Dimension variability of the M2 human molar teeth: comparisons between prehistoric and medieval samples

Ozana-Maria Petraru[1,2], Vasilica-Monica Groza[1], Luminita Bejenaru[1,2], Mariana Popovici[1]

[1] Romanian Academy – Iaşi Branch, "Olga Necrasov" Center of Anthropological Research, Iasi, Romania; Th. Codrescu Street, no. 2, 700479, Iasi, Romania

[2] "Alexandru Ioan Cuza" University of Iaşi, Faculty of Biology, Iasi, Romania; Carol I Boulevard, no. 20A, 700505, Iași, Romania

SUMMARY

Teeth are a valuable source of information for studies regarding past human populations in archaeological and forensic contexts. In dental anthropology, the linear measurements of tooth crowns are used for assessing morphological variability and sexual dimorphism in both modern and past human populations. The aim of this research is to evaluate the M2 molar crown variability in archaeological human populations from Prehistory (Chalcolithic and Bronze Age, ~ 5000-1150 BCE) and Middle Ages (13^{th}-17^{th} centuries) discovered in sites from North-Eastern Romania. The objectives of this study emphasize on the diachronic comparison of the M2 molar crown variables between prehistoric and medieval samples (1), and the assessment of sexual dimorphism expression (2). The two crown measurements, mesio-distal (MD) and bucco-lingual (BL) diameters, were performed using ImageJ software on occlusal digital images acquired stereo-microscopically. The crown index (CI), crown area (CA) and the sexual dimorphism index (SDI), along with the two linear measurements, were subjected to univariate and multivariate statistical analysis.

Our results show that the variation coefficient (CV) differs for the MD variable in the female upper M2 molars, being higher in the medieval sample than the prehistoric one; also, a higher variability is remarked for the mandibular molar in the medieval sample than in prehistoric one. In females, the MD and CA variables for mandibular M2 molars and the BL and CA for maxillary molars showed significant statistical differences between the medieval and prehistoric mandibular teeth, with higher values for the exemplar from Middle Ages. Similar result was obtained in males, for the CA variable in the upper M2 molars. In our study, the sexual dimorphism manifested at the M2 crown molar was highlighted in the prehistoric sample, though less in the medieval one.

Key words: M2 molar teeth – Crown measurements – Sexual dimorphism – Archaeological human populations – Nord-Eastern Romania

INTRODUCTION

Dental anthropology is an interdisciplinary research area that involves several directions of study such as physical anthropology, dentistry,

Corresponding author:
Luminita Bejenaru. Romanian Academy – Iaşi Branch, "Olga Necrasov" Center of Anthropological Research, Iasi, Romania; Th. Codrescu Street, no. 2, 700479, Iasi, Romania. E-mail: lumib@uaic.ro

Submitted: December 6, 2021. **Accepted:** March 14, 2022

https://doi.org/10.52083/SAYF5787

biology, paleontology, and paleopathology (Moreno-Gómez, 2013). The unique preservation of teeth is based on their hard tissues (i.e., enamel, dentine, and cementum), teeth being a valuable source of information for studies regarding the past human populations in archaeological and forensic contexts (Eboh, 2017; Jeon et al., 2020; Higgins and Austin, 2013; Hillson, 2005; Watson and Haas, 2017). In physical anthropology, teeth have been studied by various methodologies concerning age at death estimation (Bertrand et al., 2019; Brothwell, 1981), dental wear and dental calculus as bioindicators of diet (Green and Croft, 2018; Cummings et al., 2018; Fiorenza et al., 2018), cultural modifications (Wasterlain et al., 2016; Smith-Guzmán et al., 2020), dental diseases (Hillson, 2001; Wasterlain et al., 2020; Garot et al., 2019; Marchewka et al., 2014), inter- and intra-populational variations of shape and size (Gómez-Robles et al., 2015; Black, 2014; Takahashi et al., 2007; Kondo et al., 2005).

A number of studies showed that genetic, environmental, and epigenetic factors have a great influence on dental morphology (Kondo and Manabe, 2016; Townsend et al., 2012; Farzin et al., 2020).

Several studies of dental anthropology approached the linear measurements of tooth crowns for assessing the sexual dimorphism in both modern human populations (Zorba et al., 2011; Zúñiga et al., 2021) and past ones (Petraru et al., 2020; Yoo et al., 2016; Górka et al., 2015), as well the dental variability between ethnic groups (Brook et al., 2009; Hasegawa et al., 2007). Most studies of the tooth crown size variability are based on the measurement of the mesio-distal and bucco-lingual diameters (Petraru et al., 2020; Zorba et al., 2011; Kondo et al., 2005; Yoo et al., 2016), although other alternative measurements have been reported (Hillson et al., 2005; Zorba et al., 2013). Due to their sexual dimorphism and resistance to postmortem alteration process, teeth, by crown dimensions, are essential in assessing sex when other skeletal parameters are not reliable (Zorba et al., 2013; Petraru et al., 2020). Several studies showed that the canine (particularly the mandibular canine) is the most sexually dimorphic tooth (Scherer, 2018; Magalhães et al., 2021). The adjacent teeth around the canines (i.e., lateral incisors and first premolars), along with the molar teeth (especially the mandibular teeth) also show dimensional variations due to sexual dimorphism (Zorba et al., 2011; Kondo et al., 2005).

Although odontometric research is well-known in both archaeological human populations and forensic contexts, there are few studies regarding dental variability and sexual dimorphism on molar crown in samples from North-Eastern Romania (Petraru et al., 2020; Petraru et al., 2017). Considering the consequences of genetic influence, environmental factors, like variation of food resources exploitation, and the interference of cultural factors, we suppose that dental variability is increasing in time being correlated with a decreasing sexual dimorphism in teeth.

The aim of this study is to assess M2 molar crown variability in samples of archaeological human populations discovered in North-Eastern Romania. Knowing the importance of teeth as indicators of the intra- and inter-population variability, the objectives of this study emphasize the diachronic comparison of the M2 crown variables (mesio-distal and bucco-lingual diameters, crown area, and crown index) between medieval and prehistoric samples (1), and the expression of sexual dimorphism at the M2 molar crown (2).

MATERIALS AND METHODS

Material

The dental material is represented by the M2 molars (maxillary and mandibular molars) (Fig. 1) (n = 284) belonging to human skeletons discovered in archaeological sites from North-Eastern Romania (Fig. 2; Table 1). The M2 molar was chosen, while for the first molar - M1, was avoided due to its variable morphology and usually high degree of wear. Furthermore, only the molars without pathologies, an integrated tooth crown and an occlusal wear that does not exceed a 'moderately advanced wear' (Smith, 1984, Tomczyk et al., 2020) were considered. All molars, related to different age categories (Table 1), were considered for the size analysis, as, once formed, teeth do not change their size (Górka et al., 2015). The material under study dates, according to the archaeological inventory, from Prehistory (Chalcolithic and Bronze Age ~ 5000-1150 BCE), and the Middle Ages (13^{th}-17^{th} centuries) (Table 2). Some published data regarding the dimensional variability of M2 molar dating from the Bronze Age (n = 54) (i.e., Trușești and Cândești samples published previously by Petraru et al. (2020)) were included in this research due to the comparative approach. The molars from the "Curtea Domnească" necropolis of the 17^{th} century, which have been subjected to a previously odontometric study based on caliper measurements (Petraru et al., 2017), were reanalyzed with Image J (n = 133) and no statistically significant differences were obtained between the two dimensioning (BL: $t = 0.321$, $p = 0.749$; MD: $z = 0.289$ $p = 0.772$); thus, all dental material was studied by the same method in order to avoid error interpretation. The human skeletons discovered in the mentioned archaeological sites were previously studied in terms of age at death and sex estimations, demography, pathologies and odontometrics (Petraru et al., 2017; Petraru et al., 2020) (Table 2). The dental material used in this study is currently preserved in the osteological collection of the "Olga Necrasov" Center of Anthropological Research, Romanian Academy - Iași Branch.

Methods

The molars selected to be studied were prepared for measurements by removing the exogenous grit/ impurities using ethanol, hydrogen peroxide, and cotton wool (Petraru et al., 2020). The teeth were placed under the stereomicroscope being situated in the dental alveoli, or positioned in the specific anatomical orientation if the teeth

