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Linking rheological properties and bioprinting for enhancing tissue constructs

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Bioprinting is a cutting-edge technology for processing biomaterials for tissue engineering applications. This process requires soft materials with tailored rheological properties to achieve precise deposition and structural fidelity in printed constructs. This study presents a comprehensive investigation correlating rheological properties such as viscosity, shear-thinning behavior, thixotropy, gelation kinetics, and elastic modulus with the printing process parameters. By understanding how these rheological properties influence the bioprinting process, resolution, and structural integrity of constructs, we can optimize bioink formulations before their use in a 3D printer. To achieve this, three inks composed of polysaccharides (CMC, Pectin) and nanoparticles (nanocrystal cellulose and Laponite) were studied. Firstly, the inks were prepared in different ratios and investigated through a series of rheological analyses, including flow curves, small amplitude oscillatory shear, and three interval thixotropy tests using an Anton Paar Rheometer. Results showed that the rheological properties of each ink are significantly influenced by their composition and crosslinking density. Next, we explore various printing parameters such as flow rate, printing speed, needle type, and needle diameter to determine the printing window of these hydrogels. We noted that inks with high viscosity values exhibited challenges in extrusion, leading to nozzle clogging and poor print quality. In contrast, inks with middle viscosity around 200-400 Pa.s and pronounced shear-thinning behavior facilitated smooth flow through the nozzle during printing, ensuring structural integrity post-deposition. Compositions with low viscosity and flow behavior closer to Newtonian showed weak gelation and poor printing quality. The gelation kinetics in the inks is crucial in stabilizing the printed structures, enabling filament formation, and preventing fusion and collapse during printing and subsequent handling. Furthermore, depending on the application, the flow rate and printing speed can be adjusted to create thinner or thicker structures to suit it. Overall, this study highlights the role of engineering the rheological behavior of soft material used in the bioprinting process to ensure tissue constructs with enhanced resolution, structural integrity, and mechanical properties.