

Characterizing cell adhesion and migration on surfaces biofunctionalized with nanopatterned collagen matrices

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We have recently developed a method for creating ultrathin collagen type I matrices on non-biological surfaces in which individual collagen fibrils are almost perfectly ordered on the nanoscale. Initial experiments showed that fibroblasts seeded on our nanopatterned collagen matrices polarize strongly and migrate in the direction of the aligned fibrils. The ability to regulate the adhesive and migratory behaviour of cells, combined with the excellent biocompatibility of collagen, make nanopatterned collagen matrices a promising tool for the surface biofunctionalization of so-called “smart” biomaterials.

Using live-cell/time-lapse atomic force microscopy (AFM), we have studied the interaction between fibroblast cells with the matrix on a nanoscale level and show that cell alignment involves collagen matrix deformation. Because of the high tensile strength of collagen fibrils, cells are able to build up traction and move directionally when they pull longitudinally on the fibrils. In contrast, due to their high-pliability, collagen fibrils offer only low mechanical resistance when cells pull on them laterally, preventing the creation of traction and cell movement. Cell polarization therefore reflects anisotropic mechanical properties of the collagen matrix.

Cell alignment and matrix contraction was strictly Mg^{2+} -dependend, pointing towards a role for collagen-binding integrin receptors in mediating cellular adhesion to these matrices. In agreement,

CHO wild-type cells, which lack endogenous collagen-binding integrin receptors, adhered poorly to the collagen matrix, while CHO cells stably expressing the integrin α_2 subunit (CHO-A2) adhered and spread rapidly. This indicated that $\alpha_2\beta_1$ integrin was able to mediate a firm attachment of these cells to collagen. In order to quantitate $\alpha_2\beta_1$ integrin-mediated adhesion, we measured adhesion forces of single cells to the collagen matrix by AFM force spectroscopy. Forces required for cell detachment were significantly higher for CHO-A2 cells compared to wild-type cells. In conclusion, we have characterized the adhesion of different cell types to highly-ordered collagen type I matrices and show that cell polarize on these matrices by anisotropically deforming them in a $\alpha_2\beta_1$ integrin-dependent manner.