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Application of Kvaal's Age Estimation Method in Maxillary Central Incisor: A CBCT Study

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Abstract

Background: Radiographic dental age estimation methods are viable both for living and deceased people. One such method is the indirect assessment of quantified secondary dentinal deposition through measurements of tooth and pulp. Kvaal, *et al.,* developed a method for chronological age estimation based on pulp size using periapical dental radiographs. There is a need to test this method of age estimation in the Indian population on living individuals not requiring tooth extraction. The current study aimed to assess the applicability of Kvaal's method in maxillary permanent central incisor using CBCT. **Materials and Methods:** The study included 185 CBCT images of the individuals, ranging in age from 14 to 64 years. CBCT images were evaluated for the maxillary central incisor and metric measurements were taken from which ratios were derived. Using the ratios, a linear regression equation was derived, from which the age of an individual was predicted. **Result and Conclusion:** The correlation between the individual ratio and the chronological age was calculated using the Pearson correlation coefficient. The age of the individual was predicted using a linear regression equation with a SEE ranging from 10.05 to 12.78 years. When the samples were divided into various age groups, the Standard Error of Estimate has drastically reduced. The radiographic pulpal morphometric analysis used in present study can be recommended to assess the age of an adult for forensic purposes.

Keywords: Age Estimation, CBCT, Kvaal's Method, Maxillary Central Incisor, Secondary Dentin

Introduction

Forensic is derived from the Latin word 'forum' where legal matters are discussed. Odontology refers to the study of teeth, or dentistry. According to the Federation Dentaire Internationale [FDI], forensic dentistry is the branch of dentistry that deals with the proper handling and examination of dental evidence as well as the proper evaluation and presentation of dental findings in the interest of justice[1].

Teeth and the oral structures play an important role in the identification of an individual. Age estimation using the dentition enacts an important step in human identification. In forensic odontology, proper identification is required for ethical, humanitarian, and official records, particularly in legal and criminal investigations[2].

Currently, the need for developing more accurate and non-invasive methods for age estimation as part of the identification of adult individuals in forensic scenarios is increasing globally[3]. Literature describes several techniques that address age estimation in adults. The various methods are divided into three categories: (1) Morphological methods; (2) Biochemical methods; (3) Radiological methods[4]. Radiographic age assessment is a simple, non-invasive, and reproducible method that can be used on both the living and the unknown dead, in both identification cases and archaeological investigations[5].

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Age estimation up to puberty can be performed by the development process, dental radiographs (intraoral periapical radiographs, bitewing radiographs, orthopantomographs) or a combination radiographic techniques. But, after third molar development, it becomes increasingly difficult to assess age accurately and so only the aging process and regressive changes of teeth are helpful at adult age[6].

In adult and subadult populations, regressive tooth changes have been linked to chronological age[7]. As the patient ages, the volume of the pulp cavity gradually decreases because of the secondary dentin deposition in the pulp cavity wall[8]. These morphological changes in the pulp cavity serve as one of the most promising predictors for age estimation.

Secondary dentin deposition is a regular, ongoing process that is modified only by caries or specific types of abrasion and that can be studied radiologically. The study by Kvaal, *et al.,* (1995) was one of the first investigations that developed an indirect age estimation method in adults based on the amount of secondary dentin deposition using the relationship between age and pulp size as measured on periapical dental radiographs. The authors showed a correlation between age and the calculated ratios, and they presented regression formulas for estimating chronological age. Since this initial study, several other studies have tested the reproducibility of the Kvaal, *et al.,* method using different radiological techniques and different regression formulas[9,10].

The current study aimed to assess the applicability of Kvaal, *et al*., method in maxillary permanent central incisor using CBCT.

Materials and Methods

The radiographic study included 185 CBCT images collected retrospectively in the Department of Oral Medicine and Radiology from patients aged 14 to 64, regardless of gender or religion, who had visited for dental treatment. These patients were grouped by a difference of 10 years into 5 age groups. They were Group I, Group II, Group III, Group IV and Group V in the age range of 14.00-23.99 years, 24.00-33.99 years, 34.00-43.99 years, 44.00-53.99 years and 54.00-63.99 years, respectively.

