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GENERAL BIOLOGY

Dental Microwear and Mesowear of the *Microtus* Voles Molars before and after Experimental Feeding of Owls

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Abstract—In small mammals, the degree of micro- and mesowear of molars depends on the feed hardness, abrasiveness, and some other characteristics. Analysis of micro- and mesorelief of the paleontological material is used for reconstruction of some animal diet parameters. Small mammals pass through a series of complex transformations on the way from the objects of biocenosis to paleontological objects. Bone remains underwent transformations during accumulation and fossilization. In particular, bone remains from ornithogenous deposits were exposed to the bird digestive system elements. We have experimentally studied changes in some parameters of the narrow-headed vole (*Microtus gregalis*) molars derived from the owl pellets. Comparison of the same samples before and after exposure to the digestive system of the polar owl (*Nyctea scandiaca*) and eagle owl (*Bubo bubo*) showed that the tooth enamel microrelief undergoes serious changes and therefore, provides no information on the intravital diet of voles. A different degree of preservation of the characteristics of the mesorelief was shown. Depending on this, an assessment of their applicability to paleoreconstructions was given.

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The study was aimed at enhancing the resolution of paleoecological analysis, in particular, the small mammal diet reconstruction from meso- and microrelief of molars derived out of ornithogenous deposits. The experimental approaches and the natural sample analysis showed that both micro- and mesoreliefs are indicative of a number of diet characteristics ([1–5] and [6–10], respectively). The use of these techniques is limited by an incomplete preservation of the paleontological material. The bone remains and teeth preservation in ornithogenous deposits were evaluated in a series of reports [11–15]. Nevertheless, the experimental approaches required for detailed analysis of the preservation status of the dental meso- and microrelief. We have experimentally evaluated the degree of changes in the lower molars (m1) of a narrow-headed vole, which were exposed to the digestive system components of two owl species. The size, meso- and microrelief of m1 were examined in the original state and after extraction from the owl pellets.

Experimental owl feeding carried out in the Holzan, The Birds of Prey Rehabilitation Center. One polar owl and one eagle owl were used, which were fed at two stages with the vole jaws ($n = 27$) together with the standard food (one-day-old chickens). The birds regurgitated the pellets with specimens in a day after feeding. In the next-day pellets, no specimens were found. In total, the material of four pellets has been analyzed.

We used the left jaws of a narrow-headed vole form the laboratory colony of the Institute of Plant and Animal Ecology, Ural Branch, Russian Academy of Science. The jaws were cleaned from soft tissues manually without boiling or chemical application and dried after that. All parameters were characterized on the same specimens before and after digestion. The molars from pellets were identified from the individual characteristics of the chewing surface. The microrelief was studied using microphotographs of the anterior enamel wall of three enamel loops (T1, T2, and T5) of the first lower molar (m1). The photographs were obtained at magnifications of 700× and 1500× on a TESCAN VEGA3 electron scanning microscope. In comparing the enamel microwear of the original specimens and of the specimens after digestion, both the main elements of the microrelief (pits and scratches) and the damage area (microsplits) of the enamel prism anterior wall were taken into account [1]. Evaluation of the T1–T5 prism mesorelief (the relief type and depth) and of wear angle of the m1 chewing surface was made according to a technique that we have earlier developed [6] using a Leica EZ4 light binocular microscope at magnifications of 20× and 30×. The chewing surface length and the tooth length on the lateral surface were estimated [6]. The averages of two measurements

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Table 1. Changes in the dimensional parameters of the narrow-headed vole teeth with different degree of destruction after the effect of the digestive substances of owls

