An investigation of the fluid structure interaction in articular cartilage across disparate scales

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Articular Cartilage (AC) is a highly specialised connective tissue found at opposing surfaces in mammalian joints. Its principal function is to provide a smooth bearing surface, which promotes low friction articulation thus facilitating continuous operation under relative motion. Although AC undergoes high contact pressure with minimal friction and wear, its low capacity for intrinsic healing or repair leaves it prone to degeneration. This results in a high demand for cartilage repair, with approximately 10,000 injuries per year warranting surgery in the UK[1]. Despite this clinical importance, a lack of understanding of the tissue renders successful repair techniques elusive. Currently these are invasive, require extensive revision and fail to produce repair tissue exhibiting the same mechanical and functional properties of native AC. The complex material composition of AC makes it notoriously difficult to model accurately. Intrinsic inhomogeneity, attributed to a stratified composition, contributes to inaccuracies with single scale modelling approaches. This project aims to couple an immersed fibrous network (micro-scale) model with a continuum (macro-scale) model to create an innovative multi-scale poroelastic model of the fluid structure interaction arising within AC. Heterogeneous multi-scale methods are applied, using homogenized stress, strain and velocity from the micro-scale to populate the macro-scale elasticity and permeability tensors. Currently, a continuum-continuum model is in development for self-validation of the multi-scale model. Once established, a fibrous network model of the micro-scale behaviour will facilitate representation of the inherent anisotropy and depth-dependent properties of AC. The resulting multi-scale model will be calibrated using experimental data and clinical collaboration.

[1] D. Spitaels *et al*., ‘Epidemiology of knee osteoarthritis in general practice:a registry-based study’, BMJ Open(2020), DOI:10.1136/bmjopen-2019-031734.