Physical and numerical simulation of 3D polymeric scaffolds for load-bearing tissue engineering and cell-based gene therapy
DiRaddo, Robert; El-Ayoubi, Rouwayda; Yousefi, Azizeh-Mitra

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Physical and numerical simulation of 3D polymeric scaffolds for load-bearing tissue engineering and cell-based gene therapy

Speaker: Robert DiRaddo, Ph.D.
Rouwayda El-Ayoubi, Ph.D., Azizeh-Mitra Yousefi, Ph.D.
(Industrial Materials Institute – NRC)

Regenerating load-bearing tissues requires 3D biomimetic scaffolds that balance temporary mechanical function with the physiological requirements. Moreover, biomaterial structures capable of efficient gene delivery, via embedded cells, provide a potentially fundamental tool for the treatment of acquired or hereditary diseases. This talk will focus on the development and use of physical and numerical simulation techniques for predicting the in-vivo behaviour of porous polymer scaffolds. The following needs are targeted; (1) minimal tissue engineering and drug design costs, (in particular in-vitro studies); (2) optimal scaffold architectures to assure adequate scaffold-tissue construct properties during structural evolution (in vitro and in vivo); (3) delivery of therapeutic gene product (cell-based gene therapy) using genetically engineered stem cells.

Biomechanical performance prediction, coupled with the kinetic models of scaffold degradation and tissue growth, could be a useful tool for permitting the design of scaffolds mimicking the properties of host tissues while providing optimal drug/protein release and tissue in-growth. We present a computational scaffold design approach, aiming to produce scaffolds that could address both mechanical and physiological requirements for tissue engineering and gene therapy applications. Parallel to the numerical developments and in collaboration with various hospital research centres, our team has also designed and fabricated polymer scaffolds with controlled architectures that promote cell viability, and oxygen/nutrient transport. The in vivo behavior of these scaffolds is physically simulated via a controlled experimentation protocol, including cell growth, drug delivery monitoring and biomechanical characterization.

In two series of studies, genetically-engineered murine bone marrow-derived mesenchymal stromal cells (MSCs) and canine chondrocytes were seeded onto the designed scaffolds, with different macro/microporosity levels, and were cultured under static and dynamic conditions. Cell attachment, growth, and cell activity were monitored over a period of two weeks by histological study, scanning electron microscopy, and MTT assay. These studies showed that the designed constructs could promote cell viability and release of therapeutic proteins, and demonstrated their capacity for a dual role, as scaffolds for tissue regeneration and as delivery systems for gene products.

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