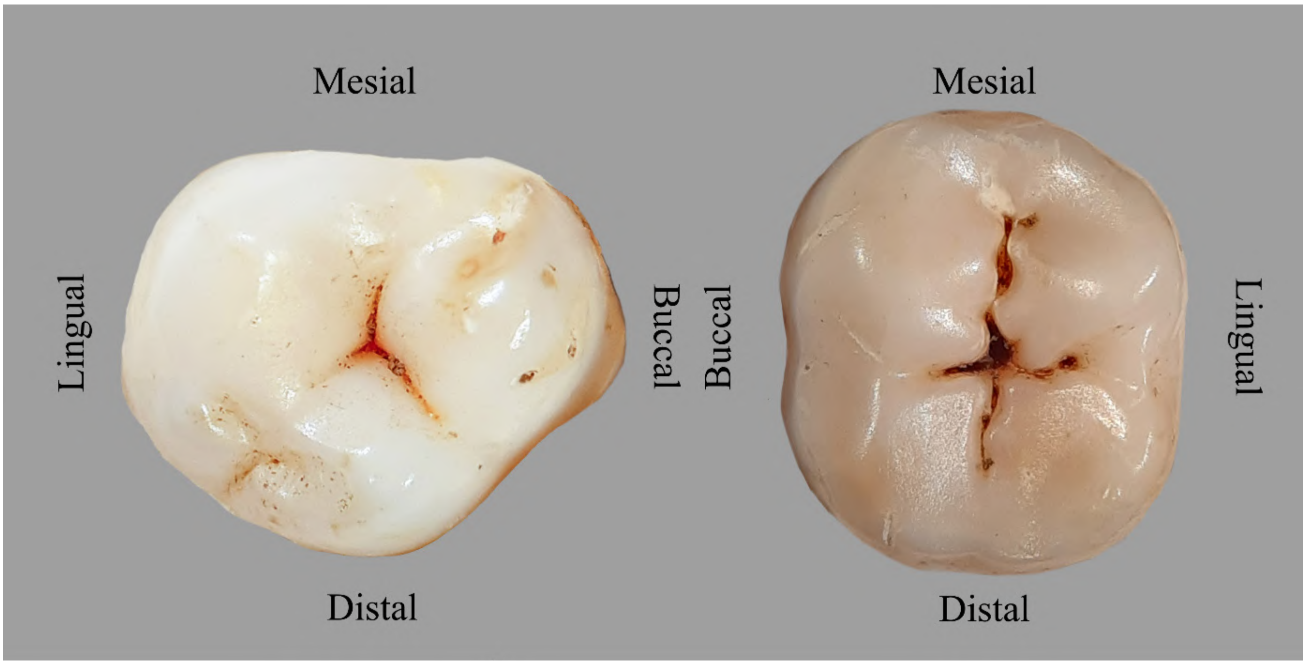

Fig. 1.- Occlusal surface of left maxillary M^2 molar (left) and left mandibular M_2 molar (right).

Table 1. M2 molar teeth selected for the study.

Distribution of M2 molars according to the position in the skull			
Upper right M2 molar (M^2_r)	Upper left M2 molar (M^2_l)	Lower right M2 molar (M_{2r})	Lower left M2 molar (M_{2l})
n = 71	n = 70	n = 79	n = 64
Distribution of M2 molars according to age at death category proposed by Buikstra and Ubelaker (1994)			
Adolescents (12-20 years)	Young adults (20-35 years)	Middle adults (35-50)	Old adults (> 50 years)
n = 28	n = 118	n = 115	n = 23

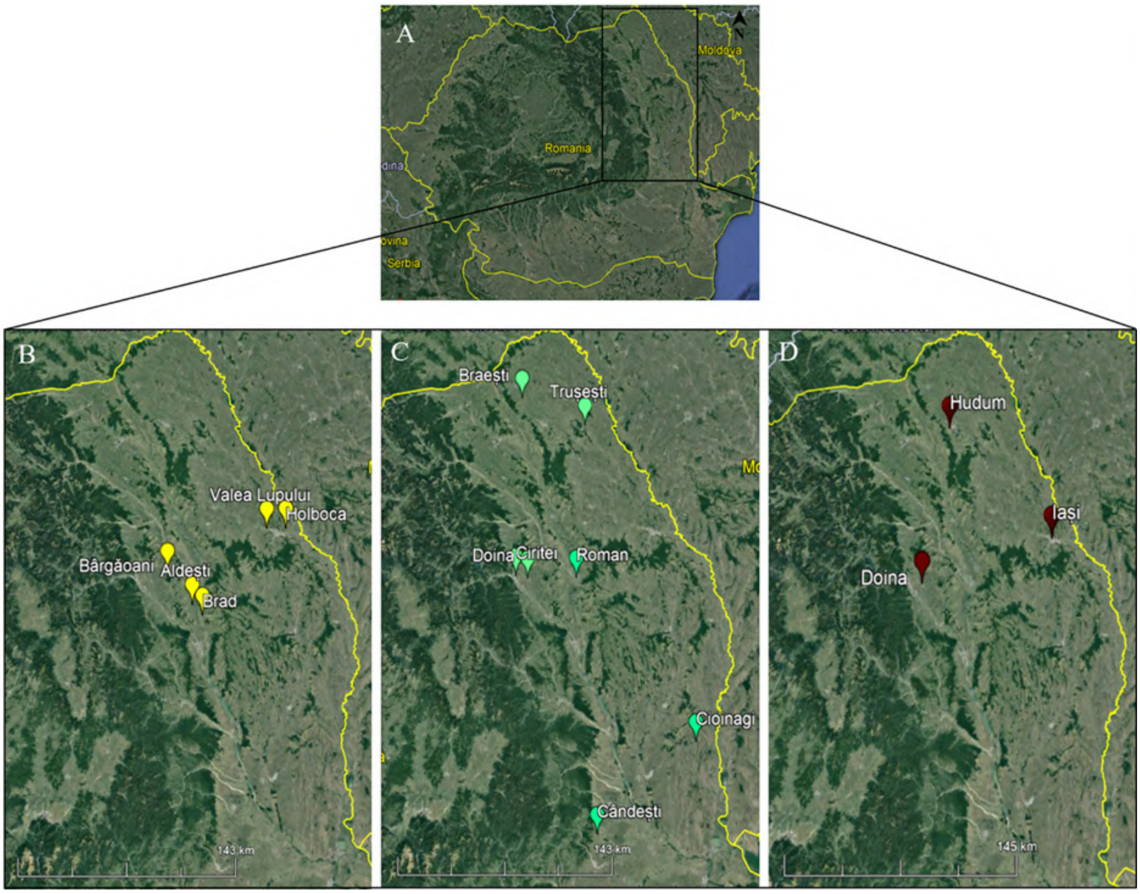

Fig. 2.- Location of archaeological sites: **A** – Nord-Eastern Romania area; **B** – archaeological sites from Chalcolithic (5000-3800/3700 BCE), **C** – archaeological sites from Bronze Age (3500-1200/1150 BCE); **D** – archaeological sites from Middle Ages (13th – 17th centuries).

Table 2. List of archaeological sites considered in the study.

Period		**Archaeological site / County**	**Dental samples**	**Skeleton sample Reference**	**Odontometric *ImageJ* data Reference**
Prehistory	Chalcolithic	Brad / Neamț	n = 3	Necrasov and Onofrei (1972)	Inedit
		Aldești / Neamț	n = 3		Inedit
		Valea Lupului / Iași	n = 3	Antoniu and Roșca-Gramatopol (1966)	Inedit
		Holboca / Iași	n = 19	Necrasov and Cristescu (1957)	Inedit
		Bârgăoani / Neamț	n = 3	Necrasov et al. (1972)	Inedit
	Bronze Age	Cioinagi / Galați	n = 7	Cristescu et al. (1965)	Inedit
		Cândești / Vrancea	n = 20	Miu (1999)	(Petraru et al., 2020)
		Roman / Neamț	n = 3	Diaconu et al. (2016)	Inedit
		Trușești / Botoșani	n =34	Cristescu and Miu (1999)	(Petraru et al., 2020)
		Ciritei / Neamț	n = 3	Cristescu (1961)	Inedit
		Braești / Botoșani	n = 4	Miu (1992)	Inedit
		Doina / Neamț	n = 2	Archive data*	Inedit
Middle Ages	13th-14th centuries	Hudum / Botoșani	n = 34	Miu et al. (2003); Archive data*	Inedit
		Doina / Neamț	n = 13	Necrasov and Botezatu (1964); Archive data*	Inedit
	17th century	"Curtea Domnească"/ Iași	n = 133	Groza (2015)	Inedit

* Data from the Archive of "O. Necrasov" Centre of Anthropological Research

were detached from the skull (Petraru and Bejenaru, 2019). The teeth were placed under stereomicroscope so that the cement-enamel junction plane was perpendicularly situated to the optical axis of the camera lens (Galbany et al., 2016; Górka, 2016; De Castro and Nicolas, 1995; Al-Khatib et al., 2011; de Castro et al., 2001; Martín-Albaladejo et al., 2017).

Dental micrometry

Digital images of occlusal surfaces of the M2 molars were recorded using a Carl Zeiss Stemi 2000-C stereomicroscope with a Canon Power Shot G9 attached. The images were processed and calibrated (in mm) using ImageJ software (Abràmoff et al., 2004). Two maximum crown diameters were taken by ImageJ software: bucco-lingual (BL) diameter and mesio-distal (MD) diameter. The MD diameter was taken as the maximum width of the tooth crown in the mesio-distal plane (Kazzazi and Kranioti, 2018), while BL diameter was taken as the widest point of the tooth crown in the bucco-lingual plane, perpendicular to the MD (Nava et al., 2021; Takahashi et al., 2007; Pilloud and Scott, 2020). In the dental samples in which inter-proximal facets were observed, the MD length was estimated according to the method proposed by Wood and Abbott (1983). The crown index (CI = BL diameter x 100/MD diameter), and the crown area (CA = BL diameter x MD diameter) were used to characterize the overall crown size, but no the shape (Kondo et al., 2005; Kondo and Manabe, 2016). The sexual dimorphism index (SDI = M-F/ F x 100; M - male mean value; F - females mean value) was also used (Harris and Foster, 2014; Zorba et al., 2011).

Statistical analysis

Intra-observer error of dental measurements was achieved by blind tests in which 20 molars were randomly examined. The BL, and MD variables were measured twice with one month between measurements, by the same researcher. The Shapiro-Wilk test was computed for the data distribution in order to perform the asymmetry analysis, bivariate analysis of the M2 molar variables (BL, MD, CA, CI). Student's T-test and Mann-Whitney tests were used to compare the BL and MD values as independent groups of the left and right mandibular/maxillary molars.

Descriptive statistics and relationships between measurements were investigated through univariate and multivariate statistical analysis using XLSTAT and PAST softwares (Hammer et al., 2001). Pearson's and Spearman's tests were used to analyze the correlations between the BL and MD measurements (Ratner, 2009; Razali and Wah, 2011).

