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Age Estimation Using the Tooth Coronal Index on Mandibular First Premolars on Digital Panoramic Radiographs in an Indian Population

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A B S T R A C T

Objectives: Age estimation is a crucial aspect of forensic odontology, and the Tooth Coronal Index (TCI) has been widely used for forensic purposes in determining age. The aim of this research was to evaluate the effectiveness of TCI in age estimation.

Materials and Methods: A retrospective study was conducted, and TCI was calculated for the mandibular first premolar in 700 digital panoramic radiographs. Age was divided into five groups: 20-30 years, 31-40 years, 41-50 years, 51-60 years, and >61 years. Bivariate correlation was used to establish the relationship between TCI and age. Linear regression was calculated for the different age groups and genders. Inter-observer reliability and agreement were assessed using one-way ANOVA. P-values less than 0.05 were considered statistically significant.

Results: Comparison of the mean difference from actual age showed underestimation in males aged 20-30 years and overestimation in males over 60 years of age. The least difference between actual and calculated age was found in females aged 31-40 years. Inter-age comparison using ANOVA for females demonstrated a statistically highly significant difference from actual age in all age groups (P<0.01), with the highest mean in females aged 51-60 years and the lowest in females aged 31-40 years. Inter-group comparison of mean TCI revealed statistically non-significant differences in males and statistically highly significant differences in females (P<0.01).

Conclusion: Age estimation using TCI on mandibular first premolars can be recommended as an easy, non-invasive, and less time-consuming method. This study suggests that regression formulas were more accurate for males aged 31-40 years.

Keywords: Forensic Dentistry; Age Determination by Teeth; Radiography, Panoramic; Forensic Medicine

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INTRODUCTION

Determining the age of an individual is a significant topic in forensic science as it can provide important evidence for birth records, immigration purposes, and retirement benefits. It is a crucial aspect of forensic anthropology and odontology, contributing to the development of a biological profile of the individual [1]. Age estimation is also important in cases of human trafficking, as it helps in determining criminal responsibility, adult status, and age of marriage. Various methods can be used for age estimation, taking into account chronological age, skeletal age, and dental age [2].

Various physiological systems can be utilized for age estimation, such as long bones, skull bones, and teeth. In determining the age of sub-adult individuals after death, the synostosis of secondary ossification centers and the status of development and eruption of teeth are currently used. However, the determination of the age of adults is more complex [3]. Therefore, forensic odontology plays a crucial role. Radiographs, computed tomography (CT), and magnetic resonance imaging (MRI) are imaging modalities used to estimate age in living individuals by examining skeletal indicators, such as epiphyseal fusion of the medial clavicle, ecto- and endo-cranial sutures, pubic symphysis, and costal cartilage ossification [4]. Of all these indicators, teeth are the most durable and resilient, resisting the influence of taphonomic processes and disintegrating very slowly [5]. As a result of the continuous process of dentin deposition, dental pulp can be considered an indicator of age, as it regresses in size with increasing age [6]. Age estimation using radiological examination of teeth is a simple, nondestructive method that does not require extraction [7,8].

Teeth are preferred over bone mineralization in forensic and archaeological investigations because they are resistant to various taphonomic processes, diseases, drug intake, and endocrine status [9-11]. In 1985, Ikeda et al. [12] formulated the Tooth Coronal Index (TCI), which Drusini et al. [13] later used on a sample of 433 individuals and found to be a valuable tool in age determination. Several studies have tested the usefulness and reliability of TCI on various populations in different geographic locations [1,12,13]. TCI was found to be useful in forensic applications in an Australian population by Karkhanis et al [1]. However, precise age estimation equations put forward for the Western population using measurements of secondary dentin deposition have produced unacceptable errors in forensic age estimation when applied to the Indian population [14]. In 2017, Koranne et al. concluded that regressive equations derived from TCI were applicable for age estimation for patients aged between 20 and 60 years and that there was no gender difference in TCI [14]. The aim of this study was to estimate age using tooth measurements on panoramic radiographs of intact teeth, and to assess the reliability of TCI in age assessment in an Indian population.

