements in the axial, coronal, and sagittal sections



Statistical analysis:
The obtained data were subjected to correlation and regression analysis using SPSS software version 25.0 (IBM Corp., USA). The standard error of estimate (SEE) was calculated to estimate the standard deviation of the estimated age using the PTR values. The coefficient of determination (R2) was calculated to measure the predictive power of PTR in different orthogonal planes for age estimation in the given sample.

RESULTS

The mean age of the study sample is 34.41 years, and the mean pulp-to-tooth area ratio of the maxillary central incisors, lateral incisors, and canines in multiplanar sections was calculated and depicted in Tables 1 & 2.
The Pearson correlation coefficient between age and PTR based on tooth type and section type was calculated (Table 2).
Table 3 and 4 depicts the regression equation, standard estimate of error, and coefficient of determination of teeth of interest in all three sections (i.e., axial at the level of CEJ, mid-sagittal, and mid-coronal).
A paired sample t-test was used to analyze the intra-observer variation between the initial and subsequent measurements, and there was no statistically significant variation ($p > 0.05$).

Table 1. Sample size distribution.

Age range (years)	Sample size distribution	
12-30	43	Mean age: 34.41 Median: 35
31-50	42	
51-70	15	

Table 2. Mean values of continuous variables

Variable		Mean	Std. Deviation
Age (years)		34.41	13.479
Class of Tooth studied			
Maxillary central incisors	PTR axial	.0626	.02035
	PTR sagital	.1523	.03875
	PTR coronal	.1482	.04959
Maxillary lateral incisors	PTR axial	.1269	.52383
	PTR sagital	.1507	.04371
	PTR coronal	.1430	.04066
Maxillary canines	PTR axial	.0503	.01955
	PTR sagital	.1924	.05117
	PTR coronal	.1261	.03715

Table 3. Age correlations with the type of tooth and the sections studied.

Type of tooth		Correlation coefficient (r)	p-value
Maxillary central incisor	Axial section at the level of CEJ	-.540	.000
	Mid sagittal	-.623	.000
	Mid coronal	-.500	.000
Maxillary lateral incisor	Axial section at the level of CEJ	.059	.541
	Mid sagittal	-.522	.000
	Mid coronal	-.255	.007
Maxillary canine	Axial section at the level of CEJ	-.530	.000
	Mid sagittal	-.625	.000
	Mid coronal	-.493	.000

Table 4. Regression equation to calculate the age.

Type of tooth		Regression equation (Y = age	Standard estimate of error (SEE) in years
Maxillary central incisor	Axial section at the level of CEJ	Y = 56.779 + (-357.485 * PTR axial)	± 11.5
	Mid sagittal	Y= 67.419 + (-216.77 * PTR sagittal)	± 10.0
	Mid coronal	Y = 54.567 + (-135.992 * PTR coronal)	± 11.3
Maxillary lateral incisor	Axial section at the level of CEJ	Y = 34.217 + (1.515 * PTR axial)	± 14.3
	Mid sagittal	Y= 58.676 + (-161.008 * PTR sagittal)	± 11.7
	Mid coronal	Y = 46.493 + (-84.483 * PTR coronal)	± 14.0
Maxillary canine	Axial section at the level of CEJ	Y = 52.786 + (-365.482 * PTR axial)	± 10.4
	Mid sagittal	Y= 66.103 + (-164.735 * PTR sagittal)	± 08.0
	Mid coronal	Y = 56.950 + (-178.729 * PTR coronal)	± 12.2

Table 5. Regression analysis for all three planes combined for each tooth

Tooth	R	R^2	p-value for the model	Regression equation (Y = age in years)	Standard estimate of error (SEE) in years
Central	.696	.484	.000	Y = 73.914 + (-179.85 * PTR axial)+ (-133.93*PTR sagittal)+ (-52.99*PTR coronal)	9.817
Lateral	.531	.261	.000	Y= 61.197 + (1.02*PTR axial)+(-152.31 * PTR sagittal)+(-27.69*PTR coronal)	11.58
Canine	.698	.472	.000	Y = 73.47 + (-149.62 * PTR axial) +(-112.038 * PTR sagittal) (-82.533 * PTR coronal)	9.79

