

Morphometric analysis of pulp size in maxillary permanent central incisors correlated with age: An indirect digital study

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Abstract

Context: Teeth are hardest part of the body and are least affected by the taphonomic process. They are considered as one of the reliable methods of identification of a person in forensic sciences. **Aim:** The aim of the following study is to establish morphometric measurements by AutoCad 2009 (Autodesk, Inc) of permanent maxillary central incisors in different age groups of Udaipur population. **Setting and Design:** Hospital-based descriptive cross-sectional study carried out in Udaipur. **Materials and Methods:** A study was carried out on 308 subjects of both genders with the age range of 9-68 years. Standardized intra-oral radiographs were made by paralleling technique and processed. The radiographs were scanned and the obtained images were standardized to the actual size of radiographic film. This was followed by measuring them using software AutoCad 2009. **Statistical Analysis Used:** *F*-test, *post-hoc* test, Pearson's correlation test. **Results:** For left maxillary central incisor, the total pulp area was found to be of 38.41 ± 12.88 mm and 14.32 ± 7.04 mm respectively. For right maxillary central incisor, the total pulp size was 38.39 ± 14.95 mm and 12.35 ± 5 mm respectively. Males ($32.50, 32.87$ mm²) had more pulp area when compared with females ($28.82, 30.05$ mm²). **Conclusion:** There was a decrease in total pulp area with increasing age which may be attributed to secondary dentin formation.

Key words: Central incisor, forensic dentistry, morphometric analysis, pulp size, radiograph

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Website: www.jfds.org	Quick Response Code 
DOI: 10.4103/0975-1475.172438	

Introduction

Forensic identification is a multidisciplinary team effort relying on positive identification methodologies as well as presumptive or exclusionary methodologies.^[1] Forensic dentistry (Odontology) is the dental specialty that relates and applies dental knowledge to legal problems, which is more usually concerned with identification of

a victim, or an assailant.^[2] Thus forensic dentistry relies on the indestructibility of the teeth, its uniqueness in each individual's age, sex and race. The new scientific advancements involving dental anthropology, photography, bite mark analysis, serology, microscopic analysis and soft-tissue investigations that have been designed to extract increasing amounts of identifiable information from oral structures mirror the fortunes of the individual concerned.^[3,4]

Human identifications is the forensic odontologist's primary duty, which involves law enforcement agencies charged with responsibility of evidence from cases of violent crime, child abuse, missing individuals and mass disasters scenario's.^[5] In each discipline, there is need to develop scientific evidence relative to the questions of facts regarding identification on general rules of acceptance, reliability and relevance. Most techniques applied are used by all or most of the disciplines, may be for different purposes.^[6] Basically there are four methods used for age estimation, which are visual, radiographic, histological and chemical method.^[7-9] Further, radiographic two-dimensional images can be maintained for a longer period of time and they can be refined by digitization.

Age is progressive inevitable change among living beings and estimation of this is required for the identification, which in turn is necessary for legal forensic purposes.^[10,11] Due to their individuality and specificity, dentition and finger prints are two of the most scientifically reliable methods of identification. In cases where finger prints are not available, such as after burn or destruction or decomposition of remains, the comparison of post-mortem dentition to ante-mortem dental records can be used for identification.^[12,13] The dentin, cementum and dental pulp show age related physiologic and pathologic changes.^[14,15] One such change is the deposition of secondary dentin throughout the life,^[16] which results in reduction of length and width of the root canal.^[17] The age estimation of dental pulp is usually done using radiographic method and digital method.^[18,19]

The aim of the present study was to establish morphometric measurements of permanent maxillary central incisors in Udaipur population at different age groups by indirect digitization of intra-oral periapical radiograph method. The objectives were to determine the pulp size of left and right maxillary central incisors, to compare the pulp size of both the incisors and to correlate the pulp size with age as well as gender distribution.

Materials and Methods

The present study was conducted in Department of Oral Medicine and Radiology of Darshan Dental College and Hospital, Loyara, Udaipur for a duration of 5 months from

February to July 2008. Informed consent was obtained from the subjects prior to the study and ethical clearance was obtained from the Institute's ethical committee.

