Characterization of an Alginate-Based 3D Extrusion Bioink with Varying Concentrations of Polyvinyl Alcohol for Cartilage Engineering

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INTRODUCTION: The treatment of cartilage degeneration remains a significant challenge in orthopedic surgery as current treatment options do not confer adequate long-term outcomes. 3D bioprinting offers a novel approach to the treatment of cartilage disorders. Bioinks containing alginate have shown potential for fabrication of 3D scaffolds, but the optimal concentration or additives has yet to be elucidated. We aim to characterize a 3D extrusion alginate-based bioink composed of varying concentrations of polyvinyl alcohol (PVA) for application in cartilage regeneration.

METHODS: A bioink consisting of 15% w/v medium viscosity sodium alginate (Alg), 5% gum arabic (GA), and various concentrations of polyvinyl alcohol (PVA) was 3D-bioprinted into a grid lattice structure using a BIO-X 3D bioprinter and crosslinked with calcium chloride. Compression testing was performed immediately after fabrication to evaluate the elastic modulus. Constructs were analyzed for swelling behavior at 0 and 48 hours in culture and for degradation at 0 and 28 days in culture.

RESULTS SECTION: The addition of 10, 15, 20 and 25% w/v PVA significantly increased hydrogel degradation after 28 days in culture ($p \leq 0.001$). The addition of 10, 15, 20 and 25% PVA significantly reduced hydrogel swelling ($p \leq 0.01$). The elastic modulus significantly increased in the 15% PVA group compared to baseline (0.18 vs 0.48 MPa, $p \leq 0.05$) (Figure 1).

DICSUSSION: For tissue-engineered cartilage constructs to be clinically relevant they must possess physical properties that mimic the native environment. Our results show that incorporation of PVA confers faster degradation rate, decreased degree of hydrogel swelling, and enhanced mechanical properties when added in a 1:1 ratio of alginate. Additionally, the elastic modulus of these engineered constructs approached that of native cartilage (0.45-0.8MPa). These results suggest that Alg-PVA-GA is a promising bioink candidate for cartilage regeneration.

SIGNIFICANCE / CLINICAL RELEVANCE: The addition of PVA to an alginate-based bio ink not only improved the mechanical properties, but also optimized its degradation and swelling behavior, making it a promising additive for future therapeutic interventions aimed at cartilage regeneration and long-term functional restoration through 3D tissue engineering.

IMAGES AND TABLES:

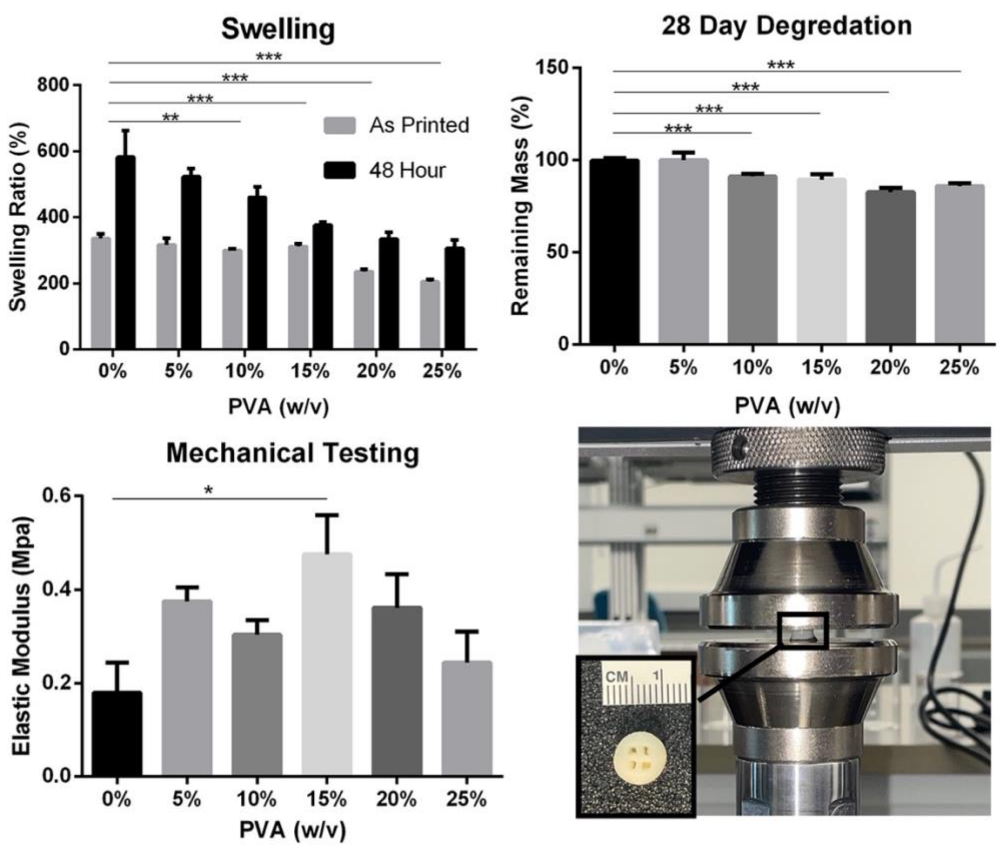

Figure 1. Physical and mechanical characteristics of 3D bioprinted hydrogels. (A) Swelling behavior as printed and after 48 hours in culture. (B) Degradation after 28 days in culture presented as % remaining mass after normalization to the as printed weight. (C) Results of mechanical testing presented as elastic modulus. (D) Representative image of compression testing performed on the fabricated hydrogel samples. Error bars represent SD, *p<0.05, **p<0.01, ***p<0.001.