Original Article

Digitized Radiovisiographic Analysis of Dental Pulp of Permanent Mandibular First Molar and Second Premolar for Age Estimation Using Tooth Coronal Index Method

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Abstract

Background: Teeth have become a valuable index to estimate age of an individual in forensic odontology. The advent of radiovisiography (RVG) has led to accurate calculation of dental age, which may be due to more precise RVG images than other radiographic techniques. **Objectives:** The study aimed at estimating the age of an individual from mandibular premolar and molar through tooth coronal index (TCI) measured from digital intraoral radiographic images (RVG). **Materials and Methods:** Using RVG 176 periapical radiographs of mandibular second premolar and first molar of individuals of either sex aged 20–70 years residing in Chhattisgarh were taken by paralleling angle technique for the study. The RVG images of selected teeth were analyzed and height of the crown, i.e., coronal height and the height of the coronal pulp cavity, i.e., coronal pulp cavity height of each tooth were measured in millimeters using KODAK software to calculate TCI. The real age of a subject was compared with TCI of tooth and the acquired data was subjected to Pearson's correlation test. Bland and Altman regression analysis was carried out to estimate limit of agreement between the two measurements (real and calculated age). **Results:** Negative correlation was observed between the real age and TCI of mandibular first molar ($r = -0.149$, $P = 0.166$) and second premolar ($r = -0.20$, $P = 0.061$). The difference between real age and calculated age for premolar ranged from − 38.11 to 23.51 years (mean difference 7.30) and for first molar it was from − 34.82 to 25.22 years (mean difference 4.799), which suggested acceptable agreement. **Conclusion:** TCI method provides accurate estimation of age from RVG images of teeth. RVG is convenient to use, has low radiation dose, and produces sharper images than other imaging methods.

Key words: Age estimation, radiovisiography, tooth coronal index

Introduction

Identification of deceased and living individuals is utmost important for any forensic or medicolegal process. In forensic dentistry or odontology, dental tissues are used for estimation of chronological age of individuals for orthodontic treatment, pediatric, and legal issues.[1] Although skeletal remains could be used to estimate age, teeth are more reliable maturity indicators due to low variability from environmental factors, nutritional or endocrine diseases. Moreover, dental tissues are more resistant to thermal, chemical, or mechanical stimuli and could be preserved for long time after death than other developmental tissues, or even bones.[2-4]

Several methods of age estimation have been reported in forensic literature. In children age is calculated mainly from stages of development and eruption of tooth.[5] In adults morphologic, histological, and biochemical methods analyze various forms of tooth modification such as tooth wear, dentin transparency, tooth cementum annulation, racemization by aspartic acid, and apposition of secondary dentin. These methods require tooth extraction and are invasive for living individuals.[3] To overcome this limitation, noninvasive radiographic methods have been developed that are simple

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and require less expertise. Digital radiography is better option for patients than conventional due to decrease in radiation exposure, better quality of images, less duration of time, and accuracy of measurements. Digital radiographic methods also enable the clinician to save the images electronically for record maintenance of patients.[6,7] Studies have estimated age by measuring pulp/tooth ratio of teeth on radiographs based on the concept that deposition of secondary dentin throughout life leads to reduction in dental pulp size.[3,8] Several studies from forensic literature have used orthopantomograph images for age estimation of an individual by tooth coronal index (TCI) method.[3,9-12] So, this was the first study conducted with an aim to evaluate reliability of radiovisiography (RVG) for dental age assessment using TCI.

Materials and Methods

Subjects and materials

The study was conducted in the Department of Oral Medicine and Radiology, New Horizon Dental College & Research Institute, Bilaspur, Chhattisgarh, India. Ethical clearance was taken from Institutional Ethical Committee prior to the study. Patients of either sex were included in the study based on inclusion and exclusion criteria.

Inclusion criteria

Patients of both sexes more than 18 years, mentally fit, having fully erupted mandibular left second premolar and first molar with no defects were included in the study.

Exclusion criteria

Uncooperative subjects, mentally compromised subjects, subjects not willing for study or did not give written consent, subjects in which RVG sensor could not be placed, subjects having carious/grossly decayed second premolar, molars or periapical pathology, prosthesis, restored/root canal treated teeth, missing selected teeth, severely attrited or fractured selected teeth, rotated or malaligned selected teeth, teeth with any developmental anomalies, and RVG with distorted image were excluded from the study.

Study design

According to eligibility criteria, 200 subjects were assessed. Among them, 20 subjects did not meet the inclusion criteria and 4 subjects refused to participate for the study. Therefore, 176 subjects were enrolled for the study between April 2017 and September 2017. Informed consent was taken from all the enrolled subjects.

