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CHRONOLOGICAL AGE ESTIMATION USING PULP VOLUME AND TOOTH VOLUME RATIO IN CANINES: A CBCT-BASED ANALYSIS.

Dentistry

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ABSTRACT

Objective: To evaluate the correlation between chronological age and the pulp/tooth volume ratio in maxillary and mandibular canines using cone beam computed tomography. **Methods:** Cone beam computed tomography scans of 120 subjects (60males, 60females) aged 20-70 years were analyzed. Pulp and tooth volumes of maxillary and mandibular canines were measured using semi-automatic segmentation. The pulp/tooth volume ratio was calculated. **Results:** A significant negative correlation was observed between pulp/tooth volume ratio and chronological age ($r = -0.847$, $p < 0.001$). Maxillary canines showed a stronger correlation ($r = -0.862$) than mandibular canines ($r = -0.831$). The regression model derived from maxillary canines represented higher accuracy (R^2=0.743, SEE=±5.21 years) compared to mandibular canines (R^2=0.691, SEE=±5.86 years).No significant gender differences were observed ($p= 0.083$). **Conclusion:** Cone beam computed tomography based pulp/tooth volume ratio measurement in canines provides a reliable and non- invasive method for age estimation in adults. Maxillary canines appear to be more accurate predictors of age than mandibular canines. The regression equations developed can serve as valuable tools in forensic investigations and age estimation.

KEYWORDS

Age Estimation, Cone Beam Computed Tomography, Pulp/tooth Volume Ratio.

I INTRODUCTION

Age estimation is a crucial component of forensic identification and plays a significant role in both legal and anthropological contexts [1].Among various biological parameters used for age estimation, dental age has proven to be particularly reliable due to the resistance of teeth to environmental influences, postmortem changes, and various taphonomic processes [2].

Traditional dental age estimation methods have primarily utilized two-dimensional radiographic techniques which inherently limit the accuracy of volumetric assessments [3].The progressive deposition of secondary dentine throughout life results in a gradual reduction of the pulp cavity, creating a strong correlation between pulp size and chronological age [4].This relationship forms the biological basis for age estimation methods using dental structures. The emergence of three-dimensional imaging technologies, particularly cone beam computed tomography (CBCT), has revolutionized dental imaging by enabling precise volumetric measurements of teeth and their internal structures [5]. CBCT offers several advantages over conventional computed tomography, including lower radiation dose and higher spatial resolution. [6].

Canines are often selected for age estimation studies due to their longevity in the oral cavity, single root morphology, large pulp dimensions and lower susceptibility to wear compared to other tooth types [7]. Several studies have demonstrated significant correlations between pulp/tooth volume ratio (PTVR) and chronological age using different imaging modalities [8,9]. However, the comparative accuracy of maxillary versus mandibular canines in age prediction models remains insufficiently explored.

The present study aims to evaluate the correlation between chronological age and PTVR in both maxillary and mandibular canines using CBCT.

II MATERIALS AND METHODS

The study protocol was approved by the institutional ethical committee (EC/NEW/GIDSR/2025/4466). CBCT scans of 120 patients (60 males, 60 females) aged between 20 and 70 years (mean age: 44.6 ± 14.3 years) were retrospectively selected from the radiology department database. The sample was stratified into five decadal age groups (20-30, 31-40, 41-50, 51-60, and 61-70 years), with 24 subjects (12 males, 12 females) in each group.

A Inclusion Criteria:

(1) complete formation of canine roots, (2) absence of periapical lesions, (3) absence of root canal treatment, (4) absence of extensive restorations, (5) absence of severe attrition or abrasion, and (6) absence of dental anomalies.

B Exclusion Criteria:

(1) Presence of pathological lesions, (2) history of trauma, (3) developmental abnormalities, and (4) poor quality CBCT images.

C CBCT Acquisition and Image Processing

All CBCT examinations were performed using the Vatech A9 (Model:PHT-3OCSS, Version:1.02) scanner with the following parameters: 94 kVp, 7.3 mA , 80x80 mm field of view,0.20 mm voxel size, and exposure time of 15.5 seconds. The DICOM data were imported into 3D Slicer software (EZ3D-I version 5.2) for segmentation and volumetric analysis.

