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**The accuracy of BAF method for dental age estimation in
Montenegrin children aged 10–12 years**

Тачност методе *BAF* за процену денталне старости црногорске деце
старости 10–12 година

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

Тачност методе *BAF* за процену денталне старости црногорске деце старости 10–12 година

SUMMARY

Introduction/Objective The aim of the study was to test the accuracy of Belgrade Age Formula (BAF) formula 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 mandibular canine and second molar were used in order to calculate dental age with 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 6 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 94.0 and 83.6 for females and males.

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

Keywords: dental age; age estimation; BAF; Montenegrin

САЖЕТАК

Увод/Циљ Циљ истраживања био је да се испита тачност формуле *Belgrade Age Formula (BAF)* за процену денталне старости узорку деце из Црне Горе.

Методе 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 *BAF* формуле 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. Проценат учесника чија се процењена дентална старост разликује 6 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 94,0 и 83,6 за жене и мушкарце.

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

Кључне речи: дентална старост; процена старости; *BAF*; Црна Гора

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, in addition to medical sciences, can be a considerable process in determining the chronological age of a person which provide valuable information for researchers in 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 them) forensic medicine, archeology and in other fields [5].

Over time, different ways of estimating the 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 that are observed on different types of X-rays. The European formula, developed by Cameriere and co-workers in 2006, is currently one of the most used quantitative methods for dental age estimation [6]. The European formula analyzes the different linear parameters of permanent teeth with incomplete development on panoramic radiography of the patient [5, 6]. The accuracy of European formula has been confirmed in many studies, compared with other methods for assessing dental age, in different population [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 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 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 BAF was tested only for Serbian and Italian population [8].

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

METHODS

A sample of 160 panoramic radiographs of healthy Montenegrin's children (80 females and 80 males) aged 10.00–12.99 years were collected to perform 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, Bosnians, Albanians, Serbs and Montenegrins, selected panoramic radiographs were retrieved from medical histories of patients with Montenegrin heritage that was established by their name and surname.

Sex, date of birth, panoramic radiography date record, medical history and patient's identification number were documented by the researcher who didn't assess the dental age. The inclusion criteria were: 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 previous orthodontic treatment, 26 panoramic radiographs were excluded. Therefore, panoramic radiographs of 134 age-matched Montenegrin's children (67 females and 67 males) were included in the final study group. All panoramic radiographs were recorded in 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.

BAF regression formula was applied for dental age estimation [8]. Mandibular left permanent teeth, except the third molar, were evaluated on panoramic radiographs. Sex,

number of teeth with completed development, apex width (the area between the mesial and 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

Results are presented as count (%), means $\pm$ standard deviation or median (25th-75thPercentile) depending on 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 SPSS 20.0 (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.).

RESULTS

The study included 134 patients, both sexes. The chronologically youngest patient was 10.07 years old and the oldest 12.99 years old. The mean difference between estimated dental age with BAF method and chronological age was -0.088 ± 0.64 years; while absolute difference was 0.52 ± 0.39 years. Tables 1 showed that the average values were very similar, respectively the relative and absolute differences are approximate, which indicated 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 showed that person and time of measurement had not influenced measurement values.

Linear, logical regression indicated that CA was found as an independent predictor for BAF 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 was 94.0 and 83.6 for females and males respectively.

The correlation between BAF and CA is positive, strong, and statistically significant ($r = 0.822$, $p < 0.001$) (Figure 1). There is better correlation in male population ($r = 0.831$, $p < 0.001$) than in female population ($r = 0.826$, $p < 0.001$). The graph shows central groupings as they are diluted to higher values (Figure 1). The Bland-Altman method shows no systematic error, although there are few 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 emergence 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 and his colleagues published in 2007 the research with study sample that included participants from several countries and European formula was used for determining dental age [5]. The authors analyzed over 2000 orthopantomographic radiographs of children

aged 4 to 16 from a different European country, 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 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 formula [8, 20–23].

