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Age Estimation Using Pulp/ Tooth Volume Ratio By Cone Beam Computed Tomography

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Abstract: The formation of secondary dentin leads to an age related decrease in the pulp cavity. Hence the pulp volume can be useful for age estimation using the three-dimensional processing of the radiographic images of the teeth- such as the modern Cone Beam Computed Tomography (CBCT) which allows the adoption of a non destructive, reliable and rather accurate method for dental age estimation.
Aim: The aim of the present study was to develop a non-invasive, conservative, reliable, accurate and simple method of dental age estimation by mean of the analysis of the volume decrease phenomenon which affects the pulp cavity of the teeth using three-dimensional radiographic images of the CBCT.
Materials and Methods: The sample of single rooted teeth wasselected from20 CBCT radiographs in North Indian subjects of any gender and age between 15 and 60 years. The images consisting of the maxillary central incisor and canine of either side were selected in DICOM file format (OnDemand 3D software version:1-0-10). The ratio of "pulp/ tooth volume" has been obtained and then correlated with the age of the subject. The results have been statistically analyzed.
Results: There was a moderate correlation between chronological age and pulp/ tooth volume ratio.
Conclusion: The presented method is a promising tool in the procedure for age estimation, permitted by the high technological level achieved by the currently available machines for the CBCT.
Keywords: Age Estimation, Pulp/ Tooth Volume Ratio, cone beam CT, Forensic Odontology,

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I. Introduction

Age is one of the triad of information that is vital in reconstructive identification of bodies where no circumstantial evidence is available and visual recognition is not possible (e.g., skeletal remains) [1]. But the role of age prediction in forensic investigations is not just limited to post-mortem reconstructive identification; in addition, age changes can also be utilized in the context of crime investigation. For example, age estimation can be vital to determine the quantum of punishment delivered to the accused wherein minority/ majority status hinges on such evidence. Age estimation techniques are also useful for demonstrating substantive proof of birth records and age for immigrants (legal and otherwise) and those seeking retirement benefits. Therefore age estimation may be necessary for the living and deceased, and may apply to children, adolescents or adult age-groups.[2]

Age determination is one of several indicators employed to establish identity and has become increasingly important in forensic science. It is important for the identification of corpses and living individuals in a multicultural society. It is used to clarify legal queries in delineating juvenile and young adults in spheres pertaining to employment, labour acts and criminal offences. It plays a crucial role in Forensic Medicine, especially in connection with crimes and accidents[1, 2].

Forensic Odontology is a branch of forensic medicine and, in the interests of justice, deals with the proper examination, handling and presentation of dental evidence in a court of law. It primarily deals with identification based on recognition of unique features present in an individual's dental structures. It also plays a major role in identification of unknown in disasters or events that result in multiple fatalities that may not be identifiable through conventional methods[2].

A previously reported pilot study on dental age estimation based on extracted teeth focused on tooth images obtained by a microfocus CT (mCT) [4]. From these 3D digital images tooth and pulp were segmented

using a custom-made software. The ratio of pulp and tooth volume, which was calculated by voxel counting, was eventually correlated with age. Nowadays, similar 3D digital tooth images may be acquired from living individuals using a cone-beam CT. The clinical introduction of cone-beam CT creates new opportunities to get threedimensional tooth radiographs, resulting in a reasonable image quality at a low radiation dose (skin dose 1.19 mSv [5], total dose 20 microSv per examination).

Our present study combines both aspects and aims at developing a voxel counting software to calculate the pulp/tooth volume ratio based on the cone-beam CT tooth images.[yang]

II. Materials and methods

The research was carried out on **40 single rooted teeth of 20 individuals with age ranged between 17 – 60 yrs**(mean age: 34.7 years; number of females: 9; number of males: 11; Table 1) using the **DICOM** file of CBCT image which were transferred in **On Demand software.**

On each of cone beam CT image the original six teethwere selected.Image of single rooted teeth from axial section at the cemento enamel junction was obtained.Region of interest (ROI) was selected for getting minimum and maximum threshold of pulp and calcified tooth region separately for each tooth (11,13) of each individual.After Separation and segmentation of tooth and pulp cavity, the volume was calculated in mm^3 as shown in Fig. 3.After all measurements, pulp volume to tooth volume ratio was calculated. All measurements were performed by a single observer.

