

ORIGINAL ARTICLE / ОРИГИНАЛНИ РАД

The accuracy of Belgrade Age Formula method for dental age estimation in Montenegrin children aged 10–12 years

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SUMMARY

Introduction/Objective The aim of the study was to test the accuracy of Belgrade Age Formula (BAF) for dental age estimation on the sample of Montenegrin children.

Methods The radiographs of 134 Montenegrin children (67 females and 67 males) saved as “jpeg” files were analyzed with Image J software. Sex, the number of teeth with complete development, apex width and tooth length of the mandibular canine and second molar were used in order to calculate dental age with the BAF formula.

Results The discrepancy between estimated dental age and chronological age was -0.088 ± 0.64 years; the absolute difference was 0.52 ± 0.39 years. The percentage of participants whose estimated dental age differed six months from their chronological age was 61.2 and 53.7 for females and males, respectively, while the percentage of participants whose estimated dental age differed 12 months from their chronological age was 94 and 83.6 for females and males, respectively.

Conclusion The BAF may be an accurate approach for estimating dental age in Montenegrin children aged 10–12 years with uncompleted tooth development. However, BAF has to be evaluated on a larger sample of Montenegrin infants in future studies.

Keywords: dental age; age estimation; BAF; Montenegro

INTRODUCTION

Numerous external and internal factors affect individual growth and development [1]. These effects can be manifested differently on the maturation of children and their development. Assessing biological age is important for determining the degree of maturity of a child, which has already become a standard diagnostic procedure in many areas of medicine and dentistry [2]. In orthodontics, assessing the maturity of the patients can help clinicians to define the type of orthodontic treatment, appropriate time to begin and the prognosis of proposed orthodontic treatment [3]. Initiating orthodontic treatment at the right time leads to shortening the duration of treatment and makes it more efficient [3]. Moreover, this assessment could help clinicians to recognize the beginning of the pubertal growth spurt, a period of intense changes in growth that can be additionally helpful for the treatment of orofacial skeletal discrepancies [3]. Approximately, the start of the pubertal growth spurt is expected around 10 years for females and 12 years for males [4].

Estimating biological age can be a considerable process, in which valuable information is, in addition to medical sciences, provided by researchers of other scientific fields such

as anthropology (examination of skeletal remains), criminology (identification of undocumented persons, for example in major accidents when it is difficult to identify the persons), forensic medicine, archeology, and others [5].

Over time, different ways of estimating biological age of children and adolescents have been developed. The biological age of a patient is most often based on the analysis of skeletal and dental changes observed on different types of X-rays. The European formula, developed by Cameriere et al. [6] in 2006, is currently one of the most used quantitative methods for dental age estimation. The European formula analyzes different linear parameters of permanent teeth with incomplete development on panoramic radiography of the patient [5, 6]. The accuracy of the European formula, compared with other methods for assessing dental age, in different population, has been confirmed in many studies [7].

Recently, a group of authors developed a new regression formula for assessing dental maturity. Belgrade Age Formula (BAF) is also a quantitative method that uses panoramic radiography for dental age analysis [8]. The parameters included in the BAF are the sex of the patient, the number of permanent teeth on the left side of the lower jaw with complete root development, the tooth length, and the apex width of the canine and the

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second molar with incomplete apex closure [8]. By reducing the number of teeth whose length and apical width are measured, the process of determining dental age is accelerated and the procedure is facilitated, whereby equally accurate results could be obtained [8]. However, the accuracy of the BAF was tested only for Serbian and Italian populations [8].

The aim of the study was to examine the applicability of BAF on Montenegrin children in late mixed and early permanent dentition with incomplete teeth development.

METHODS

A sample of 160 panoramic radiographs of healthy Montenegrin children (80 females and 80 males) aged 10–12.99 years were collected to perform a cross-sectional retrospective study. Ethical principles for medical research involving human subjects defined by the Declaration of Helsinki were the main guide according to which we designed the study. Ethics Board of the University of Montenegro, Faculty of Medicine, approved this study (KCCG No. 03/01-13013/1).

The analyzed panoramic radiographs that were randomly taken from the medical histories of patients from the Clinical Center of Montenegro were recorded between 2018 and 2020 as part of a standard clinical or diagnostic procedure. Parents or guardians have signed an agreement informing them that any dental documentation, including panoramic radiography, may only be used for scientific or educational purposes without any possibility of revealing the child's identity. Since the population of Montenegro is composed of Croats, Bosniaks, Albanians, Serbs, and Montenegrins, selected panoramic radiographs were retrieved from medical histories of patients with Montenegrin heritage established by their name and surname.

Sex, date of birth, panoramic radiography record date, medical history, and a patient's identification number were documented by a researcher who did not assess the dental age. The inclusion criteria were as follows: healthy children without systemic or development disorders that could potentially have an impact on the growth and development of the craniofacial complex, with no previous orthodontic treatment and absence of any alveolar bone pathology. The exclusion criteria were poor quality of panoramic radiography, dental agenesis, hyperdontia and the presence of impacted or rotated mandibular teeth. Due to systemic disorders, dental agenesis, and a previous orthodontic treatment, 26 panoramic radiographs were excluded. Therefore, panoramic radiographs of 134 age-matched Montenegrin children (67 females and 67 males) were included in the final study group. All panoramic radiographs were recorded in a computer as "jpeg" files and Image J software (Public domain open-source software, National Institute of Mental Health Bethesda, Maryland, USA) was used for all required measurements. Date of record and date of birth were gathered in an Excel spreadsheet, chronological

age was calculated and expressed in decimals with the "yearfrac" function.

The BAF regression formula was applied for dental age estimation [8]. Mandibular left permanent teeth, except the third molar, were evaluated on panoramic radiographs. Sex, the number of teeth with completed development, apex width (the area between the mesial and the distal inner side of the open apex), and tooth length of the canine and the second molar are parameters needed to calculate the BAF formula. The difference between dental age and chronological age was assessed; an overestimation or an underestimation depending on whether the result was positive or negative. After a four-week interval, 20 panoramic radiographs were reevaluated by the researchers to determine the intra- and inter-examiner reproducibility.

Statistics

The results are presented as count (%), means \pm standard deviation or median (25th–75th percentile) depending on the data type and distribution. Intra- and inter-observer reliability of age estimation was verified one month after the first measurement on 20 randomly selected panoramic radiographs. All p values less than 0.05 were considered significant. All data were analyzed using the IBM SPSS Statistics for Windows, Version 20.0 (IBM Corp., Armonk, NY, USA).

RESULTS

The study included 134 patients, both sexes. The chronologically youngest patient was 10.07 years old, and the oldest one was 12.99 years old. The mean difference between estimated dental age with the BAF method and chronological age was -0.088 ± 0.64 years; while absolute difference was 0.52 ± 0.39 years. Table 1 shows that the average values are very similar, respectively the relative and absolute differences are approximate, which indicates the accuracy of the BAF method.

Intra- ($r = 0.98$, $p < 0.001$) and inter-observer ($r = 0.84$, $p < 0.001$) reliability of age estimation shows that the person and the time of measurement had no influence on the measurement values.

Linear, logical regression indicated that chronological age was found as an independent predictor for the BAF

Table 1. The mean chronological age (CA), estimated age (based on Belgrade Age Formula – BAF) and residuals (mean differences between them, i.e., BAF - CA) in the Montenegro population

CA/Sex	n	CA mean \pm SD	BAF mean \pm SD	BAF - CA mean \pm SD	Absolute value BAF - CA mean \pm SD
female					
10–10.99	21	10.45 \pm 0.26	10.29 \pm 0.51	0.16 \pm 0.54	0.43 \pm 0.35
11–11.99	26	11.53 \pm 0.29	11.43 \pm 0.63	0.10 \pm 0.51	0.43 \pm 0.29
12–12.99	20	12.53 \pm 0.29	12.28 \pm 0.64	0.05 \pm 0.65	0.54 \pm 0.34
male					
10–10.99	21	10.43 \pm 0.25	10.51 \pm 0.6	-0.08 \pm 0.66	0.54 \pm 0.37
11–11.99	26	11.55 \pm 0.28	11.46 \pm 0.54	0.08 \pm 0.36	0.30 \pm 0.22
12–12.99	20	12.53 \pm 0.29	12.31 \pm 1.13	0.22 \pm 1.06	0.97 \pm 0.44

Table 2. Regression equation

Sample	B	95% CI B	95% CI B	Slope	95% CI for SLB	95% CI for SLB	Adjusted R2	R2	p	
Total sample	0.53	-0.94	2	0.95	0.82	1.07	0.79	0.62	< 0.001	
Sex	Male	1.34	-0.95	3.74	0.87	0.67	1.08	0.52	0.53	< 0.001
	Female	-0.34	-2.18	1.50	1.02	0.86	1.18	0.71	0.71	< 0.001

B – unstandardized coefficients B, intercept; CI – confidence interval; SLB – slope lower bound

