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Age Estimation by Pulp/Tooth Area Ratio of Maxillary Canine Teeth on Cone-beam Computed Tomography Scans

Shirin Sakhdari [1], Mahmoud Ghasemi [2], Sahel Shahrestani [3]

[1] Oral and Maxillofacial Radiology Department, Faculty of Dentistry, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran.
[2] Periodontology Department, Faculty of Dentistry, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran.
[3] Periodontology Department, Faculty of Dentistry, Shahed University, Tehran, Iran.

Corresponding author:
Sahel Shahrestani, Periodontology Department, Shahed University Faculty of Dentistry, Tehran, Iran

sahelshahrestani7@gmail.com

Abstract

Background and Aim: This study aimed to assess the accuracy of age estimation by pulp/tooth area ratio (PTR) of maxillary canine teeth on cone-beam computed tomography (CBCT) scans.

Materials and Methods: This descriptive analytical study was conducted on 99 CBCT scans of patients between 18 to 71 years with fully erupted sound maxillary canine teeth. The CBCT scans were evaluated in five sections namely the mid-sagittal section, mid-coronal section, and axial planes [cementoenamel junction (CEJ) section, root section at one-quarter distance from the CEJ, and mid-root section] using OnDemand software. The tooth and pulp surface areas and PTR were calculated. The absolute error of age estimation was calculated by the regression test.

Results: In females, PTR of the CEJ section (-0.338) and one-quarter root section of the axial plane (-0.459; P=0.003 and P=0.000, respectively), and in males, PTR of the mid-root section of the axial plane (-0.346) and mid-sagittal section (-0.455; P=0.013 and P=0.002, respectively) had significant correlations with age. The mean absolute error of age estimation in the present method, compared with the chronological age of individuals, was 7.227 years. In 39.5% of the cases, the obtained regression formula could estimate age with less than 5 years difference. No significant difference was noted in age estimation for males and females in this method.

Conclusion: It appears that PTR on CBCT images of maxillary canine teeth has a significant correlation with chronological age. The obtained formula in this study could estimate age with acceptable accuracy (less than 7.5 years).

Keywords: Age Determination by Teeth; Cone-Beam Computed Tomography; Cuspid; Dental Pulp; Dental Records; Forensic Dentistry

Introduction

Age estimation is highly important for forensic identification. It is also useful in crime investigations and identification of illegal immigrants. According to Rai et al. [1], dental radiography was first used by Schuller in 1921 for forensic identification.

In 1995, the amount of secondary dentin deposition was quantified on dental radiographs, and its correlation with age was analyzed for the first time [2]. The most commonly applied methods for age estimation include the Gustafson and Johanson analyses, assessment of dentin translucency, and formation of cementum ring [3, 4]. Of these methods, assessment of secondary dentin deposition in the pulp chamber appears to be accurate. In some age determination methods, tooth cross-sections and dental radiographs are used to assess the size of pulp chamber. Panoramic and periapical radiographic modalities are often used for this purpose [5-7] especially when dental age is used to estimate the rate of development in young individuals [8, 9].

Previous methods based on two-dimensional (2D) radiographic modalities mainly had several shortcomings such as distortion and inaccurate magnification of images [10]. At present, CBCT can be used to eliminate many of the problems related to age estimation [11]. Several recent studies used CBCT to measure the tooth surface area. Uğur Aydın and Bayrak [12] found no significant difference between males and females in pulp/tooth surface area ratio (PTR) of maxillary central incisors while Rai et al. [1] found a direct correlation only between PTR in the axial plane and age.

To the best of the authors' knowledge, PTR was not assessed in five sections using OnDemand software. Also, no previous study is available on pulp to tooth area measuring in five sections in the Iranian population. Due to the lack of studies and the information gap related to this issue, this study aimed to assess the accuracy of age estimation based on the PTR of maxillary canine teeth on CBCT scans using OnDemand software in an Iranian population.

