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Original communication

Dental age estimation on Bosnian–Herzegovinian children aged 6–14 years: Evaluation of Chaillet's international maturity standards

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ABSTRACT

Background: Dental age estimation in children plays an important role in forensic dentistry. The most commonly used method for age estimation was developed by Demirjian in 1973 on a French–Canadian sample. It generally overestimates dental age in many populations. International maturity standards were formed to obtain a predicted age with more confidence when ethnic origin was not available.
Objectives: The aim of this study was to evaluate the applicability of Chaillet's international scores in the dental age assessment on Bosnian Herzegovinian (BH) children.
Methods: Orthopantomograms of 1772 children, 980 girls and 792 boys aged 6.04–14.90 years, were assessed using Chaillet's international maturity tables and curves. The dental ages for both genders were compared to the chronological ages through a paired *t*-test.
Results: Mean overestimation using Chaillet's international maturity standards were 0.09 ± 0.83 for girls and 0.28 ± 0.90 for boys. The absolute accuracy of residuals between the dental and chronological age were 0.65 ± 0.52 years for girls (Median: 0.52 years) and 0.73 ± 0.60 years for boys (Median: 0.57 years).
Conclusion: The Polynomial compound formula was recommended to predict dental age with more accuracy for results of international maturity standards on BH children.

1. Introduction

Age estimation on living individuals and skeletal remains has importance in legal and forensic medicine, human anthropology and bioarchaeology. Forensic odontology encompasses a wide range of clinical, laboratorial, radiographic and other available methods for age estimation using teeth. The development and maturation of teeth in growing children brings two main approaches to assessing their age. These are the evaluation of clinical emergence in the mouth and the radiographic evaluation of the mineralization of crowns and roots of primary and permanent dentition.[1] The clinical emergence of both in deciduous and permanent teeth is affected by different local factors, including feeding habits, local trauma and the pathology of deciduous teeth. The mineralization and growth of crowns and roots is a continuous processes that goes on, until the closure of apices of teeth, and these are less affected by some local and systemic factors.[2] In order to quantify a continuous process from the first traces of cusps mineralization until root apex closure, many authors suggested a different number of radiographic stages, ranging from three stages suggested by Hunt and Gleiser,[3] sixteen stages suggested by Moorrees et al.,[4] twelve stages by Haavikko[5] to possibly 40 stages suggested by Nolla.[6] Additionally, a different number of teeth was used for radiographic evaluation; from only one tooth, being the lower first molar suggested by Hunt and Glasser[3] to the evaluation of all permanent teeth in both jaws, suggested by Nolla[6] and Haavikko.[5]

In 1973 Demirjian et al.[7] introduced a method based on the evaluation of seven permanent teeth from the left side of the lower jaw, excluding the third molar, by choosing one of eight

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radiographic stages of crown and root mineralization. Each tooth is scored with appropriate points according to the relevant radiographic stage in order to quantify dental maturation. The sum of these points of all seven teeth presents a dental maturity score on a scale from 0 to 100, similarly to Tanner and Whitehouse hand and wrist maturity system.[7] Several papers showed a great variability of estimated age, generally an overestimation, compared to French–Canadian standards.[8] In order to obtain a predictable age with more confidence some authors suggested the adaptation of Demirjian's method including the polynomial or regression analysis or the creation of new dental developmental tables and curves.[9–15]

Ideally, age estimation in a specific population should be done by the usage of different methods provided by existing literature and practices as well as the development of new methods to ensure the application of the most adequate technique.[8] Previous studies on dental age using OPGs of BH children, showed an overestimation by Demirjian's and by Willems' methods. Haavikko's method underestimated for both genders and Cameriere method overestimated for girls and underestimated for boys.[16,17] Chaillet et al.[18] introduced adopted dental development tables and curves as a result of a study of radiographs from 8 countries using Demirjian's method in order to construct international dental age estimation standards when the ethnic origin is unknown. In conclusion, the aim of this study was to evaluate the accuracy of international maturity curves by Chaillet for age estimation in BH children.

2. Subjects and methods

2.1. Subjects

The study sample consisted of 1772 OPGs of Bosnian–Herzegovinian children, selected from a radiographic collection held by the University of Sarajevo Faculty of Stomatology and principal regional public dental institutions in Bosnia and Herzegovina in order to encompass Bosnians, Croats and Serbs who represent the major ethnic make up of the country. The Radiographs of 980 girls and 792 boys aged 6.04–14.90 years were dated from year 2000–2011 (Table 1).

