Viscoelastic and Growth Mechanics in Engineered and Native Soft Tissue

S.C. CALVE, H. NARAYANAN, K. GARIKIPATI, K. GROSH AND E.M. ARRUDA

Department of Mechanical Engineering
University of Michigan
Ann Arbor, Michigan 48109, USA
arruda@umich.edu

Tendons are biological composites consisting of densely packed parallel fibrils of type-I collagen, which reinforce other proteins and a ground substance comprised of cells and proteoglycans capable of holding considerable amounts of water. While the tensile properties of tendon can be attributed to the type-I collagen fibrils, the fluid content plays important roles in the transport of nutrients and in the compressive load-bearing ability, as well as influencing the viscoelastic material properties of the tissue. Motivating our mathematical modelling, we examine the mechanical response, including strain rate dependence, hysteresis, strain softening and recovery, of both native tendon and our biological model—*in vitro* scaffold-free self-assembled engineered tendon [1]—by culturing these constructs in bioreactors that apply static and cyclic physiological loads over the course of construct development. This also helps us gain insight into the role of mechanics on the assembly and organisation of tendons.

Our mathematical modelling effort aims to describe and simulate this rich observed behaviour by building upon our recently-proposed general formulation of growth [2], making it applicable to the biophysics of growth in tendon. Formulated within the context of open system continuum thermodynamics, the model incorporates quantities pertinent to the physics of multi-phase reacting systems, and deduces balance laws and a constitutive framework obeying the dissipation inequality. The nonlinear partial differential equations that arise from the theory are solved using a staggered finite element scheme, and several numerical examples are solved exhibiting the viscoelastic aspects of the mechanical response, as well as other biophysics of growing tendon under different loading conditions.

References

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