ORIGINAL ARTICLE

Estimation of age by Kvaal's technique in sample Indian population to establish the need for local Indian-based formulae

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Abstract

Context: Age estimation using radiographs by Kvaal and coauthors has shown to be reliable method, possible variation in ethnicity restricts its use in sample Indian population. **Aims:** Thus this study was aimed at evaluating the accuracy of age estimation formula of Kvaal and coauthors developed for Norwegian population. **Materials and Methods:** From the subjects (1-100) between the age group 20 and 50 years digitized intraoral periapical (IOPA) radiograph of maxillary central incisors was taken and length and width of the teeth were measured and their ratios were calculated and applied to Kvaal and coauthors formula. The estimated age and chronological age were compared, less accurate results were found in sample Indian population. Modified Kvaal's formula was then developed by using regression analysis of the ratios and to evaluate the accuracy of this formula, the study was repeated using same criteria and methodology on another subjects (101-200). **Results:** Using Kvaal's formula standard error of estimated age was more in sample Indian population when compared with Norwegian population. Then modified Kvaal's formula was developed and applied to sample Indian population, which showed accurate results. **Conclusion:** This study concludes that formula which was derived from Norwegian population is not applicable to sample Indian population.

Key words: Age estimation, dental radiographs, Kvaal's method, maxillary central incisor, secondary dentin and dental pulp

Introduction

Age estimation is of great importance for the identification of victims of accidents and crimes. In case of living individual such as refugees and adopted children who have no acceptable identification documents, confirmation of chronological age is required in order to avail the civil rights and social benefits.[1]

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Antemortem age estimation can be done by processing radiographs of long bones and teeth. Postmortem age estimation involves analyzing the remains of bones and teeth directly and also by using radiographs.[2] Teeth show great resistance to postmortem alterations caused by humidity, high temperature, microbial activities, and mechanical forces.[3] Also, developmental and physiological changes of the tooth can be related to chronological age. Hence, for these reasons teeth can be better predictors of age compared to bone.[4]

With advancing age, secondary dentin is deposited along the walls of the dental pulp chamber, leading to a reduction in the size of the pulp cavity. This age-related change can be evaluated from ground sections and from dental radiographs of the teeth.[5] Ground sections require tooth extraction and preparation of microscopic sections. These

methods are destructive in nature and time consuming. Also, they may not be acceptable for ethical, religious, cultural, and scientific reasons.[2]

Dental radiography is a simple technique, used regularly in dental practice which can be employed in forensic age estimation as a nondestructive method.[2] Intraoral periapical radiographs have been employed for age estimation for various reasons.[2] Though age estimation using radiographs by Kvaal and coauthors has shown to be reliable method, possible variations in ethnicity restricts its use in sample Indian population. This has also been substantiated by the study conducted by Babshet and coauthors in local population.[6]

Essentially while age estimation using radiographs is undoubtedly a practical, convenient, and fairly accurate method; questions remain on the uniformity of the results obtained while using a single formula for varied ethnicity.

Aims and objectives

Our study comprised of two parts. In the first part, we evaluated the accuracy of Kvaal's formula in sample Indian population while comparing the results with those obtained by them in the Norwegian population. In the second part of the study, we developed a new formula (modified Kvaal's formula) for a sample Indian population by using the ratios from first part of the study and tested it again on another group of subjects and compared the results obtained by using Kvaal's formula and modified Kvaal's formula to establish the need for local Indian-based formulae.

Materials and Methods

The 200 study subjects included were males/females between the age group 20 and 50 years visiting the Department of Oral Medicine and Radiology, for routine check-up. Exact chronological age of the patient was recorded with date of birth, as per patient's information.

In the first part of the study, intraoral periapical (IOPA) radiograph of maxillary central incisors was taken from (1-100) 100 subjects using paralleling cone technique to avoid angulations changes. These IOPA radiographs were digitized using HP Scanner (X-ray scanner A_3), and images were transferred to computer. Length and width of the teeth were measured using Image-Pro Plus II software (Media, Cybernetics, USA) [Figures 1-5].

