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Pulp width as an indicator of age estimation - A CBCT study in Indian population at tertiary care hospital

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Introduction

Forensic identification is a multidisciplinary act that utilizes various methods relying on team effort as well as methodologies which may be speculative or conventory. Forensic odontologists utilize parameters such as age, race, sex, and ethnicity on both living and dead individuals.[1] The first treatise on forensic odontology as a subject in its own right was written in 1898 by Dr. Oscar Amoeba, who is generally recognized as the father of Forensic Odontology. In 1770's Paul Revere, a practicing dentist in US, identified the remains of his friend, Dr. Joseph Warren from the silver bridge made by him. This is thought to be the first case of identification of a person by a dentist. [2]

Giving identity to an individual in both the living and the dead is one of the most important aspects in forensics. The most important aspect of personal identification is age estimation, especially necessary in cases of unidentified dead bodies, in cases of unavailability of ante-mortem information record and where personal profile has to be recreated. In addition, age estimation is also done in archaeological specimens dating back to thousands of years. In every discipline, it is required to develop scientific evidence regarding identification based on relevance, reliability and acceptance. [1,3]

Numerous maturity markers like morphological age, skeletal age, secondary sexual characteristics, psychological development and dental age have been utilized for age estimation in situation where the accurate age of the individual is not known or uncertain.[4]

Dentition is relatively resistant to environmental and chemical influences so methods based on the assessment of teeth are considered advantageous for this reason.[5]

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.[6] The study of radiographs of teeth would be non-destructive and simple and can be applied to living and deceased persons. In children and adolescents age estimations are based on the developmental stage of the deciduous and

permanent dentition (Demirjian et al. 1973; Gustafson and Koch 1974; Olze et al. 2004). In adults several methods have been applied concentrating on changes of the teeth. Among them, the secondary dentine has turned out to be one of the most efficient parameters. (Solheim 1990, 1993).[7] Primarily, these are based on the formation of secondary dentin, studied since 1950 and the subsequent narrowing of the pulp cavity, which can be observed in dental radiographs, leading to the proposal of minimally invasive methods. [8-11] The aim of present study was to estimate the age of an individual based on the 3D radiographic evaluation of the pulp width of the maxillary central incisor.

Material & method

The radiographic study was conducted in Department of oral medicine & radiology on total 100 CBCT images collected retrospectively from the data of radiology department at tertiary care hospital, Ahmedabad, Gujarat between the age ranges of 15–55 years irrespective of sex from Carestream 9300C model machine. (Carestream Health, Inc., 150 Verona Street, Rochester, New York 14608-USA)

Inclusion criteria

- CBCT images which were taken as a part of routine investigations and treatment purpose.
- Good quality images without any technical error.
- Clear visible area of interest containing well aligned, integrated sound maxillary anterior dentition with good occlusion.

Exclusion criteria

- CBCT having poor quality of images, gross distortion, not readable to allow proper measurements of the area of interest,
- Any developmental anomalies, severe attrition, malposed, fractured, restored, teeth with dental caries, root-canal treated tooth, tooth with root canal calcification, pulp stone, pathologies where anterior dentition was affected.

Sample size calculation:[12]

Sample size calculation was based on 95% level of confidence interval under standard deviation of the earlier study and considering margin of error two years 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 74 CBCT images.

From each of the selected CBCT images pulp width measurements were performed in sagittal (labiolingual) (Fig.1) and coronal (mesiodistal) section (Fig.2) in CS 3D imaging software at two levels as follows; Level A1 - was located at CEJ on the mesial side of the maxillary central incisor in coronal section and labial aspect of tooth in sagittal section. Level B1 - was located at middle third of root on the mesial side of the tooth in coronal section and labial aspect of tooth in sagittal section.

Measurements were recorded either from right or left side of the maxillary central incisor whichever is best suited.

All measurements were performed by a single observer and randomly selected 30 CBCT images of 100 samples were revaluated after 1 month by same observer and second observer in order to check intra-observer and inter-observer agreement. All data were collected in an Excel spreadsheet, Excel (version 2019 Microsoft) and subjected to Statistical analysis.

