Modeling and simulation of the coupling between trabecular bone adaptation and microdamage repair though remodeling

Taiji Adachi*[1], Tsuyoshi Muto[1], and Young Kwan Kim[1]

[1]Kyoto University – Japan

Abstract

Physical exercise maintains and improves bone structure and its strength, whereas excessive exercise leads to the accumulation of microdamage in the mineralized bone matrix, which in turn decreases bone strength and increases fracture risk. In this complex phenomenon, the coupled adaptation and microdamage repair are regulated by mechanosensory osteocytes embedded in the bone matrix through bone remodeling activities of osteoclasts and osteoblasts. To better understand this complex mechanobiological coupling in bone, by using an in silico experimental platform based on a voxel finite element method (1, 2), we performed remodeling simulations on the osteoporotic trabecular bone cube, which was reproduced under reduced physiological loading conditions, under various mechanical loadings. The spatiotemporal dynamics of coupled bone adaptation and microdamage repair were studied, and quantitative and qualitative changes in trabecular bone structure were evaluated. In addition, potential clinical applications of this simulation platform will be discussed, including methods to predict the impact of the combined effects of exercise and drugs in the treatment of osteoporosis.
(1) Kameo Y, et al., Sci Adv, 6-10 (2020) eaax0938.
(2) Kim YK, et al., JBMR Plus, 8-1 (2024) ziad003.

*Speaker