Title: Photocrosslinkable Graphene-Enhanced Biomaterial Inks for Improved Printability and Structural Fidelity

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Abstract

Background: Multimaterial bioinks combine complementary properties for tunable functionality. Graphene provides electrical and mechanical strength, while gellan gum (GG) ensures structural support and biocompatibility. Their integration into a photocrosslinkable system enables stable, high-precision constructs, offering a promising platform for next-generation biofabrication.

Material and methods: GG was methacrylated under basic conditions (pH 8-9) to produce GGMA, with ~30% modification confirmed by 1H-NMR. Bioinks were prepared by dissolving 1.5% w/v GGMA in 0.5% w/v Irgacure followed by addition of 0.25%, 0.50%, or 1.00% w/w graphene. Rheological measurements assessed flow behavior and viscoelasticity, and inks were printed using extrusion-based bioprinting. For cell-laden formulations, human dermal fibroblasts (5×10^6 cells/mL) were mixed into the precursors.

Results and Discussion: The flow behavior of inks formulations was characterized by rheological measurements. The biomaterial ink formulations exhibited excellent printability, viscoelastic properties, and high shape fidelity. The modified hydrogel formulations possess optimal shear-thinning properties, ensuring smooth extrusion while maintaining printability. This is critical for achieving high-resolution constructs with precise geometry, as observed in the printed scaffold. All inks were printed in grids and cylinder structures with high resolutions and stackability. However, 0.5 % graphene exhibited better shape fidelity and higher stability. The viability of cell-laden bioprinted constructs was assessed at Days 1,3, and 7. The cells were uniformly distributed and exhibited elongated morphologies, indicative of good attachment and viability after printing.

The developed photocrosslinkable multimaterial bioinks showed excellent rheology, printability, and structural stability, with 0.5% graphene performing best, effectively overcoming single material bioinks limitations.