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Tooth Coronal Pulp Index as A Tool for Age Estimation: An Institutional Based Retrospective Cone Beam Computed Tomography Study

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Abstract

Background: Age estimation in forensic odontology is a crucial step for biological identification and of a prime importance in various clinical destinity. Age estimation based on teeth is one reliable approach as teeth are the hardest part of the body and could be preserved for a long time without gross changes. Thus age estimation from tooth coronal index (TCI) using cone beam computed tomography is based on reduction in the size of the dental pulp cavity with advancing age as a result of deposition of secondary dentin. ***Aim:*** The aim of the study is to evaluate the reliability of dental age assessment through tooth coronal index (TCI) method. ***Methodology:*** A Retrospective study involving 120 CBCT images from the age of 20–60 years where retrieved from the department data base. The ages where further divided into eight groups (Group I–VIII). Mandibular 2nd premolar and 1st molar either of one side is considered. Then TCI was calculated for each tooth and regressed. Age estimated was compared with the chronological age to evaluate the reliability of age assessment through TCI. Statistical analysis was done using SPSS version 19. ***Results:*** TCI of 1st molars showed statistically highly significant values and thus regression analysis was done to obtain an equation. Thus, the best dental age estimation was obtained in age group of Group I, VIII with the mean error of ±2 years; whereas in the other age Groups II–VII with the mean error of ±4 years. ***Conclusion:*** As dental professionals, we can continue to play a key role by maintaining quality records. Teeth are more resistant to thermal, chemical and mechanical stimuli and thus considered as one of the reliable indicators. Thus this present study of TCI was carried out using CBCT which showed negative correlation with age; i.e. when age increases the TCI values decreases and this method can be considered as one of the reliable parameters in estimating the age of the individual because of its accuracy.

Keywords: Age estimation; Secondary dentin; Cone beam computed tomography; Mandibular 2nd premolar and 1st molar

Introduction

The term forensics means the "forum or a place where legal matters are discussed".[1] "Kieser-Nielsen"[2] defined Forensic odontology as the branch of dentistry deals with proper handling and estimation of dental evidence and proper evaluation and presentations of dental findings in the interest of dental science. The three paramount important steps in forensics are: age estimation, gender determination and personal identification. Age is one of the prerequisite factors, which plays a key vital principle in every aspect of life. Age estimation plays an essential role in the field of pediatric endocrinology, orthodontic treatment and diagnosis, in current issues such as child labor, child marriage, children trafficked for commercial and sexual exploitation, increase in number of persons without legal documentation of birth, committed

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crimes, in illegal immigration,[3] in identifications of victims of mass disaster, crashes, accidents. Thus age estimation in living and deceased individual is of paramount importance.[4] Age estimation could be estimated by various methods such as Dental age, Mental age and Skeletal age. Here, Dental age is considered to be the most superior because it is seldom affected by systemic, nutritional and endocrine status.[5] Most of the individuals would have been to dentist in their mean course of life and thus their antemortem data would be available which helps in victim identification more precisely. Teeth contain enamel outermost covering with Dentin underneath both of which are hardest tissue that are resistant to decomposition, followed by pulp which is the innermost soft tissue core.[6]

Dentin is of three types: Primary dentin, secondary dentin and Tertiary dentin. Secondary dentin forms once tooth is completely erupted and in function. This forms slowly throughout the lifespan and are deposited continuously by the odontoblasts lining the pulp chamber due to which there is a decrease in the size of the pulp cavity with increase in age clinically known as pulp recession. Thus the deposition of dentin could be best visualized in the radiographic methods. Bodecker 1925 identified the opposition of secondary dentin as being related to chronological age.[7] The size of the pulp decreases with age due to the deposition of the secondary dentin. In 1985, Ikeda et al. developed tooth coronal index (TCI) for age estimation by taking radiographs on extracted teeth. In 1993, Drusini[8] had studied age estimation by TCI by taking radiographs on living person. Where TCI is,

$$\text{Tooth coronal index (TCI)} = \frac{\text{Coronal pulp cavity height (CPCH)}}{\text{Crown height (CH)}} \times 100$$

Most of the studies done for estimation of age using two-dimensional radiographs such as periapical radiograph, Orthopantomograph. This present study focuses age estimation using CBCT, a three dimensional imaging modality that provides better image accuracy without any geometric distortion.

Aim and Objectives

To evaluate the reliability of dental age assessment through tooth coronal index (TCI) method.