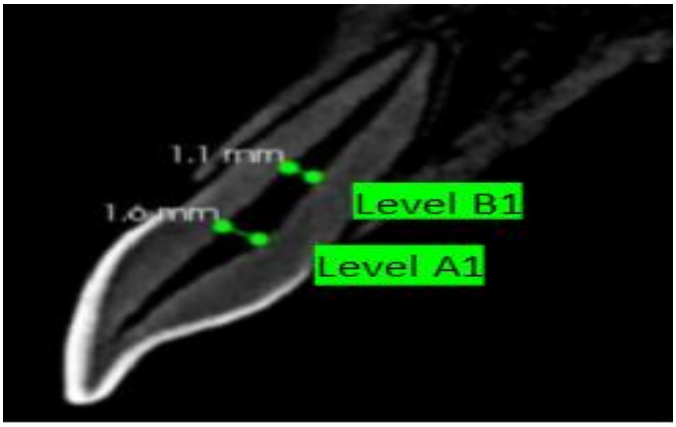

Fig 1: Measurement of pulp width at CEJ & middle third of root in sagittal section.

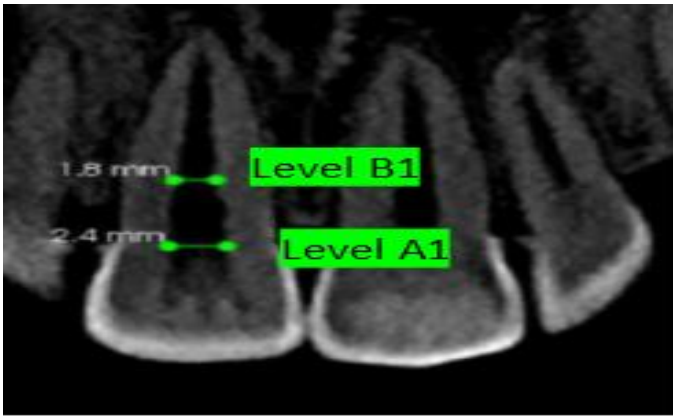

Fig 2: Measurement of pulp width at CEJ & middle third of root in coronal section.

Statistical Analysis

Statistical Package for Social Science (SPSS version 22) was used for statistical analysis. The data were presented as mean ± standard deviation and proportion. Mean pulp width at CEJ and middle third of root in different sex and age group were compared by using independent t test. Constant and coefficient value for different age groups at different level of pulp width were derived. Linear regression analysis was done to obtain regression formula for age estimation. Paired t test was performed to compare the mean estimated age with the known mean age of the study subjects. The level of significance was set 5%.

Results

Demographic characteristic of study subjects was depicted in Table 1. The mean chronological age was 33.56 years in males and 32.29 years in females. The mean values of pulp width at CEJ in females were 1.50 mm (sagittal section) and 1.55 mm (coronal section) and 1.54 mm (sagittal section) and 1.63 (coronal section) in males. The mean values of pulp width at middle third of root in females were 0.97 mm (sagittal section), 1.03mm (coronal section) and 1.03mm (sagittal section), 1.11 mm (coronal section) in males. Intra observer and interobserver reliabilities of the morphological variables of present study showed high values in both the section of CBCT. Descriptive statistics of measured variables in right and left side of maxillary central incisors was demonstrated in Table 2. The p value obtained from unpaired t-test was greater than 0.05. This suggests statistically no significant difference was present between right and left side of teeth. Comparison of mean values of the pulp width at the CEJ and middle third of root in both sex was performed using t- test and no significant difference was found statistically. (Table 3) Mean width of pulp decrease as age advances which was statisticallysignificant. (Table 4)

Pearson correlation test showed the negative correlation existed between age and pulp width. (Fig.3- 6) This was suggestive of the fact that as age increases, the pulp width decreases. Pulp width at middle third of the root was found to be a better predictor of age when compared to the pulp width at CEJ of maxillary central incisor. ($p < 0.001$) (Fig.4, 6) Linear regression analysis was performed, using the formula, $y = a+bx$. where, y is the estimated age, a is the constant, b is the coefficient and x is the corresponding pulp width at the CEJ and middle third of root. The value of constant and coefficient for each age group is given in Table 5. The independent variables (pulp width at different level) were entered into the equations simultaneously to predict chronological age (dependent variable). The regression equations

derived in present study were depicted in Table 6. The mean chronological age obtained in the study was 32.88 years. The mean estimated age obtained in the study using the regression equation was 32.88 years suggestive of statistically no significant differences were present between the mean of chronological age and estimated age. (Table 7)

Table 1: Demographic characteristic of study subjects.

