Transforaminal Lumbar Interbody Fusion: Which Construct Configuration Provides the Optimal Biomechanical Stability?

INTRODUCTION:
Transforaminal lumbar interbody fusion (TLIF) remains an appealing surgical option for relieving radicular symptoms and obtaining arthrodesis. However, the optimal antero-posterior construct configuration to adequately stabilize the segment remains unknown.

PURPOSE:
The objective of the current investigation was to evaluate the acute stability afforded by a PEEK TLIF spacer (standard and crescent shaped) with unilateral and bilateral posterior, segmental instrumentation using finite element (FE) analysis.

MATERIALS AND METHODS:
An experimentally validated, three-dimensional, ligamentous FE model of the L3-5 spinal segments was used (Fig 1). The range of motion (ROM) in the intact model was used as the baseline. The model was then modified to simulate surgical decompression at L4-5 via a complete facetectomy (unilateral or bilateral), partial annulotomy and a full discectomy. The following reconstructive options were then applied to the decompressed segment (Fig 1): 1) Unilateral spacer + unilateral rod; 2) Crescent spacer + unilateral rod; 3) Unilateral spacer + bilateral rod; 4) Crescent spacer + bilateral rod; 5) Bilateral spacer + bilateral rod. A finite sliding contact with a coefficient of friction of 0.2 was defined between the spacer(s) and the endplate to simulate the bone-implant interface. Titanium and PEEK material properties were defined to the posterior instrumentation and cage(s), respectively. The inferior surface of the L5 vertebra remained immobilized throughout load simulation. A bending moment of 10 Nm was applied to recreate flexion (Flex), extension (Ext), left and right lateral bending (LB and RB) and axial rotation (left (LR) and right (RR)). ROM and maximum stresses in the posterior instrumentation were computed and compared for different models.

RESULTS:
There was a significant decrease in ROM with all reconstructive conditions when compared to intact (Fig 2). However, unilateral posterior fixation failed to adequately stabilize the operative segment in LB regardless of the shape of the spacer used. In this plane, over 50% of intact ROM remained; compared to less than 10% when bilateral pedicle screw fixation was used. Furthermore, the calculated stress at the cephalad pedicle screw/rod interface was 5 times greater for unilateral posterior constructs under Flex, and exceeded the stresses observed in bilateral pedicle screws by a factor of 3 under LB (Fig 3). Similarly, the shape of the interbody spacer did not appear to affect the stress levels experienced by posterior implants.

DISCUSSION:
The data suggest that for a TLIF procedure interbody spacers combined with bilateral posterior fixation offer greater stability compared to unilateral posterior augmentation. Moreover, shape or number of interbody implants did not appear to profoundly impact segmental stability when bilateral pedicle screws were used. Finally, the increased posterior instrumentation stresses observed in all loading modes with unilateral pedicle screws may accelerate implant loosening or construct failure.

SIGNIFICANCE:
The current study provides information about optimal TLIF configuration that may be useful in designing and testing different spacers/posterior fixation systems.

REFERENCES: