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MICROWEAR STUDIES OF EARLY AFRICAN HOMINID TEETH

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Abstract

Studies of microwear on fossil hominid teeth have become an important approach in paleoanthropology. Since there are very few samples of early hominids from East Africa with suitable teeth, this paper presents a review of the occurrence of some dental wear characteristics to provide a data base for reconstructing the diet of the early hominids.

Distinctive microwear features such as furrows, crenulations, stress lines and deep grooves, are interpretive tools that can be used in a biomechanical approach. Occurrence of the same dental microwear patterns in extant species with known dietary differences is indicative of foods that have probably been exploited in fossils.

Key Words: Teeth, Fossils, Microwear, Diet.

Introduction

Wear of dental tissues starts soon after tooth eruption and is a result of normal masticatory function. In paleoanthropology the subject of dental wear continues to generate interest because of its relevance to dietary interpretations of early members of the human family. Dietary reconstruction is ultimately based on a combination of evidence including analogical arguments concerning anatomical, structural and behavioral specializations of living species, and experimental evidence of modifications of enamel and dentine with a variety of substances.

Tooth wear patterns have traditionally been used to reconstruct occlusal events during mastication (e.g., Butler, 1952). More recently it was suggested that surface microwear patterns result from dietary preferences. Dietary interpretations may involve either quantitative analyses of features of wear (Teaford and Walker, 1984) or the study of weighted qualitative differences between and within specific samples. For instance, using the latter approach, Walker (1981) found that among modern primates, fruit-eaters have a unique microwear pattern. Because australopithecines have similar microwear patterns to those of extant frugivorous anthropoids, Walker suggested that the diet of *Australopithecus* consisted predominantly of fruits.

The purpose of this note is to describe some dental microwear features for various early hominids and to investigate some of the possible food choices of these animals.

Material and Method

Specimens of *Australopithecus* examined were discovered in Tanzania at Garusi and Laetoli by Kohl-Larsen and Mary Leakey (Leakey *et al.*, 1976) and in Ethiopia at Hadar by Taieb, Coppens and Johanson (Johanson *et al.*, 1982). They date from approximately three to four million years ago, and they will be compared with two more recent hominid taxa, *Australopithecus* boisei and *Homo habilis*. The *A. boisei* samples are from Olduvai and Peninj in Tanzania (Leakey, 1959;

Leakey and Leakey, 1964), and they represent the last species of the genus from approximately 1.5 million years ago (Tobias, 1967). The early representatives of the genus *Homo*, dated at nearly two million years, are the types of the species *H. habilis* discovered in northern Tanzania at Olduvai (Leakey *et al.*, 1964). The sample sizes are small in large part due to the high incidence of postmortem damage in the early hominid fossil record.

Microwear details are from photographic and scanning electron microscopic (SEM) analyses of replicas of the dental occlusal surfaces. The whole surface was examined under the SEM with nitrocellulosic negative impressions since a single copy provides fewer artifacts than does the two step copying procedure required for a positive cast.

To give a picture of the functional wear of hominid teeth, a table listing the features of microwear related to oral food processing has been given in an earlier paper (Puech *et al.*, 1983a). The classification offers an approach to analyzing food habits of hominids from various ecological and cultural perspectives. This note will review additional wear features that can be attributed to certain physical, mechanical and morphological characteristics of how food items, and abrasives on food, wear away enamel and dentine.

Results and Discussion

The most dramatic features, and indeed, the main ones, analyzed on the dental occlusal wear surfaces are striations, small pits and micro-flakes. These can be caused by any number of causes including the following: **a**) dust and debris from soil collected on foods; **b**) abrasives present in food, **c**) enamel fatigue due to cyclic loading and; and **d**) high stress during clenching (tooth-to-tooth contact during static loading or very slow movement). These causes may also produce other features named furrows, crenulations or stress lines, presented below.

