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Age estimation from pulp tooth area ratio of mandibular canine using an orthopantomogram: A cross-sectional study

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Abstract

Background: Age estimation of living adult individuals can be accomplished with limited methods. Radiographic dental methods based on secondary dentin deposition have been described as one of them. In the present study, the relationship between chronological age and the ratio of pulp to tooth area using available panoramic images of mandibular canine by Kvaal's technique was carried out for the age estimation in the study population.

Materials and Methods: 24 orthopantomogram images (OPG) of mandibular canines between 16-56 years were collected from the archives and pulp tooth area ratios were measured. Age was estimated using the regression equation obtained.

Results: It was observed that variables M', 'L', and 'r' correlated highly with age and were included in the regression model. Statistical analysis indicated that the regression equation with selected variables explained 94.4% of the total variance. There was no significant difference between chronological and estimated age (p>0.05) signifying that the derived formula is appropriate for all the selected age groups.

Conclusion: The derived population-specific regression equation can be potentially used for the estimation of the chronological age of the study population.

Keywords: OPG; Kvaal's Method; Age estimation; Canine

1. Introduction

Identification is the establishment of one's individuality. Age is one of the essential factors in establishing the identity of a person [1]. In forensic science, age estimation, particularly age estimation utilizing teeth [2], plays a vital role in the identification of unknown human bodies. It is important not only to assist in the identification of the deceased but also to clarify criminal and civil culpability, rectify birth records, and other social difficulties for surviving individuals [3].

Age estimate has been done using a variety of methods based on skeletal and dental changes. Teeth are the strongest and longest-lasting physical structure, are highly resistant to external forces and are protected by the hard and soft

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tissues of the face when compared to bones. Age estimation plays an important role in the identification of unknown human bodies in forensic science, especially age estimation using teeth [2]. Different methods have been applied for age estimation according to various skeletal and teeth changes. Compared to bones, teeth are the strongest and longest-lasting physical structure, are highly resistant to external factors, and are protected by the hard and soft tissues of the face. Because of these advantages, teeth are a better biological indicator of age than other skeletal parameters [4].

Various methods for calculating dental age have been reported in the literature. Morphological and radiological approaches are two of them. The most often utilized morphological procedures necessitate tooth extraction, which is both time-consuming and costly [5]. The radiographic method of age estimation is straightforward, rapid, cost-effective, non-mutilating, and non-invasive [6]. A series of changes in teeth occur in adulthood as a result of environmental influences, such as enamel attrition, secondary dentin deposition, and other changes in periodontal tissues and roots. Because of its gradual production throughout life, secondary dentin is highly connected to age. As a result, the pulp/tooth ratio is thought to be a potentially relevant parameter for estimating age [4].

Kvaal et al. [7] published a method for estimating age based only on secondary dentin development in 1995. This approach was subsequently put to the test by several additional researchers, who found it to be quite accurate in a variety of populations [8]. Paewinsky et al [9] discovered in 2005 that the size of the pulp cavity on digital panoramic radiographs (OPGs) can also be used to estimate individual age. Following that, the validity of Kvaal et al's age estimation methodologies was assessed in OPGs by different ethnic groups, which revealed differences in different populations. As the canine is the longest-living tooth in the dental arch, and according to Study [8], secondary dentin development in mandibular canines has a higher association with chronological age than other teeth, the mandibular canine is selected in the study.

Therefore, this study aimed to investigate the relationship between chronological age and the ratio of pulp to tooth area using available panoramic images of mandibular canine by Kvaal's technique.

2. Material and methods

The study was conducted after obtaining ethical clearance from the institutional ethical committee. This study included age and gender-matched 24 OPG images of mandibular canines of age group 16-56 years. The subjects were distributed according to the age group 16-26. 27-36, 37-46, 47-56 years. Data with the date of birth details of individuals were included in the study. Images were selected from the OPG image archives of the Department of Oral Medicine and Radiology, Yenepoya Dental College, Yenepoya University, Mangalore.