Materials and Methods

This analytical diagnostic study was conducted on 99 CBCT images of patients between 18 and 71 years, using the "confidence interval for one correlation" feature and considering $\alpha=0.05$, R=0.5, and correlation coefficient of 0.3 between PTR and chronological age. The study sample was consisted of 51 females and 48 males. Ethical approval was granted by the Iran National Committee for Ethics in Biomedical Research (No: IR.IAU.DENTAL.REC.1399.175). The CBCT images used in this study had been obtained for diagnostic/therapeutic purposes. The patients' age at the time of radiography was first calculated by subtracting their date of birth from the date of radiography. In this study, only sound fully erupted maxillary canine teeth were evaluated, and teeth with restorations, caries, wear, root resorption, cracks, periapical lesions, orthodontic, prosthodontic, and endodontic treatments, or developmental anomalies were excluded. All CBCT scans had been taken with Carestream9300 CBCT scanner (Kodak, France) with the exposure settings of 5 x 10 cm field of view, 10 mA, 90 kV, and 0.180 mm voxel size. The images had been obtained in standard conditions. The occlusal plane of the patients was parallel to the horizontal plane, and their mid-sagittal plane was perpendicular to the ground. The CBCT images were imported to OnDemand software version: 1.0.10.5385 (CyberMed, Korea), and five sections were obtained from each tooth in three planes, with a slice thickness of 1 mm and a slice interval of 0.1 mm. All CBCT images were assessed by one oral and maxillofacial radiologist with more than 10 years of experience in reading scans. The occlusal plane of the images was first parallelized to the horizontal plane, and in the axial plane, images were obtained at three sections: at the level of the cementoenamel junction (CEJ), at the mid-root, and at one-quarter distance from the CEJ. Next, in the axial plane, a curve was drawn over the maxillary arch. Using the reconstructed panoramic image, the mid-sagittal and mid-coronal sections were also made. Using the "Smart Pen" tool in the

"Area" feature of OnDemand software, a minimum of 15 points were marked around the pulp, and a minimum of 30 points were marked around the tooth to outline the pulp and tooth. The tooth and pulp surface areas were calculated on each of the five sections (Figure 1). Next, the PTR was calculated and recorded for all five sections. The obtained values were used in regression formulae to assess their correlation with chronological age, gender, and standard error (1). Two weeks later, 10 CBCT images were randomly selected and measured again by the same observer to assess intra-examiner reliability.
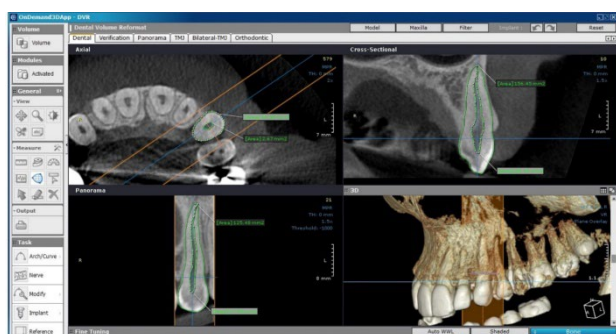

Figure 1. Axial, sagittal, and coronal views of the maxillary canine on a CBCT scan in OnDemand 3D Dental software. The outer line defines the area of the tooth. The inner line defines the area of the pulp.

Results

Table 1 presents the demographic information of the participants. In females, of the five sections evaluated, PTR at the CEJ (P=0.003) and one-quarter distance from the CEJ (P=0.000) sections had a significant correlation with age. In males, PTR at the axial mid-root (P=0.013) and mid-sagittal (longitudinal plane) sections (P=0.002) had a significant correlation with age (Table 2).

According to the PTR with significant correlations with age, the following formulae were designed for age estimation in males and females:

Estimated age in females = (X1 × -290/465) + (X2 × -232/598) + 68/309

X1: PTR at the cross-section at one-quarter distance from the CEJ

X2: PTR at the axial plane CEJ section

Estimated age in males = (X1 × -158/869) + (X2 × -414/823) + 82/481

X1: PTR at the mid-sagittal section

X2: PTR at the axial plane mid-root section

Table 1. Demographic information of the participants

Gender	Number	Minimum age	Maximum age
Female	51	18	69
Male	48	18	71

Table 2. Correlation of PTR at different sections with age in males and females

Gender	Cross-section	P value	Correlation coefficient
Females	CEJ in the axial plane	0.003	-0.338
	One-quarter distance from the CEJ in the axial plane	0.000	-0.459
Males	Mid-root in the axial plane	0.013	-0.346
	Mid-sagittal section	0.002	-0.455

The mean absolute difference of estimated age from the chronological age of individuals was 7.227 years. In other words, a mean error of 7 years existed in age estimation compared with the chronological age of individuals (Table 3).

