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Application of Kvaal et al.'s age estimation method to panoramic radiographs from Turkish individuals

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ABSTRACT

Age estimation of living adult individuals can be accomplished with limited methods. Radiographic dental methods based on the pulpal narrowing with secondary dentin formation have been presented. In the present study, Kvaal et al.'s method, one of the radiographic dental age estimation methods, was applied to panoramic radiographs from Turkish individuals. The correlation between chronological and estimated ages was examined and the feasibility of length and width measurements of pulp cavity was evaluated for age estimation. The study population consisted of 123 patients with ages ranging from 14 to 57 years. The measurements of the length and width of six types of teeth on digitized panoramic radiographs were performed, and the ratios between tooth and pulp cavity measurements were calculated. Age was estimated using the linear regression models presented by Kvaal et al. and Paewinsky et al. High differences were observed between chronological and estimated ages. Measurement ratios showed no significant or weak correlation with age. The linear regression models were derived using variables that were significantly correlated with age. The determination coefficients of the models varied from 0.035 to 0.345. In conclusion, a 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. The length and width of the pulp cavity, measured according to the method of Kvaal et al. using panoramic radiographs, were insufficient to precisely estimate the age of Turkish individuals.

1. Introduction

Age estimation plays an important role in the practice of forensic science. It is necessary not only to aid identification of the dead, but also for living individuals to clarify criminal and civil liability and social issues. Particularly in Turkey, age estimation is frequently used due to incorrect birth records [1–3]. In addition, the demand for age estimation is rising in some countries due to increased numbers of immigrants and refugees without valid identification documents [4,5].

Dental age estimations can be made using a number of methods, which may be divided into two groups. The first, based on the emergence and formation of teeth, is used in individuals whose dental development is not complete. The second, based on age-related changes in teeth, is used in individuals whose dental development is complete [6]. Most methods for adults cannot be used in living individuals because they require tooth extraction [7–13]. Thus, several authors have presented radiologic techniques for dental age estimation in living adults. Few are known, and all are based on one- or two-dimensional radiographic measurements of the reduction in the dental pulp cavity associated with advancing age due to secondary dentin formation [14–16].

Based on a Norwegian sample, Kvaal et al. [14] suggested a method that involves measurements of the length and width of the pulp cavity and tooth on periapical radiographs. The ratios between pulp cavity and tooth measurements were correlated with age, and regression models were derived to estimate the age of unknown subjects. Paewinsky et al. [17] modified this method by using digitized panoramic radiographs and developed new regression models that included only width ratios. Bosmans et al. [18] showed the applicability of this method to panoramic radiographs, especially when measurements of all six types of teeth were taken. Meinl et al. [19] evaluated the method by using digital panoramic radiographs from young adults, and concluded that Kvaal et al.'s [14] original and Paewinsky et al.'s [17] modified regression models could not be applied to a young Austrian sample. Landa et al. [20] reported that the method could not be applied to digital panoramic radiographs. Sharma and Srivastava [21] evaluated the feasibility of Kvaal et al.'s method for estimation

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of the age of adults using digital intraoral periapical radiographs and concluded that the method could be used for age estimation.

The aim of this study was to examine the correlation between chronological and estimated age using Kvaal et al.'s [14] original and Paewinsky et al.'s [17] modified models. We also evaluated whether measurements of the length and width of the pulp cavity can be used for age estimation, applying Kvaal et al.'s [14] method to panoramic radiographs of Turkish individuals.

2. Materials and methods

The investigational protocol described herein was approved by Hacettepe University Local Ethics Committee (LUT 07/75). Informed consent was obtained from all patients. The study group consisted of patients who applied to the Department of Dentomaxillofacial Radiology for routine dental examination. The age, sex, and medical history of the patients were recorded. Patients were selected based on the following criteria: absence of disease that could cause pulp calcification, such as atherosclerosis or renal disease; no history of corticosteroid therapy, orthodontic treatment, or bruxism; and possession of six types of teeth without restoration, dentinal caries, abrasion, erosion, attrition exceeding the fourth degree [22], or traumatic occlusion.

Panoramic radiographs were obtained from 143 patients with an orthopantomograph (OP100; Instrumentarium Corp., Tuusula, Finland) by the same dentist (HÖE). Radiographs were scanned with an Epson Expression 10000 XL (Seiko Epson Co., Nagano, Japan) at 8-bit, 600-dpi resolution and saved as tagged image file format (TIFF) files. Twenty of 143 panoramic radiographs were excluded from the study due to distortion, superposition, or insufficient density, which impeded measurement. The remaining 123 panoramic radiographs were used for measurement. The study population consisted of 75 women and 48 men, with ages ranging from 14 to 57 years.