Statistical analysis. All measurements together with known chronological ages and calculated dental ages according to the formulas developed on the original technique were statistically analysed by means of differences between chronological and calculated ages were analysed using the Student's t-test and the standard error of the estimated age was calculated. Finally, Pearson correlation coefficients between chronological age and the obtained ratios were calculated.

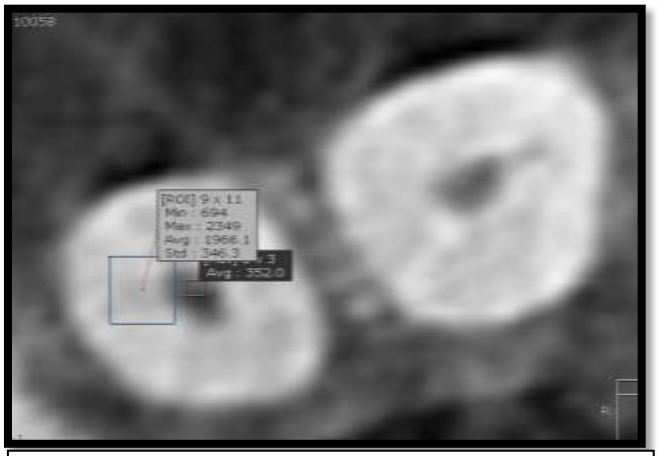


Figure 1: Threshold values by selecting ROI.

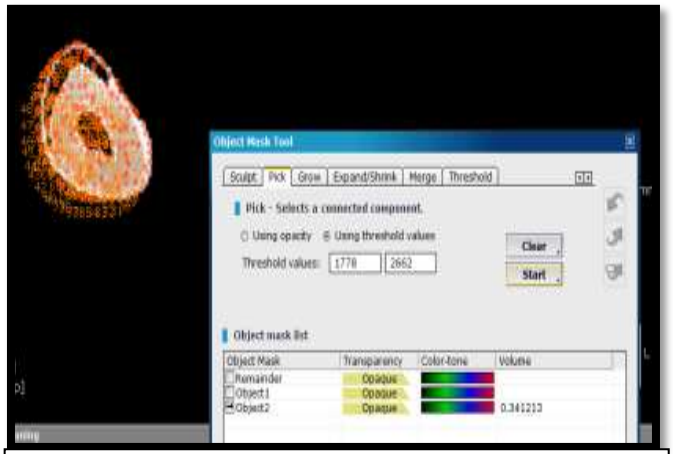


Figure 2: Volume measurement using selection and segmentation of tooth by Pick pointer.

segmentation of tooth by Pick pointer.

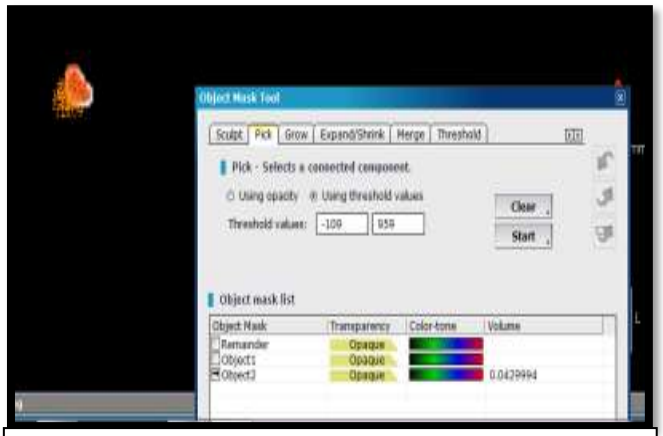


Figure 3: Volume measurement using selection and segmentation of pulp by Pick pointer.

III. Results

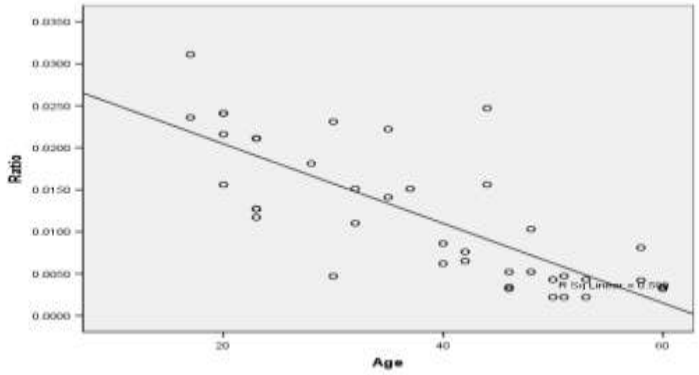
The pulp/ tooth volume ratios varied from 0.0022 to 0.0231 for maxillary central incisor and from 0.0032 to 0.0311 for maxillary canine. There was a moderately significant correlation i.e. R = -0.599 between chronological age and Pulp/ tooth volume ratio in the given set of data for all teeth, R= -0.533 for maxillary central incisor and R=0.562 for maxillary canine. Our study determined R^2 = 35.8% for all teeth, R^2 = 31.6% for maxillary canine and R^2= 28.4% can be explained for maxillary central incisor, which weremoderately significant**.**

