Local stress-strain distribution and load transfer across cartilage matrix at micro-scale using combined microscopy-based finite element method

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Articular cartilage is the load-bearing tissue that consists of proteoglycan macromolecules entrapped between collagen fibrils in a three-dimensional architecture. To date, the drudgery of searching for mathematical models to represent the biomechanics of such a system continues without providing a fitting description of its functional response to load at micro-scale level. We believe that the major complication arose when cartilage was first envisaged as a multiphasic model with distinguishable components and that quantifying those and searching for the laws that govern their interaction is inadequate. To the thesis of this paper, cartilage as a bulk is as much continuum as is the response of its components to the external stimuli. For this reason, we framed the fundamental question as to what would be the mechano-structural functionality of such a system in the total absence of one of its key constituents-proteoglycans. To answer this, hydrated normal and proteoglycan depleted samples were tested under confined compression while finite element models were reproduced, for the first time, based on the structural microarchitecture of the cross-sectional profile of the matrices. These micro-porous *in silico* models served as virtual transducers to produce an internal noninvasive probing mechanism beyond experimental capabilities to render the matrices micromechanics and several others properties like permeability, orientation etc. The results demonstrated that load transfer was closely related to the microarchitecture of the hyperelastic models that represent solid skeleton stress and fluid response based on the state of the collagen network with and without the swollen proteoglycans. In other words, the stress gradient during deformation was a function of the structural pattern of the network and acted in concert with the position-dependent compositional state of the matrix. This reveals that the interaction between indistinguishable components in real cartilage is superimposed by its microarchitectural state which directly influences macromechanical behavior.

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