Exclusion criteria for OPGs were: incomplete dental records including the absence of the recorded date of birth and date of radiograph, low quality panoramic radiographs, agenesis or extraction of permanent teeth from the lower jaw, recorded systematic diseases, premature birth and congenital anomalies. Patients' personal data were not collected except for the date of birth, date of radiograph and gender and their parents or guardians had signed an agreement with the dental institutions concerned that dental records and radiographs could only be used for research and educational purposes without the possibility of jeopardizing their confidentiality. The chronological age for each child was determined by the date of the radiograph and the date of birth after converting both to a decimal age according to Eveleth and Tanner.[19]

Table 1
Age and gender distribution of the sample of orthopantomograms.

Age group	Girls	Boys	All
6.00–6.99	30	31	61
7.00–7.99	81	50	131
8.00–8.99	126	103	229
9.00–9.99	213	153	366
10.00–10.99	139	135	274
11.00–11.99	162	136	298
12.00–12.99	138	103	241
13.00–13.99	67	57	124
14.00–14.99	24	24	48
6.00–14.99	980	792	1772

2.2. Method

The OPGs were photographed using a Kodak EasyShare Z812-IS Digital Camera. The digital images were stored and examined by using the Corel Draw software package (Corel Draw v.12.0, 2003, Corel Corporation, Ottawa, Canada). The developmental stages of seven permanent teeth, excluding the third molar, from the left side of the mandible were evaluated using an eight-grade scale marked with an alphabet (A–H) according to Demirjian's criteria.[7] Then, the dental age was calculated using international maturity tables and median curves from Chaillet et al., specific for girls and boys.[18]

2.3. Statistical analysis and data management

SPSS Statistics 17.0 for Windows (SPSS Inc., Chicago, IL) and MS Excel 2003 (Microsoft Office 2003, Microsoft, Redmond, WA) were used for all statistical analysis and data management.

The evaluation of mineralization stages was done by the first author. For intra-observer repeatability and inter-observer reproducibility 177 (10%) randomly selected OPGs were reexamined two months after examination by the first and the fourth author (EN). Kappa was used to measure repeatability of Demirjian's stages for each tooth.

The intra-observer repeatability and inter-observer reproducibility of dental age was tested with intra-class correlation coefficient (ICC).[20]

The difference between the chronological age between girls and boys was tested with independent samples *t*-test.

The correlations between dental age as a result of international maturity standards and the chronological age and coefficients of determination were verified by the linear regression analysis for girls and boys separately.

Analyses were made for each gender and age cohort (i.e. children between 10.00 and 10.99 years of age) would be included in the 10 years cohort and so on. The accuracy of the method was determined by mean difference between dental age and chronological age (DA–CA) or mean residual. Paired samples *t*-test was applied to assess the significances of the difference between dental age (DA) and chronological age (CA) for both genders and age cohort separately. Due to multiple testing, the exact probability for each evaluated difference is reported. Tests with a P value less than 0.0025 can be considered significant according to Bonferroni correction.[21]

The absolute accuracy or prediction error, which reports only the time distance from true age, was calculated for both genders separately.

Different polynomial functions were explored in calculations of dental age as the dependent variable versus a maturity score as independent variable, for both genders separately, in order to increase the proportion of variance explained.

3. Results

The Kappa for repeatability of developing stages ranged from 0.75 to 0.89 for intra-observer repeatability and from 0.69 to 0.89 for inter-rater reproducibility (Table 2).

The estimated ICC (95% confidence intervals) for the calculated dental age were for intra-observer repeatability was 0.969 (0.958–0.977), and for inter-observer reproducibility was 0.961 (0.946–0.971). There was no statistically significant difference in the chronological age between girls and boys, t (1770) = 0.751 (P = 0.453). Strong linear correlation between the international

Table 2
Comparison of Demirjian's mineralization stages according to the method of Chaillet (2005) for intra-observer repeatability and inter-observer reproducibility. Data from 177 OPGs.

