THE BIOMECHANICAL PROPERTIES AND STABILITY OF LUMBAR SPINAL MOTION SEGMENT FOLLOWING LUMBAR POSTERIOR DECOMPRESSION SURGERIES

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INTRODUCTION:
Intervertebral disc damage and excision have shown to significantly alter lumbar spine mechanics. Laminectomy and facetectomy have been shown to increase spinal motion and increase stress experienced by the annulus. However, the changes in lumbar spinal stability corresponding to sequential decompressive procedures as would be performed in a standard posterior surgical approach to lumbar decompression have not been well characterized.

An unstable joint exhibits an abnormally large deformation or joint movement corresponding to an applied load of physiological magnitude. Methods and metrics for quantifying the stability of spinal motion segments have been proposed previously. The neutral zone (NZ) metric is believed to be the most sensitive indicator for spinal instability. Therefore the purpose of this study was to determine the change in biomechanical properties including stability due to four successive lumbar decompression procedures. The constructs that were evaluated included: intact, partial bilateral laminectomy, total laminectomy, discectomy, and total bilateral facetectomy. We hypothesized that with each successive decompressive surgery there would be differences in the biomechanical properties, including loss of neutral zone stability (increase in NZ), of the lumbar motion segments.

METHODS:
Fifteen fresh-frozen bovine lumbar motion segments and three fresh-frozen adult cadaveric motion segments (L1-L2, L3-L4, and L5-S1) were prepared for biomechanical testing. The specimens were secured into the fixtures of an EnduraTEC eight degree-of-freedom testing device (Bose Corporation, Minnetonka, MN), for flexibility testing. The flexibility testing protocol consisted of a nominal axial preload of 10N followed by four cycles of pure moment loading (+/- 4Nm) in flexion and extension. Peak moment was selected to be nondestructive but sufficient to demonstrate variation between the testing constructs. Specimens construct types in order were: Intact: without any surgery, Partial: partial bilateral laminectomy, Total: total bilateral laminectomy, Disectomy: total laminectomy and partial disectomy, Facetectomy: total laminectomy, partial disectomy, and facetectomy. With consideration for a subsequent stabilization study, only one-third of the bovine post-disectomy specimens underwent a facetectomy procedure.

Descriptive statistics (means, standard deviations, and range) for neutral zone (Wilke, 1998), hysteresis, peak flexion angle, peak extension angle, and total range of motion were analyzed. Non-parametric statistical testing for paired samples (Wilcoxon Signed Ranks Test) was used for comparison testing between each of the five different constructs. All calculations were performed on the fourth bending cycle, allowing for adequate pre-conditioning of the specimens.

RESULTS:
Neutral Zone
Posterior decompression surgeries effected neutral zone changes in the bovine specimens ($\chi^2 = 10.170, p = 0.017$), however no significant differences were detected between the intact, partial laminectomy, and total laminectomy groups (Figure 1). Disectomy induced the greatest change in NZ mechanics and was significantly different compared to each of the previous three conditions. Similar trends were noted in the human cadaveric specimens.

Hysteresis
Discectomy produced an increase in hysteresis in flexion ($p=0.050$), extension ($p=0.048$), and combined flexion and extension ($p=0.013$) (Figure 2).

Range of Motion
There were no statistically significant differences in peak extension ROM between the first four constructs ($\chi^2 = 1.017, p = 0.707$), however differences were present in peak flexion ROM ($\chi^2 = 8.546, p = 0.036$).

DISCUSSION:
Lumbar posterior decompression surgery is a common surgical procedure indicated for individuals with degenerative disc disease. Surgical intervention often alters the passive stability of the lumbar spine as osseous, ligamentous and discal structures are compromised. In order to optimally treat patients with lumbar spine dysfunction, it is important to understand the sequential biomechanical consequences of lumbar spine decompression surgery. The results of this study suggest that neutral zone stability and bending energy storage and dissipation (hysteresis) will be compromised following disectomy, but that partial and total laminectomy do not produce a significant biomechanical effect. The hypothesis that after each successive surgery there would be measurable differences in biomechanical properties of the spinal motion segment was not validated by this study.

CONCLUSION:
Intervertebral disc perforation and excision have shown to significantly alter lumbar spine mechanics. Neutral zone stability and bending energy dissipation change after disectomy but not after partial or total laminectomy.