Original Article

Comparative Analysis of Kvaal's and Cameriere's Methods for Dental Age Estimation: A Panoramic Radiographic Study

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ABSTRACT

Background and Aim: Age estimation is one of the indicators employed to identify an individual in forensic sciences. Teeth are frequently used as they can be preserved for long time even after many of the tissues have disintegrated. The radiological techniques of age estimation such as Kvaal's and Cameriere's are simple, noninvasive, and reproducible. These are less time-consuming and do not necessitate extraction. Hence, a study was conducted to evaluate and compare the accuracy of Kvaal's and Cameriere's methods for dental age estimation using panoramic radiographs.

Materials and Methods: Panoramic radiographs of 120 patients within the age group of 20–60 years, reporting to the Department of Oral Medicine and Radiology over a period of 3 years were selected from the archives of database based on inclusion and exclusion criteria. Radiographs of patients were divided according to age into four groups with an interval of 10 years, each group comprising of 30 individuals (15 males and 15 females). The mandibular cuspid, first bicuspid, and second bicuspid on either left or right side were selected for analysis as these teeth are not likely to undergo wear and tear. The required measurements were performed using Adobe Photoshop CS5 for both the methods.

Results and Conclusion: The data were subjected to Pearson's correlation analysis, Stepwise linear regression analysis, Student's unpaired *t*-test, ANOVA, and Bonferroni *post hoc* analysis. Kvaal's method was found to be ideal compared to Cameriere's method to predict age. The best tooth to be considered for predicting age using Kvaal's method was found to be tooth number 34.

Key Words: *Age estimation, panoramic radiography, pulp/tooth area ratio, radiographic method*

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Introduction

Age estimation is an important step of dental profiling in forensic sciences. It has applications in postmortem identification as well as living individuals, in whom chronological age is under dispute.[1] The first known attempts that used teeth as an indicator of age originated from England during the early 19th century. Edwin Saunders, a dentist, was the first to publish information regarding dental implications in age assessment by presenting a pamphlet entitled "Teeth A Test of Age" to the English parliament in 1837.[2] Several authors have reported different techniques for dental age estimation in forensic literature. Among those are morphological, biochemical, and radiological techniques.[2,3]

Most commonly used morphological techniques are based on assessment of teeth (*ex vivo*).[2] These methods require extraction and preparation of microscopic sections of at least one tooth from each individual. These methods cannot be used in living individuals and in cases where it is not acceptable to extract teeth for ethical, religious, cultural, or scientific reasons.[3] Apart from that, these methods necessitate destruction of dental evidentiary material.[4] The morphological features assessed include attrition, secondary dentin, periodontal attachment, translucent apical zone, cementum apposition, and root resorption.[3]

The biochemical methods are based on the racemization of amino acids. The racemization of amino acids is a reversible first-order reaction and is relatively rapid in living tissues in which metabolism are slow. Aspartic acid has been reported to have the highest racemization rate of all amino acids and to be stored during aging. In particular, L-aspartic acids are converted to D-aspartic acids and thus the levels of D-aspartic acid in human enamel, dentine, and cementum increase with age.[2]

The radiographic methods neither require tooth extraction nor processing. They utilize radiographic images for age

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estimation which is simple, noninvasive, and reproducible. These methods can be utilized on living as well as the unknown dead.[2] Further, procedures such as digitalization of panoramic radiographs and computer-assisted image analysis avoid the bias in observer's subjectivity and improve reliability, accuracy, and precision.[5]

In 1994, Kvaal and Solheim presented a method which combines radiological and morphological measurements, and therefore, extraction was still required. At least for some teeth, regression formulas were calculated omitting the use of morphological parameters. As a continuation of this method, Kvaal *et al*. reported a method which is based on radiological measurements only. The method uses length and width measurements of the tooth and dental pulp on radiographs.[4]

One of the best-known features of aging is a reduction in size of the pulp chamber, caused by the continual secretion of dentinal matrix by odontoblasts. In 1925, Bodecker ascertained that the apposition of secondary dentine was correlated with chronological age. Secondary dentine has been studied by several methods: Sectioning and radiographs or radiographs alone. One such method based on radiographs alone was given by Cameriere *et al*. This method investigates the relationship between age and the ratio of the pulp/tooth (P/T) area in digitalized radiographs.[6]

Taking into account several previous studies on Kvaal's and Cameriere's methods, the main aim of this study is to verify and compare the accuracy of Kvaal's and Cameriere's methods for dental age estimation using panoramic radiographs.

