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The coronal pulp cavity index: A forensic tool for age determination in adults

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ABSTRACT

Background: Various biochemical and histological methods are available for human age determination which are invasive and may require extraction of teeth. The present study aims to assess the accuracy of age estimation from tooth-coronal index (TCI) of known age and sex individuals and to present a noninvasive method for age estimation.

Materials and Methods: This retrospective study comprised 88 patients, which included 54 males and 34 females. An orthopantomogram of these individuals were taken, and premolars and molars in the same were evaluated. The height of the crown (coronal height [CH]) and the height of the coronal pulp cavity (coronal pulp cavity height [CPCH]) was digitally measured on the computer screen. The TCI given by Ikeda *et al.* in 1985 (TCI = [CPCH × 100]/CH.) was computed on each tooth and regressed on real age of the sample. The mean, median, range, and standard deviation of the computed index were calculated. The correlation between the actual age and the estimated age was calculated using *t*-test. $P < 0.05$ was considered significant.

Results: Results revealed that there is a significant correlation between the TCI with age. Increase in TCI observed with age; however, it showed no significant sex difference.

Conclusion: TCI is a precise, noninvasive and easily used reliable biomarker for age estimation and is applicable to both living and dead individuals.

Key Words: Age, estimation, forensic science, noninvasive

INTRODUCTION

Age estimation is an important part of one's identification process in the discipline of forensic science. Declaration of age is not only important for legal, ethical issues, and death reports but also an essential for living persons to clarify criminal and civil liability and social issues.[1] Human teeth proved to be the most reliable biological marker in forensic science as they withstand death and sustain themselves for many thousands of years without changes.[2,3]

Various morphological, biochemical, and histological methods are available for human age determination with the help of teeth.[4-6] These methods are invasive and require extraction of the teeth. With the advancement of radiology in forensic science, radiographic images can be utilized for age estimation *in vivo* and *in vitro*, with the advantage of being noninvasive.[7,8] Progressive modification of the coronal pulp cavity throughout the life occurs due to continuous deposition

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of the secondary dentin by odontoblasts. The secondary dentin formation is diverse for different teeth, for example, in molars the greatest dentin formation occurs on the floor of the pulp chamber and lesser amounts are deposited on the occlusal and lateral walls.[9]

The outermost covering of the tooth crown, enamel and the outermost covering of the surface of the root, cementum followed by dentin underneath, are hard tissues resistant to decomposition. The innermost soft core of pulp is protected by these structures.[9,10] Radiographic examination of the teeth gives affirmative information regarding the size of pulp chamber which can be correlated with the chronological age.[7] Kvaal *et al*. used deposition of secondary dentin by measuring pulp radiolucency and correlated it to age.[11] On the basis of measurements on various radiographic and morphological parameters discussed in many studies, formulae on such basis were developed.[7,12] As the values may be different for individuals from different ethnical groups, the reproducibility of these parameters is uncertain.[13,14]

We decided to carry out a study to correlate the size of the pulp chamber in premolar and molar teeth with the chronological age of the patients. On the other hand, the tooth-coronal index (TCI) (TCI = Length of the coronal pulp cavity/Length of the crown × 100) was measured by Ikeda *et al*. and then was computed for each tooth and regressed on real age.[9] The present study aims to assess the accuracy of age estimation from TCI of mandibular second premolar and first molar of right quadrant using panoramic radiographs of known age and sex individuals and to develop regression equations that can be used in the Indian population.

Aims and objectives

The aim of this study is to evaluate the TCI on panoramic radiographs free of technical errors and correlate it with the chronologic age. The objective of this study is to present a method for assessing and evaluating the change in the pulp dimension at the level of cementoenamel junction and its correlation to different age groups and to assess the accuracy of digital panoramic radiographs as a simple, noninvasive tool for age estimation in adult.

MATERIALS AND METHODS

This retrospective study sample consisted of 88 patients, comprising 54 males, 34 females. Subjects aged between 20 and 40 years and belonged to the same geographical population, Navi Mumbai, Maharashtra, India. This was a retrospective study conducted after obtaining approval from the Institutional Ethics Committee. The principal investigator was blinded about the identity of the cases regarding age and sex. A panoramic radiograph of known sex and age were obtained and second premolar and first molar of the right mandibular quadrant were evaluated. This study included 176 intact teeth (88 premolars and 88 molars) from 88 Indian individuals (54 males and 34 females). Measurements on all orthopantomograms with a fully visible pulp cavity were taken. However, orthopantomograms with teeth that were fractured, restored, and teeth with gross evidence of hypercementosis or grossly decayed were excluded. The height of the crown (coronal height [CH]) and the height of the coronal pulp cavity (coronal pulp cavity height [CPCH]) was digitally measured Dicom software (Digital Imaging and communication in medicine) on the computer screen. With this measurement, the coronal tooth cavity index was calculated for each tooth with the help of following formula, as suggested by Ikeda *et al*.[9] TCI = (CPCH × 100)/CH [Figure 1].

