Repairing actively pumping heart tissue with mussel-inspired tissue adhesive

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Inspired by Mother Nature: Sea mussels resist the stormiest surf with ease. They hold on to the surface with protein threads. Empa researchers are using this property for a novel tissue glue for wound treatment. Credit: Pixabay

If the heart muscle is damaged, repairing the constantly active organ is a challenge. Empa researchers are developing a novel tissue adhesive inspired by nature, which is able to repair lesions in muscle tissue. They have taken advantage of the incredible ability of marine mussels to

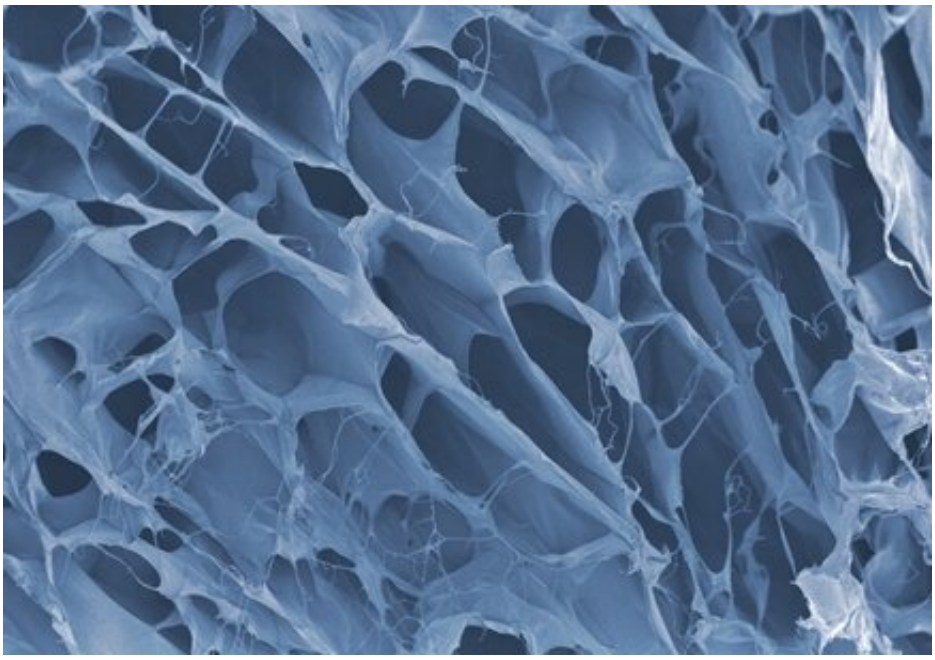
adhere to any kind of surface.

On wind- and wave-swept coasts, sea mussels adhere stoically to rocks, boats and jetties. With super powers that rival Spider-Man's, the mussel's foot holds on to the surface, as its glands produce fine threads which, unlike spider silk, remain firm under water and yet highly elastic. Two proteins, mfp-3 and the particularly sulfurous mfp-6, are components of this sea silk. As structural proteins, they are especially interesting for biomedical research because of their fascinating mechanical properties and their biocompatibility.

Challenging conditions

Researchers from Empa's "Biomimetic Membranes and Textiles" lab in St. Gallen have made use of these properties. Claudio Toncelli's team was looking for a biocompatible tissue glue that would adhere to the beating heart while remaining elastic, even under the most challenging conditions. After all, if heart muscle tissue is damaged, for instance by a heart attack or a congenital disorder, the wounds must be able to heal, even though the muscle continues to contract.

"Actually, collagen is a suitable basis for a wound glue, a protein that is also found in human connective tissue and tendons," says Toncelli. For example, gelatin consists of cross-linked collagen that would be very attractive for a tissue adhesive. "The structure of gelatin already comes very close to some of the natural properties of human connective tissue," he adds. However, the hydrocolloid is not stable at body temperature, but liquefies. So in order to develop an adhesive material that can securely connect wounded areas on internal organs, the researchers had to find a way to incorporate additional properties into gelatin.



The novel biopolymer with mussel proteins exhibits a fine yet robust microstructure via scanning electron microscopy at 1000-fold magnification (colored). Credit: Empa

The tissue adhesive made of mussel protein is able to adapt to the finest structures of complex surfaces, as this impression of a heart-shaped casting mold shows (colored). Credit: Empa

Under pressure

"The muscular foot of mussels excretes strongly adhesive threads, with which the mussel can adhere to all kinds of surfaces in water," explains Toncelli. In this sea silk, several proteins interact tightly. Inspired by nature's solution for dealing with turbulent forces under water, the

researchers equipped gelatin biopolymers with functional chemical units similar to those of the sea silk proteins mfp-3 and mfp-6. As soon as the gelatin sea silk gel makes contact with tissue, the structural proteins cross-link with each other and ensure a stable connection between the wound surfaces.

The researchers have already investigated how well the novel hydrogel actually adheres in lab experiments that are usually used to define technical standards for so-called bursting strength. "The tissue adhesive can resist a pressure equivalent to human blood pressure," says Empa researcher Kongchang Wei. The scientists were also able to confirm the outstanding tissue compatibility of the new adhesive in cell culture experiments. They are now trying hard to advance the clinical application of the "mussel glue."

More information: Kongchang Wei et al. Mussel-Inspired Injectable Hydrogel Adhesive Formed under Mild Conditions Features Near-Native Tissue Properties, *ACS Applied Materials & Interfaces* (2019). DOI: 10.1021/acsami.9b16465

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