Radiographic data of mandibular canine which is missing/impacted/carious/filled/ prosthetically restored/ malposed /had periapical or pulpal pathologies or morphological abnormalities including attrition/abrasion/ erosion were not taken into consideration. These images were obtained from the patients who underwent orthopantomogram examination for various diagnostic purposes, which were acquired using the Planmeca ProMax machine that uses AGFA NX software for the images. Ethical clearance was obtained from the Ethical Committee, Yenepoya University before the onset of the study.

After selecting the OPG image of a mandibular canine (either right or left) from the archives following measurements were taken using GIMP software:

- Maximum tooth length(T'),
- Maximum pulp length (P'),
- Maximum root length from cement enamel junction to root apex (R'),
- The pulp and root width at level A (CEJ), at level C (mid root length), and at level B (mid-point between CEJ (A) and mid root length (C) are made.

Ratios between the length and width measurements of the same tooth were calculated to avoid measurement errors due to differences in magnification of the image on the radiograph. The ratios calculated according to Kvaal's technique were:

- Pulp length /root length (P),
- pulp length /tooth length (R),
- pulp/root width at three different levels A, B, and C (a', b', and c'),

- Mean of all ratios(M),
- Mean of length ratios(L),
- Mean of width ratios(W).

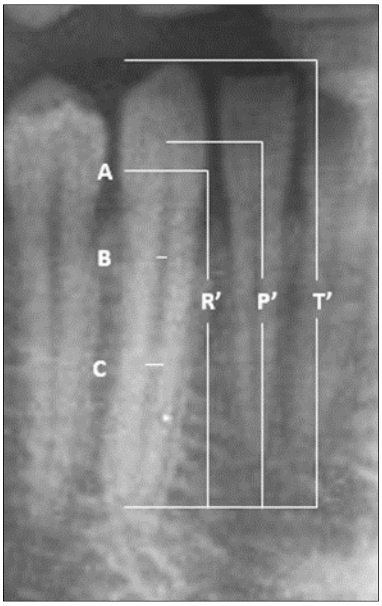

Figure 1 Measurements performed according to the method of Kvaal et al. [7] on panoramic radiograph

Chronological age was calculated by subtracting the date of birth of the individual from the date of radiographic exposure.

3. Results

Age and gender distributions are tabulated (Table 1).

Table 1 Age and gender distribution of the study groups

			Sex		Total
			F	M	
Age group	16-26	Count	3	4	7
		% Within Age group	42.9%	57.1%	100.0%
	26-36	Count	2	2	4
		% Within Age group	50.0%	50.0%	100.0%
	36-46	Count	4	3	7
		% Within Age group	57.1%	42.9%	100.0%
	46-56	Count	3	3	6
		% Within Age group	50.0%	50.0%	100.0%
Total		Count	12	12	24
		% Within Age group	50.0%	50.0%	100.0%

Pearson's correlation is used to correlate chronological age with the morphological parameter. We observed that chronological age significantly correlated with a, a', b', c', P, R, A, B, C, M, W, and L.

3.1. Multiple Regression Analysis

R square is 0.944 (94.4). The regression model is significant with p<0.001.

Subjects' age was modeled as a function of the morphological variables (predictors), and to optimize the model, a stepwise linear regression analysis was performed to find these statistically significant predictors of chronological age (Table 2).

Table 2 Stepwise regression analysis

Coefficients						
Model		Unstandardized Coefficients		Standardized Coefficients	t	p-value*
		B	Std. Error	Beta		
3	(Constant)	116.086	9.783		11.866	<p0.001
	M	-363.005	15.952	-1.091	-22.756	<0.001
	L	79.873	15.015	0.253	5.320	<0.001
	r	0.100	0.038	0.099	2.610	0.017

a. Dependent Variable: chronological; *p value< 0.001 =Significant

Following regression equation was obtained.