Study

Aims

1. To estimate the dental age using digital panoramic radiographs by Kvaal's method
2. To estimate the dental age using digital panoramic radiographs by Cameriere's method.

Objective

1. To assess and compare the age differences between the estimated dental age and chronological age by Kvaal's and Cameriere's method
2. To determine the most accurate method of age estimation out of the two methods.

Materials and Methods

Digital panoramic radiographs of 120 patients comprising of 60 males and 60 females within the age group of 20–60 years, recorded during the period 2012–2015 were selected based on inclusion and exclusion criteria from the archives of database (Sirona Orthophos XG5 Digital OPG Machine) [Figure 1]. Since the study was retrospective, patient's consent could not be obtained. Ethical clearance was obtained from the institutional ethical committee.

Images were recorded as high-resolution JPEG files with patient's identification number, sex, date of birth, and date of radiograph taken. The chronological age was calculated by subtracting the date of radiograph taken from the date of birth. Three teeth were selected on the panoramic radiograph-mandibular cuspid, first bicuspid, and second bicuspid on either left or right side. In most of the cases, the left side of the mandible was considered for uniformity. In cases where exclusion criteria did not facilitate the selection of teeth on the left side of the mandible, teeth from the right side were analyzed. The reason for selecting these teeth was that these teeth are least likely to undergo wear and tear. The measurements were carried out on the panoramic radiographs for all three types of teeth with the aid of the computer program Adobe Photoshop CS5 (Adobe Systems Incorporated, San Jose, California, USA).

Figure 1: The panoramic machine (Sirona Orthophos XG 5 Digital Orthopantomograph Machine)

Inclusion criteria

Digital OPGs from patient's database within the age group of 20–60 years having mandibular cuspid, mandibular first bicuspid, and mandibular second bicuspid on either the left or right side.

Exclusion criteria

Digital OPGs from patient's database with following pathologies in the teeth selected for measurements:

1. Impacted teeth
2. Teeth with large carious lesions, vestibular radiopaque fillings, and crowns
3. Teeth with pathological processes in the apical bone visible on the radiograph
4. Root-canal treated teeth
5. Teeth with severe attrition
6. Orthopantomograms showing badly rotated teeth
7. Teeth with large areas of enamel overlap between neighboring teeth.

Study sample

Radiographs of patients were divided into four age groups [Table 1] with an interval of 10 years, each group comprising 30 individuals (15 males and 15 females).

Methodology

Kvaal's technique

The following measurements were carried out on OPGs [Figure 2]:

1. The maximum tooth length – T length
2. The pulp length – P length
3. The root length on the mesial surface from the cementoenamel junction (CEJ) to the root apex – R length
4. The root and pulp width at level A (CEJ) – R width at A, P width at A
5. The root and pulp width at level C (midroot) – R width at C, P width at C
6. The root and pulp width at level B (midpoint between the CEJ and midroot) – R width at B, P width at B).

Vertical measurements were done by dragging two horizontal lines from the top ruler and horizontal measurements were done by dragging two vertical lines from the left hand corner ruler [Figure 3]. 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. These ratios were: pulp/root (P/R) length, P/T length, tooth/root length, and P/R width at three different levels: at the enamel–cementum junction (A), at the midroot length (C), and at the midpoint between the CEJ and midroot level (B) (P/R at A, B, and C).

Table 1: Age and genderwise distribution of the study sample

Group	Age group (years)	Number of individuals
Group I	>20 and ≤30	30 (15 males and 15 females)
Group II	>30 and ≤40	30 (15 males and 15 females)
Group III	>40 and ≤50	30 (15 males and 15 females)
Group IV	>50 and ≤60	30 (15 males and 15 females)
Total		120

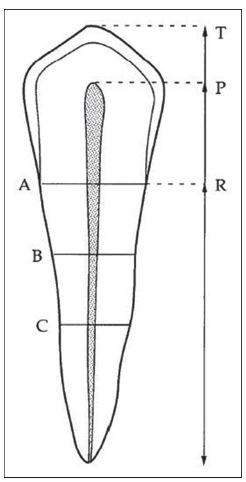

Figure 2: The measurements required for Kvaal's method

Cameriere's technique

The following measurements were carried out on OPGs [Figures 4 and 5]:

1. Pulp chamber area
2. Tooth area.

This was done using the polygonal lasso tool. It was used to click in the premolar image to set the starting point of the premolar shape; the cursor was moved to a close point of the tooth profile and clicked again. A straight line from the first point selected was drawn. Clicking was continued to set endpoints for subsequent segments along the premolar profile [Figure 4].

A minimum of 20 points from each tooth outline was identified and connected with the line tool. The selected area was copied and pasted on a new layer, which gets added to the active working area superimposed on the premolar image. This new layer was renamed "premolar" and added to the layer palette [Figure 4].

To select the pulp chamber area, the same procedure as previously done for the premolar was done following the pulp chamber profile with the polygonal lasso. A minimum of 10 points were marked on the pulp outline. The pulp chamber

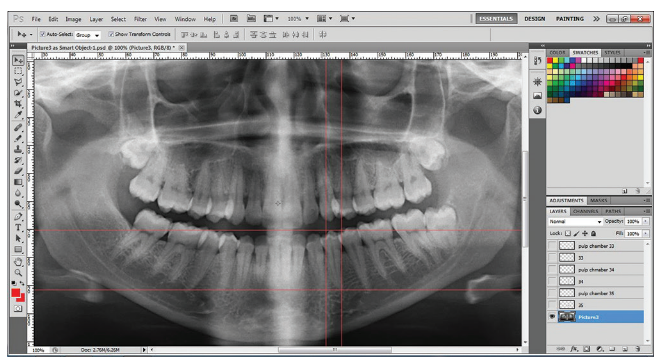

Figure 3: Vertical and horizontal measurements done using the ruler given on top and left hand corner

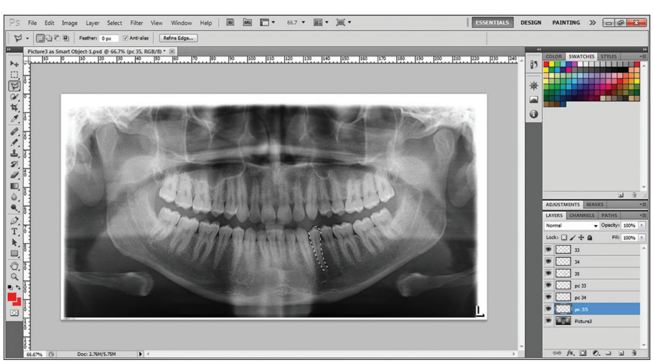

Figure 4: Premolar area selected using polygonal Lasso tool

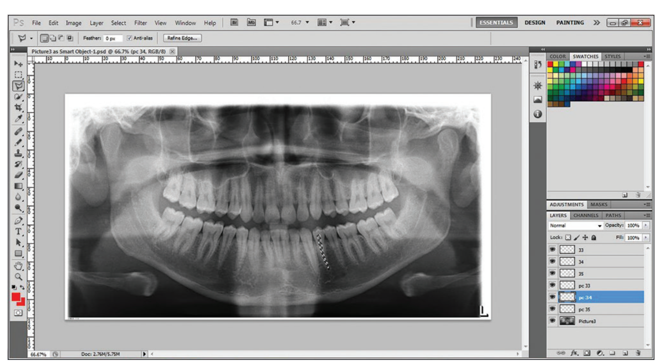

Figure 5: Pulp chamber area selected using polygonal Lasso tool

selection was copied and pasted to a new layer and renamed as "pulp chamber" [Figure 5].

The new "pulp chamber" layer contained only the premolar pulp chamber area pixels and the "premolar" layer contained the entire premolar area pixels.

To know the pixels in each layer, the histogram palette (windows > histogram) and the "pulp chamber" layer was activated by clicking on the layer name in the layer palette. In the histogram palette, the option selected layer was chosen. This shows the number of pixels contained in the "pulp chamber" layer. This value represents the first needed variable (pulp chamber area).

Next, the "premolar" layer was selected to read the number of pixels contained in the entire premolar. This value represents the second needed variable (tooth area).

To avoid measurement errors due to differences in magnification of the image on the radiograph, the ratio between the pulp chamber area and tooth area was calculated (P/T area).

Results

The data were subjected to Pearson's correlation analysis, stepwise linear regression analysis, Student's unpaired *t*-test, ANOVA, and Bonferroni *post hoc* analysis. The statistical analysis was performed by IBM SPSS Statistics for Windows, (Version 22.0. Armonk, NY: USA).

Regression equations were derived for dental age estimation based on the analysis of individual teeth [Tables 2 and 3]. Regression equations were derived for all six teeth using Kvaal's method and for tooth number 34 and 43 using Cameriere's method. No significant values were found for tooth numbers 33, 35, 44, and 45 using Cameriere's method. Hence, regression equations could not be derived for these teeth.

