Location of Prophylactic Vertebral Cement Above Long-Segment Fusion Constructs Affects Endplate Stress: A Finite Element Model

Anoli A. Shah[1], Joseph Zavatsky[2], Robert McGuire[3], Hassan Serhan[4], Vijay K. Goel [1]

[1]Engineering Center for Orthopaedic Research Excellence (E-CORE)
Departments of Bioengineering and Orthopaedic Surgery
Colleges of Engineering and Medicine
University of Toledo, Toledo, OH 43606
[2]Spine & Scoliosis Specialists, Tampa, FL 33613
[3]University of Mississippi Medical Center, Jackson, MS 39216
[4]DePuy Spine Inc., Raynham, MA 02767

INTRODUCTION

Proximal junction kyphosis (PJK) is a well-described post-operative complication associated with long-segment fusion constructs often utilized in the treatment of kyphotic and scoliotic deformities. The surgical creation of a stiff upper segment along with patient osteoporosis has been suggested as etiologies. Prophylactic vertebroplasty has been proposed to reduce the rate of PJK, but results in the transfer of force to the next cranial unadulterated vertebral level, which is at risk of failure. An *in vitro* biomechanical study has already been performed using 15 fresh frozen T6-pelvis specimen, which were instrumented from T10-S1 and a tapered dose of prophylactic vertebral cement was injected into T10 (UIV), T9 (UIV +1), and T8 (UIV + 2) and loaded in flexion until failure. Results demonstrated tapering the dose of vertebral cement significantly reduced the rate of vertebral fractures. In this present study, an experimentally validated finite element (FE) model was used to explore the hypothesis that the location of the tapered cement within the vertebral bodies may further influence the rate of PJK.

MATERIALS AND METHODS

A validated FE T6-pelvis spinal model was used for the analysis. An osteoporotic model was developed and modified by the insertion of screws and rods from T10-S1, and the placement of a tapered dose of vertebral cement into T10 (UIV, 4cc), T9 (UIV + 1, 3cc), and T8 (UIV + 2, 2cc). Various cement locations (anterior, right lateral, and left lateral; Figure 1) and configurations (staggered; Figure 2) were analyzed and compared to the surgically accepted gold standard of central cement placement within the vertebra. Load was applied 10mm anterior to the center of the T6 vertebrae to simulate a flexion moment and the pelvis was fixed (Figure 3). Endplate stresses (T7-T10) along with posterior ligamentous strain were recorded.

RESULTS

Anteriorly placed cement at T8 resulted in a 21% decrease in maximum superior endplate stress as compared to as the surgically accepted gold standard of centrally located cement. Anteriorly placed cement at T9 resulted in a 26% decrease in maximum superior endplate stress when compared to centrally placed cement. Maximum stress at the superior and inferior endplates of T7 was similar for anterior vs. centrally placed cement. There was no benefit in staggering the cement and resulted in T7-T10 endplates stress and ligament strain that were similar to centrally placed cement. Posterior ligamentous strain was reduced approximately 2% at the T8-T9 level with anterior placement of cement when compared to centrally located cement.

DISCUSSION

Parametric analyses afforded the ability to simulate different cement configurations. The results demonstrate that anterior placement of prophylactic vertebral cement is potentially advantageous when compared to the surgical gold standard of centrally placed cement in this FE model. A decrease in maximal endplate stress is beneficial, and translates to an increase in force required for endplate failure. Stresses at the endplates of T8 and T9 reduced considerably with anteriorly placed cement, and one could extrapolate that these vertebral bodies would be less prone to fracture and PJK. Posterior ligamentous strain was also reduced with anteriorly placed cement. However, alternating or staggering cement placement did not affect endplate stress or ligamentous strain.

SIGNIFICANCE

This study may benefit patients and surgeons when long-segment fusion constructs are indicated. The effect of anterior cement placement when prophylactic vertebroplasty is utilized may result in a biomechanical advantage reducing endplate stress and rates of PJK, proximal junctional failure (PJF), and revision surgery. Further clinical evaluation is required.

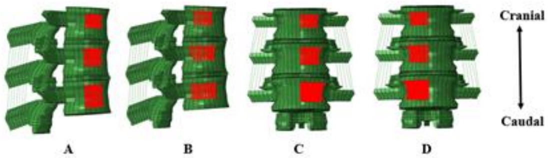

Figure 1: Cement positions- (A) Anterior, (B) Center, (C) Lateral Left, (D) Lateral Right

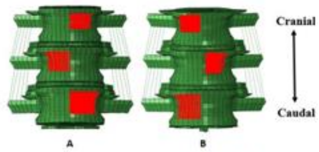

Figure 2: Alternating cement positions- (A) T8 Left-T9 Right-T10 Left,
(B) T8 Right-T9 Left-T10 Right

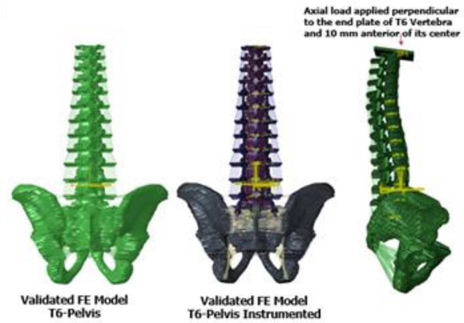

Figure 3: Finite element model