Two-criteria Dental Aging Method Applied to a Bosnian Population: Comparison of Formulae for Each Tooth Group Versus One Formula for all Teeth

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Abstract

The purpose of this study was to obtain age estimation formulae using the length of periodontosis, transparency of the root and root height in each tooth group for the current male population in Bosnia and Herzegovina and to compare these formulae with Lamendin's and Prince's formulae. The research was undertaken on 847 single rooted teeth from 200 identified deceased persons, individuals who died between the ages of 23 and 85 years. Periodontosis, transparency and root height were measured according to Lamendin's procedure. All teeth were grouped in two ways: according to the tooth groups and to the age groups. The highest coefficients of correlation are obtained for maxillary canines (R = 0,731) and mandibular canines (R = 0,706) and the maxillary lateral incisors showed the lowest mean error (ME = 6,63 years). In age groups, the lowest mean error was obtained in the 40-49 years age group (ME = 5,15 years). Equations developed in this study give statistically significantly better age estimations in comparison to the original Lamendin and Prince formulae for the whole sample as well as for each tooth group, except for mandibular central incisors. Age estimation with models developed for each tooth group (except for mandibular lateral incisors) was statistically significantly better than models based on the whole sample.

KEY WORDS: forensic age estimation, teeth, Lamendin and Prince method, Bosnian population

Introduction

In the anthropological assessment of unidentified deceased persons, age estimation is the most important and the most challenging. In Bosnia and Herzegovina, after the war from 1992 to 1995, for determination of age, more importance was given to dental age estimation methods as the number of exhumed human remains where some parts of the skeleton has deteriorated and where skulls were separated from the rest of the skeleton increased. In 1950 Gustafson introduced (1) the first statistical method for age assessment based on six dental criteria. Lamendin et al. used two of these variables, periodontosis and transparency of the root, in a study of French population, "not to propose another improved or modified Gustafson method but rather to present a really simplified one" (2). This method proved to be reasonably accurate in comparison to other intact dental and skeletal age estimation methods (3, 4). Prince and Ubelaker (5) modified Lamendin et al.'s method, including the length of the tooth root into a regression analysis, using the tooth sample from the Terry collection. This skeletal collection is housed at the National Museum of Natural History, in Washington, D.C. and represents over 1600 disarticulated individuals of known sex, ancestry and age at death (6). A large number of researchers have tested various dental methods on other populations and proposed introduction of independent standards for age estimation in a certain population (7-10). To this date no study relevant to the applicability of existing dental methods to the Bosnian population has been published. In neighboring Croatia, Miličević (11) studied the applicability of the Bang-Ramm (12), Kvaal and Solheim (13) and Johanson (14) methods to the Croatian population. He also developed modifications of the mentioned methods adequate for the Croatian population. Brkić et al. applied a range of procedures and methods in analyzing dental status for the purpose of identification of victims of the previous war in Croatia (15-17). Lamendin and Prince have developed only one formula for all tooth groups. The fact that the growth and development of teeth does not happen at the same time is well known so certain authors developed diferent formulae for certain groups of teeth in their studies (12, 18). This study applies the Lamendin et al. (2) and Prince and Ubelaker (5) methods to the remains of missing persons exhumed in Bosnia and Herzegovina. The purpose of this study was to obtain age estimation formulae from the length of periodontosis, transparency of the root and root height in each tooth group for the current male population in Bosnia and Herzegovina and to compare those formulae with those of Lamendin et al. and Prince and Ubelaker.

Materials and Methods

The sample consisted of 847 single rooted teeth from 200 identified deceased persons from the recent war in Bosnia and Herzegovina. The exact date of birth and at least the month and year of death was known for all persons. Ages ranged from 23 to 85 years, with a mean age of 42,09 years and a standard deviation of 12,53 years. The method of measuring periodontosis, transparency of the root and root height, presented by Lamendin et al. (2) was applied and a sliding digital caliper was used to make measurements in millimeters. A negatoscope was utilized to illuminate the transparency of the tooth root. All measurements were taken from the labial surface of the tooth. All measured teeth were separated in two ways. The first included division by tooth groups, so six groups was reached; three groups in the mandible and maxilla: central incisors, lateral incisors and canines (Table 1). Age was equally distributed through all tooth groups, with a mean age from 41,02 years and a standard deviation of 11,37 years for mandibular central incisors to a mean age of 42,26 years and a standard deviation of 12,59 years for maxillary canines. For each mentioned tooth group, as well as for the entire sample, formulae based on the Lamendin et al. and Prince and Ubelaker models, later called Sarajlić/Lam and Sarajlić/Prince respectively,