Pearson's correlation analysis was conducted to observe the relationship between chronological age and predicted age by Kvaal's method [Table 4]. A moderate-positive correlation was noted between the predicted age and chronological age for tooth numbers 33, 34, 35, 43, 44, and 45 with the correlation coefficients being r = 0.54, 0.55, 0.51, 0.44, 0.48, and 0.51 which was statistically significant at p value < 0.001. Pearson's correlation analysis was conducted to observe the relationship between chronological age and predicted age by Cameriere's method [Table 4]. Using tooth numbers 34 and 43, the test revealed a weak-positive correlation between the predicted age and chronological age with the correlation coefficient being r = 0.21 which was statistically significant at p value < 0.001.

In this study, Kvaal's method was found to be ideal compared to Cameriere's method to predict age as there was higher correlation between the estimated dental age and chronological age by Kvaal's method. The best tooth to be considered for predicting age using Kvaal's method was found to be tooth number 34 with highest r = 0.55 [Table 4].

Student's unpaired *t*-test was performed to compare the predicted age difference between the two methods with respect to tooth numbers 34 and 43 [Table 5]. The mean estimated dental age using Kvaal's method for tooth number 34 was 39.00 and Cameriere's method was 37.97. Hence, the mean difference between estimated dental ages using these two methods was 1.03 and this difference was statistically significant (p value = 0.01). The mean estimated dental age using Kvaal's method for tooth number 43 was 37.50 and Cameriere's method was 35.71. Hence, the mean difference between estimated dental ages using these two methods was 1.78 and this difference was statistically significant (p value = 0.001). Comparison between the predicted ages by the two methods and the chronological ages was done using ANOVA followed by Bonferroni *post hoc* analysis [Table 6].

Discussion

This study was conducted to compare Kvaal's and Cameriere's method of age estimation using panoramic radiographs of Indian population. The radiographic images were saved as high-resolution JPEG files and then imported to Adobe Photoshop CS5 image editing software program. The teeth considered for analysis were mandibular canine, first bicuspid, and second bicuspid on either the left or right side. The reason being, canines are usually the last remaining teeth in the oral cavity followed by premolars. In addition, they are the least likely to undergo wear and tear compared to other teeth of the oral cavity. Moreover, these teeth are single rooted with large pulp areas making them easy to be analyzed.[7] In most of the cases, the left side of the mandible was considered for analysis. In cases where exclusion criteria did not facilitate the selection of teeth on the left side of the mandible, teeth from the right side were analyzed. The data were subjected to statistical analysis and results were assessed.

We were able to derive regression equations for all six teeth using the Kvaal's method. Whereas, for Cameriere's method, regression equations could be derived for tooth numbers

Table 2: Stepwise linear regression model for predicting the age using Kvaal's method

Tooth number	Regression formula	Adjusted R^2	p value
33	Age = 104.7 × X1 + 100.6 × X2 − 1.1 × X3 − 48.9	0.31	<0.001*
34	Age = 81.1 × X1 + 180 × X2 − 69.6 × X4 − 1.7 × X3 + 3.7 * X5 − 36.6	0.40	<0.001*
35	Age = 97.4 × X1 + 11.7	0.21	<0.001*
43	Age = 26.5 × X6 − 5.1	0.49	<0.001*
44	Age = 147.2 × X1 + 26.1 × X7 − 33.2	0.54	<0.001*
45	Age = 148 × X1 − 2.8	0.38	<0.001*

*Statistically significant. X1: P/R at A, X2: P/T, X3: R length, X4: P/R, X5: R width at C, X6: P Width at A, X7: P width at C

34 and 43 only [Tables 2 and 3]. The other teeth could not yield significant values for regression. This could be due to the lower sample size at the subcategory level and requirement of less number of parameters (tooth area, pulp chamber area, and P/T area) selected for this method. It was found that the regression equations for both the methods varied between the individual teeth that were considered for analysis in this study. The objective of considering individual teeth rather than all the teeth was to derive separate regression equations which can be utilized even in the absence of one or more teeth.

This study revealed that Kvaal's method was more ideal compared to Cameriere's method to predict age. The R^2 and r values showed higher correlation between the estimated dental age and chronological age using Kvaal's method [Tables 2-4].

