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TRACE ELEMENTS AND DENTAL MICROWEAR AS THE INDICATORS OF DIET STRATEGIES IN INDIVIDUALS FROM THE CEMETERY OF BOROVCE (8^{th}–12^{th} C. AD, PIEŠŤANY DISTRICT, SLOVAKIA)

ABSTRACT: The aim of the study was to determine the diet of the historical human population using trace elements in dental tissues and dental buccal microwear. Although 466 individuals had been buried in the cemetery, preservation of the remains did not allow analysis of all of them. 34 permanent premolars and one permanent molar from 35 individuals were analysed for trace elements. Dental microwear was studied in 26 permanent molars of the same individuals. Both trace-element and microwear analyses were performed on 26 individuals, of the remaining nine individuals' only trace elements were analysed. All analysed teeth were intact, with fully developed roots, without dental calculus and macro-abrasion. Concentrations of Sr, Zn, and Ca, and their ratios, were used to determine the relative proportions of plant and animal protein in the diet. Samples were analysed using optical emission spectrometry with inductively coupled plasma. The values of the Sr and Zn concentrations indicate that a diet of the examined population was of a mixed character. A higher intake of animal protein was detected in individuals of higher social status. Apparently, within the population there were individuals whose content of trace elements in dental tissue did not reflect the way of feeding, resp. social status, but was instead related to their health.
Buccal microwear was studied in molds of buccal surfaces and observed at 100× magnification with a scanning electron microscope (SEM). Length and orientation of striations were determined with the SigmaScan Pro 5.0 image analysis program. The results obtained from microwear analysis correspond with those from trace-element analysis and showed that the population consumed a mixed diet, which contained higher proportion of abrasive components. The way of feeding of this historical population could be similar to recent populations of hunters and gatherers, and the greater density and length of scratches may have been caused by other technology of food preparing.

KEY WORDS: Paleodiet – Strontium – Zinc – Buccal microwear – Middle Age

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INTRODUCTION

The cemetery of Borovce is located in western Slovakia about 10 km southwest of the famous spa town Piešťany (*Figure 1*). Archaeological research at the site began in 1985 and ran intermittently until 2009. On the site were excavated 440 graves with skeletal remains of 466 individuals (Domonkošová Tibenská *et al.* 2007). Cemetery is dated to the period from the end of 8th century AD until the mid of 12th century AD and it is interesting with the occurrence of niche graves. In the area of the middle Danube flow, burial in these types of graves was not discovered and also it is not typical for this area. Total of 99 niche graves of "podmol" type and one niche grave of "tunnel" type were found here. So far, it is not clear what kind of settlement was here and who was buried at this cemetery. The findings, which were found here, indicate that it was not an ordinary country settlement. According to burial furnishing, people who lived here belonged to elite and obviously this locality was a significant craft, trade and defensive centre (Staššíková-Štukovská 1996).

Considering that the set of skeletal remains is large, in addition to the basic anthropological analysis (Šefčáková *et al*. 2006), there were observed the markers of non-specific stress (Obertová, Thurzo 2004, Obertová 2005), diseases and pathological changes (Šefčáková *et al.* 2001, Staššíková-Štukovská *et al.* 2005, Bodoriková *et al.* 2006, Domonkošová Tibenská *et al.* 2007, Petrušová Chudá 2007, Dörnhöferová, Beňuš 2010), but also some unusual taphonomic aspects of some burials (Thurzo *et al.* 2000). Šefčáková and Krištín (2001a, 2001b) and Šefčáková (2003) performed a paleo-ecological study, in which they reconstructed a dietary habits of the individuals based on a wide range of trace elements in bone tissues.

The aim of the study was the reconstruction of dietary habits on the basis of trace-elements analysis in dental tissues supplemented with observation of dental buccal microwear changes. The results of our study will contribute to the expansion of existing knowledge about the way of life not only of the population of Borovce, but also about life conditions of medieval populations living in our territory.

The content of trace elements in bone and dental tissues provides an important information about the historical populations diet (Schutkowski 1995, Szostek *et al.* 2003, Szostek *et al.* 2009), whether the diet of plant origin or diet enriched with animal proteins predominate in specific population (Sandford 1992, Wolfsperger 1992). By examining a wide spectrum of elements it is possible to reconstruct dietary habits with respect to sex, social status, lifestyle and the way of obtaining the food of the social groups.

Strontium (Sr) is the most monitored trace element during the reconstruction of dietary habits. In skeletal material the concentration of Sr is in inverse proportion to an organism's position in the trophic pyramid, hence the higher the individual is in the food

FIGURE 1: The map of Slovakia with the cemeteries of Borovce and Gáň.

chain, the smaller amount of Sr bone and dental tissues contains. The highest concentration of Sr is in plants, because they absorb it directly from the environment, while mammals accumulate Sr indirectly by consumption of plants or other animals. Herbivores have higher Sr concentrations than carnivores, and omnivores (like humans) are intermediate between herbivores and carnivores (Sandford 1992, Larsen 1997, Szostek, Głąb 2001, Szostek *et al.* 2003, Sponheimer *et al.* 2005). The highest value of Sr is in herbivores (400–500 ppm), next is in omnivores (150–400 ppm), and the lowest is in carnivores (100–300 ppm; Lambert *et al.* 1984). It is known that the Sr content in hard tissues changes with the age of individuals. Newborns have low Sr concentrations in bones because of discrimination against Sr by the mother's placenta, and equally low during breastfeeding. Significant fluctuations in the Sr values occur during growth and transition from breastfeeding to solid food; therefore it is recommended to investigate mainly adults (Smrčka 2005).

Zinc (Zn) is a good indicator of protein diet. Zinc is presented in higher concentrations in a diet rich in animal protein. Comparing Sr and Zn values makes it possible to derive a proportion of animal diet components (Smrčka 2005). The lowest values of Zn are in herbivores (90–150 ppm), next in omnivores (120–220 ppm), and the highest in carnivores (175–250 ppm; Lambert *et al.* 1984). Sandford and Weaver (2000) proposed that the relationship between Zn concentration and mode of nutrition was disputable. However, they indicated a positive correlation between the amount of accumulated zinc and a protein diet. Similar conclusions were propounded by Smrčka (2005), Schutkowski *et al.* (1999) and Herrmann and Grupe (1988) who used Zn/Ca and Sr/Ca ratios for a differentiation of individuals into social groups.

Monitoring of dental microwear changes is used to predict the dietary habits of historical populations for several decades (Walker *et al.* 1978, Gordon 1982, Puech, Albertini 1984, Lalueza *et al.* 1996).

The microscopic defects on the enamel surfaces are classified into three categories: scratches, pits, and other surface defects (Gordon 1982). The number, length, and orientation of the microwear defects of a buccal dental surface have great informative value for the interpretation of nutritional preferences (Puech 1982, Puech, Albertini 1984). The formation of microwear damages is strongly influenced by the presence of abrasive particles in food, acidity and hardness of diet, force and also the direction of activity of the maxillo-mandibular apparatus (Walker *et al.* 1978, Gordon 1982, Teaford 1994). It has been proven that, in a population fed by mixed or meat food, there was a tendency to a low density of scratches and a higher proportion of vertical scratches while in agricultural populations, with a higher content of tassel and a higher ratio of abrasive elements (phytoliths) in food, horizontal scratches dominated and their density was higher (Lalueza *et al.* 1996). Phytoliths are micro-crystals of calcium oxalate (CaC_2O_4), silica (SiO_2), resp. carbonates, found in plant tissues. In the process of vegetable food mastication, the phytoliths are liberated from plant tissue and and teeth are exposed to their grinding effect (Danielson, Reinhard 1998). It is assumed that the occurrence of scratches presented in historical agricultural populations was also influenced by the grinding of seeds with a stone mill (Del Rincón 1998). Even contemporary populations from arid areas of a desert manifest with greater wear in consequence of the presence of abrasive sandy elements in diet (Smith 1984).

MATERIAL AND METHODS

The reconstruction of dietary habits was done on basis of trace-element concentrations in dental tissues and buccal microwear in the selected individuals. We analysed total of 35 permanent teeth from 35 individuals (*Table 1*). Only 26 individuals were suitable for monitoring of both indicators – trace-element and microwear. In a sample of remaining nine individuals, only trace elements were analyzed. Dental microwear could not be analysed because of damaged (broken) enamel on mesio-buccal molar cusp.