- To estimate the dental age of the individuals using tooth coronal index (TCI).
- To compare the estimated dental age to the chronological age of the individual.
- To evaluate the reliability and accuracy of age assessment using tooth coronal index (TCI).

Materials and Methods

Total of 120 CBCT images which were collected from the department database from the age ranges from 20 to 60 years. The ages were further grouped into (Group I–VIII). Each group contains 15 CBCT images and mean interval between each group was 5 years. All the images were recorded in Planmeca Promax 3D Mid Pro Face machine and were processed using Planmeca Romexis software.

Inclusion Criteria

Good image and morphology of selected teeth with complete root formation (i.e. mandibular second premolar and mandibular first molar).

Exclusion Criteria

Carious/grossly decayed, Prosthesis/Restored selected teeth, Severely attrition/fractured/rotated/malaligned, Teeth with any developmental anomalies.

Step 1

- Horizontal line traced between cemento-enamel junction of tooth which is considered to be the division between anatomical crown and root.
- The traced horizontal line has been cross checked in coronal and axial view. In coronal view the mid-sagittal plane splits the tooth into two equal halves. In axial view the axial plane touches the outer tooth surface (Fig. 1).

Step 2

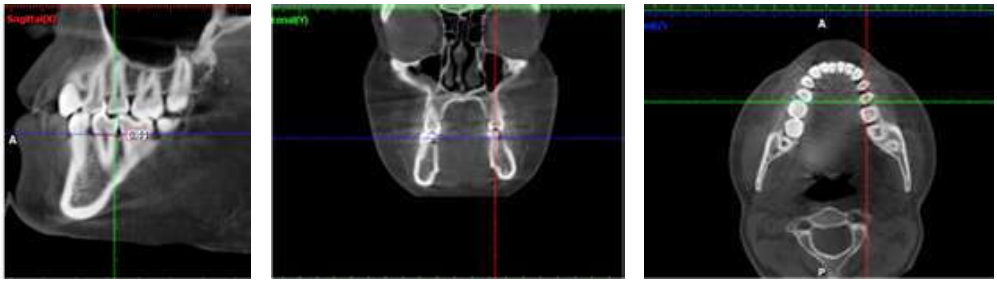
- Crown height (CH) measured vertically from Horizontal line to the highest cusp (Fig. 2a and 2b).

Step 3

- Coronal pulp cavity height (CPCH) measured vertically from horizontal line to the highest pulp horn (Fig. 3a and 3b).

Step 4

$$\text{Toot- crown index} = \frac{\text{Coronal pulp cavity height (CPCH)}}{\text{Coronal height (CH)}} \times 100$$



Sagittal view Coronal view Axial view

Fig. 1:

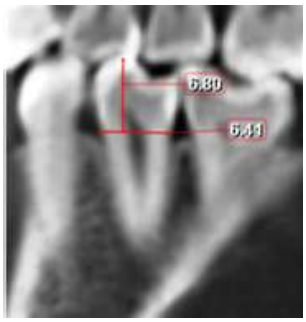


Fig. 2a: Measurement of mandibular 2nd premolar coronal height in Sagittal view.

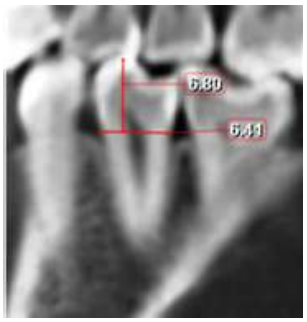


Fig. 2b: Measurement of mandibular 1st molar coronal height in sagittal view.

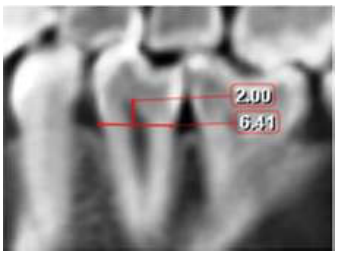


Fig. 3a: Measurement of mandibular 2nd premolar pulpal height in sagittal section.