There was a negative (inversely proportional) correlation between chronological age and Pulp/ tooth volume ratio.The overall mean of actual age of patients is 37.95±13.37 and pulp/tooth volume ratio was 0.01±0.01 of all teeth, 38.05±13.72 and pulp/tooth volume ratio 0.01±0.01 for maxillary central incisor, and 37.85±13.36 and pulp/tooth volume ratio 0.01±0.01 for maxillary canine.Regression analysis yielded a statistically significant but moderate negative correlation between pulp/tooth volume ratio and age. Regression formula for maxillary central incisor was Age = 53.461+ (PTVR × 1,196.219) and for maxillary canine was Age = 53.418+ (PTVR × 1415.733). The mean of chronological age 39.95±13.37 years and estimated age 41.92±9.88 years. This indicates moderately significant correlation (R = 0.088) for all teeth. The square root of mean square error was 11.45 years.

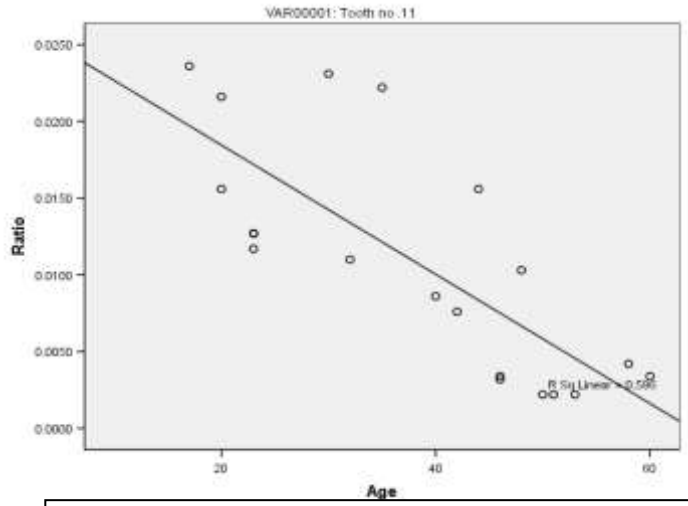
Table 1: shows mean and standard deviation for all teeth.

	Mean	**SD**	**SE mean**	**Mean difference**	**t-test**	**p- value**
Chronological age	39.95	13.37	2.11	-3.97	-1.747	0.088
Estimated age	41.92	9.88	1.56			

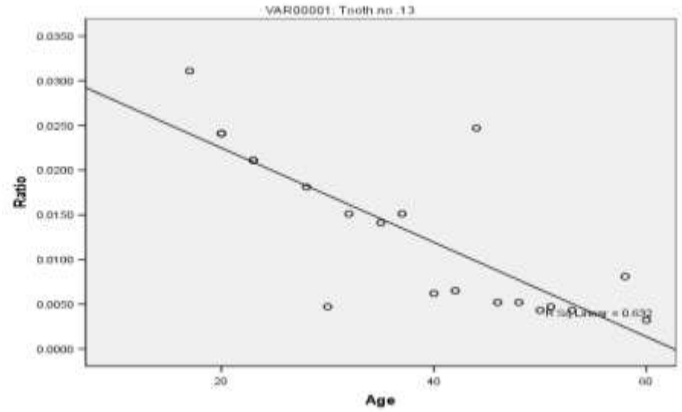
Table 12: shows mean and standard deviation for all teeth.



Graph 1 plot scatter diagram: showing relation between chronological age and pulp tooth volume ratio for all teeth.



Graph 3 plot scatter diagram: showing indicating relation between chronological ageand pulp tooth volume ratio for maxillary canine.



IV. Discussion

In our study the observed relations between pulp/ tooth volume ratio and age were stronger for women than men this value corresponding to the study conducted by Kvaal et al.[1]

The overall mean of actual age of patients was 37.95±13.37 and pulp/tooth volume ratio was 0.01±0.01 of all teeth.

