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Mammalian dental function and wear: A review

Peter S. Ungar*

Department of Anthropology, University of Arkansas, Old Main 330, Fayetteville, AR 72701, USA

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Abstract

This paper presents a brief synopsis of work on relationships between mammalian tooth form and function, and considers the role of dental wear in studies of mammal teeth. Mammalian teeth function both as guides for chewing and as tools for initiating and propagating cracks through food items. They tend to vary in form and structure with the mechanical properties of foods a species has evolved to eat; and we can learn a lot about relationships between teeth and diet by comparing species. One area of special interest is tooth wear. Dental structure and chemistry combine in ways that lead wear to sculpt occlusal surfaces so a tooth can develop or maintain its functional efficiency. Dental wear, especially that on microscopic scales, can also serve as a proxy for diet in fossil species, as specific types of food leave distinctive patterns.

Keywords: Biotribology; Microwear; Enamel microstructure; Dental topographic analysis; Food oral processing

Contents

*Tel.: +1 479 575 6361; fax: +1 479 575 6595.
E-mail address: pungar@uark.edu
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1. Introduction

Tooth crowns are important biosurfaces that receive considerable attention from biotribologists. Most focus on ***human*** teeth, given clinical implications of tooth wear and failure [1]. But *Homo sapiens* is just one of tens of thousands of vertebrate species with teeth, and one of hundreds of thousands of animal species that have hardened structures in or around the oral cavity used in food acquisition and processing [2]. We can learn a lot about dental biotribology by extending our studies to the teeth of other species, especially other mammals. Mammalian teeth are like natural experiments wherein dental form, structure, and function are varied [3]. They allow us to explore basic principles about how teeth work, and to discover alternative solutions to the fundamental challenges that they face – acquiring and processing foods without being broken or worn away in the process. The study of mammalian teeth is important both for "pure science" reasons (e.g., understanding how nature works and what animals in the past ate), and for applied ones (e.g., the development of bio-inspired designs).

This paper presents a brief synopsis of some studies of mammalian tooth form, function, and wear. It is not a comprehensive review – the literature is far too vast for that. Rather, it offers a starting point to touch on some of the major issues, so that those interested in the subject can begin to organize this massive body of work.

2. Dental function

Before we can consider how mammalian teeth wear, we need to understand how they work. Researchers have recognized for centuries that teeth function on two different levels. Cuvier [4] knew it two centuries ago when he described ungulate teeth as flat to allow horizontal motions, but with alternating bands of enamel and dentin for grinding vegetation. On one level, mammalian cheek teeth are guides for chewing. Crown shape can limit masticatory movements as opposing teeth come into and out of contact. On a finer level, they are tools for fracturing objects, and the form of the occlusal surface itself should reflect specific tooth–food interactions. These levels correspond roughly to Butler's [5] "internal" and "external" environments, or to Evans and Sanson's [6] "geometry of occlusion" and "geometry of function" respectively. We can consider each of these separately.

2.1. Teeth as guides for chewing

The idea that tooth shape relates to the mechanics of chewing dates back at least to Ryder's [7] work in the 19th Century, but the concept as we know it today was developed largely by George Gaylord Simpson early in the 20th Century.

2.1.1. Tooth shape and facets as indicators

Simpson [8] was most interested in paleobiology, which he defined as "an attempt to consider a very ancient and long extinct group of mammals not as bits of broken bone but as flesh and blood beings". And much of his early work focused reconstructing how early mammals chewed by examining the shapes of fossil teeth and the directions of scratches on their wear facets. His earliest study on the subject focused on multituberculates, an enigmatic but very successful group of fossil mammals that lived between about 165 and 35 million years ago [9]. Multituberculate cheek teeth have two or three rows of up to eight cusps each, arranged front to back (Fig. 1).

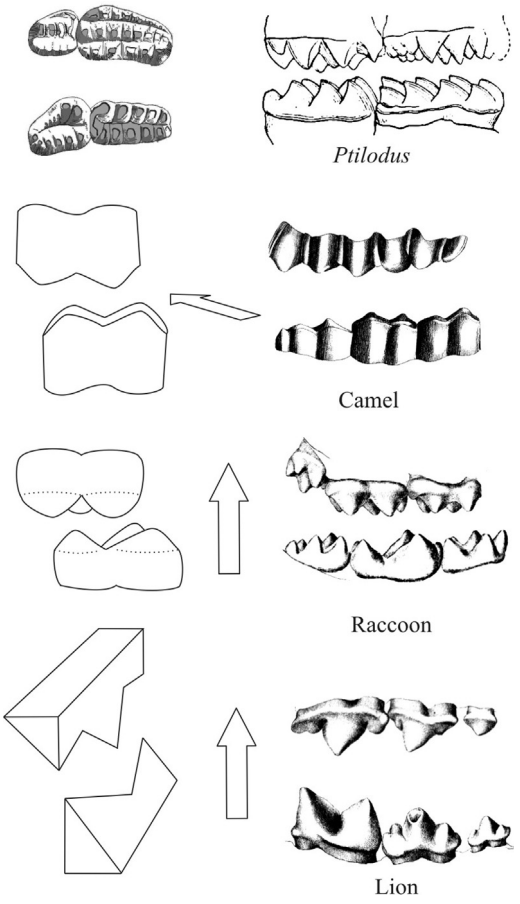

Fig. 1. Chewing directions and tooth shapes. *Top*: the multituberculate *Ptilodus* (upper and lower teeth occlusal view on left, side view on right). *Other images*: idealized cheek teeth (left) and upper and lower molars (right) of a camel (with lateral grinding motion); a raccoon (with vertical crushing motion); a lion (with vertical shear motion). *Ptilodus* modified from Osborn [198]. Other tooth images modified from Giebel [199].