ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 12, Issue, 01, pp.9373-9380, January, 2020

DOI: https://doi.org/10.24941/ijcr.37766.01.2020

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

DENTAL AGE ASSESSMENT BY PULP-TO-TOOTH VOLUME RATIO OF MAXILLARY CANINE BY CERVICAL AXIAL SECTION OF CBCT- A RETROSPECTIVE STUDY OF NORTH INDIAN POPULATION

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ARTICLE INFO

Article History:
Received 25th October, 2019
Received in revised form
18th November, 2019
Accepted 29th December, 2019
Published online 30th January, 2020

Key Words:
Age Estimation;
Cone-Beam Computed Tomography;
Pulp-Tooth Volume Ratio.

ABSTRACT

Background: Age estimation from teeth is a key indicator to establish identity in forensic cases. CBCT provides several advantages compared to conventional radiographic methods which has been used regularly in forensic cases. **Purpose:** Dental Age estimation by pulp-to-tooth volume ratio using cone-beam computed tomography. The Retrospective study will attempt to establishing a correlation between the chronological age of a certain individual and the pulp/tooth volume ratio using Cone-beam computed tomography. **Materials and Methodology:** In this study a total of 50 scans (25 males and 25 females) respectively were collected from the archives of a imaging centre located in Delhi-NCR region. Out of this 50 scans, 20 scans (i.e 10 males and 10 females) of age group between 15-75 years were selected for the study based on the inclusion & exclusion criteria of the study. **Results:** Mean difference and Standard error difference between the Chronological and Estimated age was not significant as p> 0.05, that is the difference between the Chronological and Estimated age was less. The Pearson Correlation(r) were highly significant, p<0.01. Estimated age was more accurate in middle age. Regression formula for maxillary canine (overall) Age = 48.009 – (973.172 × Pulp/ Tooth Volume Ratio). **Conclusion:** In our study standard error difference between chronological and estimated age is ±4.09781 years. There was a negative correlation between chronological age and Pulp/ tooth volume ratio, as the advancing age is associated with a decrease in the pulp/ tooth volume ratio.

Citation: *Dr. Vikash Ranjan, Dr. Sambuddha Chakrabarty, Dr. Soumendu Bikash Maiti and Dr. V. Naveen Shankar.* **2019.** "Dental age assessment by pulp-to-tooth volume ratio of maxillary canine by cervical axial section of cbct- a retrospective study of north indian population", *International Journal of Current Research*, 12, (01), 9373-9380.

INTRODUCTION

Age estimation is one of several indicators employed to establish identity in forensic cases. Most frequently, Age estimations from teeth are used, as teeth may be retained long after all other tissues, even bone, have degenerated, but unlike bone they can also be investigated directly in living individuals. The dental age estimation methods most often requires extraction, and some of them also need prepared for microscopic sections of at least one tooth. These methods are tedious and costly, and a damaging approach may not be acceptable for ethical, religious, cultural, or scientific reasons. A study of radiographs of the teeth is a non-destructive, straightforward method to obtain information and is a technique used regularly in most dental surgeries, but it is rarely employed in methods of age estimation (Kvaal, 1995).

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Techniques for chronological age estimation in children based on dental maturation may be divided into those using the atlas approach and those using scoring system whereas in adults there are morphological and radiographical techniques (Willems, 2001). Changes that are detectable with increasing age are attrition, periodontal disease, and deposition of secondary dentine, root translucency, cementum apposition, root resorption, color changes and increase in root roughness. Gustafson in 1950 suggested the use of six retrogressive changes and ranked them on arbitrary scale, allotting 0-3 points according to degree of the change. Error obtained in this morphometric method resulted in several modification in subsequent studies. Johanson in1971 in his research used same six criterions but different ranking scale and then estimated the age of an individual. Solheim used in situ teeth and eight variables which included two of color estimate, two for periodontosis, and two for attrition, crown length and sex (Singh, 2004). The apposition of secondary dentine is also often taken into account, because the pulp is surrounded not only by hard tissue such as enamel but also by dentine, which changes during an individual's life. Canines were chosen for a number of reasons: they have the longest functional survival rate in the mouth, undergo less wear as a result of diet than posterior teeth, and also suffer less wear than other anterior teeth due to their particular work, and have the largest pulp area amongst the single rooted teeth and thus the easiest to analyze (Cameriere, 2009). CBCT provides a non-invasive alternative for age estimation which is an important aspect of forensic dentistry. Enough data for volumetric image construction is captured by a single rotational sequence. The target region is scanned in a single rotation therefore, the radiation exposure is less. CBCT may be very useful in some forensic procedures, offering several advantages for pre-mortem forensic and post-mortem forensic imaging including good resolution for skeletal imaging, relatively low cost, portability, and simplicity. The pulpo-dentinal complex (dentin, cementum, and the dental pulp) shows physiologic and pathological changes with advancing age (Jawaid, 2014).

MATERIALS AND METHODS

This retrospective double blind study comprised a total of 50 CBCT scans i.e 25 males and 25 females respectively were collected from the archives of a imaging centre located in Delhi-NCR region. Out of this 50 CBCT scans, 20 CBCT scans (i.e 10 males and 10 females) of age group between 15-75 years were selected for the study based on the inclusion & exclusion criteria of the study. Inclusion Criteria comprising of patients within the age range of 15-75 years & canine upto root apices. Exclusion Criteria are canine with caries, filling, or crown restoration, periapical pathologies, anomalies, fracture of maxilla & space infection. CBCT scans were obtained for various reasons such as impacted teeth, dental anomalies, implant planning or orthodontics. Single maxillary canine tooth were assessed retrospectively from patients. Teeth with caries, filling or crown restorations, periapical pathologies, anomalies or pulpal pathosis were excluded. All CBCT images were taken with the same device (Kodak CS9300, Carestream Health, Rochester, NY) using 60–90 kVp, 2–15 mA and 12–28 s scanning time. For volumetric measurements, CBCT scans were exported as DICOM files and then imported into a volumetric rendering software capable of measurements of vector-based segmentation in On Demand software. On each of CBCT image maxillary canine was selected. Image of axial section at the cemento-enamel junction was obtained. Profile tool was selected for getting minimum and maximum threshold of pulp of each individual. After Segmentation of tooth and pulp cavity, then pick tool was used in which minimum and maximum threshold had been entered, then desired area such as tooth and pulp was marked with the pick tool, separately using their respected maximum and minimum threshold, then the volume was calculated in cc. After all measurements, pulp volume to tooth volume ratio was calculated. All measurements were performed by a observer no.1 without any knowledge of chronological age. After the study, Estimated age will be compared with Chronological age in the presence of observer no.2.

RESULTS AND DISCUSSION

Several studies suggested that the measurement of the pulpal size area in canines revealed better secondary dentinal deposition than the other teeth groups with smaller pulp areas. Smaller size of such single-rooted teeth may lead to less clear images and inaccurate pulp tooth ratio measurement.

Table 1. Overall list of subjects with chronological and estimated age

Case no.	Name	Chronological Age (years)	Estimated age (years)
1.	Chanderkanta	42	37.84
2.	Srijna	44	51.16
3.	Mehak	26	32.18
4.	Zeenat	60	53.40
5.	Akhtar	55	53.06
6.	Anjali	40	47.25
7.	Mohini	50	51.15
8.	Farzana	17	12.06
9.	Nisha	19	25.48
10.	Veedhant	30	35.02
11.	Aizaz	16	12.36
12.	Nagesh	55	52.21
13.	Lalit	40	46.64
14.	Vivek	40	46.34
15.	Vedant	37	42.98
16.	Anil	53	47.98
17.	Neeraj	32	36.56
18.	Rajnesh	30	28.84
19.	Neeraj	38	34.68
20.	Nikhil	25	26.01

Table 2. Distribution of mean and standard deviation of Chronological age & Estimated age