Regression equation:Estimated age=116.086-363.005*M+79.873*L+0.1*r

The regression equation with selected variables explained 94% of the total variance (R^2 = 0.944)

Table 3 Correlation between chronological age and estimated age:

	N	Correlation	p-value
Chronological & Estimated age	24	0.989	<0.001

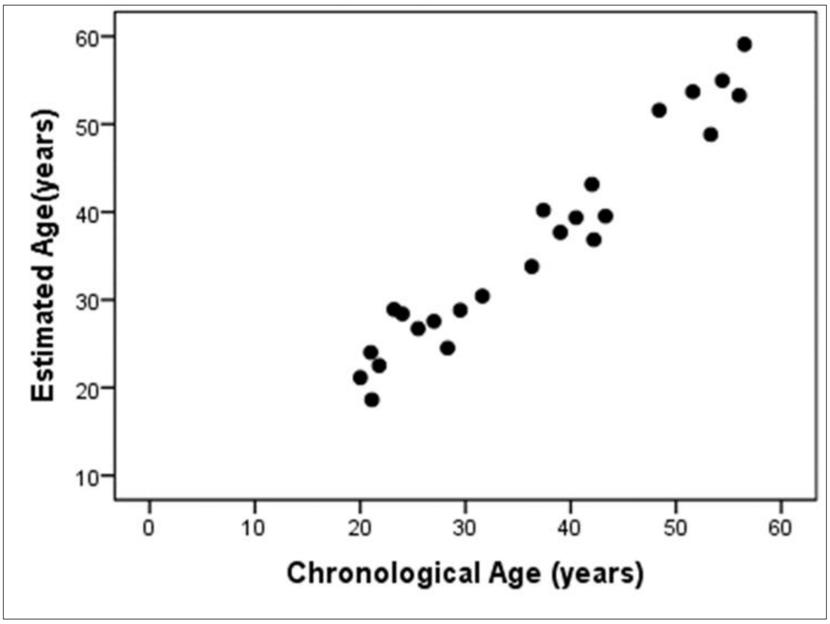

Figure 2 Scatter plot: Correlation between estimated and chronological age

The paired t-test is used to compare chronological age and estimated age. We observed that there is no significant difference(P<0.001) between chronological age and estimated age. The scattered plot graph (FIG 2) shows that the values are equally distributed; hence, the regression model fits the trend of the data reasonably well.

Table 4 Comparison between chronological age and estimated age in males and females

Sex		Mean	N	Std. Deviation	p-value*
F	Chronological	36.7675	12	12.64613	0.118
	Estimated age	35.3886	12	12.98043	
M	Chronological	36.0600	12	12.69383	0.079
	Estimated age	37.4192	12	11.51635	

*p value<0.05 - significant

Paired t-test is used to compare chronological age and estimated age. We observed that there is no significant difference between chronological age and estimated age in males and females.

Table 5 comparison between chronological age and estimated age in each age group

Age group (Years)		Mean	N	Std. Deviation	p-value*
16-26	Chronological	22.3729	7	1.93765	
	Estimated age	24.3343	7	3.86028	0.103
26-36	Chronological	29.1000	4	1.95448	
	Estimated age	27.8314	4	2.50529	0.260
36-46	Chronological	40.1029	7	2.62603	
	Estimated age	38.6548	7	2.93745	0.219
46-56	Chronological	53.3667	6	3.02038	
	Estimated age	53.5741	6	3.43496	0.877

*p value<0.05 – significant

There was no significant difference between chronological and estimated age (Table 4) for any of the age groups (P-value < 0.05) thus signifying that the derived formula is appropriate for all the selected age groups.

4. Discussion

Age estimation is of great importance for the identification of victims of accidents and crimes. In the event of living individuals without valid identification documents, such as refugees and adopted children, certification of chronological age is essential to obtain civil rights and social benefits [7]. Age estimations from teeth are frequently used, because teeth may be preserved long after all other tissues, even bone, have disintegrated, but unlike bone, they can also be inspected directly in living individuals [7]. Dental age estimation in adults is usually accomplished using a variety of approaches. Most of these procedures necessitate tooth extraction and, in most cases, tooth sectioning/processing, which may not be possible in living people. As a result, several authors have presented radiologic procedures for estimating dental age in living humans. Few are known, and they're all based on one- or two-dimensional radiography measures of the shrinkage in the tooth pulp cavity caused by secondary dentin development as people become older [3].

