Range-of-Motion Analysis of Sequential Ponte Osteotomies in a Continuously Loaded Full Thoracic Spine Cadaveric Model with Attached Ribcage

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Disclosures:

Introduction: Ponte osteotomies (POs) are often performed by surgeons at adjacent levels in the thoracic spine to obtain more flexibility in a rigid spine during posterior-only spinal fusion surgeries to help in correcting deformities such as Adolescent Idiopathic Scoliosis (AIS) and Scheuermann’s Kyphosis (SK). The currently accepted clinical “rule-of-thumb” for amount of sagittal flexibility gained per level of PO is at least 5 degrees; this measure has been found via radiographic analysis of surgeries.¹,² While some biomechanics researchers have begun to study POs on cadaveric models,³ the flexibility change has not been biomechanically verified in a full thoracic cadaveric model with attached ribcage. Further, while it has been shown in a few studies that POs provide minimal additional flexibility in lateral bending and torsion, these measurements have also not been quantified in a full thoracic cadaveric model with attached ribcage. The purpose of this study is to quantify the flexibility in all modes of bending gained by sequential POs so that surgeons can better understand the benefits of utilizing POs in rigid deformity fusions. The hypothesis of this study is that the current clinical “rule of thumb” will be verified and that each PO level will enable approximately 5 degrees of increased sagittal flexibility while providing minimal change in additional flexibility in the lateral bending and axial rotation modes.

Methods: Five human cadaveric thoracic specimens (all male, 69.0±2.8 years) with intact true ribs were dissected to exclude skin, adipose tissue, and muscles. T1 and T12 were rigidly potted (Bondo™, 3M, St. Paul, MN) and mounted in a novel 6 degree-of-freedom spine testing machine with angular displacement measurement capabilities in the direction of applied moment (Applied Test Systems (ATS), Butler, PA). An Optotrak Orthopaedic Research Pin which included three non-collinear markers was inserted into the potting of T1 to track overall range-of-motion (ROM) (Northern Digital, Inc., Waterloo, Ontario, Canada). Figure 1 shows the test setup. Pure moments were applied at T1 at 0.5 degrees per second to ±5Nm for five cycles continuously through the range of motion in lateral bending (LB), flexion-extension (FE), and axial rotation (AR). Each specimen was tested in five sequential conditions: (1) intact, (2) after a one-level T9-10 PO, (3) after a two-level T8-9 PO, (4) after a three-level T7-8 PO, and (5) after a four-level T6-7 PO, with the POs performed by an orthopaedic spine surgeon or neurosurgeon to ensure correct technique. All five specimens were successfully tested without incidence (n=5). ROM analysis between T1 and T12 was conducted in all three modes of bending using the third cycle of testing of the ATS angular displacement data. Results were normalized to the intact condition to account for specimen variability, and ROM values were reported as a percentage increase when compared to the intact condition. Student t-tests were performed to determine significance (p < 0.05) as compared to the intact condition.

Figure 1: Test setup with full thoracic spine and attached true ribs.
Results: Figure 2 shows the percent changes in flexibility in LB, FE, and AR for all test conditions. Significant results were found only in FE, and the mean percentage increase and degree increase in overall flexibility was: (1) 7.1±4.6 percent (p=0.026) and 1.35±0.86 degrees (p=0.025) for a single PO, (2) 8.0±7.3 percent (p=0.070) and 1.50±1.42 degrees (p=0.077) for a two-level PO, (3) 11.0±11.0 percent (p=0.088) and 2.09±2.19 degrees (p=0.100) for a three-level PO, and (4) 13.5±8.6 percent (p=0.025) and 2.74±2.03 degrees (p=0.039) for a four-level PO. The maximum increase in FE flexibility for any specimen at a one-level PO was 9.2 percent, or 1.96 degrees. The results showed a trend in overall ROM increase in AR with increasing PO levels, with a mean percentage increase and degree increase in overall flexibility after four POs of 4.4±5.6 percent (p=0.171) and 1.38±1.40 degrees (p=0.093), respectively. No significant results or clear trends were observed in LB.

Discussion: The results of this study support the clinical practice of utilizing POs to increase of sagittal flexibility in fusion patients with rigid spines. However, the amount of FE correction potential to be gained from POs was not found to be equal to the clinical “rule-of-thumb” of at least 5 degrees per PO. Additionally, the FE flexibility added by performing sequential POs comes into question, as a four-level PO roughly doubles the sagittal ROM, not quadruples as might be expected. Future studies should examine if the amount of sagittal correction potential may be more dependent upon the level at which the PO is performed and not upon the number of sequential POs. Although some cadaveric studies on POs report increases in the ROM of LB and AR, those studies were not conducted on a full, intact thoracic spine with ribcage. Compared to studies done on partial thoracic specimens without a full ribcage, this study shows a lower correction potential for POs in FE and insignificant results in LB and AR, likely due to the substantial support provided by the ribcage. This suggests that more work should be done to determine the role that an intact ribcage plays in biomechanical thoracic spine testing. Although no significant changes were found in LB, it is still unknown if the POs improve a surgeon’s ability to manipulate the spine in other ways, including translating the apex of a coronal plane deformity toward the midline in AIS surgeries. A future study should analyze the combination of POs and rib osteotomies to improve LB and AR correction potential. Currently, more specimens are being tested to increase statistical power of this study, and additional parameters such as neutral zone, elastic zone, and local changes between vertebral levels will be analyzed.

Significance: Ponte osteotomies are posterior-only procedures performed by surgeons to gain spinal flexibility in Adolescent Idiopathic Scoliosis and Scheuermann’s Kyphosis spinal deformity correction surgeries when the patient exhibits a rigid curve. Results of this study show that: (1) sagittal flexibility is most influenced by Ponte osteotomies, but not to the degree currently speculated in clinical practice, and (2) there is a need to further investigate the influence of the ribcage on biomechanical assessment of flexibility.

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References: