PAKISTAN JOURNAL OF HEALTH SCIENCES
https://thejas.com.pk/index.php/pjhs
ISSN (P): 2790-9352, (E): 2790-9344
Volume 5, Issue 7 (July 2024)

Original Article

Forensic Age Estimation by Maxillary and Mandibular Canines Pulp-Tooth Ratio Using Cone-Beam Computed Tomography in Adult Population of Peshawar, Pakistan

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ARTICLE INFO

Keywords:
Forensic Odontology, Pulp/Tooth Ratio, Cone-Beam Computed Tomography, Canines

How to Cite:
Zeb, M., Khan, O., Syed, S., Shazia, S., Khan, Y., Haq, R. U., & Hanif, A. (2024). Forensic Age Estimation by Maxillary and Mandibular Canines Pulp-Tooth Ratio Using Cone-Beam Computed Tomography in Adult Population of Peshawar, Pakistan: Forensic Age Estimation by Canine Pulp-Tooth Ratio. Pakistan Journal of Health Sciences, 5(07). https://doi.org/10.54393/pjhs.v5i07.1817

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Received Date: 4th June, 2024
Acceptance Date: 25th July, 2024
Published Date: 31st July, 2024

ABSTRACT

Age estimation is a vital aspect of forensic sciences and numerous age estimation methods are suggested in dentistry, emphasizing the need for easy and quick technique appropriate for adults. Forensic age estimation can be performed using physical, biochemical, histological, and radiological methods. However, Cone-Beam Computed Tomography (CBCT) offers a promising approach in this regard. **Objective:** To estimate the age on the basis of maxillary and mandibular canines' Pulp-Tooth Ratio (PTR) using CBCT in adults and developing age estimation standards for local population based on PTR. **Methods:** A cross-sectional study was performed at Prime Teaching Hospital, Operative Dentistry and Oral Surgery department of Peshawar Dental College, and Khyber Teaching Hospital for Dentistry, Peshawar, from October 2019 to April 2020. CBCT images of maxillary and mandibular canines of 222 individuals were taken using consecutive sampling technique. PTR was estimated and correlation between age and PTR was determined using linear regression. **Results:** The mean documented age of patients was 36.31 ± 13.44 years. When linear regression was run on individual parameters, only upper left maxillary tooth area (mm^2) was found significant with $p < 0.01$ and $R = 0.132$, with regression model as Age = 26.64 + 0.072 (x). The overall model was found as, Age (years) = 35.519 -0.165 (Upper right maxillary tooth area (mm^2) + 0.298 (Upper right maxillary pulp area (mm^2)) + 0.316 (Upper left maxillary tooth area (mm^2)) + 0.090 (Upper left maxillary pulp area (mm^2)) -0.102 (Lower left mandibular tooth area (mm^2)) -0.211 (Lower left mandibular pulp area (mm^2)) -0.087(lower right mandibular tooth area (mm^2)) + 0.082 (lower right mandibular pulp area (mm^2)). **Conclusions:** Age can be estimated by maxillary and mandibular canines' PTR using CBCT. Using the obtained regression model, age estimation for the adult population can be performed using CBCT scans.

INTRODUCTION

Forensic Age Estimation (FAE) is of crucial importance in forensic science as well as medical and legal conditions like diagnosis, management, prognosis, criminal proceedings, and identification [1]. Understanding of chronological age is essential when official documentation lacks real age. Usually court of law and other civil agencies need this type of expert opinion [2]. FAE is performed using multiple techniques and these techniques are commonly used in combination to find out the accurate age. Determination of secondary sexual, psychological, skeletal, and dental development are a few common methods [3]. As teeth are less impacted by environmental, hereditary, nutritional, hormonal, and pathological factors, these are commonly used structures for age estimation in both deceased and alive individuals [4]. Physical, biochemical, histological, and radiological methods may be used to estimate age from dentine. However, biochemical and histological techniques have limited advantages due to increased time, complex laboratory procedures, and extensive operator experience required for FAE [5]. Radiological method is