We selected 35 permanent teeth to trace-element analysis – 34 premolars and one molar (Appendix 1). We selected only teeth which were weakly fixed in the alveoli or could be easily removed from the alveoli in order to avoid destruction or damage of teeth. We analysed only intact teeth with fully developed roots, without dental caries, calculus, and macrowear. Before the trace-element analysis, each tooth was washed with distilled water and dried at room temperature. Chemical analyses were performed at Geological Institute, Faculty of Natural Sciences in Bratislava (Slovakia). The analyses were made by the optical emission spectrometry with inductively coupled plasma using an ICP OES Jobin Yvon 70 Plus (France). Exact analytical procedure is listed in Domonkošová Tibenská *et al.* (2010) and Bodoriková

TABLE 1: Numbers of examined individuals.

	Infans II 7–14	Juvenis 15–20	Adultus 20–40	Maturus 40–60	Total
Males	0	5	9	2	16
Females	0	4	10	4	18
Undetermined sex	1	0	0	0	1
Total	1	9	19	6	35

et al. (2013). The amounts of Ca (in %), Zn, and Sr (in mg/kg) were determined in samples of dental tissues.

Dental microwear was analysed on 26 permanent molars (Appendix 2). Microwear changes were observed on dental replicas. The teeth were cleaned with 96 % ethanol. Two steps were imposed in the preparation of the replicas. In the first step, negative dental casts were obtained by hydrophile vinylsiloxane-elite HD light body fast setting and putty soft normal setting easy mix (producer Zhermack, Italy). The positive moulds were made using epoxy resin (Epoxy 372, P 11 – producer Movychem, Slovakia) in the second phase. Finally, the tooth replicas were sputter-coated with a gold layer at the State Geological Institute of Dionýz Štúr in Bratislava (Slovakia). Prepared dental samples were observed with a SEM JXA-840A-Electron probe micro-analyser JEOL. Pictures were taken on the buccal surface of mesiobuccal cusp in middle thirds of the tooth. Pictures were digitalized as jpg format – 1000×800 pixels image. The following parameters were used for digitizing: ampere 3×10–9A to 6×10–9A, accelerating voltage 20 kV, 100× magnifications and working distance between 15 and 39 mm. The obtained SEM pictures were subsequently enhanced with the program ACDSee 7.0, and a 0.56 mm^2 enamel patch was cropped (resolution 648×648 pixels, 150 dpi) in all images for surface standardisation (Pérez-Pérez *et al.* 1994; *Figure 2*). Four categories of microwear scratches were differentiated using 45° orientation with the semi-automatic software SigmaScanPro 5.0: H – horizontal (0° to 22.5° and 157.5° to 180°), MD – mesio-distal (for the lower left and upper right teeth: 112.5 ° to 157.5°; for the lower right and upper left teeth: 22.5° to 67.5°), V – vertical (67.5° to 112.5°), and DM – disto-mesial (for the lower left and upper right teeth: 22.5° to 67.5°; for the lower right and upper left teeth: 112.5° to 157.5°).

Ten variables were analyzed 1) NH – number of H scratches; 2) NMD – number of MD scratches; 3) NV – number of V scratches; 4) NDM – number of DM scratches; 5) NT – total number of striations; 6) XH – average length of the H scratches; 7) XMD – average length of the MD scratches; 8) XV – average length of the V scratches; 9) XDM – average length of

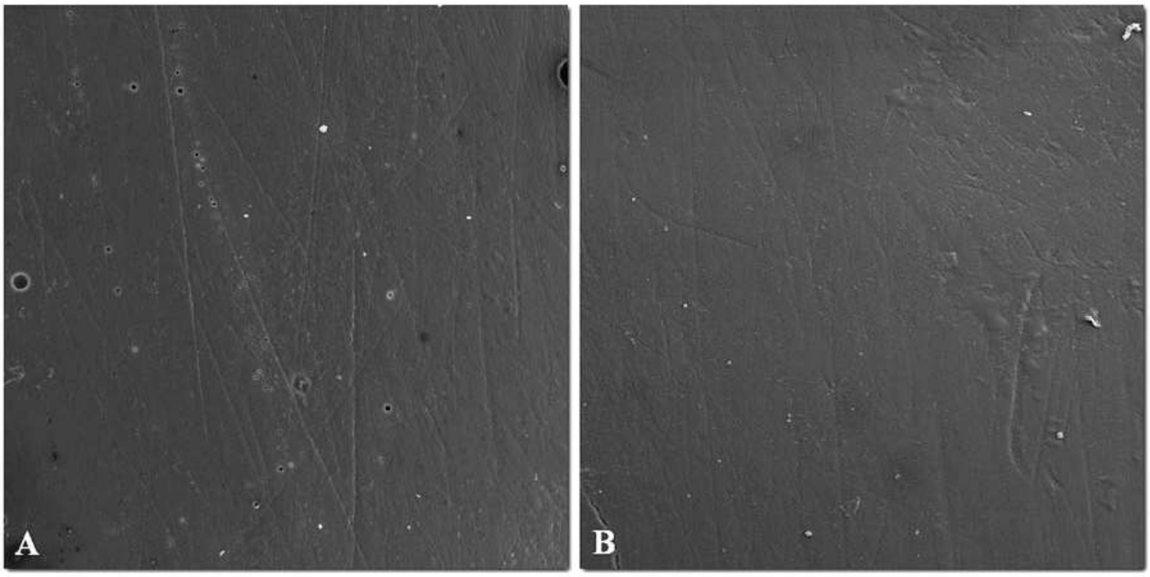

FIGURE 2: SEM images of selected individuals from Borovce. Each square enhanced with the program ACDSee 7.0, and surface analysed covers 0.56 mm^2 of buccal enamel surface. A) The grave 271 dated to the Arpadian period, adult female, upper second permanent molar. B) The grave 351 dated to the Pre-Great Moravian period, juvenile male, lower first permanent molar.

the DM scratches; 10) XT – average length of all scratches (modified method of Lalueza *et al.* 1996).

Statistical analyses were performed with R software (R Development Core Team 2012). All of the hypotheses were tested against two-sided alternatives on significance level α=0.05. For multiple comparisons, Benjamini-Yekutieli (BY) correction of significance level (Benjamini, Yekutieli 2001) was applied. Normality assumption hypothesis was tested by Kolmogorov-Smirnov goodness-of-fit test without BY correction (Venables, Ripley 2002), where all data met this assumption (p>0.05). To test sexual dimorphism, to compare non-adult and adult individuals, and individuals with and without burial furnishing and to compare diachronic differences we used two-independent sample Student t-tests with Welch approximation of degrees of freedom. The same test we used for testing the inter-population differences between individuals of cemetery Borovce and Gáň (Domonkošová Tibenská *et al.* 2010, Bodoriková *et al.* 2013). To test a dietary strategy based on buccal microwear and analysis of inter-population differences we used two-independent sample Student t-tests with Welch approximation of degrees of freedom and BY correction as well.

To emphasize the difference between trace-element analysis and microwear analysis, the latter is *meta-analysis* like comparison having only mean, standard deviations and sample sizes from 11 selected populations. In this setting, the comparison was performed based on the effect sizes (mean differences; see Bodoriková *et al.* 2013) with Borovce as a control population. Additionally to univariate analyses, multivariate analyses of (1) "density variables" (NH, NMD, NV, NDM, and NT) and (2) "length variables" (XH, XMD, XV, XDM, and XT) were carried out as well. The effect sizes standardized by its standard deviations were used to calculate Euclidean distance matrix among all 12 populations followed by multidimensional scaling to reduce dimensionality of the data. For visualisation purposes, the projection to two dimensions was used. Finally, minimum spanning tree method was applied to connect all the vertices representing 12 populations together where the sum of the distances between connected vertices (sum of the length of all branches) is minimal (Bodoriková *et al.* 2013).

RESULTS AND DISCUSSION

Trace-element analysis

The soil environment in Borovce is alkaline and dry, thus it fulfil the conditions for good preservation of skeletal remains. Since we had no samples of soil from the cemetery, we could not test whether there were any diagenetic changes in dental tissues. Šefčáková (2002) observed the contamination and preservation of bones based on proportion of calcium and phosphorus (Ca/P) in cortex and spongiosis of femurs from right and left sides. The average values of Ca/P ranged from 2.25±0.16 to 2.28±0.13. Comparing the ratio of well-preserved bones (2.21±0.09; Schutkowski *et al.* 1999) we can conclude that the skeletal material is perfectly preserved. Based on these facts, we suppose that there were no diagenetic changes in dental tissues of individuals from Borovce.

