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Correlation of Chronological Age with Tooth Wear in Archaeological Populations

Ana Družijanić[1], Marin Vodanović[2], Mario Šlaus[3], Vesna Čapkun[4] , Hrvoje Brkić[2]

[1]Dental Clinic Split, Split, Croatia
[2]Department of Dental Anthropology, School of Dental Medicine, University of Zagreb, Croatia
[3]Croatian Academy of Sciences and Arts, Zagreb, Croatia
[4]Department of Biomedicine and Health Research, Medical School Split, University of Split, Croatia

A B S T R A C T

Knowing that attrition and abrasion are most common wear processes of dental hard tissue, which occurs along with aging, the aim of this paper is to determine the correlation between dental age and loss of dental hard tissue on archeological bone residues. For the purpose of this research, the collection of skeletal remains of the Croatian Academy of Sciences and Arts (HAZU) was used. The study includes 392 samples of the remains of both upper and lower jaws from 7 Croatian archaeological sites, whereas 4 of them from continental and 3 of them from coastal Croatia. The remains of bones belong to two different archeological periods, late antiquity and early Middle Ages. Visa Metrix computer system was used on digital photography of occlusal tooth surfaces to measure total exposed area of dental hard tissue and surface of dental hard tissues damaged by attrition and abrasion. Data provided were defined in sq. cm, and as such were inserted in excel table and processed statistically. In the statistical analysis of data, Shapiro-Wilk test, Mann-Whitney U test and Kruskal-Wallis test were used. There is a statistically significant correlation between the total teeth number and estimated chronological age ($\chi^2 = 46.3$, $\eta^2 = 0.23$, $p < 0.001$). Total number of teeth negatively correlates with chronological age ($r = -0.41$, $p < 0.001$). The total surface area of the teeth available decreases with the estimated chronological age ($r = -0.39$, $p < 0.001$), while the proportion (%) of the total damaged area of the teeth in relation to the total available area increases with the estimated chronological age ($r = 0.622$, $P < 0.001$). The proportion of damaged surface in overall teeth surface increases with the estimated chronological age ($r = 0.686$; $p < 0.001$) both in males and females ($r = 0.534$; $p < 0.001$). The lifelong loss of hard tooth tissue positively correlates with chronological age in both sexes despite of historical period. The loss of hard tooth tissue due to attrition and abrasive changes, and with usage of Vista Metrix Inc. computer system can now be used to determine age in forensic dentistry as well as forensic anthropology and archeology.

Keywords: *forensic dentistry, forensic anthropology, determination of dental age*

Introduction

The orofacial system and teeth are often the subject of bio archaeological or paleostomatological researches. After the death of an individual, if proper body care techniques (e.g. mummification) have not been applied, soft tissue decay occurs. Calcified tissue that is made up of bones and teeth can be preserved in its original form for a long time. The age of an individual is determined by defining the degree of growth or decay of different skeleton parts. As a result, the "biological" or "bone" age of that person is defined[1].

Teeth, in unchanged form, from the moment of death of the person, can remain preserved for thousands of years. As such, they represent a great source of information and data on an individual's life, such as age, gender, race, lifestyle, dietary habits, professional activities, illnesses, etc. The analysis is carried out by the same techniques as those applied to living people[2].

Age, gender and race are three basic demographic and anthropological traits of each individual. Thus, determination of age at the time of death, together with sex and race, is the most common feature obtained from dental profiling, and therefore represents basic components of each dental profile.Techniques which can determine age in the moment of death depend whether they are applied on child population when the growth and development of the tooth has not yet been completed, or on adult age, when

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the growth and development of teeth has finished[3]. At the time of tooth development, age determination is based on the knowledge of biological changes that mark the growth and development of teeth[4,5]. As the chronology of these changes depends on many factors such as genetic factors, constitution, endocrine status, nutrition, race, age can only be determined approximately[6].

In children, age estimation at the moment of death is based on growth and development of teeth and jaw, most commonly are used radiological and atlas techniques[7–10]. Radiological techniques are based on the jaw analysis and radiological pictures of teeth, showing visible tooth growth and comparing with standardized values. The most renowned radiological techniques used in childhood are techniques by Demirijan, Haavikko, Moorrees and Cameriere's techniques[11]. Atlas techniques are similar to radiological techniques; radiological pictures of jaw and teeth are compared with growth and developmental images in specific atlas. The most commonly used atlas technique is the one developed by Schour and Massler[11].

When the growth and development of the teeth is finished, it is increasingly difficult to determine the chronological age, so the evaluation is based on, sometimes, barely visible, but permanent changes in the structure of hard tooth tissues[6]. Evaluation of dental age can be obtained on the basis of tooth microstructure analysis, chemical composition within the tooth, or on the basis of morphological and lifelong changes in the teeth. Evaluation and determination of the dental age are used for identifying the remains of a recent human being, identifying the identity and age of living asylum seekers in developed parts of the world who are not registered in the Registers of the countries they originate from, as an additional proof of age or other age limits, and in archeological research[12].