DISCUSSION

Dental age estimation is a discipline of forensic dentistry that uses factors such as tooth development, biochemical alterations, and modifications following the completion of the teeth to determine dental age.[12] The present study calculated the pulp-to-tooth area ratio of the maxillary anterior teeth using 3D CBCT images. CBCT enables multiplanar cross-sectional images with 3D reconstruction in a single scan, in addition to nominal anatomic superimposition and geometric distortion.[11] Permanent maxillary anterior teeth are chosen considering the simplicity of the pulpal morphology as well as the fact that the incisors and canines are less likely to be affected by attrition and/or carious processes compared to the posterior teeth.[13] In addition, the relatively longer roots with wider pulp areas offer ease in the metric analysis of the pulp-to-tooth area.[13] Alkarni et al. proved that no significant statistical difference between the left and right sides of the jaw was noticed. Hence, maxillary anterior teeth on either side were chosen in this present study.[13] The pulp-to-tooth area was measured as the method of calculating tooth and pulp area may be more indicative of changes within teeth than the one-dimensional measurements of length and width made by Kvaal et al. Additionally, calculating area is easier and requires less equipment than computing pulp and tooth volumes.[11,13] Among the permanent maxillary anterior teeth studied, except the PTR of lateral incisors in their axial sections all three planes for all tooth types were significantly (negatively) correlated to age (Table 3). The findings are consistent with Rai A et al. and Muralidhar et al.[14,15] The linear regression equation to calculate the age in years depicted a lower Standard Error of Estimate [SEE] (±08.0 yrs) in maxillary canines in their mid-sagittal sections (Table 4). An overall superior predictive power in age estimation was observed in the mid-sagittal plane compared with the other planes of study. One possible explanation for the superior accuracy of measurements at sagittal sections over axial ones could be the ratio being unaffected by image distortion from teeth that are misaligned.[16] This is per the studies conducted by Lee et al. and Affiy MM et al., who used CBCT images in the buccolingual and axial dimensions of maxillary canines to measure PTR in Korean and Egyptian populations, respectively. The authors further proposed that the reliability of sagittal measurements in age estimation could be due to a larger PTR of the images in the sagittal section than in axial section images.[16,17] A CBCT study by N. Jagannathan et al**,** using extracted human mandibular canines was used to estimate the age by modifying Yang's formulae and stated that the pulp-to-tooth volume ratio of mandibular canines is a useful predictor of age.[18] The study results directed for a population-specific formula for age estimation. The regression equation in the current study was specific to each tooth type studied and the pulp-to-tooth area ratio served as a useful predictor of age. In a study where maxillary and mandibular second molars were studied for age-related changes in the anatomical configuration of pulp volume, M A Helmy et al observed a statistically significant increase in the pulp chamber volume with an increase in age. This study also noticed significant differences in the pulp volume between males and females. The dependence and correlation of the pulp metrics with that of the chronological age are consistent with the findings in the present study. However, the regressive pulpal morphometrics were not studied among males and females independently in the present study.[19] On the other hand, a study conducted by Sironi et al using the Bayesian method for evaluating age-related dental evidence found the influence of gender upon the narrowing of pulp was uneven.[20] The significance of PTR of the mandibular canines in age estimation was proven to be diverse based on a variety of studies.[4,16,18,21,22] A C Pires et al in their CBCT study to estimate the age among the Portuguese population found that there are statistically significant differences between the chronological age and the dental age of individuals using pulp/tooth ratio, and concluded that Kvaal's formulae for age estimation are not reproducible in the Portuguese population when applied in CBCT which is in contrast with the present study.[23] In a pilot study, V Pinchi et al observed that the pulp chamber's narrowing is a dependable indicator of an adult's age, and CBCT is a simple, conservative method that provides precise tooth volume calculations. The suggested method is predicated on a geometric approximation of the upper central incisor volumes derived by free image processing software and assessed by CBCT.[24] Studies by Wu et al. and Haghanifar et al. are conclusive about the reliability of the maxillary central incisors in age estimation in comparison with that of the maxillary canines, which depicted a higher predictive power and lower SEE in maxillary central incisors.[21,25] Studies by Biuki et al. and Gulsahi et al. used teeth and pulpal volumes and found maxillary incisors as the better and superior means for age estimation.[26,27] The multiple regression analysis with all the planes combined for each tooth type showed a SEE of ±9.8 yrs and ±9.79 yrs for maxillary central incisors and canines respectively, which reveals a comparable accuracy of these teeth types in age estimation using PTR (Table 5). Furthermore, the SEE values < ± 10 years are of pertinent forensic value in age estimation studies. The limitation of the current study is that it excludes the possibility of inter-observer bias. Studying the pulp volume although sophisticated would give a deeper insight into the metric analysis however, the current study's primary objective included only linear measurements. Furthermore, the limited sample size in this study makes it difficult to apply the formula broadly.

