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Dental Age Estimation Using the Pulp/Tooth Ratio in Lower Canines in Population of Bosnia and Herzegovina

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SUMMARY

Background/Aim*:Dental age estimation in adults is a challenging process due to the lack of sufficient information on the accuracy of dental methods applied in the identification of persons without information on identity. Previous studies on dental age estimation in adults suggested that each method should be tested on a population other than one which was used to develop the specific method. The aim of this study was to estimate dental age in adults from Bosnia and Herzegovina with the radiographic analysis of the pulp/tooth ratio of lower canines and to determine differences from chronological age.* ***Material and Methods:*** *The sample for the research comprised 50 periapical radiographs, with visible intact lower canine teeth, derived from an archive of the Department of Dental Morphology, Dental Anthropology and Forensics. After the selection process, all radiographs were digitalized. Additional information used is the chronological age and sex of the person to whom the images belonged. The measurements of the pulp space and the lower canine tooth were performed using the ImageJ computer methods. The results of measurements were entered in formulas for assessments of dental age, as per equations given by the authors.* ***Results:*** *The research has shown that there is a significant difference in examined population between the dental age estimated by the analysis of pulp/tooth ratio of lower canine teeth and the chronological age. The standard error of regression for Cameriere model was 14.12 years, and this model proved to be statistically significant (p= 0.0017). Kvaal-Solheim model from 1994 has shown a standard error of 15.07 years, and did not prove to be statistically significant (p= 0.054), while another model from 1995, by the same authors, shows a standard error of 14.64 years, and it proved to be statistically significant (p= 0.011).* ***Conclusions:*** *It is possible to estimate dental age by means of pulp/tooth ratio. However, it is necessary to conduct further research that will include a larger number of examinees and different age groups and also consider the specificity of teeth in Bosnia - Herzegovina's population to acquire more accurate data on accuracy and reliability of those methods in this population.*

Keywords: Tooth/Pulp Ratio, Dental Age, Lower Canine

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Introduction

Identification represents a procedure of comparing a certain number of identifiers characteristics, where a congruence or difference between compared characteristics is being assessed[1]. Dental identification, that is the identification via dental methods, proved to be necessary both during a war and a peacetime[2]. Assessment of the age of an individual at the time of the death is one of the main goals of experts in the fields of

forensics, judicial medicine, bioarcheology and forensics anthropology. If there is no data about a chronological age, age assessment can be done[3,4]. Chronological age, secondary gender characteristics, teeth development, bone maturation, measuring of a height and weight are just some of biological indicators used for determination of the age, or maturation[5]. Forensic dental medicine engages in identification of a human body, or a part of a body, using dental techniques, analysing bite marks found on the body of a victim, and determining the identity of a perpetrator: determination of responsibility and negligence of a dental medicine doctor, as well as a medical and legal aspects in cases of oral tissue trauma[4, 6].

In order to do an adequate assessment of the dental age, it is important to be familiar with changes characteristic to specific phases of growth and development, that is the maturing of teeth. A chronology of these changes depends on many factors such as physical development, genetic influence, person's constitution, endocrinology status, nutrition or a race.

After the growth and development of teeth are finished, assessment of a dental age is based on changes in structure of hard dental tissues, caused by a physiological aging[5,6]. Some of the methods used for the assessment of the dental age are invasive, and require an extraction of a tooth from the jaw, and a preparation of a thin section of a dental material. However, dental age can be estimated with non-invasive procedures, such as the analysis of radiographic dental parameters[4]. The techniques of a computer-assisted of radiographs are often used in practice. The advantages of these radiographic methods are simplicity of analysis, the possibility of image enhancements, and the possibility of image storage and their accessibility for unlimited analysis. Nevertheless, dental age estimation in adults is a challenging process due to the lack of sufficient information on the accuracy of such dental methods when applied on a population other than one which was used to develop the specific dental age estimation method. Considering that researches by other authors in the world had shown that population specificities in assessment of dental age exist, it is necessary to test each method on populations different that the one which is used for the development of the method.

The aim of this study was to estimate dental age in adults from Bosnia and Herzegovina with the radiographic analysis of the pulp/tooth ratio of lower canines and to determine differences from chronological age. The hypothesis of the research was that there is a significant difference between the assessed dental age and the chronological age derived by the analysis of the tooth/pulp ratio.

