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Nanofibrous Hyaluronic Acid/Gelatin Methacrylate Hydrogels Enhance Cartilage Regeneration

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BACKGROUND

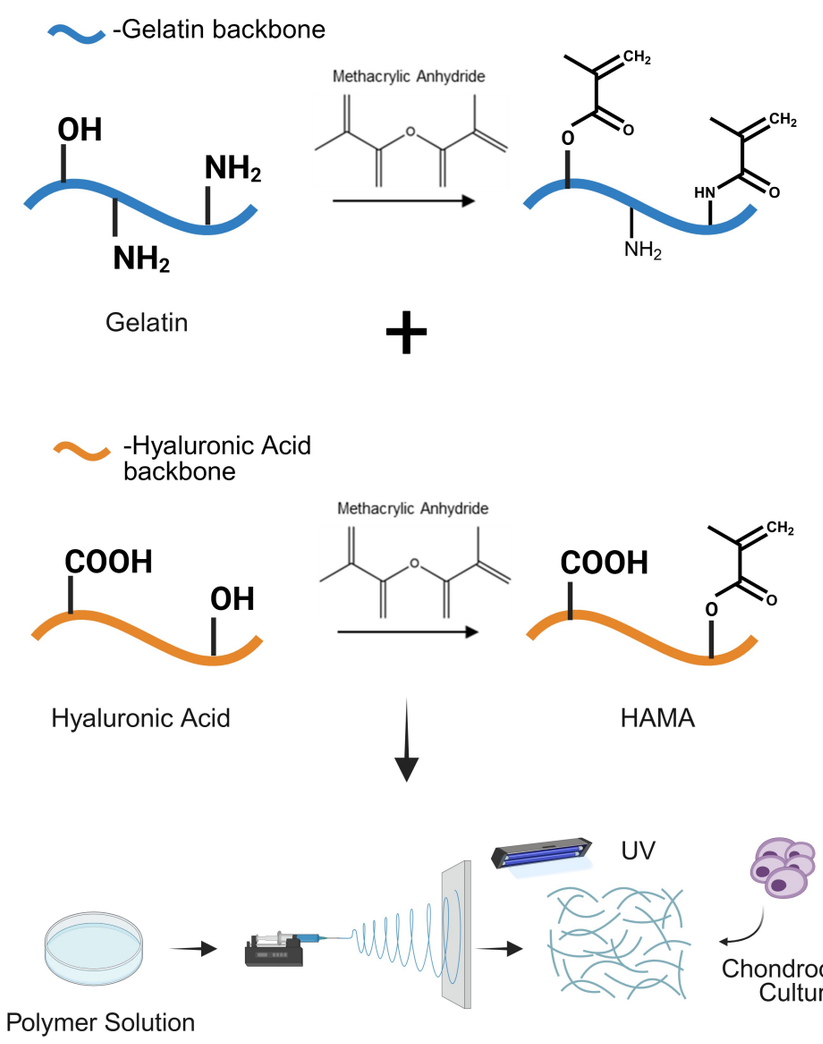
Hyaluronic acid (HA) hydrogels are widely explored for cartilage tissue engineering due to their biocompatibility, intrinsic bioactivity, and anti-inflammatory behaviour. However, the high viscosity of HA limits its ability to form fibrous structures that mimic the nanofibrous extracellular matrix (ECM) of hyaline cartilage. Incorporating gelatin improves electrospinnability while introducing bioactive cell-adhesion motifs and enhancing mechanical stability. Developing nanofibrous HAMA/GelMA hydrogels has the potential to replicate native chondrocytes ECM and support cartilage regeneration.