The measurements included

- Length of the tooth
- Length of the root
- Length of the pulp
- Pulp and root width at three different levels:
  - At the enamel cementum junction (ECJ)
  - At the midpoint between the ECJ and mid root level
  - At the mid root level.

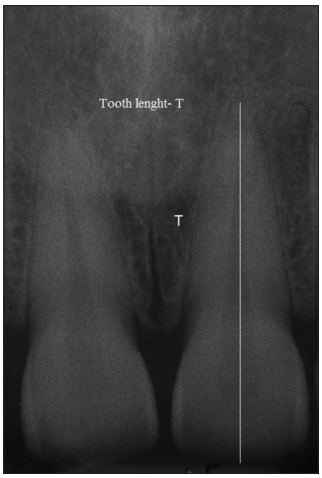

Figure 1: Tooth length- T

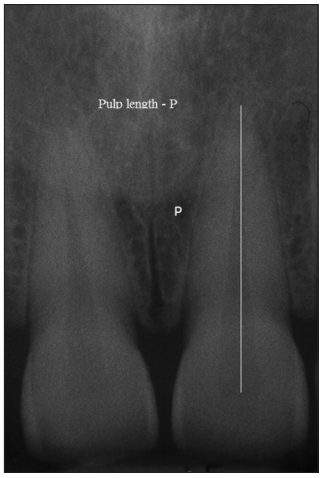

Figure 2: Pulp length- P

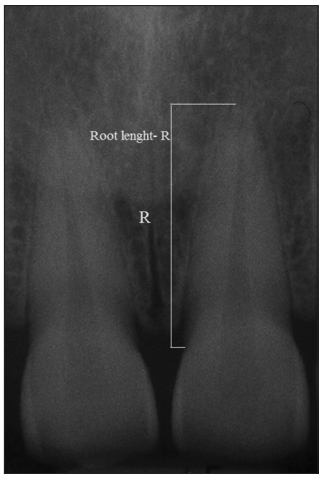

Figure 3: Root length- R

Ratios were calculated based on measurements taken in order to avoid errors due to differences in magnification of the image on the radiograph.

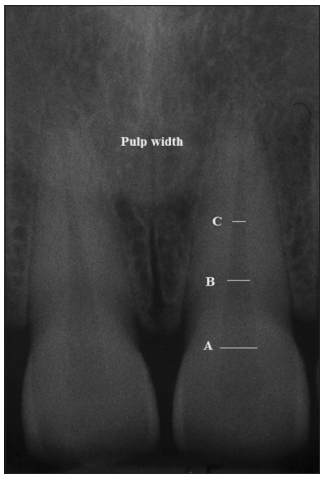

Figure 4: Pulp width at three different levels

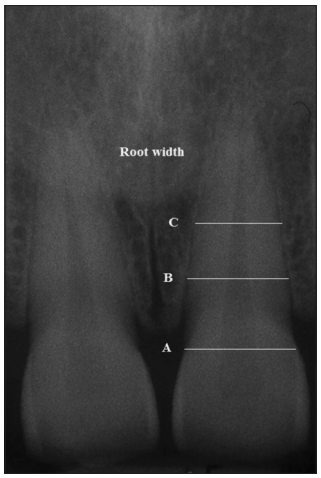

Figure 5: Root width at three different levels

The ratios calculated were:
- P = Pulp length/root length
- R = Pulp length/tooth length.

Ratios of the pulp/root width at three different levels:
- At the ECJ (A)
- At the midpoint between ECJ and mid root level (B)
- At the mid root level (C).[7]

The obtained values were applied to the formula developed to estimate the age from maxillary central incisor given by Kvaal and coauthors.

AGE = 110.2 -201.4 (M) -31.3 (W − L)

$$M = \frac{P + R + A + B + C}{5}$$

$$W = \frac{B + C}{2}$$

$$L = \frac{P + R}{2}$$

W = Mean value of width ratios from level B and C
L = Mean value of length ratios P and R
W − L = Differences between W and L,[7]

The estimated age was compared with the chronological age recorded and the efficacy of the formula in estimating the age was evaluated. It was found that the Kvaal's formula produced less accurate results in our population when compared to the results obtained by them in Norwegian population.

