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Optical Manipulation of Stem Cells

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INTRODUCTION: Mechanical microenvironment has been shown to have a great impact on proliferation and differentiation of stem cells. To quantitatively determine the effect of fluid mechanical forces on stem cells, it is essential to apply and maintain a well-defined exterior force on a single stem cell. Optical tweezers have been widely used for manipulating single biological cells and performing sophisticated biophysical/biomechanical characterizations. Advantages of using tweezers include non-contact force for cell manipulation, force resolution as accurate as 100 aN, and amiability to liquid medium environments. This study aims to develop a novel optical-mechanical system which can be employed to generate a range of shear forces on mesenchymal stem cells (MSCs) and quantitatively characterize the resulting effects on MSCs including deformation, viability and gene expression profiles of MSCs. This understanding helps designing new means of delivering stem cells for regenerating tissues or optimizing current delivery systems.

METHODS:. Stem cells of passage 5 were used. The cells were attached to RGD (Arg-Gly-Asp, Sigma-Aldrich, UK) coated microparticles (averaged 3.19 um, Spheotech Inc., USA). The commercial available optical tweezers (Cell Robotic, Inc, USA) which is driven by a Windows XP based software is used in this present experimental work. The experimental setup was shown in Figure 1. The source of laser is Nd:YAG at a wavelength of 1064nm pumped by a 1.5W diode. Laser is then reflected through dichroic mirrors and focused by an inverted microscope (Nikon optical microsystem) before it reaches the objects. The cells were pumped into a microfluidic device or in-house chamber which is placed on the invert microscopy platform. The flow rate can be varied to exert different shear stress on the stem cells.

RESULTS: A bead-attached stem cell can be manipulated under this optical-mechanical system in three different ways when it is exposed to fluid flow field while trapped by laser beam: it may flow with fluid as the cell has not attached to the bottom; it may rotate under certain fluid forces (partially attached to the surface bottom); and the bead may be pulled away but the cell is not moving or rotating (fully attached to the surface bottom). The fluid velocity of 40μm/s is found to be the escape velocity of the bead-attached cells, and equivalent shear force is calculated to be about 7.5 pN.

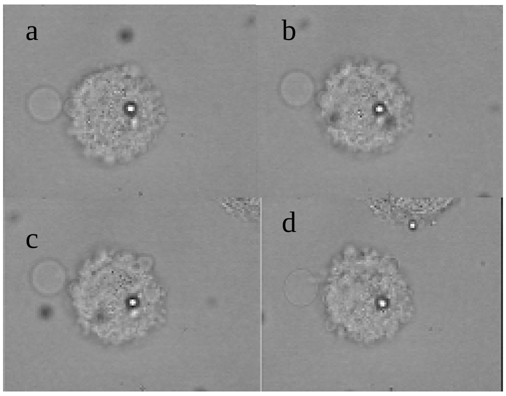

Fig. 1:Optical tweezers drag the microparticle-attached stem cell in a microfluidic channel at different positions from (a) to (d).

DISCUSSION & CONCLUSIONS: Several new enabling techniques have been developed for optical-mechanically manipulating and characterizing stem cells. Bead-attached stem cells have been successfully manipulated at various speeds in physiological medium. Quantitative analyses of the nanomechanical forces on the cells during cell manipulation/delivery have been performed.

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