

# Age estimation based on Pulp-Tooth Area Ratio of maxillary canine using Cone Beam Computed Tomography

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## ABSTRACT

**Introduction:** Dental age estimation based on the Pulp Tooth area ratio (PTR) of the maxillary canines obtained from Cone Beam Computed Tomography (CBCT) image may be a reliable method for age estimation in living or deceased individuals.

**Objectives:** To determine the age estimation based on PTR of the maxillary canines in three planes (sagittal, coronal and axial) with the help of CBCT images in Nepalese population.

**Methodology:** CBCT images were used for the age estimation by determining the PTR of maxillary canines. For each tooth, midsagittal, midcoronal, and three axial sections at cemento-enamel junction (CEJ), one-fourth root level from CEJ, and midroot were assessed. The radiographic images were saved as JPEG file and processed using Image J software. PTR were calculated and data obtained were subjected to regression analysis; their correlation to chronologic age as well as the standard error of the estimate (SEE) were derived.

**Results:** Our study included, 43 (57.33%) males and 32 (42.66%) females with mean age of 30.25 years. The mean of PTR for maxillary canines were 0.053797 at CEJ, 0.067992 at one-fourth root level from CEJ and 0.053794 at midroot in axial section, 0.138715 at midsagittal plane and 0.108110 at midcoronal plane respectively. The PTR for maxillary canine was found to be statistically significant at mid coronal plane ( $p < 0.05$ ).

**Conclusion:** This study showed that PTR calculation of maxillary canines is a reliable parameter with a significant correlation for human age estimation and concluded that CBCT can be used as a conservative approach with reasonable accuracy.

**Key words:** Age determination by teeth; Cone beam computed tomography; Pulp/tooth area.

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## INTRODUCTION

An important aspect of forensic investigation is age estimation of living or deceased individuals by contributing to their biological profile<sup>1,2,3</sup> however in living individuals, it is considered in cases of child abuse, immigration, criminal prosecution and civil cases such as pension claims.<sup>4,5</sup> Teeth are one of the strongest structures in the human body, and the age determination by teeth with the aid of radiodiagnostics has been of paramount interest.<sup>6</sup>

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Cameriere et al.<sup>7</sup> proposed method for age estimation by measuring the tooth in two dimensional (2D) radiographic images (periapical and panoramic radiographs); specifically, the pulp/tooth area. Cone Beam Computed Tomography (CBCT) has been used as a useful tool which provides accurate anatomical information on sagittal, axial, coronal, and multiplanar sections for diagnosis and treatment planning for clinical applications in dentistry to investigate the relationship between age and secondary dentin accumulation such as pulp tooth area ratio (PTR), pulp volume, and pulp tooth volume ratio.<sup>8</sup>

Hence, the aim of our study was to determine the age estimation based on PTR of the maxillary canines in three planes (sagittal, coronal and axial) with the help of CBCT image data in Nepalese population.

## METHODOLOGY

A cross-sectional observational study was carried out to determine the PTR of Maxillary canines in the CBCT image records of radiographically evaluated cases for the age estimation. Information relating to age and gender from the patients record file in the Department of Oral Medicine and Radiology was taken. This study was conducted from 20<sup>th</sup> March till 10<sup>th</sup> April, 2023 in the Department of Oral and Maxillofacial Pathology, Kantipur Dental College Teaching Hospital and Research Center (KDCH), Basundhara, Nepal. The study was conducted after taking approval from the Institutional Review Committee of KDCH (Ref No: 01/23). CBCT images of maxillary canine with normal anatomy were included in this study. Images which were not able to rotate, blurred or incomplete images; decayed tooth, restored tooth or endodontically treated tooth; tooth with ceramic/metal crowns or orthodontically treated and calcified root canal or root resorption were excluded from the study.