Table 2 shows the results of trace-element analysis. The average concentration of Sr (162.60 mg/kg) indicates that the population consumed a diet with mixed to animal food. The average concentration of Zn (128.74 mg/kg) indicates that the observed individuals consumed from plant to mixed food.

Within the observation of intragroup variability we investigated whether there were any intersexual differences, age differences and differences between individuals buried with burial furnishing (rich) and without burial furnishing (poor; *Table 3, Figure3*). We did not find any statistically significant differences between males and females, and between non-adults and adults. But observing the differences between individuals buried with and without burial furnishing, we found out a significantly higher concentrations of Zn and Zn/Ca in individuals from higher social classes. This indicates an increased intake of food with animal protein in individuals with higher social status. We also examined if there were any differences between individuals of different time periods. According to Staššíková-Štukovská (2005) there existed four-time

TABLE 2: Sum of element concentrations in dental tissues of examined individuals. Ca concentration in %, Sr and Zn in mg/kg; N – number of individuals; SD – standard deviation.

	Ca	Sr	Zn	Sr/Zn	Sr/Ca	Zn/Ca
N	35	35	35	35	35	35
Mean	31.64	162.60	128.47	1.28	5.14	4.07
SD	1.91	60.62	12.05	0.49	1.85	0.41
Median	31.86	169.70	127.40	1.29	5.37	4.07
Minimum	27.78	34.13	101.60	0.27	0.95	3.35
Maximum	35.80	409.60	151.30	3.22	12.58	5.15

periods of burial within the cemetery – pre-Great Moravian (8th century – the first third of the 9th century AD), Great Moravian (second period of 9th century – the first third of 10th century AD), post-Great Moravian to Arpadian (second third of the 10th century – the first third of 11th century AD) and Arpadian (11th century AD). From the Arpadian period we had sample of only three individuals, therefore they were excluded from testing and we tested differences only among individuals from pre-Great Moravian (eight individuals), Great Moravian (12 individuals) and post-Great Moravian (12 individuals). However, we did not detect any significant differences among these individuals. This indicates that the population diet during the period of 8th century to the first third of 11th century did not significantly change. Regarding the three mentioned individuals from Arpadian period we excluded from analysis, they were the skeletal remains of women who belonged to higher social status (according to their burial furnishing). The average concentration of Sr was relatively low (88.10±20.18 mg/kg). It corresponds to their social status, because it indicates consumption of food rich in animal protein. The average concentration of Zn was close to the average of the entire population (127.33±13.70 mg/kg). However, the sample is too small to deduce the general conclusions.

Generally, we can conclude that individuals from Borovce consumed a mixed diet. We found the increased intake of food with animal protein in individuals from higher social classes. Within the population there were individuals where the content of trace elements in dental tissues did not reflect the dietary habits, resp. social status, but was related to their health.

We compared the cemetery in Borovce with the cemetery in Gáň (Galanta district, Slovakia) dated to the 9th–10th century AD (*Figure 1*). Both cemeteries are located in western Slovakia and are distant from each other about 50 km. Based on similar climatic and soil

TABLE 3: Results of two-sample testing of the intra-population differences in mean trace-elements values – females v. males, non-adults v. adults, burial with v. without furnishing, and among individuals from different periods. * p<0.05; N – number of individuals. One individual of undetermined sex was excluded from testing of intersexual differences. The individuals from the Arpadian period were excluded from examination according to dating because of very small sample (N=3).

			Ca		Sr		Zn		Sr/Zn		Sr/Ca		Zn/Ca	
	Category	N	Mean	*p*-value	Mean	*p*-value	Mean	*p*-value	Mean	*p*-value	Mean	*p*-value	Mean	*p*-value
Sex	Females	18	31.36	0.352	159.76	0.746	128.44	0.966	1.25	0.738	5.08	0.833	4.10	0.584
	Males	16	32.00		167.01		128.26		1.31		5.23		4.02	
Age	Non-adults	25	31.34	0.105	153.48	0.291	127.85	0.660	1.21	0.354	4.91	0.386	4.09	0.593
	Adults	10	32.38		185.39		130.03		1.44		5.70		4.01	
Burial furnishing	Yes	22	31.25	0.102	152.09	0.260	131.90	0.039*	1.15	0.109	4.84	0.310	4.23	0.002*
	No	13	32.30		180.38		122.68		1.49		5.63		3.80	
Dating	Pre-Great Moravian period	8	31.51	0.537	168.09	0.356	130.72	0.786	1.30	0.453	5.35	0.433	4.16	0.858
	Great Moravian period	12	32.03		191.83		132.16		1.45		5.96		4.13	
	Pre-Great Moravian period	8	31.51	0.809	168.09	0.242	130.72	0.239	1.30	0.683	5.35	0.268	4.16	0.222
	Post-Great Moravian period	12	31.72		148.33		123.58		1.23		4.73		3.91	
	Great Moravian period	12	32.03	0.682	191.83	0.111	132.16	0.087	1.45	0.320	5.96	0.142	4.13	0.195
	Post-Great Moravian period	12	31.72		148.33		123.58		1.23		4.73		3.91	

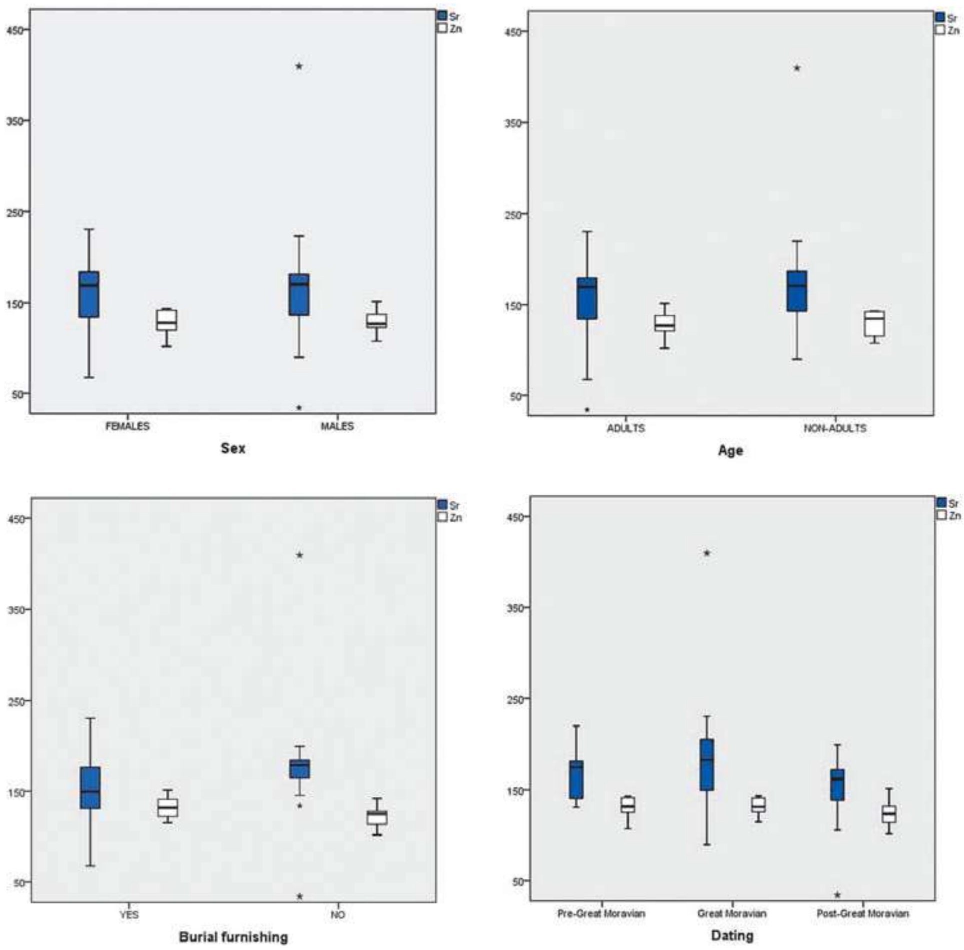

FIGURE 3: Boxplots showing the trace elements concentrations in males and females; non-adults and adults; individuals with and without burial furnishing; and individuals from the pre-Great Moravian, Great Moravian and post-Great Moravian periods.

