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The Teeth of the Tyrannosaurs

by William L. Abler

Their teeth reveal aspects of their hunting and feeding habits

Understanding the teeth is essential for reconstructing the hunting and feeding habits of the tyrannosaurs. The tyrannosaur tooth is more or less a cone, slightly curved and slightly flattened, so that the cross section is an ellipse. Both the narrow anterior and posterior surfaces bear rows of serrations. Their presence has led many observers to assume that the teeth cut meat the way a serrated steak knife does. My colleagues and I, however, were unable to find any definitive study of the mechanisms by which knives, smooth or serrated, actually cut. Thus, the comparison between tyrannosaur teeth and knives had meaning only as an impetus for research, which I decided to undertake.

Trusting in the logic of evolution, I began with the assumption that tyrannosaur teeth were well adapted for their biological functions. Although investigation of the teeth themselves might appear to be the best way of uncovering their characteristics, such direct study is limited; the teeth cannot really be used for controlled experiments. For example, doubling the height of a fossil tooth's serrations to monitor changes in cutting properties is impossible. So I decided to study steel blades whose serrations or sharpness I could alter and then compare these findings with the cutting action of actual tyrannosaur teeth.

The cutting edges of knives can be either smooth or serrated. A smooth knife blade is defined by the angle between the two faces and by the radius of the cutting edge: the smaller the radius, the sharper the edge. Serrated blades, on the other hand, are characterized by the height of the serrations and the distance between them.

To investigate the properties of knives with various edges and serrations, I created a series of smooth-bladed knives with varying interfacial angles. I standardized the edge radius for comparable sharpness; when a cutting edge was no longer visible at 25 magnifications, I stopped sharpening the blade. I also produced a series of serrated edges.

To measure the cutting properties of the blades, I mounted them on a butcher's saw operated by cords and pulleys, which moved the blades across a series of similarly sized pieces of meat that had been placed on a cutting board. Using weights stacked in baskets at the ends of the cords, I measured the downward force and drawing force required to cut each piece of meat to the same depth. My simple approach gave consistent and provocative results, including this important and perhaps unsurprising one: smooth and serrated blades cut in two entirely different fashions.

The serrated blade appears to cut meat by a "grip and rip" mechanism. Each serration penetrates to a distance equal to its own length, isolating a small section of meat between itself and the adjacent serration. As the blade moves, each serration rips that isolated section. The blade then falls a distance equal to the height of the serration, and the process repeats. The blade thus converts a pulling force into a cutting force.

A smooth blade, however, concentrates downward force at the tiny cutting edge. The smaller this edge, the greater the force. In effect, the edge crushes the meat until it splits, and pulling or pushing the blade reduces friction between the blade surface and the meat.

After these discoveries, I mounted actual serrated teeth in the experimental apparatus, with some unexpected results. The serrated tooth of a fossil shark (*Carcharodon megalodon*) indeed works exactly like a serrated knife blade does. Yet the serrated edge of even the sharpest tyrannosaur tooth cuts meat more like a smooth knife blade, and a dull one at that. Clearly, all serrations are not alike. Nevertheless, serrations are a major and dramatic feature of tyrannosaur teeth. I therefore began to wonder whether these serrations served a function other than cutting.

The serrations on a shark tooth have a pyramidal shape. Tyrannosaur serrations are more cubelike. Two features of great interest are the gap between serrations, called a cella, and the thin slot to which the cella narrows, called a diaphysis. Seeking possible functions of the cellae and diaphyses, I put tyrannosaur teeth directly to the test and used them to cut fresh meat. To my knowledge, this was the first time tyrannosaur teeth have ripped flesh in some 65 million years.

I then examined the teeth under the microscope, which revealed striking characteristics. (Although I was able to inspect a few *Tyrannosaurus rex* teeth, my cutting experiments were done with teeth of fossil albertosaurs, which are true tyrannosaurs and close relatives of *T. rex*.) The cellae appear to make excellent traps for grease and other food debris. They also provide access to the deeper diaphyses, which grip and hold filaments of the victim's tendon. Tyrannosaur teeth thus would have harbored bits of meat and grease for extended periods. Such food particles are receptacles for septic bacteria—even a nip from a tyrannosaur, therefore, might have been a source of a fatal infection.