Materials and Methods

For the purpose of this study, the collection of skeletal remains stored in the Croatian Academy of Sciences and Arts (HAZU) was used. The study included a total of 7 archaeological sites in Croatia, whereas 4 from continental and 3 from coastal Croatia. The remains belong to two archeological periods, late antiquity and early Middle Ages. The remains dating back to the late antiquity period were found at 4 sites from continental Croatia – Zmajevac, Štrbinci, Osijek and Vinkovci and at one site from coastal Croatia – Zadar, whereas from the period of the early Middle Ages two findings were analyzed from coastal Croatia – Velim Velištak and from continental Croatian-Radašinovci.

Only teeth and skeletal skulls of the adults were used in the research. Gender and age information of each remain is obtained from the archives of the Croatian Academy of Sciences and Arts. Due to the relatively poor preservation of children skulls (skeleton remains estimated to belong to people under the age of 15) and the impossibility of performing measurements, the research was done with adult remains exclusively. As this paper is based on Croatian Academy of Sciences and Arts samples, the chronological age is known. Measuring abraded tooth surfaces, occlusal surfaces and incisional tooth line and the mutual comparison of measures taken was the method to get the correlation between known chronological age and estimated dental age.

The remains of the jaw and teeth were initially photographed and the measures were taken from 392 photographs of teeth and jaw specimens using Vista Metrix Inc. computer system. The sample consisted of a total of 129 male jaw residues and 75 remains of female jaw from both historical periods and from all the above mentioned sites (Table 1). The study included a total of 182 remains of the upper and 210 remains of the lower jaws. The sample consisted of a total of 4478 teeth of which 1570 molars, 1242 premolars, 655 canines and 1011 incisors. Digital photographs of the remains of certain jaws were made with the Panasonic LUMIX DMC-TZ50 photo camera at a 90 degree angle, and with each sample in the picture there is a 1cm calibrated scale.

The Vista Metrix Inc. computer system is a program that allows quantitative editing of graphical, digital images, graphs, folders and obtaining metric data which are otherwise impossible to obtain. The system consists of a transparent pattern that is overlaid with a photography or material that is to be edited. Such a sample contains a metering tool that is adjusted over the photo and the needed editing option is chosen from the range of editing options.

The Vista Metrix Inc. computer system was used to measure the total visible area of hard dental tissue as well as the tooth wear. Carioze lesions were not included in measurements, and the teeth with extensive caries were led as lost teeth. The surface data were expressed in sq. cm and were inserted in Excel table and as such were processed statistically. As such, the Vista Metrix Inc. computer system enables collecting the graph data, measures of the distance and surface of curved paths, determines the color value of different points, and provides the measures of angles and line lengths. The processed graph values, distances, surface and color values can be stored as Excel or as text files, and as such can be used in analyses or studies.

Statistical analysis

The data required for statistical data processing were inserted in the excel table and then switched to the SPSS 20 statistical package. Statistical distribution of numeric variables, have significantly deviated from the regular distribution by Shapiro-Wilk test. Analysis of the statistical significance of difference between the two variables of the two groups was made by Mann-Whitney U test and among several groups by Kruskal-Wallis test. The strength of the link after the Mann-Whitney test was determined by r ($r = z / \sqrt{n}$), and after Kruskal-Wallis test η^2 (according to formula χ^2 / (n-1). All reliable intervals were given at 95% level, and the intervals of reliability of the difference between the two medians were calculated using the method proposed by Bonett and Price. In the data processing we used χ^2 test, univariate and multivariate regression analysis in order to determine the correlation of the investigated variables with the estimated chronological age of the samples. Correlation strength was determined by determination coefficient R^2. The level of statistical significance was determined at $p < 0.05$.

Results

The study included 392 photographs of the upper and lower jaw remains. Division of samples by sex criteria ($\chi^2 = 0.591$; $p = 0.442$) as well as by chronological age ($\chi^2 = 4.68$; $p = 0.861$) did not much differ statistically by the periods tested (Table 1). Division of samples according to the estimated chronological age did not much differ statistically regarding the sex ($\chi^2 = 6.0$, $p = 0.734$) (Table 1).