To ensure the accuracy of the technique used for measuring TCI the detailed reference points used were cervical line that connect two landmarks to be measured, the mesial and distal cemento-enamel junction points, and divides the tooth into crown and root. Crown height is the maximum perpendicular distance from the cervical line to the tip of the highest cusp of teeth. While coronal pulp cavity height is the distance from the cervical line to the coronal tip of the pulp chamber. All these measurements were analyzed by two observers and the mean recorded to minimize intra- and inter-observer errors. The TCI was calculated using mean values and subjected to regression analysis.

Statistical analysis

The data collected was statistically analyzed using the SPSS (Statistical package for Social Sciences) After

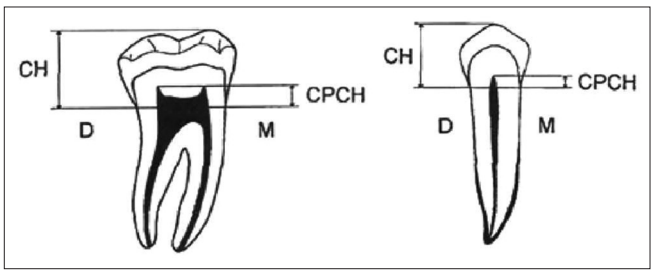


Figure 1: Schematic representation of measurements taken of panoramic radiographs.

the TCI was computed for each tooth, regression analysis on the real age of the sample was done. The mean, median, range and standard deviation of the computed index was calculated. The correlation between the actual age and the estimated age was calculated using the *t*-test.

RESULTS

The analysis of the studied number subjects is summarized in Table 1. Mean of the comparison of the age of both males and females using unpaired *t*-test with $t = 0.353$ and $P = 0.725$ is summarized in Table 1. The mean value of CH, CPCH, and TCI in premolars and molar for males and females were significant statistically as shown in Tables 2 and 3. The comparison of CH, CPCH, and TCI in different age groups in premolars and molars for males and females were highly significant statistically as shown in Tables 4 and 5. The correlation of TCI in the different age group of both sexes was highly significant for premolars and molars as shown in Tables 6 and 7 and Graph 1 and was concluded that TCI can be a good predictor of age in both premolars and molar.

Followed by the calculations, a simple linear regression was carried out with significant correlation by regressing the proportional coronal pulp cavity length (TCI) on the actual age for each group of teeth, for the combined sample.

DISCUSSION

In adults, age estimation would be challenging as the development of dentition completes by this age and there is no clue which could be reliable to assess the age.[15] The two criteria that can be utilized for age determination in adults are assessment of the volume of pulp cavity and of third molar development.[15] The length of the coronal pulp cavity shows a significant correlation with individual chronological age. The reduction in the size of the pulp cavity resulting from a deposition of secondary dentine with aging can be assessed by radiographs.[16] Assessment of the pulp/tooth index is an indirect quantification of secondary dentin deposition.[17] This study measures the morphometric values of pulp on digital panoramic radiographs for the mandibular second premolar and first molar of the right quadrant, thereby calculating the TCI for each tooth. The aim of this study is to evaluate the TCI on panoramic radiographs and correlate it with the chronologic age.

The panoramic radiograph has the advantage of displaying all the mandibular and maxillary teeth on a single film.[18] The computer-assisted image analysis avoids the bias inherent in observer subjectivity, which

Table 1: Comparison of age (mean±standard deviation) of males and females using unpaired *t*-test

Gender	Number of samples	Mean±SD
Males	54	29.59±5.8
Females	34	29.12±6.6
t	-	0.353
P	-	0.725

SD: Standard deviation

Table 2: Comparison of coronal pulp cavity height, coronal height and tooth-coronal index (mean±standard deviation) in male and female subjects using unpaired test (45-2nd premolar)

Gender	Number of samples	Mean±SD		
		CPCH	CH	TCI
Males	54	1.95±0.4	7.27±0.7	27.18±5.4**
Females	34	1.91±0.4	7.06±0.8	27.11±6.2
T	-	0.592**	1.295	0.062
P	-	0.555*	0.199*	0.951*

**P*>0.05 - Non significant, ***P*<0.05 - Significant. SD: Standard deviation; CPCH: Coronal pulp cavity height (mm); CH: Coronal height; TCI: Tooth-coronal index

Table 3: Comparison of coronal pulp cavity height, coronal height, and tooth-coronal index (mean±standard deviation) in male and female subjects using unpaired test (46-1st molar)