Character	Degree of tooth destruction	Direction of change	Minimum–maximum	Average value	Average, %	*n*	*T*	*Z*	*P*
Length of chewing surface	0–2	–	0–0.45 mm	0.15 mm	5.42	20	0	3.70	0.01
	0	–	0–0.10 mm	0.05 mm	1.90	8	0	2.20	0.01
	1	–	0.05–0.20 mm	0.11 mm	4.20	6	0	2.20	0.05
	2	–	0.20–0.45	0.31 mm	11.20	6	0	2.20	0.05
Length of lateral surface	0–2	–	0–0.33 mm	0.1 mm	3.54	20	0	3.52	0.01
	0	–	0–0.07 mm	0.03 mm	1.10	8	0	1.82	0.06
	1	–	0.05–0.12 mm	0.09 mm	3.50	6	0	2.20	0.05
	2	–	0.12–0.32	0.21 mm	7.40	6	0	2.20	0.05
Wear angle	0–2	+	−1.77°–9.78°	2.33°	3.22	20	31.5	2.55	0.01
	0	–	−1.77°–0.60°	−3.44°	−0.40	8	9	1.26	0.20
	1	+	0–6.20°	2.50°	3.50	6	0	2.02	0.05
	2	+	0.55°–9.78°	5.60°	7.80	6	0	2.20	0.05

–, decrease; +, increase.

were used in analysis. A point scale was used to divide the samples into groups according to the degree of destruction [14].

The results were processed statistically using nonparametric methods. After owl feeding, the changes in the molar dimensional parameters of two owl species were estimated using the Mann–Whitney test (U). The tooth sizes before and after experimental feeding were determined using the Wilcoxon T-test (T and Z-score).

Eleven out of 13 jaws eaten by the eagle owl and 9 out of 14 jaws eaten by the snowy owl were found in the pellets. The teeth remained in jaws; in one case, an isolated molar was found in a pellet. In each of four pellets, the following degrees of tooth destruction were determined (according to [14]): 0, light microscopy revealed no signs of erosion; 1, a mild degree of enamel dissolution extending no more than one third of a tooth on the outstanding tooth corners; 2, a medium degree of tooth destruction (enamel gaps on the tooth outstanding corners reached the middle of the tooth height and the longer gaps were on some prisms).

The magnitude of changes in the size parameters of the teeth after exposure to substances of the digestive system of the two species of owls did not differ significantly (the chewing surface length: $U = 47.0$; $p = 0.84$; $n1 = 9$, $n2 = 11$; the lateral surface length of a tooth: $U = 45.5$; $p = 0.76$; $n1 = 9$, $n2 = 11$; the chewing surface wear angle: $U = 47.0$; $p = 0.85$; $n1 = 9$, $n2 = 11$). Evaluation of the degree of tooth destruction was performed on a united sample of two owl species. The relief type and depth could be determined only on the teeth with the degree of destruction 0 ($n = 8$) and 1 ($n = 6$). At degree 2 of tooth destruction ($n = 6$), the changes were so severe that evaluation was pointless.

The enamel microrelief underwent significant changes in all groups of preservation. In most cases, the microrelief elements that were noted on the original samples were not fixed after digestion (Fig. 1). On a few specimens, with degree 0 of destruction, the large micro-damages were noted, similar to the original ones, and new damages were recorded.

The dimensional tooth parameters changed after the exposure to gastric juice: the chewing surface length and that of the lateral tooth surface reduced. The wear angle of the chewing surface increased (the angle became more obtuse) (Table 1). Within the group with the degree 0 of destruction, the relief type changed in 7.5% of prisms, while the depth of relief remained unchanged. In the group with the first degree of destruction, the relief type changed in 66.7% of prisms, and the relief depth, in 13% of prisms.

Thus, electron microscopy revealed dissolution of the tooth tissue surface layers in all specimens studied, including teeth where no signs of erosion were determined by the light microscopy. The enamel microrelief of teeth derived from the owl pellets underwent severe changes in all preservation groups and therefore, provided no any information on the intravital vole diet. The chewing surface length was reduced significantly even within the null preservation group. The remaining features studied did not change significantly in this group and therefore, these teeth can be used in paleoreconstructions without any substantial assumptions. Teeth with degree 1 of erosion underwent significant changes in the chewing surface and lateral surface length, in wear angle and the type of prism relief. The depth of prism relief remained unchanged and therefore, this group can be used in reconstructions with respect to this parameter. In teeth with destruction degree 2, the relief type and

