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Age Estimation by Pulp/ Tooth Volume Ratio of Maxillary Second Molar in Cone Beam Computed Tomography Images of Bangalore Population

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Abstract

Objectives

After tooth eruption, the size of the pulp cavity decreases with age owing to deposition of secondary dentine. The aim of this study was to investigate the relation between the chronological age and the ratio of pulp volume to tooth volume measurements using CBCT images of right maxillary second molar tooth.

Methods

Right maxillary second molar CBCT scans of patients older than 16 years of age were collected from the archives. Patients with CBCT scans of teeth were seen in detail and patients with known chronological age were included. Teeth with caries, filling or crown restorations, periapical pathologies were excluded. Consequently, 100 teeth were evaluated. The pulp volume and the tooth volume of each was measured and then the pulp volume/ tooth volume ratio was calculated. Simple linear regression analysis was performed to predict age.

Results

The pulp volume/ tooth volume of all teeth ranged between 0.023 – 0.038 in males and for females it ranged between 0.024 – 0.034. A negative correlation was found between the pulp volume/ tooth volume ratio and age. Considering measurements of the pulp volume/ tooth volume, there was significant difference in the intercept between both the sexes (p=0.007).

Conclusions

This study revealed that pulp volume/ tooth volume ratio was sex dependant and maxillary second molar is a potential tooth for considering age estimation of the Bangalore population.

Keywords

Age- estimation, Cone beam computed tomography, Pulp-tooth volume ratio, Secondary dentine.

Introduction

Dental age estimation (DAE) is one of the important aspects in forensic odontology [1,2]. An increasing trend for DAE is observed in living as well as deceased individuals (due to migration, marriage, pensions, non-identifiable body remains, corpses in natural calamities etc.) [3,4].

Teeth are highly resistant to mechanical, chemical, or physical influences and time [5,6] with minimal impact from age-related changes. Therefore, estimating age through the analysis of teeth carries a significant utility [7]. Many age estimation methods based on teeth have been established. Some of the methods were developed considering the time of tooth emergence and tooth calcification in oral cavity [8-11]. Examination based on the stage of dentition helps in age estimation in children and adolescents but is having no usefulness in adults as the development of permanent dentition gets completed by then [7]. The methods which are based on organic characteristics of teeth such as amino acid racemization and C^{14} isotope were also introduced [12,13]. However, these methods demand more time and require state of the art laboratory equipment. The major drawback with these methods is tooth extraction which is unethical and in living individuals. Wearing- off dental hard tissues is another routinely used method for age estimation [14,15]. The drawback of this method being its questionable accuracy as, the attrition of tooth is highly dependent on diet and personal habits [16-18].

Secondary dentine keeps on getting deposited once the apical end of root has completely developed, and tooth begins to function in the oral cavity. This apposition continues throughout a person's whole life. This apposition of secondary dentine serves as a significant morphological dental age predictor [19]. This apposition decreases the pulp cavity size and is also predisposed to act upon by local factors like attrition, deep carious lesions and varying osmotic pressure etc. [20-24]. Many two-dimensional images like panoramic [25] or periapical radiograph [26] have been used to quantify the size of pulp cavity and correlate it with age. In recent years, with the wide use of 3-D imaging in practice, three-dimensional image datasets obtained from cone beam CT, CT and Micro CT have been applied by many authors to establish the potential relationship between age and volume ratio of pulp cavity to entire tooth [27-33]. These studies led to the conclusion that pulp/tooth volume ratio is a useful indicator for age.

There is a plethora of studies on estimating age by using the pulp/tooth volume ratio using the volume estimates of pulp chamber, however, secondary dentine is also deposited in the radicular portion of the tooth also decreasing the radicular pulpal volume. Also, most of the studies have included single rooted teeth using CT and cone-beam computed tomography (CBCT), however, there is a dearth in studies using multirooted teeth as human dentition consists of single and multi-rooted teeth both. Thus, this study was conducted on right maxillary second molar due lack of studies and to estimate age using the pulp/tooth volume ratio of right

maxillary second molar along with its correlation with the chronological age.

