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DENTAL MICROWEAR SIGNATURES OF AN EARLY LBK POPULATION FROM VEDROVICE, MORAVIA, THE CZECH REPUBLIC

ABSTRACT: Deciphering the dietary habits of past people is fundamental to understanding their subsistence economy and their way of life. Gaining information on diets of the past can be achieved in several ways. In this study, the dental microwear signatures from twenty-two individuals from the early LBK site of Vedrovice, the Czech Republic, was examined to infer the diet regime for each individual as well as for the population as a whole.

The microwear pattern suggests a diet that required a fair amount of compression forces: the population had a high proportion of pit features which were fairly large in size, and the striation features were on average wide but fairly short. There was also evidence of a fair amount of shearing forces: the high standard deviation for striation lengths suggests an inclusion of tough and resilient food sources in the daily diet that required much grinding. No significant differences in the dental microwear pattern were detected between the sexes, although females tended to have more features on average that were of smaller dimensions. This suggests that there were only minimal differences in the diet of males and females.

The dental microwear signatures of the population reflect a highly heterogeneous diet showing similarities to both hunter-gatherer societies and early settled populations showing an increasing reliance on domesticated plants and animal species. Based on the dental microwear signatures, it is very likely that the people of the early LBK site of Vedrovice had not yet fully embraced agriculture and reliance on domesticated species.

KEY WORDS: Human dental microwear – Diet – Neolithic

INTRODUCTION

Interest in deciphering the diet of past human populations has a long history. This pertains especially to detecting when there is a transition from one economy to another. A special focus has been on the transition from a reliance of wild food resources through hunting, fishing, and gathering to a settled agricultural economy where domesticated plants and animals predominate. Inference of past diets can be gained through the discovery of direct evidence of food items, including containers and tools used for food preparation or storage found at settlement sites. However, botanical and animal remains can only give a picture of potential diet (Jones 2000, Meadow 1989, O'Connor 1997) and such remains do not give an indication of individual variability in diet or access to food resources. The presence of dental calculus on teeth is considered to reflect a protein-rich diet (Dobney, Brothwell 1986), while caries reflect a diet high in carbohydrates (Larsen *et al*. 1991, Lukacs 1992, Temple, Larsen 2007). Coprolites can give good clues as to what was actually consumed but are rarely recovered (Poinar *et al*. 2001). Indirect methods such as examining stable isotope signatures in bone, hair or teeth (e.g. Bocherens *et al*. 2007, Macko *et al*. 1999, Robinson 2000, Schulting *et al*. 2008, Thompson *et al*. 2008) provide evidence of what was actually consumed by individuals. However, with this technique it is only possible to determine what the individual's diet may have been over an extended

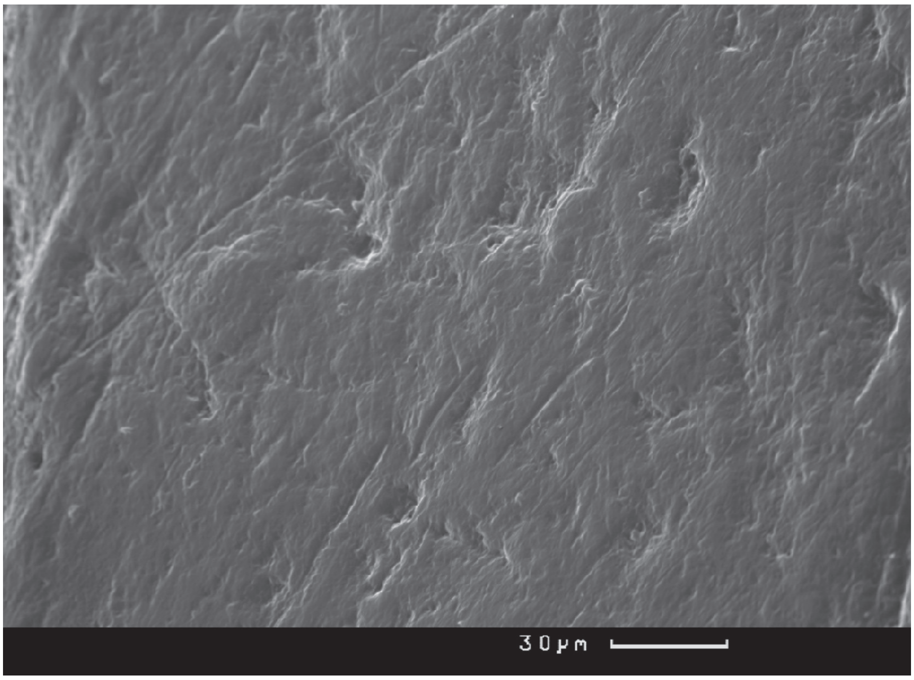

FIGURE 1. Image of facet 9 from Vedrovice 43/77 mandibular second right molar. SEM taken at 500× magnification.

period of time, in the range of the last 10 to 20 years of life (Richards *et al.* 2008). Hair and nails may provide a more limited time frame but such materials are only rarely recovered. Dental macrowear (Chamberlain, Witkin 2002, Kaifu 1999, Smith 1984) and evidence of wear or residues on tools (Clemente, Gibaja 1998, Kealhofer *et al*. 1999) may provide alternative indirect evidence of diet. Dental microwear is the only technique that can give a signature of what the individual consumed over the last few weeks prior to death, although buccal wear signatures reflect a longer time frame (Jarošová 2008). However, occlusal dental microwear is ephemeral, and the turn-over rate is in the range of just a few weeks (Teaford 1994, Teaford, Oyen 1989), and has therefore been referred to as the "last supper effect" (Grine 1986).

Ideally, all the above mentioned methods should be applied when studying the food economy of past populations. By using a holistic approach it is more likely that a realistic reconstruction of individual diets will be achieved. Such an approach is what we are presenting with the Vedrovice Project. In the present study, the dental microwear signatures of the early LKB population from Vedrovice are examined, with the aim to infer diet, and any significant differences between males and females, or different age groups.