Material and Methods

The set sample for the research comprised 50 periapical radiographic images of lower canine teeth, previously obtained from adults aged 18 to 69. For inclusion, all canines on radiographs had to be visible outlines of the endodontic space and the whole canine tooth itself. Radiographs of lower canines with advanced abrasion, dental restorations, signs of endodontic treatments, and/or periapical and periodontal pathology were excluded. Additional information used are chronological age and sex of the person to whom the images belonged, excluding the identity of the person. All radiographs used in the research are derived from an

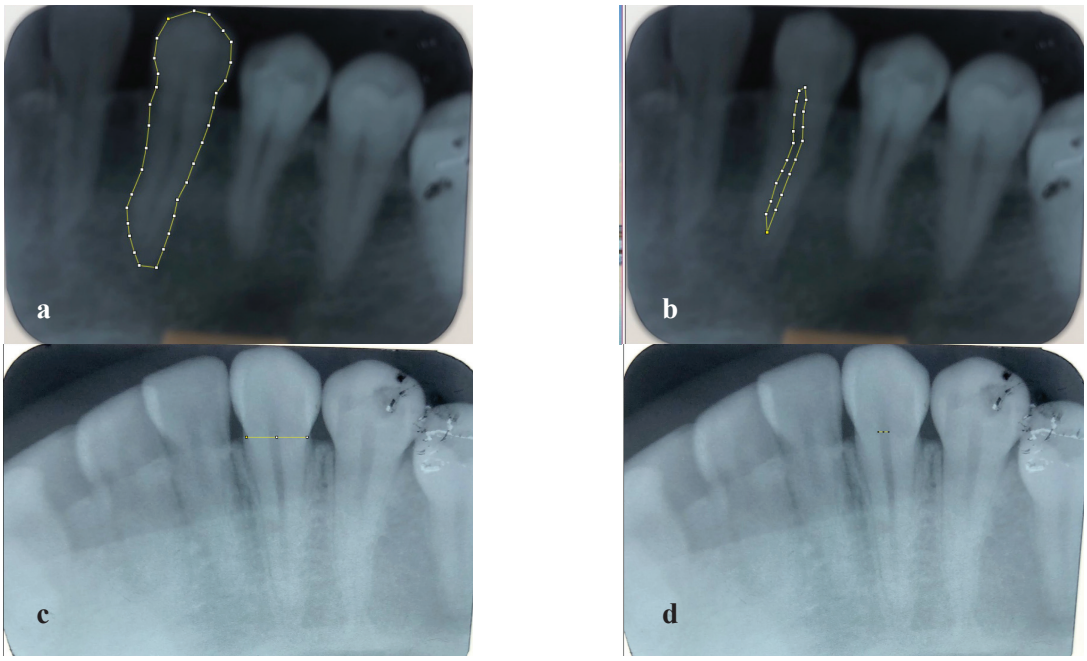

Figure 1. a) bordering of the complete lower canine tooth; b) bordering of the lower canine tooth pulp space; c) mapping of the root dimension at the cementoenamel junction; d. mapping of the pulp dimension at the cementoenamel junction.

archive of the Department of Dental Morphology, Dental Anthropology and Forensics. The research has been approved by the Ethics committee of The University of Sarajevo – The Faculty of Dentistry with Dental Clinical Center, decision number 02-3-4-59-1-10/2021. After the selection, the periapical images were digitalized and imported into ImageJ computer software for analysis. A tool for polygonal selection was used to outline the endodontic area and tooth area of the lower canine on each radiographic image, in order to obtain surface area measurements according to the Cameriere method (Figures 1:a,b). Software tool for linear measurements was used to obtain linear dimensions (length and width) of the tooth, root and root canal according to the Kvaal-Solheim methods (Figures 1:c,d and 2). Results of measurements were entered in formulas for assessments of dental age, as per equations given by the authors. The estimated dental age was compared to the chronological age for each sample. Statistical analysis of obtained data included descriptive statistics for sample analysis, correlation analysis between measured morphometric characteristics and chronological age, and linear regression analysis.