Materials and Methods

This study was conducted in the Department of Oral Medicine, Diagnosis & Radiology, Government Dental College and Research Institute, Bangalore. 100 CBCT images of right maxillary second molar were collected retrospectively from the database in the department, after verifying the birth date of all subjects from the patient information system which were previously acquired in the patient's interest for diagnosis or treatment purpose which were stored in the format of Digital Imaging and Communications in Medicine (DICOM), thus, eliminating superfluous radiation exposure. The inclusion criteria were good quality CBCT images showing complete right maxillary second molar teeth and subjects of age sixteen and above (closed root apex) while teeth with caries/ restoration, pulpal/ periapical pathologies and with developmental disturbances were excluded from the study.

All the CBCT images were acquired using a Carestream CS 9000 CBCT unit (Carestream, France) with standard exposure parameters (70 kVp, 10 mA, 18-27s) and constant slice thickness of 200 µ. The Field of view (FOV) included 5 cm × 5 cm. CBCT images were viewed in a computer-generated randomized sequence using CS 3D Imaging software, in an ambient viewing condition on a 19" desktop computer which had a screen pixel resolution of 1024 x 768 by two oral radiologists who were trained and calibrated. The DICOM files were then exported to a 3D image semiautomatic segmenting and voxel-counting software ITK-SNAP 3.6 (Open-source software, www.itksnap.org) for the calculation of pulp cavity/ tooth volumes (Fig. 1).

All the measurements which were calculated by the two examiners were re-evaluated after an interval of 15 days on a computer-generated random sequence, hence eliminating the memory bias. Assessment of Intra- and interobserver agreement was done using intraclass correlation coefficient. Assessed data was then entered on a spread sheet (Microsoft Excel 2010) for the statistical analysis using SPSS software (version 22.0, SPSS, Inc., Chicago, IL, USA). A linear regression analysis was executed with the pulp/tooth volume ratios and chronological ages using SPSS software.

Fig. 1: Final segmented image of the pulp and the tooth

Results

The age of the study subject's images ranged between sixteen to sixty years comprising a total of 58% males and 42% females (Fig. 2). The calculated mean pulp/tooth volume ratios ranged between 0.023 – 0.038 in males, however, for females it ranged between 0.024 – 0.034 amongst different age groups. The mean value of pulp/tooth volume ratio was 0.028 with a standard deviation of 0.004 and a median of 0.024.

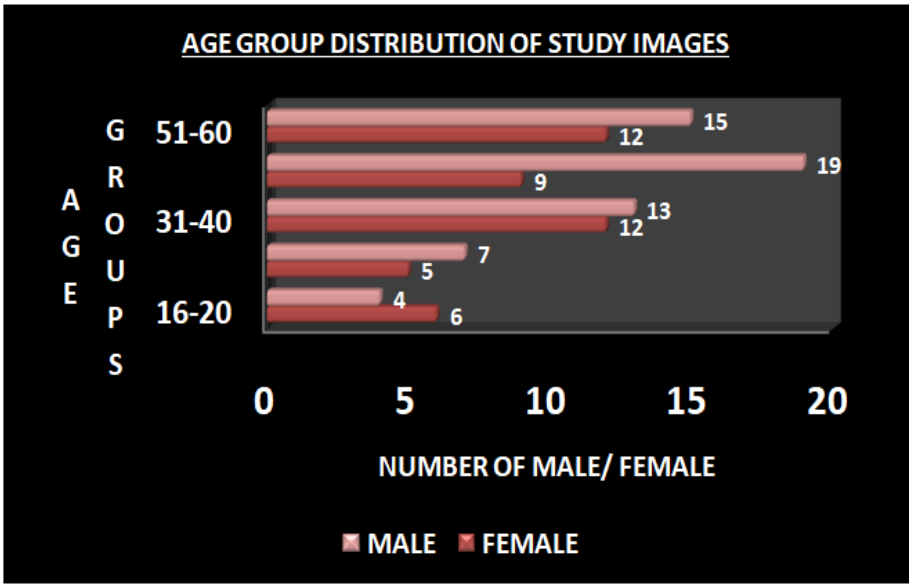

Figure 2: Showing sample distribution across age-groups and different sexes.