DOI: https://doi.org/10.54393/pjhs.v5i07.1817

preferred by odontologists due to its time efficiency, cost-effectiveness and the noninvasive nature. Odontometric estimation can be performed using two dimensional (panoramic and periapical radiograph) and three dimensional [Computed Tomography (CT), or Cone-Beam CT (CBCT)] radiographs for age estimation using dental structures. 2D radiographs have limited visualization of dental structures due to distortion and superposition [6]. On the other hand, three dimensional radiographs provide more consistent ant accurate results. But, exposure to ionizing radiation is a debatable matter in both clinical and forensic settings, so there should be careful evaluation of radiation dose in each individual [7]. CBCT provides precise structural evidence on sagittal, axial, coronal, and multi-planar sections for identification and management planning for healthcare providers. Resultantly, CBCT has been used in multiple studies to identify the relationship between age and secondary dentine growth like Pulp Tooth Area Ratio (PTR), pulp volume, and pulp tooth volume ratio [8-10]. Adult age estimation is challenging task. However, Kvaal method provides accurate PTR estimates in adults using radiographs of maxillary and mandibular canines [11]. Numerous studies have been conducted using this method in different populations to make standards for their respective age estimations [11-13]. However, there is a scarcity of literature on forensic odontology in Pakistan.

This study aimed to estimate the age on the basis of maxillary and mandibular canines' PTR with CBCT in adults and to develop age estimation standards for local population based on PTR.

METHODS

It was a cross-sectional study. It was conducted from March 2023 to August 2023 at Isra university hospital Hyderabad after the authorization of Institutional ethics committee, Isra University, Hyderabad (IU/DM&DR/2023/5266). A specific criterion of inclusion and exclusion was designed. All individuals more than 21 years of age suffering from with T2DM and pre-diabetes were included in this study. Patients with chronic kidney and liver diseases, cancer, bone and mineral disorders, and drug use that interfered with the metabolism of Ca and PO4 were excluded. The sample size was calculated by using population proportion 26.3%. The confidence interval of 95% and error margin of 6.5%. 170 patients were selected with 85 patients in each group. Group A included patients with diabetes mellitus presented in outdoor patients' department of admitted in emergency ward of Isra university hospital. Group B included patients with prediabetes with fasting blood glucose levels of 101-125 mg/dl or HbA1c levels of 5.7-6.4%. Random distribution was done in groups named as Group A (diabetes patients) and Group B (pre- diabetics). Written informed consent was taken from the participants and structured study Performa was designed to collect the data. Blood was withdrawn to measure fasting blood glucose levels, HbA1c levels, total serum calcium levels and serum phosphate levels. HbA1c was compared in both groups to establish the baseline glycemic control status of each group and to confirm the classification criteria for diabetes and prediabetes. The demographic data like age, gender and BMI was also calculated. To compare the mean values of two independent groups (Group A: patients with diabetes and Group B: patients with prediabetes), the study used an independent t-test for continuous variables such as fasting blood glucose levels, HbA1c levels, serum calcium levels, and serum phosphate levels. The results were presented as means and standard deviations. The analysis was performed using SPSS version 24.0. Demographic data are presented as percentages, calculated in Excel. A p-value of ≤0.05 was considered statistically significant. The findings were interpreted in the context of the study objectives and existing literature.

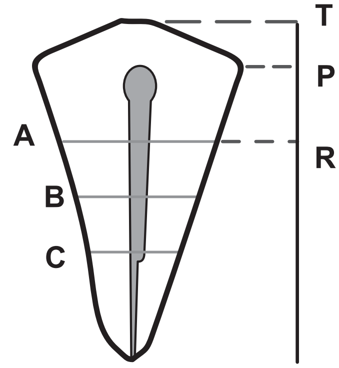

Figure 1: Dental Measurements in Kvaal's PTR Method [15]

RESULTS

The study comprised of 222 individuals. There were 145 (65.32%) male and 77 (34.68%) female cases. The mean documented age of patients was 36.31 ± 13.44 years with minimum and maximum age as 18 and 60 years. Descriptive statistics of maxillary and mandibular tooth and pulp area is shown in table 1. In this study, the mean upper right and upper left maxillary tooth area was 138.44 ± 20.54 mm2 and 134.64 ± 24.71 mm2, respectively. The mean lower left and lower right mandibular tooth area was 129.74 ± 26.86 mm2 and 129.28 ± 24.12 mm2, respectively. The mean upper right and upper left maxillary pulp area was 21.50 ± 14.36 mm2 and 21.03 ± 14.57 mm2, respectively. The mean lower left and lower right mandibular pulp area was 20.48 ± 17.50 mm2 and 18.48 ± 13.46 mm2, respectively (Table 1).