In the second part of the study, modified Kvaal's formula was developed by using the ratios obtained from first part of the study.

The obtained formula is as below:
Age = 33.5 – 18.6 (M) -3.49 (W − L)

M = Mean value of all the ratios excluding T (T = tooth length)
W = Mean value of width ratios from level B and C
L = Mean value of length ratios P and R
W − L = Differences between W and L

The study was repeated by applying modified Kvaal's formula on another 100 subjects (101-200) to compare its efficacy against the Kvaal's formula in Indian population.

Results

Pearson correlation test showed the negative correlation existed between the ratios and chronological age. The correlation between the age and ratios B (pulp and tooth width ratio at the midpoint between ECJ and mid root level), C (pulp and root width ratio at the mid root level), and W (mean value of width ratios from level B and C) were highly significant. The correlation between the age and ratios A (pulp and root width at the enamel cement junction), P (pulp length/root length), R (pulp length/tooth length), L (mean value of length ratios P and R), and M (mean value of all the ratios excluding T) were significant [Table 1].

In the first part of the study these ratios were applied to age estimation formula using maxillary central incisor given by Kvaal and co-authors. Standard error of estimated age (±12.3 years) from sample Indian population [Table 2] was more compared to standard error of estimated age (±9.5 year) in Norwegian population as the study conducted by Kvaal and coauthors.

In the second part of the study, modified Kvaal's formula for sample Indian population was derived.

That is, Age = 33.5 -18.6 (M) -3.49 (W − L)

Using another 100 subjects same ratios were calculated and applied to the modified Kvaal's formula and age estimation

was done. Standard error of estimated age of these subjects was ± 6.5 years [Table 3].

Standard error of estimated age by modified Kvaal's formula (±6.5 years) was less when compared to standard error of estimated age of Kvaal and coauthors formula in Norwegian population (±9.5 years).

Standard error of estimated age by modified Kvaal's formula (±6.5 years) was less when compared to standard error of estimated age of Kvaal and coauthors formula (±12.3 years) in sample Indian population [Table 3].

Discussion

Age is one of the essential factors in establishing the identity of a person. Estimation of the human age is a procedure adopted by anthropologists, archeologists, and forensic scientists.[4]

Table 1: Correlation coefficients between chronological age and ratios of measurements from dental radiographs and mean of the ratios from either of maxillary central incisor, *n*=100 (1-100)

Measurements	Relationship with age		
	r-value	*P* value	Significance
T	−0.30	<0.01	S
P	−0.21	<0.05	S
R	−0.22	<0.05	S
A	−0.38	<0.01	S
B	−0.52	<0.001	HS
C	−0.52	<0.001	HS
M	−0.37	<0.01	S
W	−0.57	<0.001	HS
L	−0.20	<0.05	S
W-L	−0.16	<0.10	

P value: Level of significance <0.05. HS: Highly significant; *r*: Correlation coefficient; S: Significant; B: Pulp and tooth width ratio at the midpoint between enamel cementum junction and mid root level; C: Pulp and root width ratio at the mid root level; W: Mean value of width ratios from level B and C; A: Pulp and root width at the enamel cement junction; P: Pulp length/root length; R: Pulp length/tooth length; L: Mean value of length ratios P and R; M: Mean value of all the ratios excluding T; T: Total length

Table 2: Age estimation of the sample Indian population using Kvaal's formula (subjects 1-100)

Kvaal's formula	SEE (years) in comparison with chronological age
Age=110.2-201.4 (M)-31.3(W-L)	±12.3

SEE: Standard error of estimate

Table 3: SEE comparison between Kvaal's formula in sample Indian population and modified Kvaal's formula

Kvaal's formula in sample Indian population	Age=110.2-201.4 (M)-31.3 (W-L)	±12.3
Modified Kvaal's formula in sample Indian population	Age=33.5-18.6 (M)-3.49 (W-L)	±6.5

