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.

Introduction

Proximal junctional kyphosis (PJK) is a form of adjacent segment degeneration observed at the cranial-most aspect of long instrumented constructs following adult spinal deformity (ASD) surgery. Quantitatively, proposed definitions of PJK have varied widely from Proximal Junctional Angles (PJA) greater than 10 to 20 degrees with varying degrees of fracture, spondylolisthesis, and ligamentous failure.[1-5] PJK has been found to result in increased pain, poorer outcomes and diminished quality of life following ASD surgery.[6] Proximal junctional failure (PJF) represents an extreme progression of PJK, often requiring revision surgery secondary to debilitating pain, declining functional status, and complications including neurologic injury (Figure 1).[7]

Although the etiology of PJK and PJF are multifactorial, soft tissue trauma and an abrupt transition from stiff spinal instrumentation to a comparatively mobile cranial spine are substantial components of the pathology.[8] A number of efforts to prevent or delay PJK onset have been proposed including ligamentoplasty,[7,9,10] sublaminar hooks, hinged-pedicle screws, cement augmentation, spinal bands, or cerclage wire.[11] These methods, however, may add substantial time, effort, and risk to already lengthy and complex operations. Thus, a method for preventing or delaying PJK/PJF via a simple, quick, and effective technique would be particularly advantageous. We describe a novel technique involving placement of an interlaminal fixation construct (IFC) between the upper instrumented vertebra (UIV) and UIV+1. Additionally, we provide preliminary biomechanical data of effectiveness for transitioning flexibility cranial to long fusion constructs.

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 Vertebrae (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.

Furthermore, two clinical cases of interlaminar fixation utilization in patients at risk for PJK and PJF are reported. PJA was measured preoperatively and at all postoperative time-points. Patients were followed clinically and radiographically for progressive kyphosis.

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.

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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-

Figure 1. Proximal Junctional Failure following adult deformity surgery.

Figure 2. Construct 2 with pedicle screw instrumentation and rod fixation at T8 and T9 with an IFC between T7 and T8.

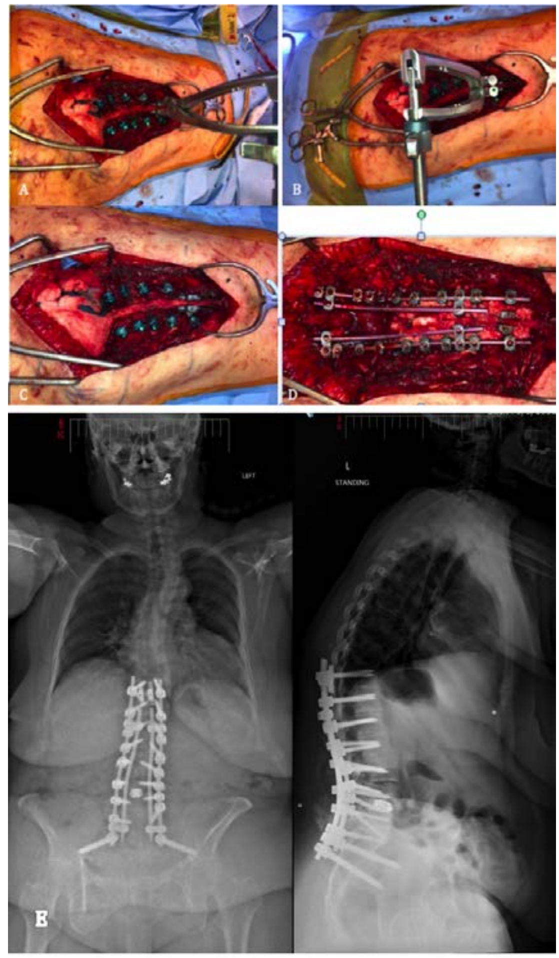

Figure 3. Identification of appropriate interspinous level and application of interspinous device with inserter compressor (A). Compression of inserter compressor and further tightening with threaded wingnut screw (B). Removal of device (C) and placement of bone graft (D). Final shots to confirm placement of hardware (E).