For each subject, the right maxillary and mandibular canines were selected for analysis.When the right canine did not meet the inclusion criteria, the left canine was used instead. The teeth were segmented using a semi-automatic approach based on threshold values, followed by manual editing to refine the segmentation. The pulp was segmented separately using adjusted threshold values specific to pulp tissue, followed by manual refinement. The volumes of the tooth and pulp were calculated in cubic millimeters (mm^3) and PTVR was derived. (Figure 1,2)

To assess intra- observer reliability, 30 randomly selected CBCT scans were re-measured by the same examiner after a two-week interval. For inter-observer reliability, the same 30 scans were independently analyzed by a second examiner.

III Statistical Analysis

Statistical analysis was performed using SPSS software (version 28.0, IBM Corp., Armonk, NY, USA).The Shapiro - Wilk test was used to assess the normality of data distribution. Intra- and inter-observer

reliability were evaluated using intraclass correlation coefficients (ICC). Pearson's correlation coefficient was calculated to determine the relationship between chronological age and PTVR. Simple and multiple regression analyses were performed to establish age estimation models. The standard error of estimate was calculated for each regression model. Independent samples t-test was used to compare the mean values between genders. Statistical significance was set at $p < 0.05$.

IV RESULTS

All the vales of tooth volume (mm^3), pulp volume (mm^3) and ptvr (%) in maxillary canine and mandibular canine were expressed in terms of mean and standard deviation respectively in different age groups. A comparasion was done for tooth volume (mm^3), pulp volume (mm^3) and ptvr (%) b/w maxillary canine and Mandibular canine by using the un-paired "t" test / in-dependent " t "test at .05 level of signficance. Also, karl- pearsons correlation cofficient was assessed and Regression equation was established b/w ptvr and chronological age in maxillary Canine and mandibular canine respectively. Simple and multiple regression analyses were performed to establish age estimation models. Also, comparsion was made For b/w maxillary canine and mandibular canine corresponding to different age.

Groups at .05 level of significance by one way anova-f test and un-paired "t" test respectively. A p- value less than / equal to ($p \leq .05$) was considerd as significant. All the data was entered in m.s. excel sheet and statistical calculation was done by S.p.s.s. –software (28.00) version.

Table 1. Mean Tooth Volume, Pulp Volume and PTVR by Age Group

Age Group (years)	n	Maxillary Canine			Mandibular Canine		
		Tooth Volume (mm^3)	Pulp Volume (mm^3)	PTVR (%)	Tooth Volume (mm^3)	Pulp Volume (mm^3)	PTVR (%)
20-30	24	783.4 ± 112.5	48.2 ± 8.3	6.15± 0.72	614.7 ± 89.2	35.6 ± 6.4	5.79± 0.68
31-40	24	792.1 ± 108.4	42.6 ± 7.8	5.38± 0.65	623.5 ± 94.6	31.8 ± 6.1	5.10± 0.63
41-50	24	775.8 ± 115.2	36.1 ± 7.2	4.65± 0.59	608.9 ± 91.8	27.2 ± 5.8	4.47± 0.57
51-60	24	769.3 ± 110.8	30.2 ± 6.9	3.93± 0.54	602.4 ± 88.5	22.8 ± 5.5	3.79± 0.52
61-70	24	758.7 ± 116.3	24.5 ± 6.4	3.23± 0.48	594.1 ± 92.3	18.3 ± 5.1	3.08± 0.47
Total	120	775.9 ± 112.6	36.3 ± 10.9	4.67± 1.21	608.7 ± 91.3	27.1 ± 8.2	4.45± 1.12

Table 2. Pearson's Correlation Coefficients (r) Between PTVR and Chronological Age

ToothType	Overall (n=120)	Males (n=60)	Females (n=60)	p-value (gender difference)
MaxillaryCanine	-0.862*	-0.851*	-0.875*	0.083
Mandibular Canine	-0.831*	-0.819*	-0.842*	0.083
Combined	-0.847*	-0.835*	-0.858*	0.083

*Significant at $p<0.001$

Table 3. Simple Linear Regression Models for Age Estimation

Tooth Type	Regression Equation	R^2	SEE (years)
MaxillaryCanine	Age=86.42 -8.94×PTVR	0.743	±5.21
Mandibular Canine	Age=82.76 -8.57×PTVR	0.691	±5.86