Dental Microwear

During mastication, microscopic damage occurs to the occlusal enamel surface of the molar teeth, which is referred to as dental microwear. This damage usually falls into one of two categories, either round to oval pit features or narrow, elongated striations (*Figure 1*). Since enamel is the hardest material within the body, only objects as hard as or harder than enamel can cause dental microwear. There are a few food items which are sufficiently hard to cause damage to the teeth. Phytoliths, silica bodies present in many plant species, have a hardness that may exceed that of enamel (Danielson, Reinhard 1998, Lucas, Teaford 1995, Piperno 1988, but see Sanson *et al*. 2006). Silica can also enter the mouth from extra dietary sources. It may be present within the soil, and by adhering to poorly cleaned food can be inadvertently ingested (Ungar *et al.* 1995). Silica can also be a contaminant from stone tools used to prepare food, e.g. grinding cereals on a stone quern (Teaford, Lytle 1996). A third possibility is that irregularities on the enamel surface can scratch the opposing surface during mastication (Gordon 1982, 1988, Teaford, Runestad 1992, Teaford, Walker 1984, Walker 1984).

By what processes microwear is formed is still not completely understood. It has been suggested that the frequency and size of the microscopic damage are correlated with the degree of compression and shear the molar teeth are exposed to during the mastication process (Gordon 1982, 1988, Lucas 2004). Hard and brittle foods require high compression during mastication, and result in a higher frequency of pits on the enamel surface. The harder the food consumed, i.e. the more compression required, the larger the pits. Resilient and tough foods, in contrast, require more shear and grinding during mastication. Shearing of food usually results in a higher frequency of striations. The length of the striations is influenced by the level of shear, while the width is influenced by the amount of compression taking place at the same time (Maas 1991). Experimental studies have suggested that pit size is predictably related to the size of particles causing microwear. This is less clear for striation widths because enamel microstructure has a significant influence on this dimension (Maas 1991).

Primate Models

We model our understanding of how dental microwear mirror diet based mainly on studies from extant non-human primates (Daegling, Grine 1999, Nystrom *et al*. 2004, Rose, Ungar 1998 and references therein, Teaford 1994, Teaford, Glander 1991, 1996, Teaford, Robinson 1989, Teaford, Runestad 1992, Teaford *et al*. 1996, Ungar 1994). From studies on living primates with known diets (it is preferable that the food consumed hours or days prior to sampling should be recorded to avoid factors such as seasonal variations) it has been possible to correlate the incidence of features of different size and shape with broad dietary habits. Mastication of leaves generates a preponderance of striations, and the few pits produced tend to be small in size. Fruit-eating produces characteristically many pits and few striations. The mean pit size tends to increase in proportion to the hardness of the food, with the largest pits seen in animals that habitually eat fruits with hard seeds or are seed feeding specialists (Teaford 1988, Teaford *et al*. 1996, Teaford, Walker 1984). Softer (usually riper) fruits generate fewer microwear features, with a high percentage of small pits (Teaford, Oyen 1989, Teaford, Runestad 1992), a pattern also seen in obligate faunivores (Strait 1993). Such pits may be formed not by interaction with the food itself, but by forces developed during shearing tooth-on-tooth contact that cause "plucking" of enamel prisms, which are ground against opposing occlusal surfaces (Gordon 1982, 1988, Teaford, Runestad 1992, Teaford, Walker 1984, Walker 1984).

Previous Studies on Human Dental Microwear

Even though much research has been conducted on nonhuman primates to serve as inferential models, less is known about the dental microwear patterns of prehistoric and historic human populations. This is in part because it is more difficult to characterise or correlate specific microwear signatures to specific food items due to the highly varied human diet (Teaford 2008). There are all too few studies on human populations with known diets, in part because the diet of most extant human populations are so highly refined, and thus not a good model for the diet of past human populations.

Over the last decade or so, microscopic wear on dental enamel has been used as indirect evidence of diet, and most research on human diet adaptation based on dental microwear has focussed on the occlusal molar wear pattern (e.g. Gambarotta 1995, Hojo 1989, Mahoney 2006a, 2006b, 2007, Molleson *et al*. 1993, Nystrom, Cox 2002, Pastor 1992, 1993, Schmidt 2001, Teaford *et al*. 2001, Ungar, Spencer 1999) since the anterior teeth may be used for non-dietary purposes (Bax, Ungar 1999, Larsen 1997, Molnar 1972). However, it is also possible to distinguish between populations that include a large portion of meat in their diet to those that eat mainly a vegetarian diet by examining the striation pattern on the buccal side of teeth (Fine, Craig 1981, Jarošová 2008, Lalueza *et al*. 1996, Pérez-Pérez *et al*. 1994, 2003).

Most studies have focussed on the differences in microwear patterns of human populations in transition from a hunting, fishing and gathering to agriculturally based economy (in the United States – Schmidt 2001, Teaford 1991, Teaford *et al*. 2001, Ungar, Spencer 1999, the Levant – Mahoney 2002, 2006a, 2006b, 2007, Molleson *et al*. 1993, the Indian subcontinent – Pastor 1992, 1993, Europe – McLaughlin 2007, Nystrom, Cox 2002). All studies show a general trend of progressive dietary change: the microwear pattern in hunter-gatherer populations reflects a hard-object diet with many abrasive inclusions, typical of a population consuming mainly uncooked wild grains, cereals, fruits, roots, tubers, and roasted or dried meats. Such a diet results in a high frequency of pits, especially large pits, wider striations (Schmidt 2001, Teaford 1991) and increase in feature density (Hojo 1989, Molleson *et al*. 1993, Puech *et al*. 1983, Teaford, Lytle 1996). Agricultural societies have a softer diet, due to the introduction of pottery vessels for cooking, and show a microwear pattern with fewer and smaller pits. However, some early agricultural populations from the Levant show microwear patterns suggesting a hard and abrasive diet, and it has been suggested that this pattern is due to the reliance on large grained cereals (Mahoney 2002, 2005, Molleson *et al*. 1993). However, it is not only food items that contribute to tooth wear, differences in food processing techniques can also have a significant impact. Teaford and Lytle (1996) found significant differences in rates of tooth wear between populations consuming maize ground on igneous rocks (less wear) and maize ground on sandstone rocks (increased wear). Thus, depending on food preparation methods, more abrasives may be included in the diet, which may make the dental microwear signatures less distinguishable from those of pre-agricultural populations (Molleson *et al*. 1993, Teaford, Lytle 1996).

