

Case Report

The Junctional Ladder Technique: A Muscle-Sparing Hybrid Instrumentation Strategy for Adult Spinal Deformity Correction and Proximal Junctional Kyphosis Mitigation

Running Title: Junctional Ladder Technique

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Abstract

Background: Proximal junctional kyphosis (PJK) and proximal junctional failure (PJF) remain important complications after long-segment adult spinal deformity reconstruction. Abrupt construct stiffness, disruption of the posterior tension band, paraspinal muscle injury, poor bone quality, and aggressive sagittal correction may increase junctional stress.

Technique: The Junctional Ladder Technique combines percutaneous corticocancellous pedicle screws with tower attachments at the lower-thoracic proximal construct and modular reduction-head screws in the open lumbar and lumbopelvic construct. The intended biomechanical and biologic rationale is to preserve proximal thoracolumbar musculature and posterior soft tissues while permitting controlled deformity correction and rod reduction. When clinically indicated, distal fixation may include S2-alar-iliac (S2AI) screws and bilateral sacroiliac (SI) joint fusion implants; this distal SI fusion component is separate from the proximal junctional protection strategy.

Cases: Two adults with symptomatic degenerative thoracolumbar scoliosis and sagittal malalignment underwent long-segment reconstruction using the Junctional Ladder Technique. Both had failed nonoperative treatment. Postoperative imaging demonstrated substantial coronal correction and maintained proximal alignment at six months, without radiographic PJK or clinical PJF in the available follow-up. Both patients had more than 50% improvement in recorded visual analog scale and Oswestry Disability Index measures.

Conclusion: These two cases demonstrate the feasibility of a hybrid muscle-sparing proximal construct for adult spinal deformity correction. The technique should be regarded as hypothesis-generating rather than proven preventive therapy. Larger comparative cohorts with standardized, longer-term radiographic and patient-reported outcomes are required.

Keywords: adult spinal deformity; proximal junctional kyphosis; proximal junctional failure; hybrid instrumentation; minimally invasive spine surgery; paraspinal muscle preservation; sacroiliac joint fusion

Introduction

Adult spinal deformity encompasses degenerative coronal and sagittal malalignment that may cause pain, functional limitation, and impaired health-related quality of life. In appropriately selected patients who remain symptomatic after nonoperative care, long-segment reconstruction may restore alignment and improve function. However, transition-related complications at the upper end of a rigid construct remain a major concern.

PJK is generally described as a postoperative increase in kyphosis immediately cephalad to the upper instrumented vertebra (UIV), although thresholds and measurement methods vary. PJF represents the more severe end of the same spectrum and may include vertebral fracture, implant or ligamentous disruption, instability, neurologic compromise, and revision surgery. Published series and reviews report wide variation in PJK incidence because of differing definitions, patient populations, constructs, and follow-up intervals [Bridwell et al., 2013; Cho et al., 2014; Glattes et al., 2005; Lau et al., 2014].

The Junctional Ladder Technique was developed as a hybrid approach that combines minimally invasive proximal fixation with conventional open lumbar correction. Its central principle is preservation of the lower-thoracic paraspinal musculature and posterior soft-tissue envelope at the UIV while retaining the reduction capability required for complex deformity correction. This report describes the technique and presents two illustrative cases selected because complete preoperative and postoperative radiographs and incision documentation are available.

Technique Concept and Rationale

The technique is intended for selected adult deformity constructs terminating in the lower thoracic region, commonly between T9 and T12, with distal fixation extending to the sacrum or pelvis. The proximal fixation is inserted percutaneously through small paramedian incisions. This avoids a continuous wide midline exposure across the lower-thoracic transition zone and is intended to preserve the multifidus, longissimus, and erector spinae attachments and reduce disruption of the posterior tension band.

Modular instrumentation permits three functional head configurations: standard tulip heads, reduction heads, and percutaneous tower heads. At the proximal levels, corticocancellous pedicle screws are inserted with percutaneous towers under fluoroscopy or navigation. In the lumbar spine, modular reduction-head or tower screws are placed through the open deformity-correction exposure. Rods are contoured to the intended thoracolumbar profile, introduced proximally through the percutaneous towers, and captured distally within the lumbar and pelvic reduction heads. Sequential set-cap advancement and reduction clips distribute reduction forces across multiple fixation points rather than concentrating correction on one or two screws.

The Junctional Ladder concept is not dependent on a single interbody approach. It may follow anterior lumbar interbody fusion, lateral or oblique interbody fusion, or posterior/transforaminal decompression and interbody reconstruction. T12 fixation may be omitted when proximal towers would interfere with an upper-lumbar decompression or cage trajectory, provided the final construct and bone quality permit safe fixation. Cement augmentation of proximal tower screws optional depending on the degree of osteoporosis.