Relationship between age and pulp–tooth volume ratio was plotted separately for males (Fig. 3) and females (Fig. 4). The calculated Pearson correlation coefficient (**r**) was -0.747 for males while it was -0.758 for females showing very high strength of association. The regression analysis considering age as dependant and the pulp–tooth volume ratio as independent variable showed a high $\mathbf{r^2}$ for the either sex ($\mathbf{r^2}$=0.558 for males; $\mathbf{r^2}$= 0.575 for females). It also yielded following linear regression equation:

Age for males = 0.04 + (-3.02E – 4 X Pulp/ Tooth Volume)

Age for females = 0.04 + (-2.44E – 4X Pulp/Tooth Volume)

The relation between the age and pulp/tooth volume ratio was stronger for women than for men and the difference in relation was statistically significant **(p = 0.0007)**. The entire procedure of separation, segmentation, and volume calculation needed 15-20 minutes per tooth.

The Intraclass correlation coefficient measured 0.821 showing good agreement (Guideline by Koo and Li) [34]. A difference of ±10 years with respect to the chronological age was noted for 17.24% of the male subjects, however, in females it was for 21.42%.

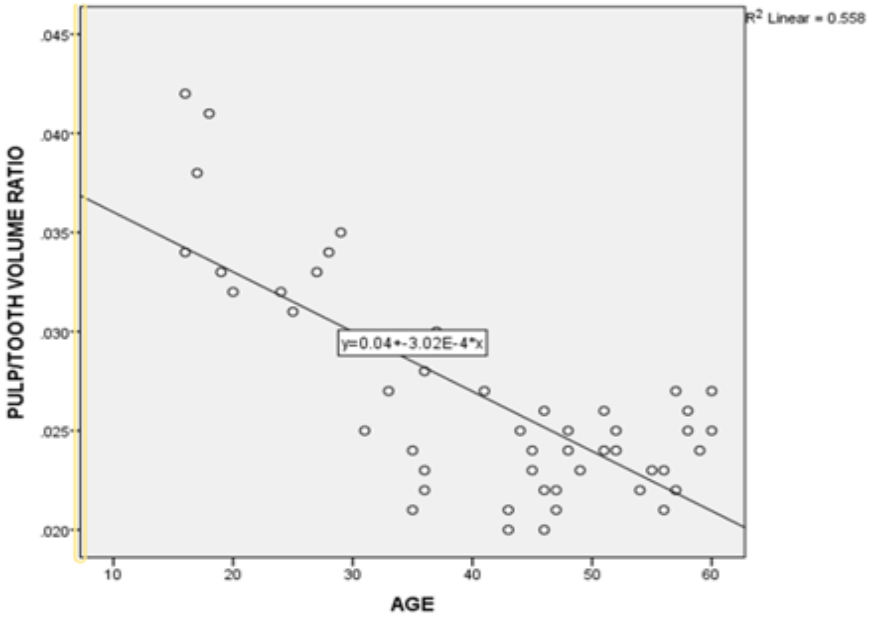

Figure 3: Relationship between age and pulp–tooth volume ratio of males

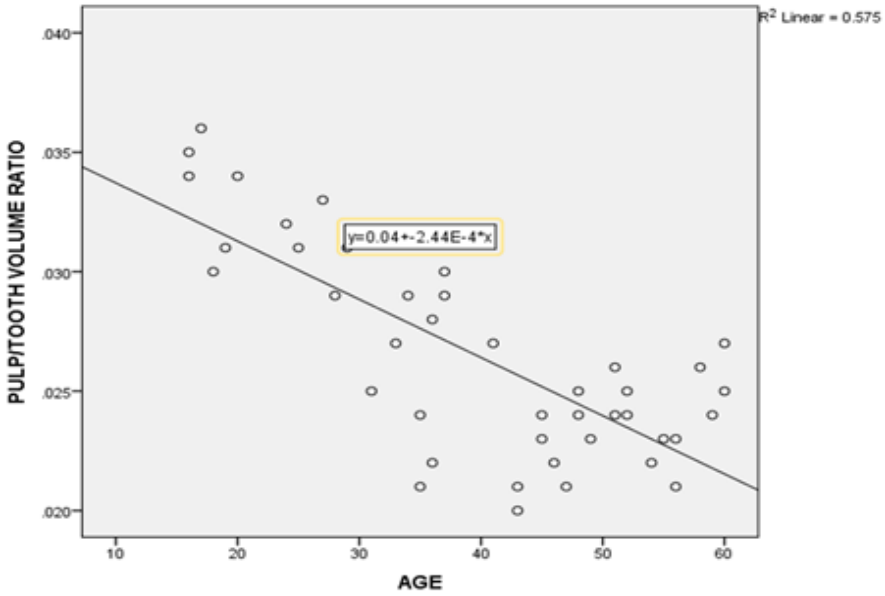

Figure 4: Relationship between age and pulp–tooth volume ratio of females

Discussion

DAE plays a pivotal role in forensic odontology by aiding in identification purposes not only in deceased individuals but also in living individuals at multiple stages of life. Multiple methods of determining age from dental hard tissues have been put forth in the literature, however, many of these methods are limited to a particular subset of age group [9-11], require sophisticated equipment, or require invasive techniques [12-13].

Secondary dentine apposition is a constant process which is continuous through-out an individual's life [3]. This laying down of secondary dentine decreases the overall area/ volume of the pulp space.Thus, the decrease in volume of pulp chamber was considered as one of the measures to estimate the age of an individual.

Few of the 2-D imaging modalities like periapical and panoramic Radiographic methods have been applied for estimating the decrease in pulp chamber which is a 3-D structure and hence their accuracy is questionable. Thus, a new modality like CBCT which uses 2-D X-ray detector and a cone beam reconstructing high resolution 3-D images can come handy. The other advantages of using CBCT are its easy accessibility, ease of handling, and ability to offer (from a single scan) a dataset of multiplanar cross-sectional and 3D reconstructions [3].

Contrary to the other studies in which pulp chamber/cavity to tooth volume ratio was used as an indicator for DAE, this study used the whole volume of pulp chamber and radicular pulp in toto. The reason for which was the relationship between advancing age and the apposition of the secondary dentine.