Tooth	31	32	33	34	35	36	37	Mean Kappa
	Kappa							
Intra-observer Repeatability	0.85	0.75	0.88	0.81	0.81	0.76	0.89	0.82
Inter-observer Reproducibility	0.88	0.69	0.84	0.85	0.80	0.78	0.89	0.82

maturity score and the chronological age was 0.902 for girls and 0.903 for boys ($P < 0.001$), for both genders. The proportions of explained variances were 0.814 and 0.815 for girls and boys, respectively. The mean age difference ± SD (SD – standard deviation) for all age groups were 0.09 ± 0.83 for girls and 0.28 ± 0.90 for boys. The chronological age and the dental age using international maturity scores for girls and boys, and the difference between dental and chronological age for both genders and age cohort are shown in Table 3.

There were no statistically significant differences in 7, 9, 10, 11 and 12 years age groups in girls and in 10, 12, 13 and 14 years age group in boys. The statistically significant difference – an overestimation was seen in the 6 and 8 years age groups in girls and in the 7, 8, 9 and 11 years age groups in boys. Statistically a significant underestimation of age was seen in the 13 and 14 years age group in girls. Fig. 1 shows the distribution of mean differences between the dental age and the chronological age using the method by Chaillet in girls and boys, respectively. The absolute accuracy or mean prediction error was 0.65 ± 0.52 years for girls (Median: 0.52 years) which was statistically significant and better compared to boys, 0.73 ± 0.60 years (Median: 0.57 years), $t\,(1564.71) = 2.825$ ($P = 0.005$).

3.1. Polynomial function

The relationship between score, using the international maturity standards, as independent variable and chronological age as dependent variable was explored by different polynomial functions, where compound model was fitted as the best and proportion of explained variance was the highest in both genders (Table 4).

4. Discussion

The age estimation of individuals using all existing scientific methods is common practice in forensic science. Forensic odontology uses different clinical, laboratorial and radiological examinations on the teeth to determine the age of living or deceased persons.[22] The Evaluation of mineralization from OPGs is the most suitable method for age estimation using teeth in children, because a single radiograph gives the complete developmental status of dentition in children, including unmerged, impacted or missing teeth.[23]

Technically, better forensic methods demonstrate a higher accuracy or a smaller difference between the dental and chronological age and the reproducibility or the amount to which estimated ages remain consistent over repeated measurements of the same individual.[20]

The advantage of this study was that the sample was randomly drawn from the main regions in Bosnia and Herzegovina in order to have a more representative picture of the general population of children in the country.

The mean difference between the dental and the chronological age in BH children using the international maturity curves or overestimations were 0.09 ± 0.83 year and 0.28 ± 0.90 year for girls and boys, respectively (Table 3).

The previous study of accuracy of Demirjian's method in BH children showed an overestimation, which ranged from 0.60 to 2.17 years in girls and from 0.63 to 2.60 years in boys depending on the age groups of the sample of 1106 OPGs, ages 5–14.[16] Compared with Demirjian standards, international maturity standards showed a lower overestimation of dental age in BH children.

Cruz-Landera et al.[15] found on a Spanish Caucasian sample of 308 OPGs an overestimation of 0.21 ± 1.07 and 0.37 ± 1.04 years for girls and boys, respectively, using Chaillet's method which was more accurate compared with 0.88 ± 1.09 year in girls and

Table 3
Chronological (CA) and dental age (DA) [Mean and standard deviation (SD)] estimated with the international maturity curves and difference between dental and chronological age (DA–CA) and 95% confidence interval (95% CI) of DA–CA. AD – absolute difference between dental and chronological age or prediction error. Paired samples *t*-test.