TABLE 1

NUMBER (%) OF TOTAL SAMPLES BY GENDER, ESTIMATED CHRONOLOGICAL AGE, LOCATION AND HISTORICAL PERIOD

		Historical period			
		total	Late antiquity	Early Middle Ages	p*
Gender	Males	129 (63)	84 (66)	45 (59)	0.442
	Females	75 (37)	44 (34)	31 (41)	
Estimated chronological age	15–20	6 (2.9)	3 (2.3)	3 (3.9)	0.861
	20–25	17 (8.3)	10 (7.8)	7 (9.2)	
	25–30	27 (13.2)	19 (14.8)	8 (10.5)	
	30–35	49 (24)	29 (22.7)	20 (26.3)	
	35–40	37 (18.1)	27 (21.1)	10 (13.2)	
	40–45	34 (16.7)	20 (15.6)	14 (18.4)	
	45–50	14 (6.9)	8 (6.2)	6 (7.9)	
	50–55	14 (6.9)	9 (7)	5 (6.6)	
	55–60	3 (1.5)	2 (1.6)	1 (1.3)	
	60+	3 (1.5)	1 (0.8)	2 (2.6)	
Locations	Vinkovci Gepidi	7(3.4)	7 (5.3)	0 (0)	
	Osijek	13 (6.3)	13 (9.9)	0 (0)	
	Štrbinci	33 (15.9)	33 (25.2)	0 (0)	
	Zadar Relja	37 (17.9)	37 (28.2)	0 (0)	
	Zmajevac	41 (19.8)	41 (31.3)	0 (0)	
	Radašinovci	32 (15.5)	0 (0)	32 (42.1)	
	Velim Velištak	44 (21.3)	0 (0)	44 (57.9)	

* χ^2 test

There is a statistically significant connection between the total number of teeth with estimated chronological age ($\chi^2 = 46.3$, $\eta^2 = 0.23$, $p < 0.001$) (Table 2). Total number of teeth negatively correlates with chronological age ($r = -0.41$, $p < 0.001$).

TABLE 2

ARITHMETIC MEAN ± SD, MEDIAN (MIN-MAX) OF THE TOTAL NUMBER OF TEETH BY GENDER, LOCATION AND HISTORICAL PERIOD

		Total number of teeth	p
Gender	Male	21.6 ± 6.1; 23 (7–32)	0.710*
	Female	21.3 ± 6.9; 22 (7–32)	
Estimated chronological age	15–20	26.3±4.5; 27.5 (18–30)	< 0.001**
	20–25	22.8±4.8; 23 (15–30)	
	25–30	24.2±5; 24 (14–32)	
	30–35	21.9±6.6; 22 (10–32)	
	35–40	24±5.8; 26 (10–32)	
	40–45	20.3±6.1; 21 (10–32)	
	45–50	18.4±4.3; 19 (13–26)	
	50–55	14.6±5.5; 15 (6–23)	
	55+	12.3±2.6; 12.5 (9–16)	
Locations	Vinkovci Gepidi	24.5±4.6; 23 (20–30)	0.146**
	Osijek	23.2±7.9; 27 (10–32)	
	Štrbinci	23.1±6.5; 24.5 (10–32)	
	Zadar Relja	21.7±6.2; 23 (7–32)	
	Zmajevac	21±6.3; 22 (9–32)	
	Radašinovci	19.2±6.2; 20.5(6–30)	
	Velim Velištak	21.2±6.2; 22 (10–31)	
Historical period	Kasna antika	25.6± 4; 23 (12–32)	0.042*
	Rani srednji vijek	22.1±5.1; 21 (12–31)	

*Mann-Whitney U test; ** Kruskal-Wallis test

There is a statistically significant difference in the total surface area of the available teeth ($\chi^2 = 42$, $\eta^2 = 0.21$, $p < 0.001$), and the share (%) of the total damaged area in the total area of the available teeth ($\chi^2 = 97$; $\eta^2 = 0.48$; $p < 0.001$) against the estimated chronological age (Table 3). The total surface of the available teeth decreases with the estimated chronological age ($r = -0.39$, $p < 0.001$), while the proportion (%) of the total damaged area of teeth in relation to the total available area increases with the estimated chronological age ($r = 0.622$, $P < 0.001$) (Table 3).

If we observe sex, there is a statistically significant correlation between the total number of teeth ($\chi^2 = 38,4$, $\eta^2 = 0,29$, $p < 0,001$) and total tooth surface ($\chi^2 = 35,5$; $\eta^2 = 0,27$; $p < 0,001$) with estimated chronological age in males; the total number of teeth negatively correlates

TABLE 3

ARITHMETIC MEAN ± SD, MEDIAN (MIN-MAX) OF TOTAL AREA AND TOOTH WEAR OF ALL TEETH ACCORDING TO ESTIMATED CHRONOLOGICAL AGE

