Multiscale Biofabrication for Fibrocartilage Scaffolds: The Labrum as Representative Application

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The acetabular labrum, typical of fibrocartilage, is heterogeneous and anisotropic. It is crucial for joint lubrication, stability, and minimizing intra-articular stress. Labral tears are common, often caused by trauma, malalignment, or impingement. Traditional repairs, including tendon and ligament grafts, fail to fully restore labral function. Consequently, we have broadly explored the labrum's composition, architecture, mechanics, and mechanobiology to guide the development of tissue-engineered grafts that replicate its structure and function.

Similar to the meniscus, the labrum features a hierarchical and zonal variation of collagen fiber structure. Our research has detailed its surface microstructure, stiffness distribution, lubricin production, and tribological properties. The labrum's surface has a mesh-like architecture, and retains lubricin, thus reducing friction. The labrum's unique transcriptome signature and response to mechanical loading further distinguish it from cartilage. To date, scaffolds for tissue restoration fail to capture these features.

With these structural and functional targets in mind, we have combined electrospinning and melt electrowriting to produce novel three-dimensional, hierarchical fibrous scaffolds, with features on the nano- to millimeter scale. These scaffolds support extracellular matrix production and appropriate response to mechanical stretching. The heterogeneous constructs, with a fine mesh fiber surface over a structural core, exhibit native-like tribological properties and outperform homogeneous scaffolds. Proof-of-concept has been achieved with three-dimensional labrum scaffolds of appropriate size and shape.

Future work aims to develop better fixation methods, demonstrate the grafts' role in restoring joint function, and prove their effectiveness in vivo. Extension to restoration of the glenoid labrum, meniscus and annulus fibrosis is also explored.