SEE: Standard error of estimate

For age estimation, different methods are available; however, invasive methods using extracted teeth, ribs, or femur cannot be used in living individuals.[8]

Radiographic age estimation methods using teeth are advantageous when compared to other methods, by being noninvasive and providing collectability of data and simplicity in estimation.[9]

Kvaal and coauthors developed an age estimation method by using measurement of six teeth (maxillary central incisor, maxillary lateral incisor, maxillary second premolar, mandibular lateral incisor, mandibular canine, and first premolar) observed on orthopantomogram (OPG) or periapical radiographs. The measurement included length and width ratios such as pulp-root length (P), pulp-tooth length (R), tooth-root length (T), pulp-root width at ECJ (A), pulp-root width at mid-root level (C), pulp-root width at midpoint between level C and A (B), mean value of all the ratios excluding T (M), mean value of width ratios B and C (W), mean value of length ratios *P* and R (L). These ratios are used in order to compensate for magnification and angulations errors of teeth and the radiograph. Age estimation formula was formulated by using six teeth, three teeth, and also individual teeth.[7]

The present study was conducted to analyze applicability of age estimation formula of Kvaal and coauthors on sample Indian population using maxillary central incisor with age groups 20-50 years, using IOPA radiographs. Since the error of age estimation was higher with Kvaal's formula, a new age estimation formula was derived from obtained length and width ratios. The developed formula was then tested on an additional 100 subjects.

Maxillary central incisor was selected because it is a single-rooted tooth with the largest pulp area, which is often present in old age. Additionally angulation errors in radiography are avoided while using central incisors compared to canines. Maxillary anterior teeth show considerably less crowding and attrition as compared to their mandibular counterpart, and contain more secondary dentin tissue than canines.[10]

Intraoral periapical radiograph were used because they are fast, inexpensive, and routinely used in dentistry.[11] The use of a single tooth, avoids unnecessary exposure of other areas.

Ratios between the tooth and pulp measurements as suggested by Kvaal's and coauthors were calculated and used in the sample Indian population. Estimated age was found to have a standard error of ± 12.3 years, which was more when compared to standard error of ± 9.5 years in study conducted by Kvaal and coauthors in Norwegian population.

Ethnic differences and variation in the pattern of secondary dentine deposition in sample Indian population have been considered to have large differences between estimated and actual ages. A recent study by Babshet and coauthors highlighted the need for population specific equations due to differences in ethnicity.[6]

This lack of correlation can be attributed to the fact that with advancing age, secondary dentin is deposited along the wall of the dental pulp chamber leading to a reduction in the size of the pulp cavity.[5] The quantity of secondary dentin deposition is influenced by factors like racial, ethnic, diet, and lifestyle.

In the present study, correlation coefficient between the chronological age of the subjects 1-100 and width ratios B, C, and W were highly significant when compared to the length ratios. Similar results were shown by and Bosmansa *et al*.[9]

Using the regression analysis of the data recorded a modified Kvaal's formula was devised, that is, Age = 33.5 -18.6 (M) -3.49 (W-L).

Then the modified Kvaal's formula was evaluated by applying the tooth, root, pulp length, and width ratios from the sample Indian population and age estimation was done. When compared with chronological age, standard error of estimation was ± 6.5 years.

Standard error of estimated age by using modified Kvaal's formula was also less (±6.5 years) when compared to standard error of estimated age of Kvaal's formula in sample Indian population (±12.3 years).

Standard error of estimated age by modified Kvaal's formula was also less (±6.5 years) when compared to standard error of estimated age of Kvaal's formula used in Norwegian population (±9.5 years).

Conclusion

From this study we conclude that Kvaal's age estimation formula developed on Norwegian population, when applied to a different population such as sample of Indian population, shows higher error of age estimation. Hence, formula which was derived from Norwegian population (Caucasian) is not applicable to other population. Population specific formulae have to be derived to get accurate results.

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