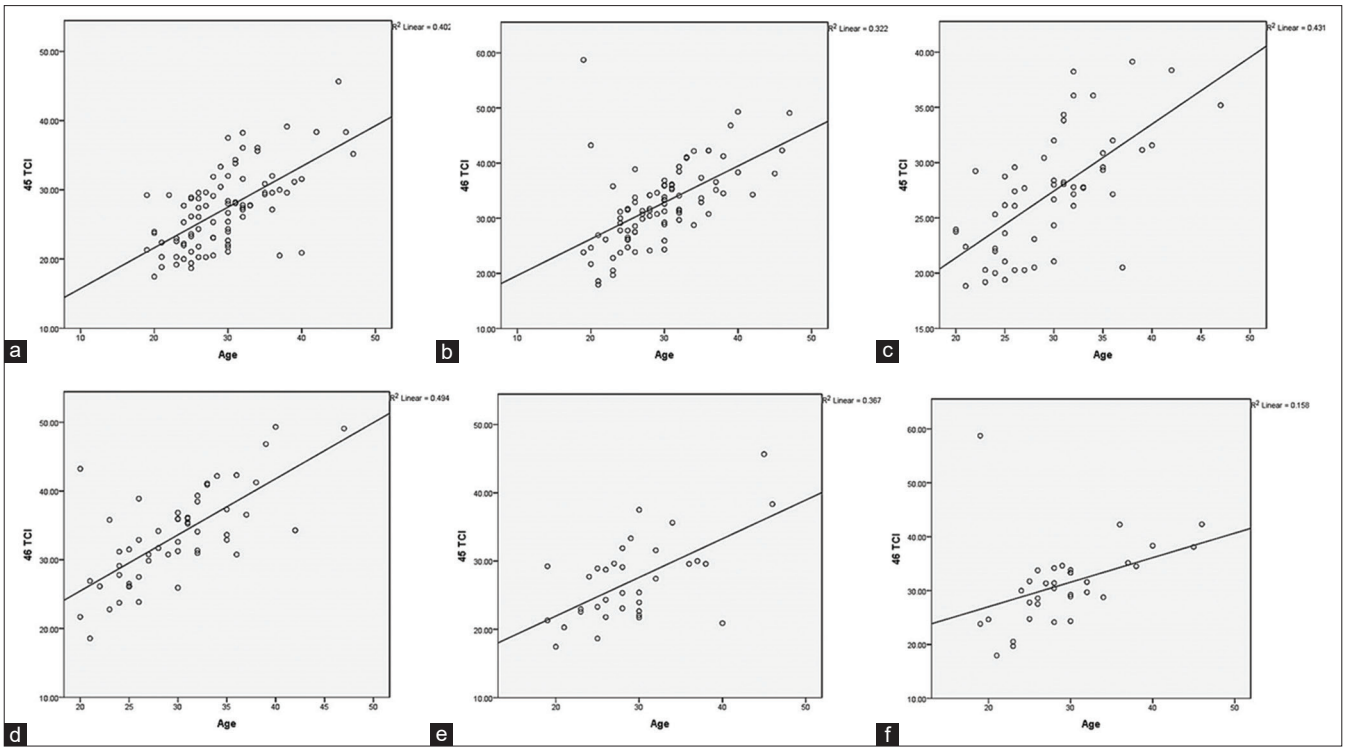
Gender	Number of samples	Mean±SD		
		CPCH	CH	TCI
Males	54	2.58±0.5	7.82±1.0	33.29±6.8
Females	34	2.32±0.5	7.53±0.9	31.14±7.6
t	-	2.275	1.230	1.383
P	-	0.025**	0.222*	0.170*

**P*>0.05 - Non significant, ***P*<0.05 - Significant. SD: Standard deviation; CPCH: Coronal pulp cavity height (mm); CH: Coronal height; TCI: Tooth-coronal index

Table 4: Comparison of coronal pulp cavity height, coronal height, and tooth-coronal index (mean±standard deviation) in different age groups using unpaired test (45-2nd premolar)

Age groups	Number of samples	Mean±SD		
		CPCH	CH	TCI
≤30 years	56	1.81±0.4	7.32±0.7	24.72±4.3
>30 years	32	2.15±0.3	6.95±0.8	31.39±5.3
t	-	4.366	2.218	6.435
P	-	<0.001**	0.029*	<0.001**

**P*<0.05 - Significant, ***P*<0.001 - Highly significant. SD: Standard deviation; CPCH: Coronal pulp cavity height (mm); CH: Coronal height; TCI: Tooth-coronal index



Graph 1: (a) Scattered plot showing regression line correlation between tooth coronal index and age in all the subjects (combined group) (45 – 2nd premolar). (b) Scattered plot showing regression line correlation between tooth coronal index and age in all the subjects (combined group) (46 – 1st molar). (c) Scattered plot showing regression line Correlation between tooth coronal index and age in all the subjects (males) (45 – 2nd premolar). (d) Scattered plot showing regression line Correlation between tooth coronal index and age in all the subjects (Males) (46 – 1st molar). (e) Scattered plot showing regression line Correlation between tooth coronal index and age in all the subjects (Males) (46 – 1st molar). (f) Scattered plot showing regression line Correlation between tooth coronal index and age in all the subjects (Females) (46 – 1st molar).