The method used in this study was capable of estimating age with a correlation coefficient of R=0.76. No significant difference was noted in age estimation for males and females in this method. Using the regression formula obtained in this study, in 39.5% of the cases, the estimated age had a difference less than 5 years with the chronological age. In 32.6%, the difference between the estimated and chronological age was 5 to 10 years. In 27.9%, the estimated age had a difference over 10 years with the chronological age (Table 4).

After 2 weeks, 10 CBCT scans were randomly selected and re-evaluated. In all cases, the intra-class correlation coefficient was found to be over 0.8, indicating high intra-examiner reliability.

Table 3. Mean absolute difference of estimated age and chronological age in males and females (in years)

Variable	Minimum	Maximum	Mean	Std. deviation
Difference between estimated and chronological age	-19.88	17.28	0.0145	9.0513
Absolute difference between estimated and chronological age	0.29	19.88	7.2274	5.3337

Table 4. Frequency of absolute differences between the estimated and chronological age (in years)

Mean difference between the estimated and chronological age	Frequency percentage	Minimum difference	Maximum difference
< 5 years	39.5	0.29	4.92
5-10 years	32.6	5.07	9.79
>10 years	27.9	10.37	19.88

It appears that PTR of maxillary canine teeth on CBCT scans has a significant correlation with chronological age of individuals. The formula designed in this study may be used for age estimation with acceptable accuracy.

Discussion

In forensic medicine, age estimation is highly important for forensic identification. The size of pulp chamber depends on the amount of secondary dentin deposition. Deposition of secondary dentin increases, and size of pulp chamber decreases with age [4]. The reduction in size of pulp chamber can be indirectly measured by radiography [13]. Previous studies used different methods for age estimation by CBCT, such as linear or surface area measurements [1]. Recently, researchers evaluated the pulp/tooth volume ratio [14]. Salemi et al. [15] discussed that PTR had a more significant correlation with age than linear measurements. CBCT has higher accuracy than 2D imaging modalities since it can provide different planes and sections, and enables 3D reconstruction of images [5]. Therefore, CBCT was used to calculate PTR in the present study. Selection of maxillary canine teeth for this study was because of the fact that maxillary canine teeth have the largest root size and longest survival in dental arch. They have been used for assessment of tooth dimensions and structure in

many previous studies [16, 17]. Since previous investigations did not find a significant difference between teeth in the right and left quadrants [18], teeth from both quadrants were equally used in the present study. Rai et al. [1] evaluated the PTR in the sagittal, coronal, and axial planes. Accordingly, in the present study, five sections were evaluated in the three spatial planes for a more comprehensive assessment. The results showed that by assessment of PTR at the suggested cross-sections, age could be estimated in both males and females with a mean absolute error of 7.22 years. In 39.5% of the cases, the difference between the estimated and chronological age was less than 5 years. The difference between the estimated and chronological age by using the formula obtained in the present study was less than 10 years, which is acceptable in forensic medicine [3, 16, 19].

Also, in a study by Bansal et al. [20], five cross-sections of maxillary central incisor and canine teeth were examined by AutoCAD software. In their study, as in the present study, axial cross-sections at the CEJ of canine teeth were better for age estimation; although the estimated average age difference was 8.25 years, which was higher than the average age calculated in the present study. In the current study, of four sections that had a significant correlation with age and were used for designing

of the age estimation formula for both males and females, three sections were in the axial plane. Haghanifar et al. [21] evaluated the PTR of maxillary and mandibular central incisors and canine teeth and reported similar results (7.45 for maxillary central incisors), although the number of examined teeth in the abovementioned study was higher than that in the present study. They assessed the axial CEJ section and the mid-sagittal section of the aforementioned teeth. They showed that maxillary central incisors had optimal potential for age estimation; however, in both males and females, the axial section had a stronger correlation with age than the sagittal section. Similar to the study by Haghanifar et al. [21], Trottier et al. [22] examined the PTR in 12 anterior teeth of the maxilla and mandible, and concluded that the correlation between PTR and chronological age was the strongest in the axial plane and in maxillary teeth. Axial sections, due to their distance from the site of occlusal load application, show lower deposition of secondary dentin compared with other sections, and thus, changes occurring in this section are mainly attributed to age rather than secondary dentin deposition due to other factors [23]. In a study by Alqarni et al, [24] maxillary central incisors and canine teeth were examined in two axial and sagittal sections. In their study, central incisors and axial sections were superior to the sagittal sections for age estimation; although, contrary to the present study and that of Haghanifar et al. [21], Alqarni et al. [24] found a weak correlation between the PTR and chronological age.

