Biomechanical Comparison of Distal Ventral Iliac Pathway to Traditional Spinopelvic Fixation Constructs: A Proof-of-Concept Study

Paul D. Korytkowski[1], John M. Panzone[1], Zachary R. Visco[2], Clarke I. Cady-McCrae[3], Nathaniel R. Ordway[1], William F. Lavelle[1], Richard A. Tallarico[1]
[1]SUNY Upstate Medical University, Syracuse, NY, [2]University of North Carolina at Chapel Hill, Chapel Hill, NC, [3]University of Rochester, Rochester, NY
Korytkop@upstate.edu

Disclosures: P.D. Korytkowski: None; J.M. Panzone: None; Z.R. Visco: None; C.I. Cady-McCrae: None; N.R. Ordway: 5; Stryker Spine; W.F. Lavelle: 5; 4-Web, Abryx, Cerapedics, DePuy Spine, Innovasis, Medtronic, Vertiflex, TruSpine; R.A. Tallarico: 5; Stryker Spine, Vertiflex.

INTRODUCTION: Traditional spinopelvic fixation techniques, such as the traditional iliac (TI) and S2-alar-iliac (S2AI) approaches, are frequently utilized to enhance stability of spinal constructs. TI screws are placed in the PSIS and directed toward the anterior inferior iliac spine (AIIS) or the superior acetabular notch. S2AI screws are placed at the interval between the S1 and S2 neural foramina, aimed at the AIIS, achieving placement of a pelvic screw that is in line with the rest of the construct. Biomechanically, the addition of pelvic screws decreases sacral screw strain and increases the load to failure of lumbosacral constructs.[1,2] Despite their utility, biomechanical failure remains a prevalent issue among traditional spinopelvic techniques, often resulting in hardware breakage and revision surgeries. The distal ventral iliac pathway (DVIP) is a novel spinopelvic fixation technique. DVIP screw placement involves utilizing a distal ventral area of the PSIS to access the distal ventral pathway, potentially addressing various shortcomings in established traditional techniques.[3] The purpose of this study was two-fold. First, to obtain baseline data regarding an effective experimental protocol for biomechanical comparison of the DVIP surgical technique to traditional techniques for pelvic fixation. Second, to examine the biomechanical effect of spinopelvic fixation compared to lumbosacral fixation.

METHODS: Eight fresh frozen lumbopelvic cadaveric specimens (L2-pelvis, mean age of 65 ± 5.8 years) were assigned to one of 4 spinopelvic fixation groups (TI, S2AI, DVIP, Dual DVIP, n=2 per group). Each specimen underwent spinal stability testing in the intact (no instrumentation), instrumented posteriorly with pedicle screws and rods with lumbosacral fixation (L4-pelvis), and instrumented without pelvic fixation (L4-S1) conditions. Testing was performed using an MTS machine in the following modes: pure compression, axial rotation, and sagittal rotation. From the overall construct load-displacement curves for each test mode, peak ROM and stiffness of each fixation condition were analyzed. Further, peak sagittal ROM at the adjacent level (L3-4) and the sacroiliac (SI) joint was evaluated by attaching motion sensors to individual vertebra. For each test mode, one-way ANOVA analysis was used to compare the analyzed parameters with the test condition as the main factor. Post hoc Tukey's test was then used to assess the significant differences between the fixation conditions.

RESULTS: ANOVA analysis showed no significant difference in peak construct ROM or stiffness across the fixation conditions during pure compression testing. In all other test modes, both the L4-S1 and the L4-pelvis conditions displayed significantly reduced peak construct ROM compared to intact ($p<0.05$). In all test modes except right axial rotation and sagittal extension, both the L4-S1 and the L4-pelvis conditions displayed significantly increased construct stiffness compared to intact ($p<0.05$). In these two test modes, only the L4-pelvis condition was significantly increased compared to intact ($p<0.05$). No significant differences were found between the L4-S1 and the L4-pelvis conditions for construct ROM or stiffness in any test modes. Peak segmental sagittal ROM was significantly reduced at the adjacent level and SI joint (Figure 1) in both the L4-S1, and L4-pelvis fixation conditions compared to the intact group ($p<0.05$), although there were no statistically significant differences between the L4-S1 and L4-pelvis groups. Preliminary data comparing sagittal ROM of the SI joint between all four techniques showed a similar decrease in ROM (Figure 2, 3), with a potential improvement in the DVIP technique, although no statistical comparisons were made due to the limited sample size.