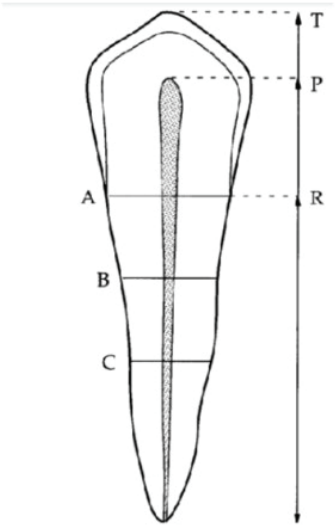

Figure 2. Diagram showing X-ray scan measurements of individual teeth

Results

Analysis of samples gathered

Review of the age structure of a sample (n= 50), points to the fact that an average age of samples was 41.18 years, with the youngest examinee at the age of 28, and the oldest at the age of 69. (Figure 3). Median of samples was at the age 40, with the interquartile range (IQR) between the values of the age of 27.25 and 54. (Table 1). Our sample consisted of 21 scans of males (42%), and 29 scans of females (58%) (Figure 3). A binomial test showed that there is statistically significant difference between the gender distribution within the examined sample (p= 0.322)

Table 1. Age structure and characteristics of examined samples

Age (n=50)	Value
Minimum	18.00
Median	40.00
Average	40.18
Maximum	69
IQR (Q1 – Q3)	27.25 - 54

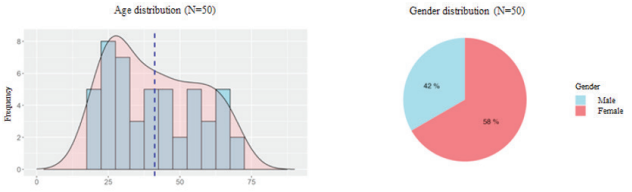

Figure 3. Histogram of the age distribution of the examined sample and diagram of the gender structure of the examined

Existing models for age prediction

We used a linear regression model according to Cameriere. A prediction model according to Cameriere uses a quotient of a pulp area and lower canine tooth area as an independent variable, based on which the age estimation is derived.

$$\text{Estimated age} = 89.456 - 461.873 \times RA_I \quad [1]$$

$$RA_I = x = \frac{\text{pulp area of the lower canine tooth}}{\text{area of the lower canine tooth}} \quad [2]$$

We analysed correlation between the RA_I parameter (the quotient of pulp area and tooth area) and the age of our examinees, which showed that in our examined sample the correlation is statistically significant (p= 0.0017), with the value of the Pearson correlation coefficient r= 0.433 (95% CI: [-0.634 – 0.176]). Further analysis of a regression model according to Cameriere, which has been applied to our data, showed that this model is statistically significant (p= 0.0017). Determination coefficient (R^2) was 0.187. The standard regression mistake for this model was 14.12 years. Figure 4 shows a comparison between an actual and an estimated age according to Cameriere model, in our sample.

A modification of the Cameriere regression model has been done in order to optimize the model for our data, which resulted in the following model:

$$\text{Estimated age} = 67.51 - 267.703 \times RA_I \quad [3]$$

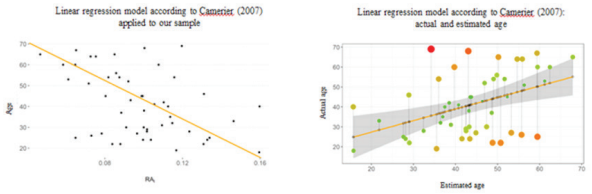

Figure 4. Linear model according to Camerier applied to our sample and comparison of an actual and estimated according to Camerier's model (2007).

Compared to the original model, there was no difference in the accuracy of the estimate by applying the modified model. We applied a linear regression model according to Kvaal-Solheim (1994) to our data.

Kvaal-Solheim predictive model (1994) uses a quotient of a pulp width at the cementoenamel junction and a root width at the cementoenamel junction as an independent variable, based on which it gives an estimated age of the examinee.

$$\text{Estimated age} = 75.9 - 174.7 \times \text{FWC} \quad (4)$$

$$\text{FWC} = \frac{\text{pulp width at the cementoenamel junction}}{\text{root width at the cementoenamel junction}} \quad (5)$$

We examined a correlation between the FWC parameter (the quotient of the width of the pulp on the cementoenamel junction and the width of the root at the cementoenamel junction) and age of our examinees, with results showing that the correlation is not statistically significant (p=0.054) in our sample, with the Pearson correlation coefficient value r = - 0.27 (95% CI: [-0.513; 0.005]).

