The influence of topographic micro- and nanostructures on cell adhesion studied by atomic force microscopy and computer simulations

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A major task in biomaterials research is the functionalization of implant surfaces to adjust their biocompatibility for specific applications. Besides numerous chemical modifications, topographic variations are frequently employed, which leads to a correlation between the surface structures and the reaction of the bio-system. However, the solid-liquid interface between a biomaterial and the adjacent tissue is complex and cell adhesion is regulated by many factors such as the electrochemical double layer, protein adsorption and the interaction of cell-surface receptors with the adsorbed proteins. In the presented study, the influence of periodically grooved micro- and nanostructures on the initial adhesion of L929 fibroblasts was studied by a combination of AFM-based single-cell force spectroscopy (SCFS) and single-molecule force spectroscopy (SMFS). The experiments demonstrate that protein adsorption was not significantly influenced by the microstructures and cell adhesion to these substrates was governed by the mechanical properties of the fibroblasts. In contrast, the adsorption of the cell adhesion protein fibronectin was significantly altered by the much smaller nanostructures and the adhesion strength of L929 fibroblasts was modulated by this effect. The experiments are supported by computer simulations in which numerical field calculation methods were combined with Brownian Dynamics and a simple mechanism for protein adsorption on topographic nanostructures was derived.