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A microstructure-informed continuum model of transversely isotropic fibre-reinforced hydrogels

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Abstract

Fibre-reinforced hydrogels are promising materials for biomedical applications due to their strength, toughness, and tunability. However, it remains unclear how the fibre network should be designed for specific applications. We present a microstructure-informed continuum model for transversely isotropic fibre-reinforced hydrogels that captures the specific geometry of the fibre network. The model accounts for slack in the initial fibre network that is gradually removed upon deformation. The mechanical model for the fibre network is coupled to a nonlinear poroelastic model for the hydrogel matrix. We find that slack in the fibre network leads to J-shaped stress-strain curves, as seen in experiments, and a more isotropic swelling of the material. The model is compared to data from time-dependent unconfined compression experiments. Although we find qualitative agreement between model and experiment, the discrepancies suggest that our model is missing important physics. We showcase how the model can be used to guide the design of materials for artificial cartilage by exploring how to maximise interstitial fluid pressure.

Keywords:

Hydrogels Microstructural modelling Fibre-reinforced materials Artificial cartilage Poroelasticity