Research Reveals Self-sharpening Mechanism in Sea Urchin Teeth

The findings have the potential to influence the design of tools for mining, boring, and machining operations.

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Video shows a 3D scan of the sea urchin teeth on jaws, which work together as a mechanical grasping. Credit: Michael Frank and Joanna McKittrick, University of California San Diego.

Even millions of chewing cycles and regular contact with rocks and hard shells can't dull sea urchins' teeth.

New research from Northwestern Engineering researchers, in collaboration with the University of California San Diego, reveals that the chemical composition and microstructure of sea urchin teeth are optimized for sharpness preservation – findings with the potential to influence the design of tools for mining, boring, and machining operations.

“We found that the superior performance of the sea urchin dentition system emerges from tooth self-sharpening during the organism life span,” said Horacio Espinosa, James N. and Nancy J. Farley Professor in Manufacturing and Entrepreneurship at the McCormick School of Engineering. “Interestingly, to account for the loss of material, the sea urchin tooth grows continuously.”


Biologists previously hypothesized that sea urchins possessed a mechanism for tooth sharpening, but the process was never quantified or directly observed. Through in situ mechanical testing instrumentation and scanning electron microscopy (SEM), the team led by Espinosa, professor of mechanical engineering, and (by courtesy) professor of civil engineering, were able to quantify the self-sharpening of sea urchin teeth.
and environmental engineering, were able to image tooth wear in 3D and generate videos revealing the mechanisms involved.

**A close look at sea urchins**

The feeding part of sea urchins is called Aristotle's lantern, which is a skeleton muscular system with five separate jaws each holding a tooth firmly in place. The jaws rest in a circular arrangement at the center of the sea urchins' bodies, working together simultaneously to allow outward protrusion and inward withdrawal of the teeth.

During the research, the team learned that the material on the outer layer of a sea urchin's tooth, called “the stone,” exhibits controlled chipping of the tooth to maintain its sharpness – a process researchers describe as similar to the sharpening of a knife by selectively removing material from the cutting edge.

“Wear-off does not blunt the tip of the tooth, but it instead sharpens it. Later, the add-up of new materials, via continuous tooth growth, will compensate for the loss during the animal's life span,” said Hoang Nguyen, a Northwestern Engineering PhD student in the Theoretical and Applied Mechanics graduate program.

“The stone” is made of high aspect ratio, small diameter fibers surrounded by an organic sheath, which allows for high resistance and shearing when damage accumulates. A nearby region called “the plate,” made up of calcite single crystals on the convex surface of the tooth, can be removed when a certain amount of the stone is removed, and this plate chipping preserves the curvature and sharpness of the teeth over time.

“We were awed by the fact that nature has found its way to tailor the design to optimize one animal in their habitat,” Nguyen said.

This discovery could be applied to tooling by imitating the gradient distribution of the materials within the sea urchin structure to design the tip of a carving tool. Once the tip becomes blunt, it could be sharpened by scratching it on a surface of a harder material.

“I am exploring ways to do additive manufacturing of materials that can exhibit the performance of natural materials,” Espinosa said. “Natural materials have an exquisite combination of size scales, morphologies, and special distributions of chemical compositions.”

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**Big Cities Breed Partners in Crime**

New model shows it is easier to find partners in high population areas