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Characteristics of Maxillary Cheek Teeth in Horses *Equus przewalskii* F. *Caballus* (LINNAEUS, 1758) from Early Medieval Excavations in Poland

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Abstract: The investigations were carried out in the permanent 65 maxillary cheek teeth of 12 adult horses *Equus przewalskii* f. *caballus* (LINNAEUS, 1758), males and females, from archaeological excavations dated back to early medieval. 14 dimensions were measured and 22 morphological details of the occlusal surface were described. The objective of the study was estimation of odontometric differences between both sexes and statistical significance analysis of the influence of the investigated factors - mostly gender and archaeological context - on measured values. Majority of obtained results indicate the lack of statistical significance ($P > 0.05$) between the mean values of measurements from four investigated excavations. Moreover, other numerous analogies between the mean values of odontologic measurements taken in other medieval horse specimens were found, especially in primitive horse breed zooarchaeological material from Poland.

Key words: Adult Horses · Lophodont Cheek Teeth · Odontological Measurements · Occlusal Surface · Early Middle Ages

INTRODUCTION

In the last decade horse cheek teeth research enabled i.a. phylogenetic description of the teeth of horses [1], hypselodontic equines paleodiet reconstruction [2], mineralization pattern and estimation of its periods for modern horses' dentition [3], supernumeraries of horse dentition description [4], time of animal death estimation based on the measurements of cheek teeth crowns [5].

Dental nomenclature of crown features in lophodontic dentition of horses has been argued over for years. Some authors referred only to basic elements of the occlusal surface morphology, that were easily distinguishable. Others modified the existing terminology or broadened it by introducing new terms [6-14]. Despite the cheek teeth morphometry was analyzed in ancestors of Pleistocene horses as well as in modern Equidae representatives [8,10,15-18], there is rather a scarcity of publications on medieval horse odontometry. Most of these papers address the three main dimensions of the occlusal surface: length/width of tooth and length of protocone. The aim of our study is to demonstrate the differences between odontometric dimensions for both genders as well as to examine statistically how factors like gender and archaeological location influence the measurements. Moreover, an odontometric parameters comparison was carried out for of zooarchaeological material dated back to European Middle Ages versus primitive horse breeds.

MATERIALS AND METHODS

Majority of the cheek teeth came from horse skulls dated to Early Middle Ages, material came from settlement centers of urban character. The same skulls had been subject of craniometric research and the results have been published in a separate paper by Pasicka *et al*. [19].

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The dental material was well preserved, not fragmented, located in the alveoli, allowing for the exact identification of its location in the upper dental arches. The animal age was estimated as morphological adult (8-9 years old) on the basis of the incisive teeth shape and size. Also identified were cheek teeth belonging to two males aged up to 21 years. Two odontometric measurements (tooth length and width) of those males aged up to 21 years were excluded from the statistical studies with young (8-9 years of age) specimen, because of the tooth wear and the changes in shape of the occlusal surface. The 65 cheek teeth were coming from 12 early medieval horses *Equus przewalskii* f. *caballus* (LINNAEUS, 1758) and had been found during archaeological excavation in: Opole (Ostrówek X-XI c.), Wroclaw (Ostrów Tumski - Cathedral Island XI-XIII c.), Kruszwica (X-XIII c.) and Wroclaw (University (W/Unw.) X-XIII c.). Sex of the analyzed horses was determined based on the presence of canines which are typical for males.

The zooarchaeological material was a part of a museum collection in the Section of Animal Anatomy Faculty of Veterinary Medicine, Wroclaw University of Environmental and Life Sciences. The cheek teeth were described with abbreviations used in veterinary practice and it is: P^2 – the 2nd upper premolar, P^3 – the 3rd upper premolar, P^4 – the 4th upper premolar and M^1 – the 1st upper molar, M^2 – the 2nd upper molar and M^3 – the 3rd upper molar. The lack of the 1st upper premolar is commonly described in horses [3].

During our investigations the maxillar cheek teeth were divided according to subsequent criteria. The first one was based on archaeological context (location of findings). The premolar teeth measurements from three archaeological sites (Opole–3, Kruszwica–2, Wroclaw Cathedral Island–5) and the molar teeth measurements from four excavations (Opole–3, Wroclaw University–2, Kruszwica–2, Wroclaw Cathedral Island–5) were taken into consideration (Tables 1 and 2).

The second partition differentiated the material according to gender, which was not possible in all investigated examples, thus only the measurements carried in 6 males (Opole–2, Kruszwica–1, Wroclaw Cathedral Island –3) and 3 females (Wroclaw Cathedral Island –2, Kruszwica–1) were included (Tables 3 and 4).

The morphological evaluation of horses was based on the occlusal surface anatomical features interpretation and odontometry. Terminology describing the crown of tooth occlusal surfaces in upper cheek teeth was introduced according to Astre [6], Pirlot [7], Gromova [8], Azzaroli [9], Musil [10], Churcher and Richardson [11], Prat [12], Evander [14] and Hibbard [20]. The scheme of measuring the occlusal surface anatomical details was implemented according to the method introduced by Musil [10].