Further examination of the Kvaal-Solheim regression model from 1994, which has been applied to our data, showed that this model is not statistically significant (p= 0.054). Determination coefficient (R^2) was 0.075. The standard regression mistake for this model was 15.07 years. Figure 5 shows a comparison between an actual and an estimated age according to Kvaal-Solheim model, in the examined population sample. Considering that the FWC parameter had not proven to be a better statistically important predictor, a modified regression model would also not have a statistically significant value. We applied a linear regression model according to Kvaal-Solheim (1995) to our data. Kvaal-Solheim predictive model (1995) uses parameter M as an independent variable, based on which it gives an estimated age of the examinee.

$$\text{Estimated age} = 158.8 - 255.7 \times \text{M} \quad (6)$$

$$\text{M} = \frac{\text{P+R+T+A+B+C}}{6} \quad (7)$$

We examined a correlation between the parameter M (mean value of all ratios) and age of our examinees, with results showing that the correlation is statistically significant (p= 0.011) in our sample, with the Pearson correlation coefficient value r = - 0.356 (95% CI: [-0.577; 0.086]). Further examination of the Kvaal-Solheim regression model from 1995, which has been applied to our data, showed that this model is not statistically significant (p= 0.011). Determination coefficient (R^2) was 0.1266. The standard regression mistake for this model was 14.64 years. Figure 6 shows a comparison between an actual and an estimated age according to Kvaal-Solheim model, in the examined sample. A modification of the Kvaal-Solheim regression model (1995) has been done in order to optimize the model for our data, which resulted in the following model:

$$\text{Estimated age} = 96.8 - 88.68 \times \text{M} \quad (8)$$

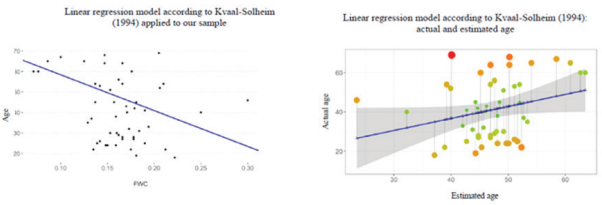

Figure 5. Linear model according to Kvaal-Solheim (1994) applied to our sample and comparison of an actual and estimated according to Kvaal-Solheim's model (1994)

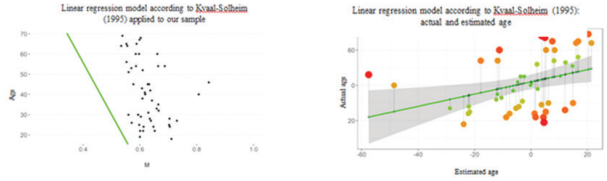

Figure 6. Linear model according to Kvaal-Solheim (1995) applied to our sample and comparison of an actual and estimated according to Kvaal-Solheim's model (1995)

This modification corrected the negatively estimated age values, but the level of mistake stayed equal to the original model and there was no difference in the accuracy of the estimation with application of the modified model, compared to the original model.

Combined model – modification of existing methods for our sample

Predictive values gathered by the Cameriere method (2007) and the Kvaal-Solheim methods (1994 and 1995) for age estimation based on morphometric parameters of the lower canine tooth showed great deviations and a high level of estimation error, for data related to our sample. In order to improve precision and quality of a chronological age estimation we started creating a regression model based on all of the morphometric parameters gathered. In order to determine variables, which needed to be included into a new, combined regression model, we evaluated correlation coefficients of a chronological age and all examined morphometric parameters (Table 2). All

of the evaluated parameters from the table we included in a multiple regression model for prediction of the chronological age:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots\ldots + \beta_i x_i \quad [9]$$

Table 2. Correlation between age and morphometric parameters

Parameter	Pearson's correlation coefficient	P value
Pulp area	-0.545	0.000*
Tooth area	-0.395	0.005*
RA_1	-0.433	0.002*
PWC	-0.459	0.001*
RWC	-0.343	0.015*
FWC	-0.274	0.054
A	-0.493	0.000*
B	-0.463	0.001*
C	-0.482	0.000*
P	-0.209	0.140
R	-0.138	0.338
T	-0.146	0.310
M	-0.356	0.011*

