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Research Article

Validity of Modified Kvaal's Method of Age Estimation in North-Indian Population Using Maxillary Lateral Incisor on Digital Panoramic Radiographs: A Retrospective Study

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Abstract

Background and Aim: Dental age estimation (DAE) is one of the vital aspects in forensic dentistry. After tooth eruption, the size of the pulp cavity decreases constantly with age owing to deposition of secondary dentine. Various methods have been devised for estimating age, but the radiographical methods have the advantage of being non- invasive, easy, and fast. Previous studies have correlated age by using pulpal length (L) to width (W) ratio of different single rooted teeth of different population subset. Yet, a dearth exists in studies on North Indian population subset. Hence, the aim of this study was to investigate the relationship between the chronological age and the ratio of pulpal L/W of maxillary lateral incisor using digital panoramic radiographs (DPRs) of North Indian population.

Material and Methods: DPRs of subjects aged 18- 60 years were collected from the archives of the database of patients who visited a private Imaging Centre in North- India based on the set inclusion and exclusion criteria. These DPRs were evaluated for 134 maxillary lateral incisors on either side (Right and Left). The pulpal L/W ratio of each tooth was measured by an Oral Radiologist using the ImageJ, open-source software and were statistically analysed.

Results: The Pearson correlation coefficient (r) was 0.939 indicating a statistically significant correlation between the pulpal L/W ratio of the maxillary lateral incisor with chronological age (P = 0.000*).

Conclusion: The ratio of pulpal L/W of maxillary lateral incisor is of paramount importance and can be used as a predictor of age in North- Indian population using modified Kvaal's method.

Keywords: Age Determination by Teeth; Forensic Dentistry; Incisor; Panoramic Radiography; Secondary Dentine

Abbreviations

DAE: Dental Age Estimation; DPRs: Digital Panoramic Radiographs; L: Length; W: Width; mm: Millimetres

Introduction

Dental age estimation (DAE) is one of the vital aspects in forensic dentistry. there is an increasing trend for DAE in living individuals (due to migration, loss in documentation, adoption, child pornography and marriage, pensions, etc.) and in deceased (due to non-identifiable body remains and corpses in natural calamities) [1]. Teeth are highly resistant to mechanical, chemical, or physical influences [2]. with minimal impact from aging. Therefore, estimating age by analysing teeth structure carries immense degree of utility.

Several methods of age estimation have been developed by many researchers [3]. Methods based on radiological analysis have the advantage of being non-invasive, simple, reliable and can be applied to both, living and deceased individuals [4]. In 1995, Kvaal., *et al*. put forth a new radiographic method using periapical films concluding the correlation between pulp/tooth ratio and age, implying its applicability in forensics [5].

Paewinsky., *et al*. in 2005 modified the method of Kvaal's on digital panoramic radiographs (DPRs) and stated its pertinence in age estimation [6]. Previous studies have established a strong correlation between the pulpal size of the maxillary lateral incisor with chronological age in comparison to other single rooted teeth [6-8].

Literature regrading Kvaal's method in deducing age in different population subset is conflicting [5,9-12]. Also, there exists a dearth in the studies on North- Indian population. Hence, this study was planned with the following objectives

- To verify the applicability of modified Kvaal's method to the North- Indian population using maxillary lateral incisor on DPRs
- To formulate regression analysis equation which can be used for estimating the age of the North Indian population.

Material and Methods

Samples

A total sample of 134 DPRs of the North-Indian population with age ranging from 18-60 years was randomly selected from the archives of the database of patients who had visited a private Imaging Centre in western Uttar- Pradesh from 2019-2021. These DPRs were evaluated for 134 maxillary lateral incisors on either side (Right and Left) (Table 1).

Age groups (In years)	Number of Maxillary Lateral Incisor teeth		Total
	Right	Left	
18 - 20	15	17	32
21 - 30	23	15	38
31 - 40	15	16	31
41 - 50	09	08	17
51 - 60	08	08	16
Total	70	64	134

Table 1: Distribution of sample into Right and Left side according to age groups.

The inclusion criteria were that the images must have complete closure of the apical foramen of the maxillary lateral incisor, and a good quality of the panoramic radiograph with respect to the anatomical coverage, density, contrast, and resolution. The radiographs were excluded if they were of poor image quality and if the maxillary lateral incisors were having any pathologic conditions (caries, periodontitis, periapical lesion, rotation, root resorption, attrition, abrasion, or impaction), two or more root canals, root and crown anomalies, an orthodontic appliance, any restoration, or a prosthesis. The chronological age of the subjects was collected from the centre's patient registry. This study was executed retrospectively, and the entire data was analysed anonymously without revealing any identity of the subjects except for the age hence, the consent form from individuals and the ethical clearance was not needed.

Image Acquisition and Analysis

DPRs were acquired using digital panoramic and cephalometric system (Kodak Dental Systems CS9000C, France) with standard exposure parameters (70 kVp, 10 mA, and 14 seconds). The DPRs were stored in the JPG format.