Measurements were performed using image analysis software (ImageJ, 1.43 n; National Institutes of Health, Bethesda, MD, USA) with 300× magnification by an oral radiologist (SU) who was blinded to the patients' information. Panoramic radiographs were optimized if necessary, and calibration was performed using a known measure. The measurements were carried out on six teeth (maxillary central and lateral incisors, maxillary second premolar, mandibular lateral incisor, mandibular canine, mandibular first premolar). The teeth were selected from either the right or left side of the jaw, depending on the sharpness of the images, since Kvaal et al. [14] reported no significant difference between sides. The other selection criteria were the absence of root dilaceration, pathology, root canal treatment, restoration, superposition, or impaction. The length and width measurements of teeth (Fig. 1), performed according to the method of Kvaal et al. [14], were: maximum tooth length (T'), maximum pulp length (P'), root length on the mesial surface from the cementoenamel junction (CEJ) to the root apex (R'), and root and tooth width at the CEJ (level A), at midroot level (level C), and at the midpoint between the CEJ and midroot level (level B). All measurements were done by a single observer; to assess intraobserver reliability, measurements on 15 randomly selected radiographs were repeated by the same observer after 2 weeks.

To compensate for any difference in the magnification or angulation of panoramic radiographs, the ratios between tooth and pulp cavity measurements and the mean values thereof were calculated: pulp/root length (P), pulp/tooth length (R) and pulp/root width at the three levels (A, B, and C), the mean of all ratios (M), the mean of B and C (W), the mean of length ratios (L), and $W - L$.

Age was calculated using the original models of Kvaal et al. [14] and the modified models of Paewinsky et al. [17]. SPSS software (ver. 11.0; SPSS Inc., Chicago, IL, USA) was used for statistical analysis of the data. Intraobserver reliability of the measurements was evaluated using the intraclass correlation coefficient. To examine the consistency between chronological and estimated age using the linear regression models described previously [14,17], mean differences and standard errors were calculated. The correlation between age and variables was evaluated using Pearson's correlation coefficient. Linear regression models were derived using variables that were significantly correlated with age.

3. Results

The sex and age distribution of the patients is shown in Table 1. The mean age of the patients was 31.78 ± 10.61 years.

Intraobserver reliability of the measurements was excellent. Measurement consistency was 98% for the maxillary central incisor, 97% for the maxillary lateral incisor, 99% for the maxillary second premolar, 97% for the mandibular lateral incisor, 98% for the mandibular canine, and 95% for the mandibular first premolar.

The standard errors of the regression equations, and the means, standard deviations, minimum and maximum values of differences between the chronological and calculated ages using the regression models of Kvaal et al. [14] and Paewinsky et al. [17] are shown in Table 2. Kvaal et al.'s [14] model, which included mandibular canine values, resulted in the lowest standard error. For this model, the distribution of the residual *versus* predicted values is shown in Fig. 2 as an example.

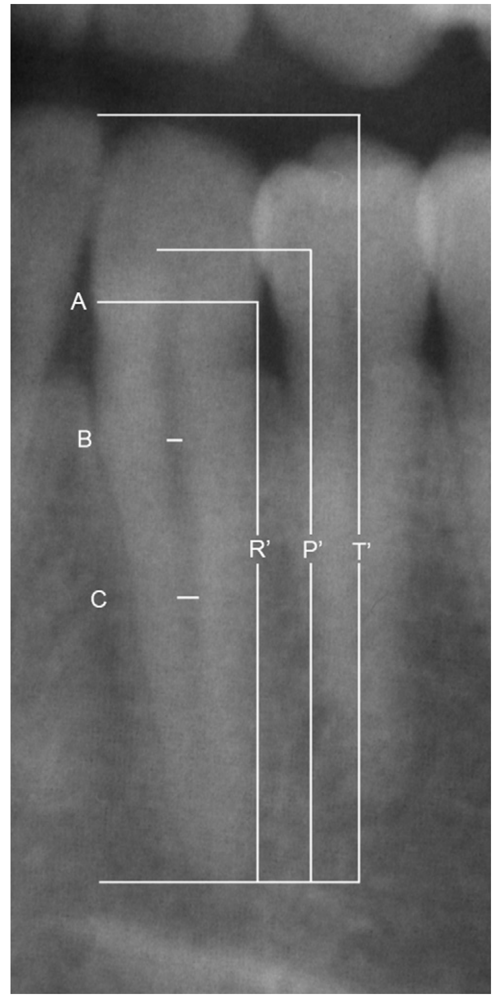

Fig. 1. Measurements performed according to the method of Kvaal et al. [14] on panoramic radiograph.

No significant correlation was observed between chronological age and the calculated ratios and their mean values, with the exception of five variables ($p > 0.05$). These were: R ratios of the maxillary central incisor, second premolar, and mandibular lateral incisor; the P ratio of the mandibular lateral incisor; and the $W - L$ values of three maxillary teeth ($p < 0.05$). Pearson's correlation coefficients (r) for these variables were 0.264, 0.217, 0.360; and −0.407 and −0.187 ($p < 0.05$), respectively (Table 3). The correlation of the mandibular lateral incisor's P ratio with age is shown in Fig. 3 as an example; this was the strongest correlation. Twenty-five linear regression models were derived, and their determination coefficients varied from 0.035 to 0.345. Some of

Table 1
Age and sex distribution of the sample studied.

Age groups	Women	Men	Total
14–24	21	17	38
24–35	18	19	37
35–46	26	10	36
46–57	10	2	12
Total	75	48	123