Age groups	Gender	*N*	CA		DA		DA–CA		95% CI of the DA–CA		AD		AD[c] median	*t*	*Df*	*P*[a]
			Mean	SD	Mean	SD	Mean	SD	Lower	Upper	Mean	SD				
6.00–14.99	Girls	980	10.40	1.91	10.49	1.91	0.09	0.83	0.04	0.15	0.65	0.52	0.52	3.559	979	<0.001
	Boys	792	10.47	1.91	10.75	2.06	0.28	0.90	0.22	0.35	0.73	0.60	0.57	8.838	791	<0.001
6.00–6.99	Girls	30	6.61	0.28	7.13	0.71	0.52	0.63	0.28	0.75	0.65	0.49	0.48	4.540	29	<0.001
	Boys	31	6.62	0.33	6.96	0.88	0.34	0.72	0.08	0.61	0.57	0.56	0.38	2.637	30	0.013
7.00–7.99	Girls	81	7.57	0.30	7.76	0.68	0.19	0.59	0.06	0.32	0.48	0.39	0.41	2.867	80	0.005
	Boys	50	7.55	0.32	7.97	0.78	0.42	0.78	0.20	0.64	0.74	0.48	0.67	3.834	49	<0.001
8.00–8.99	Girls	126	8.52	0.29	8.84	0.72	0.33	0.68	0.21	0.45	0.59	0.47	0.44	5.405	125	<0.001
	Boys	103	8.52	0.30	8.88	0.86	0.36	0.79	0.20	0.51	0.69	0.52	0.53	4.605	102	<0.001
9.00–9.99	Girls	213	9.48	0.27	10.50	0.90	0.14	0.75	0.04	0.24	0.58	0.50	0.43	2.733	212	0.007
	Boys	153	9.51	0.28	9.86	0.78	0.34	0.77	0.22	0.47	0.68	0.49	0.61	5.549	152	<0.001
10.00–10.99	Girls	139	10.48	0.27	10.50	0.90	0.03	0.85	−0.12	0.17	0.67	0.52	0.52	0.351	138	0.726
	Boys	135	10.52	0.31	10.61	0.80	0.08	0.76	−0.05	0.21	0.53	0.55	0.36	1.291	134	0.199
11.00–11.99	Girls	162	11.51	0.29	11.65	1.01	0.14	0.99	−0.01	0.30	0.80	0.60	0.64	1.849	161	0.066
	Boys	136	11.45	0.29	11.79	1.11	0.34	1.08	0.15	0.52	0.83	0.77	0.58	3.643	135	<0.001
12.00–12.99	Girls	138	12.47	0.29	12.56	0.90	0.08	0.88	−0.06	0.23	0.73	0.50	0.70	1.120	137	0.264
	Boys	103	12.49	0.30	12.81	1.14	0.33	1.09	0.11	0.54	0.94	0.64	0.79	3.053	102	0.003
13.00–13.99	Girls	67	13.45	0.30	13.09	0.62	−0.36	0.59	−0.51	−0.22	0.53	0.44	0.38	−5.053	66	<0.001
	Boys	57	13.44	0.28	13.78	0.92	0.33	0.88	0.10	0.57	0.83	0.43	0.92	2.880	56	0.006
14.00–14.99	Girls	24	14.33	0.28	13.33	0.47	−1.00	0.50	−1.21	−0.79	1.00	0.50	0.86	−9.811	23	<0.001
	Boys	24	14.30	0.23	13.99	1.04	−0.31	1.07	−0.76	0.14	0.73	0.83	0.44	−1.434	23	0.165

[b] *P* is not statistically significant because of small sample size.
[a] Results of paired *t*-test are statistically significant if *P* value is less than 0.0025 according to Bonferroni correction.
[c] Median.

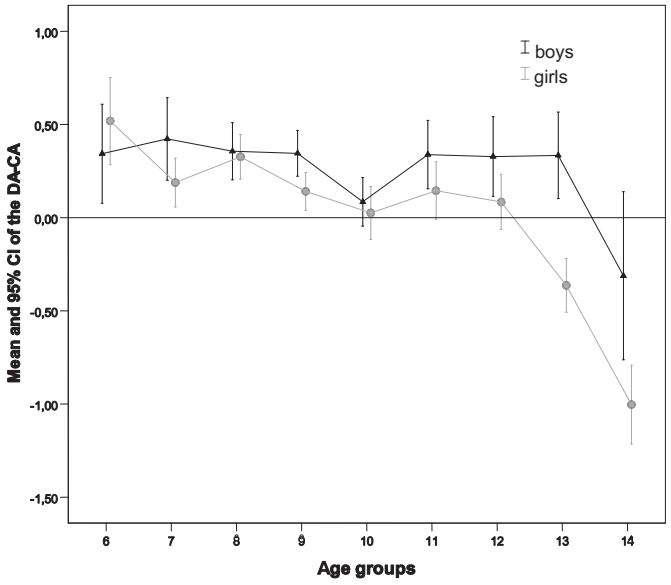


Fig. 1. The mean difference between the dental age and the chronological age (DA–CA) and 95% confidence interval (95% CI) of the DA–CA for girls and boys for each age group.

0.76 ± 1.01 year in boys using the Demirjian method. In the same study, authors found greater underestimation using the Chaillet's method in Venezuelan children, by −0.61 ± 1.07 year and −0.48 ± 0.92 year in girls and boys, respectively, comparing with Demirjian's method which underestimated age by −0.1 ± 1.04 year in girls and −0.23 ± 0.93 year in boys, respectively.

