

Bertolotti Syndrome: Type IV Effects on Kinematics of the Lumbar Spine

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INTRODUCTION: Bertolotti Syndrome (BSy) is a diagnosis of lower back pain caused by lumbosacral transitional vertebrae (LSTV), which are enlarged transverse process(es) (TP) causing contact between the sacrum and L5. LSTVs can be unilateral (a) or bilateral (b) and vary in severity, ranging from slight contact between the L5 TP and sacral ala to full bony fusion. Type IV BSy consists of a partial fusion (Type II) on one side and a full fusion (Type III) on the contralateral side. BSy can be treated either through resection of the LSTV or posterolateral spinal fusion from L5-S1. The aim of this study is to evaluate the biomechanics of the lumbar region with Type IV BSy with and without spinal fusion intervention.

METHODS: Seven (7) fresh-frozen cadaveric L1-Sacrum spines (5 male, 2 female, Age: 59.4 ± 5.0 years, BMI: 30.0 ± 6.0) were utilized for this study. Non-diseased spines were used and supplemented with 3D-printed anatomy to simulate LSTVs [1]. The L5 TPs and lateral sacrum were removed and replaced with the 3D prints. Custom fixturing was designed to collect real-time kinetic data at the LSTV throughout testing. Bilateral six-axis load cells (ATI) were placed below the simulated lateral sacrum, and loads were transferred to the LSTV junction to measure the forces that the L5 exerted on the sacrum. Motion capture markers (Optotrak) were attached to each vertebra from L2-S1 to measure functional spinal unit (FSU) kinematics throughout testing. Four (4) surgical conditions were tested: Type IIb, Type IV (alternate sides), and full surgical fusion (bilateral rods from S1-L5). Type IV was simulated by attaching a Type II LSTV to each side of the spine and fusing either the left or right side with a posterior rod from L5-S1. The L5-S1 fusion was meant to replicate the Type III component of a Type IV. Testing was performed using a simVITRO[®] robotic testing system. Twelve (12) loading profiles were applied for each condition. Torques of 5 Nm were applied in each of left and right lateral bending (LB), left and right axial rotation (AR), and flexion and extension (FE) (primary motions). An additional six (6) combined loading conditions were tested which included 5 Nm torques in axial rotation + lateral bending, flexion and lateral bending, and flexion and axial rotation. The order of these motions was randomized. All profiles terminated when force errors were minimized and movement rates were static for 5 consecutive seconds.

RESULTS: Kinematic data was evaluated at the L5-S1 and L4-L5 levels. Absolute values were analyzed, and the percentage change relative to the Type IIb state was calculated for both Type IV and full surgical fusion conditions. The range of motion in the three primary directions (AR, FE, LB) decreased on average from Type IIb to Type IV at both L5-S1 and L4-L5 (Figures 1 and 2). Motion was further constrained when comparing full surgical fusion to Type IIb. One specimen was particularly lax, resulting in large standard deviations. Additionally, Type IV left and Type IV right did not typically perform the same. Preliminary data shows that force on the sacrum decreases as the amount of fixation increases, meaning bilateral posterior surgical fusion results in the lowest force and Type IIb results in the highest force. This is consistent with a decrease in motion at the L5-S1 junction as fusion increases.

DISCUSSION: Further data interpretation is needed to determine the full extent of the biomechanics of the lumbar spine under these conditions. While preliminary data shows promising results for primary motions, the combined motions (AR+LB, FE+AR, FE+LB) may more closely represent the typical activities of daily living. Additionally, posterior spinal rods were used to simulate Type IV BSy. Future studies should consider using 3D prints to more closely represent the condition.

SIGNIFICANCE/CLINICAL RELEVANCE: The authors are unaware of any other cadaveric studies examining the biomechanics of Bertolotti Syndrome. This study provides novel insights into the biomechanics of a potential treatment option for patients suffering from Bertolotti Syndrome.

REFERENCES:

[1] Golubovsky, J.L., et al., *Development of a novel in vitro cadaveric model for analysis of biomechanics and surgical treatment of Bertolotti syndrome.* Spine J, 2020. 20(4): p. 638-656.

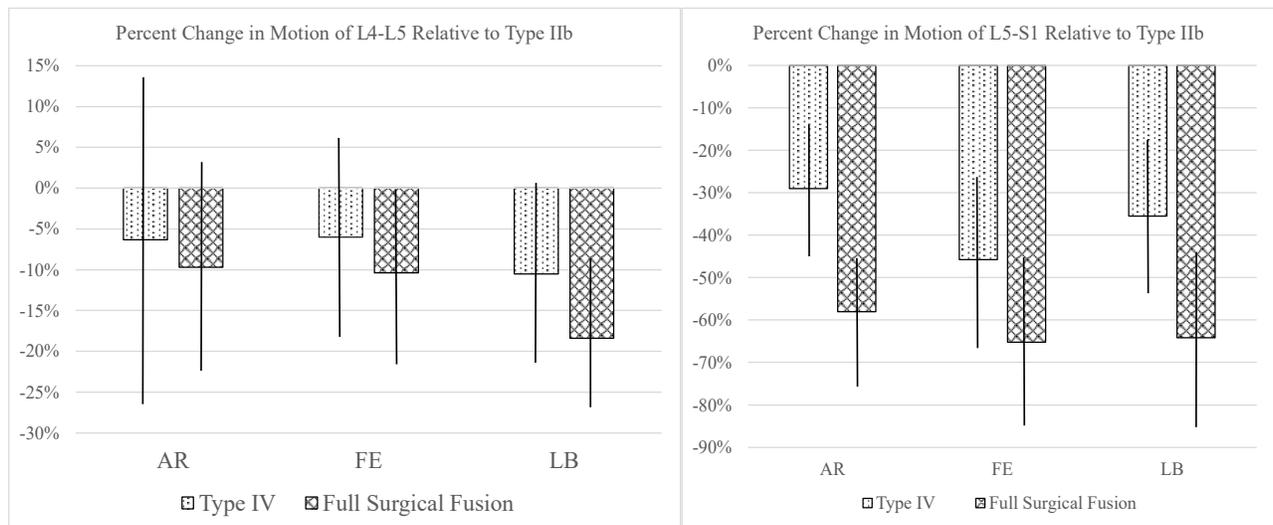


Figure 1: L4-L5 (adjacent segment) motion reduction during the three primary loading motions. The error bars represent the standard deviation.

Figure 2: L5-S1 (diseased segment) motion reduction during the three primary loading motions. The error bars represent the standard deviation.