To evaluate the accuracy of the BL, MD, CA and IC variables in assessing sexual dimorphism, the Discriminant Analysis (DA) was used. The analysis was achieved for every category of data: upper and lower M2 molars in every period (Prehistory and Middle Ages). Hoteling's test indicates how convenient is a given molar variable in the discriminant analysis; the F Statistic determines how much variation exists between the sexes and the significance level of the variance.

RESULTS

The result of the *t* test was not statistically significant (BL: N = 20; t = 0.27; p > 0.78; MD: N = 20, t = 0.37, p = 0.71).

The diameters' asymmetry between the left and right mandibular/maxillary molars was analysed and no statistically significant result was revealed (Table 3); therefore the left and right mandibular/maxillary molars were analyzed simultaneously.

Table 3. Test results for asymmetry between the left and right mandibular/maxillary BL and MD.

Test type	**$M_{2\ right}$ *vs.* $M_{2\ left}$**		**$M^{2\ right}$ *vs.* $M^{2\ left}$**	
	BL diameter	**MD diameter**	**BL diameter**	**MD diameter**
Shapiro-Wilk	W = 0.98, p = 0.66 W = 0.96, p = 0.1	W = 0.95, p = 0.005 W = 0.95, p = 0.019	W = 0.97, p = 0.28 W = 27, p = 0.26	W = 0.98, p = 0.50 W = 0.98, p = 0.60
T test/ Mann-Whitney	t = 1.02, **p = 0.307**	Z = 0.62**, p = 0.53**	t = 1.47, **p = 0.16**	t = 0.19, **p = 0.84**

The summary statistics of the bidimensional diameters are comparative shown by sex, position of the molars (mandibular and maxillary), and period, in Table 4. The bidimensional diameters for the mandibular M_2 molars are characterized by a higher mean in males comparative to females, probably due to sexual dimorphisms (BL = 9.42 mm in females and 9.72 mm in males; MD = 10.10 mm in females and 10.43 mm in males). The differences between the BL and MD variables in males *vs.* females are statistically significant (BL: z = 3.05, p = 0.002; MD: z = 2.60, p = 0.009). A difference was also observed for the superior molars M^2 but not supported by statistical significance (BL t test: t = 0.518, p = 0.605; MD t test: t = 0.906, p = 0.3665). When the dimensions were divided by period (*i.e.,* Prehistory, Middle Ages), the BL and MD values were similar for the inferior M_2 molars. In this study, the variability degree of the M2 dimensions is indicated by the coefficient of variation (CV%). Thus, constant CV% values were observed for the mandibular molars dating from Prehistory (CV% = 6.71 for BL diameter, and 6.87 for MD diameter), while a greater variability was observed for the medieval teeth from both 13^{th}-14^{th} centuries (CV% = 7.99 for BL diameter, and 8.22 for MD diameter) and 17^{th} century (CV% = 5.93 for BL diameter, and 6.83 for MD diameter). In contrast with the dimension variability of the mandibular molars, for the superior M^2 molars a higher variability coefficient is observed for both diameters in the 13^{th}-14^{th} centuries (CV% = 10.73 for BL diameter, and 10.79 for MD diameter). Similar high CV% was noted for the MD diameter of the M^2 from prehistoric sample (CV% = 10.53), while BL diameter was characterized by lower variability (CV% = 7.23).

To compare the molar dimensions in terms of diachronic and sex criteria, the medieval teeth of 13^{th}-14^{th} centuries and those of the 17^{th} century were considered together. In order to merge the samples, parametric and non-parametric tests, depending on the data distribution, were performed to test whether there are differences between the odontometric data of the 13^{th} -14^{th} centuries and those of the 17^{th} century. The results showed no statistical differences between the variables of the mandibular M2 molars (BL: t = 0.73, p =0.46; MD: z = 0.03, p = 0.96) and the maxillary ones (BL: t = 0.08, p = 0.93; MD: t = 1.44, p = 0.15). The upper M^2 molars from the female dataset are characterized by a similar variability of the mesio-distal diameter for both prehistoric and medieval samples (CV%= 8.76, and 8.20 respectively), in contrast with the variability of the bucco-lingual diameter which varies less in the prehistoric molars (CV% = 4.43) than in medieval ones (CV% = 7.05). In contrast with the dimensions of the superior molar in females, the dimensions of the mandibular molar are characterized by lower variability in the sample from Prehistory (CV% = 3.45 in BL diameter, and 4.75 in MD diameter), while in the medieval sample the variability is higher (CV% = 7.22 in BL diameter, and 6.41 in MD diameter). In the male samples, comparable CV% values were observed for the inferior molars, and for the BL diameter in the maxillary M^2 molars (CV% = 8.14 in prehistoric molars, and 7.69 in medieval ones), while different CV% values were obtained for the MD diameter in the prehistoric molars (CV% = 11.24), and medieval ones (CV% = 8.82).

The bidimensional measurements analyzed on the criterium of tooth position in the skull (mandibular and maxillary) have shown a non-normal distribution in the mandibular M_2 molars for the MD diameter (W = 0.95, p = 0.0002), and a normal distribution for the BL diameter (W = 0.98, p = 0.08). In the maxillary M^2 molars, the diameter values showed a normal distribution (BL diameter: W = 0.98, p = 0.08; MD diameter: W = 0.99, p = 0.48). When sex criteria were applied, the data for the mandibular male molars showed a non-normal distribution for the MD diameter (W = 0.96, p = 0.01), and a normal distribution data for the BL diameter (W = 0.98, p = 0.45). In the male maxillary molars, both diameter values showed a normal distribution (BL diameter: W = 0.98, p = 0.40; MD diameter: W = 0.97, p = 0.11). Similar distribution of data diameters was observed in the female molars: non-normal distribution data in the mandibular molars (BL diameter: W = 0.86, p = 0.0003; MD diameter: W = 0.91, p = 0.009), and normal data distribution in the maxillary ones (BL and MD diameters: W = 0.95, p = 0.15).

Table 4. Summary statistics of bucco-lingual (BL) and mesio-distal (ML) diameters in the M2 molars by position in skull, sex, and periods (N – number, Min – minimum, Max – maximum, Std. error – standard error, Var. – variance, Std. dev. – standard deviation, Coeff. Var. – coefficient of variance).

Tooth	N	Sex	Variable	Min	Max	Mean	Std. error	Var.	Std. dev.	Median	Coeff. Var.
M_2	143	-	BL	8.41	11.37	9.65	0.05	0.41	0.64	9.64	6.64
		-	MD	9.02	12.61	10.37	0.06	0.55	0.74	10.27	7.14
M^2	141	-	BL	7.82	12.82	10.9	0.07	0.70	0.83	10.84	7.67
		-	MD	6.53	11.61	9.00	0.07	0.71	0.84	9.05	9.36
Dimension variability of M2 molars by sex											
M_2	101	Male	BL	8.41	11.37	9.72	0.06	0.41	0.64	9.7	6.59
			MD	9.02	12.61	10.43	0.07	0.54	0.73	10.33	7.08
M_2	38	Female	BL	8.71	11.03	9.42	0.09	0.33	0.58	9.31	6.17
			MD	9.14	12.24	10.10	0.09	0.37	0.61	9.99	6.05
M^2	102	Male	BL	7.82	12.82	10.92	0.08	0.74	0.86	10.88	7.92
			MD	6.53	11.61	9.03	0.08	0.77	0.88	9.07	9.74
M^2	34	Female	BL	9.62	12.8	10.83	0.13	0.64	0.80	10.66	7.42
			MD	7.7	10.45	8.88	0.13	0.57	0.76	9.05	8.55
Dimension variability of M2 molars by period											
Prehistory (~ 5000-1150 BCE)											
M_2	53	-	BL	8.42	11.3	9.59	0.08	0.41	0.64	9.51	6.71
			MD	9.14	12.46	10.24	0.09	0.49	0.70	10.08	6.87
M^2	51	-	BL	8.9	12.68	10.6	0.10	0.58	0.76	10.61	7.23
			MD	6.53	11.62	8.79	0.12	0.82	0.91	8.86	10.53
Middle Ages (13th-14th centuries)											
M_2	27	-	BL	8.56	11.38	9.77	0.15	0.61	0.78	9.88	7.99
			MD	9.03	11.94	10.45	0.16	0.73	0.85	10.33	8.22
M^2	20	-	BL	7.83	12.82	11.05	0.26	1.40	1.18	11.34	10.73
			MD	7.08	10.37	8.90	0.21	0.92	0.96	9.01	10.79
Middle Ages (17th century)											
M_2	63	-	BL	8.46	11.03	9.66	0.07	0.32	0.57	9.6	5.93
			MD	9.22	12.61	10.44	0.08	0.50	0.71	10.42	6.83
M^2	70	-	BL	9.56	12.8	11.07	0.08	0.50	0.71	10.97	6.43
			MD	7.02	10.74	9.18	0.08	0.51	0.72	9.22	7.83
*Dimension variability of M2 molars by period and sex**											
Prehistory (~ 5000-1150 BCE)											
M_2	34	Male	BL	8.42	11.3	9.76	0.11	0.48	0.69	9.72	7.15
			MD	9.36	12.46	10.37	0.12	0.50	0.70	10.21	6.84
M^2	33	Male	BL	8.9	12.68	10.70	0.15	0.76	0.87	10.64	8.14
			MD	6.53	11.62	8.80	0.17	0.97	0.98	8.89	11.24
M_2	17	Female	BL	8.72	9.98	9.22	0.07	0.10	0.31	9.19	3.45
			MD	9.14	10.79	9.87	0.11	0.22	0.46	9.8	4.75
M^2	15	Female	BL	9.63	11.1	10.32	0.11	0.20	0.45	10.37	4.43
			MD	7.72	10.46	8.68	0.19	0.58	0.76	8.59	8.76
Middle Ages (13th – 17th centuries)											
M_2	67	Male	BL	8.46	11.38	9.70	0.07	0.37	0.61	9.69	6.33
			MD	9.03	12.61	10.46	0.09	0.57	0.75	10.43	7.22
M^2	69	Male	BL	7.83	12.82	11.02	0.10	0.72	0.84	10.96	7.69
			MD	7.02	10.74	9.15	0.09	0.65	0.80	9.19	8.82
M_2	21	Female	BL	8.76	11.03	9.59	0.15	0.48	0.69	9.42	7.22
			MD	9.36	12.24	10.28	0.14	0.43	0.65	10.27	6.41
M^2	19	Female	BL	9.86	12.8	11.24	0.18	0.62	0.79	11.22	7.05
			MD	7.7	10.27	9.04	0.17	0.55	0.74	9.22	8.20

