A fatigue microcrack alters fluid velocities in a computational model of interstitial fluid flow in cortical bone

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Abstract

Targeted remodeling is activated by fatigue microcracks and plays an important role in maintaining bone integrity. It is widely believed that fluid flow-induced shear stress plays a major role in modulating the mechanotransduction process. Therefore, it is likely that fluid flow-induced shear stress plays a major role in the initiation of the repair of fatigue damage. Since no in vivo measurements of fluid flow within bone exist, computational and mathematical models must be employed to investigate the fluid flow field and the shear stress occurring within cortical bone. We developed a computational fluid dynamic model of cortical bone to examine the effect of a fatigue microcrack on the fluid flow field. Our results indicate that there are alterations in the fluid flow field as far as 150 mm away from the crack, and that at distances farther than this, the fluid flow field is similar to the fluid flow field of intact bone. Through the crack and immediately above and below it, the fluid velocity is higher, while at the lateral edges it is lower than that calculated for the intact model, with a maximum change of 29%. Our results suggest that the presence of a fatigue microcrack can alter the shear stress in regions near the crack. These alterations in shear stress have the potential to significantly alter mechanotransduction and may play a role in the initiation of the repair of fatigue microcracks.