Table 1: Descriptive Statistics of Maxillary and Mandibular Tooth and Pulp Area

Maxillary and Mandibular Tooth and Pulp Area			Mean ± SD
Tooth Area (mm^2)	Maxillary	Upper right	138.44 ± 20.54
		Upper left	134.64 ± 24.71
	Mandibular	Lower right	129.28 ± 24.12
		Lower left	129.74 ± 26.86

DOI: https://doi.org/10.54393/pjhs.v5i07.1817

Pulp Area (mm^2)	Maxillary	Upper right	21.50 ± 14.36
		Upper left	21.03 ± 14.57
	Mandibular	Lower right	18.48 ± 13.46
		Lower left	20.48 ± 17.50

Table 1: mm^2 = millimeter square

Real-time images of mandibular and maxillary canines in the studied planes are shown in figures 2-9. Figure 2 presented the 3D sagittal section view of Cone-Beam Computed Tomography (CBCT) images, illustrating the precise measurements of the periodontal tissue remodeling (PTR) in the mandibular canines.

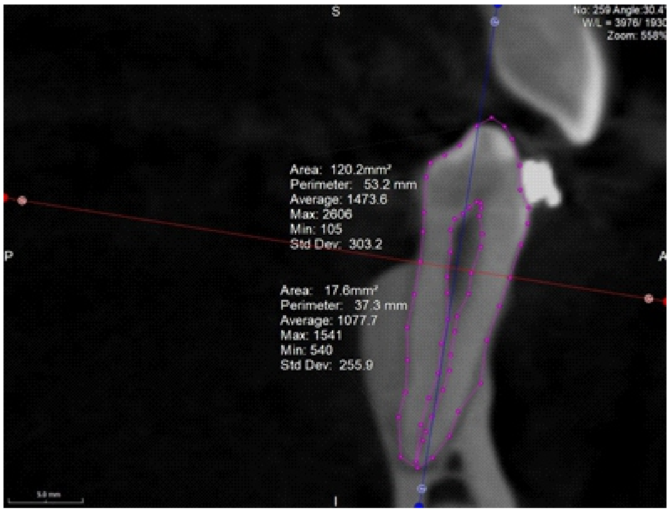

Figure 2: Measurements of PTR in the Mandibular Canines in 3D View from CBCT Images (Sagittal Section)

Figure 3 depicted the 3D sagittal section view from CBCT images, highlighting the measurements of periodontal tissue remodeling (PTR) in the mandibular canines.

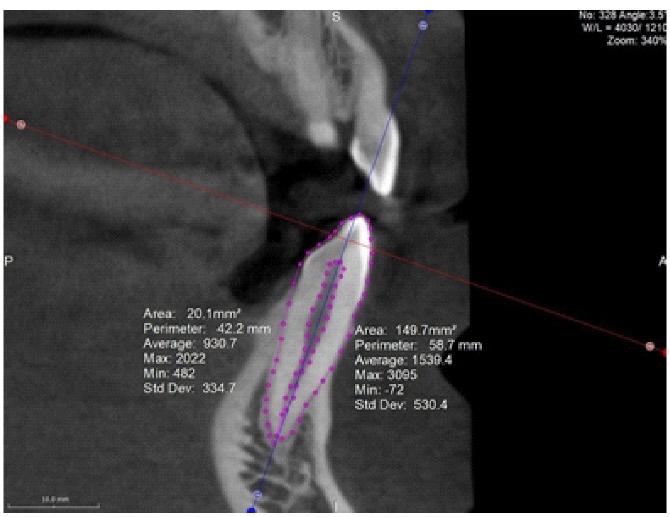

Figure 3: Measurements of PTR in the Mandibular Canines in 3D View from CBCT Images (Sagittal Section)

Figure 4 illustrated the 3D coronal section view from CBCT images, showcasing the measurements of periodontal tissue remodeling (PTR) in the maxillary canines.