A convenience sampling method was used. The sample size was calculated using the following formula  $N = 2(z\alpha + z\beta)^2 \frac{sd^2}{d^2}$ , where  $z\alpha = 1.96$ ,  $z\beta = 1.28$ ,  $sd^2 = 0.0036$  and  $d^2 = 0.0049$ . The obtained sample size was 75 CBCT images. Data information sheet (Proforma) was developed to collect information from patients CBCT images. The CBCT images data of the patients taken from the records of Department of Department of Oral Medicine and Radiology, Kantipur Dental College Teaching Hospital and Research Center, the data were

reviewed in detail according to the selection criteria for the selection of cases and the data of CBCT images were sliced in three dimensions by using CS 3D Imaging software (Figure 1). In the axial plane, three sections representing cementoenamel junction (CEJ), one-fourth root length from CEJ, and mid-root level were assessed. For the sagittal plane, curved slices oriented along the curve of the maxillary arch were delineated. The cursor was oriented parallel to the long axis of the maxillary canine to obtain the midsagittal plane. With respect to the coronal plane, oblique slicing was done to obtain the mid-coronal section along the long axis of the tooth (Figure 2).

For each image, at least 10 points were marked on the outline of the pulp (Figure 2 & 4) using Image J 1.52 p (National Institutes of Health, USA); a minimum of 30 points was also marked on the tooth outline (Figure 3). The points were connected using the line tool and area was obtained for both tooth and pulp of that image. This entire procedure was performed for all the five sections of each tooth (Figure 1). The data were entered in Microsoft Office 2007 excel spreadsheet and PTR calculated for all the five CBCT sections for each tooth. Data were collected, compiled, and analyzed by using an updated version of the Statistical Package of Social Science (SPSS). ANOVA test was used for the comparison of variables based on the distribution of the sample.

## RESULTS

The study included total of 75 CBCT images retrieved from the Department of Oral Medicine and Radiology, which comprised of 43 (57.33%) males and 32 (42.66%) females (Table 1). In this study, the mean PTR was determined at three different planes and the maximum mean value of PTR was observed as 0.138 in sagittal plane (Figure 5). The descriptive statistics of pulp-tooth ratios in axial, sagittal and coronal sections of the maxillary canines were shown in Table 2. Linear regression analysis, Pearson correlation coefficient, standard errors of estimates (SEE), and regression equations were derived for each tooth section. The regression analysis and Pearson correlation coefficient test (*r*) revealed a stronger correlation between the pulp tooth ratios and age in the coronal section measurements than compared to other sections (Table 3). The PTR obtained in the coronal plane produced a statistically significant correlation ( $P < 0.05$ ).

**Table 1: Age and Gender Distribution according to different age groups**

| Gender       | Age (years)       |                   |                   | Total (N)        |
|--------------|-------------------|-------------------|-------------------|------------------|
|              | 15-24             | 25-35             | 35-65             |                  |
| Male         | 23 (30.66%)       | 7 (9.33%)         | 13 (17.33%)       | 43 (57.33%)      |
| Female       | 15 (20.00%)       | 10 (13.33%)       | 7 (9.33%)         | 32 (42.66%)      |
| <b>Total</b> | <b>38 (50.7%)</b> | <b>17 (22.7%)</b> | <b>20 (26.7%)</b> | <b>75 (100%)</b> |

**Table 2: Correlation of pulp-tooth area ratio in axial, sagittal and coronal sections of the maxillary canines of the studied samples.**

