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Ph.D. DISSERATION DEFENSE

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Title:	Numerical and experimental analysis of 3D/4D printed functionalized fibrous biomaterial via electrohydrodynamic printing
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ABSTRACT

This thesis presents the development of biomimetic tissue constructs by integrating additive manufacturing (AM) with electrohydrodynamic (EHD) printing. The work focuses on replicating the complex fibrous microstructure of muscle tissues, specifically the spindle-like ellipsoid geometry, using a novel polymer melt-based EHD printing system. Chapter 1 introduces a numerical and experimental study of 3D/4D fibrous biomaterials. A predictive numerical model simulates microfiber formation under key bioprinting parameters, offering high control over geometry. The model is validated experimentally and supported by a dimensionless predictive formula. Chapter 2 explores scaffold functionalization for in vitro tissue models. It focuses on precise biomolecule patterning—both monolithic and gradient—on AM-fabricated scaffolds to improve cellular attachment and guidance. Various biomolecular exposure protocols and scaffold architectures are evaluated to enhance in vivo-like environments. Chapter 3 demonstrates the fabrication of suspended spindle-like structures using EHD printing. Challenges like fiber sagging and residual charge are addressed by optimizing process and design parameters. Structural and mechanical analyses validate the printed constructs, supporting their use as functional muscle spindle models. Chapter 4 introduces a 4D-printed spindle structure that morphs in response to electrical stimuli. By tuning fiber sagging and charge interactions, the structure exhibits reversible deformation. This dynamic behavior positions the model as a promising tool for drug testing and soft tissue engineering.