For each tooth 22 elements of the upper cheek teeth crown were interpreted (Figure 1) and 14 measurements were taken (Figure 2).

All measurements were taken with the use of an electronic slide caliper (0.1 mm accuracy), in the left upper dental arch. During the statistical elaboration of the mean values (no less than 3 groups), the single factor analysis of variance (ANOVA) and NIR Fisher's test were performed (Tables 1 and 2). During the mean values estimation between two groups t-Student tests were used (Tables 3 and 4). The mean values were established with statistical significance $P \leq 0.05$ and $P \leq 0.01$. All statistical calculations in this work were computed using StatSoft Statistica 9.1 software.

RESULTS

Single Factor Analysis of Variance (ANOVA) NIR Fisher's Test: The statistical analysis proved a lack of significant differences in the upper cheek teeth dimensions between the investigated groups from the subsequent archaeological sites (Tables 1 and 2).

The statistically significant differences of P^2 dimensions were identified only during the analysis of three measurements (Table 1). Measurement no. **7** highly significantly differentiated mean values obtained for horses from Opole (6.4 ± 0.66) and Wroclaw Cathedral Island (7.7 ± 0.26) (Table 1). Moreover, in measurement **7a** the mean value for horses from Wroclaw Cathedral Island (2.1 ± 0.18) was statistically significantly higher than the means for horses form Opole (1.3 ± 0.35) and Kruszwica (1.4 ± 0.01) (Table 1). Also, observation no. **13** proved to statistically significantly differentiate the horses from Opole (2.0 ± 0.13) and Kruszwica (2.9± 0.01) (Table 1).

The statistical analysis of P^3 showed only one value significantly different among horses from investigated archaeological sites (Table 1). Dimension on **7a** was statistically significantly different between horses from Wroclaw Cathedral Island (2.1 ± 0.35) and Opole (1.4 ± 0.35) (Table 1).

Analyses of P^4 pointed to a statistical difference in only one dimension between the groups investigated (Table 1). Dimension **8** turned out to be statistically significantly higher in horses from Wroclaw Cathedral Island (4.6 ± 0.46) in comparison with the mean obtained for Opole (2.9 ± 1.48) (Table 1).

Table 1: Measurements of upper premolars in early medieval horses, differentiated according to geographical sites

			Measurements (mm)													
Tooth	Archaeological Site		1	2	3	4	5	6	7	7a	8	9	10	11	12	13
P^2	Opole (n = 2)	m	35.9	24.1	6.2	2.0	8.2	2.1	6.4^{A}	1.3^{a}	4.4	3.4	2.2	15.6	13.1	2.0^{a}
		SD	3.24	1.52	2.09	0.06	1.25	0.32	0.66	0.35	0.23	0.00	2.15	3.34	0.98	0.13
	Kruszwica (n = 2)	m	35.5	22.7	5.0	3.4	8.1	2.7	7.1	1.4^{a}	4.7	3.6	2.2	14.1	13.1	2.9^{b}
		SD	2.88	2.96	0.37	0.71	0.53	0.39	0.36	0.01	0.18	0.90	0.14	1.44	0.82	0.01
	Cath. Island(n = 5)	m	36.7	24.2	6.2	4.9	10,1	2.9	7.7^{B}	2.1^{b}	5.6	3.2	2.4	12.3	13.8	2.3
		SD	1.75	1.00	0.57	2.07	1.34	1.07	0.26	0.18	0.93	1.01	0.88	1.35	0.58	0.32
P^3	Opole (n = 3)	m	28.3	26.9	5.5	5.0	10.8	3.5	7.6	1.4^{a}	3.9	3.9	4.1	13.5	12.0	4.3
		SD	1.52	1.02	0.93	1.80	2.19	1.50	0.98	0.35	1.32	0.74	1.07	1.03	0.83	1.78
	Kruszwica (n = 2)	m	27.8	24.1	5.2	5.5	11.1	4.8	7.9	1.6	4.7	4.2	3.4	12.9	12.0	3.9
		SD	1.55	3.77	0.28	0.08	1.87	0.81	0.66	0.31	0.87	0.09	0.19	1.87	0.57	0.32
	Cath. Island (n = 5)	m	28.2	26.9	5.2	5.9	10.7	4.4	7.7	2.1^{b}	4.9	4.7	3.4	13.0	11.8	3.7
		SD	1.39	0.80	0.14	0.89	0.92	0.53	0.52	0.35	0.73	0.89	1.06	2.41	0.81	1.39
P^4	Opole (n = 3)	m	27.2	25.9	4.7	5.4	11.3	4.2	7.6	1.9	2.9^{a}	3.1	3.5*	12.7	11.5	4.2
		SD	1.81	0.23	0.46	0.08	2.85	2.59	0.73	0.26	1.48	0.17	-	0.85	0.66	1.17
	Kruszwica (n = 2)	m	27.2	26.3	4.9	5.1	11.8	5.0	7.2	1.5	4.0	4.2	3.3	12.4	11.2	4.0
		SD	1.75	1.37	0.54	0.29	2.79	1.20	1.00	0.17	0.19	0.08	0.61	1.29	1.00	0.05
	Cath. Island (n = 5)	m	27.4	26.6	5.0	5.0	10.9	4.1	8.4	2.5	4.6^{b}	4.0	3.6	13.5	11.1	3.6
		SD	1.16	1.31	0.97	0.53	1.28	0.73	1.47	0.98	0.46	0.87	1.42	0.48	0.58	1.67

a, b-means in columns - marked with lowercase letters - differ statistically significantly for a given tooth, $P \leq 0.05$,