conditions, we assumed that the dietary habits might be similar. Since we have known the dating of particular graves in Borovce, in the comparison we included only individuals from graves dated to Great Moravian and post-Great Moravian period (second third of 9^{th} century AD – the first third of 11^{th} century AD). Individuals from Borovce had statistically significant higher Sr concentrations and ratio Sr/Ca (*Table 4*). Other indicators did not statistically significantly differ. Results of the analysis indicate that both populations consumed a diet with approximately similar proportion of animal protein. Considering the proportion of the plant ingredients in food, individuals from Borovce likely consumed more plant food than individuals from Gáň. Both sites are located on the Danube Lowland, which is the most productive area of Slovakia, because it is covered with loess and alluviums. Both populations lived in similar locality so we can assume that the environmental conditions, in which they lived, were about the same. Considering the environmental condition in this area, the main source of livehood was agriculture. Archaeological research has shown that it was very intense since the Migration Period (5^{th}–6^{th} century AD). In the Early Middle Ages, the main and most important employment were grain growing and livestock breeding, mainly beef-cattle and pigs. Except for grain growing, people also grew fruit trees, gathered honey from wild bees, collected medicinal plants, fished and hunted wild animals (Beranová 2011). When comparing the populations, cemetery in Borovce consisted of 440 graves with remains of 466 individuals. They were buried there during five centuries. In

TABLE 4: Results of two sample testing of inter-population differences between populations from Borovce and Gáň in mean trace element values. *p<0.05; N – number of individuals. Borovce – the graves dated to the Great Moravian and post-Great Moravian periods; Gáň – the Early Medieval cemetery dated to 9th–10th century AD.

		Borovce	Gáň
	N	24	12
Ca	Mean	31.88	31.25
	p-value	0.610	
Sr	Mean	170.08	123.28
	p-value	0.010*	
Zn	Mean	127.87	128.80
	p-value	0.885	
Sr/Zn	Mean	1.34	1.03
	p-value	0.067	
Sr/Ca	Mean	5.34	3.92
	p-value	0.007*	
Zn/Ca	Mean	4.02	4.13
	p-value	0.600	

cemetery Gáň were only 38 graves. Borovce was an important trade centre, so it is possible that the agricultural production was more developed here than in Gáň. It is also possible that the dietary habits of populations from Borovce and Gáň were similar and found differences are caused only by a small number of analyzed individuals, resp. by selection of sample.

Buccal microwear analysis

Dietary habits were also reconstructed on the basis of dental buccal microwear. On 26 permanent molars of 26 individuals, the density (numbers) and the length of four types of scratches according the orientation were observed (*Table 5*). Overall, 3347 scratches were considered in the examined population. Vertical scratches (V scratches), numbering 1720 (51.39%), were the most frequent and a higher density was found in all examined individuals (on average, 66.15 V scratches per individual). The least frequent were horizontal (H) scratches; total number of them was 244 (7.29%). In four individuals was found only one H scratch.

TABLE 5: Descriptive characteristics of location and variability of a number (NH, NMD, NV, NDM, and NT) and a length (XH, XMD, XV, XDM, and XT) of microwear changes of (in μm) of 26 individuals from Borovce. N – number of microwear scratches; SD – standard deviation.

	N	Mean	SD	Median	Minimum	Maximum
NH	244	9,38	10.45	7.0	1	52
NMD	602	23,15	14.99	18.5	7	67
NV	1720	66,15	29.23	67.5	11	120
NDM	781	30,04	19.11	26.5	5	83
NT	3347	128,73	48.21	123.5	1	290
XH	244	206.08	102.36	182.43	38.98	428.30
XMD	602	163.27	86.54	141.46	29.01	334.86
XV	1720	207.13	114.51	177.23	30.95	435.77
XDM	781	178.29	94.79	160.08	3.96	394.27
XT	3347	192.02	104.51	167.04	3.96	428.30

Regarding the length of scratches, the average length of all scratches was 192.02 μm. V scratches (207.13 μm) were approximately the same length as H scratches (206.08 μm). The longest scratch had V orientation and length 435.77 μm. The shortest scratch had DM orientation and length 3.96 μm.

The method of dental buccal microwear in recent populations was developed on the basis of the research of Lalueza *et al.* (1996). Authors examined 10 recent populations – Inuits, Fuegians, Bushmen, Australian Aborigines, Andaman Islanders, Indians from Vancouver Island, Veddahs, Tasmanians, Lapps, and Hindus (*Table 6*). According to the dietary type and the ways of food obtaining, authors established four broad dietary categories from the original 10. First group is comprised of agriculturalists – Hindus; second group is comprised of hunter-gatherers from tropical forest environment fed on the mixed food – Andaman Islanders and Veddahs; third group: carnivorous hunter-gatherers and pastors – Fuegians (hunting and fishing), Inuit (hunting), Indians from Vancouver (hunting and fishing), and Lapps (reindeer herding); and the fourth group consists of hunter-gatherer populations from arid and mesothermal environments, including Bushmen, Australian Aborigines, and Tasmanians (Domonkošová Tibenská *et al.* 2010).

TABLE 6: Comparing populations, their diet strategy, locality, and the number of individuals (Lalueza *et al.* 1996). N – number of individuals.

Group	Population	Diet strategy	Locality	N	Identification
1	Hindus	agriculturalists tropic area	Bihar and Orissa, Central India	20	Hind
2	Andaman Islanders	hunter-gatherers tropic area	Andaman Islands, Gulf of Bengal	18	Andam
	Veddahs	hunter-gatherers tropic area	Sri Lanka	9	Ved
3	Fuegian Indians	hunter-gatherers carnivora	Tierra del Fuego, Argentina and Chile	20	Ind.Fe
	Inuit	hunter-gatherers carnivora	Greenland	20	Inuit
	Indians from Vancouver	hunter-gatherers carnivora	Island of Vancouver, Canada	17	Ind.Ve
	Lapps	nomadic pastors carnivora	Norway, Finland and Russia	5	Lap
4	Bushmen	hunter-gatherers arid area	Kalahari Desert, South Afrika	15	San
	Australian Aborigines	hunter-gatherers arid area	Central, north and south of Australia	18	Austral
	Tasmanians	hunter-gatherers arid area	Tasmania	11	Tas

In order to determine the dietary strategy, we compared population of Borovce with 10 recent populations with known way of food obtaining (Lalueza *et al.* 1996) and with population of Gáň (Bodoriková *et al.* 2013). Population of Borovce had statistically significant higher average number of all scratches than all modern populations with broad dietary strategy (*Table 7*). With the H scratches density they significantly differ only from four populations: Andaman Islanders, Veddahs, Sans, and Hindus. The greatest similarity in H scratches density was with population of Lapps (NH=5.2). Considering the length of all scratches, individuals of Borovce (XT=192.02 μm) did not statistically differ from any population. We found the greatest similarity with population of Hinds (XT=191.1 μm), Inuits (XT=193.3 μm), and Veddahs (XT=193.7 μm). Individuals of Borovce had significantly longer H scratches than Inuits and Australian Aborigines. The greatest similarity of H scratches length was observed with population of Veddahs

TABLE 7: Results of testing mean difference of buccal dental microwear density by orientation and length between Borovce cemetery (control population) and 11 selected populations. [1] Lalueza *et al.* 1996, [2] Bodoriková *et al.* 2013. * statistical significant differences.