The patients were selected based on inclusion criteria (Maxillary central incisors should be free of caries, restorations, pulpal diseases, prosthesis, traumatic occlusion, fractured tooth or orthodontic treatment, have no diseases that could cause root canal calcification [e.g., atherosclerosis arthritis, gout, hypertension, kidney and gallbladder disease] and absence of advanced periodontal disease.) from those attending the out-patient of the department. Sample size was deduced from secondary data. The study group consisted of 320 patients in the age group of 9-68 years.

The clinical examination was carried out and relevant data were recorded in the preformed, pretested performa which recorded the demographic variables and the inclusion criteria. Intra-oral periapical radiography of maxillary central incisors was done using paralleling technique. The patients were explained briefly about the procedure and were made to wear lead apron. Standardized method was used for the radiography using films (IOPA Films No. 2 (31 mm × 41 mm) E-Speed Film, Eastman Kodak Company, New York, USA) and X-ray machine (Ori × 70 – X-ray machine with specifications of 70 KVP, 8 mA, 0.4 s) provided with a chair, which could be elevated or brought down to adjust the vertical height. All the films were processed manually in a well-equipped, light proof dark room.^[20]

Morphometric analysis

The radiographs taken were scanned using Epson scanner V 700-Digital image correction and enhancement technology dual lens system with 400 dpi. The scanned images were transferred to Photoshop CS, to standardize the actual size of radiographic image to joint photographic group exports. The measurements of pulp size of right and left central incisors were marked out on each radiographic image by using AutoCad software 2009 (Autodesk, Inc, drawing linear and curvilinear between multiple points minimum of 10-30. First the outline of pulp canals were made, then a linear line was drawn between the apical ends to coronal end of the pulp to get the long axis of the pulp canal. Further, the long axis of the pulp was divided into three equal parts i.e. apical, middle and coronal regions. The areas of three parts as well as total area of the pulp were measured individually. Similarly, pulp areas of all the 308 radiographic images were measured [Figure 1].

The data was compiled and tabulated in SPSS software- version 17 (SPSS Inc, Chicago). *Post-hoc* tests (for Multiple Comparisons), ratio of variance (*F*-test), Pearson Correlation and independent *t*-test were used for analysis of data.

