Dentomaxillofacial Radiology (2017) 46, 20170026
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RESEARCH ARTICLE

Applicability of Cameriere's and Drusini's age estimation methods to a sample of Turkish adults

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Objectives: The aim of this study was to investigate the applicability of Drusini's and Cameriere's methods to a sample of Turkish people.
Methods: Panoramic images of 200 individuals were allocated into two groups as study and test groups and examined by two observers. Tooth coronal indexes (TCI), which is the ratio between coronal pulp cavity height and crown height, were calculated in the mandibular first and second premolars and molars. Pulp/tooth area ratios (ARs) were calculated in the maxillary and mandibular canine teeth. Study group measurements were used to derive a regression model. Test group measurements were used to evaluate the accuracy of the regression model. Pearson's correlation coefficients and regression analysis were used.
Results: The correlations between TCIs and age were −0.230, −0.301, −0.344 and −0.257 for mandibular first premolar, second premolar, first molar and second molar, respectively. Those for the maxillary canine (MX) and mandibular canine (MN) ARs were −0.716 and −0.514, respectively. The MX ARs were used to build the linear regression model that explained 51.2% of the total variation, with a standard error of 9.23 years. The mean error of the estimates in test group was 8 years and age of 64% of the individuals were estimated with an error of <±10 years which is acceptable in forensic age prediction.
Conclusions: The low correlation coefficients between age and TCI indicate that Drusini's method was not applicable to the estimation of age in a Turkish population. Using Cameriere's method, we derived a regression model.
Dentomaxillofacial Radiology (2017) **46**, 20170026. doi: 10.1259/dmfr.20170026

Cite this article as: Boyacioglu Dogru H, Avcu N, Akkaya N, Yilanci HO, Goksuluk D. Applicability of Cameriere's and Drusini's age estimation methods to a sample of Turkish adults. *Dentomaxillofac Radiol* 2017; **46**: 20170026.

Keywords: forensic dentistry; secondary dentin; age determination by teeth; panoramic radiography

Introduction

Human dentition can be useful for individual identification due to its unique features.[1] As teeth are among the most durable tissues in living organisms and as their morphology is preserved longer than that of other organs, they have been considered effective for age estimation. Additionally, teeth have low metabolic characteristics, and information obtained from tooth development provides more accurate results than that from other structures.[2] Age estimation methods based on teeth use one of three criteria: tooth formation and growth changes, age-related changes or biochemical changes. Tooth formation and growth changes occur from the womb to adulthood. After this period, age-related gross anatomical and histological changes can be examined in adults. Attrition, periodontal condition, apical root resorption, root smoothness, dentin colouration, secondary dentin deposition, cementum deposition and dentin transparency can be considered age-related changes. Biochemical changes include aspartic acid racemization in dentine and radiocarbon uptake in

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Received 21 January 2017; revised 31 May 2017; accepted 20 June 2017

enamel. Many methods that assess these changes require extraction of the tooth and, therefore, cannot be used in living people. However, radiologic dental age estimation methods based on secondary dentin deposition can be used in living people.[3]

Secondary dentine deposition is a lifelong process; it is mainly related to age and also influenced by other factors such as attrition and caries. The size of the dental pulp cavity decreases with age. Therefore, radiological measurements of the pulp cavity are used as a valuable age indicator for adults.[4–7] Previous studies described three separate dental radiological methods using the metric system for age estimation in adults. These methods are known by the names of the researchers: Kvaal, Drusini, and Cameriere. These methods are based on measurements of the pulp cavity of different tooth types.[5–7]

In 1995, Kvaal et al[5] proposed a radiographic method that included measurements of the lengths and widths of the pulp cavity and tooth. Ratios between the pulp cavity and tooth measurements were correlated with age. This study showed, for the first time, that radiologic evaluation of secondary dentine deposition on dental radiographs could be reliable for age estimation.

In 1997, following, in part, the method developed by Ikeda et al,[8] Drusini et al[6] studied the correlation between reduction in coronal pulp cavity and age. Measurements were performed on the premolar and molar teeth based on panoramic radiographs. The crown height (CH) and coronal pulp cavity height (CPCH) were obtained as one-dimensional measurements for each tooth. The tooth coronal index (TCI) was computed as follows: TCI = CPCH * 100/CH. The correlation coefficients between age and TCI ranged from −0.92 to −0.87. Regression models were derived for age estimation using TCI.