Group	N	Mean	Std. Deviation	Std. Error Mean
Chronological age	20	37.4500	13.08464	2.92582
Estimated age	20	38.6600	12.83096	2.86909

Table 3. Comparison of means of age between Chronological age & Estimated age by independent t – test

Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		t	df	p value
		Lower	Upper			
-1.21000	4.09781	-9.50559	7.08559	-.295	38	.769*

Table 4. Distribution of mean and standard deviation of Pulp/ Tooth Volume Ratio

	N	Minimum	Maximum	Mean	Std. Deviation
Pulp/ Tooth Volume Ratio	20	.000	.046	.01085	.011429

Therefore, in the present study we did not include central and lateral incisors owing to their small pulpal sizes. In the present study there was a highly significant correlation R= -0.850 between chronological age and Pulp/ tooth volume ratio in the given set of data and the study conducted by Jagannathan N *et al.* (2011) which showed a similar correlation R = -0.63. In the study by Jagannathan *et al.* (2011), in the study group produced an MAE of 15.34 years in 72.81% of the cases. Age estimates were within ±10 years of actual age in 27.09% of the cases. Application of the formula derived by Jagannathan *et al.* (2011) to the control group yielded an MAE of 8.54 years whereas in our study standard error difference between chronological and estimated age is 4.09781 years. In a study by Someda *et al.* (2009) females tended to have higher accuracy compared to males, which is contrary to our study where males tended to have higher accuracy compared to females as standard error mean for males (3.89556 years) is less than females (4.38869 years). The R^2 value indicates how much of the dependent variable (Chronological age) can be explained by the Independent variable (Pulp/tooth volume ratio). In our study, R^2= 72.3% which is a significant which is a significant value than the result given by study of Yang F *et al*[6] that is R^2=29%.

Table 5. Correlation between Chronological Age, Estimated age and Pulp/ Tooth Volume Ratio

		Chronological Age (years)	Estimated age	Pulp/ Tooth Volume Ratio
Chronological Age (years)	Pearson Correlation(r)	1	.926**	-.850**
	p value		.000	.000
	N	20	20	20
Estimated age	Pearson Correlation(r)			-.955**
	p value			.000
	N			20

*Not significant p>0.05, **highly significant p<0.01

Table 6. Distribution of subjects into three age groups

Sr. no.	Age group	N
1.	15-35	8
2.	36-55	11
3.	56-75	1

Table 7. Distribution of mean, standard deviation and standard error of Chronological age, Pulp/ Tooth Volume Ratio & Estimated age of three age category

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Chronological Age (years)	Adults	8	24.38	6.301	2.228	19.11	29.64	16	32
	Middle age	11	44.91	6.978	2.104	40.22	49.60	37	55
	Old age	1	60.00	.	.	.	.	60	60
Pulp/ Tooth Volume Ratio	Adults	8	.02088	.011606	.004103	.01117	.03058	.011	.046
	Middle age	11	.00455	.004247	.001281	.00169	.00740	.000	.013
	Old age	1	.00001	.	.	.	.	.000	.000
Estimated age	Adults	8	26.0638	9.40929	3.32669	18.1974	33.9301	12.06	36.56
	Middle age	11	46.4809	5.90651	1.78088	42.5129	50.4490	34.68	53.06
	Old age	1	53.4000	.	.	.	.	53.40	53.40

Table 8. Comparison of mean of Chronological age, Pulp/ Tooth Volume Ratio & Estimated age of three age category by one way ANOVA

ANOVA						
		Sum of Squares	df	Mean Square	F	p value
Chronological Age (years)	Between Groups	2488.166	2	1244.083	27.654	<.001**
	Within Groups	764.784	17	44.987		
	Total	3252.950	19			
Pulp/ Tooth Volume Ratio	Between Groups	.001	2	.001	10.282	<.001**
	Within Groups	.001	17	.000		
	Total	.002	19			
Estimated age	Between Groups	2159.425	2	1079.712	18.950	<.001**
	Within Groups	968.611	17	56.977		
	Total	3128.036	19			