* - $p < 0.05$

After testing all combinations and interactions between examined variables, our result was achieved in the form of a model, which we are going to call the Combined model with the following formula:

$$\text{Estimated age} = 78.1 - 142 \times A - 0.0037 \times PP \quad [10]$$

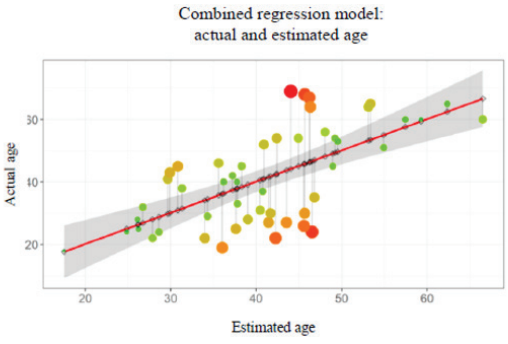

Figure 7. Comparison of an actual and estimated according to the combined model

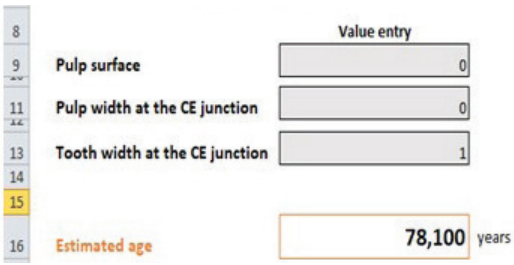

Figure 8. Display of the calculator for estimation of the age based on the Combined model

A contribution of the parameter A in the regression model was rated as statistically significant (p= 0.0014), with a standard error of 42. A contribution of the parameter PP (pulp surface) was rated as statistically significant (p= 0.0002), with a standard error of 0.00092 mm. A standard error of the combined model was 12 years, with the determination coefficient (R_2) of 0.411. Figure 7 shows a comparison between an actual and an estimated age according to the combined model, in examined population. Based on the combined model we made a calculator which estimates denal age basend on measured radiographic parameters and which is presented as a part of this paper (Figure 8).

Discussion

On a sample of radiographic image analysis obtained from adults from Bosnia and Herzegovina, our research managed to estimate dental age with the analysis of pulp/tooth ratio of lower canine teeth, using Cameriere and Kvaal-Solheim methods. None of the applied methods in this research shows an absolute congruence between a chronological and estimated age. A standard regression error tolerable in this type of research is up to 10 years. Considering that results obtained in these researches show the standard error of over 10 years, Cameriere method, as well as Kvaal-Solheim methods from 1994 and 1995, all used in this case, show deviation in estimated chronological age, which points out to the fact that these methods are not applicable in cases of lower canine teeth of population in Bosnia and Herzegovina. Possible reason could be a more rapid aging of teeth in population of Bosnia and Herzegovina compared to population in countries where these methods were originally developed. Another possible reason of this deviation could be the way of digitalization of the radiographic scans used. For that reason, it is necessary to conduct research including broader sample size, including different age groups, in order to determine differences, and find suitable radiographic parameters based on which we could obtain more accurate dental age compared to a chronological age.

Research conducted by Cameriere and associates in 2007 at the University of Bologna had a goal of examining a possible application of pulp/tooth ratio with the help of periapical radiographs as the age indicator, and comparison with the previous analysis. The analysis had shown a more precise estimation of dental age by using a combination of measurements from the periapical and the mesial X-ray scan, with the fact that mesial scan can be done only if a tooth is extracted, which limits the use of this method[7]. Results obtained during our research, using the Cameriere method show a standard error of 14.12 years. A modification of Cameriere method had been done in order to obtain more precise results. However, there was no

difference in estimation precision by applying the modified model compared to the original model. In 1994 Kvaal-Solheim and associates conducted research which had the same goal – obtaining a suitable formula for calculating the chronological age using certain parameters. Correlation coefficient was in the range of r = 0.48 up to r = 0.90. The results had shown a low degree of correlation between an estimated dental age and an actual chronological age[8]. Results of our research, in cases when Kvaal-Solheim method from 1994 was used, show a standard regression error of 15.07 years. Considering that the FWC parameter used in the Kvaal-Solheim method from 1994 did not prove to be a statistically important predictor, the modified regression model also would not have been statistically valuable. Kvaal and Solheim determined in their research that the model has the least impact in case when only lower canine teeth are used, and if all of the teeth from the jaw are included the results become significantly better, especially if teeth from both upper and the lower jaw are included. If only one type of teeth is used, the determination coefficient will always be lower, which certainly needs to be taken into account considering our research[8].