CBCT images taken as a part of routine investigations and treatment purposes for any periodontal diseases, pre-orthodontic assessment, orthodontic treatment or cosmetic treatment, wisdom tooth assessment, dentition assessment and implant or prosthetic assessment having good quality without any technical error in regards to patient positioning, head alignment, contrast was selected and a clearly visible area of interest containing well-aligned, integrated, sound maxillary anterior dentition with good occlusion, especially either of the right or left maxillary central incisor with completed root formation, were included.

CBCT images are of poor quality, have significant distortion, and are unreadable, making proper measurements of the area of interest impossible. Radiographs showing any developmental anomalies, images with severe attrition, malposition, fracture, restoration, teeth with dental caries, root-canal treated teeth, teeth with root canal calcification, pulp stones, pathologies where the anterior dentition was affected were excluded.

Sample Size Calculation[11,12]

The sample size calculation was based on a 95% level of confidence interval under the standard deviation of the earlier study and considering a two-year margin of error using the following formula.

Sample size (n) = $(z_{1-\alpha/2})2\ (\sigma)^2/(d)^2$

Where,

n = Desired number of samples

$z_{1-\alpha/2}$ = Standardized value for the corresponding level of confidence.

(At 95% CI, it is 1.96 and at 99% CI is 2.58)

d = Margin of error or rate of precision

σ = SD which is based on previous study or pilot study

The required sample size was found to be 171 CBCT images.

Sample Preparation

CBCT images that met the selection criteria were obtained from the Newtom CBCT machine (exposure parameters: scanning time: 10.8 s, 3-15 mA, 60-85kVp, field of view FOV: 6 cm x 6 cm to 16 cm to 18 cm, 360° rotation, slice thickness: 0.2 mm) in DICOM file. As part of a blind setup, each file was sequentially numbered from 1 to 185. When analyzing the radiographs, the observer did not know the chronological ages of the individuals examined. All measurements were carried out by the same observer in CS 3D imaging software (Carestream Health Inc., internal version 3.5.18.0).

General information such as date of birth, date of exposure, chronological age and gender were recorded in the proforma.

Measurements

There were no significant differences between permanent teeth on the left and right sides of the jaw, according to the literature[3,7,13-16]. Consequently, in the current study, teeth were chosen either from the left or the right side, whichever was best suited for measurement. The tangential slice of the image was used for the study. Brightness, contrast, density, and angulations of teeth were adjusted in both sagittal and coronal sections before measurement. The raw images were sliced with 0.2 mm thickness in both sagittal and coronal sections. The labiolingual measurements were performed on sagittal sections and the mesiodistal measurements of the teeth were performed on coronal section[17]. All parameters were recorded in millimeters.

Parameters of tooth were measured as follows (Figures 1 and 2):

- Maximum tooth length (t) - Distance from the incisal edge to the root apex
- Maximum root length on mesial surface (r) - Distance from the coronal pulp to the root apex
- Maximum pulp length (p) - Distance from the cementoenamel junction to the root apex
- Pulp width at level a, c, b (a-cementoenamel junction, c-midroot level, b-midpoint of c and a)
- Root width at level a, c, b (a-cementoenamel junction, c-midroot level, b-midpoint of c and a)

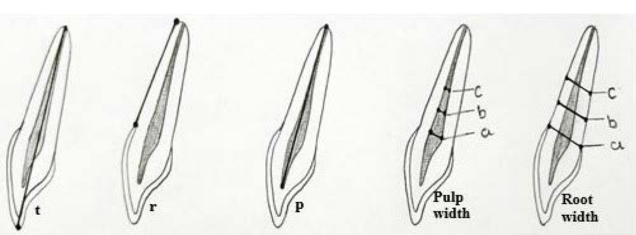

Figure 1. Diagram showing measurements of tooth (t, r, p), pulp width and root width at different levels in sagittal section of CBCT.