Table 4. Multiple Regression Model for Age Estimation

Model	Regression Equation	R^2	SEE (years)
Combined (Maxillary+ Mandibular)	Age=87.21-5.82×PTVR (maxillary)-3.91 ×PTVR (mandibular)	0.769	±4.92

Table 5. Mean Absolute Error (MAE) in Age Estimation by Age Group

Age Group (years)	n	Maxillary Canine	Mandibular Canine	Combined Model
20-30	24	4.23 ± 3.12	4.86 ± 3.58	3.95 ± 2.86
31-40	24	4.58 ± 3.45	5.12 ± 3.74	4.13 ± 3.21
41-50	24	4.87 ± 3.61	5.35 ± 3.91	4.42 ± 3.36
51-60	24	5.34 ± 3.98	5.89 ± 4.17	4.86 ± 3.62
61-70	24	5.76 ± 4.23	6.32 ± 4.52	5.24 ± 3.87
Overall	120	4.96 ± 3.68	5.51 ± 4.01	4.52 ± 3.41

Table 6. Gender – Specific Regression Equations

Gender	Tooth Type	Regression Equation	R^2	SEE (years)
Male	MaxillaryCanine	Age=85.93-8.81×PTVR	0.724	±5.36
Male	Mandibular Canine	Age=82.15-8.49×PTVR	0.671	±5.97
Female	MaxillaryCanine	Age=87.08-9.12×PTVR	0.766	±5.07
Female	Mandibular Canine	Age=83.42-8.68×PTVR	0.709	±5.72

Table 7 . Distribution of Residuals (Estimated Age-Actual Age)

ResidualRange (years)	Maxillary Canine	Mandibular Canine	Combined Model
<-10.0	3 (2.5%)	5 (4.2%)	2 (1.7%)
-10.0to-5.1	17 (14.2%)	20 (16.7%)	14 (11.7%)
-5.0to-0.1	39 (32.5%)	36 (30.0%)	42 (35.0%)
0.0 to 5.0	41 (34.2%)	39 (32.5%)	43 (35.8%)
5.1 to 10.0	16 (13.3%)	15 (12.5%)	16 (13.3%)
>10.0	4 (3.3%)	5 (4.2%)	3 (2.5%)
Total	120 (100%)	120 (100%)	120 (100%)

V DISCUSSION

The present study investigated the relationship between (PTVR) in canines and chronological age using CBCT imaging. Our findings demonstrate a strong negative correlation between PTVR and age, confirming the utility of this parameter as a reliable indicator for dental age estimation.

The strong correlation coefficients observed in our study($r=-0.862$ for maxillary canines; $r=-0.831$ for mandibular canines) are comparable to or slightly higher than those reported in previous studies. Star et al. found a correlation of $r=-0.880$ using micro-CT, while Yang et al. reported a correlation of $r=-0.818$ using CBCT [10,11].The slightly stronger correlation in our study compared to some previous CBCT-based investigations may be attributed to the higher resolution parameters employed and the systematic application of manual refinement during segmentation.

The coefficient of determination (R^2) values obtained in our regression models (0.743 for maxillary canines ; 0.691 for mandibular canines) indicate that approximately 69-74% of the age-related variations can be explained by changes in PTVR. These values are consistent with previous studies, which have reported R^2 values ranging from 0.65 to 0.78 (12-14). The standard error of estimate values (±5.21 years for maxillary canines; ±5.86 years for mandibular canines) are within acceptable limits for forensic applications and comparable to other dental age estimation methods [12].

Our findings indicate that maxillary canines provides lightly more accurate age estimates than mandibular canines, which aligns with the results reported by Tardivo et al. [13] This difference may be attributed to several factors, including the larger dimensions of maxillary canines, which facilitate more precise measurements and their more stable morphology with less variation in root anatomy compared to mandibular canines. Additionally, the greater thickness of the dentine in maxillary canines may result in a more consistent pattern of secondary dentine deposition, enhancing their predictive value for age estimation.

The multiple regression model incorporating both maxillary and mandibular canine measurements showed a modest improvement in predictive accuracy ($R^2=0.769$, SEE=±4.92 years) compared to the single canine models. This suggests that a comprehensive approach utilizing multiple teeth may enhance the reliability of age estimation, as previously proposed by Ge et al.[14] However, the relatively small improvement must be weighed against the additional time and resources required for analyzing multiple teeth.

