An Algorithmic Approach to Simulating Human Cortical Bone Microstructure and Remodeling

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The microscopic structure of bone contributes to its resistance to crack propagation and high damage tolerance under mechanical loading. In everyday life, bone accumulates tiny fractures, called microcracks. Bone exhibits a process of self-healing, called remodeling, that can replace damaged bone tissue with new healthy bone, effectively giving it a high overall resistance to damage. As people age, more microcracks form and remodeling tends to slow down, effectively increasing the number of microcracks in bone and raising the risk of catastrophic failure. This manifests in diseases such as osteoporosis. Increasing understanding of remodeling and bone's response to microdamage would allow more effective treatments for these diseases. The microstructure of bone consists of many interfaces within the material that slow or stop crack propagation. As 3D printing becomes more advanced, looking to structures found in the natural world, like bone, could guide the creation of stronger, more crack-resistant materials. In advanced material production, like engineering ceramics, this is a desirable property because the material will be able to undergo more severe conditions before it fails. Studying the distribution of these interfaces could provide a model to create improved materials. The goal of this project was to create an algorithmic process that simulated the microstructure of cortical bone. This process could be used to study the microstructure geometry and effects of remodeling speed on overall bone microstructure. A better understanding of remodeling and microstructure, and how they affect each other, would create better experimental materials and treatments for common diseases.