Institute for Biomechanics

Hydrogel injection and mechanically interlocking patch partially recover intervertebral disc mechanics while withstanding physiological load

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1. Background and Aim

- Discectomy, current gold-standard for lumbar disc herniation, provides symptomatic relief, but does not prevent re-herniation.
- Our approach combines (i) annulus fibrosus (AF) repair using a mechanically interlocked patch (iPatch) comprising polyethylene terephthalate (PET) fibers[1] (Fig.1), and (ii) nucleus pulposus (NP) augmentation with hyaluronic acid-tyramine hydrogel (HA-Tyr).

The aim was to test the influence of the viscosity of the HA-Tyr hydrogel on the mechanical function of the repaired disc after experimental herniation.

2. Methods

- Bovine caudal intervertebral disc segments (N=48) were divided into three treatment groups (each n=12) and one control group (n=12). All specimen underwent an induced injury through annulotomy and partial nucleotomy (NP volume removal of ~20%).
- Specimens of the treatment groups were repaired with HA-Tyr injection with different viscosities and with iPatch AF repair (Fig. 2).
- Control group specimens remained unrepaired to simulate discectomy (Fig. 2).
- Biomechanical testing was done in two steps:

(1) Axial and torsional parameters under compressive-tensile cycles in steps A-C (Fig. 1-2).

(2) Load capacity was determined until failure, defined as either NP herniation (control group) or hydrogel extrusion (treatment groups) (Fig. 2).

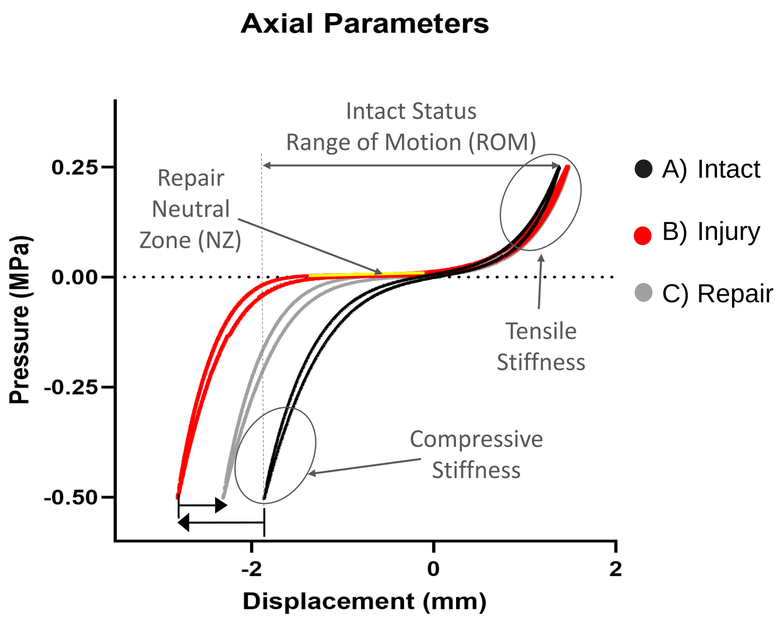

Fig. 1: Strength-displacement curve with analyzed regions.