*Not significant p>0.05, **highly significant p<0.01

Table 9. Distribution of mean of Chronological age, Pulp/ Tooth Volume Ratio & Estimated age between male and female

	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		t	d.f.	p value
			Lower	Upper			
Chronological Age (years)	-1.700	5.999	-14.303	10.903	-.283	18	.780*
Pulp/ Tooth Volume Ratio	.000059	.005251	-.010974	.011092	.011	18	.991*
Estimated age	-2.40000	5.86822	-14.72866	9.92866	-.409	18	.687*

*Not significant p>0.05, **highly significant p<0.01

Table 10. Correlation coefficient R, R^2 and Square root of mean square error for female

R	R Square	Std. Error of the Estimate
Sex = Female (Selected)		
.824	.679	8.920

Table 13. Regression model for female

Coefficients[a,b]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	47.695	3.630		13.140	.000
	Pulp/ Tooth Volume Ratio	-868.211	211.118	-.824	-4.112	.003
a. Dependent Variable: Chronological Age (years)						
b. Selecting only cases for which Sex = Female						

Regression equation for Chronological Age (years) for female Age = 47.695 – 868.211 * Pulp/ Tooth Volume Ratio

Table 11. Correlation coefficient R, R^2 and Square root of mean square error for male

R	R Square	Std. Error of the Estimate
Sex = Male (Selected)		
.925	.855	4.777

Table 12. Regression model for male

Coefficients[a,b]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	P value
		B	Std. Error	Beta		
1	(Constant)	50.106	2.481		20.192	.000
	Pulp/ Tooth Volume Ratio	-1241.333	180.950	-.925	-6.860	.000
a. Dependent Variable: Chronological Age (years)						
b. Selecting only cases for which Sex = Male						

Regression equation for Chronological Age (years) for male Age = 50.106 – 1241.333 * Pulp/ Tooth Volume Ratio

Table 13. Regression model for over all

Coefficients						
Model		Unstandardized Coefficients		Standardized Coefficients	t	P value
		B	Std. Error	Beta		
1	(Constant)	48.009	2.210		21.723	.000
	Pulp/ Tooth Volume Ratio	-973.172	142.116	-.850	-6.848	.000
a. Dependent Variable: Chronological Age (years)						

Regression equation for Chronological Age (years) for all Age = 48.009 – 973.172 * Pulp/ Tooth Volume Ratio

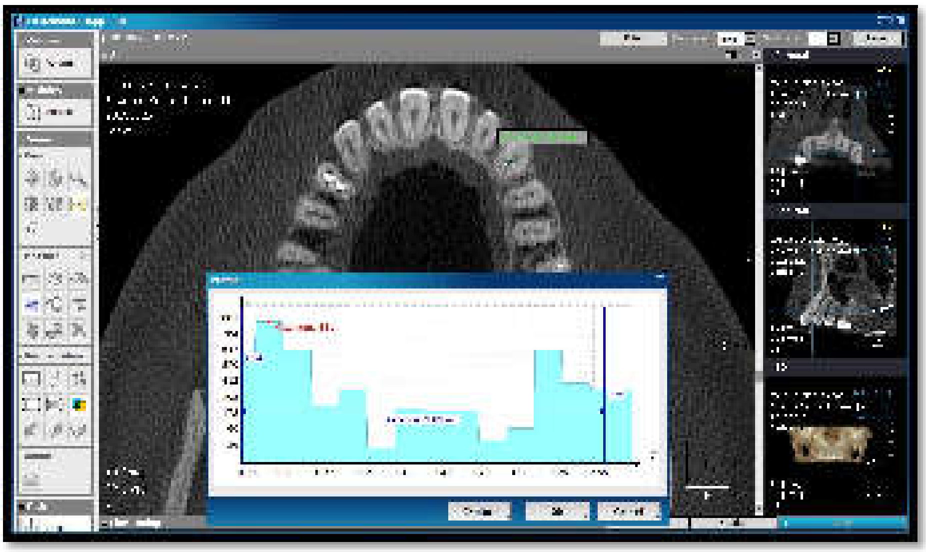


Figure 1(A) Pulp Threshold- (Maximum-881, Minimum-379)

