248a Modeling and Analysis of Bone Growth and Remodeling

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Bone provides mechanical support to joints and tendons, protects vital organs from damage, and plays an important role as reservoir for calcium and phosphate in mineral homeostasis [1]. However, in contrast to common knowledge the human skeleton is a living, dynamic tissue whose structure and shape is livelong evolving and adapting. At any time approximately 5-25% of bone surface in adults is undergoing active remodeling [2,3] at multiple sites. The change in structure and shape is achieved by a highly regulated interaction between different cells involving numerous autocrine and paracrine factors. In the process of remodeling osteoclasts resorb old bone, while osteoblasts form new bone material. Many factors influence the complex interplay between osteoclasts and osteoblasts. The pathogenesis of many disorders such as osteoarthritis, osteoporosis, and Paget's disease is related to disturbances in the osteoclast-osteoblast interaction in various forms.

Besides metabolic and hormonal influences bone remodeling and growth depends strongly on the stress acting on the bone [4], known as the mechanostat theory. Basically bone tissue can gradually adapt to the stress acting on it to achieve, in certain limits, the desired strength and keep the acting stress in physiological limits. While osteoblast are the cells that produce new bone, and osteoclast degenerate bone, so called osteocytes, which make up some 95% of the cells in bone tissues, are thought to be the mechanosensory cells of bone, see e.g. [5].

So far there have been various attempts to mathematically analyze the bone growth and remodeling process. For example models describing the dynamics of bone remodeling at the cellular level of osteoblasts and osteoclast interactions can be found in [6,7,8,9]. Examples for models depicting biomechanical properties of bone using mechanostat theory can be found in [10,11].

In this work we present an extension of the model presented in [6] that tries to capture, besides the complex osteoblast-osteoclast interactions, the mechanical stimuli detected by the mechanosensory osteocytes in a simplified way. As shown, the model captures how mechanical stress acting on the bone does influence the bone growth and remodeling. Depending on the mechanical stimuli the model describes resorbtion or formation of bone until a steady state with respect to the acting load is achieved. The model is also able to represent the case of stress fractures due to high stress and reduced bone remodeling. This simple model is thought to set a basis for the development of more detailed models capturing the behavior of bone growth and remodeling. It can be used for analyzing influencing factors in bone remodeling and growth, verification of physiological phenomena, analyzing the appearing biological control loops, and derivation of new therapy forms counteracting certain diseases.

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