* 9 molars were removed from the descriptive statistics due to the indeterminate sex of the individuals

Our results show a strong and positive correlation between the BL and MD diameters for the mandibular M_2 molars (Spearman coefficient = 0.75, $p < 0.001$), and moderate one in the maxillary M^2 molars (Pearson coefficient = 0.32, $p < 0.001$) (Fig. 3A, B). When a sex criterium was applied, the dental measurements in the mandibular M_2 molars (i.e., BL, and MD) were strong correlated in males (Spearman coefficient = 0.76, $p < 0.001$), and moderate positive correlated in females (Spearman coefficient = 0.64, $p < 0.001$) (Fig. 3C, E). In contrast with these results, for the maxillary M^2 molars, dental measurements showed a moderate positive correlation in males (Pearson coefficient = 0.39, $p < 0.001$), and no correlation in females (Pearson coefficient = 0.083, $p < 0.64$) (Fig. 3D, F). The MD and BL diameters were less correlated in the maxillary M^2 molar than in the mandibular M_2 (10%, and 57% respectively). This aspect is highlighted especially in the female molars (47% in the mandibular M_2, and 0.69% in the maxillary M^2) in contrast with the male molars (56% in mandibular M_2 and 15% in the maxillary M^2).

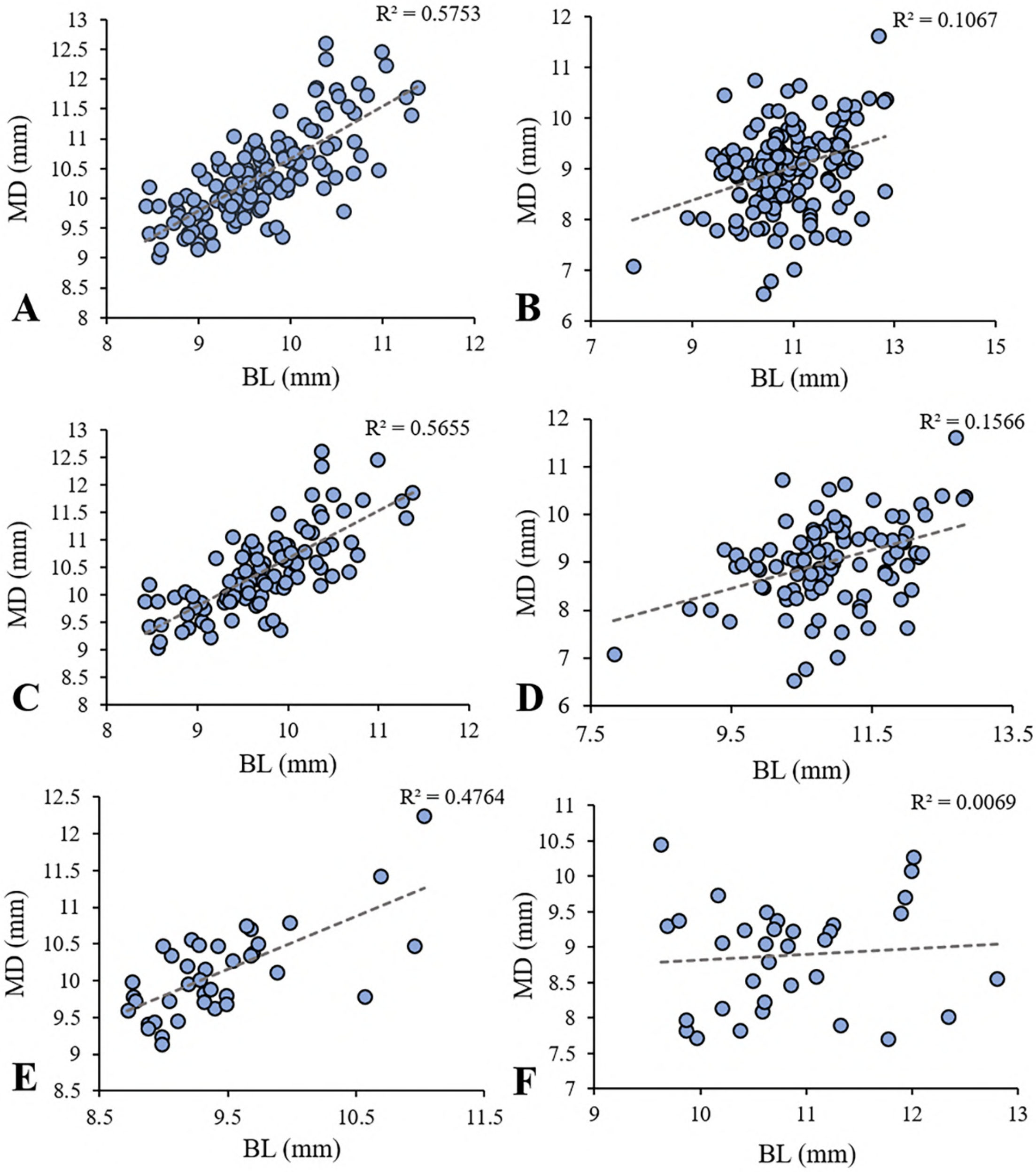

Fig. 3.- Dimension variability of the M2 human molars belonging to the archaeological populations from North-Eastern Romania: **A** – dimensions of the M_2 molars; **B** – dimensions of the M^2 molars; **C** – dimensions of the M_2 molars in males; **D** – dimensions of the M^2 molars in males; **E** – dimensions of the M_2 molars in females; **F** – dimensions of the M^2 molars in females.

The crown index (CI) can be used to obtain data regarding the crown proportions, especially in a comparative approach (Kondo et al., 2005). The CI frequency values are shown by sex and tooth position in the skull in Fig. 4. The distribution of the CI values was assessed using the Shapiro-Wilk test. The results showed that the CI values have non-normal distribution in the maxillary M^2 molars in males ($W = 0.94$, $p = 0.002$); therefore, the Mann-Whitney pairwise test was used. According to the Mann-Whitney test, a significant statistical difference was revealed between the mandibular M_2 molars in female vs. male ($p < 0.001$), probably due to the sexual dimorphism that influenced the crown proportion.

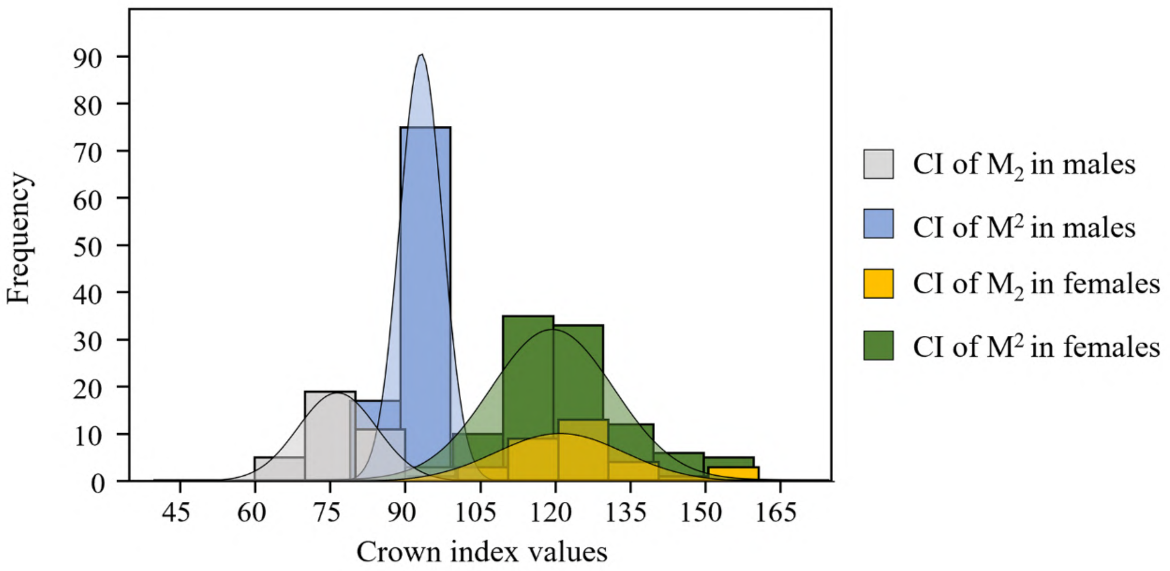

Fig. 4.- Crown index of the M2 molars by sex.

To analyze the dynamic of the tooth crown proportion in the upper and lower M2 molars, the medio-distal (MD) and bucco-lingual (BL) measurements, along with the crown area (CA), and crown index (CI) were diachronically compared. The results of data normality test are shown in Table 5.

