Proximal junctional failure prevention in adult spinal deformity surgery utilizing interlaminar fixation constructs

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Abstract

Proximal junctional kyphosis (PJK) is a common complication following fusion for Adult Spinal Deformity. PJK and proximal junctional failure (PJF) may lead to pain, neurological injury, reoperation, and increased healthcare costs. Efforts to prevent PJK and PJF have aimed to preserve or reconstruct the posterior spinal tension band and/or modifying instrumentation to allow for more gradual transitions in stiffness at the cranial end of long spinal constructs. We describe placement of an interlaminar fixation construct at the upper instrumented vertebra which may decrease PJK/PJF severity, and is placed with little additional operative time and minimal posterior soft tissue trauma.

Materials and Methods

In order to compare the effectiveness of IFCs in buffering transitions between stiff instrumented constructs and a relatively less rigid cranial spine, a preliminary biomechanical analysis of three differing constructs was performed. One human thoracic spinal segments consisting of T6 to T11 levels was stripped of muscular attachments while carefully preserving all ligamentous and disc elements. Fluoroscopy was utilized to rule out any gross anatomic abnormalities. The specimens were potted at the T6 and T11 levels using a urethane potting compound. Three constructs were subsequently tested on the one cadaver specimen: Construct 1 consisted of pedicle and rod instrumentation from levels T8 to T9 with no instrumentation at T7; Construct 2 consisted of pedicle screw and rod instrumentation at levels T8 to T9 with an IFC in between the spinous processes of T7 and T8 (Figure 2); finally, construct 3 consisted of pedicle screw and rod instrumentation from T7 to T9. A custom apparatus was used to apply pure moments of 7.5 Newton-meters to each construct about the three principal anatomical axes (flexion/extension, lateral bending and axial rotation) with a biaxial servohydraulic load frame (Instron Corp.). Range of motion (ROM) of each construct at each level with attention to the Upper Instrumented Vertebral (UIV) and UIV+1 (T7/T8 level) segment was recorded using an optoelectronic camera which tracked motion from the light emitting diode (LED) flags implanted on the specimen. The primary clinical motion of interest was flexion/extension.

Surgical technique

The IFC is implanted between the spinous process of the UIV and the spinous process of UIV+1 after completion of all instrumentation (except the UIV pedicle screws). Resection of the interspinous ligament at the UIV/UIV+1 is then performed, and the IFC is then placed (Figure 3). After the implant is placed, the UIV screws can then be placed, and may require a slightly more lateral and anterior starting point than usual on each side of the plate to avoid abutment of the devices.
Bone graft should be placed between the spinous processes of the UIV and UIV+1 to allow for interspinous fusion. Final imaging is used to ensure proper positioning (Figure 3).

Results

Biomechanical analysis

Sagittal plane total ROM between the UIV and UIV+1 (T7/T8) was lowest in the all pedicle screw construct (2.6 degrees) and highest in the uninstrumented construct (6.2 degrees). The flexibility in the IFC specimen (4.3 degrees) was lower than that of pedicle screw instrumentation but higher than that of the native spine proximal to the UIV (Table 1).

Case #1

A 77-year-old male presented with mechanical back pain and symptoms of positive sagittal balance including lumbar fatigue and progressive imbalance. He had previously undergone a L3 to L5 instrumented fusion with development of pseudoarthro-