Tooth group	11-21	12-22	13-23	31-41	32-42	33-43	All
N (teeth)	122	104	129	143	165	183	847
N (persons)	91	76	97	102	122	139	200

TABLE 1. Sample distribution by tooth group

Age group	23-29	30-39	40-49	50-59	60-69	70-79	80-89
N (teeth)	145	269	206	147	78	1	1
N (persons)	32	64	47	36	19	1	1

TABLE 2. Sample distribution by age group

were developed by applying linear regression analysis. The second grouping was according to age, including a period of 10 years, apart from the first group from the age of 23 to 29 (Table 2). Statistical analyses were performed with Arcus QuickStat (19) using the two-way ANOVA with Sheffe post hoc test in order to determine if formulae developed in this study produced more accurate age estimation then the Lamendin et al. and Prince and Ubelaker formulae. The level of significance was 0,5.

Results and Discussion

The regression equations developed for estimation of age, for the whole sample as well as for each tooth group are presented in Table 3. Coefficients of correlation were higher for maxillary than for mandibular teeth. Highest correlations with age were obtained for maxillary and then mandibular canines, which is consistent with the results published by López-Nicolás, also studying incisors and canines (20). In the Lamendin et al. study no tooth group was superior, taking into consideration the entire sample, but for the age decades 40-49, 50-59 and 60-69 maxillary incisors showed significantly better age estimation, specifically central maxillary incisors (2). Prince and Ubelaker did not present this type of results (5). Studying the transparency of teeth, Solheim had, however, the best results with mandibular second premolars (18). For this study there were not sufficient number of premolars, so further research is necessary to determine the correlation of root transparency and periodontosis of premolars with the real age and their effect on the total sample. Two-way ANOVA with the Sheffe post hoc test was utilized to determine if formulae developed in this study produced more accurate age estimation then the original Lamendin et al. formula and Prince and Ubelaker formula for the American white male population (2, 5). For the whole sample, application of the Lamendin et al. formula produced an absolute mean difference (the average difference be¬tween estimated age and actual age) of 7,57 years, stan¬dard

Model	Formulae for whole sample	R
Sarajlić / Lam	A=P×0,30 + 0,42×T + 26,63	0,632
Sarajlić / Prince	A=P×0,30 + 0,42×T + Hx0,17 + 23,89	0,633
	Formulae for maxillary central incisors	
Sarajlić / Lam	A=P×0,23 + 0,406×T + 26,66	0,628
Sarajlić / Prince	A=P×0,24 + 0,405×T + H×0,98 + 13,06	0,640
	Formulae for maxillary lateral incisors	
Sarajlić / Lam	A=P×0,06 + 0,56×T + 28,52	0,690
Sarajlić / Prince	A=P×0,07 + 0,57×T + H×0,36 + 23,26	0,692
	Formulae for maxillary canines	
Sarajlić / Lam	A=P×0,22 + 0,58×T + 22,59	0,729
Sarajlić / Prince	A=P×0,23 + 0,58×T + H×0,30 + 16,99	0,731
	Formulae for mandibular central incisors	
Sarajlić / Lam	A=P×0,31 + 0,28×T + 28,28	0,598
Sarajlić / Prince	A=P×0,31 + 0,28×T + H×0,03 + 27,85	0,598
	Formulae for mandibular lateral incisors	
Sarajlić / Lam	A=P×0,41 + 0,33×T + 27,02	0,627
Sarajlić / Prince	A=P×0,41 + 0,36×T + H×0,08 + 25,75	0,628
	Formulae for mandibular canines	
Sarajlić / Lam	A=P×0,57 + 0,52×T + 22,20	0,704
Sarajlić / Prince	A=P×0,56 + 0,51×T - H×0,39 + 29,07	0,706