In the study from 2018, the authors tested the European formula on 423 orthopantomographic radiographs of Serbian children (231 females and 191 males) aged 5 to 15 and found that formula is applicable to determine dental age in the Serbian population [19]. Zelic et al. developed a simplified formula (BAF) for estimating dental age, which was tested on the Serbian and Italian populations [8]. 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 earlier research in which the European formula or BAF was employed to estimate dental age [8]. In almost every age category, the discrepancy between predicted dental age and chronological age was less than 6 months, showing that BAF could be a reliable tool for estimating age and dental maturity of Montenegrin children. Within 6 months, the difference between estimated dental age and chronological age was assessed in 61.2 percent of females and 53.7 percent of males Montenegrin children who participated in the study. Furthermore, in 94.0 and 83.6 percent of females and males Montenegrin children, estimated dental age differed from chronological age within 12 months. BAF demonstrated greater accuracy in the Montenegrin population compared to the results of the previous conducted study in which dental and chronological age differed within 6 months in 46.3 and 44.7 percent females and males Serbian children and within 12 months in 76.3 and 74.7 percent females and males Serbian children age 5 to 14 years [8]. These results could be explained by the fact that the Montenegrin study sample was smaller and included less age categories than the Serbian study sample.

The difference between estimated dental age and chronological age assessed in male participants aged 12.00–12.99 was nearly one year (Table 1). When the BAF formula was tested on the Serbian population sample, similar findings were reported, where the highest disparities between estimated dental age and chronological age were observed in male participants aged 12.00–12.99 and 13.00–13.99 [8]. In this age category the development of all permanent teeth, or at least the development of the second molar and canine, the key predictors of dental maturity according to the BAF formula, could be completed, which might affect the final result significantly. Therefore, this finding could suggest that BAF method as well as 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 in a larger population of Montenegrin children, and determine which method provides the most accurate results, as well as the need to develop a population-specific formula for dental age estimation process.

CONCLUSION

The BAF formula could be accurate method for dental age estimation of Montenegrin's 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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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					
10.00–10.99	21	10.45 $\pm$ 0.26	10.29 $\pm$ 0.51	0.16 $\pm$ 0.54	0.43 $\pm$ 0.35
11.00–11.99	26	11.53 $\pm$ 0.29	11.43 $\pm$ 0.63	0.10 $\pm$ 0.51	0.43 $\pm$ 0.29
12.00–12.99	20	12.53 $\pm$ 0.29	12.28 $\pm$ 0.64	0.05 $\pm$ 0.65	0.54 $\pm$ 0.34
male					
10.00–10.99	21	10.43 $\pm$ 0.25	10.51 $\pm$ 0.60	–0.08 $\pm$ 0.66	0.54 $\pm$ 0.37
11.00–11.99	26	11.55 $\pm$ 0.28	11.46 $\pm$ 0.54	0.08 $\pm$ 0.36	0.30 $\pm$ 0.22
12.00–12.99	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	2.00	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

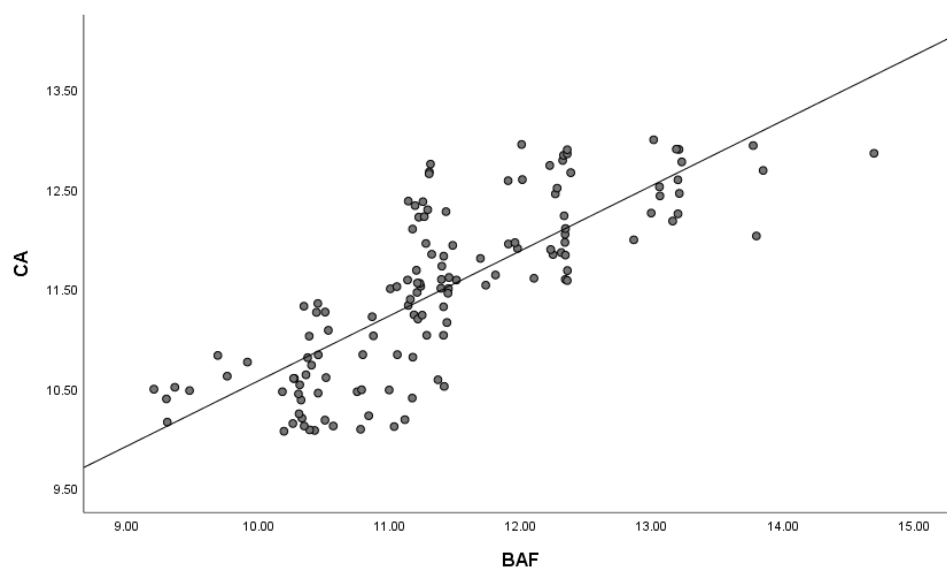


Figure 1. Plot of correlation between chronological and estimated age in total sample;
CA – chronological age; BAF – Belgrade Age Formula

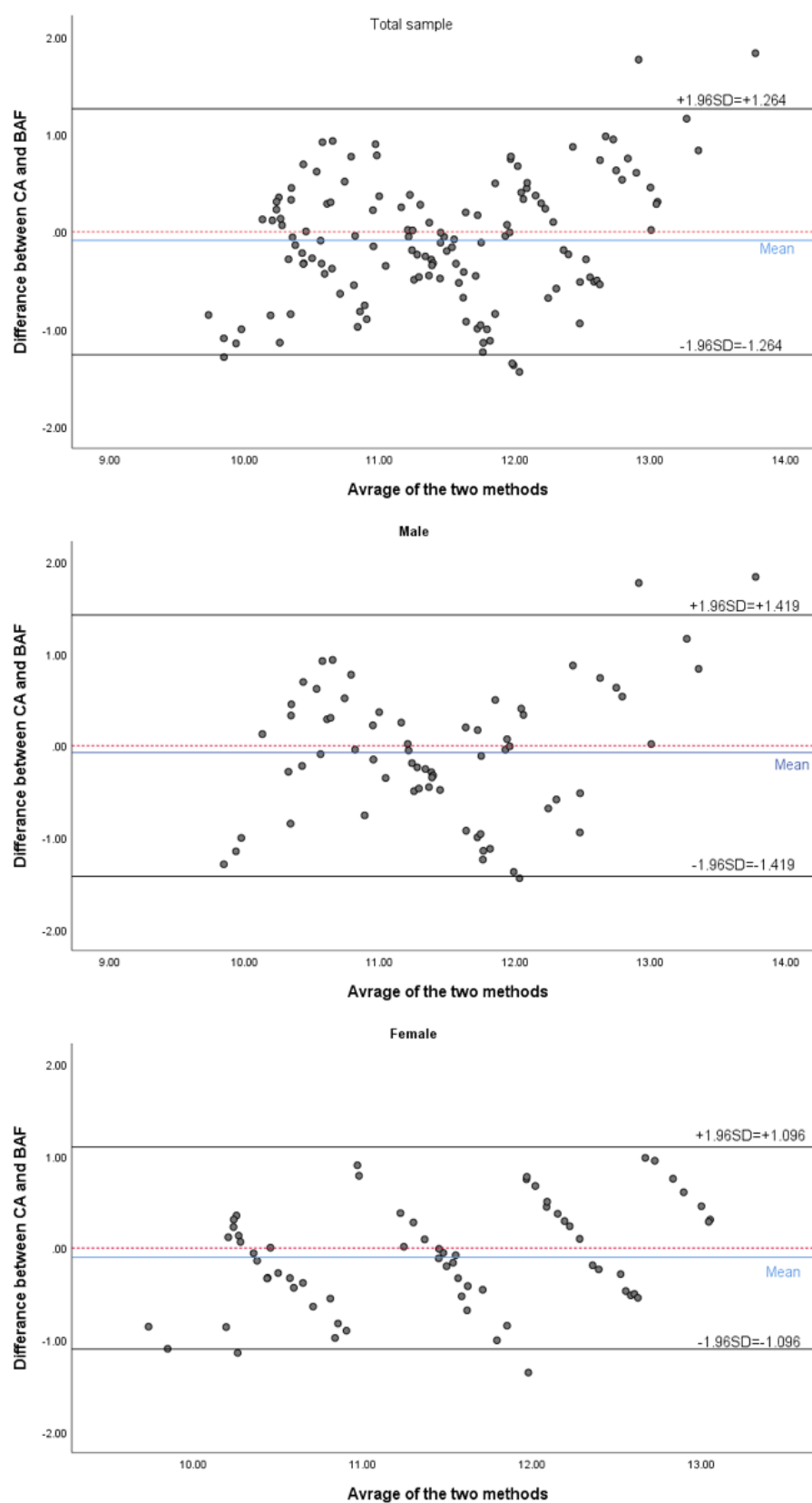


Figure 2. Bland–Altman plot;

CA – chronological age; BAF – Belgrade Age Formula