### Experimental Evaluations of Intervertebral Disc Mechanics Following Posterolateral Fusion are Dependent on Testing Protocol

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**Significance**: This study demonstrates the possible outcomes associated with two different spine biomechanical testing techniques and reports the resulting intervertebral disc mechanics due to lumbar posterolateral fusion using a finite element model.

**Introduction**: Numerous studies have sought to quantify the biomechanical effects of posterior spinal fusion and disc arthroplasty; however, the results from these studies are conflicting. Additionally, the variety of techniques utilized during biomechanical testing complicates comparing results of instrumentation studies. Two distinct methods of experimental loading protocols have emerged to test the efficacy of spinal instrumentation. The fusion hybrid model demonstrates increased intersegmental rotations at all adjacent segments. Similarly, annulus fibrosus stresses were minimally affected in the fusion model loaded with 7.5 Nm moments, while stresses increased by as much as 100% in all loading planes for the fusion hybrid model (Figure 1 Top). Predicted nucleus pressures mirrored the annulus stress predictions for all loading planes. Minimal changes in nucleus pressures were observed between the healthy and 7.5 Nm fusion configurations, while nucleus pressures increased between 20% (L2L3) and 35% (L1L2) from the healthy to the fusion hybrid configurations (Figure 1 Bottom).

#### Methods

A previously validated, three-dimensional, non-linear finite element model of the human lumbar spine (L1-L5) was used utilized in this study. Briefly, computed tomography (CT) scans of a 49 year old female cadaver were used to generate the model geometry. The final model was meshed with 8-node cubic hexagonal elements. Linearly elastic, transversely isotropic material properties were defined for the osseous tissues. Nonlinear spring elements were used to simulate the spinal ligaments, while the nucleus pulposus was modeled as a linearly elastic, nearly incompressible solid material. An orthotropic continuum approach was utilized to simulate the annulus fibrosus in which a single strain energy function characterized the contributions of the fiber and the ground substance components. A bilateral posterior fusion device was created and implanted at the L3L4 level on the intact spine model to simulate the effects of posterior spinal fusion and disc arthroplasty devices using load control testing methods and have reported a mixture of results. While all load control studies have consistently reported decreased total spine mobility due to loss of flexion at the fused segment, several studies have demonstrated increased intersegmental rotations and intervertebral disc mechanics at segments adjacent to the fusion, including a finite element study performed by Tang et al. that reported increases in nucleus pulposus pressures of 66%, intersegmental rotations of 30%, and annulus fibrosus stresses of 200% in the segment cranial to a fusion tested under load control. Other studies have shown no change in spinl kinematic or mechanical parameters in adjacent segments under the same loading protocol. The major assumption of the load control testing protocol is that fusion patients will be content to live with a limited amount of total spine mobility; however, this may not be feasible in order to perform the required activities of daily living. Thus, an argument has been put forth that the same amount of total rotation should be applied to implanted specimens as healthy specimens in biomechanical tests that intend to measure the efficacy of fusion and arthroplasty devices. This technique is also known as the hybrid method. The intent of this study was to analyze the difference in intradiscal pressure and annulus fibrosus stress measurements in fused spinal specimens tested under load control and the hybrid method using a finite element model.

#### Results

The addition of the posterolateral fusion device to the spine loaded with 7.5 Nm moments lowered total lumbar rotation, while intersegmental rotations were minimally altered in all loading directions with the exception of the fusion segment. The fusion hybrid model demonstrated increased intersegmental rotations at all adjacent segments. Similarly, annulus fibrosus stresses were minimally affected in the fusion model loaded with 7.5 Nm moments, while stresses increased by as much as 100% in all loading planes for the fusion hybrid model (Figure 1 Top). Predicted nucleus pressures mirrored the annulus stress predictions for all loading planes. Minimal changes in nucleus pressures were observed between the healthy and 7.5 Nm fusion configurations, while nucleus pressures increased between 20% (L2L3) and 35% (L1L2) from the healthy to the fusion hybrid configurations (Figure 1 Bottom).

#### Discussion

These results demonstrate that patients who tolerate decreased levels of total spine mobility after spinal fusion may not be placed at an increased risk of deleterious post-surgery effects. However, patients that attempt to achieve the same amount of spine motion after a fusion procedure may be exposed to highly elevated stresses that are detrimental to the patients’ long-term intervertebral disc health. These patients illustrate that while the overall rotation of the spine may be retained following a fusion procedure, the global kinematics of the spine do not adequately indicate the state of the local mechanics that occur in the intervertebral disc including annulus fibrosus stresses and nucleus pulposus pressures. Future studies should focus on the inclusion of the musculature to simulate the effects of spinal implantation with the hybrid testing approach, and the alteration of intervertebral disc mechanics during lifting motions when implants are included.

#### References

5. Panjabi M.; Clinical Biomechanics 22, 257-265, 2007;