Rapid prototyping to explain the biology of seahorse tails

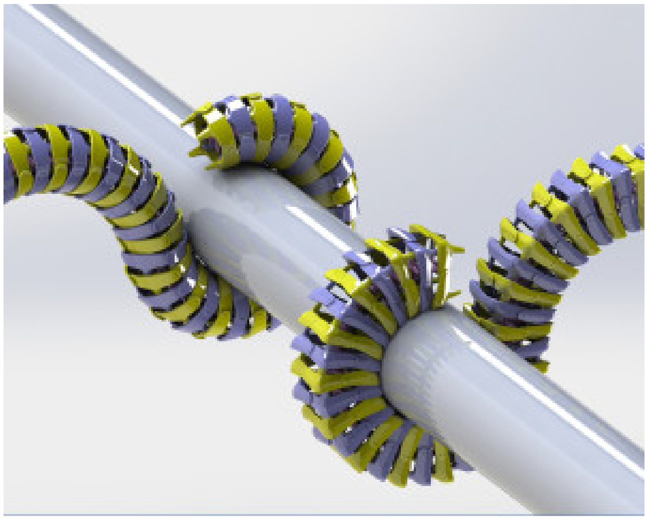

Fig. 1. Computer generated models of the square prism and cylindrical prototypes inspired by the seahorse tail.

Rapid prototyping employs the use of modern engineering tools, such as computer modeling and 3D-printing, to build physical models of new product design concepts. Applying similar techniques, our team of biologists and engineers built two 3D-printed models of a seahorse tail, one with a representative square cross-section and one with a hypothetical circular cross-section – hypothetical because seahorses do not have cylindrical tails. To explain why seahorses could have evolved square tails, we compared the mechanics of the two biomimetic prototypes in bending, twisting, impact, and crushing.

In bending and twisting experiments, we found that the square prototype (representative of a real seahorse tail) outperformed the cylindrical one. The square-prism structure provides a seahorse tail more contact surface area when grasping an object, as seen in Fig. 1. It also allows a seahorse to return its tail to a neutral resting position with ease, as evident when compared with the cylindrical prototype, which required more forceful manipulations to realign its structure after extensive bending and twisting.

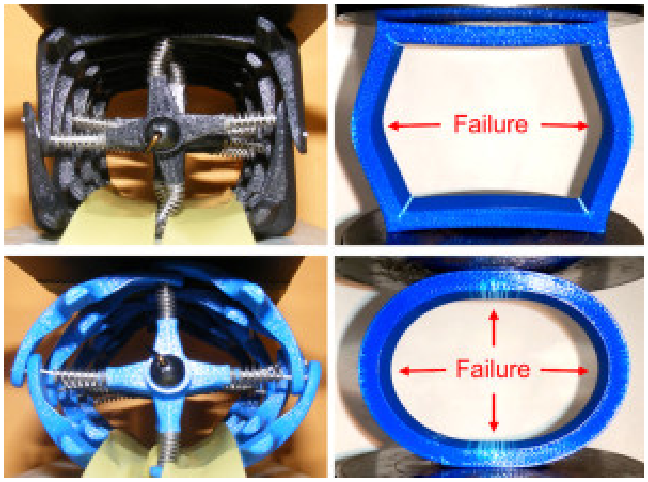

Fig. 2. Comparison of the square and circular prototypes (left) versus the solid rings without overlapping joints (right) subjected to compressive loading.

In impact and crushing experiments, the square-prism structure is also advantageous; it was stiffer, stronger, and more resilient than the cylindrical one. When hit with a rubber mallet, its overlapping joints allowed the square profile to compress linearly, whereas the circular profile expanded on impact, becoming elliptical. This shape change (from circular to elliptical) could cause unwanted damage to occur within the structure, which is mitigated by the square geometry in a seahorse tail. To further investigate the structures, we compared the two prototypes against solid rings without overlapping joints, as seen in Fig. 2. Interestingly, the skeleton of a seahorse tail evolved overlapping joints at the exact locations where a solid ring of similar dimensions exhibits compressive failure. Thus, the combined square geometry plus its overlapping joints protects seahorse tails from injuries that could be caused by the crushing forces delivered by its predators, such as the beaks of waterbirds.

Now, with a better understanding of why seahorses could have evolved square tails, we are developing new robotic technologies that mimic these basic design principles. Such devices could take the form of e.g., robotic manipulators, flexible armors, or motion-assist prosthetics, for a variety of promising ‘human’ applications.

Publication

Biomechanics. Why the seahorse tail is square.
Porter MM, Adriaens D, Hatton RL, Meyers MA, McKittrick J.
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