Variable	Groups											
	Hind[1]		Andam[1]		Ved[1]		Ind.Fe[1]		Inuit[1]		Ind.Ve[1]	
	t-statistics	*p*-value	t-statistics	*p*-value	t-statistics	*p*-value	t-statistics	*p*-value	t-statistics	*p*-value	t-statistics	*p*-value
NH	5.937	0.0001*	4.286	0.0001*	3.373	0.0019*	2.257	0.0291	2.113	0.0403	2.312	0.0259
NMD	4.879	0.0001*	3.852	0.0004*	2.745	0.0097*	4.880	0.0001*	4.451	0.0001*	4.155	0.0002*
NV	7.824	0.0001*	5.702	0.0001*	4.107	0.0002*	7.315	0.0001*	7.305	0.0001*	6.286	0.0001*
NDM	5.791	0.0001*	2.518	0.0157*	2.056	0.0478	6.328	0.0001*	5.507	0.0001*	4.618	0.0001*
NT	6.282	0.0001*	4.462	0.0001*	3.192	0.0031*	5.628	0.0001*	7.826	0.0001*	7.164	0.0001*
XH	0.490	0.6263	2.609	0.0125	0.106	0.9165	1.550	0.1282	2.926	0.0054*	0.817	0.4184
XMD	0.606	0.5478	1.665	0.1034	0.487	0.6294	0.605	0.5485	1.144	0.2587	2.470	0.0178
XV	1.834	0.0734	1.358	0.1817	0.097	0.9232	1.443	0.1557	0.283	0.7783	1.895	0.0651
XDM	1.668	0.1025	1.426	0.1614	0.615	0.5429	1.716	0.0932	1.376	0.1759	1.211	0.2329
XT	0.036	0.9711	1.418	0.1635	0.046	0.9640	1.219	0.2293	0.052	0.9587	1.589	0.1197

Variable	Groups									
	Lap[1]		San[1]		Austral[1]		Tas[1]		Gáň[2]	
	t-statistics	*p*-value	t-statistics	*p*-value	t-statistics	*p*-value	t-statistics	*p*-value	t-statistics	*p*-value
NH	0.875	0.3889	3.376	0.0017*	1.397	0.1696	1.776	0.0845	3.359	0.0022*
NMD	2.341	0.0263*	2.647	0.0117*	2.871	0.0064*	2.483	0.0180	2.607	0.0136*
NV	3.756	0.0008*	6.006	0.0001*	6.006	0.0001*	4.185	0.0002*	2.801	0.0086*
NDM	3.069	0.0046*	3.334	0.0019*	3.222	0.0025*	2.148	0.0387	2.553	0.0164*
NT	4.238	0.0002*	4.705	0.0001*	5.388	0.0001*	3.529	0.0012*	4.826	0.0001*
XH	1.485	0.1484	2.070	0.0451	3.065	0.0038*	1.389	0.1737	2.400	0.0253
XMD	0.309	0.7595	0.083	0.9347	1.679	0.1005	1.062	0.2953	0.089	0.9289
XV	0.081	0.9361	0.084	0.9333	1.154	0.2549	0.429	0.6704	0.124	0.9011
XDM	1.334	0.1926	0.042	0.9666	1.270	0.2111	1.068	0.2929	1.687	0.0930
XT	0.748	0.4606	0.566	0.5748	1.581	0.1215	0.701	0.4877	18.893	0.8677

(XH=202.1 μm). Comparing the length of V scratches, the greatest similarity was observed with population of Lapps (XV=211.05 μm), Sans (XV=204.05 μm), and Veddahs (XV=211.0 μm). Comparing the scratch density, the population of Borovce was the most similar to Andaman Islanders and Veddahs, who belongs to the group of hunters and gatherers from tropical areas, where 80% of diet was formed with plant components. Regarding the length of scratches, the population of Borovce was the most similar to populations of Veddahs and Fuegians. Veddahs belong to the group of hunters and gatherers from tropical areas, and Fuegians belong to group of hunters and gatherers with predominant consumption of meat.

Comparing the population of Borovce with population of Gáň (N=9) we found that individuals of

Borovce had significantly higher number of all scratch types (*Table 7*). We did not found any significant differences in the scratch length. Both populations had the highest average values in V scratches category. The average length of V scratches in individuals of Borovce was almost the same as in individuals of Gáň (207.68 µm). Individuals of Gáň likely fed on mixed food, while the higher number of vertical scratches indicates higher proportion of meat ingredients in diet (Bodoriková *et al*. 2013). Since individuals of Borovce had significantly higher density of scratches we assume that their diet contained a greater number of abrasive elements (*Figure 4*).

We also observed intra-population variability and investigated if there are differences in density and length of the scratches between men and women, non-adults and adults and between individuals buried with or without burial furnishing. Intersexual and age differences were not found (*Table 8, Figures 5, 6)*. When comparing rich and poor graves, we found statistically significant differences only in the number of DM scratches. Therefore, we can conclude that within the population there were no significant intersexual, age and social differences in the way of feeding. When comparing groups with different dating, we found statistically significant differences in the number and length of the MD scratches between individuals from the pre-Great Moravian and Great Moravian periods, and in the number of V scratches, total scratches (NT) and the length of the MD scratches between individuals from Great Moravian and post-Great Moravian period (*Table 8, Figures 5, 6)*. The higher number of scratches, as well as their longer length, indicate a higher abrasiveness of consumed meals in individuals from the post-Great Moravian period. Higher abrasiveness could be related to the material used for the quern-stone production. The fragments of the quern-stones found in some grave in Borovce cemetery have not been analysed yet. We do not know what materials they were made of. In our territory, quern-stones dated to the post-Great Moravian period were made of hard rocks (rhyolite, andesite and quarzite) and soft rocks (e. g. schist) in equal measure. Soft rocks were preferred for their natural roughness and have not been roughened as often as the quern-stones made of hard rocks. On the other side, the favourable feature of hard rocks is their low grindability, which provided a low degree of contamination of flour (Valasekova 2015). Further analyses of millstones from Borovce will show what types of rocks were used in this locality. In general, the results of microwear analyses indicate that a diet of individuals was similar and did not change significantly over the few centuries.

According to density and length of the scratches we assume that population of Borovce fed with mixed

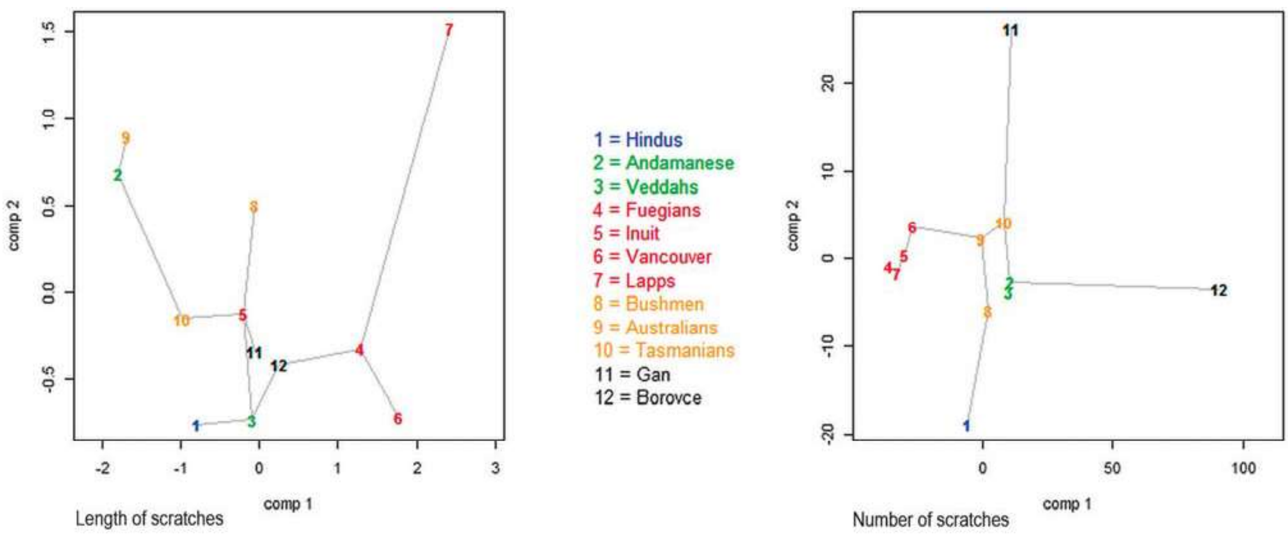

FIGURE 4: Results of multidimensional scaling method and minimum spanning tree of standardized effect size using first two components describing more than 90% of variability (left: length of microwear scratches, right: number (density) of microwear scratches).

TABLE 8: Results of two-sample testing of the intra-population differences in density and length of the scratches – females v. males, subadults v. adults, burial with v. without furnishing, and among individuals from different periods. N – number of individuals; p<0.05. The individuals from the Arpadian period were excluded from examination according to dating because of very small sample (N=2).