Role of Sacroiliac Joint Fusion and the PML Concept

Distal pelvic fixation in long-segment reconstructions employs the Ogunseinde Posteromedial-to-Lateral (PML) sacroiliac (SI) joint fusion technique, utilizing 3D-printed implant screws inserted via a transfixing posteromedial-to-lateral trajectory, as described in the author's prior publication in the Journal of Clinical Spine Surgery. In Cases 1 and 2, this technique was executed by placing bilateral 10 × 60 mm 3D-printed PML SI fusion implants under fluoroscopic inlet and outlet views, followed by S2-alar-iliac (S2AI) screws positioned caudal to the PML implants to create a comprehensive distal foundation. This distal fixation strategy reinforces the lumbosacral-pelvic junction and directly addresses coexisting SI joint pathology. Biomechanically, achieving rigid stabilization and fusion across the sacroiliac joint protects the S2AI screws from early loosening, fortifies the construct's base, and reduces the risk of distal junctional failure. It is essential to distinguish this distal PML SI fusion innovation from the Junctional Ladder's proximal mechanism: while the proximal hybrid instrumentation seeks to mitigate proximal junctional kyphosis (PJK) through paraspinal muscle preservation, the distal PML technique focuses exclusively on establishing a stable, load-sharing lumbopelvic foundation.

Operative Steps

1. Position the patient prone on a radiolucent deformity table after completion of any planned anterior or lateral stage.
2. Confirm the UIV, lower instrumented vertebra, alignment targets, bone quality, and need for pelvic or SI joint fixation.
3. Insert guidewires and percutaneous corticocancellous pedicle screws with tower attachments at the proximal lower-thoracic levels with or without cement augmentation under fluoroscopic or navigated guidance.
4. Create the lumbar midline exposure only to the level required for decompression, osteotomies, interbody work, and deformity correction, leaving the proximal thoracolumbar muscle envelope intact.
5. Place modular pedicle screws with reduction heads throughout the lumbar construct and S2AI fixation when pelvic fixation is indicated.
6. Perform decompression, facetectomies or posterior column releases, interbody reconstruction, and posterolateral preparation according to the deformity plan.
7. When indicated, add bilateral posterior medial to lateral (PML) trajectory SI Fusion around S2AI screws under appropriate fluoroscopic guidance. Confirm the implant trajectory and relationship to the S2AI corridor. The goal is to strengthen the distal construct and prevent distal junctional failure and reduce the incidence of future sacroiliac joint disease from increased stress across the SI joint from fusion to the pelvis as described by Ivanov in 2009 Journal of Spine.
8. Contour the primary rods to the intended thoracolumbar sagittal profile. Introduce each rod from proximal to distal through the percutaneous towers, then capture it within the open lumbar and pelvic reduction heads.
9. Place set caps at the proximal and distal anchors, then sequentially advance the reduction mechanisms to distribute correction forces. Perform controlled derotation, compression, distraction, or accessory-rod maneuvers as required.
10. Final-tighten all implants to the manufacturer's specifications, remove tower and reduction extensions, obtain final imaging, graft the prepared fusion bed, and close the open and percutaneous incisions.

Case Reports

Case 1

An 81-year-old black woman presented with more than five years of worsening low-back pain, a visual analog scale (VAS) score of 9/10, an Oswestry Disability Index (ODI) greater than 40, and a double thoracolumbar curve with severe lumbar scoliosis. She had failed more than one year of injections, physical therapy, and oral medication. Examination demonstrated a rotational lumbar prominence, coronal trunk shift, and preserved 5/5 motor strength without upper motor neuron findings. Standing radiographs showed an approximately 51° left lumbar curve from L1 to S1 and a compensatory right thoracic curve from approximately T8 to L2. Spinopelvic measurements included pelvic incidence 70°, pelvic tilt 30°, sacral slope 38°, lumbar lordosis 40°, and a PI-LL mismatch of 30°. MRI demonstrated thoracolumbar scoliosis, L2-3 retrolisthesis, L5-S1 anterolisthesis, and degenerative endplate change at T9-10.

The reconstruction used percutaneous 7.5 × 45 mm corticocancellous tower screws at T10-T12 and modular reduction-head screws from L2 to S1. Through an L2-to-sacrum exposure, multilevel facetectomies and interbody reconstruction were performed at L3-4, L4-5, and L5-S1 with expandable titanium cages and local autograft. Four S2AI screws were used because of deformity severity and the need for robust pelvic fixation. Contoured rods were passed from proximal to distal through the percutaneous thoracic towers and captured within the lumbar and pelvic reduction heads. Gradual reduction and derotation were performed, with an accessory rod on the right and two cross-links. There were no recorded intraoperative complications. Cement augmentation was used for the UIV and UIV + 1 pedicle screws and vertebral bodies to prevent early screw loosening and loss of fixation.

