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Finite element analysis of prestressed composite hydrogels undergoing osmotic deswelling

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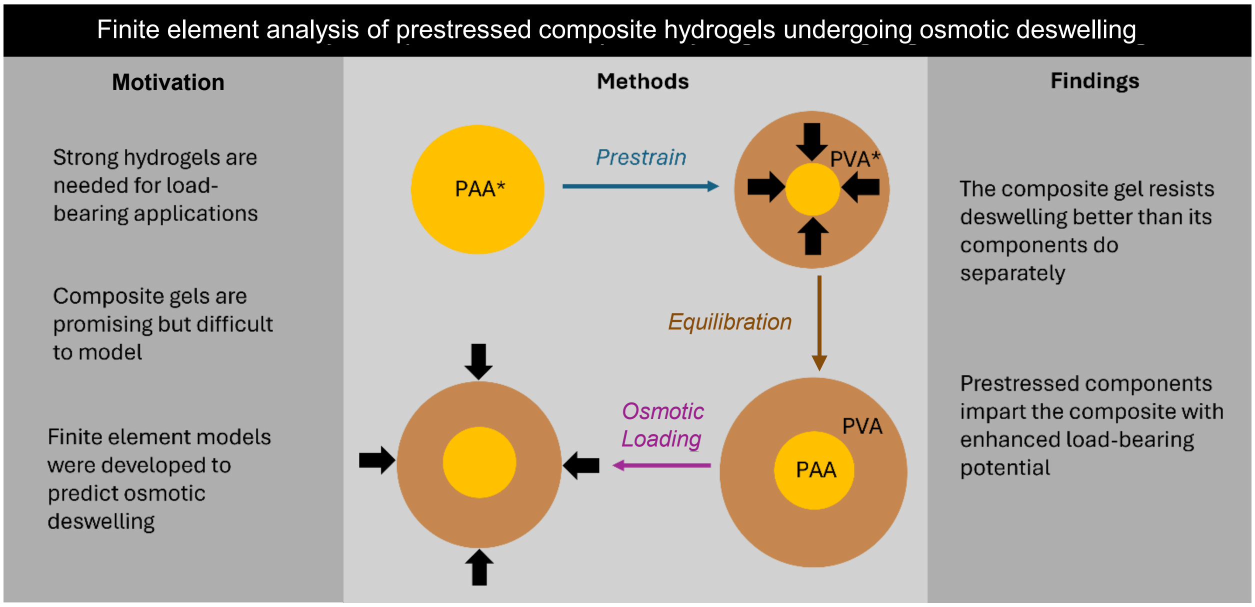
Pure hydrogels are generally soft materials, but strong, resilient hydrogels are needed for load-bearing biomedical applications. By mimicking the composition of cartilage, composite hydrogels consisting of poly(acrylic acid) microgel particles which swell within a poly(vinyl alcohol) matrix resist osmotic deswelling more effectively than their component gels and acquire enhanced load-bearing potential. Consequently, their osmotic deswelling behavior is not satisfactorily described by a single relation between elastic free energy and stretch with material property values between those of its components. Instead, continuum mechanical models of the composite gel were developed to predict its osmotic deswelling behavior using the finite element method. The models demonstrate how the composite gel is strengthened by internal stresses in its components which preexist the application of osmotic loads (i.e., prestress). One continuum model based on mixture theory assumes both gel components occupy all locations in the composite and are governed by the same hyperelastic form, but with material properties and stretches which differ from each other and the composite overall. By accounting for counter-stressed gel components, the mixture model accurately predicted osmotic deswelling in composite gels containing PVA with two different cross-link densities. A Fung hyperelastic material model fit indicated that lowering PVA cross-link density decreased its tendency to stiffen under strain. A second continuum model, in which the composite was modeled as swollen spherical PAA inclusions in a PVA background material, corroborated the state of opposing stresses in the mixture model, but suggests the two components may swell differently within the composite gel.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Motivation
Strong hydrogels are needed for load-bearing applications
Composite gels are promising but difficult to model
Finite element models were developed to predict osmotic deswelling
Methods
PAA*
Prestrain
PVA*
Equilibration
PVA
PAA
Osmotic Loading
Findings
The composite gel resists deswelling better than its components do separately
Prestressed components impart the composite with enhanced load-bearing potential