In 1925, Bodecker[10] discovered that the apposition of secondary dentin was related to age. Kvaal et al [7] proposed a method in 1995 that uses periapical radiographs to quantify the length and width of the pulp cavity and tooth. The ratios of the pulp cavity and tooth measures were associated with age, and regression models were developed to predict the age of unknown patients, with Paewinsky et al. confirming the method's applicability on orthopantomograms [9]. While the authors achieved high levels of accuracy in age prediction (mean error 3 to 4.5 years), they recommended that future studies look into "the effect of race and culture in model parameters" [11]. As a result, this research was conducted to determine the chronological age of individuals in our sample population.

In this study, the same method was applied to estimate age using orthopantomography, and different parameters were determined as outlined in the original procedure. However, only mandibular canines were chosen since studies on canines in other populations revealed the strongest association with chronological age [8]. Canines are also the oldest teeth and are subjected to less wear due to diet than posterior teeth. There were a total of 24 age and gender-matched panoramic radiographs. Because Kvaal et al. [7] found no significant differences between teeth on the left and right sides of the jaw, teeth from either side were processed, depending on which side was most suited for measurement. Various characteristics such as pulp length, tooth length, and root length and their ratios were used, as these ratios were proposed to adjust for possible magnification and angulation problems in most radiographs.

In the present study, Pearson's correlation coefficients between age and morphological variables showed that the variables 'M', 'L' and 'r' correlated highly significantly with age. (Correlation coefficient r^2-0.94). This was consistent with the study of Patel et al. [11] Subjects' age was modelled as a function of the morphological variables (predictors), and to optimize the model, a stepwise linear regression analysis was performed to find these statistically significant predictors of chronological age. It was found that the variables 'M', 'L' and r' contributed significantly to the fit, yielding the following linear regression formula:

$$\text{Estimated age} = 116.086-363.005*M+79.873*L+0.1*r.$$

The present study showed no significant influence of gender on age estimation using canine tooth measurements, which was similar to the findings of previous studies [7, 12, and 13]. In the present study, there was no significant difference between chronological and estimated age for any of the age groups ('P' < 0.05) signifying that the derived formula is appropriate for all the selected age groups. This finding was consistent with the studies by Saxena [13], Singaraju et al [14] Parikh N et al [6], and Juneja et al [12]. The differences between the current study and other studies could be affected by various factors. It is well-known that there are differences in tooth development, tooth size, and pulpal cavity shape in demographic ethnic groups.

The results of the study are promising; however, they cannot be generalized to other populations. The study was limited to the mandibular canines because it is the long-lasting tooth and is easiest to analyze due to the largest pulp area among all the single-rooted teeth. The procedure, however, cannot be used in situations where these teeth are missing. Our study population made a minor attempt to build a population-specific regression equation utilizing Kvaal's technique for dental age estimate using orthopantomography. For a more exact age estimate, further validation with bigger sample size and the inclusion of other factors in the regression model will provide deeper insight into the technique of age estimation in living persons.

Limitations

Minor observational variations are noted on measuring Maximum tooth length, Maximum pulp length, Maximum root length from cement enamel junction to root apex, the pulp and root width at level A (CEJ), at level C (mid root length), and at Level B (mid-point between CEJ (A). As the study was limited to mandibular canines, it cannot be applied for adults with missing canines. A larger sample size may be required for deeper insight into age estimation in our population. In this study, the parameters used in the original Kvaal method were measured using OPGs of the study population, to estimate the age from pulp tooth area ratio of mandibular canine.

5. Conclusion

Thus, within the limitations of the present study, it can be concluded that there is a significant correlation between age and morphological variables, and based on these variables chronological age can be determined with an accuracy of 94 % in our population. Thus, the derived population-specific regression equation can be potentially used for the estimation of the chronological age of the study population. The study also indicates Kvaal's technique of age estimation in adults can be applied on orthopantomography instead of the typical periapical radiographs if the selection criteria are respected and good quality orthopantomography with clear radiological images are used.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no conflict of interest.

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