Radiographic measurements

Detailed case history and date of birth was obtained through enrolled subjects and were sent for RVG examination. Digital intraoral radiographs of left mandibular second premolar and first molar were taken by Kodak RVG 5100 (Carestream Health, Inc., Rochester, NY, USA) with paralleling angle technique at 70 kVp, 8 mA, and exposure time of 0.4 s. The image obtained was analyzed and measurement was done using Kodak software. All the measurements were recorded in millimeters.

Measurement of Tooth Coronal Index

A straight line (cervical line) was traced from the cemento-enamel junction, which is the division between anatomical crown and root. Coronal height (CH) was measured vertically straight from the cervical line to the tip of the highest cusp according to Moss *et al*.[13] Coronal pulp cavity height (CPCH) was measured vertically from the cervical line to the tip of the highest pulp horn according to Ikeda *et al*.[14] The measurements provided the TCI of each tooth, which was then calculated as follows [Figures 1 and 2]:

$$TCI = CPCH \times 100/CH$$

The measurements were displayed in millimeter along with captured image for further identification and reference. Intraobserver measurements of three variables (CH, CPCH, and TCI) were also done. In the present study, mean estimated age by TCI was correlated with the real age of the subject.

Statistical analysis

The calculated data were entered in a Microsoft Excel spreadsheet. Statistical analysis was done using the Statistical Package of Social Science (SPSS, version 20; SPSS Inc., Chicago, IL, USA). Data comparison was done by applying specific statistical tests to find out the statistical significance of the comparisons. Quantitative variables were compared using mean values and standard deviations. Descriptive data are presented as mean ± standard deviation (SD) and range values.

Karl Pearson's product moment correlation coefficient was applied between the actual age and TCI of mandibular second premolar and first molar. A value of correlation coefficient close to +1 was considered as a strong positive linear relationship (i.e., one variable increases as the other) and a value close to −1 was considered as a strong negative linear relationship (i.e., one variable decreases as the other increases), and a value close to 0 was considered as no linear relationship. A regression analysis was then performed comparing the original age and calculated age (premolar and molar), using the approach of Bland and Altman. In particular, limits of agreement between the two readings were computed to provide a range of values within which 95% of the differences between the two readings

Figure 1: Mandibular premolar and molar images show the measurement of TCI by RVG Kodak software

were expected to fall. In addition, a graphic display was created between the actual age and TCI of mandibular second premolar and first molar, as suggested by Bland and Altman, to assess the likelihood of bias and possible outliers. Bland and Altman approach was chosen for the current analysis because the focus was on examining agreement between the two measures.

Results

The study involved a total of 176 subjects of which 108 were males and 68 were females with mean real age of 33.52 ± 12.33 years (range 20–68 years). The mean calculated age by TCI for premolar was 40.82 ± 12.53 (range 18–78 years) and 38.32 ± 11.16 for molar (range 18–70 years), respectively.

Pearson's correlation showed negative correlation between the real age and calculated age. The coefficient between the real age and TCI of mandibular first molar was 0.149 ($P = 0.166$), while that of premolar it was 0.20 ($P = 0.061$) [Figures 3 and 4]. The correspondence between the real age and calculated age readings, together with the line of equality, suggests no systematic bias in real age and calculated age.

An analysis of agreement (Bland and Altman regression analysis) was also carried out between the two measurements (real age and calculated age) on premolar and molar. The difference between real age and calculated age for premolar ranged from −38.11 to 23.51 years (mean difference 7.30) and for first molar, it was from −34.82 to 25.22 years (mean difference 4.799). The 95% coefficient of agreement was 29.3915 for premolar (1.96 times the SD of difference in the readings) and 29.0730 for molar [Figures 5 and 6]. If the differences follow a normal distribution, 95% of the differences are expected to lie in-between the mean of differences between real and calculated age with values of ±1.96 times the SD of these differences, with 95% confidence intervals (CIs) for the lower and upper limits of agreement of −43.8276 to −32.3991 and 17.7989 to 29.2274, respectively for premolar. Similarly, for molar it was −40.3875 to −29.2529 and 19.6545 to 30.7890. The regression equations to calculate dental age of