A = age in years
P = periodontosis measurement x 100/root height,
T = measurement of transparency of the root x 100/root height

TABLE 3. Developed formulae with coefficients of correlation

deviation of 5,73 and standard error mean of 0,20 while Prince and Ubelaker formula produced an absolute mean difference of 7,45, standard devia¬tion of 5,73 and standard error mean of 0,20. The formulae developed in this research, Sarajlić/Lam and Sarajlić/Prince produced the identical absolute mean differences and standard errors of mean, 7,36 and 0,19, respectively. The stan¬dard deviation for Sarajlić/Lam was 5,47 and for Sarajlić/Prince 5,46. The mean difference obtained in this study and the mean difference achieved with Lamendin et al. and Prince and Ubelaker formulae are significantly different from one another. The absolute mean difference, standard error of mean and stan¬dard deviation for each tooth group are presented in Table 4. Application of Sarajlić/Lam and Sarajlić/Prince formulae showed smaller absolute mean differences from the real age in relation with the application of the original Lamendin and Prince formula (Lam and Prince) for the total sample and also for each tooth group, excluding mandibular central incisors, where the application of Prince formula shows smaller differences. Established differences are statistically significant. Sarajlić/Lam and Sarajlić/Prince models, developed for each tooth group have demonstrated smaller absolute mean differences from the real age in relation to the application of models developed for the total sample (Sarajlić/Lam-all and Sarajlić/Prince-all). Statistically significant differences were proved, except for mandibular lateral incisors. Comparison models in which the length of the tooth root was used as independent variable (Sarajlić/Prince and Sarajlić/Prince-all) to the models in which it was not used (Sarajlić/Lam and Sarajlić/Lam-all), produced no statistically significant differences. On the contrary, comparing the original Lamendin et al (2) and Prince and Ubelaker (5) for-

	Sarajlić/Lam	Sarajlić/ Prince	Lam	Prince	Sarajlić/Lam-all	Sarajlić/ Prince-all
Maxillary central incisors						
ME	7,23	7,11	7,26	7,27	7,38	7,31
SE	0,48	0,48	0,50	0,49	0,48	0,48
SD	5,33	5,31	5,48	5,39	5,28	5,25
Maxillary lateral incisors						
ME	6,63	6,63	7,80	7,85	7,32	7,36
SE	0,49	0,49	0,60	0,61	0,53	0,54
SD	5,03	5,01	6,16	6,18	5,45	5,54
Maxillary canines						
ME	7,05	7,05	7,25	7,21	7,16	7,16
SE	0,41	0,41	0,48	0,47	0,44	0,44
SD	4,65	4,62	5,43	5,31	5,01	5,02
Mandibular central incisors						
ME	7,17	7,18	7,21	7,09	7,41	7,34
SE	0,43	0,43	0,47	0,47	0,47	0,47
SD	5,18	5,18	5,66	5,58	5,67	5,64
Mandibular lateral incisors						
ME	7,40	7,39	7,82	7,61	7,43	7,44
SE	0,42	0,42	0,45	0,43	0,43	0,43
SD	5,35	5,35	5,73	5,49	5,52	5,49
Mandibular canines						
ME	7,12	7,10	7,91	7,65	7,41	7,45
SE	0,39	0,39	0,49	0,47	0,43	0,43
SD	5,34	5,32	6,60	6,34	5,77	5,77

Absolute mean error (ME), standard error (SE) and standard deviation (SD) in years

TABLE 4. Comparison of developed formulae to Lamendin and Prince formula by tooth group