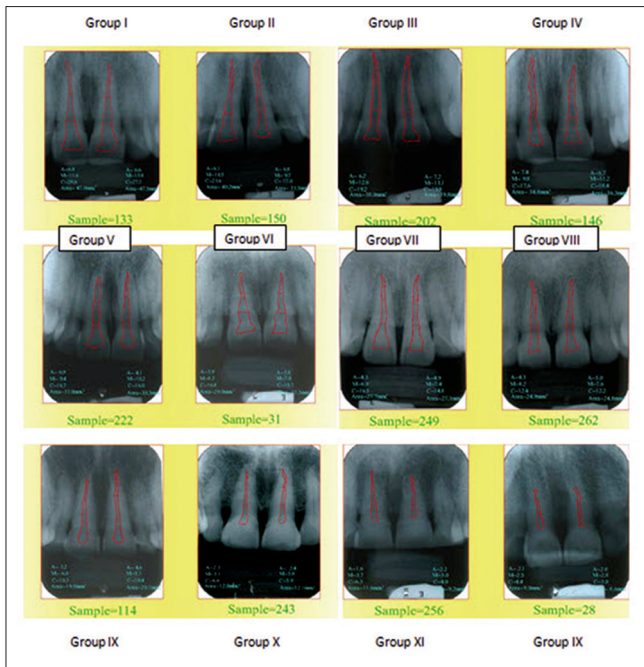


Figure 1: Morphology of pulp area in different groups

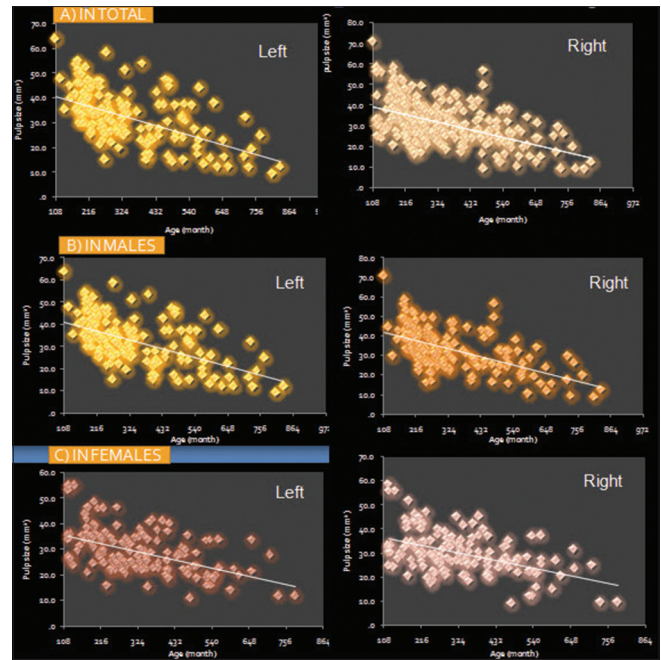


Figure 2: Relationship between age and pulp size of left and right central incisor

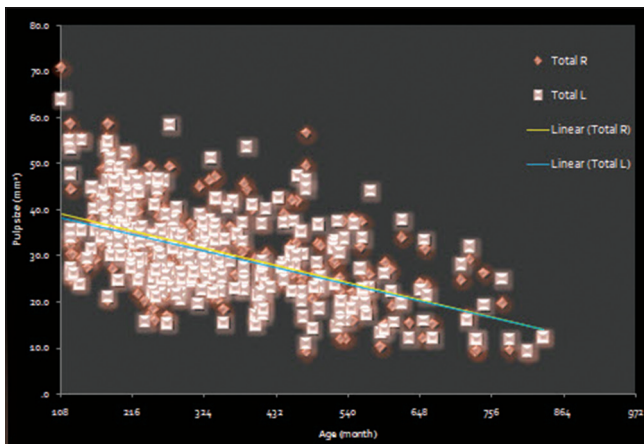


Figure 3: Relationship between right and left central incisors

Observation

The study group consisted of 320 subjects of whom 12 were excluded due to interference in image because of localized pulp calcification, impacted canines, odontomas, mesiodense and dilacerated roots. Finally the study comprised of 308 subjects of whom 162 were males and 146 females. The subjects are divided into twelve age groups i.e. I to XII of 5 years of difference, they are group I (9-13 years), group II (14-18 years), group III (19-23 years), group IV (24-28 years), group V (29-33 years), group VI (34-38 years), group VII (39-43 years), group VIII (44-48 years), group IX (49-53 years), group X (54-58 years), group XI (59-63 years) and group XII (above 64 years) respectively. This was done for the convenience of data analysis and also to know any slight variations in

measurements in different age groups, as the age range was vast with unequal representations in each group. Mean pulp area of present study for maxillary central incisor on left side was 30.75 mm² and on right side 31.537 mm². Table 1 shows the mean pulp size of maxillary central incisor according to different age groups and was found to be significant when compared. The maximum and minimum mean area with standard deviation with in age groups in the left Central Incisor, for apical pulp is 7.16 ± 3.4 mm and 2.42 ± 0.9 mm, for middle pulp 12.04 ± 4.48 mm and 4.25 ± 2.35 mm, for coronal pulp 19.20 ± 4.98 mm and 7.65 ± 3.89 mm and for total pulp area it is of 38.41 ± 12.88 mm and 14.32 ± 7.04 mm respectively. Whereas, in the right central incisor, the maximum and minimum mean area within age groups, for apical pulp is 6.75 ± 3.09 mm and 2.67 ± 0.48 mm, for middle pulp 11.66 ± 5.08 mm and 3.70 ± 1.08 mm, for coronal pulp 19.97 ± 6.79 mm and 5.97 ± 3.55 mm and for total pulp 38.39 ± 14.95 mm² and 12.35 ± 5 mm² respectively. With the increasing age, there is decrease in apical, middle, coronal and total pulp area of both left and right maxillary central incisors between the different 12 age groups which was statistically significant (*P* < 0.001) as shown in Figure 2.