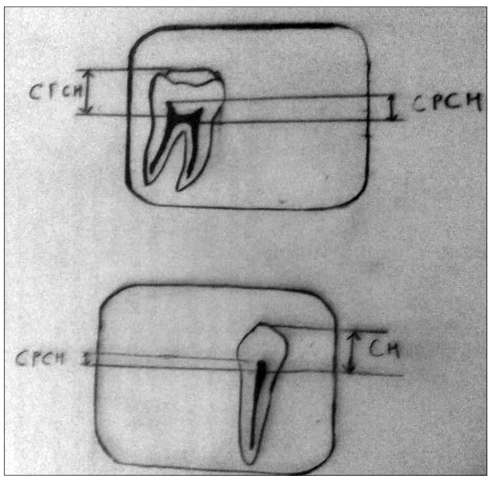

Figure 2: Pictorial representation of measurement of TCI on mandibular premolar and molar

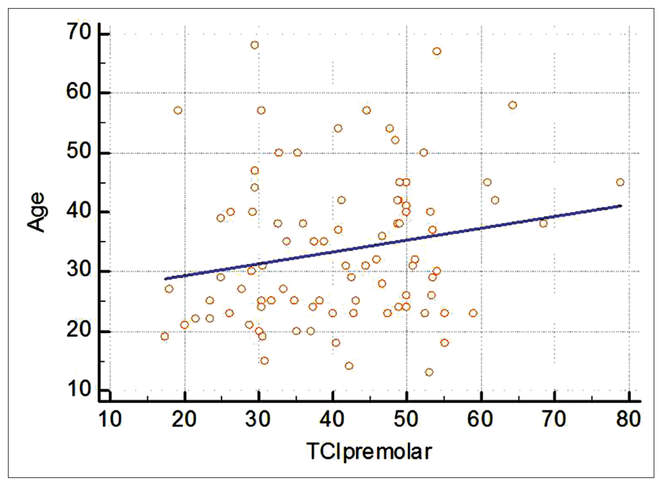

Figure 3: Pearson correlation test showing correlation between real age and TCI of mandibular second premolar

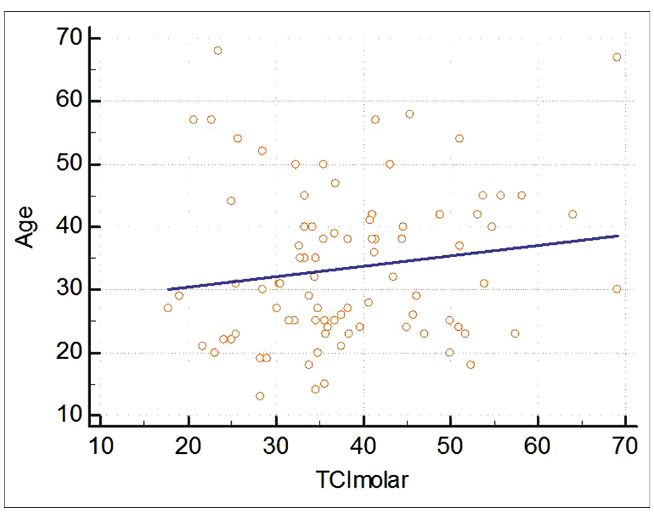

Figure 4: Pearson correlation test showing correlation between real age and TCI of mandibular first molar

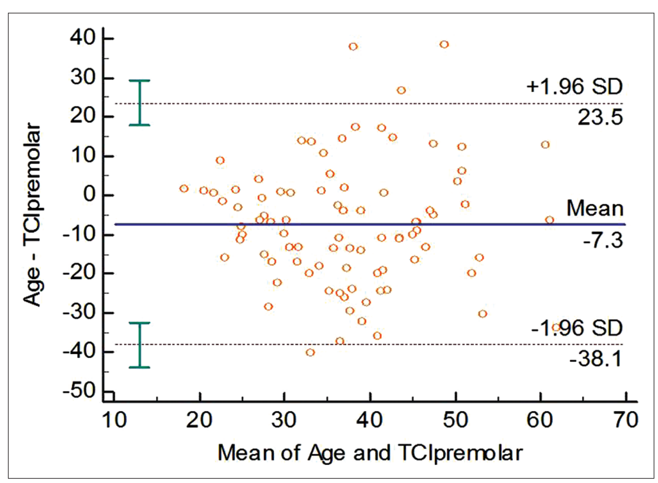

Figure 5: Bland and Altmann regression plot shows difference between real and calculated age against mean measurement for mandibular premolar

both genders were also derived for both mandibular molar and premolar, which are shown in Tables 1 and 2.