		Tooth surface (cm²)				
		total	P*	Tooth wear	Tooth wear/ total surface (%)	p*
Estimated chronol. age	15–20	12.3±3.5	< 0.001	1.4±1.7	10.2±8.6	<0.001
		11.6 (8.9–18)		0.86 (0.45–4.9)	6.4 (5–27)	
	20–25	8.3±3.1		1.3±0.69	13.3±.2	
		10 (3.8–14.1)		1.26 (0.41–2.6)	11 (6.7–29)	
	25–30	11.1±2.7		1.2±0.63	10.6±5.7	
		11.4 (3–15.3)		1.22 (0–2.5)	9.8 (0–23)	
	30–35	9.6±4.1		1.4±0.81	16.2±12.2	
		9.4 (1.9–18.3)		1.3 (0.28–3.5)	11.6 (5.8–69)	
	35–40	10.8±3.2		1.9±0.92	18.5±9.5	
		11.5 (4–16)		1.7 (0.63–4.6)	16 (7.8–51)	
	40–45	8.8±3.6		2.4±1.0	29.8±14.5	
		8.4 (2.6–15.6)		2.2 (0.57–4.6)	26.6 (11.8–73)	
	45–50	7.5±3.4		2.7±1.5	40±22	
		8.3 (2.5–12)		2.4 (1.1–5.8)	36 (14–100)	
	50–55	5.9±.7		2.6±1.4	49.8±26.2	
		6 (1.5–11.4)		2.4 (0.94–6)	53 (16–100)	
	55+	3.9±1.9		1.87±0.79	56±31.5	
		4 (2–6.6)		1.9 (1–39)	50 (26–98)	

* Kruskal-Wallis test

with the estimated chronological age (r = –0.43, p <0.001), as well as the total area of the teeth (r = –0.424, p <0.001) (Table 4). There is a statistically significant correlation between total and damaged surface area of teeth with estimated chronological age in males (χ^2 = 74.3; η^2 = 0.57; p <0.001); the proportion of damaged teeth in the total area of the teeth increases with the estimated chronological age (r = 0.686, p <0.001) (Table 4). If we observe the difference between the two historical periods, there is no statistically significant difference between the total number of teeth (z = 1.24; p = 0.215), the total surface area of the teeth (z = 1.25; p = 0.209) and the proportion of tooth wear in the total surface of the teeth = 0.666; p = 0.506) between late antiquity and early middle ages in males (Table 4).

As with males, there is a statistically significant connection between the total number of teeth (χ^2 = 16.9, η^2 = 0.22, p = 0.018) and the total surface area of the teeth (χ^2 = 20.3; η^2 = 0.27; p = 0.005) with an estimated chronological age (Table 5). The total number of teeth (r = –0.412, p <0.001), as well as the total teeth surface (r = –0.41, p <0.001), correlates negatively with the estimated chronological age in women (Table 5). There is a statistically significant connection of the total share of the tooth wear with the estimated chronological age in women (χ^2 = 31.2, η^2 = 0.42, p <0.001) (Table 5).

The proportion of tooth wear increases with the estimated chronological age (r = 0.534, p <0.001). No statisti-

TABLE 4

ARITHMETIC MEAN ± SD, MEDIAN (MIN-MAX) OF TOTAL AREA AND TOOTH WEAR OF ALL TEETH ACCORDING TO ESTIMATED CHRONOLOGICAL AGE IN MEN

		Total numb. of teeth	P	Total area of teeth (cm²)	p	Tooth wear/total area(%)	p
Estimated chronol. age	15–20	30	<0.001**	18.1	<0.001**	27	0.001**
	20–25	23.3±4.5		10.4±3.4		13.4±5.5	
		24 (16–30)		11.2 (4.4–14)		11.4 (6.9–25.4)	
	25–30	22.6±5.1		10.5±2.9		9.6±5.2	
		23 (14–30)		11 (3–14.5)		9.7 (0–18.7)	
	30–35	22.7±6.2		10.5±4.2		13.6 ±6.6	
		23 (14–32)		11.2 (3–18.3)		11.5 (5.8–27.8)	
	35–40	25.5±4.8		11.9±2.8		18.1 ±7.3	
		26 (13–32)		12 (4–16)		16 (8.5–36.5)	
	40–45	21±5.3		9.2±3.5		27.5 ±14.6	
		22 (12–32)		8.7 (3.8–15.6)		23.3 (11.8–72.8)	
	45–50	19.5±4.3		8.5±3.2		37.4 ±15	
		19 (13–26)		10.2 (3–12)		35.6 (13.9–66.9)	
	50–55	14.4±5.3		5.9±2.8		53.7±21.1	
		15 (7–23)		4.6 (2.9–11.4)		53 (20–97)	
	55+	12.2±2.9		3.9±1.9		56.2±31.5	
		12 (9–16)		3.9 (2–6.6)		50 (26.2–98.4)	
Late antiquity		22.1±6.2	0.215*	10.1±4	0.209*	22.8±18.8	0.506*
		23 (7–32)		10.9 (2.2–18.3)		16.2 (4–98)	
Early Middle ages		21±5.9		9.4±3.6		23.5±16.6	
		21.5 (9–31)		9.4 (2–16)		18.7 (0–73)	

*Mann- Whitney U test; * * Kruskal-Wallis test

TABLE 5

ARITHMETIC MEAN ± SD, MEDIAN (MIN-MAX) OF TOTAL AREA AND TOOTH WEAR OF ALL TEETH ACCORDING TO ESTIMATED CHRONOLOGICAL AGE IN WOMEN

