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Ph.D. DISSERTATION DEFENSE

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Degree:	Doctor of Philosophy
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Date:	December 8th, 2026
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Title:	Biomaterial and Architectural Strategies for Enhanced Nutrient Transport in Volumetric Bone Tissue Engineering
Chairperson:	Dr. Hongjun Wang, Department of Biomedical Engineering, School of Engineering and Science
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ABSTRACT

While the field of bone tissue engineering has advanced substantially, volumetric bone regeneration remains limited primarily due to insufficient nutrient transport and the difficulties in establishing functional vascular networks within volumetric scaffolds. Addressing these limitations requires both biomaterial and fabrication strategies to facilitate nutrient transport throughout volumetric constructs. As such, this dissertation research explores three unique yet complementary strategies by: (1) developing channeled chitosan-polystyrene sulfonate (CS/PSS) scaffolds with incorporated osteoinductive factor to promote osteogenic differentiation in volumetric constructs, (2) establishing a plant-derived sacrificial templating strategy to generate hierarchical, branched channel networks with geometries and feature sizes that are hard to reproduce using conventional 3D printing techniques, and (3) developing pre-endothelialized free-standing polymeric networks as modular interfaces for integration with volumetric cell-laden hydrogels.

In summary, CS/PSS scaffolds were first investigated as hybrid biomaterials capable of providing the structural stability and mechanical robustness required to fabricate centimeter-scale porous constructs. In addition to supporting scaffold fabrication, CS/PSS offered several functional advantages, including intrinsic mineralization capacity, localized molecular delivery, and biological performance comparable to that of native chitosan-based scaffolds. Secondly, *Luffa aegyptiaca* was investigated as a naturally derived sacrificial template for generating branched, hierarchical channel architectures. Luffa-derived free-standing PCL networks were subsequently fabricated, and their structural organization and potential transport characteristics were investigated using micro-computed tomography and computational modeling. Finally, this dissertation explores the endothelialization and integration of Luffa-derived free-standing networks into volumetric hydrogels as modular, vascular-inspired structures. By separating the fabrication of interconnected transport networks from the surrounding tissue-supporting matrix, this approach enables the

incorporation of predefined, endothelialized channel architectures into cell-laden constructs to investigate the correlation between angiogenesis and osteogenesis. Collectively, by integrating mechanically stable biomaterials, naturally derived hierarchical templates, and modular vascular-inspired networks, this dissertation research advances the development of scaffold systems designed to facilitate nutrient transport, support tissue formation, and promote future vascular integration within engineered volumetric bone constructs.