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Research paper

Effect of high-energy X-ray doses on bone elastic properties and residual strains

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ABSTRACT

Bone X-ray irradiation occurs during medical treatments, sterilization of allografts, space travel and *in vitro* studies. High doses are known to affect the post-yield properties of bone, but their effect on the bone elastic properties is unclear. The effect of such doses on the mineral–organic interface has also not been adequately addressed. Here, the evolution of elastic properties and residual strains with increasing synchrotron X-ray dose (5–3880 kGy) is examined on bovine cortical bone. It is found that these doses affect neither the degree of nanometer-level load transfer between the hydroxyapatite (HAP) platelets and the collagen up to stresses of −60 MPa nor the microscopic modulus of collagen fibrils (both measured by synchrotron X-ray scattering during repeated *in situ* loading and unloading). However, the residual elastic strains in the HAP phase decrease markedly with increased irradiation, indicating damage at the HAP–collagen interface. The HAP residual strain also decreases after repeated loading/unloading cycles. These observations can be explained by temporary de-bonding at the HAP/collagen interface (thus reducing the residual strain), followed by rapid re-bonding (so that load transfer capability is not affected).

1. Introduction

Biological tissues like bone and teeth are commonly exposed to a range of doses from X-rays, gamma and electron radiation during medical treatments, terminal sterilization and space travel. As an example, ionizing radiation is applied to the human body for the treatment of tumors around the head and neck region (Franzel and Gerlach, 2009; Kolovou and Anastassopoulou, 2007). During such treatments, in addition to targeting the tumor cells, the surrounding healthy cells are also affected, exposing the underlying bones and teeth to the applied doses which are of the order of 70 Gy (Engelmeier and King, 1983; Franzel and Gerlach, 2009). Radiation doses of 25–35 kGy are commonly used for sterilizing bone allografts which are obtained from tissue banks or donors, to prevent transmission of infection (Akkus and Rimnac, 2001; Balsly et al., 2008; Currey et al., 1997; Kolovou and Anastassopoulou, 2007; McAllister et al., 2007; Salehpour et al., 1995; Simonian et al., 1994; Vastel et al., 2004; Zhang et al., 1994; Zioupos et al., 1999). Restorative dental materials, made using extracted teeth also need to be sterilized by radiation to minimize the risk of blood-borne pathogens (Brauer et al., 2008; Franzel and Gerlach, 2009; Moscovich et al., 1999; White et al., 1994). Also of great interest is the increasing use of synchrotron X-rays to determine the structure and mechanical properties

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