Table 1. Range of motion data at each vertebral level in terms of degrees of motion after an application of 7.5 N.m moments in Axial Rotation (AR), Flexion/Extension (FE), and Lateral Bending (LB) for each of the three constructs tested (Plate, No Plate, Rods). T8 is the UIV and T7 is the UIV+1; hence, the T7T8 level is the level of interest.

	Torque applied	T6T7	T7T8	T8T9	T9T10	T10T11
Axial rotation						
Plate construct	7.5 N.m	9.5°	6.2°	4.3°	8.0°	6.2°
No plate construct	7.5 N.m	9.6°	10.8°	6.2°	8.7°	6.3°
All pedicle screw construct	7.5 N.m	9.5°	5.8°	5.1°	8.5°	6.3°
Flexion/extension						
Plate construct	7.5 N.m	5.5°	4.3°	1.4°	4.3°	4.6°
No plate construct	7.5 N.m	5.1°	6.2°	1.6°	4.2°	5.0°
All pedicle screw construct	7.5 N.m	3.5°	2.6°	0.7°	4.2°	4.0°
Lateral bending						
Plate construct	7.5 N.m	11.5°	8.9°	5.6°	7.7°	8.1°
No plate construct	7.5 N.m	12.6°	9.9°	5.7°	8.9°	7.9°
All pedicle screw construct	7.5 N.m	9.7°	4.4°	3.5°	8.2°	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.[8] 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 IFCs 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.

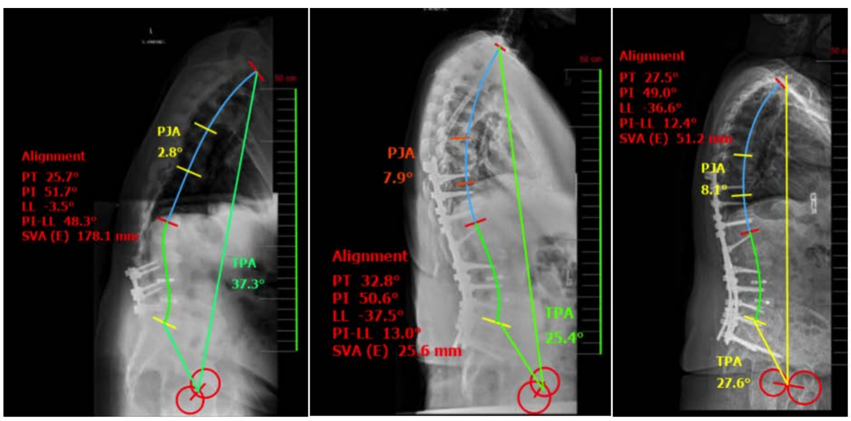

Figure 4. 5.1 degree interval kyphosis from 2.8 degrees to 7.9 degrees upon initial films postoperatively. Stable kyphosis thereafter with only a 0.2 degree change at 1 year follow up.

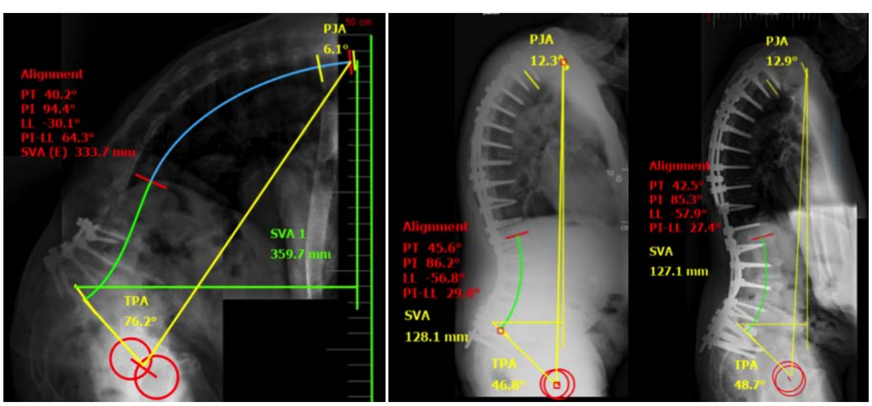

Figure 5. 6.2 degree interval kyphosis from 6.1 degrees to 12.3 degrees upon initial films postoperatively. Stable kyphosis thereafter with only a 0.6 degree change at 1 year follow up.

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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