NEWS BIOLOGY

New artificial enamel is harder and more durable than the real thing

Novel material mimics enamel's complex structure with stronger components

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Tooth enamel is the hardest tissue in the human body. GORYNVD/ISTOCK

Enamel enables teeth to take a stomping and keep on chomping. The hardest tissue in the human body is tough enough to resist dents, yet elastic enough not to crack during decades of jaw smashing. It's so incredible that scientists haven't created a substitute that can match it—until now. Researchers say they have designed an artificial enamel that's even tougher and more durable than the real thing.

"This is a clear leap forward," says Alvaro Mata, a biomedical engineer at the University of Nottingham who was not involved with the study. The advance, he says, could have uses beyond repairing teeth. "From creating body armor to strengthening or hardening surfaces for floors or cars, there could be many, many applications."

Enamel is tricky to mimic because its structure has many nested modes of organization, like wool fibers spun into yarn and then knitted into a cable-knit sweater. Calcium, phosphorus, and oxygen atoms must come together in a complex, repeating pattern to form crystalline wires. Enamel-producing cells assemble a magnesium-rich coating around those wires, which then weave together to form a strong material, which is further organized into structures that resemble bunches and twists.

Previously, researchers attempting to construct artificial enamels have struggled to achieve those different levels of organization. In the past, researchers have tried using peptides—short chains of amino acids like the ones cells use to build proteins—to guide the formation of the crystalline wires. But they haven't been able to arrange the wires into the complex structures required for enamel's elasticity and hardness.

In the new study, scientists tried to mimic nature's enamel assembly. Instead of peptides and other biological tools, they used extreme temperatures to coax the wires into an orderly formation. As with earlier construction of artificial enamels, the team built its new material from wires of hydroxyapatite—the same mineral that makes up real enamel. But unlike in most other synthetic enamels, the researchers encased the wires in a malleable metal-based coating.

This coating on the crystalline wires is the secret ingredient that makes this artificial enamel so resilient, says study co-author Nicholas Kotov, a chemical engineer at the University of Michigan, Ann Arbor. The coating makes the wires less likely to snap, because the soft material around them can absorb any powerful pressure or shock. Although the wires in natural enamel feature a magnesium-rich coating, the researchers upgraded to zirconium oxide, which is extremely strong and still nontoxic, Kotov says. The result was a chunk of enamellike material that could be cut into shapes with a diamond-bladed saw.

The new material's wires don't weave into the complex 3D architecture of natural enamel, notes Janet Moradian-Oldak, a protein chemist at the University of Southern California's school of dentistry who was not involved with the study. Still, she says, the structure of parallel wires is a little closer to true enamel than previous attempts.

To measure the hardness and elasticity of the new artificial enamel, the researchers nicked a piece of it and applied pressure until the notch spread into a fracture. The fracturing pressure and the length of the crack let them determine the toughness and strain resistance of the enamel. They also tested how easy it was to indent the enamel with a pointy diamond tip. When they pitted artificial enamel against natural tooth enamel on these tests, they found the lab-grown version outperformed its natural counterpart in six different areas, including its elasticity and ability to absorb vibrations. , the team reports today in *Science*.

Researchers have long been interested in generating artificial enamel because our bodies cannot regenerate it. The cells that create our enamel die as soon as the teeth emerge from the gums. "Half of the world has problems with enamel, and many lead to very serious conditions, up to losing teeth," Mata says. "It plays a huge, huge role in people's quality of life." And current enamel repair techniques, like the fillings available at a dentist's office, don't have that special combination of hardness and elasticity that allows natural enamel to endure for decades.

Still, Mata and Moradian-Oldak both note that this new enamel-inspired material isn't quite ready to chomp on. The researchers didn't test how well it bonds to natural enamel, which is crucial for tooth repair. And the method requires the raw materials be heated to 300˚C, carefully frozen, and then cut into shape with a diamond saw, which may be difficult (or impossible) in most dentist offices.

But exciting applications lie outside the mouth. Artificial enamel could help protect delicate electronic chips in laptops from too much jostling or even a drop, Kotov says. And re-creating enamel's properties on a larger scale could someday help engineers design building materials that could resist earthquake damage. Moradian-Oldak adds: "It opens opportunities for all sorts of applications beyond medicine."

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