MATERIALS AND METHODS

A retrospective study was conducted in accordance with the declaration of Helsinki, which was approved by the Institutional Ethical Committee (EC/PG-03/OMDR/2016, approval date: 25/10/2016). Digital Orthopantomographs (OPG) of adult patients who were referred to the Department of Oral Medicine and Radiology as an aid for the diagnosis of their chief complaint from 2017 to 2018 were studied. The panoramic radiographs were taken on a KODAK 9000C 3D Unit (Carestream Health Inc., 150 Veronal Street, Rochester, NY 14608, USA) operated at 70–80 kVp, 10 mA with an image acquisition time of 13.8 seconds. The total sample size included the Digital OPG of 700 patients. The sample size was calculated using G-Power 3.1.9.2 software and the following formula:

$$n_1 = (Z_{1-\alpha/2} + Z_{1-\beta})^2 / C(r)^2$$

$$C(r) = ½ \log((1+r)/(1-r))$$

Where r was the slope of the regression equations for predicting age from the proportion of tooth-coronal index for premolars and it was found to be -1.46. The study used a 5% error rate for both α and β, which were set at 0.05. Therefore, the power of the study, represented as (1-β), was 0.95 (95%). Based on these parameters, the sample size was calculated to be 683. To ensure adequate sample size, the final sample size was increased to 700.

The inclusion criteria were age between 20 years to 70 years which were divided into five age-groups [15,16]. The permanent mandibular first premolar (Left/Right) was selected on the panoramic radiographs. The exclusion criteria were set as follows, teeth which showed any pathology such as caries, periodontitis or periapical lesions, restored, endodontically or prosthetically restored teeth, teeth which were badly rotated or showed an enamel overlap, and teeth which showed developmental anomalies related to size, shape and structure. The TCI as proposed by Ikeda et al. [12] was used The TCI required no standardization of tooth size as it is based on two linear measurements [1]. For all measured teeth, a straight line was drawn between the cemento-enamel junctions on the mesial and distal aspects which was considered as the anatomical crown. The measurements that were acquired on the mandibular right/left first premolar on the digital OPG were as follows (Fig 1):

i) Height of the crown (CH): measured vertically from the cervical margin to the tip of the highest cusp (following Moss et al [17])

ii) Height of the coronal pulp cavity (CPCH): measured vertically from the cervical line to the tip of the highest pulp horn [12]

iii) TCI = CPCH × 100/CH

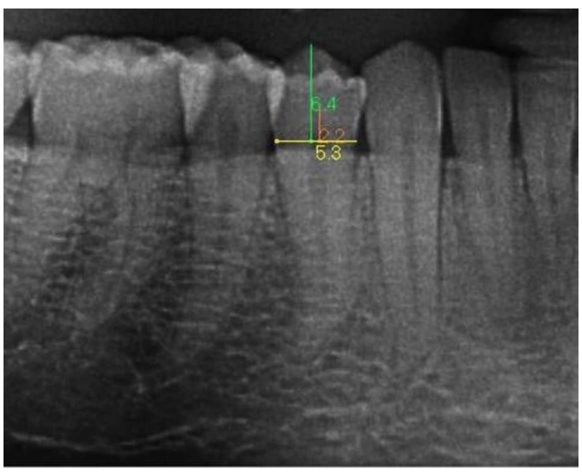

Fig 1. Cropped panoramic image showing measurements made on the mandibular first premolar (yellow line: straight line traced between the cemento-enamel junctions; green line: height of the crown; red line: height of the coronal pulp cavity)

Panoramic radiographs showed blurring in the anterior teeth region, and the projection could be taken at only one angle, hence premolars were preferred [18].

Also, mandibular teeth were preferred as they showed better visibility than the maxillary teeth on panoramic radiographs [18] and were used similar to previous studies [15,19-21].

First premolars are single rooted teeth with a large pulp area, and are convenient for measurements and morphometric analysis. Premolars were used in this study since they have also shown close correlation with age [22]. Studies using the mandibular first premolar exclusively as a tool for age estimation are limited in literature and hence this study was done using the mandibular first premolars to assess their reliability as a tool for age estimation in the adult population.