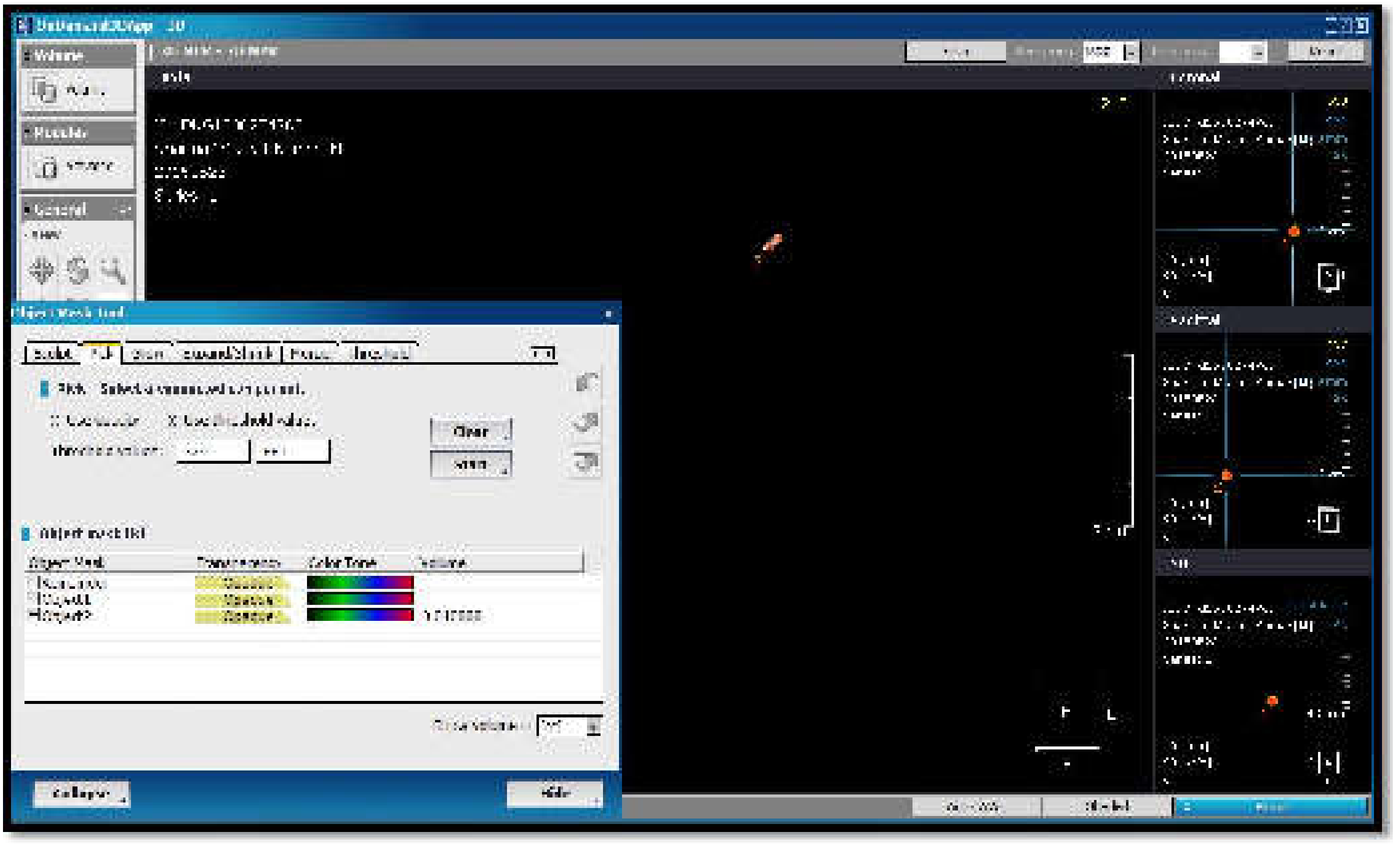


Figure 1. (B) Pulp Volume= 0.010888 Cc

Figure 1. (C) Tooth Threshold- (Maximum-1742, Minimum-1371)