Table 3: Stepwise linear regression model for predicting the age using Cameriere's method

Tooth number	Regression formula	Adjusted R^2	p value
34	Age = 108.7 × X1 + 17.3	0.07	0.006*
43	Age = 202 × X1 − 2.7	0.14	0.04*

*Statistically significant. X1: P/T area

Table 4: Correlation between chronological age and predicted dental age using the two methods for the selected teeth

Method	Tooth number	r	p value
Kvaal's method	33	0.54	<0.001*
	34	0.55	<0.001*
	35	0.51	<0.001*
	43	0.44	<0.001*
	44	0.48	<0.001*
	45	0.51	<0.001*
Cameriere's method	34	0.21	<0.001*
	43	0.21	<0.001*

*Statistically significant

This can be attributed to the higher number of measurement parameters involving tooth and pulp lengths and widths that are required for this method. We were not able to gather review of literature regarding comparative studies between the two methods. To the best of our knowledge, this study is the first of its kind.

Irrespective of the method, the best tooth to be considered for predicting age was found to be tooth number 34. The first bicuspid showed best age correlation followed by the canine and second bicuspid. These findings are in accordance with the studies conducted by Babshet[8] and Cameriere *et al*.[6] Whereas, in a study conducted by Afify *et al*.,[9] the second premolar was found to be more closely correlated with age, followed by the canine and first premolar. The differing results could be due to difference in population group and difference in the methodology.

The parameters that were found to be significant for predicting age using Kvaal's method were: P/R at A, P/T, P/R, R length and R width at C, P width at A, and P width at C [Table 2]. The other parameters were found to be insignificant for predicting age. In this study, the width measurements contributed more strongly in predicting age compared to the length measurements. This is in accordance to previous results.[3,4,10,11] An inference that could be drawn is that secondary dentine deposition occurs more consistently along the walls of the root canal than on the roof of the pulp chamber. This is supported by Kanchan-Talreja *et al*.,[12] Prapanpoch *et al*.,[13] and Philippas[14] who have also found that dentinal thickness on the pulp roof did not increase with age as it did along the pulpal walls.

It is suggested that there are several key factors which could influence the results that are to be taken into consideration. Patient factors include individual variability of tooth size, variations in patterns of secondary dentin apposition, diet, and adverse masticatory habits. Radiographic factors

Table 5: Comparison of predicted age difference between two different age estimation methods using Student's unpaired *t*-test

Tooth number	Method	n	Mean	SD	SEM	Mean difference	p value
34	Kvaal's method	360	39.00	7.09	0.37	1.03	0.01*
	Cameriere's method	360	37.97	2.92	0.15		
43	Kvaal's method	360	37.50	8.90	0.47	1.78	0.001*
	Cameriere's method	360	35.71	5.43	0.29		

*Statistically significant. SD: Standard deviation, SEM: Standard error of mean

Table 6: Comparison of predicted age difference by two different methods with respect to actual age using ANOVA followed by Bonferroni *post hoc* analysis

Tooth number	Method	n	Mean	SD	p value	Significant difference	p value
34	Kvaal's method	360	39.00	7.09	0.08		
	Cameriere's method	360	37.97	2.92			
	Actual age	360	37.82	10.89			
43	Kvaal's method	360	37.50	8.90	0.002*	C versus K	0.02*
	Cameriere's method	360	35.70	5.43		C versus A	0.003*
	Actual age	360	37.82	10.89			

*Statistically significant. SD: Standard deviation include differences in magnification of radiographs and the factors which influence the image quality such as errors in exposure, projection angle, radiation dose, accuracy of patient positioning, and tongue position.[15] The observer's ability to reproduce reference points and perform linear measurements on digital radiographs also play an important role.[12] According to Kolltveit *et al*., the main source of errors in measurement seems to be difficulties in recognizing reference points on radiographs. When the three-dimensional pulp is reproduced on a two-dimensional radiograph, its edges become blurred due to the cylindrical form of the pulp which, in turn, could also be responsible for observer variations.[16]

Conclusion

Kvaal's method was found to be more ideal compared to Cameriere's method to predict age. The best tooth to be considered for predicting age using Kvaal's method was found to be tooth number 34. This study has the limitation of undersampling at subcategory level. Reliability of inter- and intra-observer variability were also not established.

However, the present study helped us to narrow down the significant measurement parameters which could be considered for age estimation using Kvaal's method. Hence, there is a scope of pursuing this preliminary study with larger sample size to get significant values and better results. Inter- and intra-observer variability can also be included in future scope of research. The significant parameters that were found in this study need to be considered in the future studies.

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Conflicts of interest

There are no conflicts of interest.

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