Application of Kvaal’s Technique of Age Estimation on Digital Panoramic Radiographs

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Abstract

Different types of radiographs of dental structures undoubtedly offer a least destructive approach to age estimation of individuals, but most of these methods are based on the calcification stages of the developing teeth. Very limited studies have been carried out in India using Kvaal’s technique based on pulp changes on radiographs as a tool for age estimation. Further, only few studies have been reported so far, applying Kvaal’s technique on orthopantomograph. The present study has been carried out using Kvaal’s technique of age estimation from dental pulp size on digital orthopantomograph of Indian population.

Keywords: Age determination; Kvaal’s technique; Orthopantomograph

Introduction

Age determination has become increasingly important in forensic science not only for the identification of corpses, but also for living individuals in a multicultural society, to clarify legal queries among those of living individuals, to clarify legal queries among living individuals. Examination of teeth in many ways form a unique part of human body, as they are the most durable and resilient part of the skeleton [1]. It plays a crucial role in Forensic Medicine, especially in connection with crimes and accidents.

Literature reports different morphological 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 [2]. Examination of teeth in many ways form a unique part of human body, as they are the most durable and resilient part of the skeleton [1]. At times teeth are the only means of identification when the dead bodies have undergone changes so extensive, that external characteristics yield little information [3].

Teeth can be used as an indicator for age assessment morphologically, histologically and radiographically. Radiographic methods need an attention in this scenario as they seem to offer a harmless approach towards age estimation among all the commonly used methods.

Although most of the radiological methods are based on the calcification stages of the developing teeth, which seems to be less influenced by systemic factors like nutritional influence, none has witnessed the test of time for adults above 25 years, when the calcification is complete for all the teeth including the third molars [4].

Kvaal and Solheim presented a method of age estimation which combined radiological and morphological measurements which could be used on adults, but extraction was still required [5]. As a continuation of this method Kvaal et al. [6] reported a method of age estimation from intraoral periapical radiographs using the radiographic parameters. Later, study on age estimation was reported using the same technique on orthopantomograph also [7]. As not many studies have been carried out highlighting the importance of orthopantomographs in age estimation, the present study is an attempt to use the Kvaal’s radiographic technique based on the pulpal changes in teeth to estimate age from digital orthopantomographs of adults.

Materials and Methods

100 subjects of either sex between the age group of 20 and 70 years were taken up for the study. The subjects were distributed according to the age as those falling between 20-29yrs, 30-39yrs, 40-49yrs, 50-59yrs, and 60-70yrs. The subjects who satisfied the set inclusion criteria i.e. having the required complement of teeth (i.e. the maxillary central incisor, maxillary lateral incisor, maxillary second premolar, mandibular lateral incisor, mandibular canine and mandibular first premolar) free from developmental or morphological abnormalities including dental caries, periodontal diseases, restorations, prosthesis, wasting diseases, pulp stoned or calcified canals were chosen for the study. Also it was made sure that the subjects selected were free from systemic disorders like hormonal deficiencies, renal diseases, blood dyscrasias, cardio-vascular diseases and syndrome associated diseases. Authentication birth certificates were procured from the subjects and were filed with another observer, not associated with the procedure of calculation of age.

Standardized digital orthopantomographs with no positional errors were taken for each of the subjects. The digital orthopantomograph machine used was the Kodak 8000C unit radiographic dental diagnostic unit IEC-601.2.7 with anode voltage of 90 Kvp and cathode current of 15 mA, with inherent filtration of 0.5 mm eq Al and total filtration > 2.5 mm eq Aluminum, the effective focal spot being 0.5×0.5 mm, the digital sensor being a sensor Charged Couple Device + Optical fiber sensor with the dimension of matrix 2500×1244 pixels and 4096–2 bits Gray scales and size of beam sensor being 5×126 mm. The images obtained were subjected to measurements using the Dimaxis software as the measuring tool. Using the mouse-driven cursor, the reference points on the images of the teeth were defined and the numbers of pixels within the defined line were given which was converted to millimeter. Measurements of maximum tooth length, pulp length and root length on mesial surface from cemento 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) and mid root length (c) ) was made. Ratios between the length and width measurements of the same tooth were calculated in order to avoid measurement errors due to differences in magnification of the image on the radiograph. The ratios calculated according to Kvaal’s technique were: the tooth/ root length (T), pulp/root length (P), pulp/tooth length(R) and pulp/ root width at three different levels a, b and c, 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). ‘M’ was taken as the first predictor and the difference ‘W-L’ as the second predictor. Co-relation was carried and regression formulae based on statistical analysis were calculated for all six teeth, three maxillary teeth only, three mandibular teeth only and each individual tooth, using the SPSS (Version 13) software. The age was assessed and compared with the actual age using the student’s t-test.

