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Silk-based surgical implants could offer a better way to repair broken bones

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When a person suffers a broken bone, treatment calls for the surgeon to insert screws and plates to help bond the broken sections and enable the fracture to heal. These "fixation devices" are usually made of metal alloys.

But metal devices may have disadvantages: Because they are stiff and unyielding, they can cause stress to underlying bone. They also pose an increased risk of infection and poor wound healing. In some cases, the metal implants must be removed following fracture healing, necessitating a second surgery. Resorbable fixation devices, made of synthetic polymers, avoid some of these problems but may pose a risk of inflammatory reactions and are difficult to implant.

Now, using pure silk protein derived from silkworm cocoons, a team of investigators from Tufts University School of Engineering and Beth Israel Deaconess Medical Center (BIDMC) has developed surgical plates and screws that may not only offer improved bone remodeling following injury, but importantly, can also be absorbed by the body over time, eliminating the need for surgical removal of the devices.

The findings, demonstrated in vitro and in a rodent model, are described in the March 4 issue of *Nature Communications*.

"Unlike metal, the composition of silk protein may be similar to bone composition," says co-senior author Samuel Lin, MD, of the Division of Plastic and Reconstructive Surgery at BIDMC and Associate Professor

of Surgery at Harvard Medical School. "Silk materials are extremely robust. They maintain structural stability under very high temperatures and withstand other extreme conditions, and they can be readily sterilized."

Collaborating with Lin were co-senior author and Tufts chair of biomedical engineering David Kaplan, PhD, a leader in the use of silk for biomedical applications, and a team of biomedical and mechanical engineers.

"One of the other big advantages of silk is that it can stabilize and deliver bioactive components, so that plates and screws made of silk could actually deliver antibiotics to prevent infection, pharmaceuticals to enhance bone regrowth and other therapeutics to support healing," says Kaplan.

Kaplan and his team have previously developed silk-based sponges, fibers and foams for use in the operating room and in clinical settings. But until now, silk hadn't been used in the development of a solid medical device for fracture fixation.

The Tufts researchers used silk protein obtained from *Bombyx mori* (*B. mori*) silkworm cocoons to form the surgical plates and screws. Produced from the glands of the silkworm, the silk protein is folded in complex ways that give it unique properties of both exceptional strength and versatility.

To test the new devices, the investigators implanted a total of 28 silk-based screws in six laboratory rats. Insertion of screws was straightforward and assessments were then conducted at four weeks and eight weeks, post-implantation.

"No screws failed during implantation," says Kaplan, explaining that

because silk is slow to swell, the new devices maintained their mechanical integrity even when coming into contact with fluids and surrounding tissue during surgery. The outcomes suggest that the use of silk plates and screws can spare patients the complications that can develop when metal or synthetic polymer devices come into contact with fluids.

"Having a resorbable, long-lasting plate and screw system has potentially huge applications," says Lin. While the initial aim is to use silk-based screws to treat facial injuries, which occur at a rate of several hundred thousand each year, the devices have the potential for the treatment of a variety of different types of bone fractures.

"Because the silk screws are inherently radiolucent [not seen on X-ray] it may be easier for the surgeon to see how the fracture is progressing during the post-op period, without the impediment of metal devices," adds Lin. "And having an effective system in which screws and plates 'melt away' once the fracture is healed may be of enormous benefit. We're extremely excited to continue this work in larger animal models and ultimately in human clinical trials."

More information: "The Use of Silk-Based Devices for Fracture Fixation," Gabriel S. Perrone, Gary G. Leisk, Tim J. Lo, Jodie E. Moreau, Dylan S. Haas, Bernke J. Papenburg, Ethan B. Golden, Benjamin P. Partlow,Sharon E. Fox, Ahmed M.S. Ibrahim, Samuel J. Lin, David L. Kaplan, *Nature Communications*, dx.doi.org/10.1038/ncomms4385

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