A, B- means in columns - marked with uppercase letters - differ statistically highly significantly for a given tooth, $P \leq 0.01$,

* - measurement outcome for one individual, m- mean, SD- standard deviation,

n- number of teeth, m- mean from measurements 1 and 2 included only young 8 and 9 year old specimens.

Table 2. Measurements of upper molars in early medieval horses, differentiated according to geographical sites

			Measurements (mm)													
Tooth	Archaeological Site		1	2	3	4	5	6	7	7a	8	9	10	11	12	13
M^1	Opole (n = 3)	m	24.8	25.6	4.2	4.0	11.7	3.9	7.6	1.9	3.3^{a}	2.0	2.1*	11.5	10.1	3.0
		SD	0.88	0.68	0.52	0.69	2.10	0.63	1.42	0.47	1.26	0.69	-	0.63	0.50	0.13
	W/Unw. (n = 2)	m	24.4	24.3	3.8	4.2	10.5	3.9	7.7	2.1	4.2	1.4	-	14.1*	11.4	1.8
		SD	4.29	0.11	0.58	0.72	0.30	0.88	1.82	0.42	0.31	0.72	-	-	0.03	0.16
	Kruszwica (n = 2)	m	24.0	25.5	3.4	3.7	11.3	4.2	6.7	1.8	3.9	2.3	2.4	10.9	10.2	3.6
		SD	0.65	0.29	0.81	0.14	1.78	0.73	0.33	0.06	0.13	0.43	0.74	0.56	0.32	0.52
	Cath. Island (n = 5)	m	24.6	25.4	3.9	3.9	10.8	4.0	7.6	1.9	4.9^{b}	2.7	2.3*	12.7	10.3	3.3
		SD	1.56	1.76	0.88	0.45	1.34	0.54	0.58	0.27	0.65	1.14	-	0.95	0.59	1.49
M^2	Opole (n = 3)	m	25.1	24.7	4.3	3.9	12.8	4.6	8.0	1.3^{a}	3.2^{a}	2.7	1.6	11.3	10.5	3.1
		SD	1.10	0.35	0.34	0.71	3.13	0.62	1.23	0.35	0.35	1.38	0.88	0.58	0.62	0.21
	W/Unw. (n = 2)	m	26.5	25.2	3.4	3.6	12.5	4.4	7.7	2.1^{b}	4.4	2.5	3.7*	15.9*	11.0	4.1
		SD	5.66	1.43	0.35	0.13	0.43	0.70	1.20	0.42	0.97	0.83	-	-	1.87	2.22
	Kruszwica (n = 2)	m	23.7	23.7	3.6	3.3	11.7	4.9	6.9	1.8	3.9	3.3	2.2	10.7	10.0	3.6
		SD	0.18	0.19	0.94	0.01	1.79	0.24	0.06	0.07	0.55	0.96	0.44	0.75	0.38	0.01
	Cath. Island (n = 5)	m	24.8	24.8	4.4	3.8	12.1	3.9	8.0	1.9^{b}	4.7^{b}	2.6	1.7	12.4	10.6	3.1
		SD	1.25	0.91	0.98	0.65	0.98	0.58	1.70	0.31	0.81	1.04	0.30	0.40	0.54	1.70
M^3	Opole (n = 3)	m	26.0	22.4	4.2	3.5	12.3	4.0	7.6	1.1	2.3^{a}	1.8	2.0*	11.7	12.0	2.7
		SD	2.45	0.85	0.31	0.43	1.51	0.58	1.28	0.56	0.43	0.90	-	0.90	2.10	0.74
	W/Unw. (n = 2)	m	29.5^{a}	24.3	3.6	3.1	13.8	4.8	9.0	1.8	3.8^{b}	2.2	-	15.7*	12.6	3.6
		SD	3.44	3.62	0.78	0.65	1.13	0.18	1.15	0.04	0.11	1.17	-	-	2.78	1.53
	Kruszwica (n = 2)	m	27.0	21.5	3.6	3.6	13.3	5.2	8.0	1.5	3.5	1.7	2.3	11.4	9.7	3.6
		SD	3.43	0.14	0.94	0.36	1.92	0.22	0.54	0.10	0.59	0.21	0.17	1.00	1.41	0.01
	Cath. Island (n = 5)	m	24.9^{b}	21.7	4.0	3.3	12.0	4.0	7.5	1.9	3.8^{b}	2.4	1.3	12.0	9.3	3.2
		SD	0.90	1.17	1.10	0.71	1.41	0.85	1.09	1.25	0.85	1.00	0.42	0.81	0.18	0.37

a, b-means in columns - marked with lowercase letters - differ statistically significantly for a given tooth, $P \leq 0.05$,

* - measurement outcome for one individual, m- mean, SD- standard deviation,

n- number of teeth, m- mean from measurements 1 and 2 included only young 8 and 9 year old specimens

Statistical studies conducted for the measurements of upper molar teeth also proved sparse statistically significant differences in the mean values of specific groups (Table 2). However, it was noticed that the dimension no. **8** turned out to be significantly differentiating for each molar tooth of the groups presented (Table 2).