Age groups	Male N (%)	Female N (%)	Total N (%)
15 - <25 years	10 (10.0)	15 (15.0)	25 (25.0)
25 - <35 years	25 (25.0)	14 (14.0)	39 (39.0)
35 - <45 years	8 (8.0)	8 (8.0)	16 (16.0)
45 - <55 years	12 (12.0)	8 (8.0)	20 (20.0)
Total	55 (55.0)	45 (45.0)	100 (100.0)

N = Sample size

Table 2: Descriptive statistics of the measured variables in both section of CBCT according to teeth.

CBCT Section	Variables	Tooth(FDI) N = 100	Mean	SD	p value
Sagittal	A_1	11	1.55	0.39	0.44 (N.S)
		21	1.49	0.39	
	B_1	11	1.05	0.29	0.07 (N.S)
		21	0.95	0.26	
Coronal	A_1	11	1.58	0.47	0.84 (N.S)
		21	1.60	0.51	
	B_1	11	1.06	0.35	0.63 (N.S)

Table 3: Comparison of mean width of pulp at CEJ and middle third of root in different sex

Variables		At CEJ		At Middle third	
		Male	Female	Male	Female
sagittal section	Min	0.8	0.5	0.5	0.4
	Max	2.4	2.1	1.7	1.7
	Mean	1.54	1.50	1.03	0.97
	SD	0.38	0.40	0.29	0.27
	P Value	0.64 NS		0.31 NS	
coronal section	Min	0.7	0.4	0.6	0.4
	Max	2.3	2.5	2.3	2.3
	Mean	1.63	1.55	1.11	1.03
	SD	0.38	0.59	0.37	0.39
	P Value	0.40 NS		0.33 NS	

NS- Not Significant

Table 4: Mean width of pulp at CEJ and middle third of root in both section of CBCT indifferent age groups

Age group	Sagittal section		coronal section	
	CEJ	Middle third	CEJ	Middle third
15 - <25 years	1.52 ± 0.39	1.15 ± 0.32	1.78 ± 0.47	1.31 ± 0.42
25 - <35 years	1.49 ± 0.36	0.99 ± 0.25	1.66 ± 0.40	1.06 ± 0.35
35 - <45 years	1.62 ± 0.35	1.02 ± 0.18	1.31 ± 0.57	1.05 ± 0.40
45 - <55 years	1.50 ± 0.48	0.83 ± 0.26	1.46 ± 0.49	0.83 ± 0.16
P Value	0.04 S	0.05 S	0.01 S	<0.001 HS

S- Significant HS- Highly significant

Table 5: Constant and coefficient value for different age groups

Age group	Pulp width	Constant (a)		coefficient (b)		P value	
		Sagittal section	coronal section	Sagittal section	coronal section	Sagittal section	coronal section
15 - <25 years	CEJ	20.36	17.84	0.52	1.86	0.74	0.14
	Middle third	22.58	22.23	-1.24	-0.82	0.51	0.58
25 - <35 years	CEJ	29.51	27.30	-0.91	0.50	0.43	0.63
	Middle third	28.08	29.61	0.05	-1.39	0.97	0.24
35 - <45 years	CEJ	34.30	42.61	4.36	-0.95	0.003*	0.35
	Middle third	41.37	40.49	-0.01	0.81	0.99	0.58
45 - <55 years	CEJ	48.86	48.33	0.76	1.15	0.46	0.26
	Middle third	55.17	53.88	-6.17	-4.66	<0.001**	0.12
Overall	CEJ	30.88	42.18	1.31	-5.83	0.64	0.01*
	Middle third	46.42	45.05	-13.47	-11.29	<0.001**	<0.001**

R2- coefficient of determination, SEE- standard error of estimate in years

Table 6: Regression equations at different level of pulp in both section of CBCT.

Pulp width level	Regression equation	R^2	SEE in years
CEJ (sagittal section)	Age =30.88+1.31(X)	0.002	2.83
Middle third (sagittal section)	Age =46.42-13.47(X)	0.12	3.68
CEJ (coronal section)	Age =42.18-5.83(X)	0.07	2.20
Middle third (coronal section)	Age =45.05-11.29(X)	0.15	2.66

Table 7: Mean difference between the Chronological age and Estimated age.

CBCT section (N- 100)	Pulp width	Chronological age (Mean ±SD)	Estimated age (Mean ±SD)	P value
sagittal	CEJ	32.88 ± 10.98	32.88 ± 0.51	1.00
	Middle third		32.88 ± 3.81	
coronal	CEJ		32.88 ± 2.84	1.00
	Middle third		32.88 ± 4.33	

N = Sample size, P value < 0.01 significant.

