HOMOGENIZED STRAIN GRADIENT REMODELING MODEL FOR TRABECULAR BONE MICROSTRUCTURES

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Bone continuously adjusts its mass, architecture and properties to variations in its mechanical environment due to internal and external remodeling. Internal remodeling refers to the resorption or reinforcement of bone material, accompanied by the removal and densification of the architecture of cancellous bone, but no change in its overall shape. To the contrary, external or surface remodeling refers to the resorption or deposition of bone material on the external surface of the bone, resulting in a change of the external shape of the overall bone structure. Since these processes have a tremendous impact on the overall behavior and health of the entire body, bone remodeling simulations are of great importance, especially in applications dealing with bone adaptivity, such as bone implants and scaffold design, and furthermore to predict the outcome of dental or orthodontic treatment. We construct constitutive models for bone remodeling based on micromechanical analyses at the scale of a representative volume element (RVE) consisting of individual trabeculae defining the representative unit cell [1,2,3]. On the microscale, trabeculae undergo apposition of new bone modeled by a surface growth velocity field driven by a mechanical stimulus identified to the surface divergence of an Eshelby like tensor. The static and evolutive effective properties of a periodic network of bone trabeculae are evaluated by combining a methodology for the evaluation of the average kinematic and static variables over a unit cell and numerical simulations with controlled kinematics. The viscoplastic type constitutive model for growing bone is identified relying on the framework of the thermodynamics of irreversible processes. The obtained results quantify the strength and importance of the strain and strain gradient effects applied over the RVE on the overall bone remodeling process (Fig. 1).

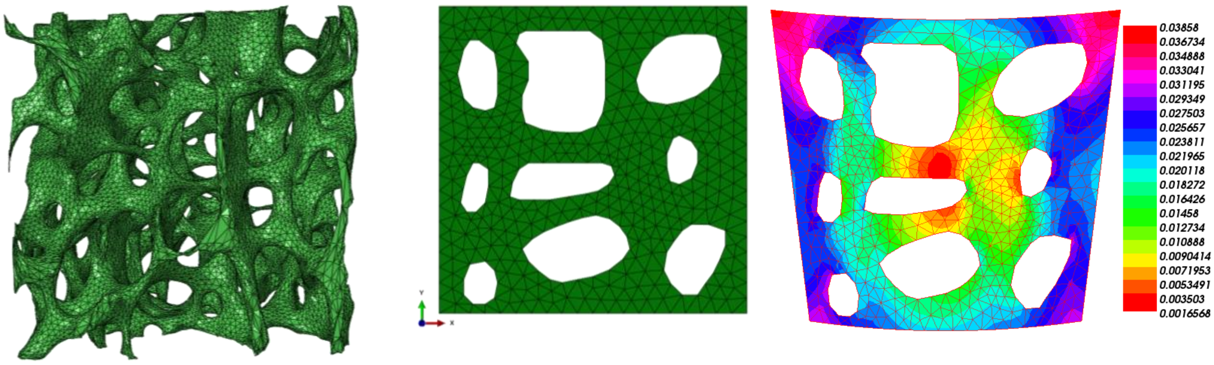

Figure 1: (a) Scan of the original 3D trabecular bone sample, (b) 2D section, and c) Distribution of equivalent strain due to in-plane bending.

References

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