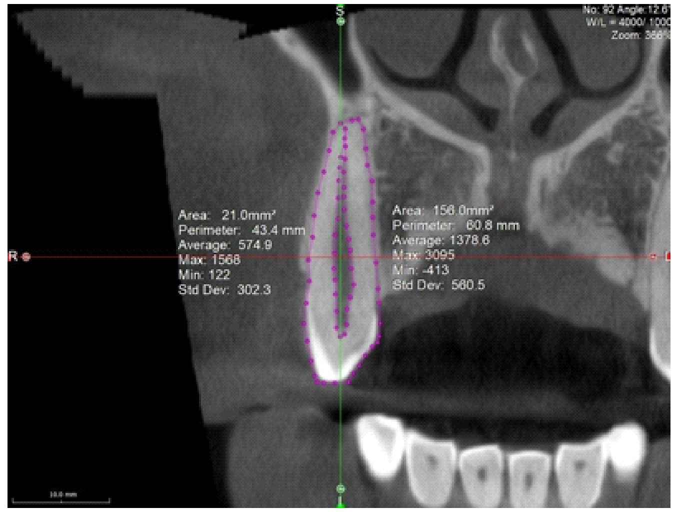

Figure 4: Measurements of PTR in the Maxillary Canines in 3D View from CBCT Images (Coronal Section)

Figure 5 depicted the 3D coronal section view from CBCT images, emphasizing the measurements of periodontal tissue remodeling (PTR) in the maxillary canines.

Figure 5: Measurements of PTR in the Maxillary Canines in 3D View from CBCT Images (Coronal Section)

Figure 6 displayed the 3D coronal section view from CBCT images, focusing on the measurements of periodontal tissue remodeling (PTR) in the maxillary canines.

DOI: https://doi.org/10.54393/pjhs.v5i07.1817

Figure 6: Measurements of PTR in the Maxillary Canines in 3D View from CBCT Images (Coronal Section)

Figure 7 presented the 3D coronal section view from CBCT images, detailing the measurements of periodontal tissue remodeling (PTR) in the maxillary canines.

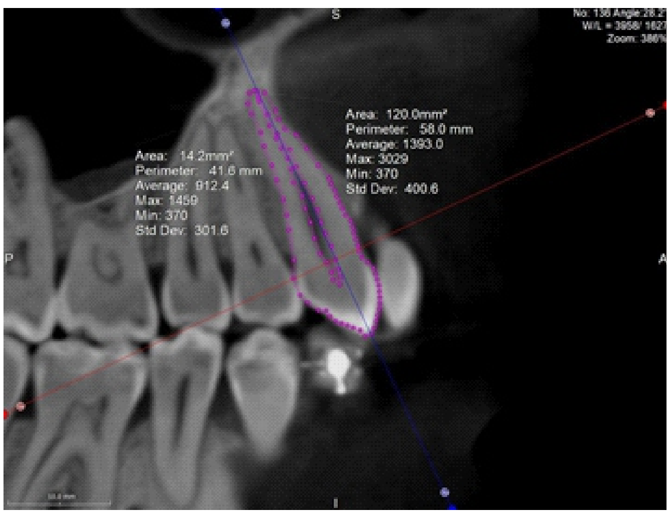

Figure 7: Measurements of PTR in the Maxillary Canines in 3D View from CBCT Images (Coronal Section)

Figure 8 illustrated the 3D coronal section view from CBCT images, capturing the measurements of periodontal tissue remodeling (PTR) in the mandibular canines.

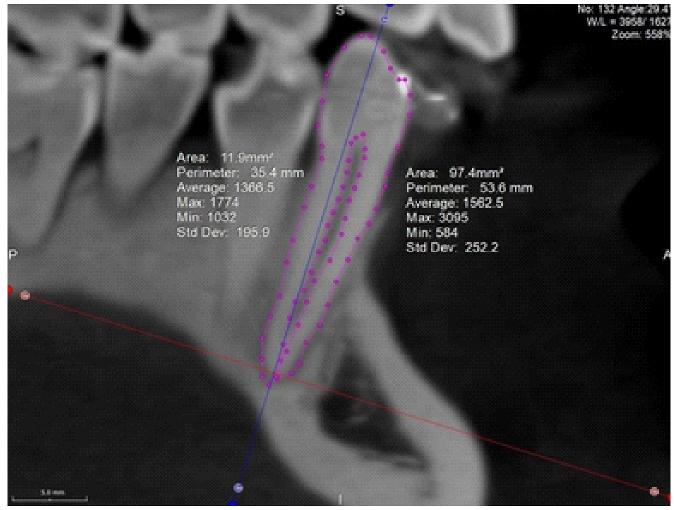

Figure 8: Measurements of PTR in the Mandibular Canines in 3D View from CBCT Images (Coronal Section)

Figure 9 displayed the 3D sagittal view from CBCT images, highlighting the measurements of periodontal tissue remodeling (PTR) in the mandibular canines.

