Nanofibrous Hyaluronic Acid/Gelatin Methacrylate Hydrogels Enhance Cartilage Regeneration

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Introduction Various forms of hyaluronic acid (HA)-based hydrogels are widely utilized in cartilage tissue engineering due to their intrinsic bioactivity, biocompatibility, and anti-inflammatory properties. However, the high viscosity of HA solutions limits their processability into fibrous structures that mimic the nanofibrous nature of the hyaline cartilage extracellular matrix. To address this, gelatin is often incorporated to improve electrospinnability while simultaneously providing bioactive cell adhesion motifs and enhanced mechanical properties. In this study, a HAMA/GelMA nanofibrous hydrogel was developed to mimic native ECM architecture and promote chondrogenic activity for cartilage regeneration.

Materials and Methods HA and gelatin were methacrylated to obtain HAMA and GelMA. Polymer solutions containing 1% or 1.5% HAMA and 5%, 7.5%, or 10% GelMA were prepared in solvent and electrospun. The resulting mats were cut into 10 mm × 10 mm samples and crosslinked using Irgacure 2959 under UV light. FTIR and NMR were used to characterize the chemical structure. After swelling in PBS overnight, the mechanical properties, swelling ratio, and degradation rate were evaluated. Finally, bovine chondrocytes were seeded onto the fibrous hydrogels and cultured for 21 days. Cell viability, ECM protein expression, and GAG/DNA content were assessed.

Results and Discussion The fibrous hydrogels showed improved structural integrity, mechanical strength, and reduced degradation with higher GelMA content. FTIR and NMR analyses confirmed the structural stability of the polymers following electrospinning and crosslinking. Confocal imaging revealed high chondrocyte viability (>80%), indicating the absence of cytotoxic residues. Notably, fibrous hydrogels demonstrated significantly higher GAG/DNA ratios compared to non-fibrous hydrogels with the same polymer concentration. Eventually, immunofluorescence staining revealed increased expression of type-II collagen and aggrecan, resembling the native hyaline cartilage.

Conclusion The results indicate that the HAMA/GelMA fibrous hydrogel represents a promising strategy for cartilage tissue engineering by combining the bioactivity of HAMA with the mechanical strength and cell-interactive properties of GelMA.