Lateral Lumbar Interbody Cages With Different Shapes Do Not Affect Endplate Stress Location But Affects Stress Magnitude: A Finite Element Study

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INTRODUCTION: Lateral lumbar interbody fusion (LLIF) has gained popularity in recent years due to the low risk associated with the surgery. The basis of LLIF is to rest the cage on the endplate's apophyseal ring, which biologically consists of stronger bone. The objective of this study was to determine if the cage shape affected the location of the stress location and magnitude when supplemented with pedicle screw fixation.

METHODS: An L4-L5 functional spinal unit (FSU) obtained from a previously validated skull to pelvis model was used for this study [1]. A 10 N*m pure moment was applied to the L4 vertebrae while the L5 vertebrae was fixed to determine the motions: extension (ext), flexion (flex), left (lb) and right bending (rb), left (lr), right rotation (rr), 400 N pre-load extension (Wpext) and 400 N pre-load flexion (Wpflex). The 400 N pre-load simulated physiologic loading. The intact model was modified to simulate LLIF surgery that consisted of nucleotomy and annulotomy on insertion and the contralateral sides. A rectangular and an arc shape cage with two different footprints: 14mm (AP) x 62 mm (ML) x 15 mm (H) and 18mm (AP) x 62 mm (ML) x 15 mm (H) were simulated within the disc space and the FSU was supplemented with pedicle screw fixation. The contact area of the rectangular shape was equivalent to the arc shaped cage for each respective footprints. The input parameters to the models were cage footprint and shape and the outputs were range of motion (ROM) and endplate stresses, used to determine segment stability and load on the endplate.

RESULTS: For the 14 mm rectangular cage, motion decreased by 89% to 95% for different loading conditions compared to the intact data, Table 1. The 14 mm arc shape cage motion decreased by 87% to 95% for different loading conditions compared to intact ROM. The 18 mm rectangular cage reduced motion by 83% to 95% for all loading conditions compared to intact. Finally, the 18 mm arc shape cage reduced motion by 86%-95%for all loading conditions, Table 1. For both footprints and all motions, the stresses were concentrated on the periphery of the endplate (See Figure 2). Then 14 mm rectangular cage simulation endplate stresses were ranged from 15.1 to 31.9 megapascals (MPa) for all loading conditions. The 14 mm arc shape cage simulation endplate stresses ranged from 8.9 to 87.7 MPa. The 18 mm rectangular cage simulation endplate stresses ranged from 18.6 to 60.3 MPa. Finally, the 18 mm arc shape cage simulation endplate stresses ranged from 16.0 to 78.0 MPa (See Figure 3).

DISCUSSION: For all footprints and cage shapes, pedicle screw fixation effectively stabilized the segment in all loading conditions. Our results also showed that the simulated cage shapes created stress concentrations on the periphery of the endplate (Figure 2). The arc shaped cage produced higher stresses than the rectangular cage in both footprints except in the extension motion for both footprints (Figure 3). For the 14 mm footprint, the arc cage increased endplate stress by 70% (flex), 81% (lb), (112% (rb), (117% (lr), 49% (rr), 88% (Wpext), 71% (Wpflex), and decreased endplate stress by 41% (ext) when compared against the rectangular shape. Similarly, for the 18 mm footprint, the arc cage increased stress by 58% (flex), 149% (lb), 149% (rb), 65% (rb), 117% (lr), 77% (rr), 151% (Wpext), 29% (Wpflex) and decreased endplate stress by 24% (ext) when compared against the rectangular shape (See Figure 3). This shows that arc shaped cage placed a higher load on the endplate than the rectangular cage. However, the endplate stresses were considerably lower than the reported ultimate strength of cortical bone [3].

SIGNIFICANCE: The results show that for similar contact area and cage footprint, there is an impact on stress magnitude but not on the stress location. The rectangular shaped cage produced lower endplate stresses than the arc shape in all motion except extension motion.

REFERENCES: [1] Palepu V. (2013). Retrieved from https://etd.ohiolink.edu/., [2] Pimenta. L. et al., (2011) *SMISS 2011 Annual Conference.* [3] Özkaya, N. et al., (2012). *Fundamentals of biomechanics: Equilibrium, motion, and deformation (page 230)*

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IMAGES AND TABLES:

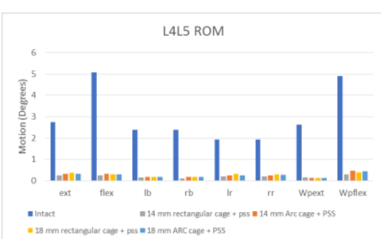

Figure 1: L4L5 segment ROM for all the different cage footprints compared with intact motion.

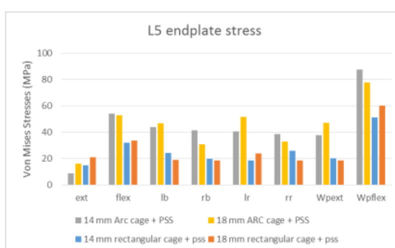

Figure 3: L5 endplate maximum stresses for each motion. The arc shape cage increased motion for both footprints except for the extension motion.

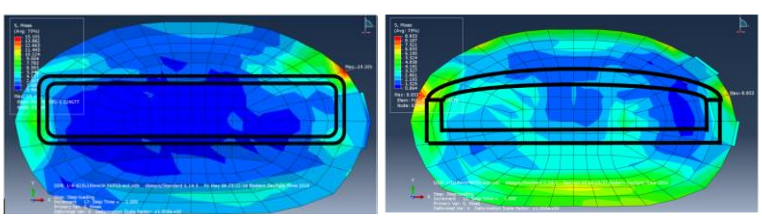

Figure 2: Stress contours after the extension motion. The image on the left is with the 14 mm (AP) rectangular cage and the image on the right is 14 mm (AP) arc cage. Note that the stress concentrations are situation on the periphery of the endplate. The stress concentrations for all motions were located on the outer portion of the endplate.