In 2004, Cameriere et al[7] studied the canine teeth because they have larger pulp areas (PAs) and experience less wear due to their specific occlusion, simplifying the analysis and making the measurements more precise. The PAs and tooth areas (TAs) were obtained as two-dimensional measurements, and pulp-to-tooth area ratio (PA/TA = AR) was used in the regression model.

In these studies[5–7] above, regression analysis was performed on the sample, and inferences were extended to the population under consideration. Several previous studies have noted that the derivation of population-specific regression models is recommended to reduce the error in estimates. Although numerous valid age estimation models are available for Western populations, few studies are available for Turkish populations.[5–7,9–13] In one study, Erbudak et al[12] applied Kvaal's method and found that the accuracy was insufficient. In another study, Misirlioglu et al[13] used Kvaal's and Cameriere's methods and obtained more accurate results using Cameriere's method. The aim of this study was to assess the applicability of Cameriere's and Drusini's methods to Turkish individuals and to derive population-specific regression models.

Methods and Materials

Materials

The investigation protocol described herein was approved by the Local Ethics Committee (GO 13/174). Optimum diagnostic quality panoramic images were selected from the digital archive of the Department of Dentomaxillofacial Radiology, Faculty of Dentistry, at the University of Hacettepe. Panoramic images were acquired in 2013 with a digital panoramic machine (Orthophos XG 5; Sirona Dental Systems, Bernsheim, Germany). Individuals older than 18 years of age were included in the study. The selection criteria included possession of a maxillary canine, the mandibular canine, the mandibular premolar, and molar teeth from either the left or right side, as well as the absence of dental anomalies, periapical pathologies, decay, crowns, severe attrition, fillings, or root canal treatment. Panoramic images of 200 Turkish individuals from 20 to 75 years of age were included in this study and were converted into a tagged image file format. These images were divided randomly into study and test groups. The study group consisted of 100 panoramic images: 40 males and 60 females with a mean age of 37.3 years (39.12 and 36.09 years for males and females, respectively). Measurements in the study group were used to derive a regression model. The test group consisted of 100 panoramic images: 50 males and 50 females with a mean age of 35.06 years (36.22 and 33.9 years for males and females, respectively). Measurements of the test group were used to evaluate the accuracy of the regression model.

Methods

Measurements were performed using the image analysis software ImageJ 1.48 n (National Institutes of Health, Bethesda, MD). The best visible teeth from the left or right side of the jaw were selected for measurements. The maxillary and mandibular canine teeth were measured following Cameriere's method. The PAs and TAs were identified, and the pulp/tooth area ratios (ARs) were calculated (Figure 1).

The pulp and tooth CHs of the mandibular premolar and molar teeth were measured following Drusini's method. A cervical straight line was drawn as a reference between the mesial and distal surface of the tooth. Two more lines parallel to the reference were drawn, after which one of the lines was moved to the highest tip of the pulp, and the other line was moved to the highest tip of the cusp. The distance from the cervical line to the highest tip of the pulp was recorded as the CPCH. The distance from the cervical line to the highest tip of the cusp was recorded as the CH. These measurements were used to calculate the TCI, as follows: TCI = CPCH * 100/CH (Figure 2). Panoramic images were shared and all measurements were performed by two observers independently. To test intra- and inter-observer agreement, 20 randomly selected panoramic images were re-examined by each observer 2 weeks after the first measurements.

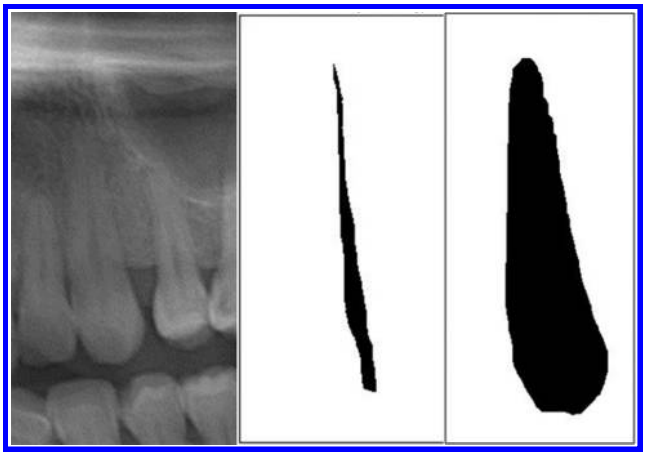

Figure 1 Measurements of the pulp and tooth area of the canine tooth according to Cameriere's method.