The mean pulp area was more in males (32.5 [L], 32.87 [R]) when compared with females as shown in Table 2 which was a significant in both right and left side mean pulp size. With the increasing age there is decrease in apical, middle, coronal and total pulp area of both left and right maxillary central incisors in both males and females among the different 12 age groups which was statistically highly significant (*P* < 0.001). The mean pulp size on the right side (31.537 ± 10.173) is more than that of the left side (30.757 ± 9.685) and was found to be

significant when compared ($t = -2.549, P = 0.011$, nosocomial sepsis [NS]) [Figure 3]. In males the mean pulp size of right (32.87 ± 10.534) and left central incisor (32.5 ± 10.356) when compared did not show any significant difference ($t = -0.908, P = 0.365$, NS). In females the mean pulp size of right central incisor (30.057 ± 9.577) was more when compare to left central incisor (28.823 ± 8.507) and was statistically significant ($t = -2.690, P = 0.008$, S). Age groups I and II had significant difference in mean pulp sizes when compared with all other age groups on the left as well as right side as shown in Table 3. But this significance was not obtained in the age groups from 44 to 64 years (group VIII-XII). The Pearson's correlation also confirmed the significant relation between age, gender and mean pulp size on both left and right side [Table 4]. Pearson correlation 'r' for males was -0.588 which was significant for apical, middle, coronal and total area with 'P' value of 0.01. Moreover same was seen with females ($r = -0.452$). The right ($r = -0.522$) and left ($r = -0.528$) central incisors mean pulp size when correlated showed a significant relation. As age increases, mean difference of pulp area at different age groups is significant at 0.05 and 0.01 level [Figure 2].

Discussion

The need to estimate the age of living or dead individuals is becoming increasingly important in forensic sciences especially for human beings. Hence a cross-sectional study was conducted to know the age and gender differences in the mean pulp size of central incisors in Udaipur, Rajasthan. Comparisons with other studies could not be carried out due to the difference in the teeth taken for the study and the varying age groups in different studies. However, a sincere attempt has been made to compare the findings.

For the total mean pulp area, significant differences were found among all the age groups except groups between II, VI, V, VI, VII and X ($P < 0.0001$), the Pearson's correlation was significant ($r = 0.85$). There was only < -0.78 of difference in mean total area of left and right maxillary central incisor with highly significant difference ($P < 0.011$). The present study values of pulp area could not be correlated to the previous studies. Kumar and Lele 2004^[7] and Prapanpoch et al. 1992^[19] These studies have used the coronal pulp area of maxillary and mandibular 2nd premolars, 1st molar of both upper and lower arches, with digital method by employing multiple points and obtaining a linear and curvilinear measurements in three age groups of 15 years difference.

With increasing age there was decrease in apical, middle, coronal and so with total pulp area of both left and right maxillary central incisors of all the 12 age groups, which was statistically highly significant $P < 0.001$. The pulp size is correlated with the age with value $r = 0.85$ which is higher when compared with value $r = 0.2$ of Cameriere et al. 2004,^[12] 2007^[21] this difference could be because of the different teeth (right maxillary canine) recorded. Paewinsky et al. 2005^[22] showed that the width ratios of pulp cavity had a significant correlation to the chronological age and coefficient of determination (r^2) was highest in the upper lateral incisors $r^2 = 0.913$. Although above studies were based upon radiographic images, but their measurements were of linear manual method.

As the age advanced there was reduction in the apical pulp area especially among elderly individuals (group IX to XII). Among the younger individuals though there was a reduction in the apical pulp area, but the mean pulp size remained uniform in middle and coronal part. The apical

Table 1: Distribution and comparison of mean apical, middle, coronal and total area of pulp of left and right maxillary central incisor

