c-axis preferential orientation of hydroxyapatite accounts for the high wear resistance of the black carp(*Mylopharyngodon piceus*) teeth

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Abstract

In nature, biomineralized materials such as exoskeletons of mollusks, bones of vertebrates and teeth of carnivores are designed for functions of protection, supporting and attack. Their excellent mechanical properties and distinctive principles of material design has long been recognized and mimicked. In this paper, our attention is focused on the pharyngeal teeth of the black carp (*Mylopharyngodon piceus*), which is a species of fresh water fish feeding on shelled snails and mussels. The pharyngeal teeth remain functional after frequent mechanical contacts with the hard mollusk shells, implying that they must have excellent wear resistance. To quantify the wear resistance of the black carp teeth, nanoscratching test is conducted on different facets of enameloid, which is the outmost layer of the teeth. In comparison to the planes of other orientations, the occlusal surface exhibits much higher scratch resistance. The subsequent X-ray diffraction analysis reveals that in the vicinity of enameloid surface the hydroxyapatite (HAp) crystallites have a preferential orientation. Specifically, most HAp crystallites have *c*-axis perpendicular, or (001) crystal plane parallel to the occlusal surface. The superior wear resistance of the occlusal surface thus can be explained by the *c*-axis preferential orientation in the enameloid and the prominent wear resistance of the (001) plane of HAp crystal, which is demonstrated by molecular dynamics simulation. Mechanics accounting for such prominence of wear resistance on the (001) plane of HAp is addressed based on the classical wear theory.

Keywords: Biomaterials, Bio-inspired mechanics, Enamel