Discussion

Identification of a person is first basis of any forensic investigation. Accurate age estimation for administrative, ethical, and medico legal issues is one of the important parameters in person identification for forensic odontologists. Edwin Saunders suggested that teeth are more reliable indicators of chronological age than other developmental tissues.[8] In 1925, Bodecker reported the relation between apposition of secondary dentin and chronological age.[9] Since then, several studies have suggested that dental pulp size decreases with increasing age as a result of continuous secondary dentin deposition, so the measurement of reduction of pulp cavity is best method to estimate dental age.[3,10-12]

Secondary dentin apposition is not uniform all over the pulpal cavity, i.e., in case of molars, it is more over the roof and floor, thus reducing the height rather than width of the pulpal chamber.[3,8] Assessment of age by reduction of secondary dentin apposition can be measured by cross-sections of teeth, histological, and radiological methods. Radiographic measurements are more accurate and have good reproducibility in comparison to other techniques.[15,16] Gustafson made an earlier attempt to estimate age by secondary dentin apposition method on periapical radiographs.[17] Later, Kvaal *et al*. and Cameriere *et al*. estimated age on radiographs by measuring pulp/tooth ratio, and negative correlation was observed with chronological age.[18,19] More precise age estimation method, TCI was introduced by Ikeda *et al*.; several studies in literature have measured TCI of mandibular teeth on panoramic radiographs and correlated it with chronological age.[14] In 1995, Kvaal *et al*. established significant correlation between TCI for molars and premolars and dental age ($r^2 = -0.650$ to -0.0799, $P < 0.01$).[18] Similar studies by Veera *et al*. (age 21–30 years, premolars $r = -0.945$, molars $= -0.961$ and for age 51–60 years, premolars, $r = -0.886$, molars $r = -0.863$), Talabani *et al*. ($r^2 = 0.49$, $P = 0.0000$) for mandibular first molar,

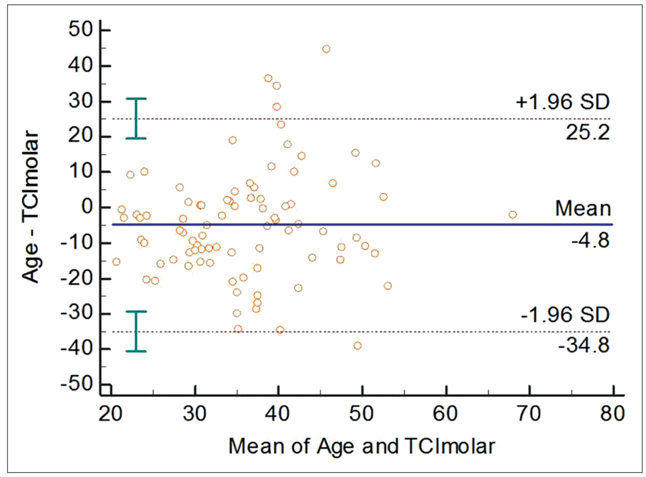

Figure 6: Bland and Altmann regression plot shows difference between real and calculated age against mean measurement for mandibular molar

Table 1: Regression equations for age estimation by Bland and Altmann regression analysis

Parameter	Coefficient	SE	95% CI	t	P	Pearson's co-relation test (R^2)
Intercept	29.0730	7.2669	14.2708-43.8752	4.0007	0.0003	0.02221
Slope	0.1514	0.1918	−0.2392-0.5421	0.7896	0.4356	
Regression equation for molar: y=29.0730+0.1514 x						
Intercept	29.3915	6.4974	16.1567-42.6264	4.5236	0.0001	0.04019
Slope	0.1220	0.1452	−0.1737-0.4178	0.8407	0.4068	
Regression equation for premolar: y=29.3915+0.1220 x						
TCI premolar male						
Intercept	25.4671	4.4384	16.6440-34.2903	5.7380	<0.0001	0.05308
Slope	0.1973	0.1040	−0.009390-0.4041	1.8976	0.0611	
Regression equation for premolar (male): y=25.4671+0.1973 x						
TCI premolar female						
Intercept	22.6601	6.2111	10.1966-35.1236	3.6483	0.0006	0.02161
Slope	0.2566	0.1503	−0.04501-0.5582	1.7072	0.0937	
Regression equation for premolar (female): y=22.6601+0.2566 x						
TCI molar male						
Intercept	27.1793	4.7230	17.7904-36.5683	5.7547	<0.0001	0.02960
Slope	0.1655	0.1184	−0.06990-0.4010	1.3977	0.1658	
Regression equation for molar (male): y=27.1793+0.1655 x						
TCI molar female						
Intercept	25.1635	6.3470	12.4274-37.8997	3.9646	0.0002	0.01911
Slope	0.1945	0.1545	−0.1154-0.5045	1.2593	0.2135	
Regression equation for molar (female): y=25.1635+0.1945 x						

