A three dimensional model for osteocyte-regulated remodling simulation at the tissue level

B. Rietbergen, van, M.G. Mullender, R. Huiskes

Orthopaedic Biomechanics

Research output: Chapter in Book/Report/Conference proceeding › Chapter › Academic › peer-review

Abstract

Several hypothetical bone remodeling models have been developed to explain trabecular bone adaptation as observed in the skeleton. So far, these simulation models have been successfully used to explain the global density distribution in whole bones but were unable to simulate trabecular adaptation process at the tissue level. In the presented study, a three dimensional bone remodeling model is introduced to simulate bone remodeling at the tissue level. The model is based on an osteocyte regulated bone remodeling hypothesis. The trabecular architecture is represented by large FE models built from identical elements to allow the application of fast solution methods. It was found that the model can explain the generation of typical three dimensional architectures during morphogenesis as a result of loading. In addition, the model can explain structural changes that take place due to bone disuse.

Original language	English
Title of host publication	Computer methods in biomechanics and biomedical engineering
Place of Publication	Amsterdam
Publisher	Gordon and Breach Science Publishers
Pages	743-83
ISBN (Print)	2-919875-00-0
Publication status	Published - 1996

Publication series

Name	Computer methods in biomechanics and biomedical engineering
Volume	1

filing in the osteoblastic tissue model suggests a considerable degree of physiologic relevance. Indian filing is common in soft tissue, but it is also found in bone metastasis (Fig. 1G–I). This osteoblastic tissue exhibited important hallmarks of the osteoblast-to-osteocyte phenotypic transition and deposition of macroscopic bone. We conclude that the resulting tissue is a relevant in vitro model of osteoblasts within regions of growing bone, such as the metaphysial areas of long bone that are otherwise difficult to access in vivo. To request permission to re-use all or part of this article, contact the AACR Publications Department at permissions@aacr.org. Through numerical simulations we demonstrate that our model can be used to explore theoretically many of the qualitative features of the role of osteocytes in bone biology as presented in recent literature. Until recently many studies of bone remodeling at the cellular level have focused on the behavior of mature osteoblasts and osteoclasts, and their respective precursor cells, with the role of osteocytes and bone lining cells left largely unexplored. This is particularly true with respect to the mathematical modeling of bone remodeling. This is under the influence of autocrine and osteoclast regulated paracrine signaling. Finally, pre-osteoblasts undergo apoptosis at a rate . The osteoblast cell population at a time is denoted by , or simply . Osteocyte apoptosis is known to trigger targeted bone resorption. In the present study, we developed an osteocyte-viability-based trabecular bone remodeling (OVBR) model. This novel remodeling model, combined with recent advanced simulation methods and analysis techniques, such as the element-by-element 3D finite element method and the ITS technique, was used to quantitatively study the dynamic evolution of bone mass and trabecular microstructure in response to various loading and unloading conditions. Different levels of unloading simulated the disuse condition of bed rest or microgravity in space. The amount of bone loss and microstructural deterioration correlated with the magnitude of unloading.