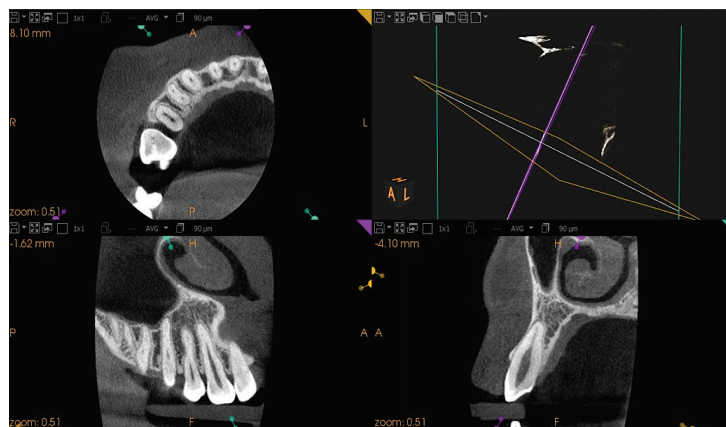
| Parameters                                             | N  | Minimum | Maximum | Mean  | Std. Deviation | Pearson's r with age | P value |
|--------------------------------------------------------|----|---------|---------|-------|----------------|----------------------|---------|
| Age                                                    | 75 | 15      | 65      | 30.25 | 13.341         |                      |         |
| PTR at CEJ (axial plane)                               | 75 | 0.01    | 0.13    | 0.05  | 0.02           | -0.215               | 0.064   |
| PTR at 1/4 <sup>th</sup> the root length (axial plane) | 75 | 0.02    | 0.17    | 0.06  | 0.02           | -0.156               | 0.181   |
| PTR at midway (axial plane)                            | 75 | 0.04    | 0.22    | 0.05  | 0.03           | -0.205               | 0.077   |
| PTR at sagittal plane                                  | 75 | 0.06    | 0.29    | 0.13  | 0.04           | -0.113               | 0.335   |
| PTR at coronal plane                                   | 75 | 0.03    | 0.22    | 0.10  | 0.03           | -0.439               | 0.001*  |

P value significant at less than 0.05 \*= pearson's correlation

**Table 3: Regression equations of pulp tooth ratio at five different sections**

| Parameters                                             | r*     | R2*   | Regression equation                                                | SEE(years) | P- value |
|--------------------------------------------------------|--------|-------|--------------------------------------------------------------------|------------|----------|
| PTR at CEJ (axial plane)                               | -0.215 | 0.046 | Age=23.123+ (-132.538× pulp tooth area ratio axial CEJ)            | 13.118     | 0.064    |
| PTR at 1/4 <sup>th</sup> the root length (axial plane) | -0.156 | 0.024 | Age=35.081+ (-71.003× pulp tooth area ratio 1/4th the root length) | 13.276     | 0.181    |
| PTR at midway (axial plane)                            | -0.205 | 0.042 | Age=34.402+ (-77.131× pulp tooth area ratio at midway)             | 13.146     | 0.077    |
| PTR at sagittal plane                                  | -0.113 | 0.013 | Age=35.279+ (-36.233× pulp tooth area ratio sagittal)              | 13.346     | 0.335    |
| PTR at coronal plane                                   | -0.439 | 0.193 | Age=47.495+ (-159.485× pulp tooth area ratio coronal)              | 12.066     | 0.001*   |

P value significant at <0.05, Pearson correlation coefficient (r), Coefficient of determination (R2), standard error of the estimate values (SEE), \*=statistically significant

**Figure 1: Cone beam computed tomography images of maxillary canine shown in three-dimensions; axial, coronal, and sagittal planes. (CS 3D Imaging software)**

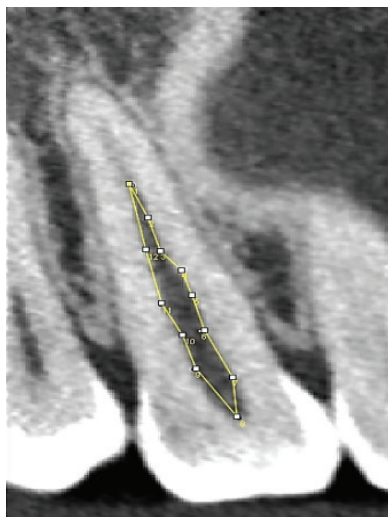


**Figure 2:** The coronal section image seen in Image J computer-aided software with points marked on the outline of the pulp.

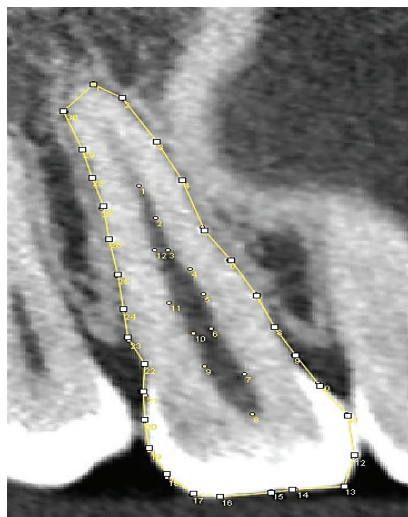


**Figure 3:** The coronal section image seen in Image J computer-aided software with points marked on the outline of the tooth.