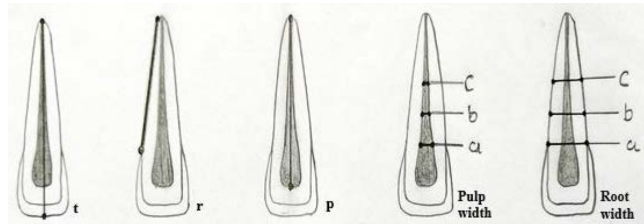

Figure 2. Diagram showing measurements of tooth (t, r, p), pulp width and root width at different levels in coronal section of CBCT.

All measurements were performed by a single observer and randomly selected 30 CBCT images of 185 samples were reevaluated after 1 month by the same observer and a second observer in order to check intra-observer and inter-observer agreement.

From above measurements a total of 10 ratios were calculated as follows:

1. T - Root length/tooth length
2. R - Pulp length/tooth length
3. P- Pulp length/root length
4. A - Pulp width/root width at level a
5. B - Pulp width/root width at level b
6. C - Pulp width/root width at level c
7. M - mean values of all ratios
8. W - Mean value of width ratios from levels b and c
9. L - Mean value of length ratios P and R
10. W-L - difference between W and L

Statistical Analysis

In Windows 10, the measurements were entered into a Microsoft Excel worksheet. The data was statistically analyzed using SPSS. Descriptive statistics were used to summarize the data. The Pearson correlation coefficient (r) was calculated to assess the relationship between the chronological and morphological variables. Linear regression models were built with age designated as the dependent variable. Different regression equations were then formulated for different age groups. After establishing the regression equation, it was applied to individual CBCT images, and an estimated age was calculated. To gauge the accuracy of the age estimation, the difference between chronological and estimated age was calculated using the student's t test. The Interclass Correlation Coefficient (ICC) and paired t-tests were applied to test the reliability and repeatability of the measured data.

Table 1. Age and gender distribution of study subjects

Age group (years)	Gender	N = 185 (%)	Minimum (Years)	Maximum (Years)	Mean (Years)	SD
Group I (14.00-23.99)	M	19(10.27%)	14.94	23.26	19.76	2.86
	F	20(10.81%)	15.95	23.96	19.42	2.55
Group II (24.00-33.99)	M	38(20.54%)	25.28	33.42	28.54	2.17
	F	26(14.05%)	24.08	33.83	27.87	2.94
Group III (34.00-43.99)	M	20(10.81%)	34.23	43.79	39.08	3.08
	F	13(7.03%)	34.08	42.49	39.15	3.15
Group IV (44.00-53.99)	M	23(12.43%)	44.45	53.27	48.96	2.61
	F	16(8.65%)	44.34	52.64	49.19	2.95
Group V (54.00-63.99)	M	05(2.70%)	54.32	58.25	55.70	1.51
	F	05(2.70%)	55.16	60.45	57.58	1.97
Total sample	M	105(56.76%)	14.94	58.25	34.72	11.44
	F	80(43.24%)	15.95	60.45	33.71	12.65
	T	185	14.94	60.45	34.29	11.95

M - Male, **F** - Female, **SD** - standard deviation

Results

In the present study, 185 CBCT images of a permanent maxillary central incisor were analyzed to measure tooth length, pulp length, root length, root width at the CEJ, pulp width at the CEJ, root width between the CEJ and mid root level, pulp width between CEJ and mid-root level, root width midway between the apex and the CEJ, pulp width midway between the apex and the CEJ. Out of 185 radiographs, 105 (56.76%) radiographs were of males and 80 (43.24%) were of females in the age range of 14 to 64 years. These subjects were grouped by a difference of 10 years into 5 groups. They were Group I, Group II, Group III, Group IV and Group V in the age range of 14.00-23.99 years, 24.00-33.99 years, 34.00-43.99 years, 44.00-53.99 years and 54.00-63.99 years respectively. Age and gender distribution of study subjects with their mean age is depicted in Table 1.