Results

This prospective study included 100 subjects of either sex between age group of 20 and 80 years for assessment of age out of which 56 were males and 44 were females (Figure 1). The mean age range of subjects in this group was 32.25 years for males and 29.08 years for females (Figure 2). Correlation and regression analysis were carried out (Tables 1 and 2). From the results of regression analysis, it was observed that the coefficient of determination R² is highest (0.385) for “Upper second premolar” indicating that age can be estimated better with this particular tooth when “M” and “W-L” are considered as predictors of age. Both “M” and “W-L” were found to be significant predictors (P<0.05). The scatter plot for age estimation from this tooth using "M" and "W-L" measurements is depicted in figures 3 and 4.

These predictors (M and W-L) were found to be effective in estimating age when used for “Upper CI” (R²=0.288). Only "W-L" was found to be significant here (P>0.05).

Similarly, the next best teeth was found to be “Lower first premolar” for estimating age using "M" and "W-L" (R²=0.248). This was followed by Lower Canine, Upper Lateral Incisor and Lower Lateral Incisor respectively.

It was observed that the coefficient of determination R² was higher (0.076) in Upper three teeth taken together compared to Lower three teeth (R²=0.049). In Upper teeth "M" was found to be a significant predictor whereas in Lower teeth, "W-L" was found to be the significant predictor.

When all the six teeth were taken together and age was estimated with "M" and "W-L" as the predictors, it was found that neither "M" nor "W-L" was a significant predictor and the co-efficient of determination was low (R²=0.017). The scatter plot diagrams for regression equations using all six teeth taking 'M' and 'W-L' measurements are depicted in figures 5 and 6.
From the above discussion we can therefore conclude that Upper second premolar would be the better tooth when using orthopantomographs for estimating age.

The age of the subjects were then estimated by substituting the values of “M” and “W-L” in the regression equation using each individual tooth, upper three teeth together, lower three teeth together and for all six of them together, and this estimated age was compared with the actual age using student’s t-test. The bar diagram depicting comparison between the mean actual age and the mean estimated age is shown in figure 7. From the comparison of actual age and estimated age given above we observe that there is no significant difference between the mean actual age and the mean estimated age in Lower Canine, Lower Lateral Incisor, Lower first premolar, Upper second premolar, Upper Lateral Incisor, Upper Central Incisor, Upper three teeth when taken together, Lower three teeth when taken together and all the six teeth taken together (P>0.05). Therefore, we conclude that “M” and “W-L” values derived from Lower Canine, Lower Lateral Incisor, Lower first premolar, Upper second premolar, Upper Lateral Incisor, Upper Central Incisor, Upper three teeth when taken together, Lower three teeth when taken together can be used as the predictors to estimate age of a person. It is also viable to take the “M” and “W-L” values of all these tooth together. Hence, “M” and “W-L” can be considered as predictors for estimating age. Also, since the coefficient of determination R2 is higher (0.385) for “Upper second premolar” in the present study, it can be concluded that this tooth can predict age most close to actual age when taking “M” and “W-L” as predictors.

**Discussion**

The aim of an ideal age estimation technique is to arrive at an age as close to the chronological age as possible. In children and adolescents, somatic development, such as skeletal maturity, height, menarche etc., has been used to assess the age when unknown. Dental age estimation has gained acceptance because it is less variable when compared to other skeletal and sexual maturity indicators [2].

**Importance of tooth in age estimation**

Tooth formation is widely used to assess maturity and predict age. Within clinical dentistry this formation aids in diagnosis and treatment planning. Chronological age, as recorded by registration of birth date, is referred to throughout an individual’s life. This information is relevant to medical and dental practice for evaluating developmental progress, for educational purposes and in legal matters [8].

Dental hard tissues, being the strongest structure in the body, are resistant to post-mortem destruction. Therefore, the use of dental evidence is the method of choice in establishing the identity of badly burned, traumatized, decomposed and skeletonised remains [9].