We also found a significant difference between sexes (stronger relationship in females) considering PV/TV in contrary to the other studies [27,35]. In accordance with our study, Someda et al [29] found a significant difference between the sexes in Japanese adults. It should be noted that greater samples for each age cohort are essential to clarify the role of sex. Further research is essential to assess the differences between measurement techniques and different populations. The validity and accuracy of the image segmentation methodology we used to measure volume on CBCT images has been previously demonstrated [19].

Authors by using ITK Snap software capable of doing vector-based segmentation technology measured the volume of pulp accurately on CBCT images. Using a computer mouse, a green border was manually drawn on each slice to delineate pulp volume and tooth volume (mm^3) which were then automatically calculated by the software. Age estimation conducted by using different third-party software and comparing their measurements would be the question of our further research.

In this study, we preferred using all the planes of acquired images for the calculation of Pulp Volume/ Tooth Volume since, it eliminated any bias in measurement. Unlike our study, authors of another study calculated only pulp chamber volume using CBCT images [19]. They found that the pulp chamber volume of maxillary first molar teeth was useful for age estimation. This finding was explained by the fact that age-related formation of secondary dentine by time results in a decrease in pulp cavity volume. They also suggested that pulp chamber volume calculation was more accurate than the whole TV calculation owing to high image contrast between pulp and dentine [19]. A difference of ±10 years with respect to the chronological age (considered acceptable in forensic odontology) was noted for 17.24% of the male subjects, however, in females it was for 21.42% which indicate the usefulness of maxillary second molar in future prospect of age estimation.

Limitations of the Study

Despite manual segmentation being better than the automatic, error occurred during the segmenting process cannot be ruled out and the results predicted by smaller sample size cannot be generalised to whole of a population.

Conclusion

In conclusion, the measurement of the pulp volume/ tooth volume using CBCT scans has provided high diagnostic images. This study revealed that pulp volume/ tooth volume was sex dependent, and the stronger correlation was found for females. Future studies may focus on modified techniques to obtain an optimized age estimation method by using CBCT images for maxillary second molar for better results.

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