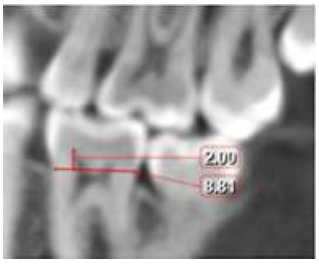
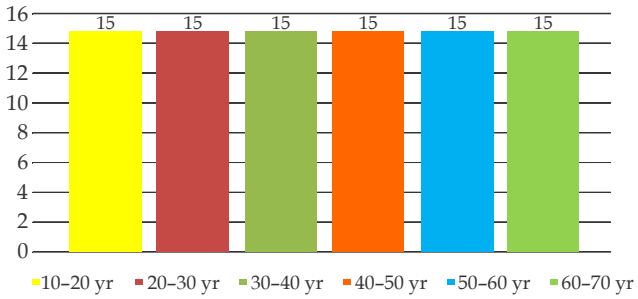


Fig. 3b: Measurement of mandibular 1st molar pulpal height in sagittal section

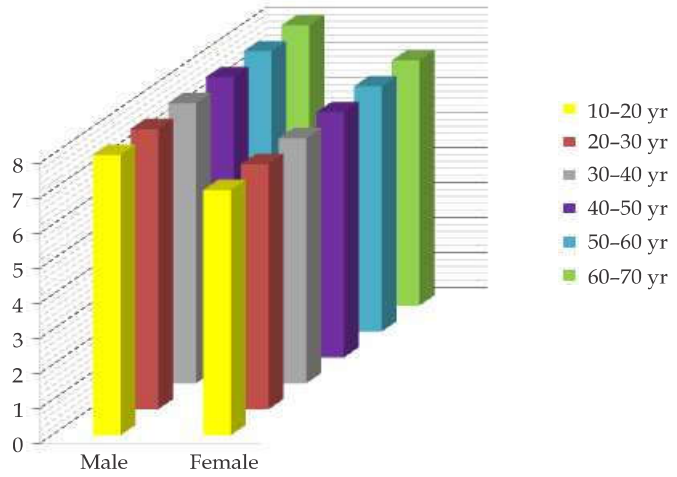
Results

The data was subjected for statistical analysis using statistical software SPSS version 19 (IBM. Corp. Chicago, USA). The data was tested for normality using Sharpiro Wilks test and was found to be parametric in distribution ($p > 0.05$). Mean, standard deviation was calculated for all quantitative data by using one way ANOVA, followed by Tukeys post hoc analysis for inter group multiple comparison. Independent student t-test was done to see the statistically significant difference between means of two intra group analyses. Pearson correlation coefficient is used to measure the association between TCI of premolar and TCI of molar followed by multivariate logistic analysis. Confidence intervals was set at 95% and p-value <0.05 was considered to be statistically significant.

- ***Graph 1 and Graph 2:*** Total of 120 samples divided as 60 males and 60 females from the age ranging from 20 to 60 years The ages were further divided into eight age groups (i.e. Group I–VIII) each constituting 15 samples was done
- ***Table 1 and Graph 3: Descriptive analysis of mean value and standard deviation of the study subjects:*** The mean of TCI of second premolar for males was calculated to be 26.91 ± 9.53, females 28.55 ± 8.76 and the mean of TCI of first molar for males was calculated to be 24.21 ± 10.28, females 23.46 ± 8.37.



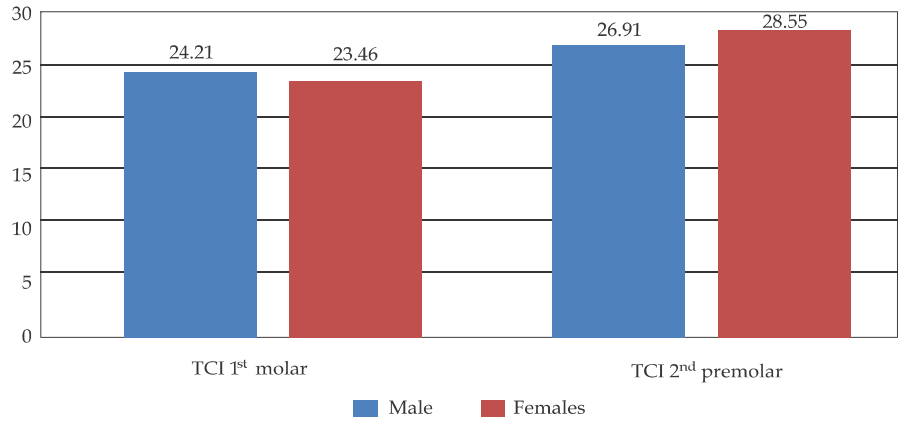
Graph 1: Frequency distribution of age groups.



Graph 2: Frequency distribution of age groups.