CONCLUSION

The present study analyzed the pulp-to-tooth area ratio in three different teeth for age estimation using three-dimensional cone beam computed tomography images, and the maxillary canines and central incisors have yielded acceptable results in predicting age. Mid-sagittal sections had the highest correlation to predict age, and the axial sections had the least correlation to predict age. Future directions: Extensive research to derive population-specific formulae is necessary. Future studies to include the impact of regressive alterations on the morphometrics of the teeth when studied radiographically.

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REFERENCES

1. Jeddy N, Ravi S, Radhika T. Current trends in forensic odontology. J Forensic Dent Sci. 2017 Sep-Dec;9(3):115-119. doi: 10.4103/jfo.jfds_85_16. PMID: 29657486; PMCID: PMC5887632.
2. Patyal, Shama & Pandey, Tejasvi. (2023). Forensic Radiology: A Spotlight on India's Current Trend and Future Prospects. Forensic Imaging. 34. 200561. 10.1016/j.fri.2023.200561.

3. Clemente MA, La Tegola L, Mattera M, Guglielmi G. Forensic Radiology: An Update. J Belg Soc Radiol. 2017 Dec 16;101(Suppl 2):21. doi: 10.5334/jbr-btr.1420. PMID: 30498810; PMCID: PMC6251081.
4. Vila-Blanco N, Varas-Quintana P, Tomás I, Carreira MJ. A systematic overview of dental methods for age assessment in living individuals: from traditional to artificial intelligence-based approaches. Int J Legal Med. 2023 Jul;137(4):1117-1146. doi: 10.1007/s00414-023-02960-z. Epub 2023 Apr 14. PMID: 37055627; PMCID: PMC10247592.
5. Kvaal SI, Kolltveit KM, Thomsen IO, Solheim T. Age estimation of adults from dental radiographs. Forensic Sci Int. 1995 Jul 28;74(3):175-85. doi: 10.1016/0379-0738(95)01760-g. PMID: 7557754.
6. Cameriere R, Ferrante L, Cingolani M. Variations in pulp/tooth area ratio as an indicator of age: a preliminary study. J Forensic Sci. 2004 Mar;49(2):317-9. PMID: 15027553.
7. Ikeda N, Umetsu K, Kashimura S, Suzuki T, Oumi M (1985) Estimation of age from teeth with their soft x-ray findings. Jpn J Legal Med 39(3):244–250
8. Santos MA, Muinelo-Lorenzo J, Fernández-Alonso A, Cruz-Landeira A, Aroso C, Suárez-Cunqueiro MM. Age Estimation Using Maxillary Central Incisor Analysis on Cone Beam Computed Tomography Human Images. Int J Environ Res Public Health. 2022 Oct 16;19(20):13370. doi: 10.3390/ijerph192013370. PMID: 36293951; PMCID: PMC9603614.
9. Juneja M, Devi YB, Rakesh N, Juneja S. Age estimation using pulp/tooth area ratio in maxillary canines-A digital image analysis. J Forensic Dent Sci. 2014 Sep;6(3):160-5. doi: 10.4103/0975-1475.137047. PMID: 25177137; PMCID: PMC4142405.
10. Chandan PK, Arora KS, Das M, Kaur P, Mohaptra S, Pareek S. Assessment of validity and reliability of Kvaal's method for age estimation among a population sample - A retrospective study. Indian J Dent Res. 2020 Mar-Apr;31(2):186-190. doi: 10.4103/ijdr.IJDR_209_18. PMID: 32436895.
11. Merdietio Boedi R, Shepherd S, Mânica S, Franco A. CBCT in dental age estimation: A systematic review and meta analysis. Dentomaxillofac Radiol. 2022 May 1;51(4):20210335. doi: 10.1259/dmfr.20210335. Epub 2022 Jan 7. PMID: 34995103; PMCID: PMC9499196.
12. Verma M, Verma N, Sharma R, Sharma A. Dental age estimation methods in adult dentitions: An overview. J Forensic Dent Sci. 2019 May-Aug;11(2):57-63. doi: 10.4103/jfo.jfds_64_19. Epub 2020 Jan 24. PMID: 32082039; PMCID: PMC7006305.