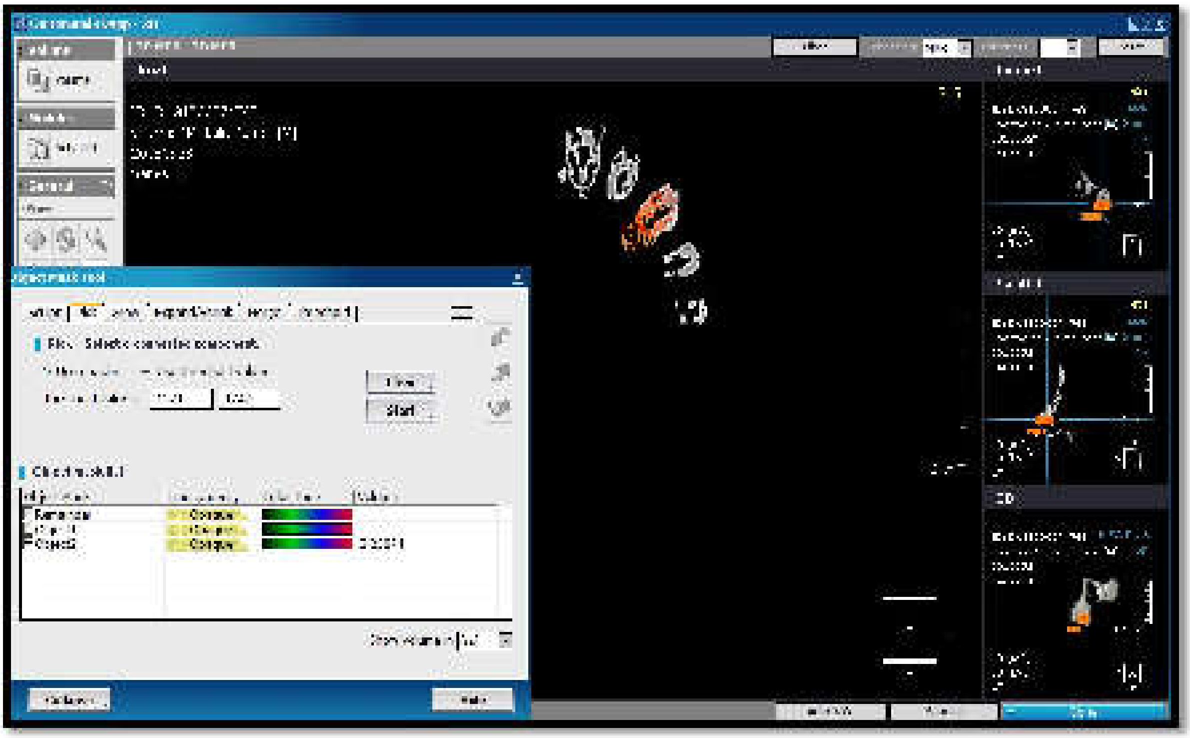
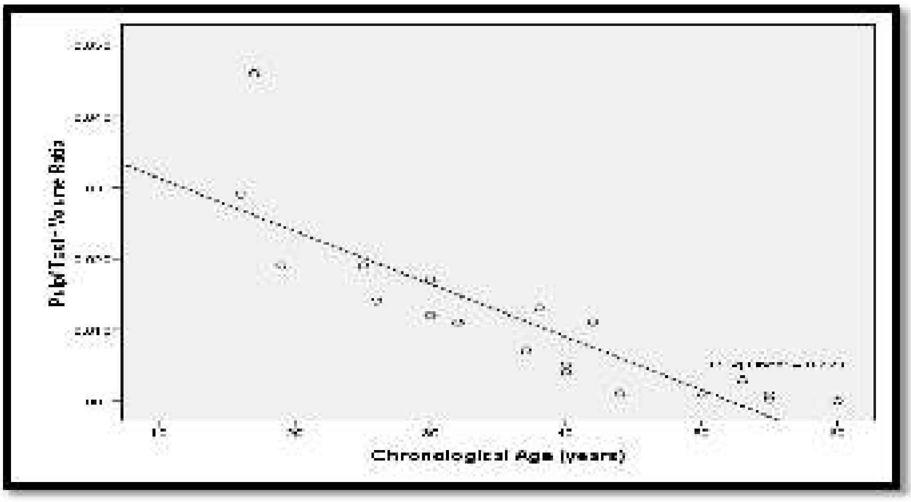