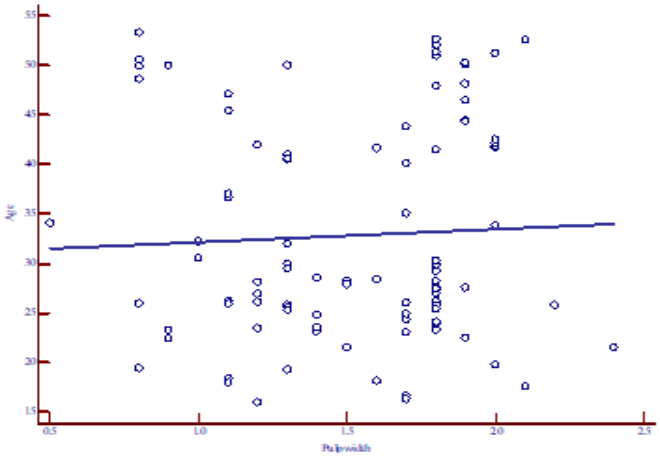

Fig 3: Correlation and regression line of pulp width vs. age at CEJ in sagittal

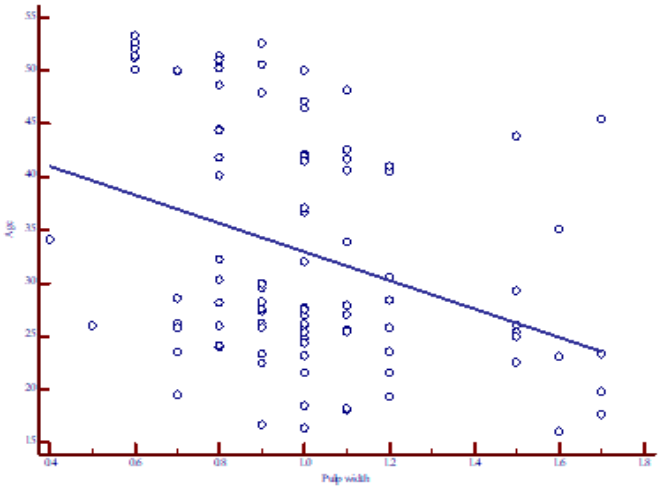

Fig 4: Correlation and regression line of pulp width vs. age at middle third in sagittal section

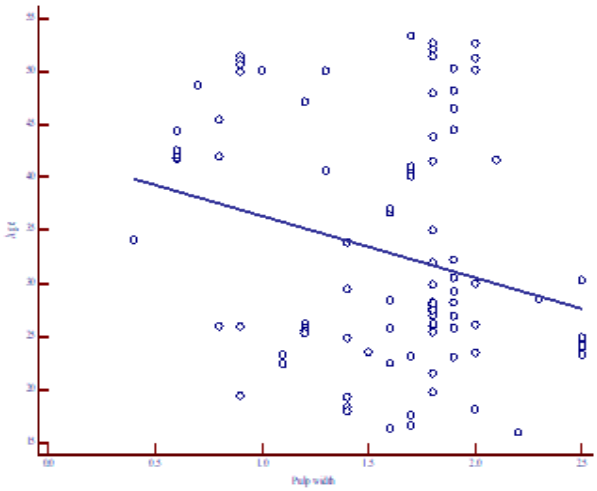

Fig 5: Correlation and regression line of pulp width vs. age at CEJ in coronal section.

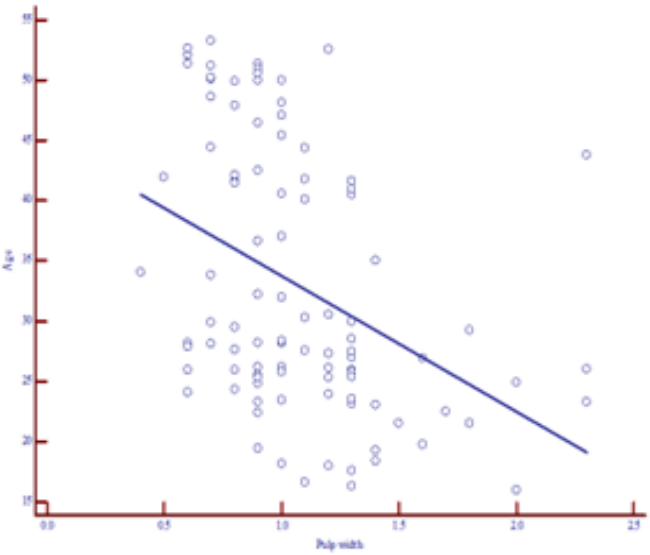

Fig 6: Correlation and regression line of pulp width vs. age at middle in coronal section.