The measurements were taken by three well-trained observers who had a similar experience in oral and maxillofacial radiology. The images were evaluated and the measurements were done using the CS9000 3D imaging dental software, after a gap of one month by all the examiners. The observations of the three observers were summarized and tabulated in an excel spreadsheet and subjected to statistical analysis using SPSS software. Inter observer reliability and agreements were assessed using one way ANOVA test to check whether any statistically significant differences existed between the observations of all three investigators. Final values of CPCH and CH were calculated taking average of three observers. TCI was calculated using the formula TCI=CPCH× 100/CH. Linear regression was calculated for various age groups and gender and was depicted using an equation and the line of best fit. $P<0.05$ was considered to be statistically significant, keeping α error at 5% and β error at 20%, thus giving a power to the study as 80%.

RESULTS

The total sample consisted of panoramic radiographs of 700 adults with 389 males and 311 females. The subject's age ranged from 20 to 70 years and they were divided into five age groups: group 1: 20 to 30 years, group 2: 31 to 40 years, group 3: 41 to 50 years, group 4: 51 to 60 years, and group 5: more than 61 years. The mean age of the study sample population was 31.57±10.995 years.

Bivariate correlation was used to determine if there was any relation between TCI and age. There was a weak correlation and negligible relationship of age and TCI ($r=0.132$, $P<0.001$).

The distribution of the mean TCI for different age groups is shown in Table 1.

Table 1. Distribution of mean tooth coronal index (TCI, mm) by age for the total sample including males and females

Age (y)	N	Mean TCI	SD	SE	Min	Max
20-30	407	34.45	4.9	0.24	0	48
31-40	155	36.37	6.32	0.5	21	74
41-50	81	35.72	7.2	0.8	21	77
51- 60	48	36.08	6.36	0.91	20	50
>61	9	36.58	7.9	2.63	24	48
Total	700	35.16	5.73	0.21	0	77

Min: minimum; Max: maximum

The strength of relation between the age and TCI with respect to different age groups was analyzed by ANOVA test. There was a statistically highly significant difference seen for the inter-group comparison of mean TCI (P<0.01) which means there was a strong relation between the two parameters "age" and "TCI". The ANOVA test showed that in males there was a statistically non-significant difference seen for the inter-group comparison of mean TCI (P>0.05), while in females there was a statistically highly significant difference seen for the inter-group comparison of mean TCI (P<0.01) (Table 2).

Table 2. Analysis of variance of mean tooth coronal index for different age groups in males and females

		Tooth coronal index				
		Sum of squares	df	Mean square	F	P
M	Between groups	158.65	4	39.66	1.16	0.327
	Within groups	13096.9	384	34.1	-	-
	Total	13255.55	388	-	-	-
F	Between groups	463.11	4	115.77	3.82	0.005
	Within groups	9262.55	306	30.27	-	-
	Total	9725.66	310	-	-	-

M: males; F: females; df: degree of freedom

Using a linear regression model, an equation was derived where age was kept as a dependent variable and TCI as an independent variable for males and females.

For Males - Age = 25.125 + 0.188 × TCI

For Females - Age = 19.200 + 0.344 × TCI

The linear regression between age and TCI for males and females is depicted in a graphical presentation (Fig 2 and 3).

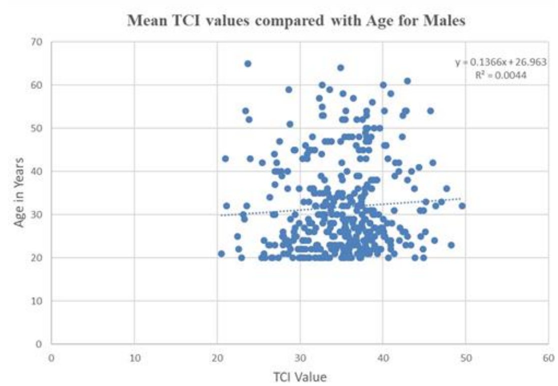

Fig 2. Graph showing linear regression between age and tooth coronal index for male subjects.

