

Discectomy Alters the Internal Strains of the Intervertebral Disc

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Introduction:

Discectomy is a surgical procedure to remove the loose nucleus pulposus (NP) following herniation. Discectomy and herniation may damage the annulus fibrosus (AF), decrease the NP pressure, and alter the load sharing between the NP and AF. Previous studies show that discectomy alters disc mechanics and causes inward bulging of the AF [1-3]. We have noninvasively quantified the internal strains of intact discs using magnetic resonance (MR) imaging. That study observed an increase in AF tensile radial and compressive axial strains with degeneration [4]. The change in AF strain was attributed to the decrease in NP pressure with increasing degeneration; placing more of the applied load directly on the AF. The effect of discectomy on internal disc mechanics remains unknown. **Therefore, the objective of this study was to quantify the effect of discectomy on the internal displacements and strains of nondegenerate and degenerate discs under axial compression.** We hypothesized that discectomy will increase internal displacements and strains, with this increase being greater for degenerate discs.

Methods:

Human lumbar spines (n=19, age 22-80) were acquired, and $T_{1\rho}$ relaxation times were calculated as a measure of degeneration ($T_{1\rho}$ times = 46-146msec) [5]. Mechanical testing and imaging was performed as previously described [4]. A high-resolution sequence was used to acquire mid-sagittal (MS) and mid-coronal (MC) MR images (3T magnet, 234 μ m/pixel, thickness = 3mm, TR/TE = 3000/113ms). A reference image was acquired under a 20N tare load. A 1000N compressive load was applied and the imaging sequence was repeated for a deformed image. Samples were rehydrated and a cruciform incision was made into the posterior-lateral AF with a #15 scalpel. Approximately 2g (wet weight) of NP material was removed, and then the samples were rehydrated and retested. The analyzed parameters include the initial disc height, change in disc height normalized to the initial height, the radial displacement at mid-disc height of inner and outer AF, the translational shift in the NP, and the average radial and axial strains in AF regions and the NP. A paired Wilcoxon test was performed to compare parameters before and after discectomy, and a Spearman's test was performed to determine whether the change in a parameter after discectomy correlated with degeneration. Significance was set at $p \leq 0.05$ and a trend at $0.05 < p \leq 0.10$.

Results:

The initial disc height was 11.3 ± 1.8 mm and was not altered by discectomy ($p > 0.7$). The normalized change in disc height was 25% more compressive with discectomy ($p < 0.05$). Similarly, the AF and NP axial strain was more compressive with discectomy (Fig 1A). The increased compressive strain after discectomy depended on degeneration level for the NP, lateral AF, and posterior AF; where nondegenerate discs were relatively unaltered, and the compressive axial strain in highly degenerated discs ($T_{1\rho} = 50$ ms) increased by 5% following discectomy (Fig 1B). The change in axial strain of the anterior AF was similar, but was not significantly dependent on degeneration ($p = 0.2$).

The radial displacement of the outer AF was not altered with discectomy ($p > 0.9$). However, the radial displacement of the inner AF decreased in the MC ($p < 0.01$) and MS ($p = 0.09$) orientations (Fig 2A). The MS inner AF radial displacement was dependent on degeneration ($p = 0.02$; Fig 2B); where nondegenerate discs were relatively unaltered, and the radial displacement in highly degenerated discs changed by -0.5 mm, from outward to inward displacement, following discectomy. The NP translated with respect to the outer AF towards the posterior (i.e. negative) with discectomy (Fig 2A), and this translation was also dependent on degeneration level ($p \leq 0.03$). Again, nondegenerate discs were relatively unaltered, while the NP translation in highly degenerated discs was 0.7 mm more posterior following discectomy. The average radial strain was tensile and increased in the lateral AF, decreased in the posterior AF and was unaltered in the anterior AF with discectomy ($p = 0.6$; Fig 3A). Unlike the axial deformation and strain and the radial deformations, the change in radial strains were not correlated with degeneration level ($p > 0.1$). That is, the observed change in radial strain was relatively uniform across all levels of degeneration (Fig 3B). The

only exception to this observation was the anterior AF radial strain, which became more tensile with discectomy in degenerated discs and was relatively unaltered in nondegenerate discs.

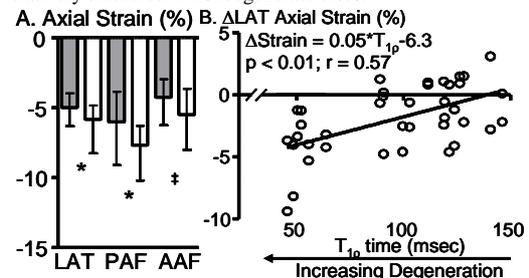


Fig 1. A) Axial strain in the lateral (LAT), posterior (PAF) and anterior (AAF) AF before (grey) and after (white) discectomy, * $p < 0.01$ & † $p = 0.06$. B) Correlation of the change in LAT axial strain with degeneration.

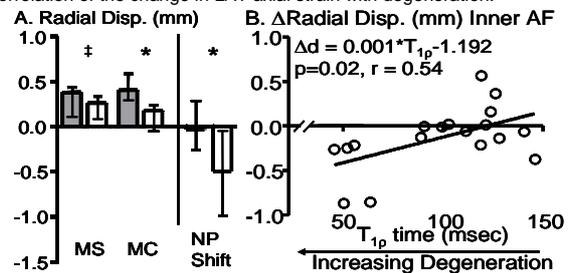


Fig 2. A) Inner AF radial displacement in the MS and MC plane and NP shift before (grey) and after (white) discectomy, * $p < 0.01$ & † $p = 0.09$. B) Correlation of the change in the inner AF radial displacement with discectomy and degeneration.

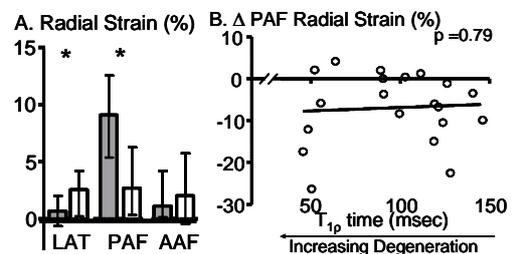


Fig 3. A) Radial strain of the lateral (LAT), posterior (PAF) and anterior (AAF) AF before (grey) and after (white) discectomy. * $p < 0.05$ B) No correlation of the change in PAF radial strain with degeneration.

Discussion:

This study evaluated the effect of discectomy on the internal displacement and strains of nondegenerate and degenerate discs. This study demonstrated that discectomy greatly alters the load sharing between the NP and AF in degenerate discs. The mechanisms for the minimal effect of discectomy on the internal mechanics of nondegenerate discs is likely due to the capacity for swelling of the remaining NP material, as observed previously [3]. In degenerate discs, discectomy caused inward bulging of the inner AF and a large shift of the NP, comparable to data in the literature [1,2]. Although the inner AF bulged inward in degenerate discs, the decrease in tensile radial strains of the posterior AF of nondegenerate discs is unclear, but may be due to the large movement of the NP towards the posterior or to changes that occur outside of the analyzed 2D imaging planes. The impact of discectomy on the internal mechanical behavior of the disc increases greatly with degeneration and may cause the lamellae to buckle or delaminate and may accelerate the degenerative cascade.

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References: [1] Seroussi⁺ JOR: 7(1) 1989; [2] Meakin⁺ Clin Biomech: 16(2) 2001; [3] Johannessen⁺ Ann Biomed Eng: 34(4) 2006; [4] O'Connell⁺ In Review 2009; [5] Johannessen⁺ Spine 31(11)