ImageJ open-source software version 1.44 (National Institute of Health, Bethesda, MD, USA) was used to analyse the pulp length and width of the maxillary lateral incisors. Pulpal length was measured as the distance from the pulp chamber roof till the apical foramen (L) and the width of the pulp was measured at the cervical region of the cementoenamel junction (W). Both the measurements were in millimetres (mm). This was in accordance with the method of Herianti., *et al*. (Figure 1 and 2) [13].

Figure 1: Measurement of pulpal length of Maxillary Lateral Incisor.

Figure 2: Measurement of pulpal width of Maxillary Lateral Incisor.

ImageJ, being a semi-automatic software, calculated the length and width, mean and standard deviation in the measurements (Figure 3).

Figure 3: Automated results generated by ImageJ software after measurements.

Further the pulpal L/ W ratio was calculated for individual tooth and the results were tabulated in Microsoft Excel Spreadsheet, version 14.0 (Microsoft Corp, USA).

The observer was an oral and maxillofacial radiologist who was blinded to the chronological age of the subjects which minimised the chances of any bias. All the measurements were carried out by the same examiner. The intra- observer agreement was tested upon by re- examination of random sample of twenty DPRs after an interval of fifteen days.

Statistical analysis

Intra- observer reproducibility was ascertained by paired t-test. Evaluation of the significance of differences between the left and right maxillary lateral incisor was performed using the independent t-test. The correlation coefficient (r), coefficient of determination (R^2), and standard error of estimate (SEE) were elucidated with simple linear regression using SPSS version 22.0 (IBM, NY, USA).

Results

The intra- observer difference between the paired set of measurement was statistically non- significant (p = 0.4). There was statistically no significant difference between the average score of left and right maxillary lateral incisors using the independent t-test (p = 0.333). There existed a statistically significant correlation between the pulpal L/W ratio of the maxillary lateral incisor with chronological age (p = 0.000*). Considering age as the dependent variable and the pulpal L/W ratio as the independent variable the regression equation deduced for estimating age was

Age = -3.257 + 1.835 × L/W ratio

The scatter plot showed that the pulpal L/W ratio increased with chronological age (Figure 4).

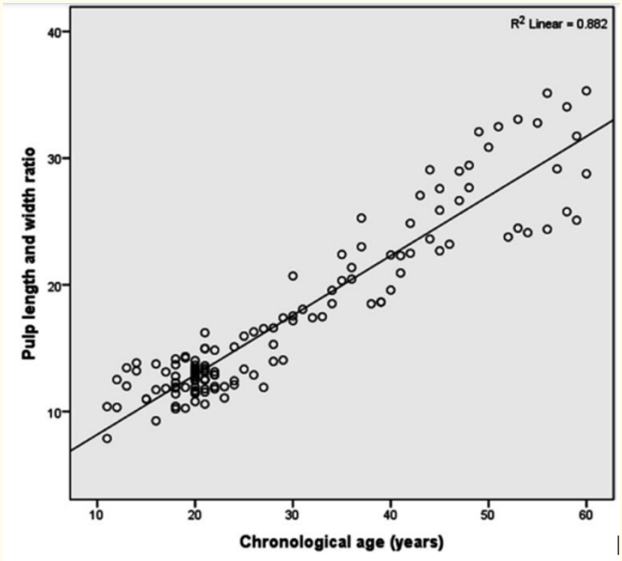

Figure 4: Plot between pulpal length and width ratio and chronological age.

Also, it yielded Pearson correlation coefficient (r) as 0.939 and coefficient of determination (R^2) as 0.882. The standard error of estimate (SEE) was 4.659.

Discussion

DAE plays a pivotal role in forensic dentistry by aiding in identification purposes not only in deceased individuals but also in living individuals at multiple stages of life. Being the hardest structure of the human body, the teeth can withstand multiple insults and hence can be utilised for providing information for estimating age of an individual. Multiple methods of determining age from dental hard tissues have been put forth in the literature, however, many of these methods are limited to a particular subset of age group [14-16], require sophisticated equipment, or require invasive techniques [17,18]. However, the methods of estimating age based on radiographical analysis are non-invasive, easy and eliminate the requirement of highly sophisticated laboratories. Secondary dentine apposition is a constant process which is continuous through-out an individual's life [19]. This laying down of secondary dentine decreases the overall area of the pulp space [20]. Kvaal., *et al*. based on this concept and using periapical radiographs, had put forth a method of age estimation which could be applied on a broader range of age groups [5].

