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Studies on the Internal Failure Mechanics of Lumbar Intervertebral Discs

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Abstract

While several mechanical disruption studies of lumbar intervertebral discs have previously been carried out *in vitro*, none have sought to examine the microstructure of the resulting tissue failures. Consequently, how various spinal postures during loading and various loading rates for a given posture affect the disc's internal failure mechanics has yet to be documented.

In the studies contained herein, ovine lumbar intervertebral discs have been mechanically disrupted by injecting radio-opaque gel into their nucleus via an injection screw inserted longitudinally through their inferior vertebra. The resulting disruption caused to each disc was subsequently examined using micro-computed tomography and microscopy in tandem.

A low-strain rate, gradual nuclear pressurization regime was used to disrupt discs positioned: neutrally, flexed 7° and 10°, and flexed 7° plus axially rotated 2°. The primary results were:

Neutral position (0° flexion)
Failure of discs always occurred within the posterior annulus. Failure resulted from the formation of sequential circumferential tears connected by short, circumferentially distributed radial tears. Consequently, the path of gel communication between the nucleus and posterior disc periphery was highly serpentine.

Flexed 7°
Compared to the neutral position, positioning discs in 7° flexion during nuclear pressurization led to the creation of radial tears that extended through the full thickness of the central posterior disc wall. Two types of radial tears occurred: mid-axial and annular-endplate. Mid-axial tears were confined to the annulus. Annular-endplate tears consisted of both annular and endplate failure; endplate failure in these tears always occurred adjacent to the mid annulus at the cartilaginous/vertebral endplate junction.

Flexed 10°
Compared to those discs positioned in 7° flexion, an additional 3° of flexion increased the proportion of radial annular-endplate type tears observed among the sample population. Also, a notable number of type II rim fractures occurred.

Flexed 7° + Axially Rotated 2°
Compared to those discs positioned in 7° flexion, the addition of 2° axial rotation reduced the proportion of radial mid-axial tears (tears confined solely to the annulus). While the proportion of radial annular-endplate tears did not change, they occurred at a substantially lower pressure than in both the 7° and 10° flexion groups.

A high-strain rate, impulse pressurization regime was used to disrupt discs positioned: neutrally, and flexed 7°. The primary results were:

Neutral position (0° flexion)
In contrast to those discs gradually pressurized while in the neutral position, impulse pressurization created predominantly radial tears. Radial tears extended through the full thickness of the central posterior disc wall, and, in all cases, incorporated tears of the superior cartilaginous endplate adjacent to the inner annulus and/or transition zone.

Flexed 7°
In contrast to those discs gradually pressurized while flexed 7°, impulse pressurization decreased the proportion of radial tears and increased the proportion of vertebral endplate failures. In all cases, those radial tears that did occur incorporated endplate tears adjacent to the outer posterior annulus at the cartilaginous/vertebral endplate junction, or within the vertebral endplate.

The results contained herein detail fundamental differences in the relative strengths of the intervertebral disc wall's components (i.e. the annulus, endplates, and their junctions). Further, the results also describe, for the first time, the microstructure of herniations created *in vitro* with clinically relevant morphologies. These findings should prove useful to both clinicians and future *in vitro* disc disruption researchers, and, hopefully, prompt both groups to better document the morphologies of the discs with which they deal.

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