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Comparative Evaluation of Modified Kvaal's Formula and Coronal Pulp Cavity Index in the Pune Population – A Cone-beam Computed Tomography-based Retrospective Study

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ABSTRACT

Introduction: The uniqueness of the human dentition serves its wide acceptance in the identification of individual in forensic science. **Aim and Objectives:** To estimate the accuracy of age by using modified Kvaal's formula and coronal pulp cavity index (CPCI) and compare the standard error and establish the technique among the Pune population. **Materials and Methods:** Four hundred cone-beam computed tomography (CBCT) scans were randomly selected with satisfying the established criteria. The second premolar was included in the study and the maximum length of tooth, root, and pulp was measured using modified Kvaal's method and CPCI by using Planmeca CBCT machine with Romexis-three-dimensional imaging software. **Results:** The results were analyzed using the Chi-square test and ANOVA. Modified Kvaal's formula was found to be the better followed by CPCI in the estimation of age among Indians with lesser error in prior. **Conclusion:** Modified Kvaal's formula is precise, noninvasive, and most reliable biomarker for age estimation than tooth-coronal index.

KEYWORDS: *Cone-beam computed tomography, forensic odontology, human identification*

INTRODUCTION

Age estimation is one of the indicators employed to establish the identity in individual and forensic science. It is an important basis for differentiating guilty from innocent legal issues, ethical issues and for deceleration for death report. The accurate estimation of age at the time of death with the help of dental remains is an important parameter for identification. Human tooth can be preserved for a long time after death without gross changes due to which it serves as an important tool in forensic science.[1-5] The literature reports different morphological, histopathological, and radiological techniques for age assessment. Dental age estimation has gained acceptance because it is less variable when compared to other skeletal and sexual maturity indicators. The secondary dentin deposition is diverse for different teeth, as age progresses.[6,7] Kvaal *et al*.[8] used deposition of secondary dentin by measuring pulp radiolucency and correlated it to age. On the other hand, the tooth-coronal index (TCI) (TCI = length of the coronal pulp cavity/length of the crown × 100) was measured and then was computed for each tooth and regressed on real age.[9] The present study aims to assess the comparative evaluation of modified Kvaal's formula and coronal pulp cavity index (CPCI) of mandibular second premolar using para-axial section of cone-beam computed tomography (CBCT) scans of known age and to develop regression equations that can be used in the Pune population.

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Materials and Methods

This retrospective study was carried out in the maxillofacial radiology center following the fundamental principles of the Declaration of Helsinki. The ethical clearance was obtained from the Institutional Ethics Committee (Approval No: ECR/328/Inst/MH/2018). This is a single-blinded study in which randomly selected 400 CBCT scans >20 years of age were anonymized by one observer. The CBCT scans which were fulfilling the inclusion and exclusion criteria were included in the study. Before starting a study, a sample size calculation was done by using this formula $N = z^2pq/d^2$, where "N" is sample size, "Z" is confidence level at 95% (standard value of 1.96), "pq" is variance of population (0.501) and "d" is absolute error or precision error (5%). In majority of studies, *P* value was considered to be significant below 0.05; hence, 1.96 was used in the formula. Therefore, a present sample size was 400. This sample size was calculated from Epi Info software C.D.C., USA (version 7.1). The sampling method was convenience sampling.

Method of data collection

To avoid interobserver discrepancy, a pilot study was performed. Ten randomly selected CBCT scans were taken from maxillofacial radiology center which has Planmeca CBCT machine with Romexis 5.0.R imaging software. In total, six parameters were defined and clarified for determining the height of crown and coronal pulp, tooth, root, and pulp length and other details were explained. Based on the definition of the specified parameters, 400 CBCT scans were evaluated and divided into five groups: Group 1 - <20 years, Group 2 - 21–30 years, Group 3 - 31–40 years, Group 4 - 41–50 years, and Group 5 >50 years. All the scans were analyzed and interpreted by two senior experienced maxillofacial radiologists. Each observer independently interpreted each CBCT scan, followed by a discussion of each radiograph between the two observers. Inter-observer variability was calculated using Fleiss and Cohen kappa statistics. Cohen's kappa shows almost perfect agreement between the two observers of the study. The inclusion criteria include individuals within the age group of 20–60 years and having mandibular second premolar. The exclusion criteria include the individuals with missing, impacted, and pathology present in mandibular second premolar.

For modified Kvaal's formula, the measurements were taken for modified Kvaal's formula using the Planmeca CBCT machine with Romexis three-dimensional (3D) imaging software. Maximum tooth length, pulp length, root length on mesial side, pulp width at level "a" (cement enamel junction [CEJ]), level "c" (mid root level), and level "b" (midpoint of c and a), root width at level "a" (CEJ), level "c" (mid root level), and level "b" (midpoint of c and a) were recorded [Figure 1].

In order to reduce the possible effects of variation in magnification and angulations of the radiographs, the following ratio was also calculated:

1. Root length/tooth length (T)
2. Pulp length/tooth length (R)
3. Pulp length/root length (P)
4. Pulp width/root width at level a (A)
5. Pulp width/root width at level b (B)
6. Pulp width/root width at level c (C)
7. Mean values of all ratios (M) mean value of width ratios from levels b and c (W).

Mean value of length ratios *P* and R (L) difference between W and L (W–L).

Age was assessed for all the individuals by using two predictors, where the mean of all ratios (M) will be taken as the first predictor, while the difference between the mean of the 2 width ratios and the mean of the 2 length ratios (W–L) will be taken as the second predictor [Figure 2].

CPCI was assessed and measurements were performed. CPCI is an index based on two linear measurements and thus requires no further standardization of tooth size. The measurements undertaken will be height of the crown (CH) and coronal pulp cavity height (CPCH). A straight line will be traced between the CEJs on the mesial and distal aspect [Figure 3]. This will defined the anatomical crown and the following measurements will be acquired after Drusini.[10]

1. CH: Will be measured vertically from the cervical margin to the tip of the highest cusp

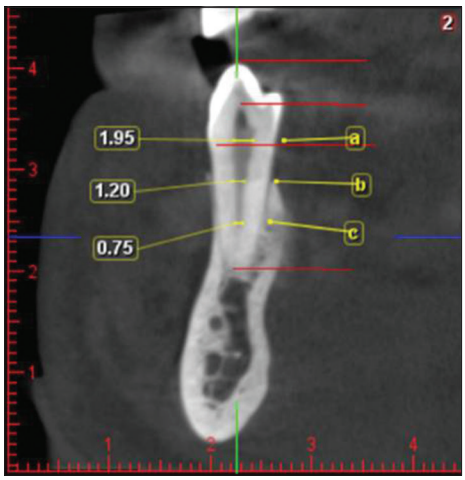


Figure 1: Para axial cone-beam computed tomography scan shows measurements at the level of c: Mid root level, and level b: Midpoint of c and a, root width at level, a: Cement enamel junction

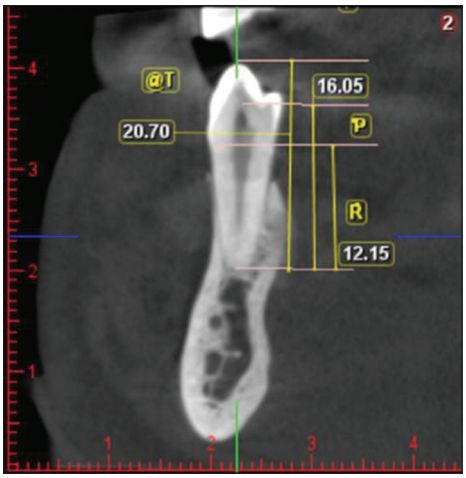


Figure 2: Para axial cone-beam computed tomography scan shows measurements of width and length ratios (W–L)

