BIOMECHANICAL ANALYSIS OF POSTERIOR STABILIZATION AT THE CERVICO THORACIC JUNCTION

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Introduction: The cervicothoracic junction is a complex anatomical site for stabilization of traumatic and degenerative disorders. It is the site of transition from the flexible cervical spine to the rigid thoracic spine, and has proven to be a difficult challenge to surgeons. Posterior stabilization is generally preferred for posterior and circumferential cervical injuries and recent changes have included a shift away from plate and screw systems toward more versatile rod and screw systems. At the cervicothoracic junction, fixation must be low profile and accommodate changes in flexibility and anatomy. 1, 2.

Relative to other parts of the spine, little is reported about fixation at the cervicothoracic junction and few studies have addressed fixation stability at this location 2, even though injuries at this level have been reported as high as 9% of cervical spine injuries 3. The objective of this study was to biomechanically test three frequently used posterior cervical fixation devices on human cadaver spines and evaluate them for stability with posterior two-column and three-column injuries at the cervicothoracic junction. This work is intended to help researchers and clinicians better understand the biomechanics of the cervicothoracic junction for better clinical outcome of treatment of injuries at this level.

Methods: Eighteen human cadaver spines (C3-T3) were procured, radiographed to rule out obvious deformities or malignancy, and carefully cleaned of muscle and adipose tissue, leaving ligamentous and bony structures intact. Each specimen was DEXA scanned for bone mineral density (BMD). Based on BMD measurements, they were assigned to one of three fixation groups such that the mean BMDs for each group were similar. The three different fixation systems used in this study were: the Synthes Cervifix and DePuy Summit systems, both posterior rod and screw systems, and the Danek Axis system, a posterior plate and screw system.

The C3, C4 and T3 vertebrae were secured in polymethylmethacrylate and placed in a biaxial testing frame, which allowed for independent control of flexion/extension, lateral bending, and axial torsion. The protocol consisted of a 60 N axial compressive load, which represents the load of the head, and pure flexion/extension, lateral bending, and axial torsion moments of ±2.5 Nm. Each specimen was tested non-destructively, with each load applied over 5 cycles at a constant rate of 2 deg/sec in flexion, extension, and lateral bending and 5 deg/sec in axial rotation; the data from the fifth cycle were analyzed. Once tested intact, the spines were destabilized with a two-column posterior injury at C7-T1 by transecting all posterior elements and the posterior half of the intervertebral disc according to Denis' three-column classification of spinal injury 4, 5. One of the three posterior fixation systems was then applied. With all fixation systems, lateral mass screws were placed at C5 and C6 and pedicle screws were placed at T1 and T2. Anteroposterior and lateral radiographs confirmed accurate screw placement. The spines were again tested in flexion/extension, lateral bending, and axial torsion, according to the aforementioned protocol. After testing with the posterior two-column injury, a three-column injury was created by cutting completely through the remaining anterior half of the intervertebral disc and the anterior longitudinal ligament (ALL). The spines were again tested in flexion/extension, lateral bending, and axial torsion.

The mean stiffness, range of motion (ROM), and neutral zone (NZ) during flexion/extension, lateral bending, and axial torsion were compared using a Bonferroni follow-up test.

Results: The mean donor age was 59 years (range: 24 to 77 years) and the mean BMD of the Danek, DePuy, and Synthes groups was 0.660, 0.602, and 0.674 g/cm², respectively. In extension, there was no significant difference in mean stiffness between the intact specimens and the two-column injury constructs for any of the systems (Figure 1). The mean stiffness of the instrumented three-column injury was significantly less than either the intact specimens or two-column injury constructs for all three fixation systems. In flexion, there was no significant difference between the mean intact and two-column injury stiffness values for any of the systems (Figure 2). However, the mean stiffness for the three-column injury was significantly less than that of the two-column injury for the Danek system, and for the DePuy system the mean stiffness for the three-column injury was significantly less than that of the intact specimen.

For all three systems tested in flexion/extension, there was a trend for the ROM and NZ to decrease from the intact specimen to the two-column injury construct. From intact specimen to three-column injury, the ROMs and NZs either increased significantly or did not significantly change from the intact specimen. In lateral bending, all three fixation systems were significantly stiffer than the intact spine for both two- and three-column injuries. Similarly, the ROMs decreased significantly for all three systems for both two- and three-column injuries. For all three systems, there was also a trend toward, or significant reduction in NZ for two- and three-column injuries when compared to intact specimens. Finally, in axial rotation, all three systems were significantly stiffer than the intact spine for both two- and three-column injuries; the ROMs also decreased significantly with all three systems for both injuries when compared to the intact specimen. The NZs were significantly reduced from the intact spine to the two-column injury for all three systems, and for the three-column injury, there was also a significant decrease, or trend toward reduction, in the NZ for all three instrumentation systems.

The only difference of statistical significance found between fixation systems was for the three-column injury in flexion, where the Synthes system was significantly stiffer than the DePuy system.

Discussion: These results suggest that all three systems adequately stabilize the cervicothoracic junction with a posterior two-column injury in flexion, extension, lateral bending and axial rotation. All systems, however, failed to provide adequate stability at this level for a three-column injury, particularly in extension, where the transected ALL and anterior disc no longer provided resistance. Thus, a three-column injury at this level would warrant supplemental anterior fixation. This study provides researchers and clinicians insight into the abilities and limitations of posterior instrumentation to stabilize two- and three-column injuries at the cervicothoracic junction.


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