Since Demirjian's method was established, many studies have shown that significant differences were found between the estimated dental age and the chronological age. Most studies indicated that the original Demirjian's scores were inadequate. Koshy and Tandon[24] showed the greatest mean overestimation in literate of 2.82 years for boys and 3.04 years for girls in South Indian children. Statistically significant overestimation of dental age using Demirjian's method was reported in many Caucasian Europeans, and many other nations.[8] According to literature, a significant underestimation of Demirjian's method was reported in Venezuelan–Indian children.[25] In order to improve accuracy of Demirjian's scores, many authors suggested the adaptation of the original method or standards.[10,25–27]

Chaillet et al.[18] have introduced international maturity standards with the initiative to overcome variations among different populations and to use them when the ethnic origin of individuals is unknown. This method is particularly recommended when natural disasters happen involving victims of a diverse origin, e.g. airplane crashes. However, this method is less accurate than tables and standards created and calculated for a specific population.[18]

Willems et al.[12] also adapted a scoring system of Demirjian's radiographic stages on radiographs of Belgian children using a weighted analysis of variance. Age scores were directly expressed in years and the estimated age was the result of summing the adopted scores of seven mandibular teeth.[12] His method reduced overestimation of dental age, which was not statistically different from the chronological age on the Belgian sample.[12] A number of papers showed that Willems' method was more accurate compared to Demirjian's method.[28–30] Mean results in this study showed some smaller overestimation compared to the results of Willems' method which was used in a previous study on OPGs of BH children (591 girls and 498 boys aged 6–13). The dental age by Willems overestimated 0.24 years in girls and 0.42 in boys, according to the study of accuracy of different radiographic methods.[17] In the same study the adopted Haavikko method using four different teeth underestimated dental age by −0.29 year for girls and −0.09 year for boys and the Cameriere method based on measurement of open apices in teeth, was the most accurate, the mean age overestimated by 0.09 year for girls and underestimated by −0.02 year for boys. Maber et al.[28] and Liversidge[31] compared the accuracy of several radiographic methods on Bangladeshi and British Caucasian children from London. Chaillet's method underestimated by −0.26 year comparing with 0.23 years of overestimation using Demirjian's method for both genders, the most accurate was the method by Willems, which underestimated dental age by −0.12 years.

In this study, statistically significant difference ($p < 0.001$) and the overestimation of age was observed in Bosnian–Herzegovinian girls and boys. The difference in the results between results using French–Canadian standards in previous study of Bosnian–Herzegovinian sample may be due the strong Amerindian contribution to French–Canadians and the Caucasian origin of Bosnian–Herzegovinians and sample size. Chaillet's method and international standards were also based on more multiethnic sample from 8 countries, mostly of Caucasian origin (Australians, Belgians, English, Finns, French, French–Canadians, South Koreans, Swedes).[18]

Among different polynomial models relating to results of the international maturity score and chronological age, the proportion of explained variance was the highest using compound function for the population in this study (Fig. 2). Cruz-Landeira et al.[15] suggested the same mathematical model being the best for the Spanish and Venezuelan study sample.

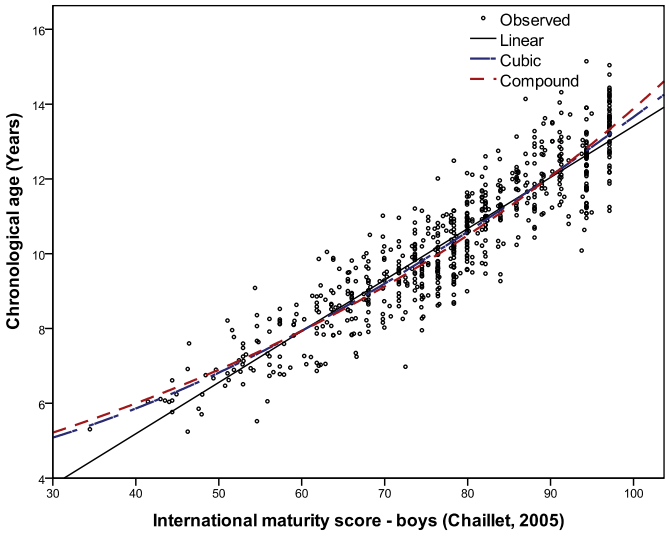
This study is cross-sectional and radiographs were drawn from available records where the number of radiographs relating to the younger age group was limited. Small numbers of children in lower age groups for this kind of cross-sectional study are common in most related studies, because there are uncommon clinical indications for panoramic radiographs for healthy children with normally developing dentition.