Variable	Category	N	NH Mean	NH p-value	NMD Mean	NMD p-value	NV Mean	NV p-value	NDM Mean	NDM p-value	NT Mean	NT p-value
Sex	Females	14	8.70	0.500	22.36	0.775	57.50	0.098	27.21	0.625	115.14	0.183
	Males	12	10.92		24.08		76.25		30.50		141.75	
Age	Non-adults	6	16.50	0.285	37.17	0.114	73.33	0.504	33.67	0.488	160.67	0.295
	Adults	20	7.25		18.95		64.00		27.25		117.45	
Burial furnishing	Yes	16	7.63	0.384	20.13	0.265	61.75	0.400	22.38	0.035*	111.88	0.085
	No	10	12.20		28.00		73.20		38.90		152.30	
Dating	Pre-Great Moravian period	5	18.60	0.295	43.20	0.046*	75.40	0.140	30.00	0.642	167.20	0.131
	Great Moravian period	8	7.38		18.38		47.75		24.75		98.25	
	Pre-Great Moravian period	5	18.60	0.234	43.20	0.059	75.40	0.989	30.00	0.886	167.20	0.395
	Post-Great Moravian period	11	6.00		18.82		75.64		31.55		132.00	
	Great Moravian period	8	7.38	0.640	18.38	0.921	47.75	0.042*	24.75	0.387	98.25	0.035*
	Post-Great Moravian period	11	6.00		18.82		75.64		31.55		132.00	

Variable	Category	N	XH Mean	XH p-value	XMD Mean	XMD p-value	XV Mean	XV p-value	XDM Mean	XDM p-value	XT Mean	XT p-value
Sex	Females	14	215.12	0.595	161.34	0.353	213.33	0.357	181.57	0.518	195.84	0.724
	Males	12	207.06		168.66		207.71		176.85		194.40	
Age	Non-adults	6	201.96	0.273	184.96	0.529	196.96	0.750	169.90	0.085	189.03	0.869
	Adults	20	218.03		153.02		214.93		182.72		197.66	
Burial furnishing	Yes	16	212.67	0.878	151.45	0.481	213.95	0.162	176.45	0.461	195.12	0.987
	No	10	210.35		180.27		205.46		181.83		195.19	
Dating	Pre-Great Moravian period	5	201.72	0.268	193.38	0.014*	206.97	0.941	174.39	0.711	194.12	0.786
	Great Moravian period	8	279.18		142.13		205.10		167.60		198.50	
	Pre-Great Moravian period	5	201.72	0.200	193.38	0.267	206.97	0.414	174.39	0.492	194.12	0.288
	Post-Great Moravian period	11	276.91		174.44		222.04		183.80		214.30	
	Great Moravian period	8	279.18	0.978	142.13	0.041*	205.10	0.477	167.60	0.410	198.50	0.483
	Post-Great Moravian period	11	276.91		174.44		222.04		183.80		214.30	

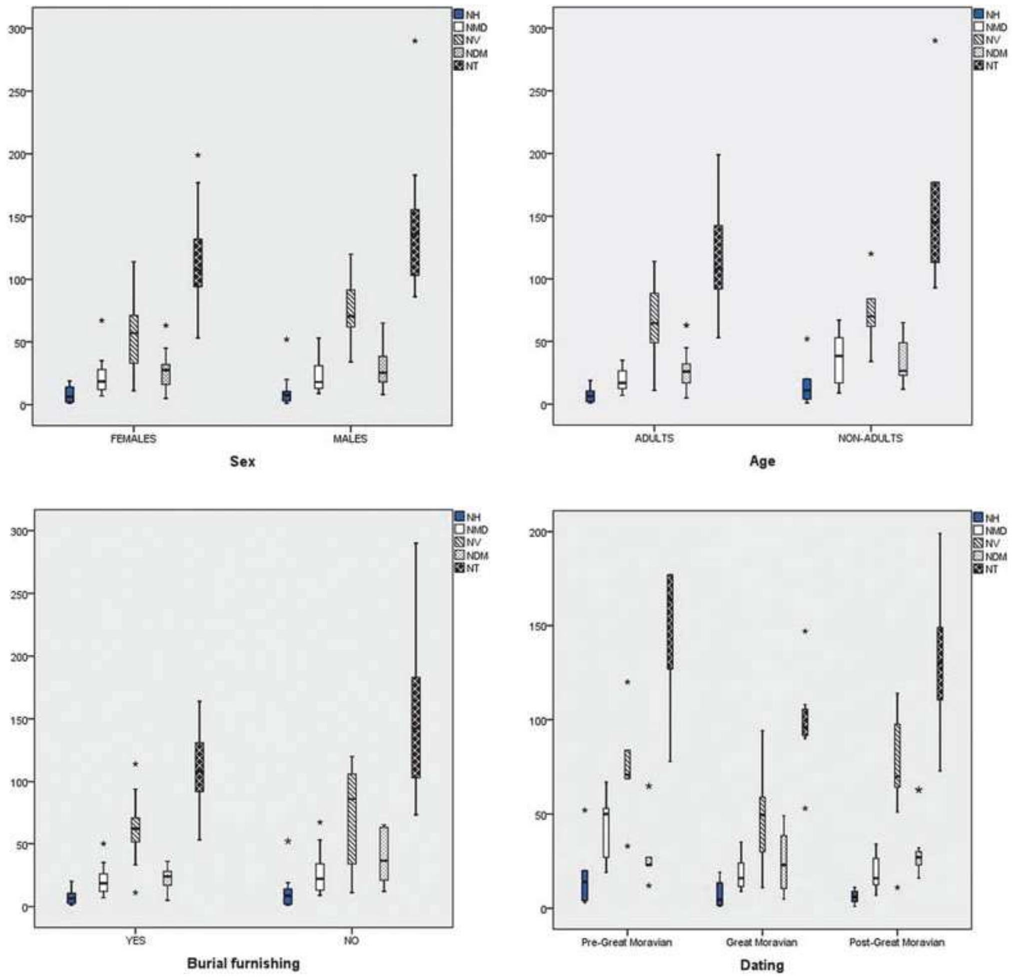

FIGURE 5: Boxplots showing the number (density) of microwear scratches in males and females; non-adults and adults; individuals with and without burial furnishing; and individuals from the pre-Great Moravian, Great Moravian and post-Great Moravian periods.

abrasive diet. According to Peréz-Peréz *et al.* (1994), the vertical scratches and low scratch density, are indicators of meat food, while horizontal scratches and their higher density dominate in agricultural populations with a higher ratio of plant food. The average scratch density in recent populations of hunters and gatherers that consume the meat and mixed food is between 32.0 and 74.8 scratches for the observed area (Lalueza *et al.* 1996). In medieval agricultural populations, the average number of 83.1 scratches was found (Pérez-Pérez *et al.* 1994). The average density of 128.7 scratches observed in the population of Borovce indicates that the diet consisted of a higher ratio of abrasive elements. The average length of scratches in recent hunters and gatherers varies from 152.0 µm to 235.2 µm (Lalueza *et al.* 1996), while the mean length in agricultural populations is 151.2 µm (Pérez-Pérez *et al.* 1994). The average length of all scratches in Borovce was 192.02 µm, which indicates that the diet of individuals contained a higher proportion of abrasive particles. Polo-Cerdá *et al.* (2007) analyzed the dietary habits of individuals from Chalcolithic and Old Bronze Age cemetery in Vall d´Uixó (Spain). In a studied population, as well as in individuals of Borovce, V scratches (39.8 %) dominated with the average length of 112.35 µm. Horizontal scratches were only 11.9 %. Authors conclude that scratch density in studied population indicates a higher abrasivity of diet than Pérez-Pérez *et al.* (2003) found in populations of recent hunters and gatherers. They suggest that a high density

