Characterisation of the mechanical properties of single chondrocytes using a micro-manipulation technique and finite element modelling

V.B. Nguyen[1], W.Q. Guang[2], C.R. Thomas[1], A.J. El Haj[2], N. Kuiper[2], and Z. Zhang[1]
[1] *Centre for Formulation Engineering, School of Engineering, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK*
[2] *Schools of Medicine & Life Sciences, Institute of Science & Technology in Medicine University of Keele, Staffordshire, ST5 5BG, UK*

Single chondrocytes with diameters of 8-15μm were compressed between two parallel surfaces by a micromanipulation technique which was used to measure the force imposed on them directly at any given deformation, and a finite element (FE) analysis applied to model the experimental data of force versus deformation in order to determine their intrinsic mechanical property parameters. Experimental results have shown that the force imposed on these cells increased when they were compressed, and relaxed to a certain extent when they were held, which might be due to the intrinsic viscoelasticity of the solid matrix of the cell and/or an apparent viscoelastic response caused by fluid loss during the compression and holding. However, using finite element analysis using ABAQUS with a linear poroelastic material model, it was found that the effect of fluid loss on the force response is very small and can be ignored. Then a linear viscoelastic material model, which has the form of the generalised Maxwell model, was used in the finite element modelling to obtain the mechanical properties of the chondrocytes. This paper demonstrates the FE modelling with the viscoelastic material model can be used to improve our understanding of the mechanical behaviour of living chondrocytes, and to determine their mechanical properties such as elastic modulus, Poisson ratio and viscoelastic parameters.

Keywords:
chondrocytes; micro-manipulation; relaxation; viscoelastic; finite element; mechanical properties