Dynamic Supramolecular Biofabrication Platform

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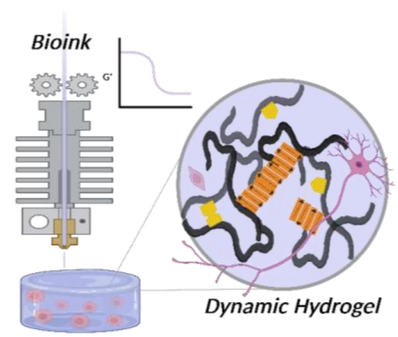
Dynamic hydrogels represent a promising class of biomaterials for engineering extracellular matrix-mimetic environments with tunable mechanical and biological properties. Here, we present a bioinspired dynamic hydrogel that combines dynamic supramolecular interactions with a modified polysaccharide network to achieve enhanced self-healing, structural resilience, and printability. Short self-assembling peptides (SAPs) were engineered as stimuli-responsive (pH-responsive depsipeptide) variants and grafted onto modified polysaccharide backbones to create dynamic supramolecular biohybrid hydrogels with extracellular matrix-mimetic properties. By integrating peptide nanofibril (PNF)-forming SAPs as supramolecular gelators within biopolymer networks, we developed biomimetic hydrogels with rationally tunable mechanical, structural, and biological characteristics. The biohybrids were analysed regarding their chemical composition (e.g., nuclear magnetic resonance spectroscopy), mechanical (gelation, rheology), different printing method and biological properties (cytocompatibility, bioactivity, multiple cell types), and evaluated for different applications.

The resulting hydrogels exhibit rapid gelation, shear-thinning behavior, autonomous self-healing, and mechanical properties comparable to soft tissues, enabling excellent performance in both extrusion-based and drop-on-demand bioprinting while maintaining high construct fidelity. Comprehensive characterization, including nuclear magnetic resonance spectroscopy, rheological analysis, and biological evaluation, confirmed the successful incorporation of SAPs and the formation of dynamic supramolecular networks. In vitro studies demonstrated excellent cytocompatibility, sustained cell viability, and favorable cell-matrix interactions across multiple cell types, supporting cellular elongation and neuronal differentiation in 3D culture.

The combination of biopolymer-derived backbones with PNF-forming SAPs introduces the self-assembling and dynamic nature of peptide supramolecular interactions into biohybrid materials. These findings highlight the potential of SAP-based dynamic hydrogels as next-generation biofabrication platforms for tissue engineering and regenerative medicine.



Overview of the dynamic hydrogel biofabrication platform.