

# Researchers discover why tendons are strong as wire ropes

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Under the electron microscope: collagen fiber bundle after mineralization with (the bone mineral) calcium phosphate. Credit: Max Planck Institute of Colloids and Interfaces

A team at the Max Planck Institute of Colloids and Interfaces (MPICI) has discovered new properties of collagen: During the intercalation of minerals in collagen fibers, a contraction tension is generated that is hundreds of times stronger than muscle strength. "This universal mechanism of mineralization of organic fiber tissues could be transferred to technical hybrid materials, for example, to achieve high breaking strength there," says Prof. Dr. Dr.h.c. Peter Fratzl, Director at the institute.

The fiber-forming structural protein [collagen](#) is found in tendons, skin and bones, among other places. The strength of bones is based on the structural interplay of soft, organic collagen fibers and the hard, crystalline mineral particles embedded in them, thus a hybrid material. The collagen gives the mineral particles an active pre-stress.

Civil engineers use a comparable mechanism in pre-stressed concrete with the aid of high-strength steel and thus produce crack-resistant structural elements. "It is also interesting from a medical or biological point of view to understand what happens in the process of mineralization in bones," says Dr. Wolfgang Wagermaier, group leader at the MPICI. He adds, "Many bone diseases are associated with changes in [mineral content](#) in bones and thus altered properties."

Dr. Hang Ping, first author of the paper, and a team have found that the artificial incorporation of different minerals into [collagen fibers](#) leads to a shortening of these fibers with stresses of up to one hundred kilograms per square centimeter. This corresponds to about one hundred times the strength of a muscle. The associated changes in the collagen structure were observed using X-ray diffraction at the BESSY II synchrotron in Berlin-Adlershof while mineralization was taking place. This contraction of the fibers apparently occurs during mineral incorporation into the collagen, putting the mineral under enormous pressure, which increases the fracture strength of the composite.

The paper, published in the journal *Science*, not only shows that this particular property of collagen contributes to the strength of mineralized tissues such as bone, but also outlines a concept that can be applied to engineered hybrid materials with outstanding mechanical properties. At the same time, the findings of this work help to better understand [biological processes](#) during the mineralization of tissues and the influence of the degree of mineralization on macroscopic material properties.

**More information:** Hang Ping et al, Mineralization generates megapascal contractile stresses in collagen fibrils, *Science* (2022). [DOI: 10.1126/science.abm2664](https://doi.org/10.1126/science.abm2664)

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