Analysis of the M^1 showed a statistically significant difference of dimension **8** mean value between horses from Opole (3.3 ± 1.26) and animals from Wroclaw Cathedral Island (4.9 ± 0.65) (Table 2).

The results obtained for M^2 tooth in case of two measurements show a significant difference between the groups investigated (**7a**: between Opole (1.3 ± 0.35) and Wroclaw University (2.1 ± 0.42) and Wroclaw Cathedral Island (1.9 ± 0.31); **8**: between Opole (3.2 ± 0.35) and Wroclaw Cathedral Island (4.7 ± 0.81)) (Table 2).

Two dimensions of M^3 tooth were statistically significant: **1** (between Wroclaw University (29.5 ± 3.44) and Wroclaw Cathedral Island (24.9 ± 0.90)) (Table 2) and **8** (between Opole (2.3 ± 0.43) and Wroclaw University (3.8 ± 0.11) and Wroclaw Cathedral Island (3.8 ± 0.85)) (Table 2).

Student's *T*-Test: In the investigated groups numerous anatomical features of the upper cheek teeth were proved with the use of Student's *t*-test to be statistically nonsignificantly different (Tables 3 and 4).

Mean values of the analyzed premolar teeth attributes were statistically non-significantly different (Table 3). The mean values in six dimensions (3, 4, 6, 7, 10 and 12) of P^2 were comparable in both sexes (Table 3). Moreover, the analyzed tooth dimensions dominated in males over females according to six mean values (1: males (36.7 ± 2.09), females (35.4 ± 2.32); 2: males (24.1 ± 1.06), females (23.3 ± 2.46); 5: males (9.5 ± 1.58), females (8.9 ± 1.01); 8: males (5.3 ± 0.99), females (4.9 ± 0.33), 11: males (14.1 ± 2.55), females (12.9 ± 1.07); 13: males (2.7 ± 0.77), females (2.4 ± 0.43)) (Table 3). Two dental dimensions mean values were greater in females than in males (7a: males (1.6 ± 0.46), females (1.8 ± 0.39); 9: males (3.3 ± 0.96), females (3.8 ± 0.37)) (Table 3).

The analysis of P^3 had also proved close to a half parameters (5, 6, 7, 7a, 11 and 12) comparable in the mean values (Table 3). Also a dominance was noted of males over females according to six attributes (1: males (28.0 ± 0.84), females (27.7 ± 1.65); 2: males (26.8 ± 0.90), females (25.3 ± 3.38); 3: males (6.0 ± 1.41), females (5.2 ± 0.20); 4: males (5.9 ± 1.52), females (5.4 ± 0.28); 8: males (4.7 ± 1.16), females (4.3 ± 0.39); 10: males (5.1 ± 2.87), females (3.6 ± 0.97)) (Table 3). Two measurements of P^3 turned out to be on average higher in females (9: males (3.7 ± 0.82), females (4.8 ± 1.12); 13: males (3.4 ± 1.28), females (4.6 ± 0.48)) (Table 3).

The occlusal surface of P^4 showed nine attributes (1, 2, 4, 5, 6, 7a, 10, 11, 12) not differentiating the investigated groups (Table 3). Mean values of three P^4 dimensions in females exceeded their values in males (8: males (3.9 ± 1.36), females (4.4 ± 0.36); 9: males (3.6 ± 0.84), females (4.3 ± 0.16); 13: males (3.4 ± 1.11), females (4.8 ± 0.64)) (Table 3). Only two dimensions of P^4 were higher in males than in females (3: males (5.1 ± 0.80), females (4.5 ± 0.15); 7: males (8.2 ± 1.33), females (7.4 ± 0.80)) (Table 3).

The molar teeth were also characterized by low number of statistically significant features differentiating the studied groups (Table 4).

The occlusal surface of M^1 showed eight attributes (1, 5, 7, 7a, 8, 9, 11, 12) with comparable mean values (Table 4). Sexual dimorphism was stronger marked in six dimensions, in five cases with female predomination (2: male (25.3± 1.14), female (25.9 ± 1.14); 6: male (3.8 ± 0.49), female (4.1 ± 0.56); 10: male (2.0 ± 0.16), female (2.6 ± 0.42); 13: male (3.1 ± 1.07), female (4.0 ± 1.08)) and in only two in males (3: males (4.3 ± 0.54), females (3.2 ± 0.81); 4: males (4.0 ± 0.44), females (3.5 ± 0.28)) (Table 4).

The M^2 morphology presented seven attributes (1, 5, 6, 7a, 10, 11 and 12) with comparable mean values in the groups investigated (Table 4).