Estimated chronol. age	Total numb. of teeth	P	Total area of teeth (cm²)	p	Tooth wear/total area (%)	p
15–20	25.6±4.6	0.018**	11.1±2.2	0.005**	6.8±2.7	<0.001**
	27 (18–30)		10.8 (9–14)		5.7 (4.9–11.4)	
20–25	22.1±5.6		9.2±2.8		13.1±7.5	
	22 (15–29)		9.4 (3.8–13.2)		10.9 (6.7–29)	
25–30	26.5±4.2		11.9±2.4		12±6.4	
	28 (20–32)		12.3 (8.4–15.3)		11.3 (4–23)	
30–35	20.8±7.3		8.2±37		20.4±17.2	
	21 (10–32)		8.1 (1.9–14.6)		16 (5.8–69)	
35–40	21.7 ±6.6		8.9±3.1		19±12.7	
	23 (10–31)		8.7 (4–14)		15 (7.8–51)	
40–45	18.6 ±7.6		7.9±3.8		25.9±13.3	
	17.5 (10–32)		7.8 (2.6–13.6)		33.9 (18.1–62)	
45–50	15.2±3.2		4.7±2.6		47.7 ±36.7	
	14 (13–20)		3.9 (2.5–8.4)		37 (15.7–100)	
50–55	14.8 ±6.5		6.2±2.8		42.7±35.2	
	15 (6–22)		6.5 (1.5–9.3)		24.2 (16–100)	
55+	no sample		no sample		no sample	
Late antiquity	22.4±7	0.121*	9.4±3.6	0.058*	22.8±19.8	0.755*
	23.5 (10–32)		9.8 (2.5–15)		16.7 (4–100)	
Early Middle Ages	19.7±6.6		7.9 ±3.3		21.5±19.4	
	21 (6–31)		8.4 (1.5–14.5)		13.8 (5.7–100)	

*Mann- Whitney U test; ** Kruskal-Wallis test

cally significant difference has been noticed in the total number of teeth ($z = 1.55$; $p = 0.121$), the total surface of the teeth ($z = 1.89$; $p = 0.058$) and the proportion of tooth wear in overall teeth area ($z = 0.312$, $p = 0.755$) in period between late antiquity and early middle Ages in women.

If we take into account certain groups of teeth, we will come up with the interesting results.There is a statistically significant connection of the surface of incisors with respect to the estimated chronological age ($\chi^2 = 18.8$; $\eta^2 = 0.10$; $p = 0.016$); between the total area of the incisor and the estimated chronological age there is a negative correlation (rho = –0,235; p = 0,001).

When comparing the sexes, there is no statistically significant difference between the total surface of the incisors between men and women ($z = 0.307$; $p = 0.759$). There is a statistically significant correlation of the share of the total affected area in relation to the estimated chronological age ($\chi^2 = 43.3$; $\eta^2 = 0.22$; $p <0.001$); (rho = 0.462; $p <0.001$), while the same one was not proven among different sexes ($z = 0.371$, $p = 0.711$) Furthermore, between the observed periods, no significant difference among the share of tooth wear in the total area of incisor and the estimated chronological age has been proved ($z = 0.899$; $p = 0.369$).

No statistically significant difference in the total surface of left canines with estimated chronological age ($\chi^2 = 13.3$, $p = 0.100$) has been proved. The coefficient of correlation between surface of left canines and estimated chronological age was not statistically significant (rho = –0.135, $p = 0.053$). The median of left canine total surface is 0.07cm² bigger in males than in females ($z = 2.9$; $r = 0.21$; $p = 0.004$). There is a statistically significant correlation of the proportion of tooth wear in the total surface of the left canines with the estimated chronological age ($\chi^2 = 61.4$; $\eta^2 = 0.32$; $p <0.001$). The proportion of tooth wear in the total surface of left canine correlates positively with the estimated chronological age (rho = 0.546, $p <0.001$).

The proportion of damaged in the total surface of left ventricular area is 4.2% higher in males than in females ($z = 2.7$, $r = 0.14$, $p = 0.007$). Research did not show statistically significant difference between the total area of the right canine with the estimated chronological age ($\chi^2 = 14.7$; $p = 0.065$); the coefficient of correlation between the total surface of the right canine and the estimated chronological age was not significant statistically (rho = – 0.134; $p = 0.055$). The median of total area of the right canines is 0.3cm² higher in males than in females ($z = 3.2$; $r = 0.23$; $p = 0.001$).There is a statistically significant correlation of the share of the tooth wear in the total surface of the right canines regarding the estimated chronological age ($\chi^2 = 51.4$; $\eta^2 = 0, 25$; $p <0,001$). The proportion of tooth wear in the total surface of the right canine correlates positively with the estimated chronological age (rho = 0.481, $p <0.001$).There is no statistically significant difference in the share of the tooth wear in total surface of the right canines between sexes ($z = 1.04$, $p = 0.300$), or between periods ($z = 1.6$, $p = 0.116$).