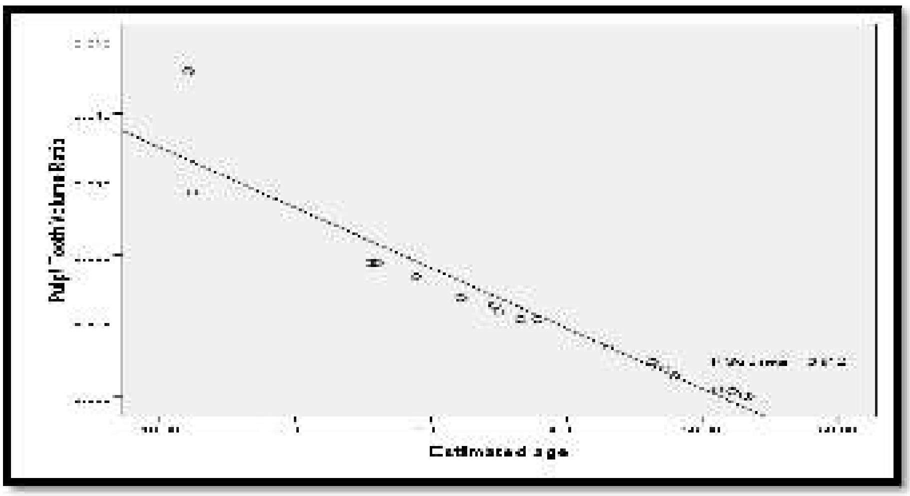