Age groups (years)		23-29	30-39	40-49	50-59	60-69
Sarajlić/ Lam	ME	8,24	5,36	5,22	8,29	13,92
	SE	0,39	0,25	0,25	0,42	0,67
	SD	4,73	4,16	3,60	5,12	5,87
Sarajlić/ Prince	ME	8,19	5,41	5,15	8,31	13,77
	SE	0,39	0,26	0,26	0,42	0,66
	SD	4,64	4,18	3,72	5,07	5,85
Lamendin	ME	6,64	4,35	6,09	10,95	17,51
	SE	0,34	0,22	0,24	0,48	0,69
	SD	4,09	3,56	3,50	5,81	6,08
Prince	ME	6,99	4,62	5,72	10,34	16,90
	SE	0,35	0,23	0,26	0,46	0,68
	SD	4,24	3,78	3,70	5,52	5,98
Sarajlić/ Lam-all	ME	8,59	5,54	5,15	8,75	14,37
	SE	0,38	0,27	0,28	0,43	0,73
	SD	4,55	4,45	4,04	5,24	6,43
Sarajlić/ Prince-all	ME	8,54	5,59	5,15	8,70	14,34
	SE	0,38	0,27	0,28	0,43	0,72
	SD	4,57	4,47	4,08	5,20	6,38

TABLE 5. Comparison of developed formulae to Lamendin and Prince formula by age group

mula for total sample, maxillary canines and mandibular lateral incisors, showed that the application of the formula developed by Prince and Ubelaker for American Caucasian males gave significantly better results in relation to the application of the Lamendine et al. formula. Looking at the mean differences for each tooth group, the smallest difference was seen in maxillary lateral incisors and then in maxillary canines and mandibular canines, while the highest correlation with the real age was noticed in maxillary canines and mandibular canines. A possible explanation lies in the fact that maxillary lateral incisors represented the smallest sample (104 teeth from 76 persons), in comparison to other tooth groups. Table 5 presents a comparison by age groups based on the application of formulae developed in this study and Lamendine et al. (2) and Prince and Ubelaker (5) formulae. Sarajlić/Lam and Sarajlić/Prince models are based on application above mentioned formulae (2, 5) developed for each tooth category in each age group. Sarajlić/ Lam-all and Sarajlić/Prince-all models express the application of Sarajlić/Lam and Sarajlić/Prince formulae developed for the total sample. Differences between all models are statistically significant, except for the 40-49 age group, comparing Sarajlić/Lam and Sarajlić/Prince with Sarajlić/Lam-all and Sarajlić/Prince-all models. The smallest deviation from real age was determined for individuals 40-49 years of age in this study; 50-59 in the Prince and Ubelaker study (5) and 60-69 in Lamendin et al. study (2). Mean age of our sample was 42,09 years while in Prince sample 52,10. Lamendin did not present the mean age of the sample, but from sample distribution it could be conclude that persons of older age were dominant. This leads to the conclusion that the smallest absolute mean difference in age groups could be a concequence of the application of linear regression analysis which gives smallest deviations in the middle range. However the impact of population differences as well as the influence of environmental factors during the post-mortem period, which for this sample was 6-10 years is also possible. The latter has already been disscused by Marcsik et al. (21) and Mandojana et al. (22). At the same time, all the above mentioned possible differences between this study and Lamendin and Prince studies could be the reason why the original Lamendin and Prince formulae show significantly smaller mean difference from real age in younger groups (23-29 and 30-39 years). Additionaly, in some teeth it was difficult to measure periodontosis precisely which could be a difference between our sample and those of Lamendin and Prince. Formulae developed in this study in comparison with the application of formulae developed by Lamendin and Prince have shown statistically signifi-

cantly smaller mean difference from real age in the age groups from 40-49, 50-59 and 60-69 years for the Bosnian population. Estimation of age for older individulas is always poblematic with constant underestimation of real age (23-25). Lamendin et al. (2) and Prince and Ubelaker (5) in their research used more teeth from the same person (Lamendin had 306 teeth from 208 persons while Prince used 400 teeth from 356 persons). This study was designed in the same way. Solheim (26) compared teeth from the left and right side and did not established any significant differences. Additional research is needed to determine whether the use of the left and right side of teeth of the same tooth group affects the results of age estimation and in what way.

Conclusion

Formulae developed in this study produced more accurate age estimation for the Bosnian population than the original Lamendin et al (2) and Prince and Ubelaker (5) formulae. Established formulae for age estimation based on teeth for each tooth group gives better results that one formula for all tooth groups. These formulae also give a more accurate estimation than the original Lamendin et al. and Prince and Ubelaker formulae. The highest correlation with real age is achieved by using maxillary canines followed by mandibular canines.

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