EE Department Seminar

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Micro/Nanoscale Technologies and Applications in Medicine

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Micro/Nanoscale Technologies play a powerful role in early diagnosis of pathogens and treatment of diseases. Early detection of and diagnosis of diseases can be used to greatly reduce the cost of patient care associated with advanced stages of many diseases such as cancer, diabetes, HIV. Micro/Nanoscale Technologies are more efficient and reliable in sensing and detection of diseases. More than 30 million people are living with HIV-1 worldwide. CD4+ T-lymphocyte counting is a standard method used to monitor HIV-infected patients during anti-retroviral therapy (ART). The World Health Organization (WHO) has pointed that a handheld, point-of-care, reliable, and affordable CD4+ T-lymphocyte counting platform is urgently needed in resource-scarce settings. To overcome this challenge, we have developed microchip-based point-of-care (POC) technologies to count CD4+ T lymphocytes at resource-limited settings. On a microchip coated with immobilized antibodies, CD4 T lymphocytes were captured from whole blood. The portable, battery operated, lensless, microchip platform showed significant correlation in CD4 T-cell counts compared with the gold standard. The device rapidly produced CD4 T-cell counts within 10 minutes using an automated cell counting program. Currently, we are developing this platform technology to achieve rapid viral load information, which determines the AIDS treatment regimen. This platform technology can potentially deliver inexpensive, rapid and simple testing to monitor antiretroviral treatment in developing countries.

In addition, micro- and nanoscale technologies are also emerging as powerful enabling tools for tissue engineering and drug discovery. The convergence of nano and microscale technologies and hydrogels has resulted in the emergence of bottom-up methods where cell-laden microgels can be used as building blocks for tissue engineering and regenerative medicine. Although various microgel fabrication and assembly methods have been developed based on modifying interfaces and using microfluidics, so far, two main challenges remain: (1) to fabricate microgels composed of multiple cell types spatially confined in 3D as functional units, and (2) to assemble microgels into large complex 3D constructs rapidly in an efficient way. In the past several years, our lab has been focusing on addressing these two challenges. (1) As for fabrication of functional units, we developed a simple, multilayer photolithography method to fabricate co-culture microgels as tissue units (co-culture units) in a high throughput manner, with control over composition of cell types and their microscale spatial organization. We demonstrate the utility of this method by fabricating four different types of co-culture units, where the quality of the units was optimized by the photomask design (i.e., via overlap ratio). (2) As for assembly of microgels, we developed several different methods based on magnetics, acoustics and printing technology. We developed a magnetic assembler that utilizes nanoparticles and microscale hydrogels as building blocks to create 3D complex multi-layer constructs via external magnetic fields using different concentrations of magnetic nanoparticles. In this method, MNPs were incorporated into microgels to create a new biomaterial that maintains the biocompatibility of hydrogels, while contributing additional capabilities for culture, magnetic manipulation, and complex 3D assembly of microgels. We also developed a simple, non-invasive acoustic assembler for cell-encapsulating microgels with maintained cell viability. The microgels were assembled via acoustic field in seconds in a non-invasive manner. Besides, we developed novel cell printing technologies where microgel fabrication and assembly are integrated into one system. With cell printing, we have successfully regenerated muscle tissues, created in vitro cancer co-culture models, and engineered controlled niches for embryoid stem cells. These methods that we present would enable a better biologically relevant in vitro platform to investigate cell–cell interactions in a 3D microenvironment, holding great potential in various areas, spanning tissue engineering, regenerative medicine, pharmacological studies and high throughput applications.

Utkan Demirci, PhD, is an Assistant Professor of Medicine and Health Sciences and Technology at Harvard University Medical School, Brigham and Women's Hospital, and MIT (Massachusetts Institute of Technology). Dr. Demirci creates nano- and micro-scale technologies enabling solutions for real world problems in medicine. Dr. Demirci is an internationally renowned scientist and his work has been recognized by numerous national and international awards, and highlighted in Wired Magazine, Nature Photonics, MIT Technology Review, AIP News, BioTechniques, and Biophotonics.