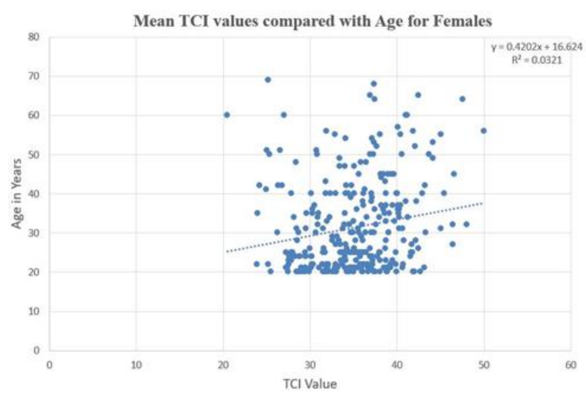

Fig 3. Graph showing linear regression between age and tooth coronal index for female subjects.

Since the above formulae were developed separately for males and females, to check whether these formulae worked among general population a random sample of 25 males and 25 females of known age (5 samples of each age group) were further taken. There was a statistically non-significant difference in inter group comparison of mean variation among males and females (P=0.71). Mean difference from actual age and calculated age using the formulae was 1.48±3.82 (standard error of mean: 0.76) for males (N=25) and 0.13±17.65

(standard error of mean: 3.53) for females. Comparison of mean difference from actual age in different age groups for males and females showed that; in male subjects there was underestimation of age in group 1 and over-estimation of age in group 5. For males, the mean difference was largest in age group 5; so it could be inferred that the formula was inaccurate for older age groups. Inter age comparison using ANOVA showed that there was a statistically non-significant difference seen in the difference from actual age in all age groups. (P>0.05) While in female subjects, it was observed that the least difference of actual age from calculated age was in group 2 and it was largest in age group 5. Inter-age comparison for females showed that there was a statistically highly significant difference seen in the difference from actual age in all age groups (P<0.01) with highest mean in age-group 4 and least difference in age-group 2 (Tables 4 and 5).

Table 4. Comparison of mean difference of actual age from calculated age in different age groups for males and females (N=5 in each age group)

					95% CI for mean		Difference from actual age	
Gender	**Age group**	**Mean**	**SD**	**SE**	**Lower Bound**	**Upper Bound**	**Min**	**Max**
Males	**Group 1**	-2.61	2.35	1.05	-5.54	0.3	-4.48	1.06
	Group 2	2.65	3.24	1.45	-1.37	6.68	-2.55	5.51
	Group 3	1	4.45	1.99	-4.52	6.53	-4.47	5.66
	Group 4	3.06	2.61	1.16	-0.18	6.3	0.14	5.29
	Group 5	3.3	3.85	1.72	-1.47	8.08	-1.05	7.55
	Total	1.48	3.82	0.76	-0.09	3.06	-4.48	7.55
Females	**Group 1**	14.501	4.19	1.87	9.29	19.71	7.19	17.2
	Group 2	2.75	1.87	0.83	0.42	5.07	0.74	4.76
	Group 3	-15.32	2.26	1.01	-18.13	-12.51	-17.85	-11.84
	Group 4	-22.7	2.27	1.01	-25.53	-19.87	-25.44	-19.2
	Group 5	21.43	7.38	3.3	12.26	30.6	12.45	30.26
	Total	0.13	17.65	3.53	-7.15	7.418	-25.44	30.26

SD: standard deviation; SE: standard error; Min: minimum; Max: maximum

Table 5. Inter-age comparison of tooth coronal index (mm) using analysis of variance for males and females