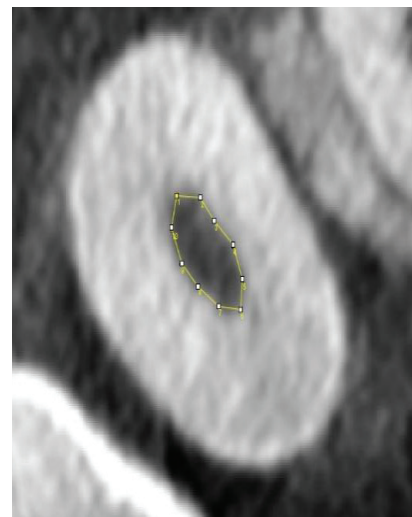


**Figure 4:** The axial section image at CEJ level seen in Image J computer-aided software with points marked on the outline of the pulp.

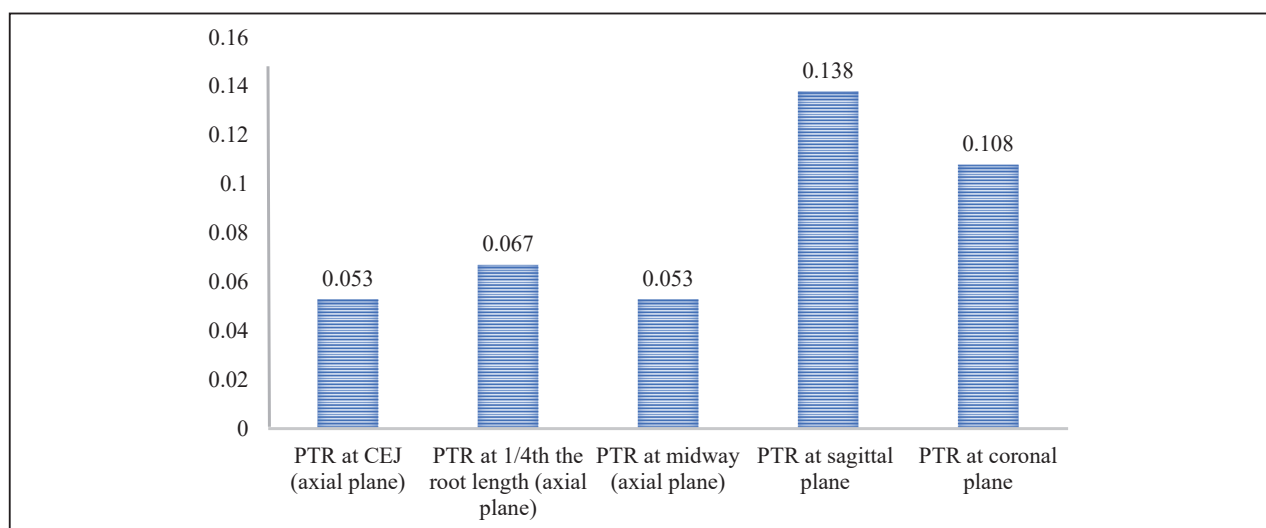


**Figure 5.** Mean Pulp tooth area ratio in Maxillary canine at five different sections

## DISCUSSION

Age estimation is an important aspect of forensic odontology. Postmortem age estimation using radiography is used extensively, using the dimensional changes of the pulp area in relation to the tooth area and the ratio. Various methods and approaches have been proposed for dental age estimation in forensic Odontology practice.<sup>9,10,11</sup> Secondary dentin apposition is an important morphological dental age predictor<sup>12-16</sup> which is defined as the formation of dentin after the completion of the primary dentin and starts at the moment the tooth root formation is completed.<sup>17-20</sup> Chronological age can be estimated in correlation with

assessment of secondary dentin since it may be more insulated from the effect of environmental factors on human remains.<sup>21</sup> According to Rai et al. in their study found that the only statistically significant correlation with age was observed for the axial plane at the CEJ. This finding might be attributed to the clearer demarcation of the pulp and the tooth outline in the CEJ section as compared to those more apically.<sup>1</sup> Afify et al. in their study found a statistically significant correlation of PTR to age in both sagittal and axial planes of the studied canine's images. In their study, regression analysis and Pearson correlation coefficient test revealed a stronger correlation between the PTR and age for the sagittal section