Table 2 shows the results of inter- and intra-examiner variations analyzed using the ICC and paired t-test. The results of the above tests showed good agreement between observers and in all the measured parameters.

Table 2. Inter- and intra-observer agreement for the measured parameters in both methods

CBCT section		Paired t-test (p value)	ICC
Sagittal	Intra-observer agreement	0.209 (N.S.)	.855
	Inter-observer agreement	0.126 (N.S.)	.861
Coronal	Intra-observer agreement	0.346 (N.S.)	.855
	Inter-observer agreement	0.116 (N.S.)	.839

ICC - Interclass correlation coefficient
N.S. - Not significant ($p > 0.05$)

The Pearson correlation was performed between the chronological age andratio of measurement in both sections of CBCT. All measured variables showed a significant negative correlation with age in both sections of the CBCT (Table 3).

Linear regression analysis was performed with age as a dependent factor and the morphological ratios as an independent factor. The coefficients of determinants and

Table 3. Pearson correlation coefficients between chronological age and ratios of measurement in both sections of the CBCT

Variables	correlationcoefficient	p value	correlation coefficient	p value
	Sagittal		Coronal	
T	-.297	0.000 (H.S.)	-.196	0.008 (H.S.)
R	-.164	0.026 (S)	-0.118	0.108 (S)
P	-.330	0.000 (H.S.)	-.227	0.002 (H.S.)
A	-.230	0.002 (H.S.)	0.061	0.407 (S)
C	-.323	0.000 (H.S.)	-.264	0.000 (H.S.)
B	-.316	0.000 (H.S.)	-.260	0.000 (H.S.)
W	-.340	0.000 (H.S.)	-.292	0.000 (H.S.)
L	-.290	0.000 (H.S.)	-.198	0.007 (H.S.)
M	-.453	0.000 (H.S.)	-0.012	0.869 (N.S.)
W-L	0.071	0.334 (N.S.)	0.023	0.752 (N.S.)

T: ratio between length of tooth and root; **P**: ratio between length of pulp and root; **R:** ratio between length of pulp and tooth; **A:** ratio between width of pulp and root at CEJ (level A); **B:** ratio between width of pulp and root at midpoint between level C and A (level B); **C:** ratio between width of pulp and root at mid-root level (level C); **M:** mean value of all ratios; **W:** mean value of widthratios from levels B and C; **L:** mean value of the length ratios P and R; **W-L:** difference between W and L.

N.S. – Not significant (p > 0.05), S - Significant (p < 0.05), H.S. - Highly significant (p < 0.001)

Table 4. Linear regression equations and standard error of estimate in both sections of the CBCT according to gender

CBCT section	Gender	Regression equation	R^2	SEE	p value
Sagittal	M	72.579-70.319(M)-17.748(W L)	.133	10.757	.001 (H.S.)
	F	116.546-120.110(M)-5.657(W-L)	.385	10.049	.000(H.S.)
	T	90.332-91.802(M)-14.390(W -L)	.225	10.588	.000(H.S.)
Coronal	M	41.127-3.310(M)+6.243(W-L)	.012	11.483	.537(N.S.)
	F	30.901+2.918(M)-.911(W-L)	.006	12.780	.804(N.S.)
	T	35.892-.438(M)+2.019(W-L)	.001	12.019	.940(N.S.)

M - Male, **F** - Female, **T** - Total sample
M - mean value of all ratios, **W-L** - difference B1etween W and L, $\boldsymbol{R^2}$- Coefficient of determination
SEE - Standard error of estimate
N.S. - Not significant (p > 0.05), **H.S.** - Highly significant (p < 0.001)

standard errors of the estimated ages for the models were tabulated (Tables 4 and 5). The Standard Error of Estimate (SEE) for the CBCT sagittal section was found to be 10.58 years and that for the CBCT coronal section was 12.02 years. The coefficient of determination for the CBCT sagittal section was 0.225 and for the CBCT coronal section was 0.001. An obtained regression formula for the studied maxillary central incisor was highly significant in the sagittal section (P = 0.000).