Table 1: Descriptive analysis of mean value and standard deviation of the study subjects

Subjects	Gender	*N* = 120	Mean ± SD
TCI 1st molar	Male	32	24.21 ± 10.28
	Female	28	23.46 ± 8.37
TCI 2nd premolar	Male	32	26.91 ± 9.53
	Female	28	28.55 ± 8.76



Graph 3: Mean distribution of TCI of 1st molar and 2nd premolar in males and females.

- ***Descriptive analysis of mean value and standard deviation for individual age groups using one way ANOVA (Table 2):*** In Group I (20–25 years) the mean of TCI of 2nd Premolar is 33.99 ± 2.17 and for 1st Molar is 36.95 ± 2.99. In Group II (26–30 years) the mean of TCI of

2nd Premolar is 31.35 ± 6.80 and for 1st Molar is 35.93 ± 3.37. In Group III (31–35 years) the mean of TCI of 2nd Premolar is 29.63 ± 3.79 and for 1st Molar is 32.27 ± 5.86. In Group IV (36–40 years) the mean of TCI of 2nd Premolar is 27.49 ± 3.80 and for 1st Molar is 29.91 ± 2.92. In Group V (41–45 years) the mean of TCI of 2nd Premolar is 23.81 ± 2.54 and for 1st Molar is 25.88 ± 3.22. In Group VI (46–50 years) the mean of TCI of 2nd Premolar is 25.6 ± 2.7 and for 1st Molar is 22.25 ± 3.07. In Group VII (51–55 years) the mean of TCI of 2nd Premolar is 22.89 ± 2.88 and for 1st Molar is 18.51 ± 5.87. In Group VIII (55–60 years) the mean of TCI of 2nd Premolar is 12.1 ± 3.07 and for 1st Molar is 13.52 ± 1.60.

Table 2: Descriptive analysis of mean value and standard deviation for individual age groups using one way ANOVA

Age group	*N*	Mean	Standard deviation	Standard error	95% confidence interval	
					Upper bound	Lower bound
TCI 2nd premolar						
20–25 years	15	33.9967	2.17786	0.88911	31.7111	36.2822
26–30 years	15	31.3557	6.80247	2.57109	22.0645	34.6469
31–35 years	15	29.6357	3.79724	1.43522	17.1239	24.1476
36–40 years	15	27.4933	3.80335	1.55271	15.5020	23.4847
41–45 years	15	23.8167	2.54545	1.03917	21.1454	26.4880
46–50 years	15	25.6867	2.73574	1.11686	22.8157	28.5576
51–55 years	15	22.8950	2.88613	0.36176	21.9651	23.8249
55–60 years	15	12.1650	3.07692	1.25615	8.9360	15.3940
TCI 1st molar						
20–25 years	15	36.9583	2.99918	1.22441	43.8109	50.1058
26–30 years	15	32.9329	3.37185	1.27444	32.8144	39.0513
31–35 years	15	32.2786	5.86970	2.21854	23.8500	34.7071
36–40 years	15	29.9167	2.92341	1.19348	26.8487	32.9846
41–45 years	15	25.8817	3.22381	1.31612	26.4985	33.2649
46–50 years	15	22.2950	3.07956	1.25723	29.0632	35.5268
51–55 years	15	18.5100	5.87790	2.39964	16.3415	28.6785
55–60 years	15	13.5233	1.60968	0.65715	14.8341	18.2126

- ***Comparison of TCI of 2nd Premolar and 1st Molar for age groups within the groups (Table 3):*** On comparison with all the age groups TCI of 2nd premolar showed statistically significant value, i.e. $p < 0.05$ and TCI of 1st molar showed statistically highly significant value, i.e. $p < 0.001$.
- ***Comparison of TCI of 2nd Premolar and 1st Molar for all age groups and among various groups were obtained.***

Table 3: Within group comparison for all the age groups were done for TCI of premolars and TCI of molars separately using ANOVA

Subjects	Groups	Sum of squares	df	Mean square	F	Sig.
TCI 999 2nd premolar	Between Groups	1781.975	7	254.568	18.394	.04
	Within Groups	581.280	42	13.840		
	Total	2363.255	49			
TCI 1st molar	Between Groups	3421.107	7	488.730	31.690	.000
	Within Groups	647.731	42	15.422		
	Total	4068.838	49			

p-value <0.05 *Statistically highly significant, *p*-value <0.001 ***Statistically very highly significant

- ***Correlations between different gender, Age, Groups, TCI of 2nd premolar and TCI of 1st molar done using Pearson's correlations (Table 4):*** TCI of 2nd premolars and TCI of 1st molars showed statistically highly significant values, i.e. $p < 0.001$. Thus either of the values could be used for nominal regression analysis.
- ***Multivariate regression analysis is done for TCI of 1st molar (Table 5):*** The correlation