TCI: Tooth coronal index, CI: Confidence interval, SE: Standard deviation

Table 2: Regression equations for age estimation of both genders

Parameter	Coefficient	SE	95% CI	t	P	Pearson's co-relation test (R^2)
Intercept	29.0730	7.2669	14.2708-43.8752	4.0007	0.0003	0.02221
Slope	0.1514	0.1918	−0.2392-0.5421	0.7896	0.4356	
Regression equation for molar: y=29.0730+0.1514 x						
Intercept	29.3915	6.4974	16.1567-42.6264	4.5236	0.0001	0.04019
Slope	0.1220	0.1452	−0.1737-0.4178	0.8407	0.4068	
Regression equation for premolar: y=29.3915+0.1220 x						
TCI premolar male						
Intercept	25.4671	4.4384	16.6440-34.2903	5.7380	<0.0001	0.05308
Slope	0.1973	0.1040	−0.009390-0.4041	1.8976	0.0611	
Regression equation for premolar (male): y=25.4671+0.1973 x						
TCI premolar female						
Intercept	22.6601	6.2111	10.1966-35.1236	3.6483	0.0006	0.02161
Slope	0.2566	0.1503	−0.04501-0.5582	1.7072	0.0937	
Regression equation for premolar (female): y=22.6601+0.2566 x						
TCI molar male						
Intercept	27.1793	4.7230	17.7904-36.5683	5.7547	<0.0001	0.02960
Slope	0.1655	0.1184	−0.06990-0.4010	1.3977	0.1658	
Regression equation for molar (male): y=27.1793+0.1655 x						
TCI molar female						
Intercept	25.1635	6.3470	12.4274-37.8997	3.9646	0.0002	0.01911
Slope	0.1945	0.1545	−0.1154-0.5045	1.2593	0.2135	
Regression equation for molar (female): y=25.1635+0.1945 x						

TCI: Tooth coronal index, CI: Confidence interval, SE: Standard deviation

and Igbigbi and Nyirenda (r ranged from −0.650 to −0.799) for premolars and molars of Malawians adults reported that TCI decreased with advancing age.[3,11,12] The results are consistent with the present study, suggesting negative correlation between TCI and chronological age (r = −0.149 and r = −0.20) for mandibular first molar and second premolar, respectively. Thus, TCI proved to be reliable coronal pulp biomarker for age estimation.

To the best of our knowledge, this is the first study conducted on Indian population in which digital radiography, RVG images were used to measure TCI. RVG was preferred due to low radiation dose and higher resolution of images with less superimposition in comparison to panoramic and conventional radiography. Several studies in the forensic literature have used RVG for assessment of age by other methods.[6,7] Joseph *et al*. conducted a study on 120 subjects aged 20–70 years and measured pulp/tooth area ratio of mandibular premolars from RVG images. Pulp/tooth area was found to be significant predictor of dental age ($P \leq 0.001$) and RVG images provided more accurate estimation of age in individuals aged between 36 and 50 years.[6] Sharma and Srivastava estimated age of 50 subjects (15–60 years) by measuring pulp size of six selected teeth by Kavaal's method on digital intraoral periapical radiographs and found significant correlation between decrease in pulp chamber size with age, with r^2 (0.198) highest for mandibular first premolar.[7] In the present study, RVG images were used to determine age of 176 subjects by measuring pulpal height of mandibular first and second premolar and demonstrated reduction of pulp cavity size with age.

In the current study, mandibular second premolar was more closely related to age (−0.20) than first molar (r = −0.0149), indicating second premolar as a more reliable predictor of dental age. Mandibular premolars and molars were mainly preferred to estimate TCI as extent of pulpal chamber is clearly visible in these teeth, which was in accordance with Veera *et al*.[3] and Drusini *et al*.[9] The agreement between real and calculated age was within acceptable limit with mean difference of 7.30 for premolar and 4.799 for first molar, which was comparable to study by Memon and Fida.[20] In our study, no systematic bias was seen between real and calculated age, and derived regression formulae could be used for age estimation of an adult population using TCI. It is recommended that forensic odontologists should address applicability of TCI method using RVG on different population, in different geographical regions, and on other single and multirooted teeth. They should also consider various environmental, racial, dietary, genetic, and cultural factors.

Conclusion

From the results of the study, it could be concluded that measurement of TCI by digital radiovisiography provides more accurate estimation of age of an individual. It is a less time-consuming, reproducible, and cost-effective method that could be easily applied to both living and dead individuals without requirement of any highly specialized equipment.

TCI showed strong negative correlation with dental age, thus emphasizing the decrease of size of pulp cavity with advancing age, but in future efficacy of this method should be further confirmed by studies on population of different racial and ethnic origins.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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