With the advent of technology, digital imaging became popular and serve as the mainstay in day-to-day clinical dentistry. DPRs have the advantage of being simple, convenient with widespread availability and deliver low radiation dose. Paewinsky., *et al*. [6]. utilised the DPRs for estimating the size of pulp cavity using modified Kvaal's method and concluded it to be a useful aid for age estimation. Bauman P., *et al*. [21]. have quoted DPRs being the "Gold Standard" of dental age estimation for evaluation of mineralisation and eruption stages for third molars. Mani SA., *et al*. [22]., Asab SA., *et al*. [23]. have highlighted the importance of using DPRs in dental age estimation and hence, for this study DPRs were considered over other radiographic modalities.

The pulp chamber of maxillary lateral incisor is relatively large and contains a single root canal which eases its analysis and measurement [24,25]. Also, on DPRs, a radiolucent air space is often found at the apex of the maxillary central incisor tooth [26]. This radiolucent space can hinder with the clear delineation and measurement, especially, on the maxillary central incisor tooth. Previous studies by Paewinsky., *et al*. [6]. in German, Li., *et al*. [7]. in Chinese, Cameriere., *et al*. [8]. in Portuguese, Herianti., *et al*. [13]. on Indonesian, Zaher., *et al*. [27]. on Egyptian, and Babshet., *et al*. [28]. on Indian population have found a strong correlation of maxillary lateral incisor with the chronological age when compared to other single rooted teeth. Thus, in the present study the maxillary lateral incisor tooth was chosen considering the above rationales.

This study inferred that the difference in pulp size between right and left maxillary lateral incisors was statistically non- significant. The findings of Kvaal., *et al*. [5], Li., *et al*. [7], Herianti., *et al*. [13], and Zaher., *et al*. [27]. were in accordance with our findings. This implies that the apposition of secondary dentin was concurrent and even on either side in the North- Indian population and that the same regression analysis equation can be applied for the right and left maxillary lateral incisors.

ImageJ, being an open-source software is easily accessible, supports easy and faster manipulation of the images for measurements thus, is widely used and especially designed for the use in the experimental and clinical dentistry. With the inbuilt facility to zooming the images and the straight- line tool, it enables an observer to play and perform reliable and consistent measurements. Another advantage of using this software is its semi- automaticity, which offer a room for the observers to perform the measurements by themselves. The practicality of this software in utility with DAE has been proved by various researchers like Karkhanis., *et al*. [10], Erbudak., *et al*. [12], and Herianti., *et al*. [13]. Cameriere., *et al*. [8]. in their study have used Adobe Photoshop software for measurements in lieu of ImageJ. The shortcoming being the non- exclusivity of Adobe Photoshop for experimental and clinical dentistry and thus, we have used Image for our study.

There was a statistically significant relationship between the pulpal L/W ratio of the maxillary lateral incisor with chronological age. The linear regression plot using the measured parameters yielded a significant association ($p = 0.000^*$). This was akin with the previous study research of Babshet., *et al*. [28]. in Indian population, which reported a significant correlation between the pulp-to-tooth-area ratio of maxillary lateral incisor and chronological age. Indira., *et al*. [29]. in their study also strongly recommended the usage of the radiographic pulpal morphometric analysis on maxillary lateral incisor in the assessment of the age of an adult.

Secondary dentine apposition, which is a continuous, age- related phenomena was considered the prime concept for performing this study. The regression equation yielded a very strong correlation ($r = 0.939$) of pulpal L/W ratio of maxillary lateral incisor

with the chronological age. This finding can be associated with the secondary dentine apposition in the north Indian population. On the contrary, the reported correlation coefficient (r = -0.2) by Zaher., *et al*. [27]. was low and they have linked this to the relatively slow apposition of the secondary dentine in the Egyptian population. Similarly, Indira., *et al*. [29]. too have shown a low correlation coefficient (r = -0.392) in their sample of population. We would like to associate this very strong correlation coefficient to a faster rate of apposition of secondary dentine in North Indians, yet this mere association warrants future studies in this regard.

Another point as a highlight which we want to discuss is the correlation between pulpal L/W ratio of maxillary lateral incisor and age was positive, when the independent variable was the pulpal L/W ratio of maxillary lateral incisor, and the dependent variable was age. This contrasts with the experimental studies of Indira., *et al*. [29]. who have done their study without magnifying the images, leaving the possibility of missing the pixels in the counting. A positive correlation (r = 0.60) similar to our study was found by Roh., *et al*. [11]. who have done their measurements at 200% magnification. Therefore, we emphasize on zooming the images (scale to be set first) for measurement purposes so that every pixel can be considered without creating a bias in the measurement.

Limitations

The errors sustained while doing a manual measurement using the ImageJ software cannot be totally ruled out also, it depends on the quality of the radiographs which were considered. The entire North Indian population may not be represented by the small sample size used in this study. More future studies are however needed in this regard using multiple software, a larger sample size and an in-depth analysis of the ethnicity to improve the accuracy.

Conclusion

Based on our findings, the L/W ratio of the pulp of maxillary lateral incisor on DPRs can be utilised as a valuable tool in deducing the chronological age of an individual of North- Indian population subset using modified Kvaal's method.

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Conflict of Interest

Nil.

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