		Difference from actual age				
		Sum of squares	**df**	**Mean square**	**F**	**P**
Males	**Between groups**	121.21	4	30.3	2.63	.065
	Within groups	230.29	20	11.51	-	-
	Total	351.51	24		-	-
Females	**Between groups**	7137.33	4	1784.33	103.787	<0.001
	Within groups	343.84	20	17.19	-	-
	Total	7481.18	24	-	-	-

df: degree of freedom

DISCUSSION

The TCI was originally developed by Ikeda et al. [12] in 1985, where the length of the coronal pulp and crown were measured and TCI was assessed on the prints of radiographs of extracted human teeth. The correlation coefficients ranged from -0.73 (female molars) to -0.89 (female premolars). No significant differences were observed in age estimation using gender specific formulae. Drusini [18,23] applied the TCI after Ikeda et al [12] in a sample of 846 intact teeth with known age and gender, using panoramic radiographs. The correlation coefficients ranged from -0.92 to -0.87, with a standard error of the estimate ranging from 5.88 to 6.66. In the present study, the TCI was calculated and regression analysis was done with age, with the correlation coefficients ranging from r=0.132 to 0.167 (P<0.01) and so it was inferred that, there was a weak correlation between age and TCI.

The results in this study were in accordance with previous studies done by Badar et al in a Pakistani sample where mean correlation coefficient (r) between chronological age and TCI was -0.27 and very weak correlation between age and TCI was found [24]. The results in this study were also in agreement with Karkhanis et al [1] who used multiple regression analysis in a Western Australian population and found the correlation coefficient was highest for the mandibular right first premolar consistently for the combined sample (r=-0.262). Similar studies on Indian populations, testing the validity of different age estimation formulae have shown results similar to our study. In an investigation by Jain et al [15] there was a significant negative correlation between chronological age and TCI of the mandibular first molar (r=-0.178) and second premolar (r= -0.187). Hatice et al [25] studied a Turkish population and showed that correlation between TCI and age was -0.230 for the mandibular first premolar. The current study was done in a metropolitan urban city and hence the population was heterogeneous in nature. The higher accuracy achieved in the study done by Drusini et al. [18,23] may be attributed to the homogeneity in their study population. Our findings were contrary to the results obtained by Drusini [18] (r=-0.73 to -0.89); Igbigbi and Nyirenda [19] in Malawi (r=-0.650 to -0.799), and recently a study done by Talabani et al. [16] in Iraq (r^2=0.49). These differences in the correlation coefficients could be attributed to the fact that dental development shows variations and deviation between individuals of the same population and between individuals of different regional and ethnic groups. The quality and amount of deposition of secondary dentin is influenced by race, ethnicity and background, diet, food habits, and lifestyle [26].

Other secondary aspects that influence TCI in terms of dimensions may be conventional or digital radiographic techniques used [27]. In digital radiography, conditions such as extraneous and peripheral light, physical characteristics of computer monitors (screen size, spatial resolution and bit depth), computer hardware and software may have an impact the observers' decisions regarding reference point to be taken for the measurements and in turn affect TCIs and may play a significant role in the differences in final results [27]. When the formulae derived from the regression between TCI and age were applied to 50 subjects (equal number of male and female subjects) other than the study population, 18 out of 25 male subjects and 5 out of 25 female subjects showed variation of less than 5 years from actual age, and could be concluded that TCI worked more accurately for males in comparison to females.

The limitation of this study was that the radiographs of the study population represented a heterogenous regional population and may not have fully represented the general Indian population. Also, since the advent of CBCT, there are many researchers who might prefer the use of CBCT over OPG for age estimation. The present study advocated the use of OPG as they were taken to address the chief complaints of patients who visited the hospital and guaranteed no additional exposure to ionizing radiation. Future studies with larger samples and teeth other than mandibular first premolars, using multiple regression analysis are therefore recommended, in order to expand on dental age estimation formulae.

CONCLUSION

The current study suggests that age estimation from TCI used on the mandibular first premolar, does not require highly specialized equipment and can be easily applied to living individuals. The results of the present investigation are valid for the limited sample size and showed that TCI worked more precisely on male population as compared to females. TCI can be used accurately for the age group of 31 to 40 years while its precision was low for the population of 20 to 30 years and those above 61 years. Our research was done on a heterogeneous population in an urbanized city of western India. However, to reduce standard errors, achieve maximum reproducibility, and develop a universal formula, similar studies should be conducted on a larger sample size that is comprehensive of all ages, races, and genders.

CONFLICT OF INTEREST STATEMENT

None declared.

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