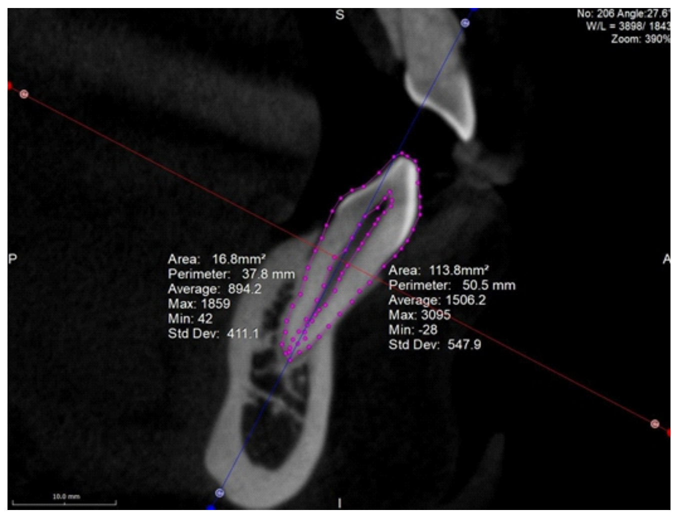

Figure 9: Measurements of PTR in the Mandibular Canines in 3D View from CBCT Images (Sagittal View)

When regression was run on individual parameters, only upper left maxillary tooth area (mm) was found significant with $p < 0.01$ and $R = 0.132$, with regression model as Age = 26.64 + 0.072 (x), as described in table 2. Here any possible value of upper left maxillary tooth area (mm) can be entered to estimate the age (Table 2).

Table 2: Regression Model for Maxillary and Mandibular Tooth and Pulp Area

Independent Variables (x)				R	R^2	B	S.E	p-Value	Model
Tooth area (mm)	Maxillary	UR	x1	0.040	0.002	0.026	0.004	0.553	Age = 32.69 + 0.026 (x)
		UL	x2	0.132	0.017	0.072	0.036	0.049*	Age = 26.64 + 0.072 (x)

DOI: https://doi.org/10.54393/pjhs.v5i07.1817

	Mandibular	LL	x3	0.030	0.001	-0.15	0.034	0.659	Age = 38.24 – 0.150 (x)
		RL	x4	0.057	0.003	-0.32	0.038	0.398	Age = 40.42 – 0.320 (x)
Pulp area (mm)	Maxillary	UR	x5	0.059	0.004	0.055	0.063	0.379	Age = 35.12 + 0.055 (x)
		UL	x6	0.087	0.008	0.08	0.062	0.918	Age = 34.63 + 0.08 (x)
	Mandibular	LL	x7	0.058	0.003	-0.44	0.052	0.392	Age = 37.22 – 0.44 (x)
		RL	x8	0.042	0.002	0.042	0.067	0.533	Age = 35.53 + 0.042 (x)

*Table 2: R = correlation coefficient; R^2 = coefficient of determination; β = regression coefficient; S.E = standard error; x = pulp/tooth area ratio; * = p≤0.05 was significant; UR = upper right; UL = upper left; LL = lower left; RL = lower right.*

In overall model, only two parameters that is upper left maxillary tooth area (mm) was found positively significant and lower left mandibular pulp area (mm) was found negatively significant, p-value < 0.05, as shown in Table 3. Hence, the overall model was found as,

Age = 35.519 -0.165 (x1) + 0.298 (x2) + 0.316 (x3) + 0.090 (x4) - 0.102 (x5)-0.211 (x6)-0.087(x7) + 0.082 (x8)