Age groups	Mean ± SD							
	Left central incisor				Right central incisor			
	Mean apical pulp area	Mean middle pulp area	Mean coronal pulp area	Mean total pulp area	Mean apical pulp area	Mean middle pulp area	Mean coronal pulp area	Mean total pulp area
I	7.17 ± 3.41	12.05 ± 4.48	19.20 ± 5.98	38.41 ± 12.88	6.75 ± 3.10	11.68 ± 5.08	19.97 ± 6.80	38.39 ± 14.59
II	5.97 ± 1.29	11.08 ± 2.19	20.82 ± 4.67	37.87 ± 6.93	6.19 ± 1.46	11.31 ± 2.41	21.69 ± 4.86	39.19 ± 7.58
III	4.88 ± 1.83	8.62 ± 2.37	17.81 ± 4.89	31.47 ± 8.54	5.02 ± 1.66	8.70 ± 2.60	17.57 ± 5.09	31.26 ± 8.56
IV	4.79 ± 1.60	8.14 ± 2.16	17.06 ± 3.53	30.00 ± 6.27	6.18 ± 6.68	8.34 ± 1.84	17.45 ± 3.98	31.97 ± 8.29
V	4.96 ± 1.49	8.71 ± 2.38	16.20 ± 5.68	30.21 ± 8.30	5.13 ± 1.59	8.78 ± 2.22	17.63 ± 5.06	31.54 ± 8.03
VI	4.78 ± 1.44	7.72 ± 2.20	14.00 ± 5.37	26.50 ± 7.74	4.83 ± 1.43	7.58 ± 2.13	14.82 ± 3.87	27.22 ± 6.54
VII	5.22 ± 2.91	7.86 ± 2.77	14.31 ± 5.32	27.39 ± 10.21	4.66 ± 1.73	8.47 ± 3.44	16.22 ± 5.90	29.35 ± 10.62
VIII	4.62 ± 2.44	6.84 ± 2.22	13.84 ± 4.38	25.30 ± 8.26	4.27 ± 1.26	6.90 ± 2.41	13.50 ± 4.27	24.68 ± 7.44
IX	3.63 ± 0.96	6.20 ± 2.37	10.03 ± 5.62	19.85 ± 8.62	4.05 ± 0.99	6.28 ± 2.43	10.58 ± 4.88	20.90 ± 7.99
X	4.76 ± 2.53	6.44 ± 2.22	9.62 ± 3.64	20.82 ± 8.12	4.00 ± 1.01	6.26 ± 1.99	10.72 ± 5.10	20.98 ± 7.72
XI	3.40 ± 1.50	5.55 ± 2.14	10.63 ± 5.55	19.58 ± 8.44	3.23 ± 0.87	5.68 ± 2.41	10.22 ± 5.71	19.13 ± 8.71
XII	2.43 ± 0.9	4.25 ± 2.35	7.65 ± 3.89	14.33 ± 7.04	2.68 ± 0.49	3.70 ± 1.09	5.98 ± 3.56	12.35 ± 5.01
Total	5.12 ± 2.01	8.77 ± 2.95	16.80 ± 5.69	30.76 ± 9.69	5.32 ± 3.01	8.89 ± 3.09	17.33 ± 5.82	31.54 ± 10.17
ANOVA	F=2.498 P=0.005, S	F=12.312 P=0.000, S	F=12.530 P=0.000, S	F=12.622 P=0.000, S	F=4.952 P=0.000, S	F=13.525 P=0.000, S	F=11.442 P=0.000, S	F=12.178 P=0.000, S

SD: Standard deviation, S: Significant, F: Ratio of variance, ANOVA: Analysis of variance