The absence of significant gender differences in our study is consistent with several previous investigations [15,16] but contrasts with others that have reported gender-specific variations in secondary dentine deposition rates. [17,18] The trend toward slightly higher correlation coefficients in females observed in our study, although not statistically significant, warrants further investigation with larger sample sizes.

The accuracy of age estimation, as measured by mean absolute error (MAE), decreased with advancing age across all models. This observation aligns with previous studies and likely reflects the increased biological variability and cumulative effects of environmental factors with aging [19] Nevertheless, the combined

model demonstrated acceptable accuracy across all age groups, with overall MAE of 4.52 ± 3.41 years.

The semi-automatic segmentation approach employed in our study demonstrated excellent reliability, as evidenced by the high ICC values for both intra- and inter-observer measurements. This highlights the reproducibility of the methodology and its potential for standardized application in forensic practice. However, the technique remains time-consuming, requiring approximately 18-20 minutes per tooth, which may limit its routine application in certain forensic contexts.

Several limitations should be acknowledged when interpreting our results. First, the cross- sectional design precludes the evaluation of age-related changes in PTVR over time in the same individuals. Second, the study population was derived from a single institution, potentially limiting the generalizability of the findings to different populations.Third, various factors that might influence secondary dentine deposition, such as occlusal forces, dietary habits, and systemic conditions, were not comprehensively controlled for beyond the established inclusion criteria.

Future research should focus on longitudinal assessment of PTVR changes, development of population-specific regression equations, automation of segmentation processes to enhance efficiency and exploration of potential confounding factors affecting secondary dentine deposition. Additionally, the integration of machine learning approaches may further improve the accuracy of age prediction models.

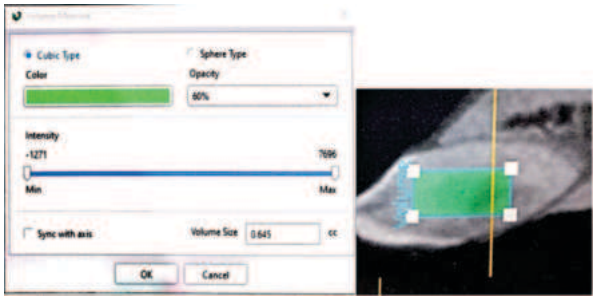

Figure 1 (CBCT Image of Maxillary Canine Representing Pulp and Tooth Volume Calculated in Cubic Millimeters.)

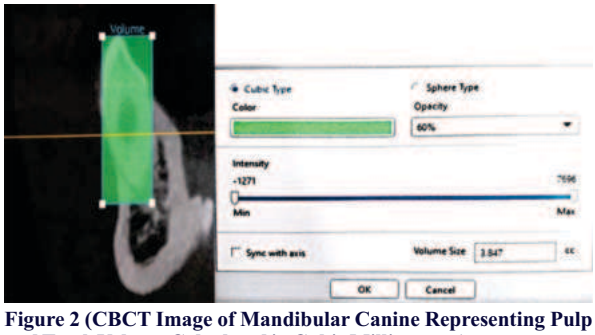

Figure 2 (CBCT Image of Mandibular Canine Representing Pulp and Tooth Volume Calculated in Cubic Millimeters.)

VI CONCLUSION

The present study concluded that CBCT-based measurement of pulp/tooth volume ratio in canines provides a reliable and non-invasive method for dental age estimation in adults. Maxillary canines demonstrated superior performance compared to mandibular canines and a combined approach incorporating both teeth slightly enhanced the predictive accuracy. The proposed regression equations can serve as valuable tools in forensic investigations, particularly in the identification of unknown individuals and age determination in legal contexts. Further refinement of the technique through automation and population-specific calibration may enhance its practical utility in forensic odontology.

