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Investigation of the porous network as a determinant of the overall stiffness of cortical bone: Mori-Tanaka model vs. ultrasound propagation

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Assessing the effect of porosity on stiffness in cortical bone remains an important issue that has already been addressed with several models. The originality of the present work is to compare two models of cortical bone: one uses a realistic porous network (voxel 20 microns) reconstructed from synchrotron radiation tomography; the other considers cylindrical pores aligned in a single direction. In the first case, overall elastic properties are evaluated indirectly by means of finite difference time domain simulation of ultrasound bulk wave propagation at 1 MHz. In the second model, effective elasticity is calculated by means of a Mori-Tanaka scheme based on Eshelby solution for cylindrical inclusions with ellipsoidal cross section. Overall properties were evaluated with the two methods for 18 porosity values, each corresponding to a reconstructed bone volume. The diagonal stiffness coefficients of the overall bone material estimated with the two methods compared well. Results for the stiffness coefficient in the longitudinal bone direction are indistinguishable, which indicates that the detailed geometry and distribution of the pores have a negligible effect on the longitudinal stiffness. For the other stiffness coefficients, the Mori-Tanaka method slightly overestimates the stiffness compared to the wave propagation evaluation.