Statistical analysis
Statistical analysis was performed with SPSS 23 (Statistical Package for Scientific Studies, SPSS Ltd, Chicago, IL). Intraclass correlation coefficients (ICCs) were used to measure the same observer at different times and to measure the reproducibility of the measurements made by different observers. The correlation between age and each of the indices (TCIs and pulp-to-tooth ARs) were calculated using Pearson's correlation coefficients (PCCs). Regression analysis was performed to build a regression model for predicting age in Turkish adults. The ages obtained using regression models from this study and Cameriere's study were compared with the actual ages of the subjects to evaluate the accuracy of the regression models. The accuracy of dental age estimation was defined as how accurately age could be predicted (measured as the mean error of the estimate, which represents the mean of the absolute values of the differences between actual age and estimated age).

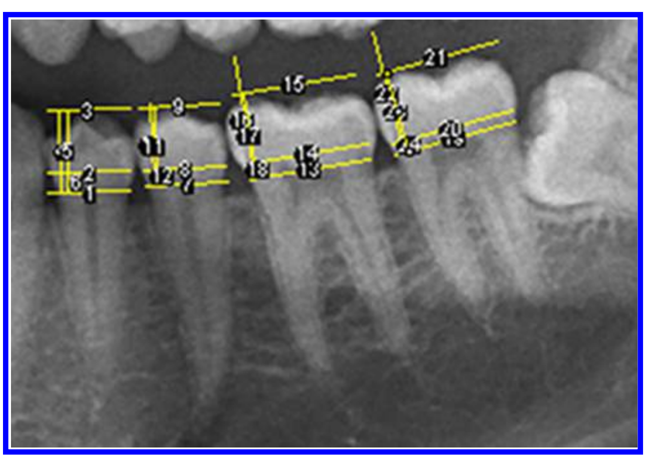

Figure 2 Measurements of the pulp and crown heights according to Drusini's method.

Table 1 Intraobserver agreement in the measurements of Drusini's method

Observers	*CPCH*				*CH*			
	1.PM	*2.PM*	*1.M*	*2.M*	*1.PM*	*2.PM*	*1.M*	*2.M*
Observer 1	0.895	0.871	0.955	0.845	0.977	0.899	0.986	0.961
Observer 2	0.955	0.906	0.940	0.926	0.978	0.972	0.975	0.978

CH, crown height; CPCH, coronal pulp cavity height. M, molar; PM, premolar.

Results

There was significant intra-observer agreement in measurements. The ICCs ranged between 0.845 and 0.955 for measurements of CPCHs, between 0.899 and 0.986 for measurements of CHs (Table 1), and between 0.940 and 0.980, and between 0.983 and 0.993 for measurements of PAs and TAs, respectively (Table 2). The ICCs for inter-observer agreement ranged from 0.746 and 0.984, which suggested good reproducibility of the re-evaluated radiographic images.

The PCCs between age and pulp/tooth ARs were negative, and the maxillary canine pulp/tooth AR (MX AR) correlation was highest ($r = -0.716$) (Table 3). The PCCs for the relationship between TCI and age were weak and excluded from further statistical analysis.

As can be seen in Table 3, all correlation coefficients were statistically significant due to the large sample size. However, the strength of the correlations was not sufficient to be used in the regression analysis. Therefore, the significance levels were not considered when determining independent variables for the regression model. Instead, the PCCs were used for variable selection. The MX ARs and the mandibular canine pulp/tooth ARs (MN ARs) were both candidates for inclusion in the linear regression analysis. However, there was a strongly positive correlation between MX AR and MN AR, which would lead to lack of fit and multicollinearity problems. Hence, only one of these variables was included in the regression analysis, and the MX ARs obtained from the study sample were used to construct the linear regression model. The validity of the estimated regression model for predicting the age of Turkish adult individuals was tested using analysis of variance (ANOVA), and the model was found to be statistically significant ($p < 0.001$). The linear regression model between the MX

Table 2 Intraobserver agreement in the measurements of Cameriere's method

Observers	*Maxillary*		*Mandibular*	
	CPA	*CTA*	*CPA*	*CTA*
Observer 1	0.975	0.993	0.971	0.990
Observer 2	0.940	0.986	0.980	0.983

CPA, canine pulp area; CTA, canine tooth area.