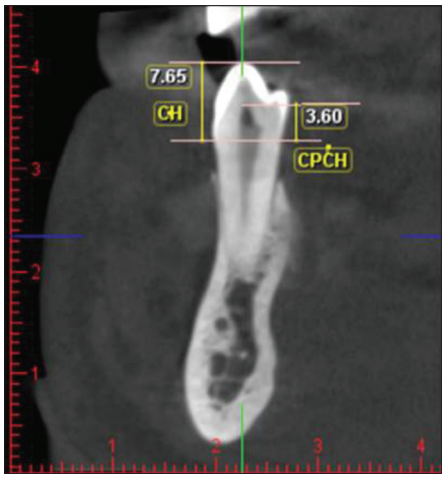


Figure 3: Para axial cone-beam computed tomography scan shows measurements by coronal pulp cavity index (CPI)

2. Coronal pulp cavity height instead of height of the coronal pulp cavity (CPCH): Will be measured vertically from the cervical line to the tip of the highest pulp horn
3. Tooth coronal index (TCI) = CPCH × 100/CH.

Statistical analysis

1. Comparison of actual age with estimated age by CPCI and modified Kvaal's methods was carried out by the ANOVA test
2. Pearson correlation coefficients were used to estimate the age by CPCI and modified Kvaal's methods.

Results

The present study included 400 CBCT scan of both gender fulfilling the inclusion and exclusion criteria were included which were further divided into five groups. The grouping was done to derive the different formulas for different age groups as the deposition of secondary dentin is not uniform throughout the life. Group 1 - <20 years, Group 2 - 21–30 years, Group 3 - 31–40 years, Group 4 - 41–50 years, and Group 5 >50 years. CBCT scans were anonymized and randomly selected from CBCT center by using Planmeca CBCT machine with Romexis-3D imaging software and all the measurements were made.

The regression equation to estimate the age of the individuals in different groups using modified Kvaal's method was derived [Table 1]. For Group 1 = (16.653 − [3.227 × M] − [6.763 × (W–L)]), Group 2 = (29.656 − [6.497 × M] + [2.448 × (W–L)]), Group 3 = (34.000 + [3.247 × M] + [1.204 × (W–L)]), Group 4 = (38.302 + [13.375 × M] + [0.400 × (W–L)]), and Group 5 = (59.687 − [19.243 × M] – [6.317 × (W–L)]) and overall regression equation is for age estimation by using modified Kvaal's method was

Table 1: Regression equations: [Using M and (W-L)]

Age group	Regression equation
Overall	32.501 − (34.907×M) − (20.549 × (W–L))
Group 1: ≤20 years	16.653 − (3.227×M) − (6.763 × (W–L))
Group 2: 21–30 years	29.656 − (6.497×M) + (2.448 × (W–L))
Group 3: 31–40 years	34.000 + (3.247×M) + (1.204 × (W–L))
Group 4: 41–50 years	38.302 + (13.375×M) + (0.400 × (W–L))
Group 5: >50 years	59.687 − (19.243×M) − (6.317 × (W–L))

32.501 - (34.907 × M) – (20.549 × [W–L]). Using these regression equations, mean and standard deviation of estimated and actual age were calculated and the mean difference between actual and estimated age were derived [Table 2]. To test the statistical significance, one-way ANOVA was used. For all five groups, *P* value was insignificant (>/0.5); hence, proves that there was no significant difference between actual age and estimated age by using modified Kvaal's method.

The regression equation to estimate the age of the individuals in different groups using CPCI was calculated [Table 3]. For Group 1 = (17.968 + [0.052 × TCI]), Group 2 = (24.879 + [0.002 × TCI]), Group 3 = (33.419 + [0.038 × TCI]), Group 4 = (46.899 – [0.073 × TCI]), and Group 5 = (57.284 – [0.060 × TCI]) and overall regression equation is for age estimation by using CPCI was (26.919 + [0.105 × TCI]). Using these regression equations, mean and standard deviation of estimated and actual age was calculated and the mean difference between actual and estimated age were derived [Table 4]. To test the statistical significance, one-way ANOVA test was used and for all five

Table 2: Mean difference between actual and estimated age using Kvaal's

Age group	Actual age (mean±SD)	Estimated age using M and (W–L) (mean±SD)	Mean difference between actual age and estimated age	*P*
Overall	30.25±9.752	30.249±2.194	0.00088±9.5098	0.999; NS
Group 1: ≤20 years	19.59±3.319	19.479±0.714	0.10774±3.3331	0.806; NS
Group 2: 21–30 years	24.93±2.893	24.907±0.599	0.01870±2.9196	0.933; NS
Group 3: 31–40 years	34.66±2.378	34.659±0.172	0.00129±2.3684	0.996; NS
Group 4: 41–50 years	44.340±3.766	44.364±0.679	−0.0221±3.8184	0.971; NS
Group 5: >50 years	55.500±3.154	55.499±0.998	0.00048±2.9918	0.999; NS

NS=Not significant, SD=Standard deviation

Table 3: Regression equations: For tooth-coronal index

Age group	Regression equation
Overall	26.919 + (0.105 × TCI)
Group 1: ≤20 years	17.968 + (0.052 × TCI)
Group 2: 21–30 years	24.879 + (0.002 × TCI)
Group 3: 31–40 years	33.419 + (0.038 × TCI)
Group 4: 41–50 years	46.899 − (0.073 × TCI)
Group 5: >50 years	57.284 − (0.060 × TCI)

TCI=Tooth-coronal index

groups *P* value was insignificant (>/0.5). Hence, proves that there was no significant difference between actual age and estimated age by using TCI.

The comparison between the actual age of individual and estimated age by using modified Kvaal's method and TCI was assessed [Graph 1]. There were no significant differences between actual and estimated age by both the methods.

Next, coefficient of determination (R^2) was higher for modified Kvaal's method (0.051) as compared to TCI (0.008) [Table 5] which indicates that age can be better estimated with modified Kvaal's method as compared to TCI by using CBCT.

Discussion

Tooth is considered a reliable body part for forensic age estimation since environment has minimal influence on it.[11] The use of radiographic methods to estimate age-dependent changes in teeth depends on the secondary dentin deposition which has been implied since long time.[12] Age estimation by radiographic evaluation is an established noninvasive technique and various studies that have been done to construct a formula for age estimation in the Indian population. Maxillary second premolar was found to be a good predictor of age, when taking "M" and "W–L" as the first and second predictors, respectively.[13] In the present study, maxillary second premolar was used which showed significant results. The present study is based on the non destructive method which was also suggested by Ikeda *et al*.[14] The extent of pulp cavity is visible in premolars on Panoramic radiographs which showed high correlation when age estimation was done by Drusani *et al*.[10] Morse *et al*.,[15] and Talabani *et al*.[16] conducted a study, a method for assessing chronological age based on the result showed the real age and the predicted age using TCI values were similar and the coefficients of correlation between actual age and predicted age were found to be very significantly high for first molars.

Digital orthopantomogram (OPG) has various advantages over conventional techniques, but the image quality and errors in patient positioning are highly influenced. The measurement by using CBCT will be accurate because of sub millimeter-resolution, free from magnification and distortion as compared to the intraoral radiographs and OPG recordings. The biggest impact on increasing measuring accuracy would be achieved using a 3D visualization of teeth without the need to transfer those recordings to another program and measure them there.[17,18]

Marroquin Penaloza *et al*.[18] studied the application of CBCT images for Kvaal's method for the first time and found similar results to those reported by Kvaal *et al*.[8] for all of the parameters. Koranne *et al*.[19] stated that the relationship between age and measurement of the TCI on mandibular first premolar in an attempt to improve the precision and reliability of age estimations. Doni *et al*.[20] conducted a study and stated that TCI has the potential to estimate age of an individual on CBCT scans. They found statistically significant difference between actual age and TCI for mandibular second premolar which was consistent with the present study. Akay *et al*.,[21] Moshfeghi *et al*.,[22] and Nouaman *et al*.[23] studied

Table 4: Mean difference between actual and estimated age using tooth-coronal index

