

New Suggestions for the Mechanical Control of Bone Remodeling

Abstract

Bone is constantly renewed over our lifetime through the process of bone (re)modeling. This process is important for bone to allow it to adapt to its mechanical environment and to repair damage from everyday life. Adaptation is thought to occur through the mechanosensitive response controlling the bone-forming and -resorbing cells. This report shows a way to extract quantitative information about the way remodeling is controlled using computer simulations. Bone resorption and deposition are described as two separate stochastic processes, during which a discrete bone packet is removed or deposited from the bone surface. The responses of the bone-forming and -resorbing cells to local mechanical stimuli are described by phenomenological remodeling rules. Our strategy was to test different remodeling rules and to evaluate the time evolution of the trabecular architecture in comparison to what is known from μ -CT measurements of real bone. In particular, we tested the reaction of virtual bone to standard therapeutic strategies for the prevention of bone deterioration, i.e., physical activity and medications to reduce bone resorption. Insensitivity of the bone volume fraction to reductions in bone resorption was observed in the simulations only for a remodeling rule including an activation barrier for the mechanical stimulus above which bone deposition is switched on. This is in disagreement with the commonly used rules having a so-called lazy zone.

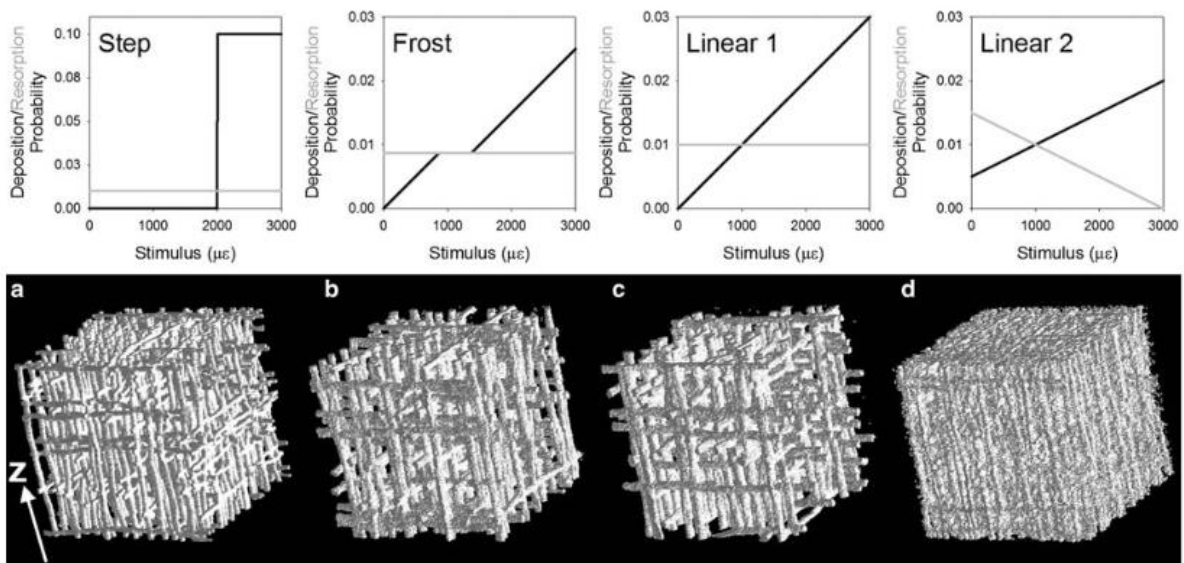


Fig. 2 a–d Bone deposition (black) and resorption (gray) probabilities for the different remodeling rules investigated (for numerical values, see also Table 1). Upper images illustrate the remodeling rules used: a step, b Frost, c linear 1, and d linear 2. Remodeling rules a–c all use constant bone resorption probabilities. Remodeling rule d has a linear response for both deposition and resorption resulting in a

net response which is equivalent to c. Lower images show the simulation output after 40 years for the different remodeling rules (a–d) applied on a cubic lattice of dimensions $256 \times 256 \times 256$ and a voxel size of $17 \mu\text{m}$. Arrow marks the main loading direction along the spine