Table 3 Correlation coefficients between age and indexes

TCIs and ARs	*Pearson correlation*	*p*
1.PM TCI	−0.230	0.021
2.PM TCI	−0.301	0.002
1.M TCI	−0.344	<0.001
2.M TCI	−0.257	<0.001
MX AR	−0.716	<0.001
MN AR	−0.514	<0.001

AR, area ratio; TCI, Tooth coronal index.

ARs and the dependent variable, age, can be described as follows:

$$Age = 77.365 - 351.193 * AR.$$

The standard error of the estimates was 9.23 years, and the proposed regression model explained 51.2% of the total variation in age. Predicted values revealed that the ages of 76% of the individuals were estimated with an error of <±10 years, which is acceptable in forensic age prediction.[14] Although the regression model is found to be valid, it is important that the model does not violate the residual assumptions, *i.e.* independently and normally distributed random errors with zero mean and constant variance. Residual analysis supported our regression model, which is applicable to the estimation of age. In Figure 3, it is graphically seen that the random errors are normally and independently distributed with zero mean and constant variance.

Gender did not influence the regression model (p = 0.452); consequently, gender was not included in the statistical model (Figure 4). The regression model derived from the study group was applied to the test group to predict individuals' age. The mean error of the estimates was 8 years. The ages of 64% of the individuals were estimated with an error of <±10 years, which is acceptable for forensic age prediction.[14] Ages in the test group were also estimated using Cameriere et al's regression model[7] for the maxillary canine, as follows:

$$Age = 99.937 - 532.775 * AR.$$

The mean error of the estimates was 10.5 years for Cameriere's regression model, whereas it was 8 years for the model derived in this study. This result showed that the regression model built in this study was more accurate for Turkish adults.

Discussion

Dental radiological age estimation is convenient, simple, and inexpensive for a medical expert to use; therefore,