HYPOTHESIS & AIMS

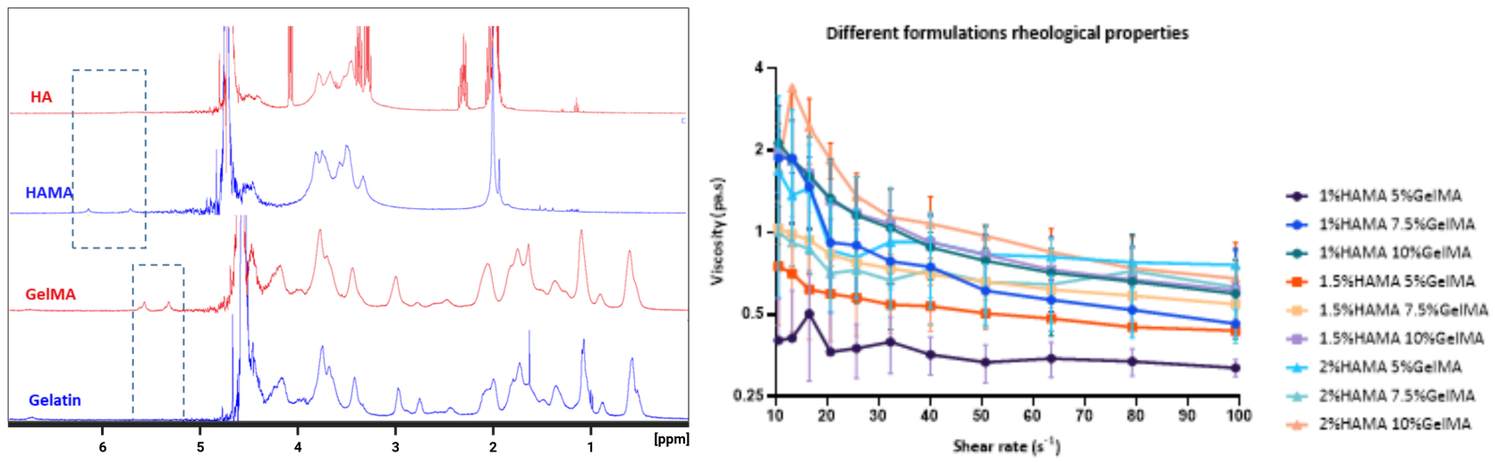
Hypothesis: A nanofibrous HAMA/GelMA hydrogel can replicate cartilage-like ECM architecture and enhance chondrocyte viability and matrix formation.

Aims: Synthesise nanofibrous hydrogels from naturally derived hyaluronic acid and gelatin using an electrospinning approach. Optimise electrospinning parameters and HAMA/GelMA concentrations to achieve formulations that best support chondrocyte interaction and performance.