| Torque applied (N.m) | T6T7 | T7T8 | T8T9 | T9T10 | T10T11 |
|----------------------|------|------|------|-------|--------|
| Axial rotation       |      |      |      |       |        |
| Plate construct      | 7.5  | 9.5° | 6.2° | 4.3°  | 8.0°   |
| No plate construct  | 7.5  | 9.5° | 6.2° | 1.4°  | 4.3°   |
| All pedicle screw construct | 7.5 | 9.5° | 5.8° | 3.5°  | 4.0°   |
| Flexion/extension    |      |      |      |       |        |
| Plate construct      | 7.5  | 9.5° | 6.2° | 1.4°  | 4.3°   |
| No plate construct  | 7.5  | 9.5° | 6.2° | 1.6°  | 4.2°   |
| All pedicle screw construct | 7.5 | 9.5° | 4.4° | 3.5°  | 4.0°   |
| Lateral bending      |      |      |      |       |        |
| Plate construct      | 7.5  | 11.5°| 8.9° | 5.6°  | 8.1°   |
| No plate construct  | 7.5  | 12.8°| 9.9° | 5.7°  | 8.9°   |
| All pedicle screw construct | 7.5 | 9.5° | 4.4° | 3.5°  | 7.5°   |
sis at L4/L5. He underwent revision T10 to pelvis instrumented realignment and fusion procedure with pedicle subtraction osteotomy at L3. Preoperatively his PJA was 2.8 degrees with initial postoperative films demonstrating an interval 5.1 degree change resulting in a PJA of 7.9 degrees. His final postop PJA at 1-year follow-up was 8.1 degrees (0.2 degree change). No evidence of PJK or PJF (Figure 4).

Case #2
A 76 year-old male presented with a severe kyphoscoliotic deformity leaving him unable to maintain frontal gaze (sagittal vertical axis (SVA) of 359.7 mm and a pelvic incidence-lumbar lordosis difference of 64.3 degrees). He had previously undergone a L3 to S1 fusion. A two-stage kyphoscoliotic deformity correction involving a T3 to pelvis fusion was performed. Preoperatively his PJA was 6.1 degrees with initial postoperative films demonstrating an interval 6.2 degree change resulting in a PJA of 12.3 degrees. His final postop PJA at 1-year follow-up was 12.9 degrees (0.6 degree change). No evidence of PJK or PJF (Figure 5).

Discussion
IFCs are easily applied with no additional posterior soft tissue disruption and minimal additional operative time. Hence, they may serve as useful adjuncts for deformity surgeons attempting to create a “softer” landing at the UIV in long posterior fixation constructs. While Cammarata et al. and Bess et al. demonstrated gradual transitions in rigidity with hook application at the UIV using computer models,11,12 Metzger et al. were unable to confirm these findings utilizing a cadaver model.13 It is possible that hooks may be too rigid to prevent PJK in some cases. Other available techniques may also lead to constructs that are too rigid at the UIV. Lange et al. biomechanically assessed hooks, spinal bands, hybrid rods, hinged-pedicle screws, and cerclage wires using calf lumbar spines and found that only spinal bands and cerclage wires were successful in reducing the rigidity of the spine just proximal to the UIV.14 All other techniques were similar in rigidity to all pedicle screw constructs.8 Furthermore, many of these constructs require substantially more soft-tissue dissection and increased operative time.

Ligamentoplasty has gained popularity recently. This procedure involves tensioning a tendon allograft or non-absorbable suture around (or through) the spinous processes of the UIV, UIV+1, and UIV-1 to reinforce disruptions in posterior soft tissue and decrease ROM at these levels.7,9,10 Pham et al. described ligamentoplasty using semitendinosus graft,9 and noted no radiographic evidence of PJK at 5.5 months in a small series of 4 patients. Safaee et al. conducted a larger study comparing a cohort of 100 patients treated with ligamentoplasty with a historical control cohort of 100 patients.7 The authors noted significant decreases in PJA (6 degrees versus 14 degrees) and PJF incidence (4 cases versus 18 cases) in the ligamentoplasty group,7 compared to the historical cohort. Further long-term clinical data for ligamentoplasty and additional biomechanical cadaver studies are still needed. Moreover, disadvantages with ligamentoplasty are similar to those of other UIV constructions mentioned previously, including potentially longer surgical times and the need for increased posterior soft tissue dissection. While large-scale biomechanical and clinical studies (including long term complications and outcomes) evaluating IFC’s continue to be necessary, our results provide preliminary support for IFCs in transitioning rigidity between instrumented and uninstrumented areas of the spine. Furthermore, the minimal soft tissue dissection required along with the ease of IFC application may make this technique an excellent clinical option for PJK prevention in select patients.

Conclusions
IFC devices may be a useful and easy-to-apply technique for reducing the severity of PJK and/or incidence of PJF. Further biomechanical and clinical research is required prior to widespread adoption.

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