Another aspect of tyrannosaur teeth encourages contemplation. Neighboring serrations do not meet at the exterior of the tooth. They remain separate inside it down to a depth nearly equal to the exterior height of the serration. Where they finally do meet, the junction, called the ampulla, is flask-shaped rather than V-shaped. This ampulla seems to have protected the tooth from cracking when force was applied. Whereas the narrow opening of the diaphysis indeed put high pressure on trapped filaments of tendon, the rounded ampulla distributed pressure uniformly around its surface. The ampulla thus eliminated any point of concentrated force where a crack might begin.

Apparently, enormously strong tyrannosaurs did not require razorlike teeth but instead made other demands on their dentition. The teeth functioned less like knives than like pegs, which gripped the food while the *T. rex* pulled it to pieces. And the ampullae protected the teeth during this process.

An additional feature of its dental anatomy leads to the conclusion that *T. rex* did not chew its food. The teeth have no occlusal, or articulating, surfaces and rarely touched one another. After it removed a large chunk of carcass, the tyrannosaur probably swallowed that piece whole.

Work from an unexpected quarter also provides potential help in reconstructing the hunting and feeding habits of tyrannosaurs. Herpetologist Walter Auffenberg of the University of Florida spent more than 15 months in Indonesia studying the largest lizard in the world, the Komodo dragon [see "The Komodo Dragon," by Claudio Ciofi; Scientific American, March]. (Paleontologist James O. Farlow of Indiana University–Purdue University Fort Wayne has suggested that the Komodo dragon may serve as a living model for the behavior of the tyrannosaurs.) The dragon's teeth are remarkably similar in structure to those of tyrannosaurs, and the creature is well known to inflict a dangerously septic bite—an animal that escapes an attack with just a flesh wound is often living on borrowed time. An infectious bite for tyrannosaurs would lend credence to the argument that the beasts were predators rather than scavengers. As with Komodo dragons, the victim of what appeared to be an unsuccessful attack might have received a fatal infection. The dead or dying prey would then be easy pickings to a tyrannosaur, whether the original attacker or merely a fortunate conspecific.

If the armamentarium of tyrannosaurs did include septic oral flora, we can postulate other characteristics of its anatomy. To help maintain a moist environment for its single-celled guests, tyrannosaurs probably had lips that closed tightly, as well as thick, spongy gums that covered the teeth. When tyrannosaurs ate, pressure between teeth and gums might have cut the latter, causing them to bleed. The blood in turn may have been a source of nourishment for the septic dental bacteria. In this scenario, the horrific appearance of the feeding tyrannosaur is further exaggerated—their mouths would have run red with their own bloodstained saliva while they dined.

PHOTOGRAPH COURTESY OF WILLIAM L. ABLER

EXPERIMENTAL DEVICE (*above*) for measuring cutting forces of various blades: weights attached to cords at the sides and center cause the blade to make a standard cut of 10 millimeters in a meat sample (*represented here by green rubber*).

The Author

WILLIAM L. ABLER received a doctorate in linguistics from the University of Pennsylvania in 1971. Following a postdoctoral appointment in neuropsychology at Stanford University, he joined the faculty of linguistics at the Illinois Institute of Technology. His interests in human origins and evolution eventually led him to contemplate animal models for human evolution and on to the study of dinosaurs, particularly their brains. The appeal of dinosaurs led him to his current position in the Department of Geology at the Field Museum, Chicago.

Further Reading

The Serrated Teeth of Tyrannosaurid Dinosaurs, and Biting Structures in Other Animals. William Abler in *Paleobiology,* Vol. 18, No. 2, pages 161–183; 1992.

Tooth Serrations in Carnivorous Dinosaurs. William Abler in *Encyclopedia of Dinosaurs*. Edited by Philip J. Currie and Kevin Padian. Academic Press, 1997.