Role of cell location and morphology in the mechanical environment around meniscal cells

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Received 21 December 2005; received in revised form 23 April 2006; accepted 23 May 2006

Abstract

Fibrochondrocytes within meniscal tissue have been shown to alter their biochemical activity in response to changes in their mechanical environment. Meniscal tissue is known to contain both spherical (chondrocytic-like) and elliptical (fibroblastic-like) cells. We hypothesize that a cell’s mechanical environment is governed by local material properties of the tissue around the cell, the cell morphology and the cell’s position within the tissue. A two-dimensional, non-linear, fiber (collagen) reinforced, multi-scale, finite element model was utilized to quantify changes in the stress, strain, fluid velocity and fluid flow induced shear stress (FFISS) within and around fibrochondrocytes. Cells differing in morphology and size were modeled at different locations within an explant 6 mm in diameter and 5 mm thick, under 5% unconfined compression. Cellular stresses were an order of magnitude less than surrounding extracellular matrix stresses but cellular strains were higher. Cell size affected both the stress and strain levels within the cell, with smaller cells being exposed to smaller principal stresses and strains than larger cells of the same shape. The pericellular matrix of an elliptical cell was less effective at shielding the cell from large principal strains and stresses. FFISS were largest around small circular cells (0.13 Pa), and were dramatically affected by the position of the cell relative to the axis of the explant, with cells closer to the periphery experiencing greater FFISS than cells near the central axis of the explant. These results will allow biosynthetic activity of fibrochondrocytes to be correlated with position and morphology in the future.