Figure 1. Comparison of SI ROM

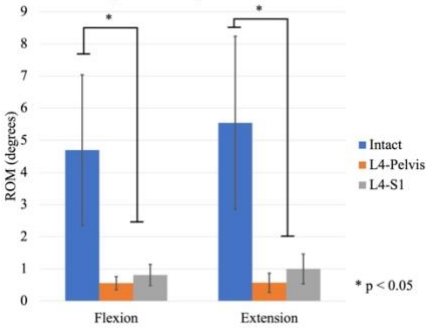


Figure 2. Comparison of SI Flexion ROM: Spinopelvic Technique

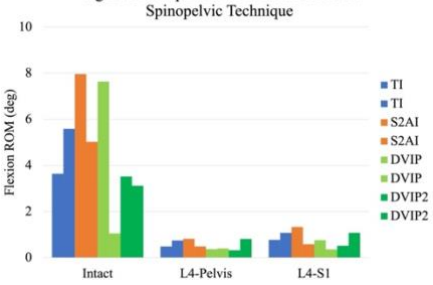
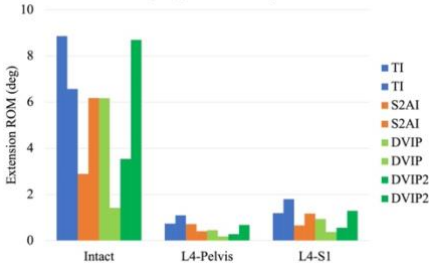


Figure 3. Comparison of SI Extension ROM: Spinopelvic Technique



DISCUSSION: Theoretically, the DVIP technique for spinopelvic fixation confers unique advantages that address limitations, biomechanical and otherwise, of traditional spinopelvic fixation techniques. The anatomical location of TI pelvic screws results in significant hardware prominence, which may predispose to pain or discomfort. Further, as these screws are not in line with the construct, they require horizontal connectors to achieve fixation, which may serve as a point of hardware failure. DVIP screw placement allows for in-line connection with the construct, eliminating the need for offset connectors. Moreover, iliac screws placed into the distal and ventral aspect of the PSIS reduces screw protrusion, potentially decreasing the incidence of pain and discomfort. Placement of the S2AI screw is a technically challenging procedure that requires extensive radiation exposure. Further, the S2AI screw traverses the sacroiliac joint, possibly placing undue biomechanical stress on the screws of the construct. Technically speaking, the DVIP screw is placed under direct visualization, making it a more approachable technique with less intraoperative radiation exposure. DVIP screws do not traverse the SI joint, potentially minimizing unnecessary biomechanical stress. The major limitation of this study was the sample size, which restricted the statistical analysis, and did not permit direct comparison between the four spinopelvic fixation groups. However, this study effectively developed a protocol to compare biomechanical parameters of these techniques. Preliminary biomechanical data collected in this study showed that, at the very least, the DVIP (single and dual) technique was equivalent to existing spinopelvic fixation (TI and S2AI) techniques. This study also suggests that spinopelvic fixation was an effective way to provide an additional anchor point of fixation even though biomechanically, a greater degree of stabilization was not shown in comparison to lumbosacral fixation alone. An additional anchor point of fixation potentially reduces the stress experienced by individual screws. Future studies examining differences in spinopelvic fixation techniques should focus on examining screw stress.

SIGNIFICANCE/CLINICAL RELEVANCE: A protocol was developed in this study that will be utilized to further assess and compare spinopelvic fixation techniques. This study suggested that when compared to traditional techniques, from a biomechanical standpoint, the DVIP spinopelvic fixation technique was at least equivalent to traditional techniques. In addition, this study showed that both lumbosacral and spinopelvic techniques are equivalent at significantly reducing ROM and increasing stiffness of distal lumbar constructs.

REFERENCES: 1. Lebwohl et al., Spine, 2002. 2. Tis et al., Spine, 2009. 3. Cady-McCrea et al., Int J Spine Surg, 2021.
ACKNOWLEDGEMENTS: Funded by the Department of Orthopedic Surgery, SUNY Upstate Medical University, and Stryker Spine