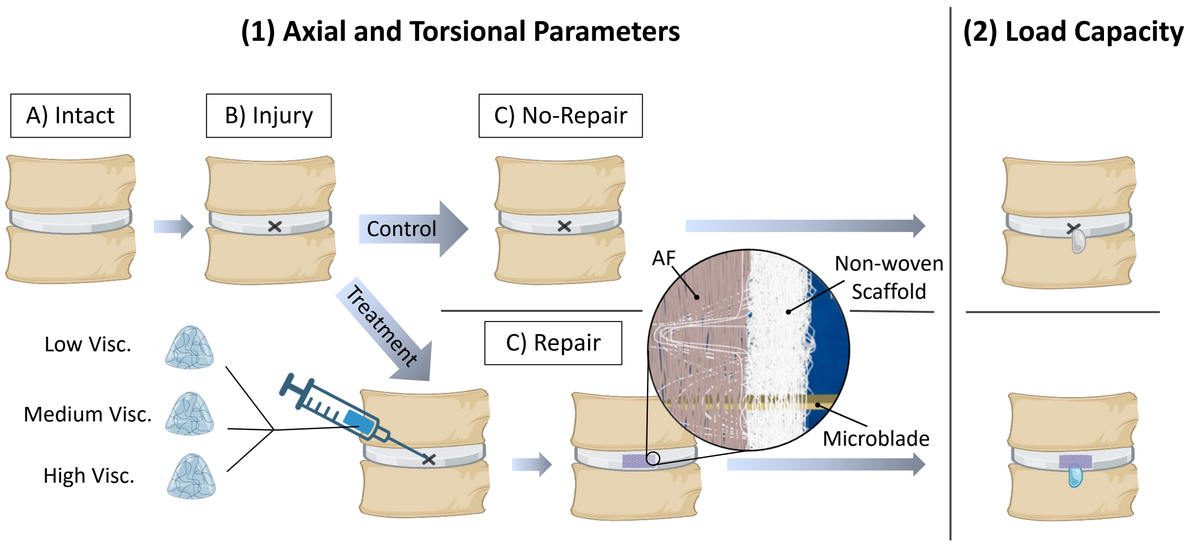

Fig. 2: Design of the protocol illustrating the difference between the control group and treatment group. Figure created with Biorender.

3. Results

- Matched mixed-effects model analysis were calculated for each axial and torsional parameter with "animal" and "level" as random effects. Differences between groups were detected with Tukey's post-hoc test. Failure strength test was compared using one-way ANOVA, revealing no statistically significant difference.

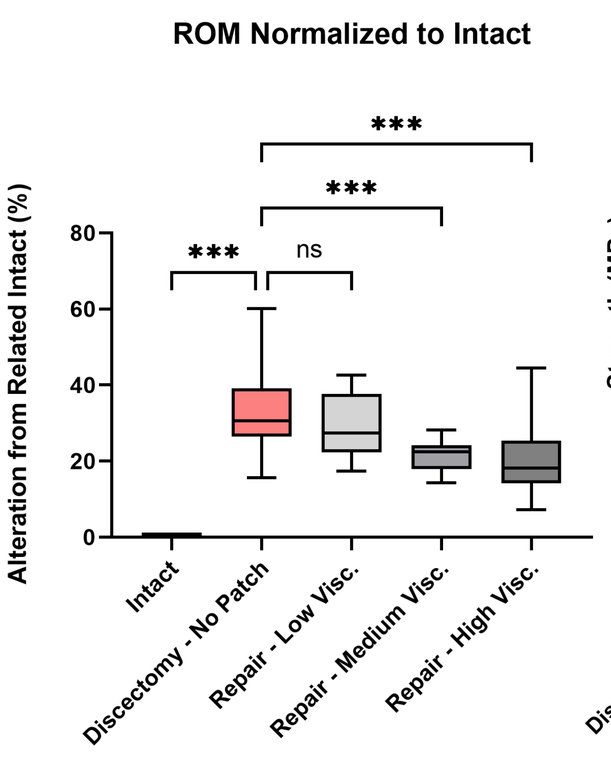

Fig. 3: : Calculated range of motion from strength-displacement curve. ***: $p < 0.001$.