The mean of chronological age and estimated age in both sections of CBCT according to age group and gender was compared using paired t-test between the mean of chronological age and estimated age and the value obtained was greater than 0.05 in all age groups of both genders suggestive of statistically no significant difference present between chronological age and estimated age (Table 6).

Table 5. Linear regression equations and standard errors of estimation in both sections of the CBCT in different age groups

Age group (years)	Regression equation	R^2	SEE	p value
Sagittal section				
Group I	20.818+.816(M)+ 2.459(W-L)	.008	2.739	.872 (N.S.)
Group II	42.416-23.408(M) -4.514(W-L)	.227	2.246	.000 (H.S.)
Group III	38.670+3.311(M)+ 2.618(W-L)	.010	3.141	.854 (N.S.)
Group IV	57.253-5.634(M)+ 5.753(W-L)	.110	2.635	.124 (N.S.)
Group V	56.131+19.777(M)+17.016(W-L)	.167	1.997	.528 (N.S.)
Coronal section				
Group I	15.148+1.888(M)-4.620(W-L)	.114	2.589	.113 (N.S.)
Group II	28.680-.625(M)-.075(W-L)	.003	2.552	.925 (N.S.)
Group III	42.468+.250(M)+5.672(W-L)	.052	3.075	.451 (N.S.)
Group IV	51.435+.280(M)+4.037(W-L)	.033	2.746	.544 (N.S.)
Group V	59.671-5.276(M)-.041(W-L)	.065	2.115	.791 (N.S.)

SEE - Standard error of estimate
N.S. - Not significant ($p > 0.05$), **H.S.** - Highly significant ($p < 0.001$)

Table 6. Comparison between chronological age and estimated age in both sections of the CBCT according to age group and gender

Age group (years)	Gender	Chronological age	Estimated age			
			Sagittal		Coronal	
		Mean±SD	Mean±SD	p value	Mean±SD	p value
Group I (14.00-23.99)	M	19.76±2.86	19.78±0.32	.969 (N.S.)	19.86±1.62	.856 (N.S.)
	F	19.42±2.55	19.40±0.46	.980 (N.S.)	19.42±0.60	.996 (N.S.)
Group II (24.00-33.99)	M	28.54±2.17	28.51±0.97	.926 (N.S.)	28.54±0.22	1.000 (N.S.)
	F	27.87±2.94	27.87±1.50	.992 (N.S.)	27.88±1.48	.983 (N.S.)
Group III (34.00-43.99)	M	39.08±3.08	39.06±0.68	.984 (N.S.)	39.08±0.82	.998 (N.S.)
	F	39.15±3.15	39.17±2.10	.968 (N.S.)	39.15±1.57	.997 (N.S.)
Group IV (44.00-53.99)	M	48.96±2.61	48.98±0.66	.978 (N.S.)	48.96±0.42	.999 (N.S.)
	F	49.19±2.95	49.30±1.21	.884 (N.S.)	49.20±1.28	.995 (N.S.)
Group V (54.00-63.99)	M	55.70±1.51	54.11±3.74	.418 (N.S.)	55.92±1.04	.838 (N.S.)
	F	57.58±1.97	57.59±1.23	.985 (N.S.)	57.58±0.91	.999 (N.S.)
Total sample	M	34.72±11.44	34.61±4.16	.913 (N.S.)	34.73±1.27	.997 (N.S.)
	F	33.71±12.65	33.64±7.90	.947 (N.S.)	33.71±0.95	.999 (N.S.)
	T	34.29±11.96	34.19±5.68	.904 (N.S.)	34.29±0.31	1.000 (N.S.)