Table 4: Pearson's correlation done between age groups, gender, TCI of 2nd premolar and 1st molar

Domains	Combined group		Gender			
			Male		Female	
	R-value	*p*-value	*R*-value	*p*-value	*R*-value	*p*-value
TCI molar	–0.040	0.662	0.042	<0.001***	0.413	<0.001***
TCI premolar	0.09	0.32	0.51	<0.001***	0.521	<0.001***

p-value <0.001*** Statistically very highly significant

were significant especially for Molars (r = –0.92). Thus the regression equation is formulated as follows:

Linear regression formula:

$$Y = a - b(X)$$

Y : Dependent variable

X : Independent variable

b : slope

a : intercept

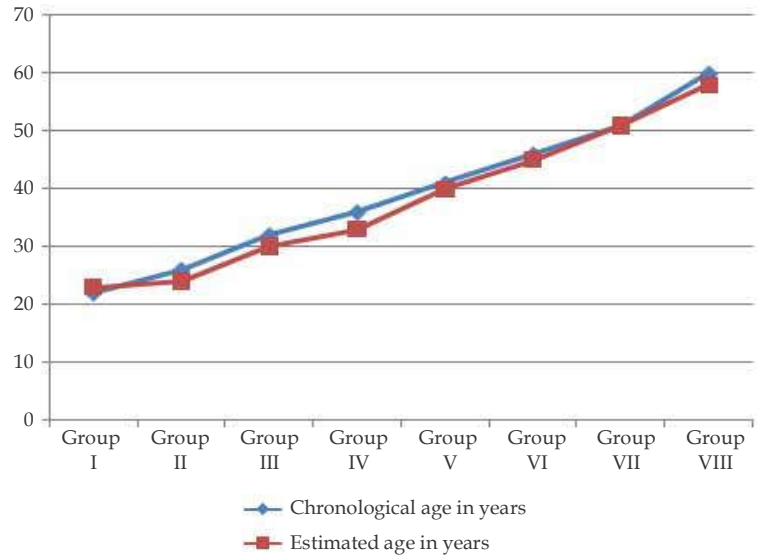
Thus, when correlating with the values of multivariate regression analysis

- *Age estimation on test random sample using the regression formula (Table 6 and Graph 4).*

Table 5: Multivariate logistic regression with respect to TCI of Ist molar

Group	Variables	*B*	*p*-value
Combined	Constant	13.99	0.001
	Intercept	2.741	0.04
Males	Constant	15.96	0.09
	Intercept	3.139	0.006
Females	Constant	18.36	0.001
	Intercept	2.506	0.02

- *Regression analysis for combined sample = 79.679–1.53 × (X) (where X is the value of TCI of 1st Molar).*
- Thus, the best estimation was obtained in age group of *Group I, VIII with the mean error of ± 2 years* whereas in the other Age *Groups II–VII with the mean error of ±4 years.*
- Clearly states that *no sex specific formula* is needed for the population and no statistical significant difference between the teeth of 1st molar right and left.



Graph 4: Line diagram depicting the comparison of chronological to estimated age.

Fig. 6: Age estimation on test random sample using the regression formula

Age groups	Chronological age in years	TCI 1st molar	Estimated age in years
Group I	22	36.9583	23
Group II	26	35.9329	24
Group III	32	32.2786	30
Group IV	36	29.9167	33
Group V	41	25.8817	40
Group VI	46	22.2950	45
Group VII	51	18.5100	51
Group VIII	60	13.5233	58

Discussion

Forensic odontology or forensic dentistry is the application of dental knowledge to those criminal and civil laws that are enforced by police agencies in the criminal justice system. Determination of age of individual in forensics is of prime importance for administrative, ethical, medico-legal issues.[9] Various studies have suggested that dental pulp size decreases with increasing in age due to deposition of secondary dentin.[10] Secondary dentin deposition is well appreciated on the floor of the pulpal chamber than on the roof suggesting that age has greater influence than does the attrition or irritation.[11,12] Several studies which were conducted for age estimation were done using Digital IOPA and Panaromic radiographs which is a 2D radiographic imaging. Hence information obtained from 2D radiograph remains inadequate in assessing fine details of the tooth structure. Thus lead to the introduction of 3D imaging technologies that is CBCT.[13] CBCT which has its greatest advantage due to its spatial resolution[14,15] which refer to the ability to identify even a minute points that are close to each other. Gustafson was the first to study on the secondary dentin deposition for age estimation using histological methods.[16] Later in 1925 Brodecker identified secondary dentin is being related to chronological age.[7]