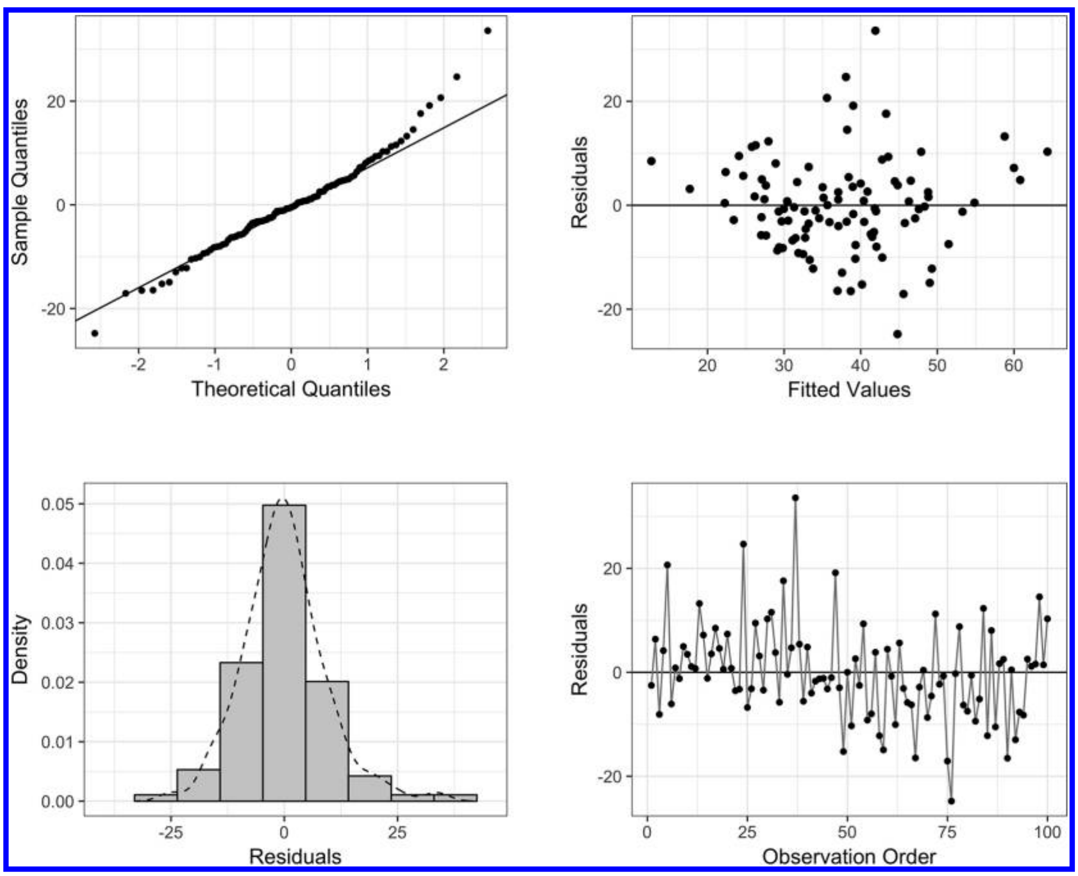

Figure 3 Residual analysis of the regression model.

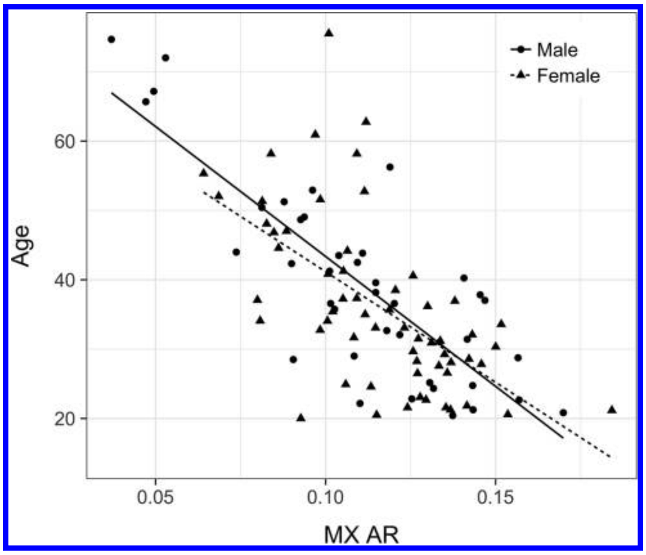

Figure 4 Plots of observed age against the predicted age using regression models including gender.

this approach is preferred for age estimation. Various imaging techniques, such as intraoral, extraoral radiography, or advanced imaging techniques (*e.g.*, cone beam CT [CBCT] or MRI) have been used in previous studies.[15–18] Panoramic images showing both the anterior and posterior teeth on a single image were preferred in this study because it is not ethical to take additional radiographs of intact teeth for the purpose of research. All measurements were performed on these single images.

Willems et al highlighted the importance of measurements made by more than one observer.[19] In this study, the first observer had 4 years of experience as an oral radiology assistant, and the second observer had 16 years of experience as an oral radiologist. A high level of inter-observer agreement was found, supporting the reproducibility of methods. This result was consistent with previous studies.[11,20,21] In Drusini's method, the ICCs for intra- and inter-observer agreement regarding the coronal height measurements made by both observers were higher those regarding the pulpal measurements. This may be due to difficulty locating the tip of the pulp horns, as the tip of the cusps are more visible than the tip of the pulp horns in panoramic images. Similar to the results for Cameriere's method, the ICCs of the intra- and inter-observer agreement regarding the tooth area measurements were higher than those regarding the pulpal area, which is probably due to the greater visibility of external tooth borders compared with pulp cavity borders.

The ratios obtained from measurements were used instead of the absolute measurements. The use of this index allowed for the elimination of individual variability in tooth size, as well as differences in the magnification of radiographs. Previous reports demonstrated that symmetrical teeth show negligible differences in adult age estimation[6,8,22,23] therefore, teeth with a distinct pulp chamber, which were suitable for measurements, were chosen.

In this study, a negative correlation between age and TCI was observed; the PCCs were −0.230, –0.301, −0.344 and −0.257 for the first premolar, second premolar, first molar and second molar, respectively. The highest correlation coefficient was obtained for the first molar. The correlation coefficients were consistent with Karkhanis et al[24] whereas they were lower than those reported by Drusini et al,[6] Igbibi et al,[25] and El Morsi et al.[26] Karkhanis studied an Australian population, Drusini studied an Italian population, Igbibi studied a Malawi population, and El Morsi studied an Egypt population. Thus, these differences may be attributed to population differences *e.g.* secondary dentin deposition and tooth dimension differences among populations may result in different TCIs.[27–29] These different TCIs will result in variation of correlations with age. Other indirect factors that influence TCI in terms of measurements may be conventional or digital radiographic techniques used. In digital radiographic techniques, some of which are used in the present study, conditions such as extraneous light, characteristics of computer monitors (screen size, spatial resolution and bit depth), computer hardware and software may influence observers' judgement regarding measurement reference point and in turn affect TCIs.[30] These factors may be responsible for differences in the results.

