Biomechanical Evaluation of an Expandable Cage in Single Segment Posterior Lumbar Interbody Fusion

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INTRODUCTION:
One of the popular methods of treating lumbar spine pathologies involves a posterior lumbar interbody fusion (PLIF) using bilateral interbody non-expandable cages. Due to the geometry of these cages, they can require extensive bony removal and nerve root retraction. Some resultant risks of the procedure include dural lacerations and post-operative neuropraxia. Expandable interbody cages may address some of these concerns and possibly decrease the risks associated with PLIF procedures. This is the first study to our knowledge evaluating the biomechanical characteristics of an expandable lumbar interbody device in a cadaveric human spine model. The objective of this study was to evaluate the biomechanical characteristics of a new expandable interbody cage in single segment posterior lumbar interbody fusion using cadaveric lumbar spines.

METHODS:
Five fresh frozen lumbar spinal segments were potted from L3 to S1 while leaving the L4/L5 segment as the only mobile functional spinal unit (FSU). Biomechanical testing was performed using a custom testing system that permits six degrees of freedom (Figure 1). The specimens were tested intact (IN), post-discectomy (PD), after interbody cage placement (CA), and after cage placement with pedicle screw fixation (PS) fixation under axial compression, flexion, extension, lateral bending and axial rotation conditions. The specimen was loaded from 5 N to 300 N for axial compression and from 0.5 Nm to 8.0 Nm for flexion, extension, lateral bending and axial rotation. A video digitizing system (WINAnalyze, Mikromak, Berlin, Germany) was used to analyze the regional deformation and displacement of the specimen (Figure 2). Subsequently, the digital video and Instron data were synchronized to create load-displacement curves. The angular displacement, stiffness, disc height and sagittal alignment were then calculated.

RESULTS:
When the cage was supplemented with pedicle screw fixation, the mean angular displacements (*) for axial rotation and lateral bending were significantly less than all other constructs (p<0.05). The same trend was seen for the extension-flexion arc, but this difference was not statistically significant.

For all torque ranges (2-3, 6-7, & 1-8 Nm), the cage alone restored stiffness to near intact levels, except for extension at 6-7 Nm, but no statistically significant difference was seen between the cage-alone and other constructs. For rotation, lateral bending, flexion, extension, stiffness of the cage plus pedicle screw construct was greater than intact, but only axial rotation showed a statistically significant increase (p<0.05) at the 1-8 Nm torque range. (Figure 3)

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DISCUSSION:
An expandable lumbar interbody cage used as a stand alone device decreases mean angular displacement and % ROM, and restores stiffness to near intact levels. Additional fixation is required to significantly decrease mean angular displacement and % ROM, and increase stiffness levels above intact. Following discectomy, the expandable cage restores disc height, but sagittal alignment is not improved until supplementation with pedicle screw fixation.

Figure 3. Histograms showing the stiffness and range of motion.

After normalizing the range of motion (% ROM), similar trends were observed, but only lateral bending showed a statistically significant decrease in % ROM (p<0.05) for cage alone vs. the other constructs. For the pedicle screw construct, rotation showed a significantly lower % ROM compared to all other constructs (p<0.05), and lateral bending and extension-flexion arc showed a significantly lower % ROM compared to post-discectomy (p<0.05).

In general, the mean angular displacement and % ROM of the cage-alone construct for all motions (axial rotation, lateral bending, extension-flexion arc) decreased compared to post-discectomy, but did not return to baseline (Figure 3). Disc height was restored to levels higher than intact, but only the anterior disc height change was statistically significant (p<0.05) (Figure 4). Sagittal alignment did not show any statistically significant differences following cage placement or pedicle screw fixation (Figure 4).

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Figure 4. Histograms showing disc height and sagittal alignments.