MATERIAL AND METHODS

The Vedrovice assemblage available for study comprised 85 skeletons (26 male, 36 female, 2 adult, and 21 immature individuals) with teeth present. Of these, 35 had second molars (either maxillary or mandibular) suitable for the preparation of negative casts. Only individuals with the second molars in full occlusion, and showing wear facets, were considered for this project. To control for potential variation in dental microwear, only second molars were considered and on these only facet 9 – a phase II crushing-grinding facet (Kay 1977), were used for this study (Gordon 1988, Teaford 1988). To the naked eye the enamel of most teeth appeared well preserved. However, under low magnification microscopy it was apparent that a large proportion of the teeth displayed highly degraded enamel surfaces, with only isolated areas of well preserved enamel present *(Figure 2)*. Quite a few teeth showed an etched appearance as if exposed to a highly acidic environment, the cause of which remains unresolved. In the end, only 22 individuals (9 males, 11 females, and 2 adolescents,

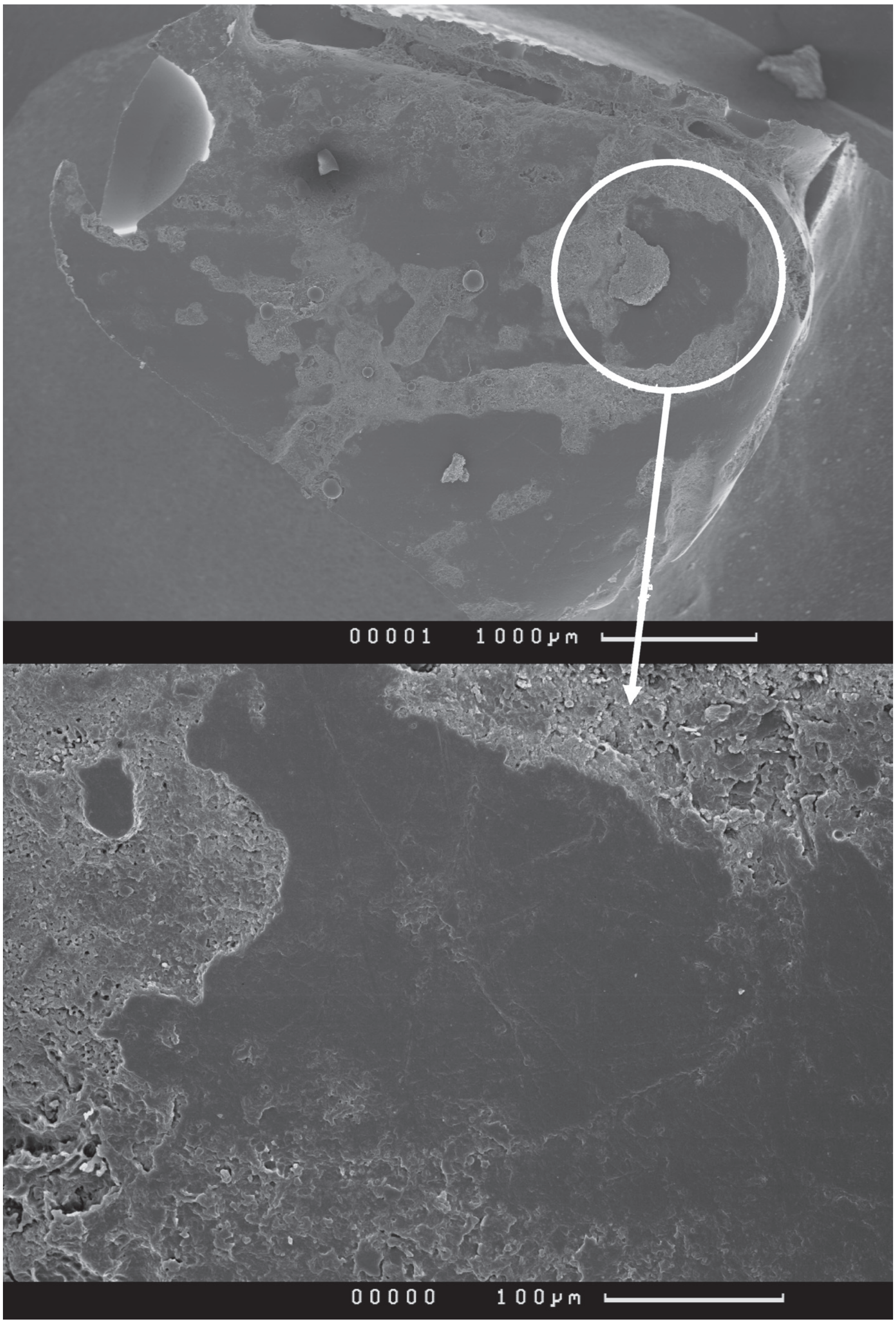

FIGURE 2. SEM image of the Vedrovice 42/77 maxillary second left molar is shown revealing the frequent eroded enamel present on the occlusal surface. Well preserved enamel appears darker in these images. Top figure shows facet 9 at a magnification of 20×. The bottom of the facet is visible in the top right. The lower figure shows the bottom of facet 9 at a magnification of 200×.

Table 1) resulted in high quality SEM images (as shown in *Figure 1*). This is a success rate of close to 26% which is not out of the ordinary for archaeological or fossil teeth (Grine *et al*. 2006, Teaford 2008).

Preparation of Positive Casts

Once it was established that the enamel of the molar teeth was in good condition, the teeth were carefully cleaned with pure ethanol using a cotton swab to remove dust and grime which may be present on the tooth surface. The teeth were allowed to air dry. Negative casts were prepared using a silicone based impression material (Coltène; President Jet, light body®) which were applied onto the occlusal surface of the tooth. Three negatives were made. The first two were used to remove any lingering dirt present on the enamel and were discarded. Only the third negative was used for making positive replicas. The negatives were allowed to degas for at least 48 hours before they were used to make positive replicas.

From the negative casts, facet 9 was excised using a scalpel blade. Each negative of facet 9 was placed on a flat base of putty (Coltène; President Putty®), and a shallow rim of putty was built up around the negative. Positive replicas were made using an araldite mixture (Araldite MY 753, hardener HY 956, Ciba-Geigy). The prepared chambers were filled to the rim with the araldite mixture (araldite and hardener were mixed 5:1), and allowed to cure for at least 48 hours.

TABLE 1. List of individual values from dental microwear analysis of the Vedrovice sample. Values reflect mean and SD, and measurements are expressed in microns (μm).