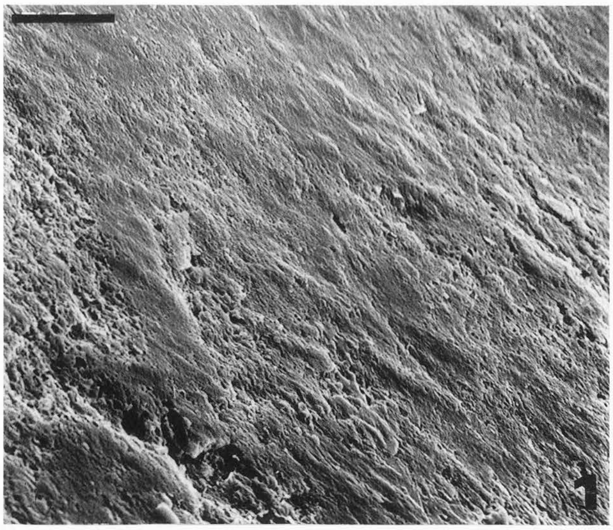
In 1967, Tobias related microscopic pits in australopithecine molars to the mastication of hard food; and in 1977, Kay confirmed, in living animals, the relationship between consumption of nuts and hard fruits, and microscopic pits. Actually the frequency of mild pitting is marked in Bushmen who use their teeth as tools and crack hard nuts with their teeth. Pits occur more on the right than on the left side and in mandibular rather than in maxillary teeth (Van Reenen and Reinach, 1986).

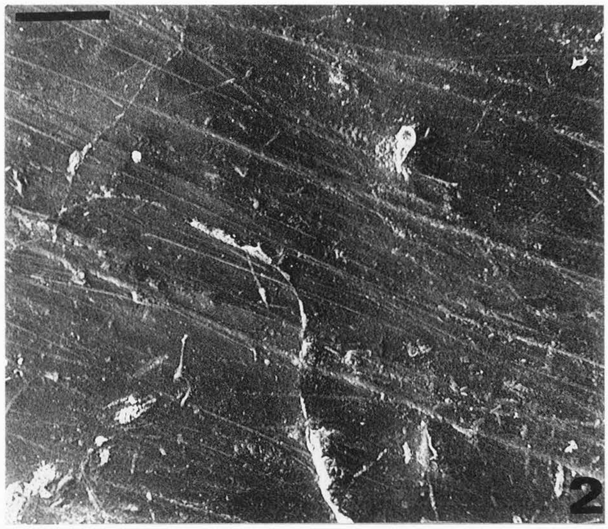
Striations on the australopithecine teeth from Hadar are very close to those observed on the Laetoli hominids (White, 1985). The relatively minor differences in number of striae may indicate that detrital wear was more intense at Laetoli than at Hadar. The diminution of detrital wear at Hadar could correspond to a diminution of diet coarseness in a more humid environment. Another possible explanation is that the diet at Hadar might have contained a large amount of very small abrasive particles that exerted an erasing and a polishing action while at the same time coarser particles made scratches. Examination of the teeth of modern animals and *Homo* has helped to give an explanation for these findings which is presented here.

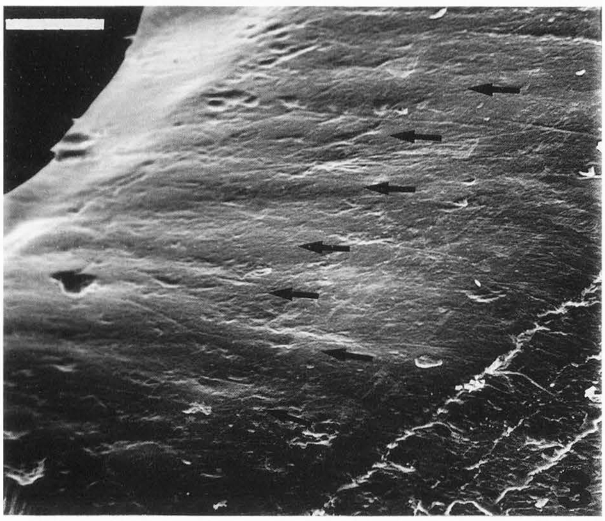
Buccal and labial sides of occlusal surfaces of teeth in *H. habilis* reveal striae and grooves predominantly bucco- or labio-lingually oriented. In incisors, this pattern suggests the "scraping" and "stripping" of items. The cohesion between the enamel prisms has been weakened by an etching action (Figure 1). The origin of this erosion has been discussed by Puech (1986). Rensberger (1978), Walker *et al.* (1978), Puech *et al.* (1986) and others postulate that the rapid wear with few striae is due to vegetable fibre. Examination of the teeth of ancient Egyptians, and also modern sheep that eat grasses, has provided an explanation. Many food plants growing in marsh land and indeed many grasses, have high concentrations of siliceous particles known as opal phytoliths. The consumption of such foods produces a great deal of tooth wear, and the enamel and dentine have a blunted appearance. Ancient Egyptians ate *Cyperus papyrus* shoots (Puech *et al.*, 1983b) and we suppose that early man did the same with swamp margin plants. It is not being suggested that opal phytoliths are solely responsible for all the wear seen on the occlusal surfaces, but because of the minute size of the particles and the hardness of the mineral, they wore away the enamel and dentine very quickly. This explanation is offered to account for the differences between the striations on the teeth of Hadar and Laetoli, as well as for the unexpected lack of striations of the teeth of *H. habilis* at Olduvai. Thus, the lower incidence of striations on the teeth of the Hadar hominids may have been due to the consumption of swamp margin plants.