VII REFERENCES

1. Schmeling A, Dettmeyer R, Rudolf E, Vieth V, Geserick G., 'Forensic age estimation: methods, certainty, and the law', Deutsches Ärzteblatt International, vol. 113, no. 4, 2016, p. 44-50.
2. Panchbhai AS, ' Dental radiographic indicators, a key to age estimation', Dentomaxillofacial Radiology, vol. 40, no. 4, 2011, p. 199-212.
3. Cameriere R, Ferrante L ,Cingolani M, ' Variations in pulp/tooth area ratio as an indicator of age: a preliminary study' , Journal of Forensic Sciences, vol. 49, no. 2, 2004, p. 7-9.
4. Murray PE, Stanley HR, Matthews JB, SloanAJ, SmithAJ, 'Age-related odontometric changes of human teeth.' , Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology, vol. 93, no. 4, 2002, p. 474-82.
5. Marroquin TY, Karkhanis S, Kvaal SI, Vasudavan S, Kruger E, Tennant M, 'Age estimation in adults by dental imaging assessment systematic review' , Journal of Forensic Sciences, vol. 275, 2017 p. 203-11.
6. ScarfeWC, FarmanAG, 'What is cone-beam CT and how does it work?' , Dental Clinics of North America, vol. 52, no. 4, 2008, p. 707-30.
7. FabbriPF, VivaS, FerranteL, LonoceN, TiberiI, CamerieR, 'Radiologicaltooth/pulp ratio in canines and individual age estimation in a sample of adult neolithic skeletons' , American Journal of Physical Anthropology, vol. 158, no. 3, 2015, p. 423-30.
8. JagannathanN, NeelakantanP, ThiruvengadamC, RamaniP, PremkumarP, NatesanA, et al, 'Age estimation in an Indian population using pulp/tooth volume ratio of mandibular canines obtained from cone beam computed tomography', Forensic Odontostomatology, vol. 29, no. 1, 2011, p. 1-6.
9. Zou L, SasakiY, Sato I, Kawaguchi M, Domon M, ToriyamaY, et al, 'A study on the pulp cavity of mandibular first molars by X-ray computed tomography', The Bulletin of Tokyo Dental College 2019;vol. 60, no. 3, 2019, p. 157-66.
10. Star H, Thevissen P, Jacobs R, Fieuws S, Solheim T, Willems G, 'Human dental age estimation by calculation of pulp/tooth volume ratios yielded on clinically acquired cone beam computed tomography images of monoradicular teeth', Journal of Forensic Sciences, vol. 56, no. S1, 2011, p. 77-82.
11. YangF, JacobsR, WillemsG, 'Dental age estimation through volume matching of teeth imaged by cone-beam CT', Forensic Science International, vol. 159, no. 1, 2006, p. 78-83.
12. Cameriere R, De Luca S, Alemán I, Ferrante L, Cingolani M, 'Age estimation by pulp/tooth ratio in lower premolars by orthopantomography', Forensic Science International, vol. 214,vol. 1-3, 2012, p. 105-12.
13. Tardivo D, Sastre J, Ruquet M, Thollon L, Adalian P, Leonetti G, et al, 'Three-dimensional modeling of the various volumes of canines to determine age and sex: a preliminary study. Journal of Forensic Sciences, vol. 56, no. 3, 2011, p. 766-70.
14. GeZP, MaRH, LiG, ZhangJZ, MaXC, 'Age estimation based on pulp chamber volume of first molars from cone-beam computed tomography images', Forensic Science International, vol. 25, no. 3, 2015, p. 139-141.
15. Someda H, Saka H, Matsunaga S, IdeY, Nakahara K, Hirata S, et al, 'Age estimation based on three-dimensional measurement of mandibular central incisors in Japanese', Forensic Science International, vol. 185, no. 1-3, 2009, p. 110-4.
16. AyadCE, HamidHM, AbdallaEA, KajoakSA, 'EstimationofageforSudaneseadults using orthopantomographs', Global Journal of Medical Research, vol. 14, no. 1, 2014, p.7-14.
17. Vodanović M, Dumančić J, GalićI,Pavičin IS, Petrovečki M, CamerieR, et al, 'Age estimation in archaeological skeletal remains: evaluation of four non-destructive age calculation methods' , Forensic Odontostomatology, vol. 29, no. 2, 2019, p. 14-21.
18. NemsiH, HajSalemN, BouaneneI, BenJomaa S, BelhadjM, MosratiMA, etal, 'Age assessment in canine and premolar by cervical axial sections of cone-beam computed tomography', Legal Medicine (Tokyo), vol. 28, 2017, p. 31-6.
19. Sakuma A, Saitoh H, Suzuki Y, Makino Y, Inokuchi G, Hayakawa M, et al, 'Age estimation based on pulp volume of a single tooth: Old things and new things', Forensic Science International, vol. 233, no. 1-3, 2013, p.371-5.