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UNDERSTANDING THE RELATIONSHIPS BETWEEN HEART VALVE SCAFFOLD GEOMETRIC STRUCTURE AND MECHANICAL BEHAVIOR USING COMPUTATIONAL MODELING

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Heart valve tissue engineers seek to produce tissues that function biologically and mechanically as well as the native tissues they are built to replace [1]. One important step in achieving this goal is designing and manufacturing tissues that mimic the complex, non-linear mechanical behavior of the native tissues. This behavior is strongly influenced by the microstructural geometry of the underlying scaffold [2], so understanding this relationship between scaffold structure and function is essential to the proper design of scaffolds.

Electrospinning can be used to create layered scaffold structures consisting of dense, long-fiber networks. In this study, we perform 3-D, non-linear micromechanical simulations of such long-fiber networks, which we have generated using a random walk procedure that mimics the electrospinning process. This realistic geometric representation is an improvement over currently-used straight fiber representations, since fiber connections and curvature are accurately represented, and the mesh has a similar appearance to real scaffolds. The networks are generated so that key geometric statistics match those of the scaffold the model is meant to simulate.

Our mechanical simulations have begun to shed light on how the evolution of the loaded microstructure produces the observed macroscopic mechanical behavior. As fibers in tension straighten and rotate toward the direction of maximum principal stress, forming long-range structures, the slope of the stress-strain curve along that direction increases. Similarly, we see fibers in compression buckle out of plane, with a corresponding reduction in stiffness in that direction. This load-induced anisotropy is further quantified by relating the applied deformation gradient to the evolution of descriptive quantities, such as the probability density function of the 3-D fiber orientation.

We compare the mechanical behavior found in the simulations with experimental results for uniaxial and biaxial in-plane loading. In addition, we plan to investigate twisting and out-of-plane bending and shear behavior in future studies. We discuss how insights gained from parametric studies can be used to guide the design of scaffolds so that the resulting engineered tissues mimic the non-linear mechanical behavior of the native tissues.

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