Kvaal and Solheim[9] conducted another research in 1995 in order to try and determine a method suitable for the estimation of the chronological age. Statistical analysis showed that the Pearson correlation coefficient between age and different ratios for each type of teeth was significant, except for the ratio between the tooth length and root, which had been excluded from further analysis. The standard regression error in the research for our paper, using the Kvaal-Solheim method (1995) was 14.64 years. Modification of the regression model, called the combined model, had been done for this method as well. The modification corrected inaccuracies, but the level of error stayed equal to the one in the original model. Standard error of the combined model was 12 years, with the determination coefficient (R^2) of 0.411.

Solheim T. conducted research in 1993, including 1000 teeth of Caucasian population, and reached a conclusion that the formulae used on certain teeth can be used for estimation of age of deceased persons in cases of identification, and archaeological research as well.

Inclusion of factors of gender and teeth colour depends on condition of a body and teeth of the deceased[10]. Research conducted by Nathalie Bosman and associates in 2004 is based on the method for calculation of dental age, based solely on radiology measurements from periapical X-ray scans of certain teeth. The sample size consisted of 197 panoramic scans of patients aged between 19 and 75. When the age is calculated based on measurements of all six teeth, or all three mandibular teeth, no significant differences were found between the actual and the estimated age. In all other cases when individual teeth were being used separately, or when only three mandibular teeth were being used, statistical analysis showed significant differences[11].

Results obtained in the research by Brkić and associates showed a significant correlation between the chronological and determined dental age, with the correlation coefficient of r = 0.85, p < 0.001. Correlation between genders was significant as well – r = 0.99 for male teeth and r = 0.98 for female teeth. The method used in this research proved to be the method used for dental age estimation in exhumated bodies and human remains in forensic analysis in Croatia[12].

Research by Cameriere and associates (2009) had a goal of testing their own method for estimation of dental age in population of Portugal. Results had shown that measuring of the pulp/tooth ratio of lower and upper canine teeth, as well as comparison of skeletal sample results of Portuguese population and skeletal samples of Italian population does not show statistically significant differences in estimation of dental age between these two samples[13]. Cameriere in 2014 conducts another research with his associates, with the main goal of testing the applicability of a new algorhythm for an automatic estimation of pulp and tooth area. The research used 70 periapical X-ray scans of upper canine teeth. The results obtained via this method do not deviate from the results obtained via the standard method, but the procedure is much quicker[14].

Zukic *et al.* published a paper in 2017, which had a goal to test five dental methods for estimation of age in adults. The research had been conducted on 60 intact single-rooted extracted teeth of the upper and the lower jaw, extracted from living examinees. Results showed that the Bang-Ramma methods are the most accurate when applied to an independent Bosnian sample while Kvaal and Solheim method, Ubelaker method and Lamendin method were less accurate[15].

Research conducted in 2020 had a goal of verifying accuracy and applicability of two age estimation methods, Kvaal and Cameriere methods, in adult Brazilians[16]. Age estimation methods proposed by Kvaal and Cameriere are simple and non-destructive, and they have proven to be repeatable and reliable. Kvaal method was more accurate for the age group 20 – 29 and 30 – 39, while the Camariere method[16] was more accurate for adults over the age 40. Limit ation of our research is a small study sample which included a wider age range. Therefore, it is possible that these radiographic dental age estimation methods would be more accurate in certain smaller age range groups, and/or if applied to other tooth groups, but our intention was to test these methods on independent sample derived from Bosnian population and see what to expect if radiographic parameters were used in dental age estimation of adults from our country in forensic cases.

Conclusions

A significant difference exists between the dental age determined by analysis of the pulp/tooth ratio of lower

canine teeth and the chronological age of the examined population

Binomial test showed that there is no statistical difference between gender distribution and the examined sample.

