3D Printing Personalized Knee Implants: Novel Computational Geometric Models for Stem Cell Regeneration in Meniscus Tears

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Importance: The most common knee injury is a torn meniscus, affecting 65% of all adults and contact-sports athletes. The meniscus is the primary cartilage in the knee, stabilizing over 85% of total loads. Currently, commercially available meniscus implants are not personalized or representative of the physiological properties of the meniscus, resulting in poor tissue regeneration and the onset of osteoarthritis. Design: This investigation 3D-printed novel composite implants by combining polycaprolactone scaffolds and gelatin/chondroitin sulfate hydrogels. The implants were personalized using patient-specific tear MRIs and latticed using computational geometry. Finite element simulations were used to optimize lattice structure under physiologically relevant knee conditions. Results: The resulting implant models were structurally and biologically characterized in comparison to the positive control, porcine meniscus tissue. The implants were able to absorb 93 times their dry weight and match the 75% water composition of porcine menisci. Scanning electron micrographs and micro-CT scans showed an open pore geometry with an average size of 215 μm, conducive to cartilage repair. Rheological frequency sweeps found a complex modulus, an indication of stiffness and elasticity, of 132 megapascals. All structural properties mimicked porcine tissue, as indicated by statistically insignificant results. The implants supported chondrogenic differentiation of ligament stem cells, as was confirmed through cell staining. MTT assay found 10-fold cell proliferation with >97% viability. Applications: Overall, the novel implant developed in this project is a viable regeneration option, important in the context of sports medicine and prevention of osteoarthritis.

Awards Won:

Patent and Trademark Office Society: Second Award of $500