13. Alqarni, A.; Ajmal, M.; Hakami, R.M.; Alassmi, A.A.; Chalikkandy, S.N.; Arem, S. Relationship between Pulp–Tooth Area Ratio and Chronological Age among Saudi Arabian Adults: A Cone Beam Computed Tomography Image Analysis. Appl. Sci. 2023, 13, 7945. https://doi.org/10.3390/app13137945
14. Rai A, Acharya AB, Naikmasur VG. Age estimation by pulp-to-tooth area ratio using cone-beam computed tomography: A preliminary analysis. J Forensic Dent Sci. 2016 Sep-Dec;8(3):150-154. doi: 10.4103/0975-1475.195118. PMID: 28123269; PMCID: PMC5210102.
15. Muralidhar N V, Nitin P, Kumareswar S, Pillai A. Pulp Tooth Ratio-Based Age Estimation of Adults Using CBCT Images. Journal of Orofacial Sciences 2021; 13: 114-120. DOI:10.4103/jofs.jofs_232_21
16. Afify MM, Salem WS, Mahmoud NF. Age estimation from pulp/tooth area ratio of canines using cone-beam computed tomography image analysis: study of an Egyptian sample. J Forensic Res 2019; 10: 1-7. DOI:10.4172/2157-7145.1000434
17. Lee S-M, Oh S, Kim J, Kim Y-M, Choi Y-K, Kwak HH, et al. Age estimation using the maxillary canine pulp/tooth ratio in Korean adults: A CBCT buccolingual and horizontal section image analysis. J Forens Radiol Imaging 2017; 9: 1–5. DOI:10.1016/J.JOFRI.2016.12.001
18. 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: 1-6. PMCID: PMC5734837
19. Helmy MA, Osama M, Elhindawy MM, Mowafey B. Volume analysis of second molar pulp chamber using cone beam computed tomography for age estimation in Egyptian adults. J Forensic Odontostomatol. 2020 Dec 30;38(3):25-34. PMID: 33507164; PMCID: PMC8565657.
20. Sironi E, Taroni F, Baldinotti C, Nardi C, Norelli GA, Gallidabino M, Pinchi V. Age estimation by assessment of pulp chamber volume: a Bayesian network for the evaluation of dental evidence. Int J Legal Med. 2018 Jul;132(4):1125-1138. doi: 10.1007/s00414-017-1733-0. Epub 2017 Nov 14. PMID: 29138952.
21. Babshet M, Acharya AB, Naikmasur VG. Age estimation from pulp/tooth area ratio (PTR) in an Indian sample: A preliminary comparison of three mandibular teeth used alone and in combination. J Forensic Leg Med 2011; 18: 350–4. DOI: 10.1016/j.jflm.2011.07.003
22. Haghanifar S, Ghobadi F, Vahdani N, Bijani A. Age estimation by pulp/tooth area ratio in anterior teeth using cone-beam computed tomography: comparison of four teeth. J Appl Oral Sci 2019; 27: e20180722. DOI: 10.1590/1678-7757-2018-0722
23. Pires AC, Vargas de Sousa Santos RF, Pereira CP. Dental age assessment by the pulp/tooth area proportion in cone beam computed tomography: is medico-legal application for age estimation reliable? J Forensic Odontostomatol. 2021 Aug 30;39(2):2-14. PMID: 34419940; PMCID: PMC8630454.
24. Pinchi V, Pradella F, Buti J, Baldinotti C, Focardi M, Norelli GA. 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 Nov;36:150-7. doi: 10.1016/j.jflm.2015.09.015. Epub 2015 Sep 30. PMID: 26458182.
25. Wu Y, Niu Z, Yan S, Zhang J, Shi S, Wang T. Age estimation from root diameter and root canal diameter of maxillary central incisors in Chinese Han population using cone-beam computed tomography. Int J Clin Exp Med. 2016; 9: 9467–72.
26. Biuki N, Razi T, Faramarzi M. Relationship between pulp-to-tooth volume ratios and chronological age in different anterior teeth on CBCT. J Clin Exp Dent 2017; 9: e688-e693. doi: 10.4317/jced.53654
27. Gulsahi A, Kulah CK, Bakirarar B, Gulen O, Kamburoglu K. Age estimation based on pulp/tooth volume ratio measured on cone-beam CT images. Dentomaxillofac Radiol. 2018; 47: 20170239. doi: 10.1259/dmfr.20170239