Standard errors of applied models were 14.12 years; 15.07 years; 14.64 years, while the standard error in case of application of the combined model was 12 years.

The research shows that specificities of biological age of teeth in population of Bosnia and Herzegovina have to be taken into account. Based on that, researches including larger number of examinees, as well as different age groups, have to be conducted in order to be able to rely with certainty on dental age estimation with pulp/tooth ratio of lower canine teeth.

IQR - interquartile range

RA_l parameter - the quotient of pulp area and tooth area

FWC parameter - the quotient of the width of the pulp on the cementoenamel junction and the width of the root at the cementoenamel junction

M parameter - mean value of all ratios:
P – ratio between pulp length (P) and root length (R)
T – ratio between tooth length (T) and root length (R)
R – ratio between pulp length and tooth length (T)
A – the ratio between the width of the pulp and the width of the root at the enamel-cement border
B – the ratio between the width of the pulp and the width of the root in the middle between the ratio A and C
C – the ratio between the width of the pulp and the width of the root in the middle between the CC border and the apex of the tooth

PP parameter – pulp surface

References

1. Radmilović Ž. Biometric identification. Policija i sigurnost, 2008;17:159-180.
2. Galić J, Brkić H, Kaić Z, Čadež J. Dentition Based Postmortem Age Identification. Acta Stomatolog Croat, 1995;29:197-210.
3. Brkić H, Kaić Z, Keros J, Šoljan M, Turković K. Forenzična stomatologija, Školska knjiga, 2000.
4. Ortner,DJ. Identification of pathological conditions in human skeletal remains. Elsevier Academic Press, 2003.
5. Mohit Gupta, R Divyashree, PR Abhilash, Mohammed Nadeem A Bijle, KV Murali. Correlation between Chronological Age, Dental Age and Skeletal Age among Monozygoyic and Dizygotic Twins. Int Oral Health, 2013;5:16-22.
6. Stefančić S, Njemirovskij V, Brkić H, Kern J. Dental age Determination Using Incremental Lines. 4th International Congress of the Croatian Dental Society, Zagreb, Croatia, 2008, 369-369.
7. Cameriere R, Ferrante L, Belcastro MG, Bonfiglioli B, Rastelli E, Cingolani M. Age estimation by pulp/tooth ratio in canines by peri - apical x – rays. J Forensic Sci, 2007:52;166-170.
8. Kvaal S, Solheim T. A Non-destructive Dental Method for Age Estimation; J Forensic Odontostomatol, 1994;12:6-11.
9. Kvaal S, Kolltveit K, Thomsen O, Solheim T. Age Estimation of Adults from Dental Radiographs. Forensic Sci Inter, 1995;74:175-185.
10. Solheim T. A New Method for Dental Age Estimation in Adults. Forensic Sci Int, 1993;59:137-147.
11. Bosmans N, Peris A, Aly M, Willems G. The application of Kvaal's dental age calculation technique on panoramic dental radiographs. Forensic Sci Inter, 2005;153:208-212.
12. Brkić H, Miroslav M, Mladen P. Forensic Determination of Dental Age of Adults. Acta Stomatolog Croat, 2008;42:267-272.
13. Cameriere R, Cunha E, Sassaroli E, Nuzzolese E, Ferrante L. Age estimation by pulp/tooth area ratio in canines: Study of a Portuguese sample to test Cameriere's method. Forensic Sci Int, 2009;193:128.e1-e6.
14. Cameriere R, De Luca S, Egidi N, Bacaloni M, Maponi P, Ferrante L, Cingolani M. Automatic age estimation in adults by analysis of canine pulp/tooth ratio: Preliminary results. J Forensic Radiol Imaging, 2015;3:61-66.
15. Zukić S, Zukanović A, Bajsman A, Vuković A. Dental age estimation in Bosnian adults. Bias, Precision and Accuracy of five methods. J Forensic Odontostomatol, 2017;35:89.
16. Miranda JC, Azevedo ACS, Rocha M, Michel-Crosato E, Biazevic MGH. Age estimation in Brazilian adults by Kvaal's and Cameriere's methods. Braz Oral Res, 2020;34:e051.

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