Optimization and Performance Modeling of Osteochondral Scaffolds for Tissue Engineering

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The use of porous scaffolds in tissue engineering holds promise since they have the potential of providing temporary mechanical support while facilitating tissue ingrowth by allowing the inclusion of seeded cells. The goal of this work is to improve the design of osteochondral scaffolds by analyzing the effect of scaffold architecture on its biomechanical performance under physiological loads using the biphasic model.

PLLA scaffolds, featuring different pore sizes (200-400 microns) and porosity levels (50% to 85%) were prepared using a 3D plotting technique. The polymer, dissolved in a solvent, was dispensed into a plotting medium to build a 3D interconnected geometry according to an input CAD file. The optimum scaffold architectures for osteochondral units were obtained based on the biphasic model, aiming to match the compressive modulus and the permeability of the constructs to those of biological tissues.

The scaffolds at 85% porosity showed similar biphasic properties to that of typical cartilage under unconfined compression tests. A modeling software was used to predict the biomechanical performance of scaffolds virtually implanted in vivo, surrounded by native osteochondral tissue. Different mechanical properties were assigned to different layers of cartilage-bone tissues to account for the variations in properties through the thickness. The comparison of simulation results under compressive loads demonstrated that the stress field inside scaffolds and that of osteochondral tissue is similar. The tissue ingrowth studies for these constructs are currently underway.

The biphasic performance prediction, coupled with the kinetic models of scaffold degradation and tissue growth will be used to optimize the construct topology and biomechanical performance during its structural evolution. This approach would allow designing scaffolds mimicking the properties of native osteochondral tissues while providing the maximum porosity to promote tissue ingrowth.