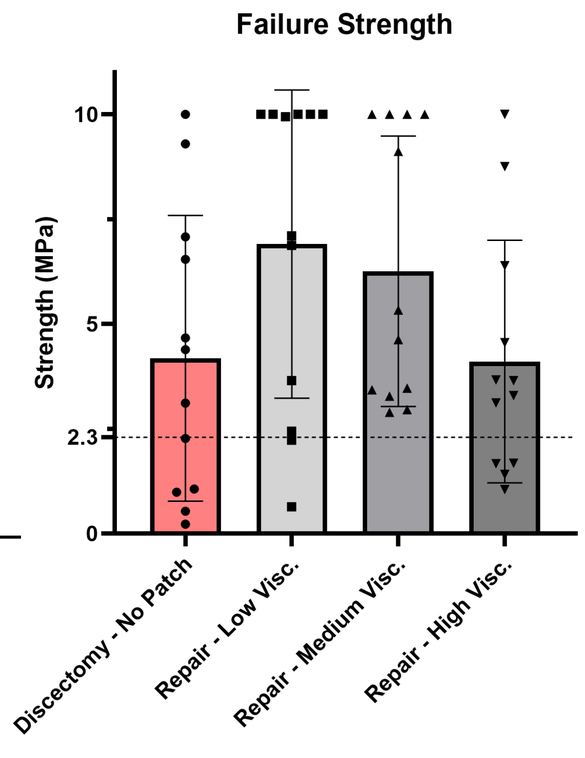

Fig. 4: Quantitative data of failure strength. The dotted line represents the physiological stress level (2.3 MPa).

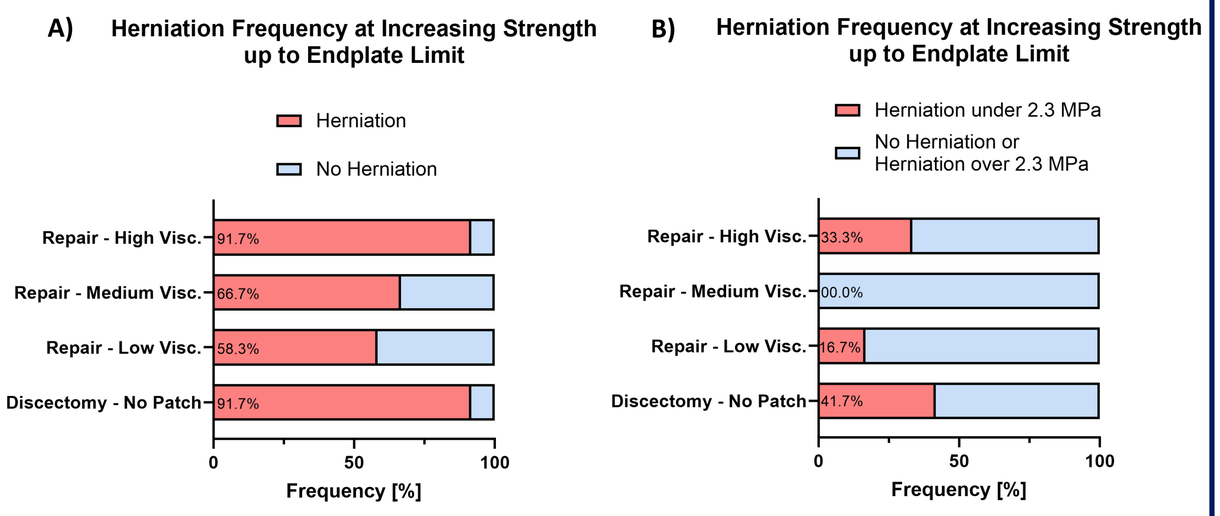

Fig. 5: Frequency of herniation **A)** up to 10 MPa (hyper-physiological stress) and **B)** under 2.3 MPa (physiological stress) expressed in percentage.

4. Conclusion

- Lower herniation risk if annulus defect is repaired with iPatch.
- Samples combining an iPatch repair with medium viscosity hydrogel successfully withstood physiological stresses (2.3 MPa).
- This study shows the **importance of an optimized viscosity of an injectable hydrogel** for the restoration of NP biomechanical parameters.
- Combining iPatch with a HA-Tyr hydrogel of medium viscosity strongly reduces herniation frequency and partially restores range of motion.

Reference

1. Meyer DC, Bachmann E, Darwiche S, et al. Rotator Cuff Repair and Overlay Augmentation by *of Sports Medicine*. Published online October 1, 2023. doi:10.1177/03635465231189802Direct Interlocking of a Nonwoven Polyethylene Terephthalate Patch Into the Tendon: Evaluation in an Ovine Model. *American Journal*

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