Resistance to Cell-induced Stiffening in Extracellular Matrix Triggers Formation of Cellular Extensions.

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Adherent cells on biopolymer hydrogels (e.g. collagen gels) form relatively few and short cellular extensions (filopodia), which enable cells to exert forces and deform their underlying matrices. Cells locally stiffen the extracellular matrix through this force-deformation-sensing feedback loop so that they can achieve optimal spreading. If the matrix is supported on the edges by solid frames (e.g. nylon fibers), these physical boundaries resist the strain stiffening of the matrix and trigger further growth and elongation of cellular extensions. The mean number and length of cellular extensions depend on the frame opening size (i.e., distance of cells from physical boundaries). When the opening sizes were 200 µm or 500 µm wide, the mean number of extensions per cell and the sum of cell extension lengths were not significantly different ($p>0.6$). In contrast, in larger grids (1700 µm width), the mean number of extensions per cell, the mean extension length, and the sum of cell extension lengths decreased (by 40-60%; $p<0.0001$). In grids of 200 µm width and grids of 500 µm width, cell-generated deformation fields extended to, and were resisted by, the grid boundaries. In grids of 1700 µm width, however, the deformation field did not extend to the grid boundaries, which significantly affects the formation of cell extensions.

We are looking for a mathematical model to understand the mechanical behaviour of fibrilar hyrogels (e.g. collagen gels) under adherent contractile cells. Since fibrilar gels exhibit non-linear elastic behaviour, one cannot use the classical plate theory to investigate the deformation field created by contractile cells. A model to predict the deformation field in fibrilar networks as a function of fiber density, network thickness, and applied forces by adherent cells will be very helpful.

Background literature

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