ID number	Sex	Age	Feature density	% pits	Pit width	Pit length	Striation width	Striation length
19/75	M	25–30	121	52.1	2.15±0.80	4.28±2.36	1.69±0.56	18.20±12.18
23/75	M	18–20	95	39.0	1.82±0.49	4.06±1.77	1.56±0.51	20.13±14.18
29/76	F	18–20	129	30.2	2.25±0.90	4.92±2.40	1.49± 0.61	19.82±18.40
42/77	F?	20–30	115	54.8	2.34±0.90	4.44±1.87	1.46±0.57	36.56±43.73
43/77	I	14	55	32.7	2.24±0.54	4.42±1.60	2.00±0.79	21.580±43.73
46/77	M	20–25	112	58.0	2.20±0.78	4.63±4.01	1.97±0.75	21.79±18.51
48/77	F	18–20	163	56.4	2.05±0.73	4.69±1.91	1.85±0.78	16.69±13.74
54/78	M	20–25	64	56.3	2.13±0.72	5.35±4.46	1.61±0.68	21.07±25.04
64/78	F	18–20	151	25.8	2.40±0.91	5.32±2.42	1.64±0.51	21.38±12.37
69/78	M	20–30	83	28.9	2.91±1.29	7.55±2.50	1.61±0.56	23.68±15.73
73/79	M	20–25	70	60.0	3.19±2.67	7.15±3.94	2.05±1.16	25.39±33.35
75/79	F	25–35	62	53.2	2.08±0.84	4.26±2.31	1.65±0.39	47.15±37.59
76/79	M	20–30	80	41.3	2.38±0.61	5.16±2.16	1.52±0.53	28.59±19.32
81a/79	F	20–30	97	30.9	2.13±0.61	4.09±1.51	1.40±0.45	26.27±23.03
86/80	F	25–35	157	36.9	1.96±1.00	4.52±2.75	1.32±0.52	17.46±12.70
88/80	M	20–30	84	33.3	2.22±0.86	5.88±3.03	1.50±0.67	38.78±39.50
91/80	F	18–20	119	36.1	1.95±0.57	5.10±2.45	1.45±0.50	21.58±28.01
93a/80	F	18–25	72	25.0	2.56±1.02	6.71±2.58	1.87±0.75	23.66±20.05
99/81	M	20–30	110	37.3	1.75±0.48	3.77±1.73	1.37±0.42	17.91±19.81
100/81	F	20–30	97	27.8	2.90±1.07	5.61±1.97	1.92±0.58	29.26±26.48
105/81	I	16–18	82	42.7	1.98±0.78	4.38±3.20	1.51±0.59	24.29±18.51
107/82	F	18–20	93	25.8	1.96±0.67	4.89±2.08	1.39±0.53	25.93±23.17

TABLE 2. Summary of the microwear data for the whole population, and for males and females. Significance values derive from a two-tailed t-test. Values reflect mean and SD, and measurements are expressed in microns (μm).

Vedrovice	Total features	% pits	Pit width	Pit length	Striation width	Striation length
Total population (n=22)	100.5±30.7	40.2±12.0	2.25±0.36	5.05±1.01	1.63±0.22	24.87±7.52
Males (n=9)	91.0±19.8	45.1±11.6	2.31±0.47	5.31±1.33	1.65±0.22	23.95±6.53
Females (n=11)	114.1±33.7	36.7±12.3	2.24±0.30	4.96±0.74	1.59±0.21	25.98±9.02
Male – female comparison	P=0.0868	P=0.1337	P=0.6924	P=0.4571	P=0.5031	P=0.5800

Capturing SEM Images and Analysis

The high resolution Araldite replicas were placed on aluminum SEM stubs and held in place using a high conductivity paint (Electrodag 1415M). The samples were sputter coated with a 20 μm layer of gold palladium (EMSCOPE, SC500) and examined with a high resolution scanning electron microscope (CAMSCAN). A secondary electron emission mode was used, with a resolution of 3.0 and an accelerating voltage of 15 Kv. The replicas were placed within the chamber at a zero tilt angle to the primary beam. All digital images were taken close to the base of facet 9, and recorded at 500× magnification. A single digitized image (1004×744 pixels), with a resolution of 0.254 microns per pixel (DPI 200), was taken for each specimen.

For quantitative analysis of the SEM images, all microwear features with sharp and well defined edges were counted and measured using a semi-automatic image analysis system (Microware Version 4.02©) developed by Peter Ungar (2002). The width and length of each feature was measured and automatically recorded. The programme translates the measurements by placing each feature into either of two categories: a pit (width to length ratio of 1:≤4), or a striation (width to length ratio of 1:>4) (Teaford, Walker 1984). The total number of features (=feature density), percent pits, mean pit width, mean pit length, mean striation width, and mean striation length were calculated. The statistical package SPSS 14.0 was used for all statistical analyses (Pearson's correlation; T-test). To reject the hypothesis that all means were equal, alpha was set to ≤0.05 (2-tailed).

RESULTS

Descriptive statistics for the Vedrovice individual sample are shown in *Table 1*, while population and sex group values are shown in *Table 2*. The feature density for the whole sample was 100.5±30.7 (median 96; range 55–163). The

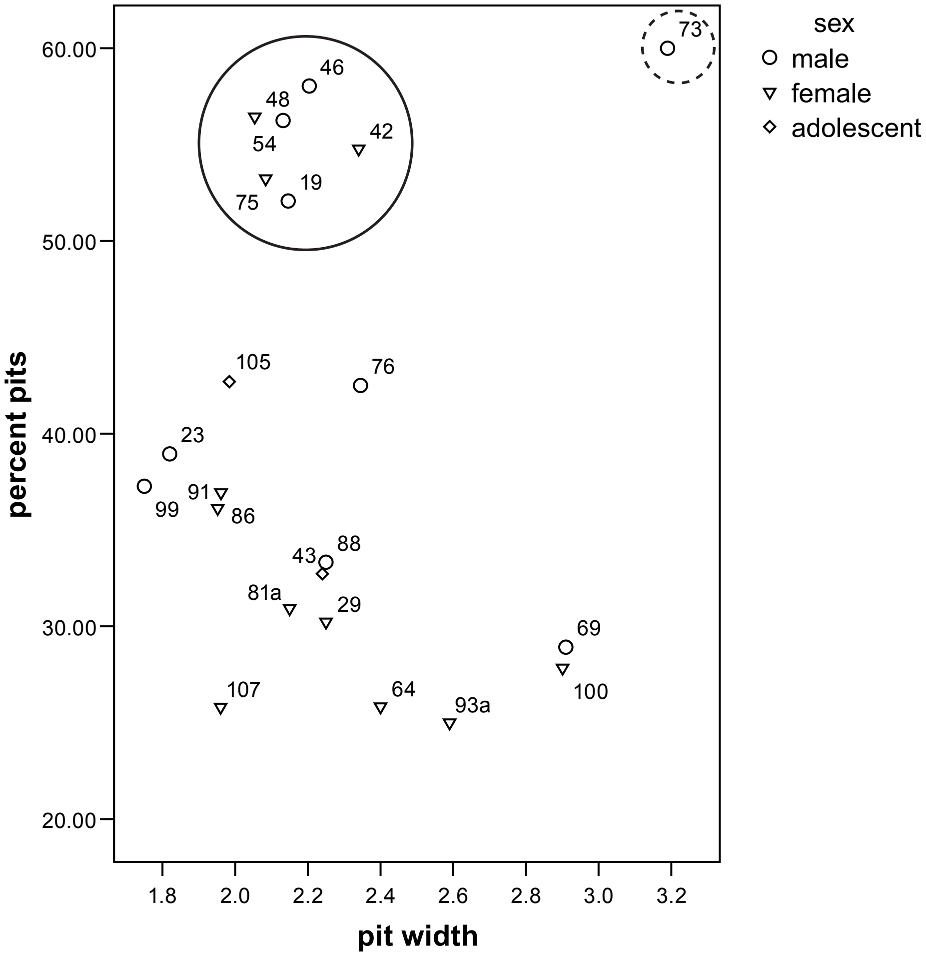

FIGURE 3. Scatterplot showing the distribution of pit frequency and pit width. One group (3 males and 3 females), circled in dashed lines, and one individual, circled in dotted lines, stand out from the rest of the population.

sample comprised a moderate proportion of pits (median 37.1%), and the pits were of moderate size (median width 2.175 µm) while the striation width was relatively broad (median 1.584 µm).

Relationship Between Pit Frequency and Pit Size

No significant correlation was found between the percentage of pits present and the size of the pits (r=–0.036; p=0.873). It was, however, possible to see some clustering within the sample, as shown in *Figure 3*. Seven individuals had between 50–60% pit features which were significantly higher than the rest of the population (33.0±5.9% vs. 55.8±2.7%; p=0.000). Only one individual (73/79) combined a large pit size with a high proportion of pits. This individual displayed the largest pits size of all individuals sampled. Two other individuals (69/78 and 100/81), a male and female respectively, also displayed large pits but the frequency was less than half that of 73/79, and well within the range of the group average.

Relationship Between Size Variables

The Vedrovice sample showed a significant correlation between the increase in pit and striation widths (r=0.592, p=0.004; *Figure 4*). When examining if there was a relationship between the width and length of the striation features, no significant correlation was found *(Figure 5)*. In most cases, striation length appeared to have little influence on striation width. There were three individuals (42/77, 75/79, 88/80) who appear to deviate from the general pattern by showing a substantial increase in striation width together with an increase in striation length. If the individuals clustering around the lower line in *Figure 5* are considered, a significant correlation between the two variables can be seen (r=0.9527, p=0.001).

Differences Between the Sexes and Influence of Age

Males had on average fewer features but more pits than females *(Figures 6* and *7)*, and all size variables were on average greater for males than for females *(Table 2)*. Females had a greater range for all variables, however, none of the differences between females and males were statistically significant *(Table 2)*. Even though females had a higher frequency of microwear features compared with males, this only approached a statistical significance (females 114.1±33.7; males 91.0±19.8; p=0.0868). One individual, 42/77, has proven to have a significant influence

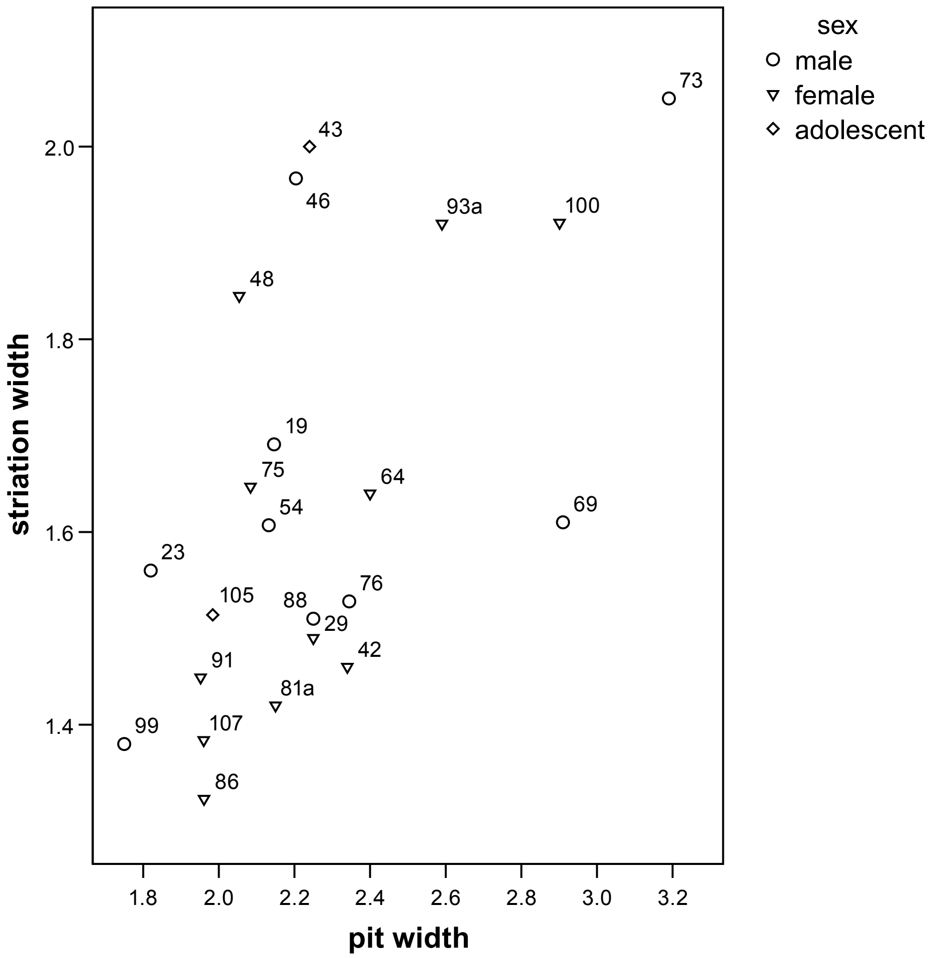

FIGURE 4. Scatterplot showing the distribution of striation width and pit width. The Vedrovice sample showed a significant correlation between pit and striation width.

on these results. The assignment of sex to this individual changed over the course of the study. Initially 42/77 was considered to be male but later classified as a female based on the presence of a preauricular sulcus. When 42/77 was included in the male cohort, the pit proportions between males and females were significantly different (p=0.0396), but when included in the female cohort this significance disappeared. If this individual is excluded, however, the difference between male and female pit frequency values only approach significance (females 34.8±11.3; males 45.1±11.6; p=0.0674).

Age, using the mean age of ranges, did not show any significant correlations for any of the variables examined here.

Individual Signature Patterns

There are a few individuals that stand out as different from the general pattern of the population. From the standard deviation *(Table 1)* it can be seen that there is some heterogeneity within the individual values, most obvious for the striation length variable. When comparing the mean to the median, all individuals showed a lower median striation length. This shows that most have a higher number of shorter striations but with a few very long striations present that bias the mean value. However, while some individuals show only a slight difference between the median and mean values, there were a few that showed a more dramatic difference, e.g. 42/77, 73/79, 75/79, 88/80. These individuals showed a clear mixture of short and long striations but with the longer ones being more common. Individual 43/77 had a large SD but the difference between mean and median was minimal, suggesting that there were a similar number of short and very long striations present in this individual. The male 73/79 stands out from the rest of the population in several ways. He had the highest number of pits and the largest pits within the population *(Figures 3* and *4)*. He also displayed the widest striations, and with little correlation between striation lengths and striation widths *(Figure 5)*. Individuals 42/77, 75/79, and 88/80 all showed a deviation from the rest of the population by having long, narrow striations *(Figure 5)*.

The two adolescent individuals (43/77, 105/81) differed from the rest of the population only in the frequency of features. Especially 43/77, a 14-year-old individual, deviated the most. However, that might be expected due to the very short time its second molar had been in functional use.

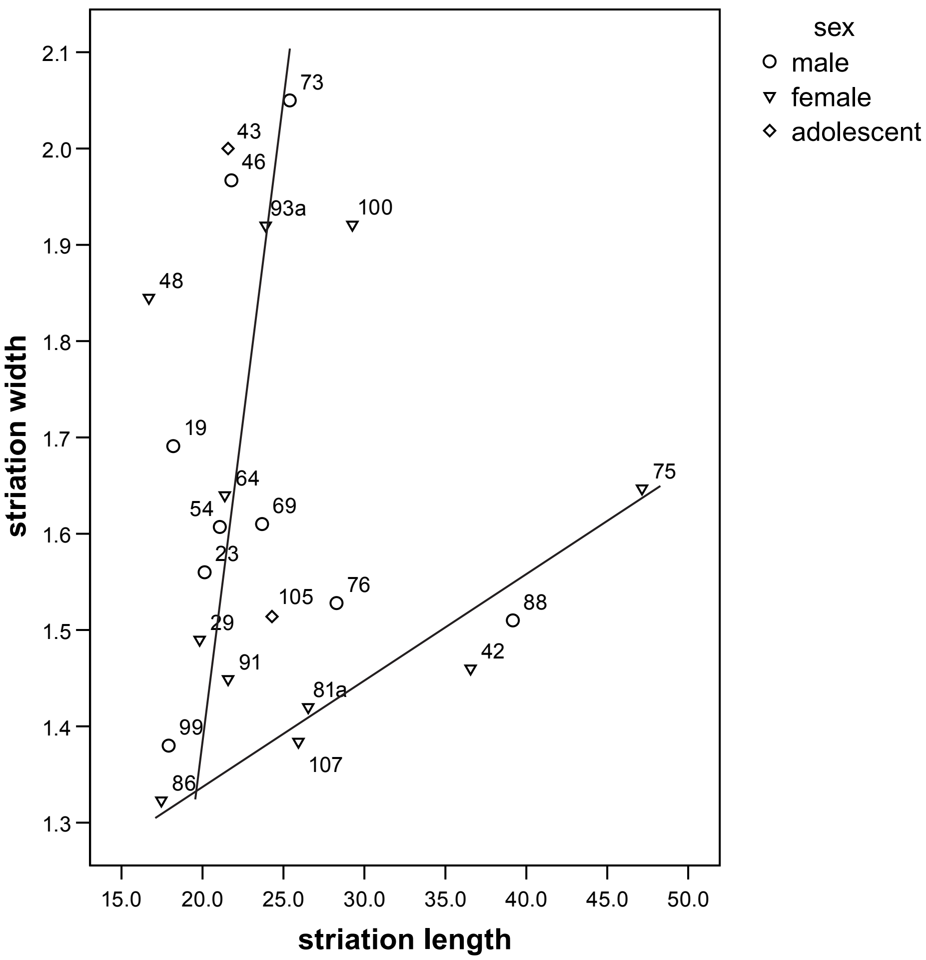

FIGURE 5. Scatterplot showing the relationship between striation width and striation length.

DISCUSSION

The dental microwear signatures of the Vedrovice population provide a mixed signal suggesting that the Vedrovice population had a complex and diverse diet, most likely comprising both domesticated and wild food resources. The relatively high frequency of pits (40.2%) suggests a diet comprising hard food objects that required much force during initial mastication. However, food preparation may be of importance here, as it is very likely that the inclusion of extra-dietary grit was responsible for at least some of the pits. The pit frequency falls within the range of hunting, fishing, and gathering populations. The pit size dimensions are, however, less clearly comparable to hunters and gatherers, but they certainly did not fall into that of established agricultural populations with a soft, well prepared diet. Pit size together with striation dimensions support a more abrasive and hard diet, and may possibly be due to inclusion of extra-dietary silica particles during food preparation although abrasive plant materials cannot be excluded.