Mean values of four dimensions of M^2, similar to M^1, in females exceeded the values obtained in males, two of these dimensions were analogous for M^1 and M^2 (2: males (24.3 ± 0.75), females (24.8 ± 0.86); 7: males (7.5 ± 0.89), females (8.2 ± 2.25); 9: males (2.4 ± 1.02), females (3.0 ± 0.91); 13: males (3.1 ± 1.34), females (3.8 ± 0.94)) (Table 4). Again in males found was a lower number of parameters exceeding the values in females, this time for M^2, (3: males (4.4 ± 0.67), females (3.8 ± 1.09); 4: males (3.9 ± 0.52), females (3.3 ± 0.62); 8: males (4.6 ± 0.94), females (3.8 ± 0.44)) (Table 4).

The analysis of M^3 proved a statistically significant difference in the mean values of dimension no. 3 between males (4.3 ± 0.65) and females (3.2 ± 0.30) (Table 4). The lack of significant differences in the mean values between genders was found for seven dimensions (2, 4, 5, 7a, 8, 9, 13) (Table 4). It was also established that in four dimensions of M^3 males surpassed females (1: males (25.7 ± 2.60), females (25.1 ± 0.47); 10: males (2.1 ± 0.46),

Table 3: Measurements of upper premolars in early medieval horses, differentiated according to gender

Tooth	Sex		Measurements (mm) 1	2	3	4	5	6	7	7a	8	9	10	11	12	13
P2	♂ (n = 6)	m	36.7	24.1	5.8	3.7	9.5	2.7	7.4	1.6	5.3	3.3	2.5	14.1	13.7	2.7
		SD	2.09	1.06	1.27	1.99	1.58	0.96	0.77	0.46	0.99	0.96	1.29	2.55	0.79	0.77
	♀ (n = 3)	m	35.4	23.3	5.8	3.6	8.9	2.7	7.3	1.8	4.9	3.8	2.5	12.9	13.4	2.4
		SD	2.32	2.46	0.75	1.33	1.01	0.28	0.40	0.39	0.33	0.37	0.83	1.07	0.95	0.43
P3	♂ (n = 6)	m	28.0	26.8	6.0	5.9	10.9	4.1	7.9	1.8	4.7	3.7	5.1	13.7	12.0	3.4
		SD	0.84	0.90	1.41	1.52	1.63	1.19	0.82	0.47	1.16	0.82	2.87	0.77	0.66	1.28
	♀ (n = 3)	m	27.7	25.3	5.2	5.4	10.9	4.4	7.7	1.9	4.3	4.8	3.6	13.5	12.1	4.6
		SD	1.65	3.38	0.20	0.28	1.13	0.18	0.26	0.49	0.39	1.12	0.97	1.71	0.75	0.48
P4	♂ (n = 6)	m	27.0	26.1	5.1	5.1	11.4	4.4	8.2	2.2	3.9	3.6	3.8	12.8	11.5	3.4
		SD	1.42	0.86	0.80	0.39	2.15	1.68	1.33	0.93	1.36	0.84	1.11	0.63	0.80	1.11
	♀(n = 3)	m	27.1	26.6	4.5	5.1	11.0	4.5	7.4	2.0	4.4	4.3	3.7	13.0	11.0	4.8
		SD	1.47	1.28	0.15	0.64	1.18	0.34	0.80	0.34	0.36	0.16	1.34	1.32	0.57	0.64

♂- males, ♀- females, m- mean, SD- standard deviation, n- number of teeth, mean from measurements 1 and 2 includes only young 8 and 9 year old specimens

Table 4: Masurements of upper molars in early medieval horses, differentiated according to gender

Tooth	Sex		Measurements (mm) 1	2	3	4	5	6	7	7a	8	9	10	11	12	13
M1	♂ (n = 6)	m	24.6	25.3	4.3	4.0	11.3	3.8	7.5	1.9	4.3	2.6	2.0	11.9	10.3	3.1
		SD	0.81	1.14	0.54	0.44	1.66	0.49	0.92	0.44	1.32	1.13	0.16	0.66	0.48	1.07
	♀ (n = 3)	m	24.4	25.9	3.2	3.5	11.3	4.1	7.2	2.0	4.2	2.3	2.6	12.0	10.2	4.0
		SD	1.69	1.14	0.81	0.28	1.46	0.56	0.88	0.15	0.45	0.30	0.42	1.59	0.62	1.08
M2	♂ (n = 6)	m	24.5	24.3	4.4	3.9	12.5	4.6	7.5	1.7	4.6	2.4	2.0	11.7	10.4	3.1
		SD	1.17	0.75	0.67	0.52	1.43	0.90	0.89	0.45	0.94	1.02	0.44	0.61	0.46	1.34
	♀ (n = 3)	m	24.8	24.8	3.8	3.3	12.2	4.2	8.2	1.9	3.8	3.0	1.9	11.7	10.6	3.8
		SD	1.35	0.86	1.09	0.62	1.62	0.80	2.25	0.16	0.44	0.91	0.05	1.42	0.79	0.94
M3	♂ (n = 6)	m	25.7	21.6	4.3[a]	3.4	12.6	4.3	7.5	1.5	3.5	1.9	2.1	12.3	10.9	3.0
		SD	2.60	1.09	0.65	0.67	1.77	1.17	0.98	1.11	1.17	0.94	0.46	0.88	1.64	0.74
	♀ (n = 3)	m	25.1	22.0	3.2[b]	3.2	12.6	4.8	8.1	1.4	3.4	2.2	1.6	11.5	9.2	3.4
		SD	0.47	0.56	0.30	0.46	0.61	0.50	0.65	0.47	0.37	0.51	0.86	1.04	0.40	0.38

a, b-means in columns - marked with lowercase letters - differ statistically significantly for a given tooth, $P = 0.05$,

