

Analysis of Spinal Instability Following Compression and Flexion-Compression Trauma to the Lower Thoracic Spine: An In Vitro Study

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INTRODUCTION: Unstable traumatic spinal injuries require surgical treatment to restore the primary stability. Spinal instability resulting from traumatic injury is a controversial topic as clear definitions are still lacking. However, a detailed understanding could support surgical treatment and contribute to the optimization of stabilizing spinal implants. Numerous experimental studies have investigated the influence of traumatic injuries on spinal instability, focusing on the cervical and lumbar spine. However, mechanical injury models or a detailed instability analysis have rarely been performed [1]. The purpose of this in vitro study therefore was to identify the most relevant biomechanical parameters describing spinal instability after compression and flexion-compression trauma to the lower thoracic spine using a mechanical injury simulation protocol and complex instability analysis.

METHODS: Twelve fresh frozen human thoracic specimens (T9-T11; 4 f / 8 m; 40-60 years) including costovertebral and costotransverse joints were dynamically loaded with pure compression (n=6) or flexion-compression (i.e. compression + 10 Nm flexural preload, n=6). A material testing machine (Instron 8871) was used to apply a displacement-controlled axial impact at a velocity of 300 mm/s up to a compression of 20% of the T10 vertebral body height after preloading the specimens with an axial compressive load of 400 N. Traumatic injury was defined as load drop of 10% during controlled compression and a clearly visible fracture in the lateral radiograph. Instability was measured before and after trauma using an universal spine tester by applying pure moments of 5 Nm in flexion/extension, lateral bending, and axial rotation. Range of motion, neutral zone, coupled rotations and coupled translations were determined. Moreover, translational instability under 100 N shear load was measured using the universal spine tester and height loss under 400 N axial compression was evaluated using the material testing machine. Statistical analysis was performed using the Friedman test in SPSS with a significance level of 0.05.

RESULTS SECTION: Traumatic injuries were generated in all specimens at a median fracture load of 5 kN (2.4 to 9.2 kN) independent of the trauma type and all were classified as AOSpine Type A1 injuries [2]. Pure compression trauma primarily led to isolated medial endplate fractures (n=5), while flexion-compression trauma mainly resulted in combined anterior endplate and superior vertebral body compression fractures (n=3). Significant instability increases after trauma ($p < 0.05$) were identified for all investigated biomechanical parameters except coupled rotations (for both trauma types) and posterior shear translation (for pure compression trauma). Highest instability increases were found for axial height loss (compression +136% / flexion-compression +200%) and neutral zone values in flexion/extension (+177% / +188%) and lateral bending (+174% / +126%) (Fig. 2). Compared to shear translations, increases in range of motion and coupled translations were generally higher.

DISCUSSION: In the present study, the effects of mild trauma to the lower thoracic spine on the resulting spinal instability were investigated to determine the most sensitive instability parameters. With regard to spinal instability in the clinic, future studies need to examine the effects of more severe compression injuries, such as burst fractures or pincer-type fractures, as well as other trauma types, such as flexion-distraction injuries. Considering the thoracic spine, the protective and stabilizing effect of the rib cage also has to be investigated in order to quantify spinal instability. In conclusion, height loss and neutral zone are the most sensitive biomechanical parameters for describing spinal instability in the lower thoracic spine after mild compression or flexion-compression trauma.

SIGNIFICANCE/CLINICAL RELEVANCE: Unstable traumatic spinal injuries require surgical fixation, while surgeons still predominantly rely on their experience and subjective feeling regarding optimum fixation strategies. This experimental study therefore provides a detailed insight into biomechanical effects of mild compression and flexion-compression trauma on multidimensional instability, potentially facilitating surgical decision making and optimizing trauma-specific fixation implants.

REFERENCES:

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- [2] Schnake et al. (2017). AOSpine Classification Systems (Subaxial, Thoracolumbar). *J Orthop Trauma* 31, S14-S23.

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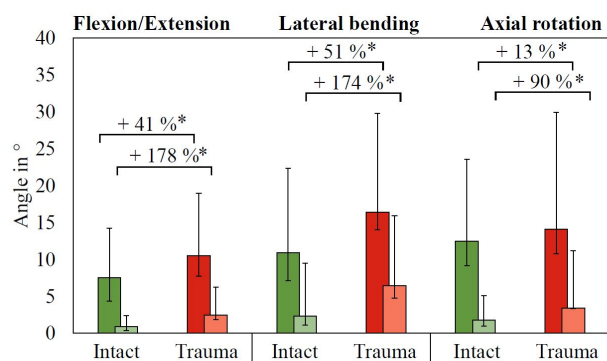


Fig. 1. Range of motion (RoM) and neutral zone (NZ) increases after compression trauma (* $p < 0.05$).

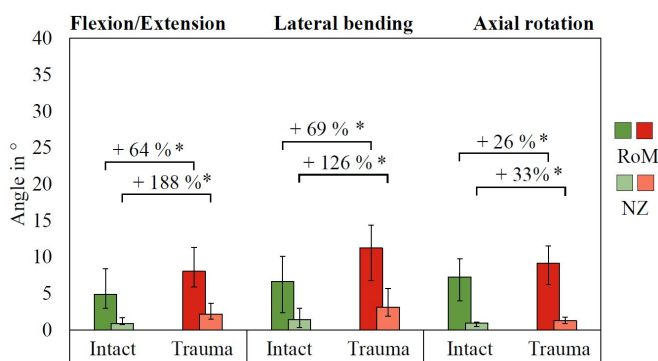


Fig. 2. Range of motion (RoM) and neutral zone (NZ) increases after flexion-compression trauma (* $p < 0.05$).