The Vedrovice sample presented diverse microwear signatures. When correlating variables such as pit frequency and pit width, it was possible to pick up some distinct clusters within the population. Since it must be assumed that people died throughout the year, these differences may reflect seasonal variation in diet, although it cannot be excluded that they may reflect true differences in diet choice. There is only one individual who may show a true difference in diet. Individual 73/79 had the highest number of pits, and the largest pits and widest striations within the population – values exceed that of most hunter and gatherer societies. Such a signature suggests a very hard object diet, requiring strong compression forces to break down the food. The fact that only one individual fell into this category, may reflect idiosyncrasies in diet choice or it may reflect a poor preparation practice of the foods.

Comparison of the Vedrovice Results with Other Studies

Despite the fact that researchers have used dental microwear methodology to infer diet of past human populations, the comparative sample of quantitative data is still rather meagre. The most extensive and detailed studies have focussed on sites in North America and the Levant. In a comparison between pre-contact and early contact coastal pre-historic populations from Florida, Teaford

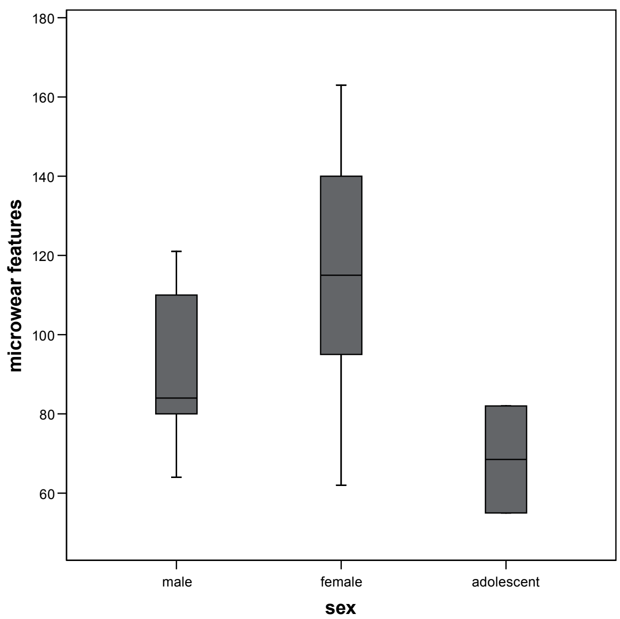

FIGURE 6. Boxplots showing distribution of microwear features for the male, female and adolescent individuals. The box represents the upper and lower quartile, the bar indicates the median value, the whiskers indicate the highest and lowest value in the sample.

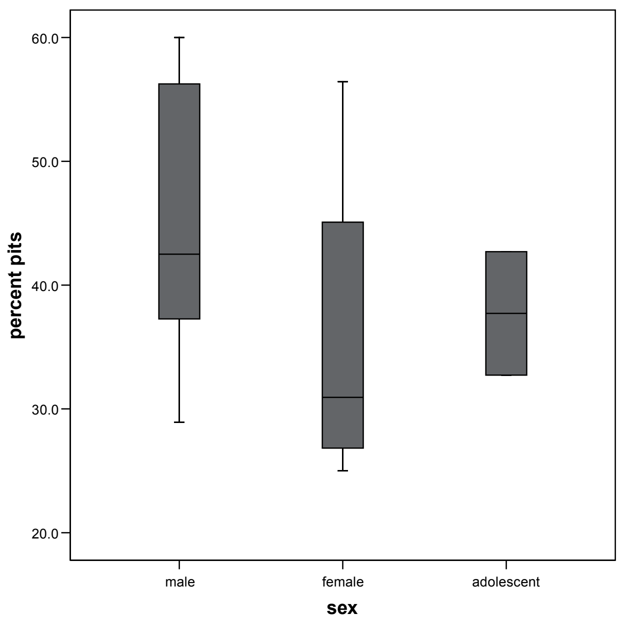

FIGURE 7. Boxplots showing distribution of the percent pits present in males, females and adolescents. The box represents upper and lower quartile with the bar indicating the median value, the whiskers indicate the highest and lowest value in the sample.

and co-workers (e.g. Teaford 1991, Teaford *et al.* 2001) found a marked decrease in pit frequency as well as size variables over time. The pre-contact populations had similar frequency of pits and striation widths as the Vedrovice population, but the pit dimensions were much greater than seen in the Vedrovice population. Schmidt (2001) examined inland populations, comparing Late Archaic to Early/Middle Woodland populations, and found that the diet became harder (increase in pit frequency and larger pits) and less abrasive (decrease in striation size dimensions) over time. However, the North American pre-historic populations may not be good models because of the difference in diet and food resources (Schmidt 2001, Teaford 1991, Teaford *et al.* 2001).

Rather, the Levant has a large number of populations from various prehistoric time periods that have been well studied, and may presently serve as the best comparison for the Vedrovice population. The early Holocene Natufian populations lived an increasingly sedentary life but continued to rely on hunting, fishing and gathering. They were followed by the first agricultural communities, the early pre-pottery Neolithic populations (PPNA) which show evidence of an increasingly sedentary life style and increase reliance on domesticated plant species, while continuing extensive harvesting of wild plants and animals. They were followed by later pre-pottery Neolithic populations (PPNB) which show an increasing reliance on domesticated livestock and cereals (Mahoney 2005, Pinhasi *et al.* 2008). There was a gradual decline in the PPNB, which was possibly due to overexploitation of the natural resources, which eventually resulted in a complete transition and reliance on agricultural resources (Pinhasi *et al.* 2008).

There is an overlap in the dental microwear signatures of the Natufian and PPNB populations, although the PPNB tends to have greater values compared with the Natufians except for pit frequency. This stands in stark contrast to the intermediate PPNA, which indicates signatures very similar to later agriculturally based populations. It has been suggested that the increases seen in the values for the PPNB populations are due to an increasing level of inclusion of extra-dietary "stone dust" during food preparation, when grinding cereals on stone mortars (Mahoney 2006b, 2007, Molleson *et al.* 1993).

The dental microwear signatures of the Vedrovice population are very similar to the PPNB showing some overlap with that of the Natufians, but no similarities to the PPNA or later agriculturally based populations. Mahoney (2007) suggested that the Natufians and the PPNB populations ate hard and brittle foods that required a fair amount of compression during mastication. The presence of a high number of wide and relatively short striations support the suggestion of a diet made up of rough and hard food staples. However, the high standard deviation seen in many individuals from Vedrovice, especially in the case of striation length, suggest that this population included food staples that were tough and resilient (e.g. stringy vegetable matter or dried meat), and required an extensive amount of grinding and shear to process. This is a pattern not seen in either the Natufians or PPNB, suggesting that the diet of the Vedrovice people was either different or more heterogenous.