Discussion

Estimation of age is important in forensic sciences as a way to establish the identity of human remains. Although several parts of the body can be used for age estimation, the poor condition of the remains often prevents their use. However, the teeth are usually more resistant to peri- and post-mortem tissue-altering effects[8]. In addition, teeth can be examined clinically and radiographs prepared with minimal radiation exposure to living individuals.

The study of morphological parameters of the teeth on radiographs is considered to be more reliable than most other methods of age estimation[18].

In 1995, Kvaal, *et al.,*[15]. reported a method that is based on radiological measurements only. They investigated periapical radiographs by examining the relationship between chronological age and the pulp size on periapical dental radiographs collected from a Norwegian sample. Following the recommendations of these authors, in the forthcoming years, various studies were done using various imaging modalities to test the reproducibility of this method on independent samples, which demonstrated conflicting results[19]. Bosmans, *et al.*,[20] applied the technique of Kvaal, *et al.,* on digital orthopantomograms and obtained age estimations comparable to those based on the original technique. Paewinsky, *et al.,*[21] also tested the method of Kvaal, *et al*., on digital panoramic radiographs, but specific regression formulae were developed by these authors for their sample. Landa, *et al.*,[22] applied the age estimation models developed for the original study population by Kvaal, *et al.,* to digital OPGs from a Caucasian population in Spain, which was contrary to the results of Bosman, *et al*. Similarly, Meinl, *et al.*,[23] applied the regression formulae developed by Kvaal, *et al.*, to digital OPGs from an Austrian population. Congruent to the results of Landa, *et al.*,[22] Meinl, *et al.*,[23] also concluded that direct application of the regression models led to a consistent underestimation of chronological age. These studies indicate that predictive accuracy is compromised when population-specific standards are not used, thus highlighting the need for contemporary population-specific data[3,22,24,25].

In various literatures different teeth were used for age estimation. Brkic, *et al.*,[26] found that the teeth of both jaws were reliable for dental age estimation, but the correlation coefficient was stronger for all types of teeth in the upper jaw. Fancy, *et al.*,[27] stated that the growth layers of maxillary teeth were more regular and distinct than those of mandibular teeth. Kvaal, *et al.,*[15] used mandibular lateral incisors, canines, first premolars, maxillary central and lateral incisors and second premolars in their study. They also found a stronger correlation coefficient in the maxillary arch as compared to the mandibular arch and in individual teeth, a stronger correlation coefficient was found in the maxillary central incisors. Different authors applied Kvaal's method to a single tooth or in a combination of different teeth using various imaging modalities, in which maxillary central incisors were found to be a better predictor of age[8,24,28-32]. Central incisors are single-rooted teeth with the largest pulp area and the lowest morphological diversity among human teeth; they also encompass more secondary dentin tissue[30,33]. Considering these, age-related morphological changes in the maxillary central incisor were determined in the present study.

In previous studies of dental age estimation from two-dimensional dental radiographs, the ratio between the pulpal size and root size and the ratio between the pulpal size and tooth size have successfully been used (Kvaal, 1995)[15]. The analysis of digital images has provided a new perspective in the field of age estimation. CBCT is an innovative invention in the field of dentistry and was first introduced in 1997 for imaging of the oral and maxillofacial regions and it provides images in three orthogonal planes[13]. Yang, *et al.*,[34] in 2006 were the first to utilize CBCT in age determination, and since then various studies on age estimation using various methods have been carried out utilizing CBCT. CBCT in dental use provides plenty of 3D volume information of the teeth on living individuals in the target area with a single scan. The measurement of the volumes of pulp and canal at different views and levels of the tooth can be operated non-destructively and accurately for age estimation[33,35]. In the present study, with the expectation of achieving greater accuracy in dental age estimation with the substantially increased quality of CBCT images, linear measurements of morphological variables were performed on sagittal and coronal sections of CBCT images of the permanent maxillary central incisor.