measurements than for the axial section measurements. The high accuracy of measurements at sagittal sections than axial ones may be due to the advantage that the ratio was not influenced by any image alteration caused by tooth malposition. Also, PTR frequently has a fault in measurement caused by small tooth area in axial sections, but the PTR of a sagittal section images is larger than axial section images. This advantage effect increases when the patient is examined with lower resolution in order to decrease the radiation dose (large area decrease measurement errors). This reason also explains the best result obtained from the maxillary canine compared with the mandibular canine as the maxillary canine size is bigger than the mandibular canine.<sup>22</sup> According to Marroquin et al. a stronger correlation was observed between the pulp/tooth ratios and age for the buccolingual measurements (sagittal) than for the mesiodistal measurements (coronal view).<sup>23</sup> Bansal et al. in their study stated that PTR of maxillary canine at sagittal section showed highest correlation and was statistically significant.<sup>24</sup> In the study done by Misirlioglu et al. from periapical radiographs found PTR correlated with age.<sup>25</sup> More significant relationship between the age and PTR in the axial section compared to the sagittal section in both genders were seen in the study done by Haganifar et al.<sup>26</sup> which was similar to the results reported by Rai et al.<sup>1</sup> These findings can be explained by the fact that the axial sections (at cervical area) are far from the occlusal stresses and are not affected by secondary dentin deposition.<sup>27,28</sup> However, Statistically significant ( $p < 0.05$ ) correlation of PTR with age was observed for the coronal plane in our study. In our study, the results did not show statistically significant correlation of PTR to age in the axial plane (at three different sections) in comparison to the study by Rai et al.<sup>1</sup> & Afify et al.<sup>22</sup> Also, our study didn't show statistically significant correlation of PTR to age in sagittal plane when compared to the study done by Afify et al.<sup>22</sup> and Bansal et al.<sup>24</sup> Considering the secondary dentin deposition pattern and orientation of pulp chamber in the buccopalatal plane, a significant correlation with age was anticipated in this plane. In the study by Dahal et al. limited applicability of pulp tooth ration in mandibular canine and premolars was obtained

in buccolingual and mesiodistal periapical radiographs. The regression formulas used were not suitable for individuals under 20 years of age and over 85 years of age as it was fabricated for a particular age range.<sup>29</sup> According to Bajracharya et al. the regression equations were for predicted age group 15-26 years with actual mean age of the subjects was 22.39 years and the mean accuracy error (chronological age – estimated age) was 5.65 to 6.40 years. Thus, indicating similarity in predicted age range.<sup>30</sup> Whereas in our study the regression analysis and Pearson correlation coefficient test ( $r$ ) revealed a stronger correlation between the PTR of maxillary canine and age in the coronal section measurements than compared to other sections within the age group ranging from 15 years to 65 years of age. (Table 3). The Standard Errors of Estimates (SEE) in the linear regression analysis for multiple sections in maxillary canines ranged from ( $\pm 12.066 - 13.346$  years) which indicates the high accuracy of those methods based on PTR calculation. Finally, it is necessary to mention that our findings were promising for dental age estimation by using CBCT ( $SEE \pm 12.066 - 13.346$  years), which will be suitable for forensic identification as  $SEE < \pm 10$  years is considered acceptable in forensic age prediction.<sup>22</sup> However, a more 3D quantification is necessary for this; hence suggesting detail information regarding PTR in future. Among several sections, sagittal sections may be undertaken, which may give a higher correlation with age.<sup>1</sup>

## CONCLUSION

Increasing availability of 3D technology provides the forensic odontologist with an imaging modality capable of providing a 3D representation of the teeth and the jaws whose benefits may be extended in several ways to the science of forensic odontology. In the present study, age estimation using the PTR in several planes was undertaken using CBCT data in Nepalese population. The study may be helpful in estimating the dental age of living as well as deceased individuals by using CBCT image data.

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**Conflict of Interest:** None

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