♂- males, ♀- females, m- mean, SD- standard deviation, n- number of teeth, mean from measurements 1 and 2 includes only young 8 and 9 year old specimens

females (1.6 ± 0.86); 11: males (12.3 ± 0.88), females (11.5 ± 1.04); 12: males (10.9 ± 1.64), females (9.2 ± 0.40)) (Table 4). In females only two dimensions of M^3 were higher than in males (6: males (4.3 ± 1.17), females (4.8 ± 0.50); 7: males (7.5 ± 0.98), females (8.1 ± 0.65)).

DISCUSSION

During archaeological excavations dental findings are usually well preserved, thus the detailed analysis of animal dentition is one of the most valuable sources of knowledge in archaeozoology [21].

An opinion exists the teeth of domestic animals are characterized with greater dimensions than in non-domesticated mammals ancestors and the length of cheek teeth row is used as an important indicator of domestication level [22]. The tooth row length is the basic indicator of domestication in dogs because the shortening process of dental rows is caused by dental abrasion. In dogs ancestors and modern wild-living Canidae the cheek teeth are settled much more loosely with larger interalveolar spaces [21,22]. According to Lasota-Moskalewska [21] also in the case of wild boar it is possible to infer i.a. on the basis of cheek dentition about their domestication and the attribute speaking of wild boar domestication is a shortened facial part of skull. It leads to smaller dimensions of teeth in domesticated form of boar-swine. Unfortunately, in case of horse there is a lack of morphological features enabling unambiguous differentiation between wild and domestic forms, as this species in its evolution did not show unidirectional changes in skeleton dimensions [12, 15, 21-23].

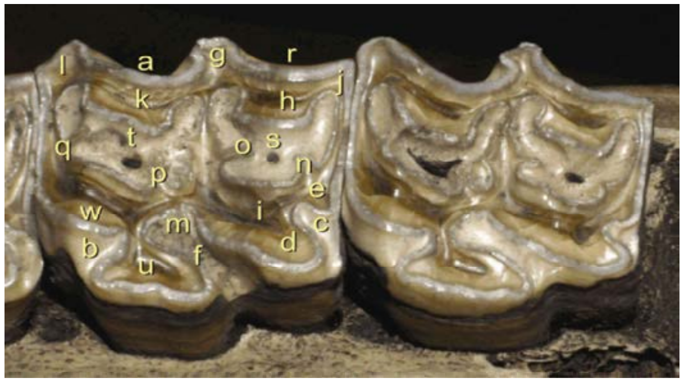

Fig. 1: Anatomical features of horse upper M1 cheek teeth crown description, occlusal surface
a: anterior interstylar face; b: front sinus (preprotoconal groove); c: hypoconal groove (posterior sinus); d: hypocone (hypocon); e: hypostyle; f: inner valley (postprotoconal valley); g: mesostyle (mesostyl); h: metacone (metacon); i: metaloph (metaconulus); j: metastyle (metastyl); k: paracone (paracon); l: parastyle (parastyl); m: pli caballin (plicaballin, plis caballine, pli-caballin, spora); n: pli hypostyle (pli-hypostyle); o: pli postfossette (pli-postfossette, plis postfossette); p: pli protoconule (pli-protoconule, plis protoconule); q: pli protoloph (pli-protoloph); r: posterior interstylar face; s: postfossette (posterior fossette, fossa lunata posterior); t: prefossette (anterior fossette, fossa lunata anterior); u: protocone (protocon); w: protoloph (protoconulus, protoconule, paraconulus).

Franck [24] introduced the basic division of horses into: eastern warm-blood (light) and western cold-blood (heavy) horses on the basis of cheek teeth studies, especially according to the upper dental arch. The investigated material proved higher tooth lengths than tooth widths among the premolars P^3 and P^4 (Tables 1 and 3). Simultaneously our results showed higher tooth width than tooth length in the 1st molar M^1 and comparable dimensions in the 2nd molar M^2 (Tables 2 and 4). Variable dimension relations, indicating the similarity to warm-blooded/cold-blooded horse breed type, can be caused by young animal age and non-uniform dental abrasion of the cheek teeth or lack of high-directional breeding.