Three variables register statistically significant differences between the prehistoric and the medieval periods in the female teeth (Fig. 5A). For the lower M2 molar, the mesio-distal (MD) diameter recorded a mean value greater in the medieval sample (MD = 10.28 mm) comparative with that of prehistoric one (MD = 9.87 mm) (U test = 109; $p = 0.042$). Also, the crown area (CA) of the mandibular molar M_2 recorded higher values in the medieval sample (98.97 mm^2) compared to the prehistoric one (91.08 mm^2) (U test = 102; $p = 0.02$).

In the upper M^2 molars, the bucco-lingual diameter (BL) and the crown area (CA) registered significant higher values for the medieval sample (U test = 46; $p = 0.00$ and U test = 51; $p = 0.001$), namely 11.24 mm in BL and 101.66 mm^2 in CA, comparative with 10.32 mm and 89.56 mm^2 for prehistoric sample.

In the male dataset, the Mann-Whitney test results highlight significant differences between the mean values only for the crown area (CA) of upper M^2 molars (U test =743; $p = 0.008$) (Fig. 5B). The CA registered higher values for this molar in the medieval sample (101 mm^2) than in the prehistoric one (96.22 mm^2).

Sexual dimorphism

In our study, the sexual dimorphism was calculated for each period separately: Prehistory and Middle Ages. In the prehistoric mandibular M_2, of the four variables investigated (MD, BL, CI, CA), the sexual dimorphism was manifested in three of them: BL (U test = 112; $p = 0.001$), MD (U test = 138; $p = 0.01$), and CA (U test = 114; $p = 0.001$).

Table 5. Normality test result for BL, MD, CA, CI variables.

Prehistory									
Lower M_2 molar – male					Lower M_2 molar – female				
Normality test	Variables				Normality test	Variables			
	BL	MD	CI	CA		BL	MD	CI	CA
W	0.979	0.868	0.984	0.916	W	0.958	0.963	0.946	0.925
p - value	0.790	0.001	0.921	0.021	p - value	0.592	0.694	0.394	0.176
Upper M^2 molar – male					Upper M^2 molar – female				
Normality test	Variables				Normality test	Variables			
	BL	MD	CI	CA		BL	MD	CI	CA
W	0.986	0.942	0.976	0.874	W	0.946	0.935	0.877	0.950
p - value	0.950	0.088	0.673	0.001	p - value	0.459	0.319	0.043	0.525
Middle Ages									
Lower M_2 molar – male					Lower M_2 molar – female				
Normality test	Variables				Normality test	Variables			
	BL	MD	CI	CA		BL	MD	CI	CA
W	0.985	0.978	0.980	0.975	W	0.893	0.900	0.848	0.886
p - value	0.622	0.303	0.389	0.200	p - value	0.029	0.035	0.004	0.019
Upper M^2 molar – male					Upper M^2 molar – female				
Normality test	Variables				Normality test	Variables			
	BL	MD	CI	CA		BL	MD	CI	CA
W	0.958	0.973	0.941	0.978	W	0.976	0.938	0.836	0.966
p - value	0.020	0.141	0.003	0.274	p - value	0.883	0.246	0.004	0.692

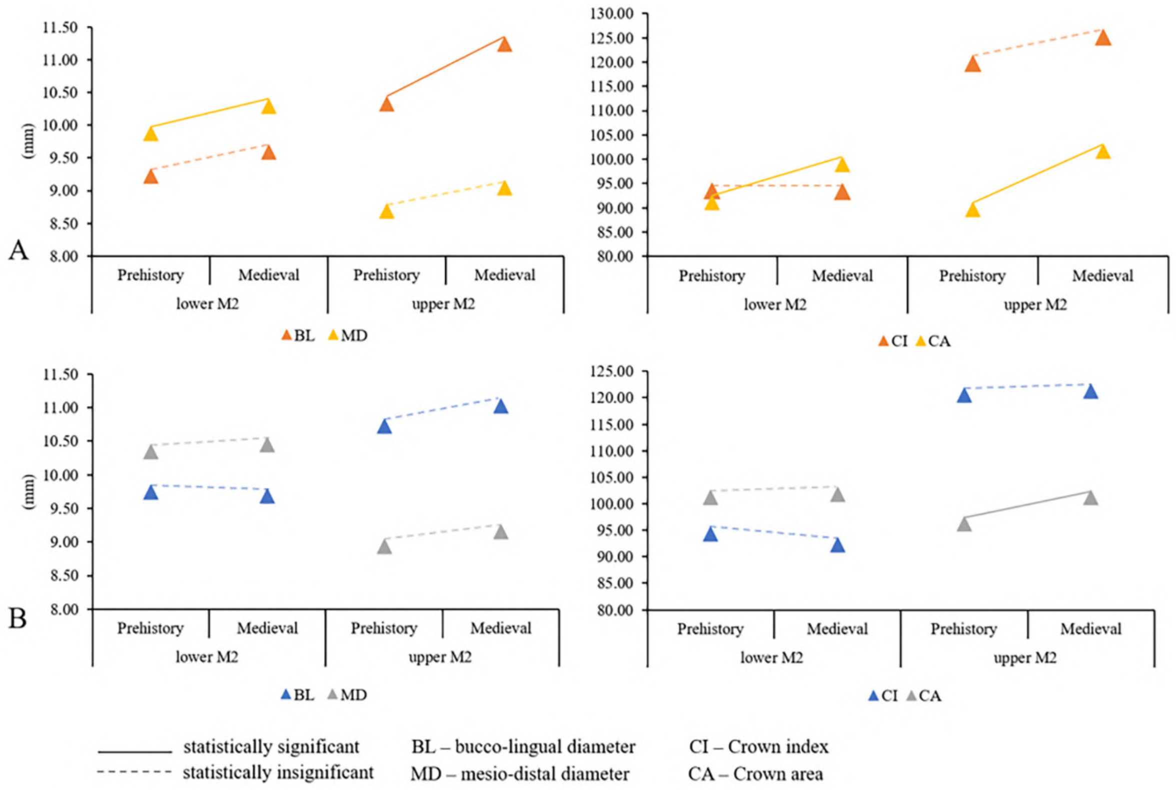

Fig. 5.- Comparative representation of the M2 molar variables (BL, MD, CA, CI) between medieval and prehistoric samples: **A**. Females, **B**. Males.

Table 6. Discriminant analysis statistics.

Stepwise discriminant analysis of dental variables				
Period	**Molar**	**Hotelling's value**	**F test**	**P value**
Prehistory	Lower M_2 molar	12.17	2.84	0.03*
	Upper M^2 molar	3.4	0.8	0.52
Middle Ages	Lower M_2 molar	1.04	0.25	0.9
	Upper M^2 molar	2.4	0.58	0.67

The correlations between the factors (F1) and original variables				
Variables	**Lower M_2 molar Prehistory**	**Upper M^2 molar/ Prehistory**	**Lower M_2 molar Middle Ages**	**Upper M^2 molar Middle Ages**
BL	0.926	-0.701	0.62	0.646
MD	0.771	-0.583	0.893	-0.347
CI	0.213	0.021	-0.421	0.783
CA	0.896	-0.796	0.821	0.105

Canonical discriminant function coefficients and Functions at Group Centroid			
Molar	**Variable**	**F1**	**Function of Group centroid**
Lower M_2 molar Prehistory	Constant	-39.596	Female: -0.675 Male: 0.383
	BL	14.077	
	MD	2.583	
	CI	-0.549	
	CA	-0.714	
Upper M^2 molar/ Prehistory	Constant	-74.156	Female: 0.395 Male: -0.185
	BL	-6.111	
	MD	9.012	
	CI	0.602	
	CA	-0.142	
Lower M_2 molar Middle Ages	Constant	-102.491	Female: -0.194 Male: 0.063
	BL	-13.542	
	MD	9.865	
	CI	1.198	
	CA	0.191	
Upper M^2 molar Middle Ages	Constant	-38.829	Female: 0.315 Male: -0.087
	BL	10.339	
	MD	3.255	
	CI	-0.275	
	CA	-0.709	

Confusion matrix for the cross-validation results:					
M2	**from \ to**	**F**	**M**	**Total**	**% Correct**
Lower M_2 molar Prehistory	F	14	3	17	82.35%
	M	16	14	30	46.67%
	Total	30	17	47	59.57%
Upper M^2 molar/ Prehistory	F	9	6	15	60.00%
	M	12	20	32	62.50%
	Total	21	26	47	61.70%
Lower M_2 molar Middle Ages	F	1	20	21	4.76%
	M	7	58	65	89.23%
	Total	8	78	86	68.60%
Upper M^2 molar Middle Ages	F	0	19	19	0.00%
	M	5	64	69	92.75%
	Total	5	83	88	72.73%
Discriminant function for M2 mandibular molar – Prehistory: F1= (-39.596) + 14.077*BL + 2.583*MD + (-0.549*CI) + (-0.714*CA).					

*Statistically significant p-value

The SDI values are close for the two variables: 6.09% for BL, and 5.06% for MD. So, for that we consider that indeed both variables play a more important role in the sexual differentiation. This idea is strengthened by the area of the dental crown (CA), calculated precisely on these two variables (BL x MD). The SDI value of CA shows a much more dimorphic role than for the two variables analyzed separately (SDI = 11.74%).

The role of variables in the sexual discrimination was also tested with Discriminant Analysis. Discriminant Analysis was achieved for every category of data: upper and lower M2 molars, and every period (Prehistory and Middle Ages). The analysis only reinforces the findings of the previous test.