The overall mean of pulp tooth volume ratio of male (0.011) and female (0.014) was gender independent in accordance with the study by **Jagannathet al**[13]and **Vandervoort et al**.[7] This finding was contrast to the study by **Agematsu et al**[8] who mentioned that ratio was slightly higher in females than males. In the study conducted by **Star et al**,[12] he observed relation between the pulp–tooth volume ratio and age was stronger for women than for men but the difference in relation was not significant (p = 0.86); moreover, there was no significant correlation between tooth types and gender (p = 0.50).

The pulp/ tooth volume ratios varied from 0.0022 to 0.0231 for maxillary central incisor and from 0.0032 to 0.0311 for maxillary canine. This indicates that the pulp/ tooth volume ratio is higher for maxillary canine followed by central incisor which was contrary with the study conducted by **Star et al**[12] where ratios were higher for the incisors followed by the premolars and the least for the canines.

There was a moderately significant correlation (R = -0.599) between chronological age and Pulp/ tooth volume ratio in the given set of data for overall teeth, R= -0.533 for maxillary central incisor and R=0.562 for maxillary canine. The study conducted by **Jagannath et al** [13] which shows similar correlation(R = -0.63). In the study given by Star et al, he mentioned R=-0.59 for all teeth which was similar to our study. He also noted individual correlation (R=-0.64 for central incisor, R= -0.27 for canine, R=-0.48 for premolar) but these were not in accordance with our study.

The R^2 value indicates how much of the **dependent variable (Chronological age)** can be explained by the **Independent variable (Pulp/tooth volume ratio)**. Our study determined R^2 = 0.358 for all teeth, R^2 =

0.284 for maxillary central incisor and R^2 = 0.316 for maxillary canine. In this case, R2= 28.4% can be explained for maxillary central incisor, which is a **moderate value** and correlate to the result given by study of **Yang et al [11] (R^2=29%)** and **Vandervoort et al**[7] (**R^2= 31%).**In the study conducted by **Star et al** [12] the squared Pearson correlations were 40.9%, 7.3%, and 22.8% explained respectively on incisors, canines, and premolars. These values were not correlating to our values.

There was a negative (inversely proportional) correlation between chronological age and Pulp/ tooth volume ratio, as the advancing age is associated with a decrease in the pulp/ tooth volume ratio as mentioned by previous studies on CBCT [11,12, 13, 26] and microCT [7, 8, 9, 10] .

In our study the regression analysis did not correlate to any previous study, because correlations may vary in different populations, age group, tooth type, machine and software used, hence, specific formula should be applied for the estimates for the given population.

The strongest Pearson correlation coefficient between the pulp/ tooth volume ratio and age was measured on maxillary canine in our study. This was contradictory because all the correlation coefficients between the variable ratios related to secondary dentine formation and age used in the **Kvaal et al**. [1] study equally, provided the highest correlation outcomes in the incisor group. The reason why there was poor correlation for canine could be attributed to low number of included canines (n = 32) and premolars (n = 15) in his study.

In our study the mean of **chronological age** 39.95±13.37 years and estimated age41.92±9.88 years. This indicates **moderately significant correlation(R = 0.088) for all teeth.** This result correlate to the by **Jagannath et al.**[13] In contrast, the use of **Yang's**[11]formula in the control group produced an estimated age± **14.78 years**, which was significantly different ($p < 0.05$) from the estimated ageobtained with our new formula. The square root of mean square error was 11.458 years which was in contrary to the study by **Yang et al**[11]where it was 8.3 years and the study by **Agematsu et al**[8] where the error was 2.611years for mandibular central incisor and 3.218 years mandibular 2nd premolar.

V. Conclusion

Although there was no statistical evidence that the relation between the pulp/ tooth volume ratio and age differs between the types of tooth ($p = 0.15$), regression formulas should be calculated separately for each tooth type.In addition, further advancements could help optimizing the accuracy and precision of the technique. Recent generations in cone-beam CT have become available, demonstrating better contrast resolution. The CBCT may bring more detail in the grayscale level range and enable improved visualization of the tooth segmentations.

A large data sample with homogeneous (or equal) age distribution should allow for even more finesse and optimization of the elaborated method. Finally, the technique can be adapted and transformed to the multi-root teeth. That would allow forensic odontologist to use the present method for age estimation using a very objective technique.