Another important aspect of horse dentition studies is the morphology of cheek teeth enamel folds. In 1888 Wilckens stated that the enamel folds composition in cold-blooded horses is more complex than in warm-bloods [22]. The investigated material analysis proved non-complex enamel folds pattern (Figure 1), therefore it can be said that the cheek teeth remains originated from horses characterized as warm-bloods. Protocone of upper cheek teeth elongated during the phylogenetic development of horses [25]. The protocone in *Equus caballus* LINNAEUS, 1758 specimens, was better developed and longer in comparison with the mentioned anatomical detail observed in other representatives of typical Equidae species dated back to Pleistocene Europe, e.g.: *Equus stenonis* COCCHI, 1867 and *Equus hydruntinus* REGALIA, 1904 [12]. According to Forstén's [26] findings for Equidae the protocone length was correlated with the tooth length and both parameters are probably dependent on the total size of an animal, indirectly i.a. on its individual energetic requirements. In our investigations no unidirectional and more so no linear relationship between the protocone length and the tooth length was found. Possibly the reason for that was young age of the analyzed horses' dental artifacts, as well as non-uniform tooth wear level.

Sexual dimorphism in the analyzed horse teeth was poorly pronounced. Influence of the factor 'gender' on the surveyed groups turned out to be significantly differentiating only in case of the measurement 3, performed on M^3 teeth. Though demonstrated was not statistically significant prevalence of males over females, with regard to mean values of the conducted measurements of both premolars and molars, as detailed in the Results section.

Moreover, the odontological parameters of cheek teeth morphology of the analyzed horses (E.przew.f.cab.) correspond with the measurements in other early medieval horses, particularly coming from Polish archaeological sites Wolin and Kolobrzeg [22,27]. In comparison with modern primitive horse breeds such as Tarpan (E. gmelini, E.cab. gmelini) [8,15] or Polish Konik horses [28] and small Lithuanian horses [29], mean values of teeth of the studied horses are comparable, however lower than the values obtained for Przewalski's horse (E.przewalskii) [8,15] and early medieval horses (E.cab. from Hornhausen and E.cab. from Nesserdeich) [30] originating from other than Polish research centers (Figs. 3-5).

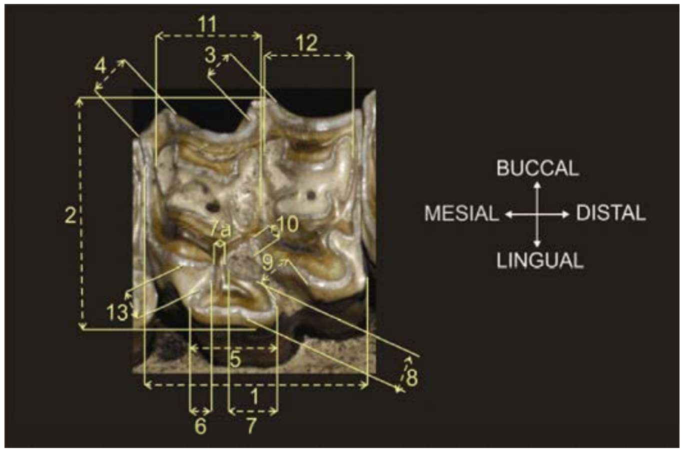

Fig. 2: Morphometric scheme of horse upper M1 cheek teeth dental crown, occlusal surface
1: tooth length (without cement); 2: tooth width (without cement); 3: mesostyle length (with enamel); 4: parastyle length (with enamel); 5: protocone length; 6: front protocone length; 7: posterior protocone; 7a: isthmus width (with enamel); 8: greatest width of posterior protocone; 9: width at the mouth of the inner valley; 10: spur length (with enamel); 11: prefossette length; 12: postfossette length; 13: greatest width at the mouth of the front sinus