The Table 6 shows the results of Discriminant Analysis. It includes the Hotelling's test, which highlights the role of the dental variables in the stepwise analysis, while F test determines how much variation exists between sexes and the significance level of variance. The DA results show that BL variable is the one that makes the biggest contribution to the functions obtained, and a stronger correlation between the variables is noticed in the test of the mandibular molar from the Prehistoric period. Also, in Table 6 the canonical discriminant coefficient and function at group centroid are presented. A group centroid is the mean discriminant score for each of the sexes. The formula to identify the sex by M2 is derived from the discrimination function coefficients (unstandardized coefficients), clearly categorizing the subjects as male or female. After calculating F value from the formula, it will be compared with the section point which is calculated as 0.

In the present study, classification accuracy in the stepwise discriminant analysis ranged between 59.57-72.73% (Table 6). Maximum accuracy of sex diagnosis was observed in the maxillary second molar (72.73% in Middle Ages, and 61.70% in Prehistory), followed by the mandibular second molar (59.57% in Prehistory, and 68.60% in Middle Ages). If we referred at the function statistically significant (p value<0.05), namely the one of the prehistoric samples, we can notice a higher accuracy for females (82.35%) than for males (46.67%).

DISCUSSION

This study explores the dental variability of permanent molar crowns in past human populations from Prehistory (~ 5000-1150 BCE) and the Middle Ages (13^{th}-17^{th} centuries), Northeastern Romania. In this research, the M2 molar teeth have been subjected to linear measurements of tooth crown (i.e., medio-distal diameter MD, and bucco-lingual diameter BL), along with two indexes (i.e., crown area CA, and crown index CI). Several studies on tooth characterization used these variables in both past human populations (Brook et al., 2009; Nava et al., 2021; Lukacs, 2019; Viciano et al., 2012) and actual ones (Zúñiga et al., 2021; Abaid et al., 2021). The results of the present study show that mandibular M2 molars in females are characterized by a mean BL value of 9.42 mm, and a mean MD value of 10.10 mm (Table 4). A higher mean value of the BL variable was obtained by Pajević and Glišić (2017) in samples from Mesolithic-Neolithic to Middle Ages from Serbia. In our study, comparable mean values to those attained by Pajević and Glišić (2017) were also obtained for the male mandibular molars. The same study conducted by Pajević and Glišić (2017) showed higher values in the male maxillary M2 molars in comparison with the data obtained for the samples belonging to archaeological sites from North East Romania.

When the period criterium was considered, differences regarding the tooth diameters were observed between the molars from Prehistory and Middle Age.

Several comparative studies on tooth dimension reveal that tooth size decreases from the prehistoric populations to the medieval ones (Christensen, 1998; Brace et al., 1987; Pinhasi et al., 2008). Pajević and Glišić (2017) reported that the BL diameter of the maxillary M2 molar decreases from the Mesolithic-Neolithic samples to the medieval ones. In contrast, our results show that the BL diameter of the maxillary molar increases from Prehistory to the Middle Ages, while the MD diameter values for mandibular molars are higher in the medieval period in comparison with Prehistory. Same increasing tendency of dental diameters was noted for the male molars, but not statistically supported. A study of Mockers et al.

(2004) shows that the MD diameter of mandibular teeth belonging to the prehistoric population from Roaix, Southern France, is smaller when compared to its size in modern Caucasian populations. Moreover, the mean value for the MD diameter of prehistoric mandibular M2 molars from Nord Eastern Romania (10.24 mm) is higher than the value obtained by Mockers et al. (2004) for the prehistoric molars from a population in Roix, France (9.75 mm). Regarding the BL and MD diameters of the medieval mandibular molars, comparable mean values were obtain by Vodanović et al. (2007) in a study approaching dental metrics in medieval samples from Eastern Croatia; the female maxillary molars from North East Romania showed slightly lower values than ones from Croatia. The crown area (CA), also known as the robustness index, is often used to characterize the overall crown size (Hillson et al., 2005; Petraru et al., 2020; Nowaczewska et al., 2013; Schmidt et al., 2011). The M2 molars from Norh East Romania show an increasing CA from the prehistoric period to the medieval one in both mandibular and maxillary molars in females. The same tendency is maintained for the upper M^2 molar in males. Similar CA values of medieval maxillary M2 molars in females from Croatia were obtained by Vodanović et al. (2007), while higher values were found in both mandibular and maxillary male molars in comparison with the data obtained for the dental samples from Romania.

Sexual dimorphism refers to systematic morphological differences between males and females of the same species (Abaid et al., 2021; Magalhães et al., 2021). Sexual dimorphism can be reflected in the human dentition especially in permanent teeth (Shankar et al., 2013; Zúñiga et al., 2021). The molars are considered among the most dimorphic teeth (El Sheikhi and Bugaighis, 2016) and even if the overall trend is known in any population, the degree of sexual dimorphism of each variable involved remains a population-specific characteristic (Garn et al., 1964; Acharya and Mainali, 2007; Zorba et al., 2011; Shankar et al., 2013). Previous studies have found that there is a statistically significant difference in tooth size between males and females, and this is due to the differences in the body size of the two sexes that occur in any human population (Schwartz and Dean, 2005; Ateş et al., 2006; Saunders et al., 2007).

While the prehistoric dental sample has been found highly dimorphic by sex, not a similar result was found in the medieval material, according to the Mann-Whitney test. As in another study conducted by İşcan and Kedici (2003), the lower M_2 is more dimorphic than the upper M^2.

The tooth dimensions typically are larger in males than in females, but the difference is not constant across populations (Barrett et al., 1964; Barrett et al., 1963; Harris and Foster, 2014). There are studies conducted on more recent material suggesting that mandibular BL is more dimorphic than mandibular MD (Yamada and Sakai, 1992; Garn et al., 1966; Zorba et al., 2011; Prabhu and Acharya, 2009), in contrast to others which mention that MD dimension is better suited than BL for sex discrimination; however, they found that better results are obtained when both MD and BL dimensions are used together (Acharya and Mainali, 2007; Barrett et al., 1964; Barrett et al., 1963). Our view is closer to the latter one if we consider the obtained results.

The stepwise discriminant analysis was done to find a reliable result on sex discrimination.

Lakhanpal et al. (2013) considered that, although BL dimension is more easily measured, its ability to correct classifications of individuals is moderate when used independently. Furthermore, if one has the opinion of choosing between the two types of linear measurements, MD should be preferred, even if it is more difficult to measure. We consider that better accuracy can be obtained when several variables are correlated. In our material, CI has a small contribution to sex discrimination, compared to the other three variables (BL, MD and CA). CI is the relationship between BL and MD and while the linear dimensions in males are usually larger than in females, this may not be true when they are taken as a relative measure (Kondo and Townsend, 2004). There are opinions according to which the crown index does not quantify the tooth size, as the crown area and linear measurements do. Harris and Rathburn (1991), and Garn et al. (1967) consider the crown index to be a description of the tooth shape rather than tooth size, being a more relevant indicator of population variations and not of sex differences.

A comparison between the maxillary and mandibular molars showed that the upper ones were more dimorphic than the mandibular molars, but statistically insignificant (p value > 0.05). Between the two sexes, the classification accuracy was higher in females than in males for cross-validated data. This could mean that males have the greatest variability of dental size and they can more often be misclassified than females. This result is in concordance with those of İşcan and Kedici (2003), Ateş et al. (2006), Peckmann et al. (2015) on crown mesiodistal and buccolingual measurements, which reported higher classification accuracy in females. A study conducted by Zorba et al. (2013) also provided similar results but for the diagonal measurements of molar teeth in a modern Greek population.

CONCLUSIONS

This paper approached dental measurements in archaeological human populations in order to assess M2 molar crown variability. The results of our study show a greater variability in the medieval female M2 teeth compared to prehistoric sample, in both maxillary (MD variable) and mandibular molars (MD and BL variables). Also, the two diameters were less corelated in the maxillary M^2 molar than in the mandibular M_2 molar, especially in females. In males, a higher variability of the mesio-distal (MD) variable was observed in the prehistory maxillary molars compared with the medieval ones. In the mandibular female teeth, significative statistical differences were obtained between the prehistoric and medieval samples (MD variable and CA variable). Also, in the maxillary molars the bucco-lingual (BL) and crown area (CA) variables showed higher values in the medieval samples.

In the male maxillary molars, the crown area (CA) variable showed significative higher values in the medieval sample than in the prehistoric one.

The discriminant analysis confirmed the sexual dimorphism on the mandibular M_2 crown in the prehistoric sample.

Further multidisciplinary studies are required to provide information concerning the influence of genetic, epigenetic and environmental factors on the dental variations.

REFERENCES

ABAID S, ZAFAR S, KRUGER E, TENNANT M (2021) Mesiodistal dimensions and sexual dimorphism of teeth of contemporary Western Australian adolescents. *J Oral Sci,* 20: 0596.

ABRÀMOFF MD, MAGALHÃES PJ, RAM SJ (2004) Image processing with ImageJ. *Biophotonics Int,* 11: 36-42.

ACHARYA AB, MAINALI S (2007) Univariate sex dimorphism in the Nepalese dentition and the use of discriminant functions in gender assessment. *Forensic Sci Int,* 173: 47-56.

AL-KHATIB A, RAJION Z, MASUDI S, HASSAN R, ANDERSON P, TOWNSEND G (2011) Tooth size and dental arch dimensions: a stereophotogrammetric study in Southeast Asian Malays. *Orthod Craniofac Res,* 14: 243-253.

ANTONIU S, ROȘCA-GRAMATOPOL ME (1966) Studiul antropologic al scheletelor din complexul mormintelor cu ocru de la Valea Lupului. *An Șt Univ „Al I Cuza" Iași, s Șt nat,* XII: 49-66.

