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Optimization of Mechanical Properties of Alginate Hydrogel for 3D Bio-Printing Self-Standing Scaffold Architecture for Tissue Engineering Applications

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Abstract : In this study, the mechanical properties of alginate hydrogel material for self-standing 3D scaffold architecture with proper shape fidelity are investigated. In-lab built 3D bio-printer extrusion-based technology is utilized to fabricate 3D alginate scaffold constructs. The pressure, needle speed and stage speed are varied using a computer-controlled system. The experimental result indicates that the concentration of alginate solution, calcium chloride (CaCl₂) cross-linking concentration and cross-linking ratios lead to the formation of alginate hydrogel with various gelation states. Besides, the gelling conditions, such as cross-linking reaction time and temperature also have a significant effect on the mechanical properties of alginate hydrogel. Various experimental tests such as the material gelation, the material spreading and the printability test for filament collapse as well as the swelling test were conducted to evaluate the fabricated 3D scaffold constructs. The result indicates that the fabricated 3D scaffold from composition of 3.5% wt alginate solution, that is prepared in DI water and 1% wt CaCl₂ solution with cross-linking ratios of 7:3 show good printability and sustain good shape fidelity for more than 20 days, compared to alginate hydrogel that is prepared in a phosphate buffered saline (PBS). The fabricated self-standing 3D scaffold constructs measured 30 mm × 30 mm and consisted of 4 layers (n = 4) show good pore geometry and clear grid structure after printing. In addition, the percentage change of swelling degree exhibits high swelling capability with respect to time. The swelling test shows that the geometry of 3D alginate-scaffold construct and of the macro-pore are rarely changed, which indicates the capability of holding the shape fidelity during the incubation period. This study demonstrated that the mechanical and physical properties of alginate hydrogel could be tuned for a 3D bio-printing extrusion-based system to fabricate self-standing 3D scaffold soft structures. This 3D bioengineered scaffold provides a natural microenvironment present in the extracellular matrix of the tissue, which could be seeded with the biological cells to generate the desired 3D live tissue model for in vitro and in vivo tissue engineering applications.

Keywords : biomaterial, calcium chloride, 3D bio-printing, extrusion, scaffold, sodium alginate, tissue engineering
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