There is a statistically significant correlation of the total surface of the left premolars in relation to the estimated chronological age ($\chi^2 = 21.5$; $\eta^2 = 0.11$; $p = 0,006$); the total surface of the left premolars correlates negatively with the estimated chronological age (rho = –0,198; p = 0.004). The median total surface of the left premolars is 0.4cm² higher in male population than in female ($z = 2.5$; $r = 0.18$; $p = 0.012$). There is a statistically significant correlation of the share of tooth wear in the total surface of the left premolars with the estimated chronological age ($\chi^2 = 35.9$; $\eta^2 = 0.18$; $p < 0.001$); the proportion of tooth wear in the total surface of the left premolars correlates positively with the estimated chronological age (rho = 0.389, $p < 0.001$). There is no statistically significant difference in the proportion of tooth wear in the total surface of the left premolars in relation to gender ($z = 0.686$, $p = 0.493$). There is a statistically significant correlation of the total surface area of the right premolars with the estimated chronological age ($\chi^2 = 30.7$; $\eta^2 = 0.15$; $p < 0.001$); the total surface area of the right premolars is negatively correlated with the estimated chronological age (rho = – 0.250; $p < 0.001$).

The total area of the right premolars is 0.3cm² higher in men than in women ($z = 2.2$; $r = 0.15$; $p = 0.024$.There is a statistically significant correlation of the share of tooth wear in total area of the right premolars with the estimated chronological age ($\chi^2 = 56$; $\eta^2 = 0.27$; $p < 0.001$); the proportion of tooth wear in total surface of the right premolars positively correlates with the estimated chronological age (rho = 0.457, $p < 0.001$).There was no statistically significant difference in the proportion of tooth wear in the total surface of the right premolars in relation to gender ($z = 0.036$; $p = 0.972$).

There is a statistically significant correlation of the total surface area of the left molars with the estimated chronological age ($\chi^2 = 33$; $\eta^2 = 0.16$; $p < 0.001$); the total surface area of the left molars is negatively correlated with the estimated chronological age (rho = – 0.310; $p < 0.001$). The median total left molar area was 0.7cm² higher in males than in females ($z = 2.8$, $r = 0.19$, $p = 0.006$). There is a statistically significant correlation of the share of the tooth wear in the total surface of left molars with estimated chronological age ($\chi^2 = 61$; $\eta^2 = 0.30$; $p < 0.001$); the proportion of tooth wear in the total left mothers surface positively correlates with the estimated chronological age (rho = 0.529, $p < 0.001$). There is no statistically significant difference in the total surface of left molar area in relation to sex ($z = 0.893$, $p = 0.372$).

There is a statistically significant connection between the total area of the right molars with the estimated chronological age ($\chi^2 = 27.9$; $\eta^2 = 0.13$; $p < 0.001$); the total area of the right molars is negatively correlated with the estimated chronological age (rho = –0.304, $p < 0.001$). There is no statistically significant difference in the total area of right molars regarding the gender ($z = 1.6$, $p = 0.115$). There is a statistically significant correlation of the share of tooth wear in the total surface of right molars with estimated chronological age ($\chi^2 = 63.4$; $\eta^2 = 0.31$; $p < 0.001$); the proportion of tooth wear in the total area of the right molars correlates positively with the estimated chronological age (rho = 0.538, $p < 0.001$). There is no statistically significant difference in the share of the tooth wear in the total surface of the right molars relative to the gender ($z = 0.118$; $p = 0.906$).

Discussion

Dental hard tissues are one of the most resistant remains of an individual after its death. As such, it is an extremely important material for paleo dental researches[18]. Since the teeth are extremely resistant to post mortal damage, they can be preserved long after the death, almost independently of the environment in which they are, and in shape and state they were at the moment of death. Likewise, there have been no dental interventions in the past, both, restorative or oral-surgical, so the epidemiology of pathological changes in dental hard tissues can be explored in its original form[12].

After the end of growth and tooth development, the evaluation of dental age is based on the changes in the structure of dental hard tissue, caused by aging, with a special emphasis on the evaluation of abrasion and attrition[10]. Today there are several procedures for determination of age at the time of death in adults. Some of these procedures presume removal of tooth from the jaw bone and bristle preparation (invasive procedures), furthermore the measurement of dentin translucency on tooth root apices, accretion of acellular cementum and root resorption. Other methods are non-invasive and are based on the analysis of radiographic dental parameters. Many methods have been developed involving these techniques and parameters and their combinations, among which the best known techniques are Gustafson, Johanson, Cameriere, Lovejoy, Uberlaker methods[8,9,18–20]. The oldest method for dental age determination is Gustafson's technique from 1950 year of the last century.