Estimating age from teeth is generally reliable as they are naturally resistant to post-mortem destruction. Therefore, the use of dental evidence is the method of choice in establishing the identity of badly burned, traumatized, decomposed and skeletonised remains [9].

Estimating age from teeth is generally reliable as they are naturally preserved long after all the tissues and even bones have disintegrated [10].

Evaluation of the dental development has usually played an important part in the process of age determination of children with unknown birth data. The dental maturity has often been considered a good indicator of chronologic age and has been regarded as superior to other methods for evaluation of an individual’s somatic maturity, such as methods based on the development of the hand skeleton [11].

Even if only a few teeth are available, one can still offer an age estimation, smoking habit, state of oral hygiene, and identification of individual features which may match with ante-mortem records. Where the subject has no teeth, useful information can still be gleaned from the study of any dentures and by X-raying the mouth and skull.

In forensic dentistry, determination of dental age using stages of tooth development to gauze an individual’s degree of maturity is one of the few biologic methods for monitoring physiologic development, and the dentition arguably is the only system available from prior to birth to early childhood [12].

The use of the dentition for the assessment of age appears to date from early in the last century. Many scientists probably made attempt

### Table 1: Correlation between age and the ratios of measurement.

| Teeth                  | Equation                       | R² (Coefficient of determination) | Significant predictors |
|------------------------|-------------------------------|-----------------------------------|------------------------|
| All six teeth          | Age = 30.1 + 3.48 M + 2.24 W-L | 0.017                             | None                   |
| Lower Canine           | Age = 61.5 - 98.6 M - 43.1 W-L | 0.219                             | M & W-L                |
| Lower Lateral incisor  | Age = 18.5 + 1.30 M - 13.9 W-L| 0.014                             | None                   |
| Lower first premolar   | Age = -17.8 + 17.6 M - 46.1 W-L| 0.248                             | W-L                    |
| Upper second premolar  | Age = 110 - 79.7 M + 34.4 W-L | 0.385                             | M & W-L                |
| Upper lateral incisor  | Age = 26.4 - 20.1 M + 22.7 W-L| 0.100                             | None                   |
| Upper central incisor  | Age = 31.1 - 85.1 M - 71.5 W-L| 0.288                             | W-L                    |
| Upper three teeth      | Age = 25.9 + 10.3 M + 3.57 W-L | 0.076                             | M                      |
| Lower three teeth      | Age = 14.9 + 0.61 M - 19.6 W-L | 0.049                             | W-L                    |

Table 2: Regression analysis.
for scientific dental age estimation describing 20 chronological stages from four months IU to 21 years; this employs histological sections which permit comparison with radiographs, but this has limited application both in age limit and because of destruction of the tooth structure [9].

Demirjian method was employed keeping calcification of teeth and scoring system as the base of the study but had limited applicability only up to the age of 21 years [4].

Sulaiman Al-Emran, provided the first scientific method of age estimation based on morphological and histological changes of the teeth, which employed six individual age related changes but did not include difference in colour or fluorescence from any tooth structure [4]. Willems modified Gustafson technique by using more detailed scale and by multiple regression analysis. But both these techniques employ destruction of the tooth specimen [12].

A study based on the concept that with advancing age the size of pulp cavity is reduced because of secondary dentin deposit had been carried out in 1995 as an indicator of age by Kvaal et al. [6].

A study published by Sharma and Srivastava [13] in 2010 mentions the use of digital intraoral periapical radiographs for estimation of age of individuals, wherein the authors have obtained population specific regression formulae to estimate age based on the Kvaal’s technique. Although the results obtained were slightly different from the original Kvaal’s study (1995) used on conventional radiographs, the authors have suggested the possibility of use of this method for age estimation.

Recently, a study has been published by Kanchan-Talreja et al. [14] in which, the original Kvaal’s formulae have been tested on digital intraoral periapical radiographs and have led to large errors in age estimation. The authors in the same study have also developed population specific formulae which again led to errors in age calculation but to a smaller extent than applying the original formulae. It is to be noted that the conventional method and prescribed instrumentation (such as stereomicroscope) used in the original study were not used in the above mentioned studies which could have been a possible reason for the variation in the achieved results.