Table 2: Gender wise distribution and comparison of mean total area of pulp

Age group	Males				Females			
	Left CI (mean±SD)	Areas (L)	Right CI (mean±SD)	Areas (R)	Left CI (mean±SD)	Areas (L)	Right CI (mean±SD)	Areas (R)
I	48.80±14.20	Apical: 5.43±2.12	47.97±20.94	Apical: 5.44±1.84	35.82±11.74	Apical: 4.78±1.84	36.00±12.65	Apical: 5.18±3.93
II	38.93±6.72	Middle: 9.31±2.99	40.83±6.84	Middle: 9.36±3.24	35.74±7.02	Middle: 8.18±2.80	35.92±8.08	Middle: 8.36±2.83
III	33.60±9.21	Coronal: 17.71±6.24	32.48±8.94	Coronal: 18.06±6.19	29.14±7.19	Coronal: 15.80±4.82	29.92±8.06	Coronal: 16.53±5.29
IV	31.60±6.71		31.04±5.83		27.96±5.13		33.15±10.69	
V	34.30±9.27		34.54±8.12		28.16±7.18		30.03±7.77	
VI	24.69±8.07		27.41±7.22		28.17±7.33		27.05±6.15	
VII	32.01±12.07		33.91±13.09		23.53±6.18		25.55±6.38	
VIII	28.03±8.91		25.98±6.59		22.57±6.86		23.38±8.29	
IX	20.74±10.89		21.14±9.69		18.37±4.22		20.50±5.91	
X	16.60±5.21		16.77±6.12		27.15±8.70		27.30±5.52	
XI	19.53±8.66		20.25±9.05		17.00±9.35		14.33±8.89	
XII	15.23±8.33		13.40±5.57		16.50±8.35		15.23±8.33	
Total	32.50±10.36	32.5±10.36	32.87±10.53	32.87±10.53	28.82±8.51	28.82-8.51	30.06±9.58	30.06±9.58
Male versus female	Apical (L): P=0.004**, S Middle (L): P=0.001**, S Coronal (L): P=0.003**, S Total (L): P=0.001**, S				Apical (R): P=0.448 (NS) Middle (R): P=0.004**, S Coronal (R): P=0.020*, S Total (R): P=0.015*, S			

CI: Confidence interval, SD: Standard deviation, S: Significant. ***Significant at 0.05 and 0.01 level

Table 3: Differences between the age groups

		Left			Right						
I age	J age	Difference	P	Significant	I age	J age	Difference	P	Significant		
I	II	0.548	0.82		I	II	-0.799	0.74			
	III	6.942	0	**		III	7.130	0	**		
	IV	8.418	0	**		IV	6.421	0.01	*		
	V	8.206	0	**		V	6.856	0.01	*		
	VI	11.913	0	**		VI	11.169	0	**		
	VII	11.027	0	**		VII	9.043	0	**		
	VIII	13.117	0	**		VIII	13.718	0	**		
	IX	18.563	0	**		IX	17.493	0	**		
	X	17.593	0	**		X	17.413	0	**		
	XI	18.830	0	**		XI	19.260	0	**		
	XII	24.088	0	**		XII	26.043	0	**		
	II	III	6.394	0		**	II	III	7.929	0	**
IV		7.870	0	**	IV	7.220		0	**		
V		7.658	0	**	V	7.655		0	**		
VI		11.365	0	**	VI	11.968		0	**		
VII		10.479	0	**	VII	9.842		0	**		
VIII		12.569	0	**	VIII	14.517		0	**		
IX		18.015	0	**	IX	18.292		0	**		
X		17.045	0	**	X	18.212		0	**		
XI		18.282	0	**	XI	20.059		0	**		
XII		23.540	0	**	XII	26.842		0	**		
III		IV	1.476	0.36		III		IV	-0.709	0.68	
		V	1.264	0.5				V	-0.274	0.89	
	VI	4.971	0.01	*	VI		4.039	0.05	*		
	VII	4.085	0.05	*	VII		1.913	0.37			
	VIII	6.176	0	**	VIII		6.588	0	**		
	IX	11.621	0	**	IX		10.363	0	**		
	X	10.651	0.01	**	X		10.283	0.01	**		
	XI	11.888	0	**	XI		12.130	0	**		

Contd...

Table 3: Contd...

