Print-and-grow within a novel granular support material for 3D bioprinting

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Three-dimensional (3D) bioprinting holds great promise for tissue engineering, with extrusion bioprinting in suspended hydrogels becoming the leading bioprinting technique in recent years. In this method, living cells are incorporated within biocompatible hydrogels (bioinks), extruded layer by layer into a granular support material followed by gelation of the bioink through diverse cross-linking mechanisms. Granular support materials are yield stress fluids composed of jammed soft particles that provide mechanical support to the extruded hydrogels.

Here we present a new granular material composed of κ-Carrageenan microgels (CarGrow) that were fabricated using water in oil emulsion. Microgel support bed was fabricated by mixing an aqueous precursor solution containing κ-Carrageenan and ionic cross-linker (KCl) with an oil phase at a high temperature in the presence of Span® 80 as a surfactant. The polymeric water droplets cure and solidify upon cooling, which allows their separation using centrifugation.

The key rheological factors of granular support materials have a significant effect on the bed performance such as viscoelasticity, shear thinning, recovery, and yield. Thus, we examined these rheological properties using oscillatory and rotational shear tests. The granular bed demonstrates shear thinning and self-healing properties that allow free movement of the needle during printing while the fast recovery maintains the printed structure. Interestingly, the viscoelastic properties of granular materials are typically explored in the linear viscoelastic region although high shear stress is applied during the printing process. Hence, we explore the nonlinear behavior of the granular bed using large amplitude oscillatory shear (LAOS) at different cross-linker concentrations. The results revealed different viscoelastic behavior under low and high strains depending on the cross-linker concentrations. At low strains, the dissipated energy of the granular bed is similar regardless of the cross-linker concentration, while at higher strains above the yield point differences were detected.

The proposed granular material CarGrow offers a unique system that provides a possibility to reduce the shrinkage and deformation of cellular hydrogels during the post-printing maturation period[1].

[1]M. machour and N.Hen *Advanced science*.**9**,34(2022)