Not many studies have been carried out on Indian population using Kvaal’s technique on digital orthopantomographs. In 2005, Bosmans et al. carried out a study on age estimation in Caucasian population using Kvaal’s technique on digital orthopantomographs. They concluded that there were no significant differences in actual and calculated ages especially when all six teeth were taken together for prediction of age [7].

In 2007, a study was published by Meini et al. to explore whether the previously presented regression formulae for age estimation could lead to statistically sound results when applied on Austrian population. From their study it was concluded that the regression formulae proposed by Kvaal et al. led to a consistent underestimation; while those reported by Meini et al. [15] resulted in an overestimation of age.

Another study to evaluate the reproducibility of the original method of Kvaal et al. using regression formulae analyzed on digital panoramic radiographs was published by Landa et al. and it was reported that the values of estimated ages were so distant from the real ages that this method must be discouraged as being a reliable one to estimate age on a direct digital OPGs sample [16].

Very recently, Erbudak et al. [17] carried out a study to estimate age of Turkish individuals using the linear regression models presented by Kvaal et al. and Meini et al. but observed high differences between the chronological and estimated ages. Further, the measurement ratios showed no significant or weak correlation with age which led to a conclusion that the method of Kvaal et al. using panoramic radiographs, were insufficient to precisely estimate the age of Turkish individuals as a significant difference of more than 12 years in the chronological and estimated ages derived using regression models in literature was found on panoramic radiographs in Turkish individuals [17].

From the facts quoted so far, it can be assumed that the original formulae although led to acceptable results in the original studies, yet, when the population set is changed, the applicability of the same formulae is questionable. Whether population specific formulae can lead to an improvement over the results is yet to be tested. The regression formulae used in the study by Bosmans et al. [7] were population specific and had led to acceptable results. Based on similar grounds, the present study has been carried out to test if population specific formulae could lead to acceptable results for age estimation. This study consisted of 100 subjects, with the age limit of 20-70 years, out of which maximum number of subjects of 46 were in the age group of 20-29 years and only a minimum of 4 subjects were in the group of 60-70 years. The age of the subjects were estimated by Kvaal’s method by using digital orthopantomographs after deriving population specific regression analysis. In our study, we have used digital orthopantomographs for assessment of age parallel to and Bosmans et al. study, whereas the original study by Kvaal et al. [6] used the conventional intraoral periapical radiographs for obtaining the regression formulae. Digital Orthopantomograph definitely offers the possibility and advantage of evaluation of all the teeth along with alveolar bone in both the jaws and their required measurements to be made on a single radiograph. Furthermore, a digital orthopantomograph can be acquired using a standard technique with high reproducibility, while the acceptability of intraoral radiographs is dependent on the techniques used and the practical training of the personnel.

In the present study the six teeth that were selected from both the jaws showed no significant difference in measurements between the teeth from the left and right side of the jaws, which is in consistence with the earlier study conducted by Kvaal et al. [6].

In Kvaal’s study [6], regression formula derived for all the six teeth together, substituting ‘M’ and ‘W’-L’ showed significant results with coefficient of determination being the strongest (R2=0.76) but in the present study, maxillary second premolar was seen to be the strongest predictor (R2=0.385).

When the calculated age was compared with actual age in the study by Bosmans et al. [7], no significant difference was found between the two, when taking all six teeth together and mandibular three teeth together where (P>0.05), which is similar to our study. Further in the study by Bosman et al. [7], a significant difference was found between the calculated age and the actual age when taking maxillary three teeth together or each of the six teeth individually. But in our study, we got no significant difference between the two when taking maxillary three teeth together or each of the six teeth individually (P>0.05). This difference in the results obtained could be explained on the fact that the software in the former study was Adobe photoshop (version 7.0) but in the present study, we used Dimaxis software as the measurement tool. The other reason could also be because of the racial difference as the original study was carried out on Caucasian population and our study was based on the Asian population.
Conclusion

This is a baseline study which was carried out to assess age of subjects using Kvaal’s method on digital orthopantomographs and a comparison was made between this estimated ages with the actual age of the subjects. The result of the study however gives inference for the feasibility of this technique in the Indian population on Digital orthopantomographs. In this study we have found “Upper second premolar” tooth as a good predictor of age, when taking “M” and “W-L” as the first and second predictors respectively. Further this study encourages future studies on a large sample size with adequate representation of samples from different age groups and sex distribution.

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