Optimizing 3d Printability in NICE Bioinks through Compositional and Rheological Analysis

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GAHARWAR Laboratory
Where NANO meets Tissue Engineering

Introduction

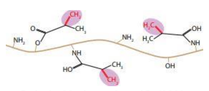
3d Bioprinting

3d bioprinting is a rapidly emerging field in tissue engineering that promises to enable custom fabrication of new tissues and organs. However, conventional bioinks have suffered from limited printability and cytocompatibility. We have recently developed a novel nanoengineered ionic covalent entanglement bioink that combines nanosilicate reinforcement and an interpenetrating ionically crosslinked network to significantly improve the printability and mechanical strength of a GelMA bioink, while maintaining a high level of cytocompatibility. In this next stage of research, we explore different compositions of NICE bioinks to examine the effects of each component on 3 important attributes of advanced bioinks: mechanical properties, 3d printability, and biocompatibility.

Methodology

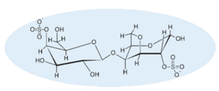
Percent Composition Manipulation

- Standard formulation of NICE bioink consists of 1% Kappa-Carrageenan, 10% Gelatin Methacrylate and 2% Nanosilicates
- Individual components of the bioink were altered
- Corresponding effects on the ink characteristics can be discerned



Gelatin Methacrylate (GelMA)
Provides cell adhesion sites, biodegradable and covalently crosslinked with UV

2D Nanosilicates
Self-recovery characteristics and induces shear-thinning effects



Kappa-Carrageenan (κCA)
Mechanical stiffness, absence of cell adhesion sites, and ionically crosslinked with KCl

Range of Component Concentrations Analyzed

GelMA	5%	7.5%	10%	12.5%	15%
Nanosilicates	0%	1%	2%	3%	4%
κCA	0%	0.5%	1%	1.5%	2%

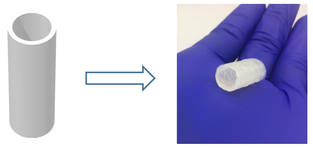
- Fifteen unique component compositions of bioinks were produced.
- Three hydrogel disks were created for each composition.
- Each disk was compression tested to measure mechanical properties
- Ink compositions were 3d printed to test the printability of the various inks
- Ink compositions underwent a set of rheology tests, including peak hold and stress sweep
- Optimal ranges of component concentrations for the NICE ink could be identified

Methodology

Testing Procedures

- Mechanical unconstrained compression testing procedure utilized compression testing with a max strain of 30% original height used to calculate compression modulus and toughness

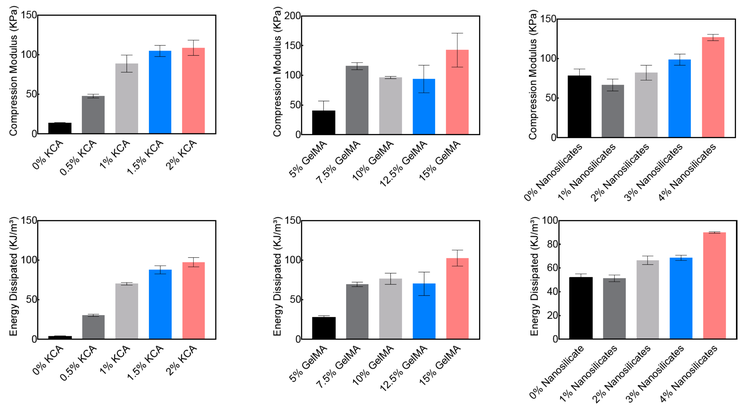
- Printability testing was performed using a 3 cm tall hollow cylinder with 8 mm internal diameter and 1 mm wall, which allow for accurate demonstration of self-recovery and print fidelity



- Peak-hold tests were designed to stimulate the shear rates and temperature changes the bioinks experience during bioprinting

Results and Discussion

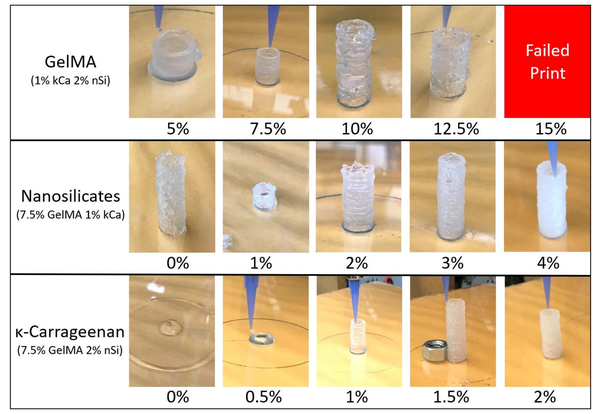
Compression Testing



- Increase in the compression modulus and energy dissipated of the sample hydrogel disks as the ink component concentrations increased
- Increasing the concentration of ink components would have a favorable outcome on the mechanical properties of the bioink and allow the bioink greater resistance to deformation

Results and Discussion

Printability Testing



- Increases in mechanical properties does not directly correlate with increase in printability

Rheology Testing

- Initial rheology tests displays shear-thinning and recoverability properties of various bioink compositions
- Component concentrations were shown to effect rate recoverability

Conclusion & Future Work

- Our results show that all 3 bioink components contribute to improved mechanical properties, including increasing compression modulus and energy dissipated
- However, increasing component concentration does not always improve print fidelity, indicating that there is an ideal range of components that maximizes printability
- Rheology data shows that recoverability and apparent viscosity depend on component concentrations
- Cell compatibility research is in progress on the most promising compositions to determine what effects these differing compositions have on viability, proliferation, differentiation, and ECM production

References

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