Tooth samples were prepared for analysis of the amount of secondary dentine deposit and dental cementum, the dentin translucency in the area of the root canal, the level of epithelial attachment and alveolar bone, as well as the possible resorptive changes on the root tip. All other procedures for dental age determination are just upgrade of this very simple technique of dental age estimation of both, recent living humans and the archeological remains[10,13–15].

If we observe the enamel with an electronic microscope, as well as the part of the tooth which covers the crown, we can see that it is much wrinkled on the surface. Along with its surface, stretches or waves of 30–100 nm width, Pickeril's line, are laid down, one to another as the roof tiles and are separated by perikymata. These are actually the ends of the growth line– Retzius strips. Towards the area of the neck of the tooth, they are getting thicker. Because of the lifelong loss of dental hard tissue, abrasion or attrition of dental enamel, perikymata is being hard to notice in the older age[10].

During a lifetime and due physical and mechanical actions, enamel is subject to wear. This phenomenon is called abrasion. It occurs during process of chewing food and may occur in different degrees and shapes. The horizontal form of enamel abrasion is more common and affects incisal edges and teeth surface of each group, while vertical enamel abrasion appears on the vertical tooth surface, especially on the incisors[16,17]. Unlike enamel abrasion, attrition means a gradual and proper loss or physiological wear of dental structures without the intervention of an abrasive agent.

Taking into account changes described, aging decreases the amount of enamel covering the dentine of teeth while the exposed dentine surface increases at the same time. This phenomenon was first described by Zsigmondy[a] in 1893 as an interstitial surface friction, while the first clinical specification was made by Broca[b], and this change was shown in five stages[10]:

0 without attrition

1 initial enamel attrition with still visible lump

2 exposed dentine

3 worn occlusal surface relief with a preserved enamel edge

4 crowns of teeth worn completely to the root of teeth [10].

Taking into account all these parameters, which become increasingly emphasized with age and tooth wear, it is possible to link the loss of hard tooth tissue and age, on the basis of which it is possible to estimate the dental age. Jong-il Yun et al. using the modified Kim's scale in the Korean population, have also correlated the loss of hard tissue with chronological age and have shown one of the age-determining methods, applicable on one certain population [21].

In our study, with samples from two different historical periods statistically not distinguished by sex and estimated chronological age, there was a statistically significant correlation between the total number of teeth with estimated chronological age, and the total number of teeth correlates negatively with the chronological age. Thus, aging decreases the total number of teeth.

Furthermore, the total area of the teeth available decreased with the estimated chronological age, while the share of total damaged teeth area in relation to the total available area increased with the estimated chronological age. This is an indication that with the rise of chronological age, loss of hard tooth tissue occurs.

Comparing the loss of the total number of teeth, the total area of the teeth as well as the tooth wear in the total tooth surface in males and females, we found that there are statistically significant correlations of all parameters with estimated chronological age in both cases. In men, the total number of teeth as well as the total area of the teeth decreases with aging while the loss of hard dental tissue increases with chronological age. In females, the total number of teeth, as well as the total surface area of the teeth, decreases with aging, while the loss of hard dental tissue increases with chronological age.

Comparing the two historical periods, there was no statistically significant difference in the above-mentioned gender parameters, which also indicates that, regardless of the historical period in which individuals lived, and in accordance with dietary and life practices of different periods and ages, we can clearly correlate the loss of dental hard tissue with chronological age.

The analysis of the loss of hard tooth tissue by different groups of teeth led to the following findings. The total area of the incisors is correlated negatively with the estimated chronological age. There was no statistically significant difference between sexes in the total incisors surface observation. The proportion of the damaged area in the total area of the incisors increased with the estimated chronological age, while there was no statistically significant difference among sexes. This finding suggests that, as the purpose of his group of teeth is hacking and cutting food, years of abrasive and attritional changes have been occurring on incisors precisely.

Looking at the canines on the left and right side, these teeth are significantly larger in men than in women. The median total area of the right canine was 0.3 cm^2 larger in males than in females, while the median total surface of left canine was 0.07 cm^2 larger in males than in females. Although we did not prove statistically significant difference between total surface area of left and right canines with estimated chronological age, there was a statistically significant connection of the damaged surface in total teeth groups surface with estimated chronological age on the left side. Consequently, the proportion of tooth wear in the total area of left canine is positively correlated with the estimated chronological age. On the right, there is also a statistically significant correlation of the proportion of damage in the total area of the right canine regarding the estimated chronological age. The proportion of tooth wear in the total area of the right canine correlates positively with the estimated chronological age. This finding can be explained by cane root exposure, either due to the position of the jaw and the appearance of bone defects such as dehiscence, either due to periodontal bone loss. As the measuring of the total tooth covering surface comprises all visible parts above the bone it could be that the loss of the tooth surface, caused by abrasion or attrition of canines, was replaced by the root surface, which was measured as the total surface of the tooth.

