4. Dental microwear and Paleoanthropology: Cautions and possibilities

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Abstract

Fifty years ago, investigators realized they could gain insights into jaw movement and tooth-use through light-microscope analyses of wear patterns on teeth. Since then, numerous analyses of modern and fossil material have yielded insights into the evolution of tooth use and diet in a wide variety of animals. However, analyses of fossils and archeological material are ultimately dependent on data from three sources, museum samples of modern animals, living animals (in the wild or in the lab), and *in vitro* studies of microwear formation. These analyses are not without their problems. Thus, we are only *beginning* to get a clearer picture of the dental microwear of the early hominins. Initial work suggested qualitative differences in dental microwear between early hominids, but it wasn't until Grine's analyses of the South African australopithecines that we began to see quantitative, statistical evidence of such differences. Recent analyses have (1) reaffirmed earlier suggestions that *Australopithecus afarensis* shows microwear patterns indistinguishable from those of the modern gorilla, and (2) shown that the earliest members of our genus may also be distinguishable from each other on the basis of their molar microwear patterns. While this work hints at the possibilities of moving beyond standard evolutionary-morphological inferences, into inferences of actual differences in tooth use, we still know far too little about the causes of specific microwear patterns, and we know surprisingly little about variations in dental microwear patterns (e.g., between sexes, populations, and species). In the face of such challenges, SEM-analyses may be reaching the limits of their usefulness. Thus, two methods are beginning to catch attention as possible "next steps" in the evolution of dental microwear analyses. One technique involves a return to lower magnification analyses, using qualitative assessments of microwear patterns viewed under a light microscope. The advantages of these analyses are that they are cheap and fast, and may easily distinguish animals with extremely different diets. The disadvantages are that they are still subjective and may not be able to detect subtle dietary differences or artifacts on tooth surfaces. Another technique involves the use of scale-sensitive fractal analyses of data from a confocal microscope. Advantages include the ability to quickly and objectively characterize wear surfaces in 3D over entire wear facets. The main disadvantage lies in the newness of the technique and challenges imposed by developing such cutting edge technology. With the development of new approaches, we may be able to take dental microwear analyses to a new level of inference.

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Introduction

Paleoanthropologists are, in many ways, like forensic scientists who travel through time. They must use any available clues to help decipher what went on, eons ago; and only by considering the total range of evidence can they begin to appreciate the limits of what can be said about past behaviors. Unfortunately, much of the evidence available to paleoanthropologists is not *direct* evidence, in the sense of something visible on a bone or tooth, caused directly by something that happened during the individual's lifetime. For instance, the relative size of certain bones may or may not be indicative of what an animal actually did, as the animal may have, for example, relatively long hindlimbs simply because its ancestors had relatively long hindlimbs. So, when looking through the evidence, paleoanthropologists are constantly forced to evaluate their data, to see what they can, and cannot, say about the hypotheses being tested.

The most common elements in the human fossil record are teeth – largely because they are the most resilient structures in the body. For the most part, they are made of inorganic materials, and they tend to remain intact well after death. Thus, it is perhaps no surprise they have provided many clues about the paleobiology of our ancestors. For instance, analyses of tooth shape have shown that species adapted to eat tough, elastic foods generally have longer molar shearing crests than do species adapted to eat hard and brittle foods (Kay, 1975; Kay and Hylander, 1978; Lucas, 1979, 2004). However, most of these studies have focused on analyses of unworn teeth (see Ungar, 2004, 2007 for a revolutionary new perspective on this topic). Yet, like death and taxes, tooth wear is one of life's inevitabilities. As soon as a tooth reaches occlusion, it begins to wear down. In some cases, such as in guinea pigs, wear even begins *in utero* (Ainamo, 1971; Teaford and Walker, 1983). Its first steps are imperceptible to the naked eye – microscopic scratches and pits nicking the surface. But those microscopic effects add up, leading to the formation of wear facets on the teeth, and eventually dentin exposure, as the overlying enamel is worn away. So, while the shape of unworn teeth can tell us a great deal about what a tooth is *capable* of processing, tooth *wear* can give us insights into how a tooth was actually used. This paper will focus on the evidence provided by microscopic wear patterns on the chewing surfaces of teeth – what is often referred to as dental microwear analyses. This is different from most other analyses of fossils, because it is *direct* evidence of past behavior – ultimately based on microscopic wear caused by food or abrasives on food during an animal's lifetime. As a result, this technique has the potential to yield information about prehistoric diet and tooth use at a unique level of resolution.

Postmortem Wear

One of the first questions that springs to mind in contemplating dental microwear analyses of fossils is: if a tooth has been lying in the ground for thousands or millions of years, how do we know that the wear on it was really caused during the animal's lifetime? Actually, it is surprisingly easy (Teaford, 1988b), because the wear patterns caused during chewing are laid down in regular patterns at specific locations on teeth (see Figure 1a). By contrast, when a tooth is buried in the ground it is subjected to wear at innumerable, unusual locations and angles (see Figure 1b) (Puech et al., 1985; Teaford, 1988b; King et al., 1999b). This so-called postmortem wear is certainly a problem when analyzing fossils – but generally not because we cannot recognize it. Instead, it is a problem because we *can* recognize it, and have to eliminate many specimens from our analyses.

Obviously, the degree of postmortem wear can be a function of many factors, such as the length of time a specimen has been exposed