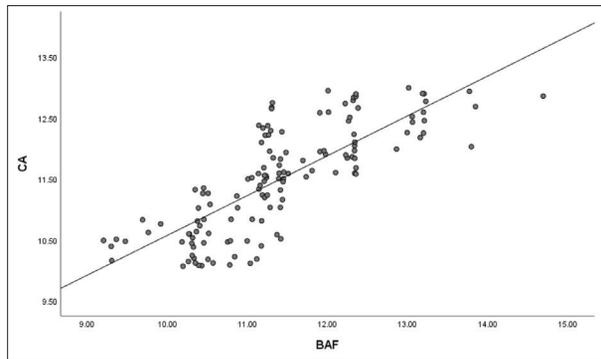


Figure 1. Plot of correlation between chronological and estimated age in total sample; CA – chronological age; BAF – Belgrade Age Formula

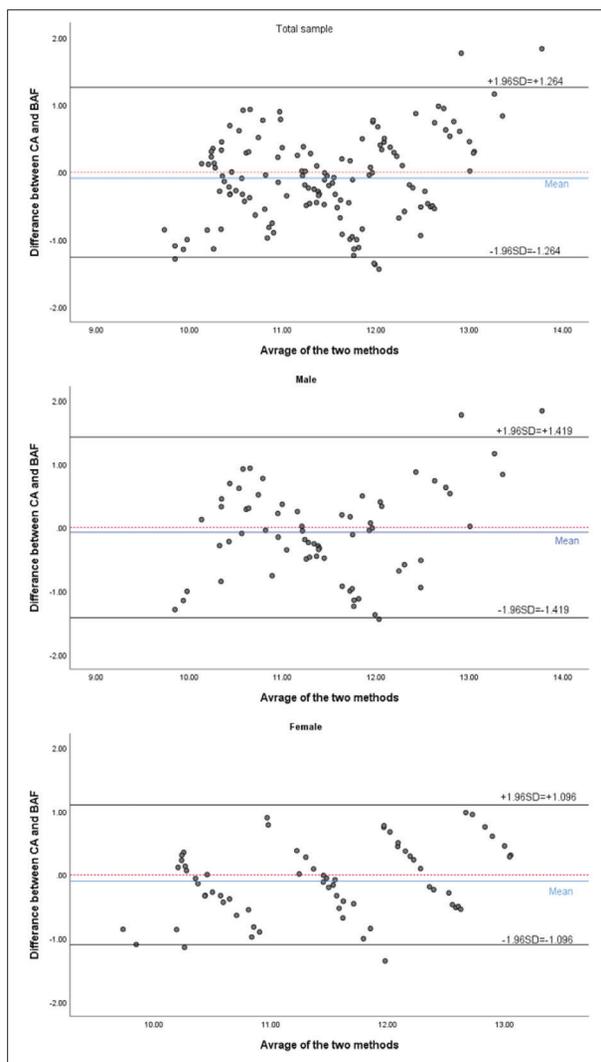


Figure 2. Bland–Altman plot; CA – chronological age; BAF – Belgrade Age Formula

in a high percentage of the total sample (Table 2). It is noticeable that in the female sample the value of the intercept is slightly lower and that the value of the slope is slightly higher compared to the male population.

The percentage of participants whose estimated dental age differed ± 6 months compared to chronological age was 61.2 and 53.7 for females and males, respectively, while within ± 12 months it was 94 and 83.6 for females and males, respectively.

The correlation between the BAF and chronological age is positive, strong, and statistically significant ($r = 0.822$, $p < 0.001$) (Figure 1). There is better correlation in the male population ($r = 0.831$, $p < 0.001$) than in the female one ($r = 0.826$, $p < 0.001$). Figure 1 shows central groupings as they are diluted to higher values. The Bland–Altman method shows no systematic error, although there are some influential outliers (Figure 2).

DISCUSSION

Dental age estimation is a method that assesses an individual’s age based on dental maturity [9]. It is an important aspect of the age estimation process, which also includes a physical examination, obtaining personal information, and skeletal maturity assessment [10]. The most used approaches for determining dental age are based on the sequence in which permanent teeth emerge and radiographic evaluation of the degree of the crown and roots’ mineralization of permanent teeth [11, 12]. The variability of tooth development and emergence is influenced by gene mutations, generalized and/or localized insults [13, 14]. Understanding the fundamental patterns of growth and development in children, as well as identifying various environmental factors that might directly or indirectly interfere with the maturation process, can be aided by studying the dental maturity [9].

Researchers generally compare the dental maturity of a specific population to previously set standards based on the findings of studies of a certain population, such as French-Canadian children [15]. The use of standards that are not specific to the population of interest has a number of challenges, and their application can lead to incorrect conclusions concerning dental maturity [15].