The present study consisted of 185 subjects' CBCT between the age range of 14 to 64 years, divided into five age groups with a difference of 10 years. The 10-year difference was kept because statistically significant shrinkage in root canals due to dentin deposition was noted with advancing age between 10 years of age[36]. Kvaal, *et al.,* suggested the minimum age included in the study be 14 years as there are other methods reliable for aging teenagers and infants, and before 14 years of age, not all the teeth have completed the apex closure, which by definition is a requirement for the formation of the secondary dentin[37].

The intra-observer and inter-observer reliabilities of the morphological variables of the present study showed high values in both sections of CBCT. The interobserver measurement consistency was 0.839-0.861, and the intraobserver reliability of measurement was 0.839-0.855. There were no significant differences between inter- and intra-observer measurement in the present study, similar to the studies conducted by Kvaal, *et al.*,[15] Cameriere, *et al.*,[38] Paewinsky, *et al.*,[21] and Zaher, *et al*[39].

In the present study, a significant negative linear relationship between the morphological ratios and chronological age was obtained in both sections of the CBCT, which indicates as age advances, there is a decrease in pulp size. This findings were similar to study done by Kvaal, *et al.*, Bosmans, *et al.*, Limdiwala, *et al.*, Mittal, *et al.*, Patil, *et al*[5,6,15,20,30]. Width ratio in the sagittal section had a higher correlation to age than width ratio in coronal section parallel to study of Penzola *et al*[3,33].

In the present study, the regression equation model was found to be significant, with the highest $R^2 = 0.385$ in females in the sagittal section and $R^2 = 0.012$ in males in the coronal section. The lowest SEE of 10.05 years in the sagittal section in females and 11.48 years in the coronal section was found in males. The regression models for Group II and III in the sagittal section and Group I, Group II in the coronal section were found significant. R^2 of the present study is lower when compared with R^2 value of the maxillary central incisor in studies conducted by Kvaal, *et al.*, Bosman, *et al.*, Talreja, *et al.*, Parikh, *et al.*[15,20,24,29] and higher than the study conducted by Erbudak, *et al.*, Karkhanis, *et al.*, Penaloza, *et al.*, Mittal, *et al.*, Ramalingam, *et al.*, Akay, *et al*[3,13,14,16,40,41].

It was found that when the regression model was derived for different age groups SEE reduced drastically similar to the results of Ramalingam *et al*[13]. Better prediction of age was found in age group II in the sagittal section and age Group I in the coronal section. Ramalingam *et al.*,[13] found better prediction in 30 to 40 years of age range. This may be attributed to the fact that in middle age, secondary dentin deposition slows down and it is consistent and after 55 years of age, the difference narrowed. Similarly in the present study also better prediction of age was found in 34 to 44 years of age range.

The age of subjects was estimated by substituting the values of 'M' and 'W – L' in the derived regression equations. It was seen that there was no significant difference found between the mean chronological age and the mean estimated age ($P > 0.05$) while comparing chronological age with estimated age using the regression formula derived in the present study, which is similar to studies done by Kvaal, *et al.*, Bosmans, *et al.*, Paewinsky, *et al.*, Singaraju, *et al.*, Ridhima, *et al.*, Saxena, *et al.*, Agarwal, *et al*[5,15,20,21,42-44].

Based on the results of this study, it can be concluded that the size of the dental pulp is reduced with age in the coronal, middle and apical regions of teeth because of continuous secondary dentin deposition. The pattern for this secondary dentin deposition varies within teeth at different levels[29,36]. In the present study, analysis of pulp size was performed at CEJ, the middle third of the root, midway between the apex and CEJ, between CEJ and mid root level. A more significant correlation was seen in the middle third of the root canal as compared to the coronal and apical region of the maxillary central incisor similar to studies by Ahmed, *et al.*, Du C, *et al.*, Agematsu, H, *et al.*, Zaher, JF, *et al.*, Ginjupally, *et al.*, Singh, *et al.*, Penumatsa, *et al*[18,33,39,45-48]. The radiographic pulpal morphometric analysis used in the present study can be recommended to assess the age of an adult for forensic purposes. This could throw light on forensic applications and medicolegal issues regarding age estimation.

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