The total surface area of the left premolars is negatively correlated with the estimated chronological age, the median total left premolars surface is 0.4cm^2 larger in males than in females. The proportion of tooth wear in the total area of the left premolars correlates positively with the estimated chronological age, and there is no statistically significant difference in the proportion of the tooth wear in the total area of the left premolars. The total surface area of the right premolars is negatively correlated

a Dr Otto Zsigmondy, Austrian dentist, first proposed the phrase 'hypoplasia of the enamel' in his paper to the 1893 World's Columbian Dental Congress at Chicago.

b Pierre Paul Broca, French physician and anthropologist, Instructions rélatives a l'étude anthropologique du systéme dentaire. Bull Soc Anthrop Paris 2(3):128–163, 1879.

with the estimated chronological age, and the median total area of the right premolars is 0.3 cm^2 larger in males than in females. The proportion of tooth wear in the total area of the right premolars positively correlates with the estimated chronological age. There was no statistically significant difference in the proportion of tooth wear in the total surface of the right premolars in relation to sex. The total surface area of the left molars is negatively correlated with the estimated chronological age, while the median total left molar area is 0.7 cm^2 larger in males than in females. The proportion of tooth wear in the total left molar area correlates positively with the estimated chronological age. There is no statistically significant difference between the total left molar area in relation to sex.

The total surface of the right molars negatively correlates with the estimated chronological age. There is no statistically significant difference in the total area of the right molars between sexes. The proportion of tooth wear in the total area of the right molars correlates positively with the estimated chronological age equally in men and women.

Conclusions

Teeth are the best and most well-preserved human organ that can be preserved for a long time in its unchanged form and which can provide a lot of information about an individual such are sex, age or race. Thinning and wearing dental enamel during life is usually caused by chewing and by the friction of the surfaces of dental bridges and nodules.

The lifelong loss of dental hard tissues correlates positively with the chronological age, and it has been shown that wear and loss of enamel, dentine, and cementum of the exposed tooth root comes with aging. This finding is equally present in both sexes, while the extent of loss of dental hard tissue is somehow more emphasized in male population. Loss of dental hard tissue due to attrition and abrasive changes can often be used to help dental identification and age estimation in forensic dentistry, as well as in anthropology and archeology.

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A. Družijanić

Dental Clinic Split, Antuna Gustava Matoša 2, 21000, Split, Croatia
e-mail: ana.druzijanic8.1ad@gmail.com

KORELACIJA KRONOLOŠKE DOBI I GUBITKA ZUBNIH TKIVA U ARHEOLOŠKIM POPULACIJAMA

S A Ž E T A K

Budući da su atricija i abrazija jedne od najčešćih promijena tvrdih zubnih tkiva koje se javljaju usporedo sa starenjem, cilj ovog rada je utvrditi korelaciju između dentalne dobi i gubitka tvrdih zubnih tkiva na arheološkim koštanim ostatcima. Za potrebe ovog istraživanja korištena je kolekcija skeletnih ostataka iz Hrvatske akademije znanosti i umjetnosti (HAZU). U istraživanje su uključena 392 uzorka ostataka gornjih i donjih čeljusti sa 7 hrvatskih arheoloških lokaliteta: 4 iz kontinentalne i 3 iz primorske Hrvatske. Koštani ostatci pripadaju dvama arheološkim razdobljima, kasnoj antici i ranom srednjem vijeku. Računalnim sistemom Vista metrix mjerile su se na fotografiranim griznim plohama zuba ukupne vidljive površine tvrdih zubnih tkiva kao i površine tvrdih zubnih tkiva oštećene abrazijom i atricijom. U statističkoj analizi podataka korišteni su Shapiro-Wilk test, Mann-Whitney U test i Kruskal-Wallis test. Postoji statistički značajna povezanost ukupnog broja zuba s procjenjenom kronološkom dobi (χ^2 = 46,3; η^2 = 0,23; p< 0,001). Ukupan broj zuba negativno korelira sa kronološkom dobi (r= –0,41; p<0,001). Ukupna površina raspoloživih zuba pada s procijenjenom kronološkom dobi (r = –0,39; p<0,001), dok udio (%) ukupne oštećene površine zuba u odnosu na ukupnu raspoloživu površinu raste s procijenjenom kronološkom dobi (r = 0,622; p<0,001). Udio oštećene u ukupnoj površine zuba raste s procijenjenom kronološkom dobi (r = 0,686; p<0,001) kod muškaraca i kod žena (r = 0,534; p<0,001). Zaživotni gubitak tvrdih zubnih tkiva pozitivno korelira sa kronološkom dobi u oba spola neovisno o promatranom povijesnom razdoblju. Gubitak tvrdih zubnih tkiva uslijed atricijskih i abrazivnih promijena koristeći računalni sustav Vista metrix danas se stoga može koristiti kao pomoć pri određivanju dobi, kako u forenzičnoj stomatologiji tako i u forenzičnoj antropologiji i arheologiji.