Discussion

It is essential to establish a person's age as such information is commonly required to assist in the establishment of identity. It may also be required in connection with some legal requirement with age of the individual.[13] While different physiologic systems are used to estimate age, teeth are considered better suited than bones. After attaining maturity, teeth continue to undergo changes, making age estimation possible.[10] 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.[14]

In the present study, CBCT images were used for pulp width measurements at CEJ and middle third of root canal for age estimation. Such images benefited from controlled magnification compared the 2D radiography images, such as panoramic and periapical ones. In addition, other advantages of CBCT images compared those of micro-CT were the lack of superimposition of dental structures, the possibility for 3D analyses, the lack of geometric distortion, the lower radiation dose compared to that of CT, and the greater FOV. [11,15]

Different teeth were used for age estimation in various literature. Brkic et al. [16] conducted study on 160 intact extracted human teeth with known age and sex of individual and they concluded that maxillary teeth were more convenient for age determination than the teeth of mandible. They are in the significant strong correlation with the known real age. The growth layers of maxillary teeth were more regular and distinct than those of mandibular teeth. (Wolfe 1969, Miller 1974) [17] Parikh et.al [10] stated that among maxillary and mandibular teeth R^2 is better with maxillary teeth than mandibular teeth. In the literature, it was also found that maxillary central incisor considered as better predictor of age estimation than other teeth as it is single rooted tooth with greater pulp width. [8,18,19] So in the present study, age related morphological changes in the maxillary central incisor was determined.

A paired t-test on pulp measurements showed that there were no significant differences between teeth from the left and the right side of the jaw similar to studies by Kvaal et al,[20] Bosman et al,[21] Talreja et al.,[22] Parikh et al.[10] in present study.(Table 2) Statistically no significant difference in mean pulpal widths between males and females were noticed (Table 3) similar to studies by Ginjupally et al. [18], Singh et al. [19] Results of present study suggests that sexual dimorphism cannot be predicted using pulp width. In contrast to this finding, Ginjupally et al. [14] Penumatsa et al. [23] found significant difference in mean pulp widths between males and females. Mean width of pulp decreases as age advances which was statistically significant. (Table 4)

In present study, the regression equation model was found with highest $R^2 = 0.12$ in sagittal section at middle third of root and Lowest SEE of 2.20 years in coronal section was found at cervical part of central incisor. (Table 6) R^2 of present study is lower when compared with R^2 value of maxillary central incisor in studies conducted by Kvaal et al, Bosman et al, Talreja et al., Parikh et al. [10, 20-22] and higher than the study conducted by Erbudak et al., Ramalingam et al., Akay et al. [4, 24, 25] Difference in R^2 value of present study and other studies could attributed to variation in population and different methodology were used by different authors in different studies.

In present study, a negative linear relationship between the width of pulp and age was obtained in both section of CBCT at cervical part and middle third which

indicates that as age advances there was decrease in pulp size. These findings were similar to study done by Kvaal et al., Bosmans et al., Limdiwala et al., Mittal et al., Patil et al. [15,20,21,27,28]

Pulp width values were substituted in the derived regression equations to estimate the age of study subjects. (Table 7) For e.g., pulp width at CEJ in sagittal section is 2 mm at CEJ and formula is Age =30.88+1.31(X) than estimated age = 30.88+1.31(2) = 33.50 years. 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 regression formula derived in present study, which is similar to studies done by Ginjupally et.al., Singh et al. , Penumatsa et al.[18,19,23] There was statistically no significant difference found between the chronological age and estimated age in present study indicating the reliability of the derived formula. So, it can be helpful for age estimation of an adult population, using pulp cavity width of central incisor.

Conclusion

There is definite overall progressive shrinkage in the morphology of pulp cavity attributed to secondary dentin formation. Thus, measurement of areas of the dental pulp is a promising method for estimation of age. As per the present study, there is no difference found between the chronological age and estimated age using pulp width at CEJ and middle third of root of maxillary central incisor. Age estimation using pulp width in CBCT diagnostic images would increase the array of methods available for the forensic profiling of living and deceased individuals. This could throw light on forensic applications and medico-legal issues regarding age estimation.

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