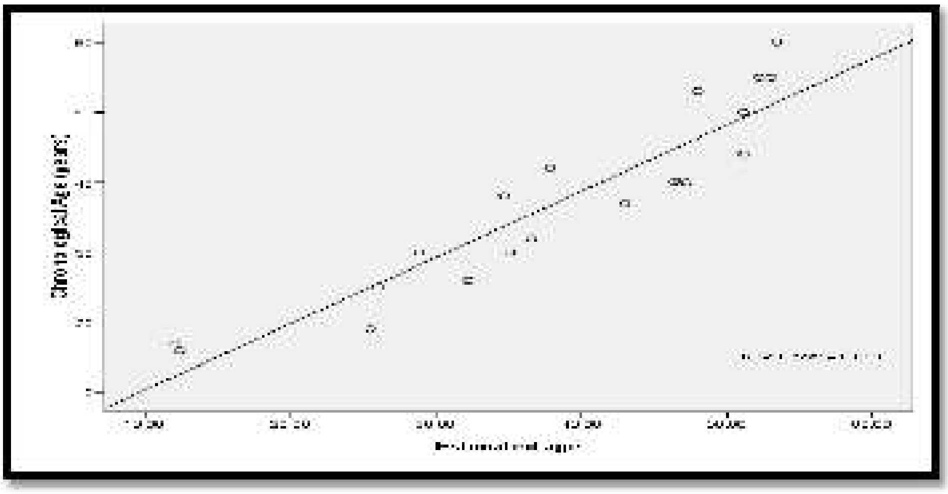
Figure 1. (d) Tooth volume=2.25874 cc



Graph 1. Correlation between pulp/tooth volume ratio and chronological age



Graph 2. Correlation between pulp/tooth volume ratio and estimated age



Graph 3. Correlation between chronological age and estimated age

The use of Yang's formula in the control group produced an estimated age has a standard deviation ± 14.78 years, whereas in our study an estimated age has a standard error difference ±4.09781 years. The square root of mean square error was 7.080 years where it was 8.3 years in the study by Yang F *et al*[6]. In the study by Yang F *et al*[6], The correlation between age and Pulp/Tooth Volume ratio is -0.54 whereas in our study correlation between age and Pulp/ Tooth Volume Ratio is -0.850, which is highly significant, p<0.01.This states that Pulp/Tooth Volume Ratio is inversely proportional to age. 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 Yang *et al*, Jagannathan *et al*. (2011) Gulsahi *et al*. (2017) Babshet *et al*. (2010) performed a study on Indian sample, resulting in an MAE of 10.76 years whereas in our study standard error difference between chronological and estimated age is 4.09781 years. Also, In a sudy by Ge *et al*. (2015) the mean absolute error was 8.122whereas in our study standard error difference between chronological and estimated age is 4.09781 years. In a study by Gulsahi *et al*. (2017) there was no significant difference in the intercept between both gender ($p > 0.05$). This study revealed that PV/TV ratio was not gender dependent. In the present study, the mean difference between male and female of Chronological Age is -1.700 and p value is 0.780, of Pulp/ Tooth Volume Ratio is 0.00059 and p value is 0.991 and of Estimated age is -2.400 and p value is 0.687, which are not significant, p>0.05. In a study by Rangari *et al*. (2018) 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. In the present study, there is significantly high correlation i.e. Correlation(r) between Chronological Age and Pulp/ Tooth Volume Ratio R= -0.850. Study conducted by Rangari *et al*. (2018) 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 were moderately significant whereas the present study determined, R^2 =72.3% for maxillary canine which is highly significant. The square root of mean square error was 11.45 years whereas in the present study, Square root of mean square error is 7.080 years. Various studies have obtained regression formula for calculating age by using pulp/tooth volume ratio such as Yang *et al.* (2006) obtained the equation of the straight line relating age and ratio of pulp/tooth volume estimated as: Age = 54.32 - (554.21 × pulp/ tooth volume Ratio).

Jagannathan *et al*. (2011) obtained the regression equation for the Indian population for maxillary canine: Age = 57.18 + (-413.41 x pulp/tooth volume ratio). Rangari *et al*. (2018) obtained the Regression formula for maxillary canine as Age= 53.418+(-1415.733×PTVR). Gulsahi *et al*. (2017) obtained the Regression formula for maxillary canine as Age = 60.5 − (479.3 × PV/TV). In our study, Regression analysis yielded a statistically significant but moderate negative correlation between pulp/tooth volume ratio and age. Regression formula for maxillary canine for males is Age = 50.106 − (1241.333 × Pulp/ Tooth Volume Ratio) and for females is Age = 47.695 − (868.211 × Pulp/ Tooth Volume Ratio). Regression formula for maxillary canine (overall) Age = 48.009 − (973.172 × Pulp/ Tooth Volume Ratio).

Conclusion

Mean difference between Chronological age and Estimated age is not significant as the difference between the Chronological and Estimated age is less. The Pearson Correlation(r) between Chronological Age and Estimated age, Chronological Age and Pulp/ Tooth Volume Ratio, Estimated age and Pulp/ Tooth Volume Ratio are highly significant, p<0.01. Estimated age is more accurate in middle age (36-55 years) than young adults (15-35years) and old age (56-75). Regression formula for maxillary canine for males is Age = 50.106 – (1241.333 × Pulp/ Tooth Volume Ratio) and for females is Age = 47.695 – (868.211 × Pulp/ Tooth Volume Ratio). Regression formula for maxillary canine (overall) Age = 48.009 – (973.172 × Pulp/ Tooth Volume Ratio).

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. 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. Also a large data sample on large geographical area is required for more accuracy of the result. That would allow forensic odontologist to use the present method for age estimation using a very objective technique.

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