How Do These Results Compare with Primate Models?
The frequency of pit features and striation widths for the Vedrovice population fall within the range of primate species that include hard objects in their diet, such as seeds and nuts, and are terrestrial (e.g. baboons; Daegling, Grine 1999, Nystrom *et al.* 2004). However, the average pit size of the Vedrovice population is significantly smaller and falls within the range of primate species such as the gelada (*Theropithecus gelada*) which is a grass feeding specialist. Thus, when considering pit frequency together with pit size, the Vedrovice population does not fall within the sphere of hard-object feeding primate species (El-Zaatari *et al.* 2005, Teaford 1994), nor do they fall within the sphere of folivorous primate species, due to the high frequency of pits. With the increasing number of dental microwear data made available, it is evident that more recent pre-historic human populations have dental microwear signatures that do not fit the available primate models. The human diet and especially the food preparation techniques have advanced to such an extent that non-human primate models are less than illuminating. What is needed is a more extensive library of data from human populations where diet can be inferred, at least partially, based on artefacts recovered from settlement sites, or location of site, stable isotope studies, etc. to build up models based on human dietary signatures.

Difference between Males and Females, and Different Age Groups
The idea of a division of labour between males and females, e.g. males as hunters and fishermen and females as gatherers, is fairly entrenched within biological anthropology and archaeology (reviewed in Fedigan 1986, Kuhn, Stiner 2006). As a consequence much effort has been taken to detect difference in for example health or diet between the sexes in prehistoric populations. Many researchers have discovered differences in caries incidences (e.g. Lillie 2008, Lukacs 1996, Temple, Larsen 2007) and in the presence of calculus (e.g. Lillie, Richards 2000) between males and females, implying that their diets were significantly different. Smrčka *et al*. (2008) found a significant difference between males and females based on carbon isotopes, suggesting that males consumed more meat than females. Jarošová (2008) also suggests a difference in diet between males and females, however this difference was more of a trend and not statistically significant. The occlusal dental microwear signatures of the Vedrovice population did not reveal any significant differences between males and females. Even though the females showed higher feature frequency and smaller features, there was too much overlap to suggest a major dietary difference between the sexes. Even when there appeared to be sub-clusters within the population, males and females were equally represented (*Figure 3*). McLaughlin (2007) in his extensive microwear study of Mesolithic and Neolithic populations from West Europe found that females, in at least some populations, had consistently wider striations than males although this difference only approached statistical significance. These results are contra to what was found in the present study where females had on average narrower striations than males (*Table 2*). The difference may be due to the location of the populations: McLaughlin mainly studied coastal populations while Vedrovice is an inland population. McLaughlin suggested that females may have consumed more shellfish than did males, and the grit associated with such foods may have resulted in the wider striations observed (McLaughlin 2007: 195).

The lack of influence by age on the dental microwear signatures may be because the age range of the sample was rather narrow (the majority were between 20 and 30 years). A greater age range may have given a different result. There are few studies that have specifically looked at the effect of age on expression of dental microwear. However, Nystrom *et al*. (2004) did not find that age had a significant influence in the case of baboons.

Does Buccal and Occlusal Dental Microwear Give the Same Signatures?
Eight individuals were analysed for both buccal and occlusal microwear (Jarošová 2008). The conclusions reached for each of these individuals are in agreement (compare tables/appendices). For example, 42/77, considered to have a soft vegetarian diet based on buccal wear, had a high percent of small pits and long narrow striations congruent with a soft vegetarian diet. Individual 100/81 considered to have a mixed diet containing a large number of abrasive particles based on buccal wear showed large pits and wide striations on the occlusal surface commensurate with a diet comprising hard objects that require substantial force to break, or the inclusion of abrasive particles. Individual 69/78 also considered to have a mixed diet with abrasive particles present based on buccal wear, showed large pits but the striations were not especially wide on the occlusal surface. Such a signature suggests a mixed diet with inclusion of some hard food objects or extra-dietary material but not as severe as seen in 73/79. Thus, it appears that the buccal and occlusal dental microwear signatures show very close agreement as to diet of the Vedrovice population.

CONCLUSION

The dental microwear present on the occlusal surface of molar teeth reflects what an individual ate during the last few weeks prior to death. It is a true reflection of the individual's diet. The dental microwear signatures from the Vedrovice population indicate a complex and mixed diet. The high frequency of pit features of relatively large size, suggests a hard object diet that required extensive force when chewing. However, it is difficult to determine if these pits were due to diet or extra-dietary inclusions in the food. It is very likely that some of the pits are extra-dietary additions, possibly due to food preparation techniques such as using quartz containing stone querns for grinding cereals, tubers or roots. For many individuals, both occlusal and buccal microwear signatures signalled the consumption of food of a softer consistency. This suggests that at least some of the pits seen on the occlusal surface could have been due to the grinding of one enamel surface against another. However, the inclusion of plant materials containing phytoliths, the only food that we know to cause scratching on dental enamel, cannot be discounted. The high frequency of long striation features present in many individuals suggests the inclusion of highly resilient and tough food items, such as stringy plant material or dried meat, which required an increasing amount of grinding during mastication. The great standard deviation especially in the case of striation length, suggest at least some individuals consumed a highly varied diet during the last few weeks prior to death.

There are few previous studies to which the dental microwear signatures of the Vedrovice population can be compared. The Vedrovice population as a whole is more similar to the late hunter and gatherer and early settled populations of the Levant (Natufians and PPNB respectively). This includes pit size as well as striation width and length. In the case of pit frequency, the Vedrovice population had fewer pits compared with the Natufians but fit well with the pre-pottery populations of the Levant. Thus, the dental microwear signatures of the Vedrovice population as a whole do not show any affinity with more recent settled populations from the Levant whose diet was based on agricultural products and domesticated animals.

The Vedrovice population showed clear intra-population diversity, which may be explained by a general seasonal variation in diet, or it may reflect true differences in diet choice. There were no significant differences in the dental microwear signatures of males and females, although females had more features on average and these tended to be of smaller dimensions. The lack of significance may in part be due to the fact that females had a wider range for all variables than did the males. Age was not a factor in the dental microwear patterns. Since the age range of the sample is rather narrow it may not be surprising that there were no predictable correlations between age and the microwear variables.

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