In contrast, the teeth of *A. boisei* are very striated similar to the teeth of the Chacma baboon. Like the Chacma baboon, *A. boisei* may have included root vegetables in its diet, thus ingesting more dust and grit, and producing micro-pits in the Peninj incisor enamel and deeply striated premolars and molars in the Peninj and Olduvai australopithecines (Figure 2).

Crenulations, or shallow parallel grooves, are best developed where no direct opposing dental contact occurs, on rounded occlusal surfaces of incisors, premolars and molars in early hominids. Crenulations in ruminants probably results from high biting forces used to crop food and break outer coverings and from powerful chewing of the cheek teeth as a function of the enamel structure (Rensberger and von Koenigswald, 1980). In







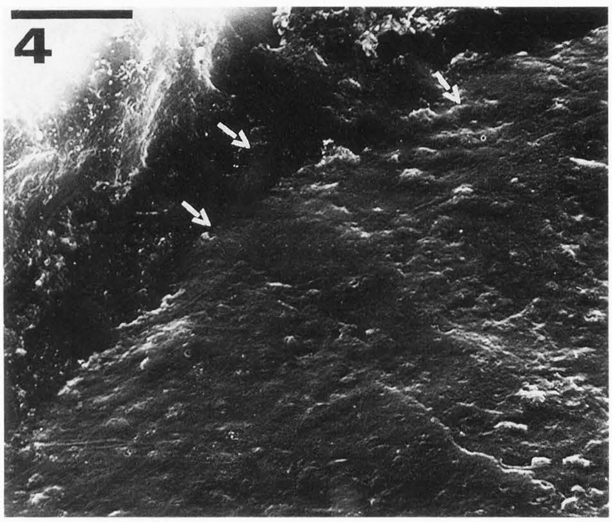


Figure 1. On occlusal enamel, furrows are running from bottom to the left top of the incisal surface of the incisor in *Homo habilis* (O.H. 16) from Olduvai. Bar = 50 μm.

Figure 2. Polished labio-occlusal enamel surface with many pits and striations on the lower left second premolar in *Australopithecus boisei* from Peninj. Bar = 100 μm.

Figure 3. Crenulations (arrows), spaced at about 200 μm, on the labio-occlusal wear surface of upper right canine enamel in early Australopithecus (L.H. 5) from Laetoli. The surface is tipped about 75° and the width of this feature is based on the image distance divided by the cosine of 75°. Bar = 100 μm.

Figure 4. Stress lines (arrows), on dentine occlusal surface of the upper lateral incisor in early *Australopithecus* (L.H. 5) from Laetoli. Bar = 10 μm.

Laetoli and Hadar australopithecines, crenulations are barely present on the flat wear facets of the canine (Figure 3). Comparisons of the dental wear in *Papio papio* have suggested behavioral analogies and an additional wear action erasing crenulations by tooth-on-tooth wear (Puech and Albertini, 1984).

In early hominids the first stages of incisor wear tend to show a more rapid rate than in other teeth (Ryan and Johanson, 1989). Examination indicates ablative dental defects like pits and flakes that are due to hard tissue fatigue. Special features called "stress lines" are also present. These are produced by a stick and slip physical phenomenon in the interaction of sliding surfaces. Oscillation occurs when the friction is reduced as the sliding speed increases, the manifestation is audible (creaking, squeaking and groaning). This is a phenomenon that develops at small sliding speeds. A negative friction characteristic must be maintained to produce this tribological phenomena (Adamson, 1967). In modern man bruxism produces stress lines perpendicular to the direction of sliding in alloy restorations (McCoy, 1983). In bruxism the fatigue that takes place depends on the resisting strength of the subject's alveolar bone. If the resisting bone is strong and dense, the fatigue will affect the coronal portions of the tooth. In Laetoli hominid 5, stress lines are present on the lateral incisor in occlusal contact areas (Figure 4). The lines are thus directly related to incisor lateral gritting considered within the normal range of activities for monkey, ape and man. In early hominid incisors, mesio-distal striae and dentinal tubules in relief are also noted on the occlusal surfaces. These marks are related to a slicing action in mastication.

