Gold Nanorods: Applications in Chemical Sensing, Biological Imaging and Effects on 3-Dimensional Tissue Culture

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Gold nanoparticles have attracted great interest in the last decade for applications in biochemical detection, imaging, and therapeutics, due to their intense optoelectronic properties.[1,2] Interest in this area has recently focused on engineering the surface of the nanoparticles, because of the ease in which the charge, functionality, and reactivity of the surface can be altered. This seminar will focus on applications of surface-engineered gold nanoparticles in chemical detection and biomedical imaging, and measure the effects surface modified gold nanorods have on the behavior of cardiac fibroblasts in 3-dimensional tissue culture.

In biological tissue, complex mechanisms of cellular response are closely linked to the mechanical environment that cells experience. The key to understanding these mechanisms may lie in measurement of local mechanical fields near living cells and between cells. We have developed a novel optical measurement technique, which combines the light elastically scattered from gold nanorods with digital image analysis to track local deformations that occur in vitro between cells, in real time, under darkfield optical microscopy. We find that measurable tension and compression exist in the intercellular matrix at the length scale of micrometers, as the cells assess, adapt, and rearrange their environment (Figure 1).[3] This technique works for both thin and thick collagen films where there is a buffer layer of collagen between the nanoparticles and the cells, but when the cells and nanomaterials are intimately mixed in a 3-D tissue construct the presence of the nanomaterials alters cellular behavior.

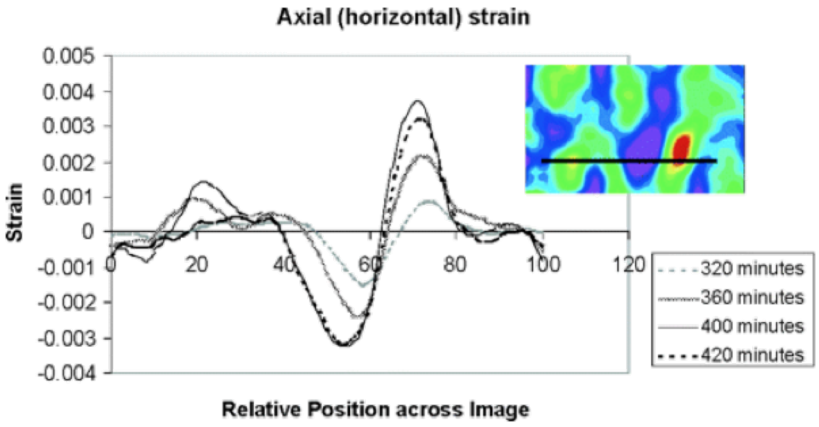

Figure 1: Plot of axial strain as a function of pixel position across the inset strain field plot at different time intervals.[3]

Cell behavior in the presence of nanomaterials is typically explored through simple viability assays, but there is mounting evidence that nanomaterials can have more subtle effects on a variety of cell functions. Numerous studies have documented the cellular uptake and cytotoxicity of gold nanoparticles in different cell types, but very little is known about how nanoparticles affect cellular function. In this work, we examine how cardiac fibroblast-mediated extracellular matrix remodeling is perturbed by gold nanoparticles. To investigate the capacity for nanomaterials to modulate this process, 3-D collagen gel constructs were prepared from neonatal cardiac fibroblasts and type I collagen with and without gold nanorods (392 nm long x 22 nm wide, overcoated with polystyrene sulfonate).[4-6] Over a 24 h period the collagen-nanomaterial composite scaffolds showed significantly less contraction than controls (Figure 2), and the reduced contraction was not due to cell death or differences in gelatinase activity. Cardiac fibroblasts suspended in the composite scaffolds exhibited a different phenotype than cells in control scaffolds, as evidenced by an upregulation of β-actin and a down regulation of α-smooth muscle actin and collagen type I mRNA.[4] The nanorods have been found to have the ability to bind proteins on the surface of the nanomaterials, which can modulate the matrix remodeling behavior of fibroblasts. It has also been found that the polyelectrolyte-coated nanorods have the ability to alter both the self-assembly and mechanical properties of a collagen construct.[5] Taken together, these data indicate that biocompatible nanomaterials have the capacity to regulate fibroblast-mediated matrix remodeling. Targeted delivery of nanomaterials may represent a novel mechanism for managing pathological cardiac remodeling.

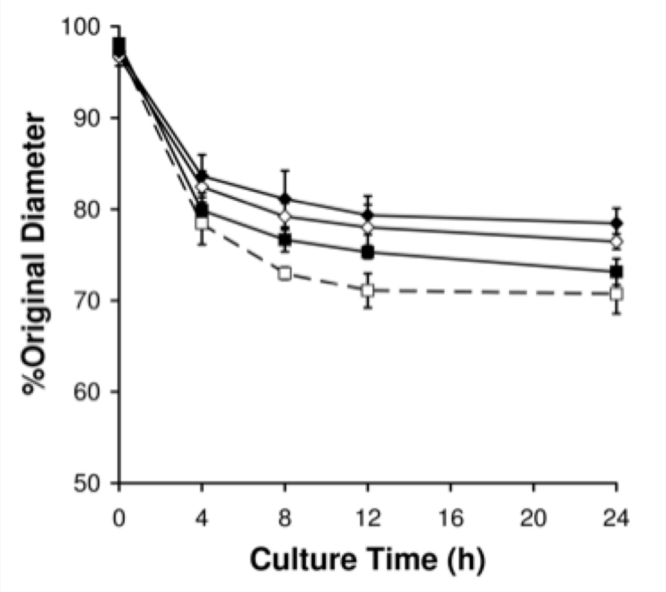

Figure 2: Gold nanorods inhibit fibroblast-mediated collagen gel contraction. This plot shows percent change in gel diameter as a function of time. (open square – 2 mg/mL Type I Collagen with 0 nanorods/mL, black square – 1.4 x 10^9 nanorods/gel, open diamond – 2.8 x 10^9 nanorods/gel, black diamond – 5.6 x 10^9 nanorods/gel)

References

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