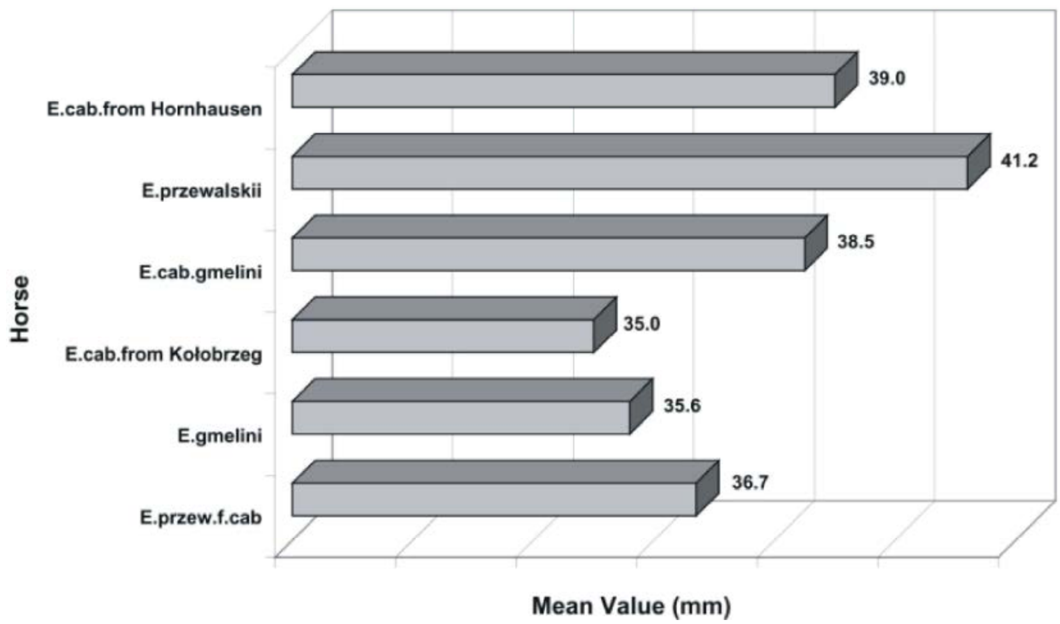

Fig. 3: Comparison of mean values of P^2 tooth's length in different horses
E. przew.f.cab. (males analyzed), E.gmelini Kuzmina [15], E.cab. from Kolobrzeg (early medieval male) Kubasiewicz and Gawlikowski [27], E.cab.gmelini Gromova [8], E.przewalskii Gromova [8], E.cab. from Hornhausen (early medieval) Nobis [30]

The results were corresponded with the results of other authors [22, 23, 27, 31] dealing with early medieval horses, as the outcomes acquired in this manuscript also prove the existence of horses with ununiform morphotype in the analyzed period. The investigated artifacts were coming from non-equal bred animals with different body size. Some of them were close to Tarpan and Polish Konik type, others according to odontological parameters to Przewalski horses, others to small Lithuanian horses, but majority of the investigated animals belonged to the range of dental features of other horses from early medieval sites in Poland.

Low level of complexicity of tooth infundibulum and enamel folds patterns in the analyzed cheek teeth artifacts prove its typical warm-blooded character and allow to qualify the investigated horses to the eastern group.

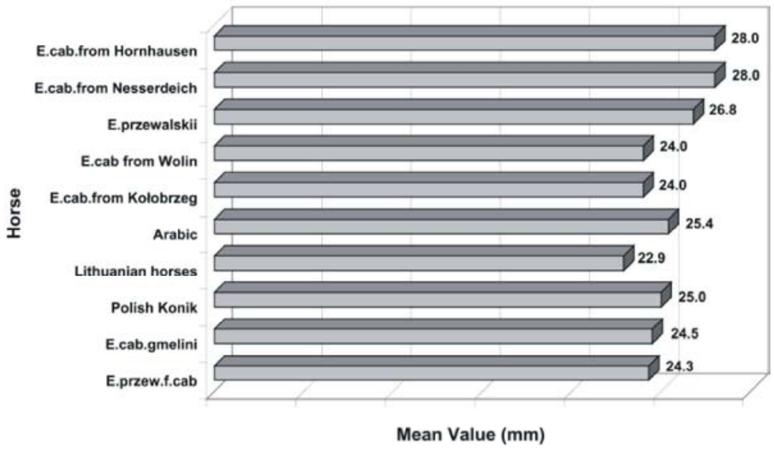

Fig. 4: Comparison of mean values of M^2 tooth's width in different horses
E.przew.f.cab.(males analyzed), E.cab.gmelini Gromova [8], Polish Konik Vetulani [28], Lithuanian horses Kwaschnin-Ssamarin [29], Arabic Kwaschnin-Ssamarin [29], E.cab. from Kolobrzeg (early medieval male) Kubasiewicz and Gawlikowski [22], E.cab. from Wolin (early medieval) Kubasiewicz [22], E.przewalskii Kuzmina [15], E.cab. from Nesserdeich Nobis [30], E.cab. from Hornhausen (early medieval) Nobis [30]

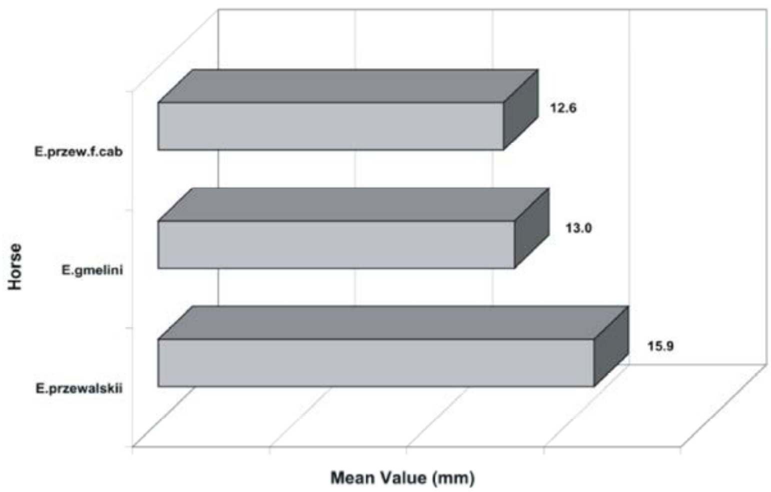

Fig. 5: Comparison of mean values of M^3 tooth's protocone length in different horses
E.przew.f.cab.(males, females analyzed), E.gmelini Kuzmina [15], E.przewalskii Gromova [8]

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