The present study focus on estimating the age using tooth coronal pulp index in mandibular 2nd premolar and mandibular 1st molar using CBCT imaging. The main principle of the study is by analyzing the secondary dentin deposition at the pulpal floor which occurs as a normal physiological process as the age advances. Our study stated TCI decreases with increasing in age which was in accordance with the study done by Philipas and applebarnum[17] in 1996 proved that the deposition is more in the floor of pulpal chamber than on the occlusal and lateral walls[18] and also with Ikeda et al. in 1985 who studied the secondary dentin deposition by analyzing in the radiographs of premolars and molars. He measured the length of the coronal pulp cavity height and coronal height[7] and also stated that TCI decreased with increasing in age.

Our study resulted that Correlations of males is higher than females and also the age estimated was very much accurate with the mean error of ± 2 years in the age Group I (20–25 years) and VIII (55–60 years) and with the mean error of ± 4 years in the age Group II (26–30 years), Group III (31–35 years), Group IV (36–40 years), Group V (41–45 years), Group VI (46–50 years), Group VII (51–55 years) which was in accordance with the study done by Drusini et al. in 1991 and 1993[19,8] considered panaromic radiograph of age ranged from 9–76 years in Caucasian individuals. He considered mandibular premolars and molars for the study and found that coefficient of correlations of the molar group was much more significant than premolars. Thus, used TCI of molars for age estimation. The estimated age in a sample of 100 teeth of both sexes (not used for the regression) with an error of ±5 years in 81.4% of cases for the male molars.

The current study states that there is no sex difference in TCI and thus no sex specific formula is needed. This is in agreement with studies done in Egyptian population by El Morsi et al.[20] in 2015, Italian population by Drusini et al.[21] in 1997, Drusini[8] in 1993, Zadinska et al.[22] in 2000, in India by Shrestha[23] in 2014, in Egypt by Khattab et al.[24] in 2013. On the other hand the results of Agematsu et al.[25] in Japan 2010, Igbibi and Nyirenda[26] in Malawi 2005 were on contradiction with ours stating that gender has a significant influence on age estimation using TCI and hence there is need for sex–specific formulae in the sampled population. This difference is mainly due to the influence of estrogen receptor on the dentin which was reported by Hietala et al.[27] in 1998 and Silvana et al.[28] in 2003 and Yokose et al.[29] in 1998.

There was a negative correlation being observed, i.e. when TCI increases when age decreases which was in agreement with Dursini et al.[21] in 1997, Zadinska et al.[22] in 2000, Nyirenda et al.[26] in 2005. But few studies El Moris et al.[20] in 2015, Shretha et al.[23] in 2014 were in contradiction stating that there was a positive correlation between TCI and age, i.e. when TCI increases the age also increases.

Moreover, the current results stated that TCI of 1st mandibular molar tooth is the most statistically very highly significant in the studied groups ($p \leq 0.05$). This was inconsistent with studies done in Italian population by Drusini[30] in 2008 who mentioned that there was no significant difference between either 1st and 2nd premolars or 1st and 2nd molars and there was a strong correlation for molars than premolars in males. In Italy Zadinska et al.[22] in 2000 proved that mandibular 2nd premolars had the highest correlation with age groups.

The variations among individuals as well as across populations and between the sexes; could be attributed to socioeconomic status, cultural and racial differences, genetic differences, difference in behavior, environmental factors, diet and disease.

Conclusion

Age estimation is an important component and fundamental question in forensic sciences in the identification of individuals. Teeth are more resistant to thermal, chemical and mechanical stimuli and also least affected by endocrine or nutritional variations and thus estimation of age using dental structures serves as a reliable approach.

This present study was carried out using Tooth coronal pulp index in CBCT shows negative correlation with age, i.e. when age increases the TCI values decreases and furthermore, the result concluded that gender has no influence on TCI. This method should be considered as one of the reliable biomarkers for age assessment because of its accuracy in living individuals of unknown personal data for human biology studies and, also in the forensic context.

Abbreviations

TCI—Tooth coronal index

CBCT—Cone Beam Computed Tomography

2 D—Two Dimensional

3 D—Three Dimensional

Conflicts of Interest: Nil

Support: Nil

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