Plenary Presentation

Fabric Dependence in Dynamic Poroelasticity: Application to Cancellous Bone Tissue

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ABSTRACT: Here the equations governing wave motion in the linear theory of anisotropic poroelastic materials are developed and extended to include dependence of the constitutive relations upon fabric - a quantitative stereological measure of the degree of structural anisotropy in the pore architecture. This approach provides a theoretical framework for the microarchitectural-dependent relationship between measurable wave properties and the elastic constants of trabecular bone, and thus represents an alternative for bone quality assessment beyond Bone Mineral Density (BMD) alone. Current diagnosis of bone loss and osteoporosis is based on measurement of the BMD or the apparent mass density. Unfortunately, in most clinical densitometetry: 1) measurements are often performed in a single anatomical direction, 2) only the first ("fast") wave, arriving to the ultrasound probe is characterized, and 3) the analysis of bone status is based on empirical relationships between measurable quantities such as Speed of Sound (SOS) and Broadband Ultrasound Attenuation (BUA) and the density of the porous medium. However, the existence of a second ("slow") wave, in cancellous bone has been reported, that is an unequivocal signature of poroelastic media, as predicted by Biot's poroelastic wave propagation theory. The present model predicts that, in isotropic media with porosity below 80%, the fast wave decreases with the porosity. At porosities higher than 80%, the fast wave exhibits a constant velocity, and the slow wave exhibits more sensitivity to changes in porosity. Thus, there exists a transition in sensitivity between the two longitudinal wave modes at approximately 80% porosity. The fast wave is sensitive to the porosity when the apparent modulus to density ratio of the solid phase is higher than that of the fluid phase, while the slow wave is sensitive to porosity when the reverse is true. Therefore, the porosity level at which this transition occurs is a consequence of the intrinsic properties of the solid and fluid constituents.