ATEȘ M, KARAMAN F, IȘCAN MY, ERDEM TL (2006) Sexual differences in Turkish dentition. *Leg Med,* 8: 288-292.

BARRETT M, BROWN T, ARATO G, OZOLS I (1964) Dental observations on Australian aborigines: buccolingual crown diameters of deciduous and permanent teeth. *Aust Dent,* 9: 280-285.

BARRETT MJ, BROWN T, MACDONALD M (1963) Dental observations on Australian aborigines: mesiodistal crown diameters of permanent teeth. *Aust Dent,* 8: 150-156.

BERTRAND B, CUNHA E, BÉCART A, GOSSET D, HÉDOUIN V (2019) Age at death estimation by cementochronology: Too precise to be true or too precise to be accurate? *Am J Phys Anthropol,* 169: 464-481.

BLACK W (2014) Dental morphology and variation across Holocene Khoesan people of southern Africa (Doctoral thesis). University of Cape Town, South Africa.

BRACE CL, ROSENBERG KR, HUNT KD (1987) Gradual change in human tooth size in the late Pleistocene and post-Pleistocene. *Evolution,* 41: 705-720.

BROOK A, GRIFFIN R, TOWNSEND G, LEVISIANOS Y, RUSSELL J, SMITH R (2009) Variability and patterning in permanent tooth size of four human ethnic groups. *Arch Oral Biol,* 54: S79-S85.

BROTHWELL DR (1981) *Digging up bones.* New York, Cornell University Press.

BUIKSTRA J, UBELAKER D (1994) *Standards for Data Collection from Human Skeletal Remains: Research Seminar* Fayetteville, Arkansas Archaeological Survey Research Series, No 44.

CHRISTENSEN AF (1998) Odontometric microevolution in the Valley of Oaxaca, Mexico. *J Hum Evol,* 34: 333-360.

CRISTESCU M (1961) Contribuția la studiul antropologic al unor schelete de la sfârșitul Epocii Bronzului (Cultura Noua) și începutul Epocii Fierului din Moldova. *Arh Mold,* I. p. 129-148.

CRISTESCU M, ANTONIU S, KLUGER R (1965) Studiul antropologic al scheletelor de la Cioinagi - Bălintești. *SCA,* 2: 29-42.

CRISTESCU M, MIU G (1999) Studiul Paleoantropologic al Scheletelor din Necropola Civilizației Noua de la Trușești - Țuguieta. In: Dîmbovița MP, Florescu M, Florescu AC (eds.) *Trușești: Monografie Arheologică.* București: Ed. Academiei Române.

CUMMINGS LS, YOST C, SOŁTYSIAK A (2018) Plant microfossils in human dental calculus from Nemrik 9, a Pre-Pottery Neolithic site in Northern Iraq. *Archaeol Anthropol Sci,* 10: 883-891.

DE CASTRO JMB, NICOLAS ME (1995) Posterior dental size reduction in hominids: the Atapuerca evidence. *Am J Phys Anthropol,* 96: 335-356.

DE CASTRO JMB, SARMIENTO S, CUNHA E, ROSAS A, BASTIR M (2001) Dental size variation in the Atapuerca-SH Middle Pleistocene hominids. *J Hum Evol,* 41: 195-209.

DIACONU V, HÂNCEANU GD, SIMALCSIK A, DANU M (2016) Un grup de morminte din Epoca Bronzului descoperit la Roman - Arhiepiscopie. *Arh Mold,* XXXIX: 347-370.

EBOH D (2017) A dimorphic study of maxillary first molar crown dimensions of Urhobos in Abraka, South-Southern Nigeria. *J Morphol Sci,* 29: 96-100.

EL SHEIKHI F, BUGAIGHIS I (2016) Sex discrimination by odontometrics in Libyan subjects. *Egypt J Forensic Sci,* 6: 157-164.

FARZIN M, GITI R, HEIDARI E (2020) Age-related changes in tooth dimensions in adults in Shiraz, Iran. *J Int Oral Health,* 12: 24.

FIORENZA L, BENAZZI S, OXILIA G, KULLMER O (2018) Functional relationship between dental macrowear and diet in Late Pleistocene and recent modern human populations. *Int J Osteoarchaeol,* 28: 153-161.

GALBANY J, IMANIZABAYO O, ROMERO A, VECELLIO V, GLOWACKA H, CRANFIELD MR, BROMAGE TG, MUDAKIKWA A, STOINSKI TS, MCFARLIN SC (2016) Tooth wear and feeding ecology in mountain gorillas from Volcanoes National Park, Rwanda. *Am J Phys Anthropol,* 159: 457-465.

GARN SM, LEWIS AB, KEREWSKY RS (1964) Sex difference in tooth size. *J Dent Res,* 43: 306-306.

GARN SM, LEWIS AB, KEREWSKY RS (1966) Sexual dimorphism in the buccolingual tooth diameter. *J Dent Res,* 45: 1819-1819.

GARN S, LEWIS A, KEREWSKY R (1967) Sex difference in tooth shape. *J Dent Res,* 46: 1470-1470.

GAROT E, COUTURE￿VESCHAMBRE C, MANTON DJ, BEKVALAC J, ROUAS P (2019) Differential diagnoses of enamel hypomineralisation in an archaeological context: A postmedieval skeletal collection reassessment. *Int J Osteoarchaeol,* 29: 747-759.

GÓMEZ-ROBLES A, DE CASTRO JMB, MARTINÓN-TORRES M, PRADO-SIMÓN L, ARSUAGA JL (2015) A geometric morphometric analysis of hominin lower molars: Evolutionary implications and overview of postcanine dental variation. *J Hum Evol,* 82: 34-50.

GÓRKA K (2016) Dental morphology and dental wear as dietary and ecological indicators: sexual and inter-group differences in traditional human populations (doctoral thesis). University of Barcelona, Barcelona.

GÓRKA K, ROMERO A, PÉREZ-PÉREZ A (2015) First molar size and wear within and among modern hunter-gatherers and agricultural populations. *Homo,* 66: 299-315.

GREEN JL, CROFT DA (2018) Using dental mesowear and microwear for dietary inference: a review of current techniques and applications. In: Croft DA, Su DF, Simpson SW (eds.) *Methods in Paleoecology.* Switzerland: Springer.

GROZA V-M (2015) *Cercetări paleoantropologice privind populația Iașului Medieval.* Iași, Editura Universității „Alexandru Ioan Cuza" Iași.

HAMMER Ø, HARPER D, RYAN P (2001) PAST-Palaeontological statistics software package for education and data analysis. *Palaeontol Electron,* 4: 9.

HARRIS E, RATHBURN TA (1991) Ethnic differences in the apportionment of tooth size. In: Kelley MA, Larsen CS (eds.) *Advances in dental anthropology.* New York: Wiley-Liss.

HARRIS EF, FOSTER CL (2014) Discrimination between American blacks and whites, males and females, using tooth crown dimensions. In: Berg GE, Ta'ala SC (eds.) *Biological affinity in forensic identification of human skeletal remains: beyond black and white.* USA: CRC Press.

HASEGAWA Y, ROGERS JR, KAGEYAMA I, NAKAHARA S, TOWNSEND GC (2007) Comparison of permanent mandibular molar crown dimensions between Mongolians and Caucasians. *Dent anthropol,* 20: 1-6.

HIGGINS D, AUSTIN JJ (2013) Teeth as a source of DNA for forensic identification of human remains: a review. *Sci Justice,* 53: 433-441.

HILLSON S (2001) Recording dental caries in archaeological human remains. *Int J Osteoarchaeol,* 11: 249-289.

HILLSON S (2005) *Teeth.* USA, Cambridge University Press.

HILLSON S, FITZGERALD C, FLINN H (2005) Alternative dental measurements: proposals and relationships with other measurements. *Am J Phys Anthropol,* 126: 413-426.

İŞCAN MY, KEDICI PS (2003) Sexual variation in bucco-lingual dimensions in Turkish dentition. *Forensic Sci Int,* 137: 160-164.

JEON CL, PAK S, WOO EJ (2020) The correlation between the tooth wear of the first molar and the estimated age from the auricular surfaces in a Joseon Dynasty population, South Korea. *Int J Osteoarchaeol,* 30: 759-768.

KAZZAZI SM, KRANIOTI EF (2018) Sex estimation using cervical dental measurements in an archaeological population from Iran. *Archaeol Anthropol Sci,* 10: 439-448.

KONDO S, TOWNSEND G (2004) Sexual dimorphism in crown units of mandibular deciduous and permanent molars in Australian Aborigines. *Homo,* 55: 53-64.

KONDO S, TOWNSEND GC, YAMADA H (2005) Sexual dimorphism of cusp dimensions in human maxillary molars. *Am J Phys Anthropol,* 128: 870-877.

KONDO S, MANABE Y (2016) Analytical methods and interpretation of variation in tooth morphology. *J Oral Biosci,* 58: 85-94.

LAKHANPAL M, GUPTA N, RAO N, VASHISTH S (2013) Tooth dimension variations as a gender determinant in permanent maxillary teeth. *JSM Dent,* 1: 1014.

LUKACS JR (2019) Deciduous dental variation in Chalcolithic India: methods, metrics and meaning. *Homo*: 3-14.

MAGALHÃES LV, BORGES BS, PINTO PHV, ALVES CP, DA SILVA RHA (2021) Sexual dimorphism applying the mandibular canine index in a Brazilian sample: a pilot study. *Acta Sci Health Sci,* 43: e54202-e54202.

