

# Ultrasound-Triggered Gelation for Spinal Disc Repair

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Lower back pain is a leading cause of disability, often associated with intervertebral disc (IVD) degeneration, which originates in the nucleus pulposus (NP), a gel-like structure within the IVD. An estimated 619 million people lived with this condition worldwide in 2020.<sup>[1]</sup> Current treatments rely on conservative methods, such as physiotherapy, or invasive surgical procedures, such as spinal fusion. Previous studies have investigated hydrogels as biomaterials for restoring the biomechanical properties of NP, but these hydrogels are either self-curing, or they rely on light-initiated radical crosslinking, which is depth-limited.

To circumvent these challenges, we present an ultrasound-triggered gelation approach as a minimally invasive process that offers spatiotemporal control to the clinician at clinically relevant depths.<sup>[2]</sup> This concept relies on the use of an injectable and biocompatible free-flowing precursor solution consisting of an anionic polysaccharide, calcium-loaded thermosensitive liposomes and glass microspheres. Following optimization, alginate was chosen as the lead polysaccharide candidate. Focused ultrasound was used to heat the implant material to just above the lipid phase-transition temperature (41 °C), leading to calcium release and on-demand ionic crosslinking, and subsequently to a free-standing hydrogel. Ex vivo experiments in nine bovine spinal units confirmed effective ultrasound-triggered gelation, and subsequent biomechanical evaluations indicated partially restored mechanical performance without material herniation. Taken together, this study presents a promising approach for in-situ ultrasound-triggered hydrogelation.

[1] GBD 2021 Low Back Pain Collaborators, *Lancet Rheumatol.* 5 (2023) E316-E329.

[2] V. A. Brans,‡ A. P. Constantinou,‡ *et al.*, *Adv. Healthcare Mater.* (2025) e01823.