		Left			Right				
I age	J age	Difference	P	Significant	I age	J age	Difference	P	Significant
V	VI	3.495	0.09		V	VI	4.748	0.03	*
	VII	2.609	0.23			VII	2.622	0.24	
	VIII	4.700	0.03	*		VIII	7.297	0	**
	IX	10.145	0	**		IX	11.072	0	**
	X	9.175	0.02	*		X	10.992	0.01	**
	XI	10.412	0	**		XI	12.839	0	**
	XII	15.670	0	**		XII	19.622	0	**
	VI	3.707	0.1			VI	4.313	0.07	
	VII	2.821	0.23			VII	2.187	0.37	
	VIII	4.912	0.03	*		VIII	6.862	0.01	**
	IX	10.357	0	**		IX	10.637	0	**
	VI	X	9.387	0.02		*	X	10.557	0.01
XI		10.624	0	**	XI	12.404			
XII		15.882	0	**	XII	19.187	0	**	
VII		-0.886	0.71		VI	VII	-2.126	0.4	
VIII		1.204	0.61		VIII	VIII	2.549	0.3	
IX		6.650	0.05	*	IX	IX	6.324	0.07	
VII	X	5.68	0.16		X	X	6.244	0.14	
	XI	6.917	0.06		XI	XI	8.091	0.04	*
	VII	12.175	0.01	**	VII	VII	14.874	0	**
	VIII	2.091	0.39		VIII	VIII	4.675	0.07	
	IX	7.536	0.03	*	IX	IX	8.450	0.02	*
	X	6.566	0.11		X	X	8.370	0.05	*
VIII	XI	7.803	0.04	*	XI	XI	10.217	0.01	**
	XII	13.061	0	**	XII	XII	17.000	0	**
	IX	5.446	0.1		VIII	IX	3.775	0.28	
	X	4.476	0.27		X	X	3.695	0.38	
	XI	5.713	0.13		XI	XI	5.542	0.16	
	XII	10.971	0.01	*	XII	XII	12.325	0.01	**
IX	X	-0.97	0.84		IX	X	-8.00E-02	0.99	
	XI	0.267	0.95		XI	XI	1.767	0.7	
	VII	5.525	0.27		VII	VII	8.55	0.1	
X	XI	1.237	0.8		X	XI	1.847	0.72	
	XII	6.495	0.24		XII	XII	8.63	0.13	
XI	XII	5.258	0.32		XI	XII	6.783	0.22	

***The mean difference is significant at the 0.05 and 0.01 level. I age: Age group, J age: Between age groups

Table 4: Pearson's correlation between age, gender and pulp size

AGEM	Pearson's correlation	Left (L)				Right (R)			
		Apical	Middle	Coronal	Total	Apical	Middle	Coronal	Total
Male	r value	-0.329**	-0.559**	-0.560**	-0.565**	-0.437**	-0.532**	-0.588**	-0.585**
	P value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	n	162	162	162	162	162	162	162	162
Female	r value	-0.272**	-0.482**	-0.503**	-0.506**	-0.162*	-0.458**	-0.452**	-0.451**
	P value	0.001	0.000	0.000	0.000	0.050	0.000	0.000	0.000
	n	146	146	146	146	146	146	146	146
Total	r value	-0.299**	-0.513**	-0.527**	-0.528**	-0.241**	-0.492**	-0.526**	-0.522**
	P value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	n	308	308	308	308	308	308	308	308

**Correlation is significant at the 0.01 level (2-tailed). AGEM: Age in months, R: Correlation, P: Probability, N: Subjects

area showed more changes when compared with middle or pulpal floor may be due to the cemental and dentinal changes. Thus our findings strengthen the fact that as age advances there is decrease in pulp area and this could be attributed to the secondary dentin deposition.

Conclusion

There is definite overall progressive shrinkage in the morphology of pulp image and decrease in pulp area with increasing age in the present study. There is decrease in apical, middle, coronal and also the total pulp area, with increasing age which can be attributed to secondary dentin formation. Apical areas showed a significant change after apexification of tooth. The pulp areas were larger in males than females.

Thus, measurement of areas of the dental pulp is a promising method for estimation of age. This could throw light on forensic applications and medico-legal issues regarding age estimation. In the future, more studies with larger sample size among different ethnic populations, using image analysis programs which can recognize pulp out lines in a radiographic images (which will be very useful in minimizing manual measurement of morphological parameters and will probably reduce both inter-and intra-observer variability) will help in finding exact differences in actual and pulp age estimation should be carried out.

Acknowledgment

My sincere thanks to the study subjects for their co-operation in the study. I would like to thank my colleagues and staff for their continuous support during the study.

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How to cite this article: Ravindra SV, Mamatha GP, Sunita JD, Balappanavar AY, Sardana V. Morphometric analysis of pulp size in maxillary permanent central incisors correlated with age: An indirect digital study. J Forensic Dent Sci 2015;7:208-14.

Source of Support: Nil, **Conflict of Interest:** None declared