Bone repair and ultrasound stimulation : an insight into the interaction of LIPUS with the lacuno-canalicular network of cortical bone through a multiscale computational study.

Bone is a complex biological tissue which remodels all along healing. Bone remodeling is the result of bone cells activation due to mechanical stresses. The osteocytes are thought to be the principal mechanosensory cells of bone. They are immersed in the lacuno-canalicular network (LCN) filled with interstitial fluid (IF). There is theoretical and experimental evidence that osteocytes are stimulated via fluid shear stress induced drag forces acting on osteocyte cell processes within canaliculi. Low Intensity Pulsed UltraSound (LIPUS) is a current clinical treatment to speed up or consolidate bone healing. But debate is still open to know how LIPUS mechanically stimulates bone regeneration. The aim of this preliminary study is to numerically investigate LIPUS stimulation from a tissue-scale model to a cellular-scale model. Two numerical models were developed with the commercial software Comsol Multiphysics. The first tissue-scale model (ModBone) simulates the interaction of the ultrasound (US) stimulation with healing cortical bone. It considers an anisotropic poroelastic matrix to evaluate the mechanical effects induced into the IF of the LCN. The second model is the cellular-scale model (ModOst) including a fluid-structure interaction model of one osteocyte process surrounded by the IF inside a canaliculus embedded in the extracellular matrix.

The IF pressure gradient induced by US stimulation in ModBone is applied as a boundary condition for the fluid in ModOst. The IF shear stress magnitude applied on osteocyte process is calculated and compared with shear stress levels cell activation recorded in literature. The shear stress induced drag forces applied on the osteocyte process are evaluated.