In this study, the correlation between the MX AR and age was negative; the respective PCC was $r = -0.716$ ($p < 0.001$). In Cameriere's[7] study on Italians, De Luca's[31] study on Mexicans, Cameriere's[32] study on Portuguese and Juneja's[33] study on Indians, the coefficients were −0.92, –0.98, −0.98 and −0.97, respectively. These results were higher than this present study's result of −0.716; this may be due to differences among populations. A similar study in a Turkish population performed by Misirlioglu[13] found the PCC to be $r = -0.70$, which is consistent with our results. Misirlioglu evaluated periapical images, whereas panoramic images were used in this study. Despite the use of different radiographic techniques, similar PCCs were found.

As several studies have shown that gender does not influence the regression model, there has been no need for a sex-specific model.[7,13,32–35] The present study supports this conclusion ($p < 0.452$), and we obtained a regression model applicable to both males and females. Thus, there is no need to know the sex of an individual prior to performing the age estimation procedure.

De Luca et al[31] supported the applicability of the regression model to anthropological samples. They applied the regression model obtained from Italian and Portuguese individuals to a Mexican anthropological sample, and the results were statistically significant. Future studies should apply the regression model obtained in the present study to an independent Turkish anthropological sample; the results of such studies may be useful in anthropological research.

Age estimation studies based on the pulp/tooth AR initially investigated the canine teeth because they have one root with a large PA, which is easy to analyse.[7] The premolar teeth were then considered.[10] Cameriere et al[11] evaluated the maxillary and mandibular central and lateral teeth; these teeth have smaller pulp dimensions and a second canal, which decreased the accuracy of age estimation. The canine teeth showed the strongest correlation among single-rooted teeth; therefore, the maxillary and mandibular canine teeth were chosen for the present study. In future studies, other single-rooted teeth, such as the central, lateral and premolar teeth, should be evaluated using Cameriere's method to generate tooth-type-specific regression models. Hence, age can be estimated more accurately for Turkish individuals who have missing teeth.

Cameriere et al[9] studied the second molar pulp/tooth AR method together with the third molar open apices method and highlighted the importance of the application of the pulp/tooth AR together with other methods. Similarly, the regression model obtained in this study may be used in conjunction with other methods to minimize errors in age estimation.

Some studies used teeth on the right side of the mouth to obtain a regression model;[35] however, the regression model cannot be used if there are no teeth on the chosen side of the mouth. For this reason, the right or left teeth that were seen clearly and were appropriate for the measurement were selected in this study, which is similar to the method used in other studies.[6,7,13,33,34,36]

One major limitation of this study is that the proposed regression model explained only 51.2% of total variation in age, which can be considered a moderate explanation. Despite this limitation, the regression model is still applicable and provides valuable information because it evaluates the validity of the regression model in an independent sample. Future studies should investigate other single-rooted teeth as additional variables that might be correlated with age to improve the explained variance. Hence, introducing additional variables that are both clinically and statistically acceptable may improve the age prediction performance of the regression model in Turkish adults. The use of this regression model is further limited by presence of intact teeth since only individuals who have intact teeth were included.

Conclusions

Drusini and Cameriere's methods were applied to panoramic images from Turkish individuals. This is the first study to apply Drusini's method to Turkish individuals, and the TCI reflected a weak correlation with age. Thus, this method should not be used to estimate age in Turkish individuals. The measurements taken using Cameriere's method showed good correlation with age; thus, a regression model was obtained from maxillary canine teeth with a standard error of 9.23 years and it is found applicable with a reasonable accuracy for age estimation in Turkish adult individuals.

Disclosure statement

This study was presented as a PhD thesis on Oral Diagnosis and Radiology in Hacettepe University, Faculty of Dentistry in 2015. Different parts of this study are presented at International Conference on Forensic Sciences, 2015, Paris and Anthropology, Radiology and Anatomy Congress, 2015, Ankara.

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