Research paper

Effect of mineral–collagen interfacial behavior on the microdamage progression in bone using a probabilistic cohesive finite element model

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A B S T R A C T

The interactions between mineral and collagen phases in the ultrastructural level play an important role in determining the mechanical properties of bone tissue. Three types of mineral–collagen interaction (i.e., ionic interactions, hydrogen/van der Waals bonds, and van der Waals/viscous shear in opening/sliding mode, respectively) have been simulated in this study, using cohesive zone-modeling techniques. Considering the inhomogeneity of bone, a probabilistic failure analysis approach has been also employed to account for the effect of mineral–collagen interfacial behavior on microdamage accumulation in lamellar bone tissues. The results of this study suggested that different interfacial behaviors cause different types of microdamage accumulation. The findings of this study may help in understanding the mechanisms of mineral–collagen interactions and its effects on the failure mechanism of bone.

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1. Introduction

Bone has a highly hierarchical structure at several length scales from subnanometers to meters (Rho et al., 1998; Weiner and Wagner, 1998). The tissue structure and property at each hierarchical level may influence the mechanical behavior of bulk bone tissues (Ruppel et al., 2008). Among them, the ultrastructural interaction between the mineral and collagen phases has been shown to play an important role in determining the elastic constants (Hellmich et al., 2004), strength (Fritsch et al., 2009), and toughening mechanisms of bone (Buehler, 2007; Nalla et al., 2003, 2005).

A number of models have been proposed recently to explain the mineral–collagen interaction in bone. Best et al. suggested two models of mineral–organic interaction using three synthesized composites; i.e., the organic phase...