In the present study, the surface area of the teeth and pulp chamber was calculated, and the results were used to create a formula for age estimation. Salemi et al. [15] evaluated maxillary canine teeth by the Kvaal's method, and found that tooth area ratios are superior to tooth length or width ratios for age estimation. Similar to the present study, they evaluated maxillary

canine teeth due to their longer survival compared with other teeth, less wear, and having a distinct pulp chamber. They found no significant difference in age estimation between males and females, which was in accordance with the present results [15].

The method adopted in the present study was similar to that of Rai et al. [1] and the same tooth type and the same sections were evaluated for calculation of PTR. However, Rai et al. [1] used AutoCAD software in their study. Unlike the present study, only the CEJ section in the axial plane had a significant correlation with age, and age was estimated with 14.7 years difference from the chronological age, which was higher than the difference between the estimated and chronological age in the present study. Controversy in the results of the two studies may be due to their smaller sample size or use of different software programs. No significant correlation was found between PTR in the coronal plane and age in males or females, neither in the present study nor in the study by Rai et al. [1].

Ugur Aydin and Bayrak [12] used the PTR of maxillary central incisors on CBCT images for age estimation. They used inVivo 5 software and evaluated the teeth only in the sagittal plane. They found a significant correlation between PTR in the sagittal plane and chronological age of individuals. Bhogte et al. [25] also estimated the PTR in mid-axial, coronal and sagittal sections of maxillary central incisors and, contrary to the study by Ugur Aydin and Bayrak [12], they concluded that the mid-sagittal sections had the least correlation for age prediction, although only 50 teeth were investigated. However, in the present study, only the sagittal plane in males had a significant correlation with age. Differences in tooth type and software programs may explain the variations in the results. However, PTR was not

significantly different between males and females in both studies.

Afify et al. [16] evaluated maxillary and mandibular canine teeth, and indicated a significant correlation between PTR and age in both males and females. Moreover, they reported that maxillary canine teeth were superior to mandibular canine teeth for age estimation. Similar to other studies, they found no significant difference in statistical analyses between males and females. In both males and females, both the mid-sagittal and axial sections had significant correlations with age, but the mid-sagittal section showed a stronger correlation. This finding was different from the results of Rai et al, [1] the present results, and those of Haghanifar et al, [21] Trottier et al, [22] and Bhogte et al, [25] who demonstrated a stronger correlation between the PTR in the axial section and age, compared with the sagittal section. The present study found a mean difference of about 7 years between the estimated and chronological age. Similarly, Afify et al. [16] estimated age with the same level of error by designing a formula based on PTR in the axial plane. However, the formula estimated age with ±4.7-8.1 years difference with the chronological age in their study.

Recently, age estimation by 3D measurement of tooth volume has gained increasing popularity, and has been the topic of many investigations. However, specific software programs should be necessarily used for the techniques based on volumetric measurements [5, 26]. Computed tomography has also been applied for dental volumetric measurements [27, 28]. Nonetheless, CBCT largely replaced computed tomography for maxillofacial imaging due to its numerous advantages [29].

A higher correlation coefficient might have been obtained between the estimation method and the estimated age of patients in the present study if a larger sample size had been used. Finding eligible sound canine teeth was difficult, which led to a relatively small sample size.

Since studies on age estimation in different populations and racial groups have used different instruments and techniques for this purpose, some differences exist in the reported results. Thus, it appears that age estimation formulae that are based on tooth structure are exclusive to the respective racial and ethnic groups.

Conclusion

It appears that PTR of maxillary canine teeth on CBCT scans has a significant correlation with chronological age of individuals. The formula designed in this study may be used for age estimation with acceptable accuracy.

Acknowledgement

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