Table 3: Overall Regression Model for Individual Parameters

Independent Variables			Maxillary UR Tooth Area (mm)	β	S.E	p-Value*	Significance
(Constant)			-	35.519	6.096	<0.001	Significant
Maxillary	UR	Tooth Area (mm)	x1	-0.165	0.096	0.089	Negative Insignificant
		Pulp Area (mm)	x2	0.298	0.211	0.159	Positive Insignificant
	UL	Tooth Area (mm)	x3	0.316	0.075	<0.001	Positive Significant
		Pulp Area (mm)	x4	0.090	0.179	0.617	Positive Insignificant
Mandibular	LL	Tooth Area (mm)	x5	-0.102	0.053	0.058	Negative Insignificant
		Pulp Area (mm)	x6	-0.211	0.076	0.006	Negative Significant
	RL	Tooth Area (mm)	x7	-0.087	0.056	0.124	Negative Insignificant
		Pulp Area (mm)	x8	0.082	0.081	0.309	Positive Insignificant

*Table 3: β = regression coefficient; S.E = standard error; * = p<0.05 was significant; UR = Upper right; UL = upper left; LL= left lower; RL = Right lower; mm = millimeter*

DISCUSSION

Adult age estimation is a challenging task in forensic medicine. Evaluation of morphological variations needs tooth sectioning, which is not possible in alive individuals. Therefore, radiographic approach is mainly employed in estimating age in living adults [16]. In 1995, Kvaal *et al.*, designed a radiographic technique to estimate age based on the deposition of secondary dentine by evaluating the pulp dimensions. It was regarded that pulp width was substantially correlated with age of the individuals [17]. Any tooth can be used for this purpose. However, canines are preferred because they mostly remain in the oral cavity until old age, have one root and pulp chamber, and pose a lower risk of caries [18]. At present, CBCT scans offer useful 3D evidence about teeth and is more frequently employed in forensic dentistry than traditional CT because of high resolution and low radiation exposure [19]. Additionally, CBCT allows determining the areas of tooth and pulp in both mesiodistal and buccolingual dimensions as well as calculating the precise volume of teeth and pulp [20]. So this study was carried out to estimate the age on the basis of maxillary and mandibular canines PTR using CBCT in adults and to get age estimation standards for Pakistani population based on PTR. A number of studies have been conducted for forensic age estimation employing CBCT [6, 20-23]. In an Indonesian study, it was found out that PTR of lower canine had a higher reliability in estimating age, p<0.05 [24]. Another study stated that the ages of the people of Iranian descent can be dependably calculated by subjecting the canines of the upper jaw to CBCT and analyzing their PTR (R^2 = 0.392) [6]. The findings of the previous literature also showed that there is an inverse relationship between pulp area and age [20]. This finding was relatable to the findings of the current study where lower left mandibular pulp area was found negatively correlated with age. A few more studies validated the results of the current study. Afify *et al.*, concluded that with r=.919, the sagittal CBCT images of the maxillary canines were more accurate and correlation of PTR and age was high [25]. Another study also used regression model and reported that the CBCT of maxillary canines provides high correlation between PTR and age (r = 0.532) [26]. Salemi *et al.*, reported that there was a strong correlation between PTR and estimated age (r = 0.88) using CBCT [19]. However, Molina *et al.*, reported that measuring canines PTR was not a reliable approach for FAE. Instead, upper incisors had the highest coefficient of determination (R^2 = 0.366), contrary to the findings of the current study [5].

CONCLUSIONS

Through the findings of this study, it is concluded that age can be estimated by using CBCT of maxillary and mandibular permanent canines PTR. Specifically, two parameters such as upper left maxillary tooth area was found positively correlated and lower left mandibular pulp area was found negatively correlated for age estimation. Using the obtained regression model, age estimation for the adult population can be performed using CBCT scans.

Authors Contribution

Conceptualization: MZ
Methodology: MZ, OK
Formal analysis: AH
Writing, review and editing: SS[1], SS[2], YK, AH, RUH

All authors have read and agreed to the published version of the manuscript.

DOI: https://doi.org/10.54393/pjhs.v5i07.1817

Conflicts of Interest

The authors declare no conflict of interest.

Source of Funding

The authors received no financial support for the research, authorship and/or publication of this article.

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