The Role of the Nucleus Pulopsus in Compressive Biomechanics of the Human Lumbar Disc

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Objectives

The understanding of the nucleous pulposus (NP) effect on the inververtebral disc mechanics is useful for a correct design of biomaterial for disc augmentation. Load transfer in a healthy disc occurs by generating hydrostatic pressure within the disc, which creates tension in the annulus fibers. Partial removal of the nucleus pulposus has been shown to decompress herniated discs, relieve pressure on the nerve roots, and in some cases, alleviate disc pain, but this procedure changes the response to (1) loading and (2) geometry eventually causing an instability of the vertebral segment. The effect of partial and full removal of the nucleus tissue on the mechanical behavior of the human intervertebral disc was investigated here.

Methods

Six cadaver lumbar specimens (L1-L5) were tested in axial compression. Initial intervertebral disc height was measured by a calibrated X-ray image. Preconditioning was performed in displacement control at 3% of initial disc height (DH) for 50 cycles. The intradiscal pressure was collected by a pressure transducer (PMC–Model 060S) inserted through the anterior annular wall. The disc was tested in load control with a 5 cycle sawtooth load at 0.1Hz from a tension of 150N to compression of 1500N. Under a 50N compressive load (to simulate lying prone), a nucleotome was used to remove tissue from the NP. The nucleotome application was performed in four different steps, each one 5 minutes long with a posterolateral approach. At the end of each denucleation period the disc was tested according to the protocol. The effect of different degrees of nucleus removal on the biomechanics of the disc was examined using the 5th loading cycle on each test. Disc height (DH), compressive and tensile range of motion (cROM, tROM), compressive neutral zone (cNZ), compressive stiffness and intradiscal pressure were used to quantify the results.

Results

In Figure 1 the relative changes in DH, cROM , tROM and cNZ during each denucleation step were normalized to the equivalent value for the intact disc. Figures 2 and 3 show the relative changes in stiffness and intradiscal pressure normalized to those of the intact values after each denucleation period at different loads. The progressive removal of NP tissue causes a reduction in DH as shown in Figure 1 and a decrease of the intradiscal pressure as reported in Figure 2. There is a corresponding increase of cROM and tROM (Figure 1).

Discussion

The increase in tROM is consistently larger than the increase in cROM because, initially, the pressurized nucleus causes a tensile stress in the annulus wall that limit the displacement in traction. Figure 2 shows that the pressure in the nucleus decreases by increasing the application time of the nucleotome. However the pressure after 5 minutes is about 5% less than the pressure after 10 minutes, this phenomena could be due to the collapse of the disc on itself after 10 minutes of nucleus removal. Figure 3 shows that the role of the annulus is dominant in the higher compressive load levels. The stiffness of the disc is consistently changed at lower load levels by the nucleus tissue removal, while for the higher load levels (800N and 1400N) the stiffness resembles the values measured for the intact disc. Overall, increased mobility is observed with a denucleated condition. The physiological and pain consequences of this instability are not well understood.

References

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Acknowledgements

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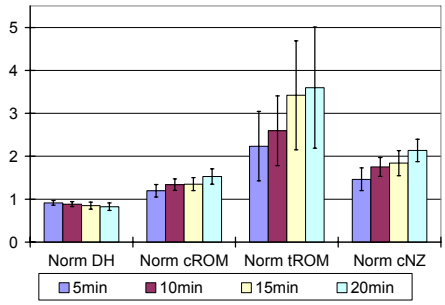

Figure 1: Changes in DH, cROM , tROM and cNZ with increased denucleation, normalized to intact disc values

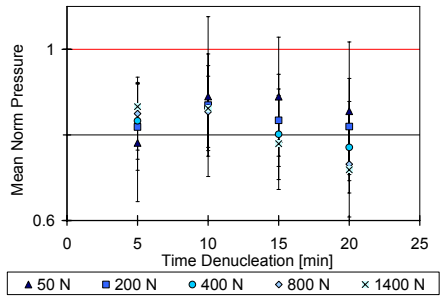

Figure 2: relative changes in intradiscal pressure with denucleation show a decrease in pressure

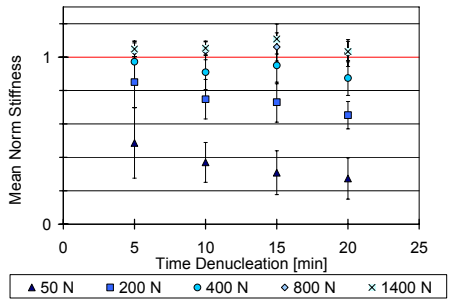

Figure 3: Normalized stiffness is reduced at lower load levels, but not at higher load levels for the denucleated discs