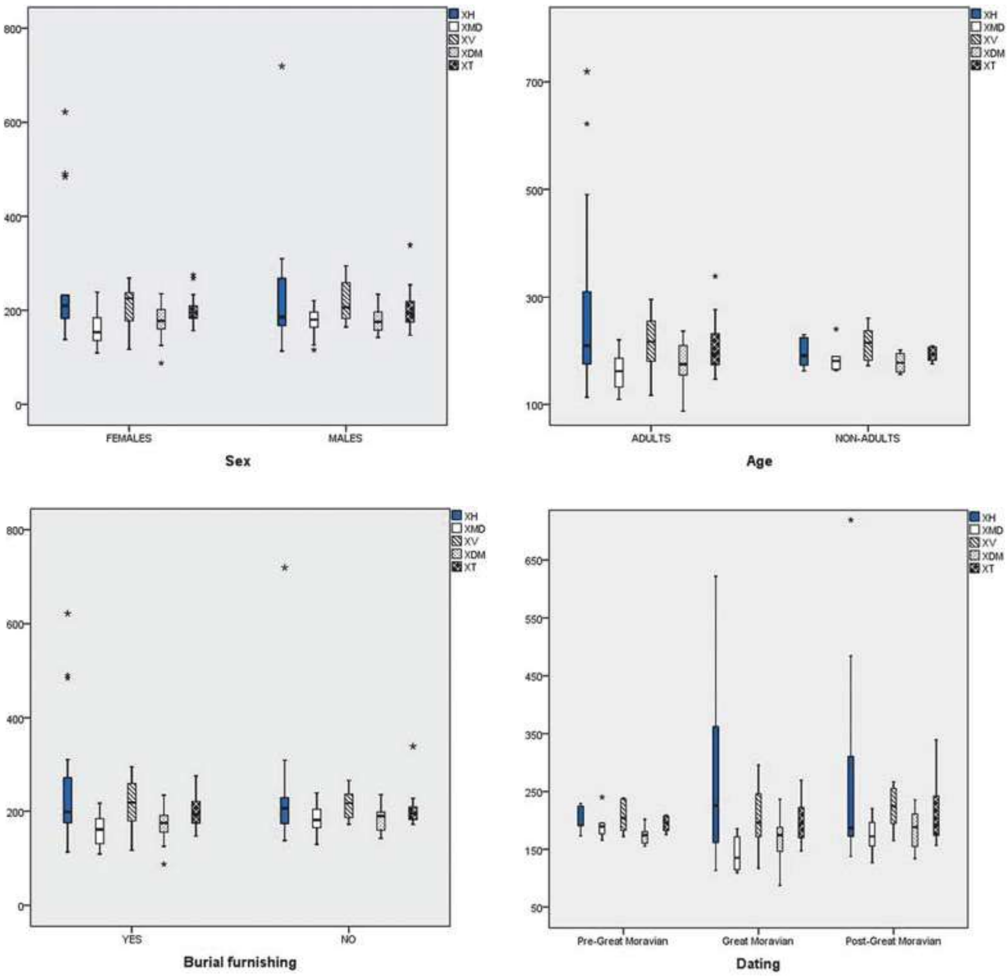

FIGURE 6: Boxplots showing the length (in μm) of microwear scratches in males and females; non-adults and adults; individuals with and without burial furnishing; and individuals from the pre-Great Moravian, Great Moravian and post-Great Moravian periods.

of microwear in historical populations may be more related to the way of food preparing than to the ratio of plant food in diet. That means that the way of feeding of historical populations could be similar to recent population of hunters and gatherers. Greater density and length of scratches is caused by different technology of food preparing. The Slavs are known to consume a variety of barley porridge, millet and other cereals, which had to be milled in a hand mills called millstones (Beranová 2011). Flour was rough milled and it contained particles of silicium, calcium and sandstone from abrasive stones. These particles were released during the milling process. Therefore, a diet of historical populations was more abrasive than a diet of recent populations.

Minimum and maximum values of trace elements concentrations and microwear changes in population of Borovce

In the examined population, we also paid attention to the individuals with minimum and maximum concentrations of trace elements and numbers of microwear changes. We attempted to determine whether the results correspond with each other and if there are some relationships among the observed results, gender, age, and social status of the individuals.

Regarding the trace elements, we focused on the minimum and maximum concentrations of Sr. In our previous studies (Domonkošová *et al.* 2010, Bodoriková *et al.* 2013) we found that the Sr content varied more than Zn. We found that the large variations in Sr content are related to the social status, respectively to health status of observed individuals. In study from Borovce, the Sr content also varied more than Zn.

The lowest concentration of Sr was found in a male aged of 20–30 years from grave 130. This man also had the highest Ca concentration (35.80 %). The Zn concentration was close to the average. We found several pathological changes on skeletal remains (evidence of *cribra orbitalia* and hypertrophy of parietal bones) and skeletal abnormalities (*spina bifida* and 6 lumbar vertebras; Petrušová Chudá 2007). However, we did not find any other pathological changes, so we could not determine the cause of death of the man. Considering the burial furnishing, the man belonged to the poor social class. The low Sr concentration indicates an increased intake of animal protein. So there is no relation between the low Sr concentration and social status in the case of this individual. Considering that he was a young male from the lower social class, we can assume that he worked manually and therefore he consumed a diet rich in animal protein. As regards the microwear changes, from total number of 120 scratches in this male, 68 were vertical oriented. Their average length was 203.08 µm. There were only 11 H scratches, average length was 186.59 µm. The prevalence of vertical scratches indicates a higher ratio of meat in diet, while the great length of scratches indicates the presence of abrasive elements. Therefore, the results indicate that this man consumed from mixed to animal diet, which correspond with the results of trace-element analysis. Therefore, it is possible that this young man, though according to burial furnishing he belonged to poorer social class, consumed a diet rich in animal proteins.

The highest Sr value (409.6 mg/kg) was found in a male aged 16–25 years from grave 62. According to burial furnishing he also belonged to poorer social class. There were no pathologic changes on skeletal remains. Very high Sr concentrations indicate that the man consumed a diet mainly of plant origin. As he was a young man, we would expect that he consumed rather a diet rich in animal protein, respectively a diet consisting of approximately the same proportion of plant and animal ingredients. Regards the microwear changes, from the total number of 93 scratches, 49 were disto-mesial, 34 were vertical and only one was horizontal. Orientation of the scratches indicates intake from mixed to meat diet. The average length of vertical scratches was 225.75 µm. That indicates the presence of abrasive elements in a diet. In this case the results of buccal microwear analysis do not correspond with the results of trace-element analysis. Considering he was a young man we assume that he consumed from mixed to meat food. Therefore, in this case we are not sure whether the high Sr concentration really indicates the consumption of mostly plant diet or this man suffered from a disease which resulted in increased absorption of Sr in gastrointestinal tract.

The lowest number of microwear changes was observed in a woman aged 50–60 years from grave 64, who belonged to a higher social class. No pathological changes were found in skeletal remains. From the total number of 53 scratches, 35 were mesio-distal, 11 were vertical, and only two scratches were horizontal. The length of scratches, especially in the horizontals, is interesting. The average length of all scratches was 234.89 µm, the average length of H scratches was 621.85 µm. Results of the analysis indicate that this woman consumed a diet that contained a lower proportion of abrasive ingredients. With regard to the trace elements, the concentration of both micro-elements was increased. Sr content was 230.3 mg/kg; Zn concentration was 140.5 mg/kg. The values indicate a high content of plant components and also higher content of animal proteins in the diet. Given the increasing age and social status of this woman, it is possible that she consumed mixed to meat food with a lower proportion of abrasive particles.

The highest number of microwear changes was recorded in a male from poor grave 351, who died at the age of 16–25 years. A hint of *cribra orbitalia* was observed in the skeletal remains. This young man had total number of 290 scratches with an average length 182.18 µm. Vertical scratches were the most frequent (n=120), horizontal scratches were the least frequent (n=52). The high number of microwear changes indicates that this man consumed food containing a high proportion of abrasive elements. With regard to the trace elements, the individual had the second lowest concentration of Zn in the examined population (107.1 mg/kg) and the relatively high content of Sr (186.9 mg/kg). The results of both analyses indicate that this male probably consumed mostly plant food with a very high proportion of abrasive particles.

CONCLUSIONS¨

The results obtained from trace-element and buccal dental microwear analyses indicate that population of Borovce probably consumed a mixed diet. The diet also contained a relatively high proportion of abrasive elements. Apparently, there were no differences between men and women in the way of feeding. However, significantly higher concentrations of Zn and Zn/Ca in individuals with higher social status indicate that these individuals had increased intake of animal proteins. Comparing the individuals from different periods showed that the way of feeding in the population had not significantly changed during several centuries. Archaeological research has shown that agriculture was the main source of livelihood. For most people in the Early Middle Ages, grain cultivation and production of domestic livestock, mainly cattle and pigs, were the main and the most important sources of food. In addition to grain cultivation, they grew fruit trees, gathered medicinal plants, fished and sometimes hunted wild animals. The way of feeding of historical populations could be similar as in recent populations of hunters and gatherers; however, a diet was more abrasive. That could be caused by different technology of food preparation.

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APPENDIX 1: List of individuals examined for trace elements.

Grave No.	Sex	Age	Dating	Burial furnishing	Tooth (FDI)	Ca (mg/kg)	Sr (mg/kg)	Zn (mg/kg)	Sr/Zn	Sr/Ca	Zn/Ca
14	Male	Juvenis	Pre-Great Moravian	Yes	35	33.70	137.9	143.1	0.96	4.09	4.25
49	Female	Adultus	Great Moravian	Yes	44	30.65	150.3	141.2	1.06	4.90	4.61
55	Female	Juvenis	Pre-Great Moravian	Yes	44	33.57	219.8	142.7	1.54	6.55	4.25
62	Male	Juvenis	Great Moravian	No	44	32.56	409.6	127.4	3.22	12.58	3.91
64	Female	Maturus	Great Moravian	Yes	44	31.13	230.3	140.5	1.64	7.40	4.51
83	Male	Adultus	Great Moravian	Yes	45	34.10	184.0	135.0	1.36	5.40	3.96
84	Female	Adultus	Great Moravian	Yes	34	31.06	188.1	126.4	1.49	6.06	4.07
107	Male	Adultus	Great Moravian	Yes	15	35.02	222.8	141.0	1.58	6.36	4.03
121	Female	Adultus	Post-Great Moravian	No	44	31.40	145.8	113.2	1.29	4.64	3.61
130	Male	Adultus	Post-Great Moravian	No	44	35.80	34.1	124.7	0.27	0.95	3.48
135	Female	Adultus	Post-Great Moravian	Yes	14	31.79	173.7	119.2	1.46	5.46	3.75
141	Male	Juvenis	Post-Great Moravian	Yes	34	32.99	143.7	135.7	1.06	4.36	4.11
145	Female	Adultus	Great Moravian	Yes	44	32.75	133.5	143.3	0.93	4.08	4.38
146	Male	Maturus	Post-Great Moravian	Yes	35	29.36	105.7	151.3	0.70	3.60	5.15
156	Male	Adultus	Great Moravian	No	34	32.56	179.0	125.1	1.43	5.50	3.84
164	Female	Adultus	Post-Great Moravian	Yes	34	30.03	159.1	128.1	1.24	5.30	4.27
188	Female	Adultus	Great Moravian	No	34	32.68	184.1	126.4	1.46	5.63	3.87
208a	Female	Juvenis	Great Moravian	No	44	33.01	182.0	142.4	1.28	5.51	4.31
210	Female	Juvenis	Post-Great Moravian	No	44	33.69	164.8	114.9	1.43	4.89	3.41
216	Male	Maturus	Post-Great Moravian	No	44	32.12	179.3	110.0	1.63	5.58	3.42
221	Male	Adultus	Pre-Great Moravian	Yes	45	28.06	176.6	130.4	1.35	6.29	4.65
251	Male	Adultus	Great Moravian	Yes	44	29.82	148.8	122.6	1.21	4.99	4.11
262	Female	Adultus	Post-Great Moravian	No	45	28.52	199.5	101.6	1.96	7.00	3.56
271	Female	Adultus	Arpadian	Yes	44	33.25	107.6	120.6	0.89	3.24	3.63
276	Male	Adultus	Post-Great Moravian	No	44	31.94	133.6	137.4	0.97	4.18	4.30
284	Female	Adultus	Arpadian	Yes	34	27.78	67.3	118.3	0.57	2.42	4.26
287	Female	Adultus	Arpadian	Yes	44	29.28	89.4	143.1	0.62	3.05	4.89
321	Female	Juvenis	Pre-Great Moravian	No	44	32.49	176.6	140.0	1.26	5.44	4.31
323b	Undetermined	Infans II	Pre-Great Moravian	Yes	44	30.78	143.1	132.4	1.08	4.65	4.30
351	Male	Juvenis	Pre-Great Moravian	No	44	31.97	186.9	107.1	1.75	5.85	3.35
378	Female	Adultus	Pre-Great Moravian	Yes	44	31.42	130.7	130.3	1.00	4.16	4.15
387	Female	Adultus	Pre-Great Moravian	Yes	34	30.06	173.1	119.8	1.44	5.76	3.99
388	Male	Juvenis	Great Moravian	Yes	44	29.05	89.5	114.6	0.78	3.08	3.94
434	Male	Adultus	Post-Great Moravian	Yes	44	31.86	171.0	122.1	1.40	5.37	3.83
436	Male	Adultus	Post-Great Moravian	No	36	31.14	169.7	124.7	1.36	5.45	4.00

APPENDIX 2: List of individuals examined for buccal microwear. NH – number of H scratches; NMD – number of MD scratches; NV – number of V scratches; NDM – number of DM scratches; NT – total number of striations; XH – average length of the H scratches; XMD – average length of the MD scratches; XV – average length of the V scratches; XDM – average length of the DM scratches; XT – average length of all scratches.

Grave no.	Sex	Age	Dating	Burial furnishing	Tooth (FDI)	NH	NMD	NV	NDM	NT	XH	XMD	XV	XDM	XT
14	Male	Juvenis	Pre-Great Moravian	Yes	47	20	50	71	23	164	172.96	165.54	182.62	180.19	175.33
49	Female	Adultus	Great Moravian	Yes	37	18	11	47	32	108	233.95	159.17	165.90	173.04	183.01
55	Female	Juvenis	Pre-Great Moravian	Yes	46	4	27	69	27	127	191.76	189.37	203.91	201.53	196.64
62	Male	Juvenis	Great Moravian	No	26	1	9	34	49	93	230.11	185.69	225.75	194.93	209.12
64	Female	Maturus	Great Moravian	Yes	47	2	35	11	5	53	621.85	113.27	116.91	87.56	234.90
83	Male	Adultus	Great Moravian	Yes	46	7	28	94	18	147	140.46	183.70	295.76	167.21	196.78
84	Female	Adultus	Great Moravian	Yes	46	9	20	52	13	94	182.83	109.22	209.42	125.27	156.69
107	Male	Adultus	Great Moravian	Yes	47	1	19	62	8	90	113.29	115.79	182.99	175.68	146.94
121	Female	Adultus	Post-Great Moravian	No	27	7	34	11	21	73	137.67	136.26	224.32	188.12	171.59
130	Male	Adultus	Post-Great Moravian	No	36	11	13	68	28	120	186.59	164.87	203.08	142.28	174.21
135	Female	Adultus	Post-Great Moravian	Yes	37	6	7	114	28	155	205.12	178.50	176.92	133.79	173.58
141	Male	Juvenis	Post-Great Moravian	Yes	37	8	17	62	26	113	162.30	163.23	260.85	175.37	190.44
145	Female	Adultus	Great Moravian	Yes	36	2	12	56	28	98	490.25	140.99	266.24	180.45	269.48
146	Male	Maturus	Post-Great Moravian	Yes	26	10	25	70	25	130	311.25	216.94	259.49	235.66	255.83
164	Female	Adultus	Post-Great Moravian	Yes	16	1	8	67	32	108	484.18	147.72	251.46	223.78	276.79
188	Female	Adultus	Great Moravian	No	47	19	13	26	45	103	220.69	129.24	177.81	236.70	191.11
216	Male	Maturus	Post-Great Moravian	No	37	1	13	106	63	183	719.28	204.23	209.78	224.05	339.33
262	Female	Adultus	Post-Great Moravian	No	27	2	28	106	63	199	171.05	172.02	238.56	190.88	193.13
271	Female	Adultus	Arpadian	Yes	17	11	14	71	36	132	177.08	135.77	227.73	221.25	190.46
276	Male	Adultus	Post-Great Moravian	No	37	10	16	89	27	142	173.59	188.16	267.05	159.83	197.16
284	Female	Adultus	Arpadian	Yes	36	15	18	58	16	107	214.12	184.34	270.13	161.48	207.52
321	Female	Juvenis	Pre-Great Moravian	No	36	14	67	84	12	177	190.45	240.37	237.40	160.36	207.14
351	Male	Juvenis	Pre-Great Moravian	No	46	52	53	120	65	290	224.39	176.67	171.92	155.73	182.18
387	Female	Adultus	Pre-Great Moravian	Yes	36	3	19	33	23	78	229.04	194.94	239.00	174.16	209.29
434	Male	Adultus	Post-Great Moravian	Yes	26	5	12	51	18	86	185.15	126.38	164.40	149.80	156.43
436	Male	Adultus	Post-Great Moravian	No	47	5	34	88	16	143	309.81	220.57	186.57	198.22	228.79

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