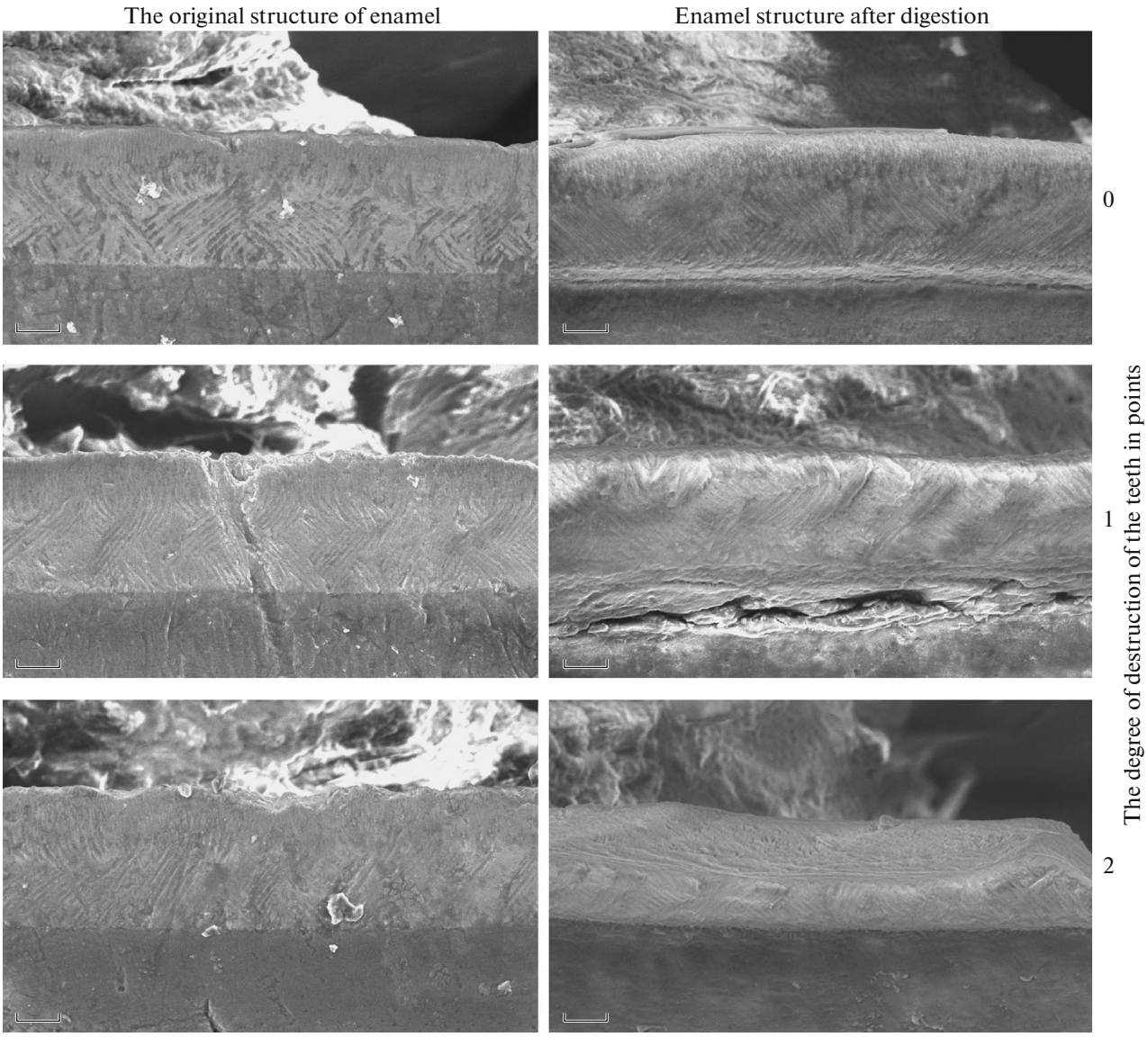

Fig. 1. Changes in the enamel microrelief of teeth with three different degrees of destruction caused by the effect of the digestive substances of owls (scale, 15 μm).

depth cannot be evaluated, they have substantial changes in all dimensional parameters and therefore, these specimens should be excluded from analysis. The data on the changes that we have found can improve the accuracy of reconstruction of the small mammal diet on the basis of specific features of their molar wear.

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest. The authors declare that they have no conflict of interest.

Statement on the welfare of animals. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

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