Table 5: Comparison of coronal pulp cavity height, coronal height, and tooth-coronal index (mean±standard deviation) in different age groups using unpaired test (46-1st molar)

Age groups	Number of samples	Mean±SD		
		CPCH	CH	TCI
≤30 years	56	2.33 (0.5)	7.88 (0.8)	25.65 (6.5)
>30 years	32	2.74 (0.5)	7.41 (1.3)	37.38 (5.3)
t	-	3.779	2.119	5.714
P	-	<0.001**	0.037*	<0.001**

**P*<0.05 - Significant, ***P*<0.001 - Highly significant. SD: Standard deviation; CPCH: Coronal pulp cavity height (mm); CH: Coronal height; TCI: Tooth-coronal index

Table 6: Correlation coefficient and *P* value in the total sample

Teeth (TCI)	Combined group	
	r (correlation coefficient)	*P*
45-2nd premolar	0.634	<0.001**
46-1st molar	0.568	<0.001**

***P*<0.001 - Highly significant. TCI: Tooth-coronal index

supplies a relatively exact method of measurements, improves reliability and consequently the statistical data analysis.[11] The present study is based on the nondestructive method suggested by Ikeda *et al.* found a high correlation that the extent of pulp cavity is visible in premolars and molars in panoramic radiographs as shown by Drusini and El Morsi.[14,15]

The present study reveals that age correlation and TCI in different age groups are sizeable in both premolars and molars. The study results are in agreement with the study results done by Drusini *et al.*,[19] Zadinska *et al.*,[20] Shrestha.,[6] Khattab *et al.*,[21] and Karkhanis *et al.*[22] that there is no sex difference in TCI. As stated by these studies, sex of individual appears to have no significant influence on age estimation, so that sex-specific formulae are not necessary for age estimation in specimens of unknown sex. This result is contradictory to that of Agematsu *et al.*[23] Igbigbi and Nyirenda[24] who mentioned that due to influence of estrogen on the formation of secondary dentin, gender has a significant influence on age estimation using TCI and hence there is need for sex- specific formulae in the sampled population.[11]

Table 7: Correlation coefficient and *P* value in males and females

Teeth (TCI)	Males	
	r (correlation coefficient)	*P*
45-2nd premolar	0.657	<0.001**
46-1st molar	0.703	<0.001**
Teeth (TCI)	**Females**	
	r (correlation coefficient)	*P*
45-2nd premolar	0.606	<0.001**
46-1st molar	0.397	0.020*

*P<0.05 - Significant, **P<0.001 - Highly significant. TCI: Tooth-coronal index

However, the results obtained prove that there is a positive correlation between TCI in the present work and age and the correlation is more in females than males, i.e., the index increases with increasing age. This is in favor of the study by Shrestha[6] in India which mentioned that TCI increases with increasing age. However, negative correlation between TCI and age was given by Drusini *et al*.[19] Zadinska *et al*.[20] Igbigbi and Nyirenda[24] and Karkhanis *et al*.[22] This could be explained by the relatively young age of the present work samples as the age ranged from 20 to 40 years with mean age of 25.51 ± 0.84 years; so the decrease in pulp cavity due to dentin deposition is not evident.

Moreover, the study shows that the mean TCI of premolars is larger than the molars and it is higher in males than in females, respectively. These findings are supportive to that of Igbigbi and Nyirenda[24] who mentioned that the TCI for molars were lower than those of premolars. This has been explained by the fact that the mandibular molars have morphological diversity than premolars. Hence, in different age groups, the difference in the decrease in pulp chamber value was not clear in molars than in premolars.

The present study devices a simple, practical, noninvasive, cost-effective method for the morphometric analysis of the coronal pulp chamber reduction using TCI on the digital panoramic radiographs. The results of the study should be viewed with caution as the study sample was small. Hence, there is a definite need for similar studies with large Indian population.

CONCLUSION

TCI is an excellent forensic tool for age estimation. The potential of TCI using digital panoramic radiography is useful as a biomarker of aging with increasing availability of digital radiographic systems in the dental institutes and offices. Thus from the present work, it could be concluded that TCI is a precise, noninvasive and not time-consuming; and does not require highly specialized equipment and is applicable to both living and dead individuals. Furthermore, the result concluded that gender has no effect on TCI.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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