Cameriere et al. [5] published in 2007 a research with a study sample that included participants from several countries, and the European formula was used for determining dental age. The authors analyzed over 2000 orthopantomographic radiographs of children aged 4–16 years from different European countries, including Croatia, Germany, Slovenia, Spain, Italy, Kosovo*, and the United Kingdom [5]. One of the findings of the study was that nationality had no impact on the age estimation process [5]. In

* Editorial note: this designation is without prejudice to positions on status, and is in line with UNSC 1244 and the ICJ Opinion on the Kosovo declaration of independence.

the years thereafter, a significant number of studies have validated the accuracy and reliability of this method for determining dental maturity [16–19]. A great number of researches have also modified the European formula and created their own population-specific formulas [8, 20–23].

In a study from 2018, the authors tested the European formula on 423 orthopantomographic radiographs of Serbian children (231 females and 191 males) aged 5–15 years and found that the formula is applicable to determine dental age in the Serbian population [19]. Zelic et al. [8] developed a simplified formula (BAF) for estimating dental age, which was tested on the Serbian and Italian populations. The BAF was found to be more accurate for dental age estimation in the Serbian population (particularly in females), although the accuracy of both the BAF and the European formula was nearly identical in the Italian group [8]. Therefore, we decided to test the BAF formula in Montenegrin children who are in the mixed dentition stage since it has been shown that BAF could be a reliable method for assessing the dental age in other populations as well as the Serbian population [8].

The findings of this study revealed that dental age calculated with the BAF formula underestimated the chronological age of Montenegrin children. This finding is consistent with an earlier research, in which the European formula or the BAF was employed to estimate dental age [8]. In almost every age category, the discrepancy between the predicted dental age and chronological age was less than six months, showing that the BAF could be a reliable tool for estimating age and dental maturity of Montenegrin children. Within six months, the difference between the estimated dental age and chronological age was assessed in 61.2% of female and in 53.7% of male Montenegrin children who participated in the study. Furthermore, in 94% and 83.6% of female and male Montenegrin children, respectively, estimated dental age differed from chronological age within 12 months. The BAF demonstrated greater accuracy in the Montenegrin population compared to the results of a previously conducted study in which dental and

chronological age differed within six months in 46.3% and 44.7% of female and male Serbian children, respectively, and within 12 months in 76.3% and 74.7% of female and male Serbian children, respectively, aged 5–14 years [8]. These results can possibly be explained by the fact that the Montenegrin study sample was smaller and included fewer age categories than the Serbian study sample.

The difference between the estimated dental age and chronological age assessed in male participants aged 12–12.99 years was nearly one year (Table 1). When the BAF formula was tested on the Serbian population sample, similar findings were reported, according to which the highest disparities between the estimated dental age and chronological age were observed in male participants aged 12–12.99 years and 13–13.99 years [8]. In this age category the development of all permanent teeth, or at least the development of the second molar and the canine, the key predictors of dental maturity according to the BAF, could be completed, which might affect the final result significantly. Therefore, this finding could suggest that both the BAF method and the European formula should be applied in children with incomplete tooth development. Future research should compare the accuracy of other qualitative and quantitative methods for assessing dental maturity of a larger population of Montenegrin children, and determine which method provides the most accurate results and help develop a population-specific formula for dental age estimation process.

CONCLUSION

The BAF could be an accurate method for dental age estimation of Montenegrin children with incomplete tooth development; however, the additional research with large sample is needed to confirm this assumption.

Conflict of interest: None declared.

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Тачност методе Београдске формуле старости за процену денталне старости црногорске деце узраста 10–12 година

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САЖЕТАК

Увод/Циљ Циљ истраживања био је да се испита тачност методе Београдске формуле старости (БФС) за процену денталне старости узорка деце из Црне Горе.

Метод Радиографски снимци 134 црногорске деце (67 девојчица и 67 дечака) сачувани су као *jpeg* фајлови и анализирани су софтвером *Image J*. За израчунавање денталне старости помоћу БФС коришћен је пол, број зуба са завршеним развојем, ширина врха корена и дужина мандибуларног очњака и другог молара.

Резултати Неслагање између процењене денталне и хронолошке старости је $-0,088 \pm 0,64$ године; апсолутна разлика

је била $0,52 \pm 0,39$ година. Процент учесника чија се процењена дентална старост разликује шест месеци од њихове хронолошке старости био је 61,2 и 53,7 за девојчице и дечаке, док је проценат учесника чија се процењена дентална старост разликовала 12 месеци од њихове хронолошке старости био 94 и 83,6 за жене и мушкарце.

Закључак БФС може бити тачан метод за процену денталне старости код црногорске деце узраста 10–12 година са незавршеним развојем зуба. Међутим, БФС мора бити испитана на већем узорку деце из Црне Горе у будућим студијама.

Кључне речи: дентална старост; процена старости; БФС; Црна Гора