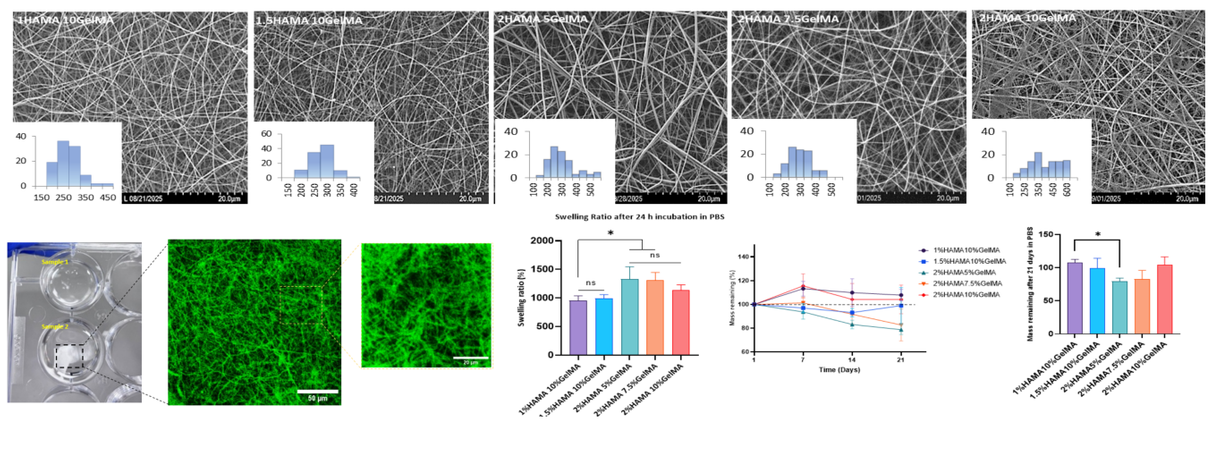
METHODS



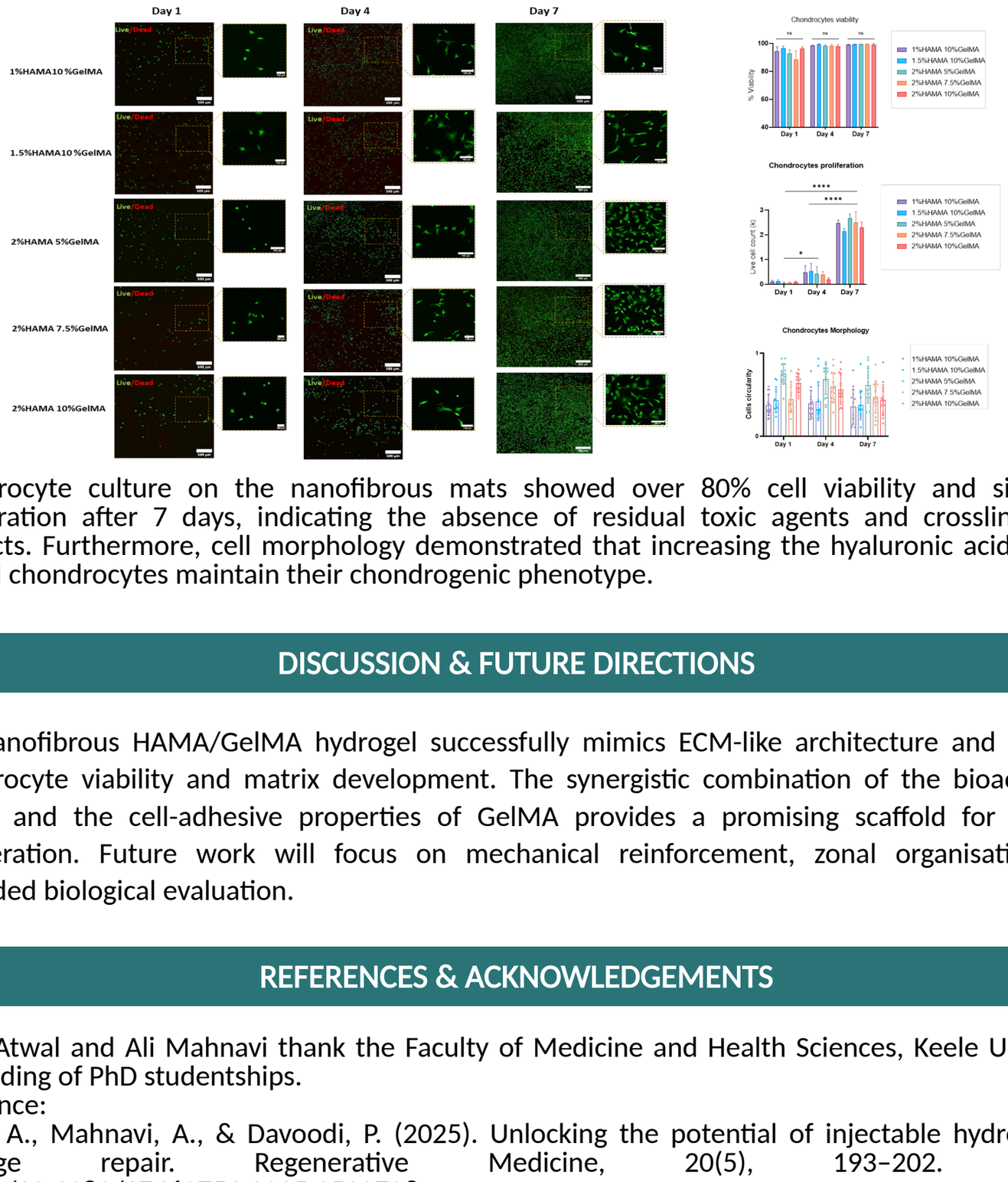
RESULTS



^{1}H NMR spectra confirming successful methacrylation of HA (HAMA) and gelatin (GelMA). Rheological profiling of different HAMA/GelMA formulations demonstrating viscosity characteristics suitable for electrospinning.



SEM images of optimised formulations showing nanofibrous morphology with fibre diameters ranging from approximately 250–600 nm. Swelling ratio and stability analysis in PBS indicate successful crosslinking and structural retention of the nanofibrous mats.



Chondrocyte culture on the nanofibrous mats showed over 80% cell viability and significant proliferation after 7 days, indicating the absence of residual toxic agents and crosslinking by-products. Furthermore, cell morphology demonstrated that increasing the hyaluronic acid content helped chondrocytes maintain their chondrogenic phenotype.

DISCUSSION & FUTURE DIRECTIONS

The nanofibrous HAMA/GelMA hydrogel successfully mimics ECM-like architecture and supports chondrocyte viability and matrix development. The synergistic combination of the bioactivity of HAMA and the cell-adhesive properties of GelMA provides a promising scaffold for cartilage regeneration. Future work will focus on mechanical reinforcement, zonal organisation, and expanded biological evaluation.

REFERENCES & ACKNOWLEDGEMENTS

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Reference:

Atwal, A., Mahnavi, A., & Davoodi, P. (2025). Unlocking the potential of injectable hydrogels for cartilage repair. Regenerative Medicine, 20(5), 193–202. https://doi.org/10.1080/17460751.2025.2520708