VI. References

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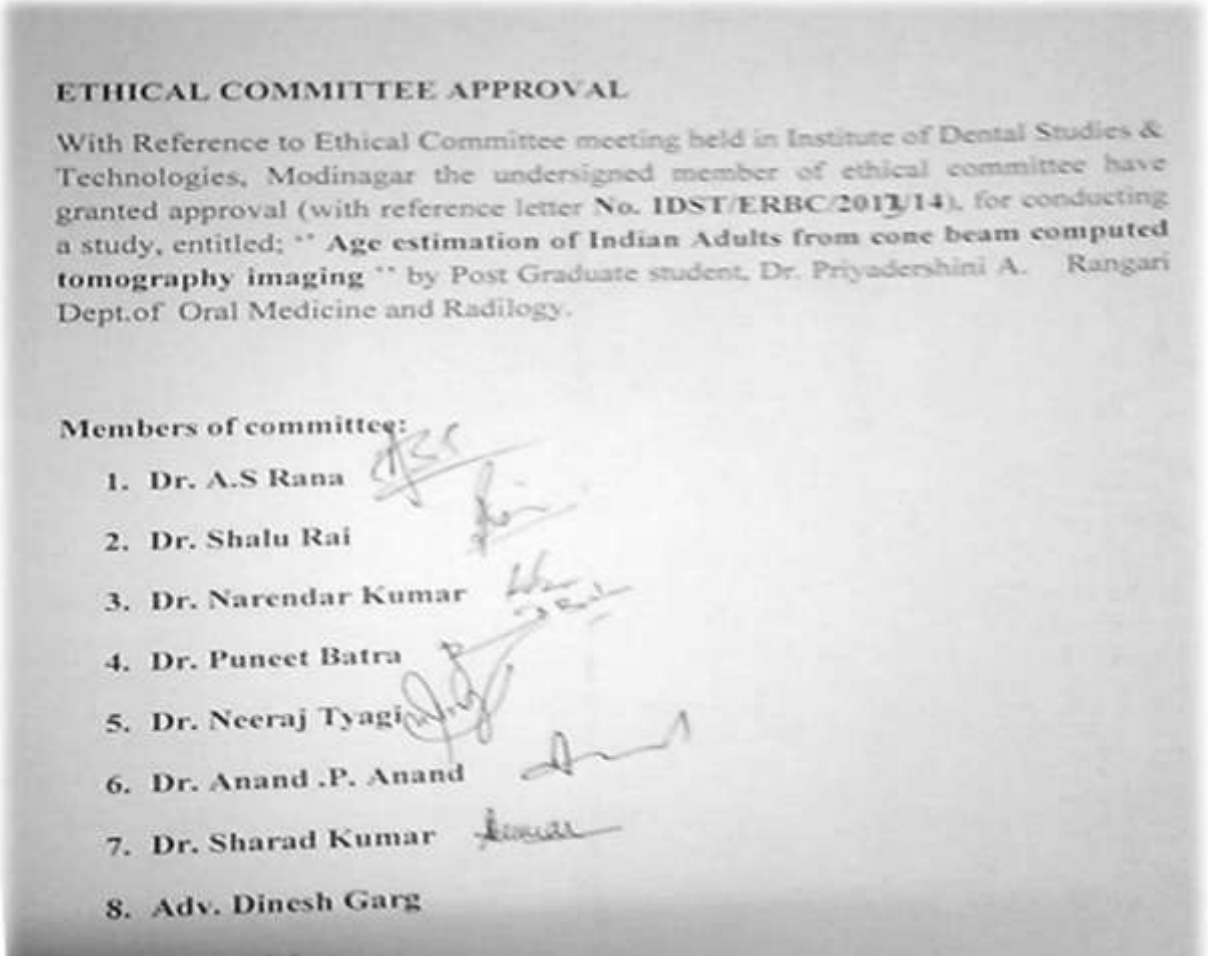

ETHICAL COMMITTEE APPROVAL

With Reference to Ethical Committee meeting held in Institute of Dental Studies & Technologies, Modinagar the undersigned member of ethical committee have granted approval (with reference letter **No. IDST/ERBC/2013/14**), for conducting a study, entitled; " **Age estimation of Indian Adults from cone beam computed tomography imaging** " by Post Graduate student, Dr. Priyadershini A. Rangari Dept.of Oral Medicine and Radilogy.

Members of committee:

1. **Dr. A.S Rana**
2. **Dr. Shalu Rai**
3. **Dr. Narendar Kumar**
4. **Dr. Puneet Batra**
5. **Dr. Neeraj Tyagi**
6. **Dr. Anand .P. Anand**
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