Older age groups were also reduced in number of OPGs. Haavikko et al.[32] and Cameriere et al.[29] suggested that there is no reason to test dental age using developing teeth, excluding the third molar, over the age of 13. They agree with Liversidge[31] that from the age of 13, only a small number of children will not have achieved complete root development of the second premolar and second molar. In practice, only a few radiographs will be available for analysis, so the higher age groups are smaller and these children are the ones who are slow to reach maturity. This is a manifestation of development data being slightly skewed to the right. Even with a large test sample, it is not unusual to find a small number of children with delayed tooth formation and estimated age will be considerably underestimated, like in this study for the oldest age group (Fig. 1). The absolute difference in age estimation reports only the time distance from the true age and does not consider

Table 4
Parameters of polynomial functions.

Gender	Function	Equation	R	R^2	EE
Girls	Linear	$Y = -0.768 + 0.139^*x$	0.902	0.814	0.825
	Cubic	$Y = 5.270 + 0.00048x^2 + 0.0000035x^3$	0.909	0.825	0.799
	Compound	$Y = 3.345^*1.014^x$	0.913	0.833	0.077
Boys	Linear	$Y = -0.229 + 0.136^*x$	0.903	0.815	0.823
	Cubic	$Y = 4.491 + 0.00106x^2 - 0.0000013x^3$	0.906	0.821	0.810
	Compound	$Y = 3.533^*1.014^x$	0.911	0.829	0.078

Linear function $Y = a + bx$, cubic function $Y = a + bx + cx^2 + dx^3$, compound function $Y = a^*b^x$, where Y is chronological age and x is international maturity score.
R – Correlation coefficient.
R^2 – proportion of explained variance.
EE – standard error of estimate.



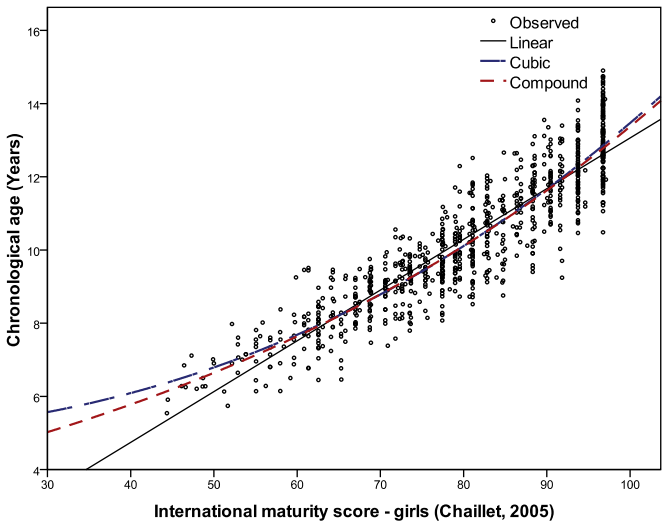


Fig. 2. Scatter plots of international maturity scores against the chronological age for Bosnian–Herzegovinian girls and boys. The lines represent mean regression predictions in the compound function model.

whether the dental age is overestimated or underestimated.[31] The absolute difference of each age group was highest in 14-year age group for girls (1.00 year) and 12-year age group for boys (0.94 year). The lowest absolute difference was in 7-year age group for girls (0.48 year) and 10-year age group for boys (0.53 year). Estimated age was less accurate in older age groups because a fewer developing teeth were left for age estimation and calculation, except third molars – which were not used in Chaillet's method.

Liversidge[31] studied data from Maber et al.[28] using a British sample, and calculated the absolute difference of residuals evaluated by various radiographic methods with the addition of several other methods. Median of absolute difference using Chaillet's method was 0.55 year which is comparable with our results.

5. Conclusion

The international standards provided by Chaillet may be suitable for age estimation in Bosnian–Herzegovinian children and the proportion of explained variance was highest when the compound function was used for both genders to convert the results of international maturity scores to the dental age.

Conflict of interest

None declared.

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None.

Ethical approval

Ethical Committee of the School of Dental Medicine University of Zagreb, Croatia, approved this study.

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