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Unveiling the resistance to penetration of the radular teeth of the *Cryptochiton stelleri*

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ABSTRACT

The tongue of the *C. stelleri* is provided with numerous rows of highly mineralized teeth composed of a soft organic chitin matrix and hard magnetite rods. The shell of the tooth is characterized with the highest modulus and hardness of any known biomineral. Similar to other biological materials (i.e., nacre and conch), the tooth is provided with mineral bridges, nanoscale asperities and roughness, and a microstructure composed of stiff piled rods wrapped in a matrix of soft organic material. Despite the advanced microscopic techniques used today, not much has been said about the influence of the geometrical aspects in the complex microstructure. To test the effect of the geometrical parameters in the mechanical properties measured by indentation test (E_r, H), a set of biomimetic designs composed of stiff rods surrounded by weak interfaces have been manufactured. Postindented samples show that it is possible to replicate the localized damage and crack tolerance observed in the tooth with rapid prototypes. Results indicate that a variation in the aspect ratio of the rods can lead to a 50% increase in the stiffness and a 30% increase in the hardness measured. It is also observed that the rod like microstructure can mitigate catastrophic failure with interface cracking, rod failure, and material debonding. Computational models suggest that inelastic deformation of the rods at early stages of indentation can vary the resistance to penetration, in which the mechanical behavior of the system is influenced by interfacial shear strain and high plastic stresses in the rods. It is also shown that the design of the rod-like microstructure can be tailored to abrasion resistant or fracture tolerant materials. In this study, it is demonstrated that additive manufacturing is a useful technology that can be used to unveil the mechanical behavior of intrincated microstructures.