On labial surfaces of early hominid front teeth, no additional deep grooves have been observed. These grooves, deeper than striations, are present in monkey (Chacma baboon) and man, and are due to the intensive use of the front teeth as tools to assist the hands. In the early hominids discussed here, the material in contact with the labial dental surfaces was not hard enough to produce these grooves or they did not use their teeth as tools as much as the modern analogues.

Conclusion

It is impossible to determine the brittleness, modulus of elasticity, indentation resistance and other mechanical properties that fossil enamel and dentine had during life. Further, age determination at death frequently requires invasive technology that cannot be used on the sparse fossil record. Therefore, studies of the rates of wear of early hominid teeth are inconclusive. For instance, we cannot weigh the relative effects of polishing versus detrital wear on the teeth from Laetoli as compared with the teeth from Hadar. Conclusions can only be based on qualitative features of wear and it can be inferred by analogy with Bushmen that hard food and abrasive particles have produced important dental wear in *Australopithecus*, and that the rapid wear that occurs in *H. habilis* at Olduvai due to an erosive, polishing and high stress action, results from the consumption of large quantities of plant fiber.

The evidence of wear, together with the paleoecological data from the different sites, yields the following possibilities for early hominid diets: etching may be due to acidic food and polishing by mastication of Cyperaceae and Gramineae. It has been established that acid Cyperaceae fruits were common in *H. habilis* habitat (Bonnefille, 1984). Ancient Egyptians ate *Cyperus papyrus* root which was also present at Olduvai in swamp-margins and river banks. This starchy food could have provided part of the caloric needs of *H. habilis*. The evidence of dental microwear supports the paleoecological reconstruction of the way of life that places "handy man" at Olduvai in flood plain settings with swamp vegetation. Absence of deep grooves (gashes) in early hominid incisors labial surfaces and its presence in later hominids is assumed to be related to behavioral changes associated with hand performance modifications.

Dental microwear has provided some evidence that the two hominid species at Olduvai, *A. boisei* and *H. habilis*, ate different foods. This difference in tooth wear probably reflects a difference in culture; synchronism does not mean common life. I have suggested that Homo made an "arrangement" with *A. boisei* rather than exterminating him (Puech, 1986).

The means of subsistence follows environmental and cultural changes. With a similar culture, the habitat supplies the diet that determines the abrasive quality of the bolus producing the wear pattern. Early hominids from Hadar and Olduvai both lived on a well-watered savanna woodland, near a lake. Consequently, differences in tooth wear observed in *Australopithecus* and *Homo* from Olduvai mainly depend on cultural behavior. This may also be the reason why we have observed tooth wear that is much the same in *H. habilis* from Bed 1 as in Bed 2 (Puech, 1986) and the very close tooth wear in australopithecines from Garusi, Laetoli and Hadar (Puech *et al.*, 1986).

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Discussion with Reviewers

T. Hojo: In the paper, the author states: "The cohesion between the enamel prisms has been weakened by an etching action (Figure 1)". Do you think that these features could be the remnant of abraded striae or grooves that have been etched by the chemical action? Similarly, could the "stress-lines" shown in Figure 4 also be remnants of striae or grooves due to erosion? Is it possible that this erosion could have occurred in the soil under the post-mortem conditions?

Author: Fossil enamel and dentine can suffer acid post-mortem degradation to their surfaces although a basic environment is needed to preserve bones and teeth (Poole and Tratman, 1977). At Olduvai and Laetoli, acid dissolution and alkaline corrosion have been strongly influenced by the composition of the sedimentary beds' solutions, the presence of inhibitors such as fluoride, and the conditions of exposition. When microscopic examination of the surfaces was possible, we have noted that the post-mortem treatment has roughened the surface, but generally enamel and dentine architectural patterns are more clearly seen than for actual teeth.

When a heavily striated enamel surface is treated with acid solutions, the etchant appears to more selectively attack the peaks than in grooves and depressions, so as to wash away the weakened enamel relief (Dennison and Craig, 1978; Lee *et al.*, 1972). The presence of glossy enamel furrows gives proof that, at most, only slight chemical post-mortem action, may have occurred (Figure 1). Similarly, the laminated appearance of the dentine and the presence of fine striae normal to the 'stress lines' seem to be of mechanical origin but do not exclude a post-mortem chemical action (Figure 4).

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