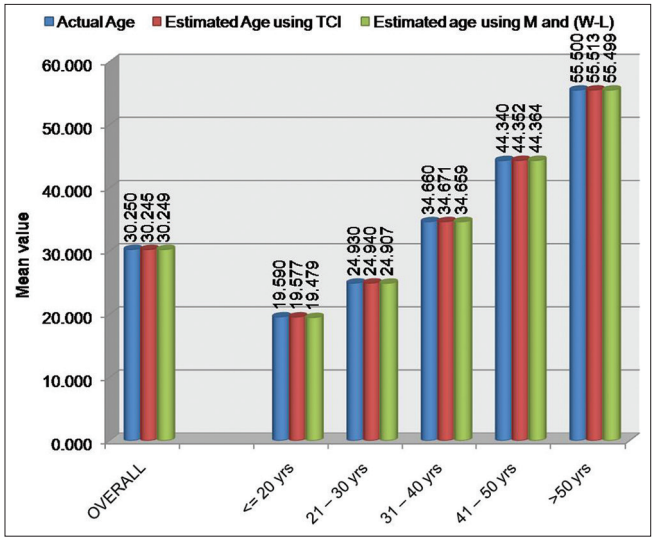
Age group	Actual age (mean±SD)	Estimated age using TCI (mean±SD)	Mean difference between actual age and estimated age	*P*
Overall	30.25±9.752	30.245±0.896	0.0052±9.715	0.991; NS
Group 1: ≤20 years	19.59±3.319	19.577±0.449	0.0088±3.357	0.984; NS
Group 2: 21–30 years	24.93±2.893	24.940±0.016	−0.0143±2.893	0.948; NS
Group 3: 31–40 years	34.66±2.378	34.671±0.353	−0.0103±2.350	0.964; NS
Group 4: 41–50 years	44.340±3.766	44.352±0.647	−0.0109±3.731	0.985; NS
Group 5: >50 years	55.500±3.154	55.513±0.402	−0.0130±3.129	0.985; NS

TCI=Tooth-coronal index, NS=Not significant, SD=Standard deviation

Table 5: Correlation of estimated age using Kvaal's and tooth-coronal index

Overall	Regression equation	R^2	SE	*t*	*P*
TCI	26.919 + (0.105×TCI)	0.008	9.723	1.843	0.066
Kvaal's (W-L) M	32.501 − (34.907×M) – (20.549 × (W–L))	0.051	9.526	−0.225	0.000

SE=Standard error, TCI=Tooth-coronal index



Graph 1: Comparison between actual age and estimated age by TCI and modified Kvaal's formula

application of the Kvaal's method by using CBCT on various populations and concluded that CBCT provides better visualization of the reference points and accurate measurements in dental age estimation by using Kvaal's method. They found that the measurements made by Kvaal's are reproducible with CBCT and there is a correlation between age and the dental parameters. In the present study, accuracy of age estimation was done by comparing actual age with modified Kvaal's formula and CPCI. The present study showed the statistically significant difference between actual age with modified Kvaal's method and with TCI which is consistent with the studies done earlier. Chandan *et al*.[24] studied validity and reliability of Kvaal's method for age estimation and he found that coefficient of determination (R^2) is highest in canines and premolars and concluded that age can be better estimated by premolars on CBCT. In the present study, coefficient of determination (R^2) was higher by using modified Kvaal's method as compared to TCI.

Conclusion

Therefore, from the present study, it was observed that both the methods can be used as reliable indicator of age and modified Kvaal's formula being the better followed by CPCI among the Pune population. The modern technology CBCT provides the ability to process images very quickly, being accurate, and better resolution can be used for the age estimation in forensic science.

Key message

Every dentist should realize their social responsibility of maintaining dental records of their patients so that they can be used for the identification in the event of any disaster. Furthermore, it is a part of good clinical practice protocols.

Future prospects

The CBCT gives precise details of tooth with three-dimensional images which can be used readily and reliably in forensic identification. The study sample should be drawn from around India and have a large sample size.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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