MARCHEWKA J, SKRZAT J, WRÓBEL A (2014) Analysis of the enamel hypoplasia using micro-CT scanner versus classical method. *Anthropol Anz,* 71.

MARTÍN-ALBALADEJO M, MARTINÓN-TORRES M, GARCÍA-GONZÁLEZ R, ARSUAGA JL, DE CASTRO JB (2017) Morphometric analysis of Atapuerca-Sima de los Huesos lower first molars. *Quat Int,* 433: 156-162.

MIU G (1992) Caracteristicile antropologice ale scheletelor descoperite la Brăești (județul Botoșani) apațінând culturii Noua. *SCA,* 29: 17-23.

MIU G (1999) Cercetări paleoantropologice complexe asupra populațiilor aparținând Culturii Monteoru (Doctoral thesis). Universitatea „Alexandru Ioan Cuza" din Iași, Iași.

MIU G, SIMALCSIK R, STUPU M (2003) La nécropole féodale de Hudum (Départament de Botoșani) XIII[e]-XIV[e] siècles. Analyse démographique. *Ann Roum Anthropol,* 40: 3-9.

MOCKERS O, AUBRY M, MAFART B (2004) Dental crowding in a prehistoric population. *Eur J Orthod,* 26: 151-156.

MORENO-GÓMEZ F (2013) Sexual dimorphism in human teeth from dental morphology and dimensions: A dental anthropology viewpoint. In: Moriyama H (ed.) *Sexual Dimorphism.* IntechOpen.

NAVA A, FIORIN E, ZUPANCICH A, CARRA M, OTTONI C, DI CARLO G, VOZZA I, BRUGNOLETTI O, ALHAIQUE F, CREMONESI RG (2021) Multipronged dental analyses reveal dietary differences in last foragers and first farmers at Grotta Continenza, central Italy (15,500–7000 BP). *Sci Rep,* 11: 1-14.

NECRASOV O, CRISTESCU M (1957) Contribuţie la studiul antropologic al scheletelor din complexul mormintelor cu ocru de la Holboca - Iaşi. *Probleme de Antropologie,* III: 73-147.

NECRASOV O, BOTEZATU D (1964) Studiu antropologic al scheletelor feudale timpurii de la Doina (sec. XIII-XIV). *SCA,* 2: 137-155.

NECRASOV O, ONOFREI M (1972) Contribution a l'anthropologie de la population neoeneolithique du complexe Horodistea-Foltesti. *Ann Roum Anthropol,* 9: 3-9.

NECRASOV O, ANTONIU S, FEDOROVICI C (1972) Sur la structure anthropologique des tribus neo-eneolithiques appartenant a la culture des amphores spheriques. *Ann Roum Anthropol,* 9: 9-25.

NOWACZEWSKA W, DĄBROWSKI P, STRINGER CB, COMPTON T, KRUSZYŃSKI R, NADACHOWSKI A, SOCHA P, BINKOWSKI M, URBANOWSKI M (2013) The tooth of a Neanderthal child from Stajnia Cave, Poland. *J Hum Evol,* 64: 225-231.

PAJEVIĆ T, GLIŠIĆ B (2017) Dental occlusion analysis in the Mesolithic–Neolithic Age, Bronze Age, and Roman to Medieval times in Serbia: Tooth size comparison in skeletal samples. *Arch Oral Biol,* 77: 44-50.

PECKMANN TR, MEEK S, DILKIE N, MUSSETT M (2015) Sex estimation using diagonal diameter measurements of molar teeth in African American populations. *J Forensic Leg Med,* 36: 70-80.

PETRARU O-M, BEJENARU L (2019) Overview on microscopic methods for dental wear evaluation in paleodiet studies. *Ann Roum Anthropol,* 56: 5-14.

PETRARU O-M, GROZA V-M, BEJENARU L (2017) Morphometric variability of the molar tooth M2 in the skeletal series discovered in the 17th century necropolis from Iasi (Iasi county, Romania). *An Şt Univ „Al I Cuza" Iaşi, s Biol anim,* 63: 55-61.

PETRARU O-M, BEJENARU L, GROZA V-M, POPOVICI M (2020) Dimensional variability of the human second molar (M2) in Bronze Age populations from North-East Romania. *RAASI*: 101-109.

PILLOUD MA, SCOTT GR (2020) Dentition in the estimation of sex. In: Klales AR (ed.) *Sex Estimation of the Human Skeleton.* San Diego: Elsevier.

PINHASI R, ESHED V, SHAW P (2008) Evolutionary changes in the masticatory complex following the transition to farming in the southern Levant. *Am J Phys Anthropol,* 135: 136-148.

PRABHU S, ACHARYA AB (2009) Odontometric sex assessment in Indians. *Forensic Sci Int,* 192: 129. e1-129. e5.

RATNER B (2009) The correlation coefficient: Its values range between+ 1/– 1, or do they? *J Target Meas Anal Market,* 17: 139-142.

RAZALI NM, WAH YB (2011) Power comparisons of shapiro-wilk, kolmogorov-smirnov, lilliefors and anderson-darling tests. *JSMTA,* 2: 21-33.

SAUNDERS SR, CHAN AH, KAHLON B, KLUGE HF, FITZGERALD CM (2007) Sexual dimorphism of the dental tissues in human permanent mandibular canines and third premolars. *Am J Phys Anthropol,* 133: 735-740.

SCHERER AK (2018) Dental Metrics. In: Varela SLL (ed.) *The Encyclopedia of Archaeological Sciences.* Chichester: Wiley Blackwell.

SCHMIDT C, OUSLEY S, SCHMIDT M (2011) Brief communication: Correcting overestimation when determining two-dimensional occlusal area in human molars. *Am J Phys Anthropol,* 145: 327-332.

SCHWARTZ GT, DEAN MC (2005) Sexual dimorphism in modern human permanent teeth. *Am J Phys Anthropol,* 128: 312-317.

SHANKAR S, ANUTHAMA K, KRUTHIKA M, KUMAR VS, RAMESH K, JAHEERDEEN A, YASIN MM (2013) Identifying sexual dimorphism in a paediatric South Indian population using stepwise discriminant function analysis. *J Forensic Leg Med,* 20: 752-756.

SMITH-GUZMÁN NE, RIVERA-SANDOVAL J, KNIPPER C, ARIAS GAS (2020) Intentional dental modification in Panamá: New support for a late introduction of African origin. *J Anthropol Archaeol,* 60: 101226.

SMITH BH (1984) Patterns of molar wear in hunter–gatherers and agriculturalists. *Am J Phys Anthropol,* 63: 39-56.

TAKAHASHI M, KONDO S, TOWNSEND GC, KANAZAWA E (2007) Variability in cusp size of human maxillary molars, with particular reference to the hypocone. *Arch Oral Biol,* 52: 1146-1154.

TOMCZYK J, MYSZKA A, REGULSKI P, OLCZAK KOWALCZYK D (2020) Case of pulp stones and dental wear in a Mesolithic (5900±100 bc) individual from Woźna Wieś (Poland). *Int J Osteoarchaeol,* 30: 375-381.

TOWNSEND G, BOCKMANN M, HUGHES T, BROOK A (2012) Genetic, environmental and epigenetic influences on variation in human tooth number, size and shape. *Odontology,* 100: 1-9.

VICIANO J, ALEMĀN I, D'ANASTASIO R, CAPASSO L (2012) Alternative dental measurements: Correlation between cervical and crown dimensions. *Boll Soc Ital Biol Sper,* 85.

VODANOVIĆ M, DEMO Ž, NJEMIROVSKIJ V, KEROS J, BRKIĆ H (2007) Odontometrics: a useful method for sex determination in an archaeological skeletal population? *J Archaeol Sci,* 34: 905-913.

WASTERLAIN S, NEVES M, FERREIRA M (2016) Dental modifications in a skeletal sample of enslaved Africans found at Lagos (Portugal). *Int J Osteoarchaeol,* 26: 621-632.

WASTERLAIN SN, RUFINO AI, FERREIRA MT (2020) Dental caries and intentional dental modification in a skeletal sample of enslaved Africans from Lagos, Portugal (15th–17th centuries). *Int J Osteoarchaeol,* 30: 109-113.

WATSON JT, HAAS R (2017) Dental evidence for wild tuber processing among Titicaca Basin foragers 7000 ybp. *Am J Phys Anthropol,* 164: 117-130.

WOOD B, ABBOTT S (1983) Analysis of the dental morphology of Plio-pleistocene hominids. I. Mandibular molars: crown area measurements and morphological traits. *J Anat,* 136: 197.

YAMADA H, SAKAI T (1992) Sexual dimorphism in tooth crown diameter of the Cook Islanders. In: Smith P, Tchernov E (eds.) *Structure, function and evolution of teeth.* London: Freund Publishing House, Ltd.

YOO H-I, YANG D-W, LEE M-Y, KIM M-S, KIM S-H (2016) Morphological analysis of the occlusal surface of maxillary molars in Koreans. *Arch Oral Biol,* 67: 15-21.

ZORBA E, MORAITIS K, MANOLIS SK (2011) Sexual dimorphism in permanent teeth of modern Greeks. *Forensic Sci Int,* 210: 74-81.

ZORBA E, SPILIOPOULOU C, MORAITIS K (2013) Evaluation of the accuracy of different molar teeth measurements in assessing sex. *Forensic Sci Med Pathol,* 9: 13-23.

ZÚÑIGA MH, VICIANO J, FONSECA GM, SOTO-ÁLVAREZ C, ROJAS-TORRES J, LÓPEZ-LÁZARO S (2021) Correlation coefficients for predicting canine diameters from premolar and molar sizes. *JDS,* 16: 186-194.