At six months, standing radiographs showed more than 50% correction of the coronal deformity with maintained proximal alignment. No radiographic PJK or clinical PJF was identified in the available six-month follow-up. Recorded VAS and ODI values improved by more than 50% from baseline. At 12 months, there was no change in the radiographic findings, and clinical improvement was maintained, with lower VAS and ODI scores than preoperative values. Perioperative data included an operative time of approximately 4 hours, estimated blood loss of 500 mL, and a hospital length of stay of 2–4 days. No transfusion was required. There were no perioperative complications or reoperations. The patient was discharged home with home health services.

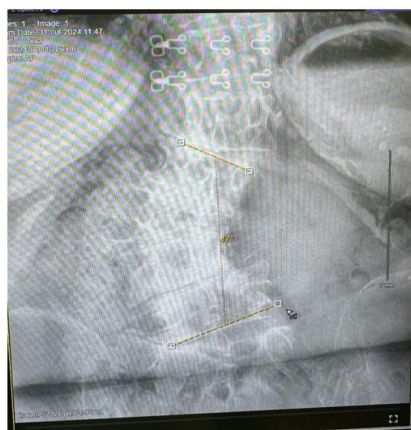


Figure 1: shows preop lumbar scoliosis with significant lumbar scoliosis Apex Left L2-3 with Lateral listhesis at L3-4 severe concavity from L1-5. CSVL courses through T12.

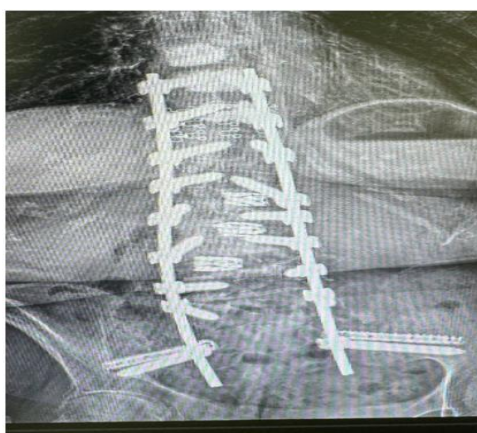


Figure 2: At 6 months Postop correction of significant adult lumbar scoliosis using junctional ladder technique, preserving the multifidus proximally. cement augmentation at UIV, UIV -1, and UIV +1.

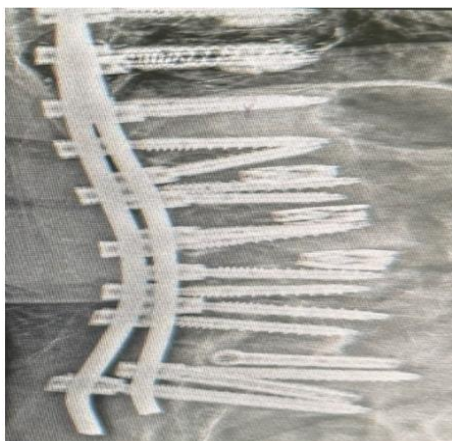


Figure 3: At 6 months Postop Lateral with restoration of some of disc height and increased Lordosis in adult lumbar scoliosis using junctional ladder technique, preserving the multifidus proximally. cement augmentation at UIV, UIV -1, and UIV +1.



Figure 4: Clinic Visit at 6 months clinically balanced bilateral shoulders with minimal pain. Using Walker for support and driving.

Case 2

A 74-year-old man presented with severe low-back pain, VAS 9/10, ODI greater than 40, and degenerative double-curve thoracolumbar scoliosis after failure of facet injections, radiofrequency ablation, physical therapy, and medication. He walked with a forward-flexed posture that remained actively correctable. Strength and sensation were preserved. Standing radiographs demonstrated approximately 20°-25° leftward scoliosis from T11 to L5. Pelvic incidence was 52°, lumbar lordosis approximately 24°-25°, sacral slope 26°, pelvic tilt 30°, and PI-LL mismatch greater than 25°. MRI demonstrated multilevel disc and facet degeneration, foraminal stenosis from L2-3 through L4-5, scoliosis, and multilevel spondylolisthesis.

The patient underwent a T11-to-pelvis hybrid reconstruction. Percutaneous 7.5-mm corticocancellous pedicle screws with tower attachments were placed at the proximal levels with modular reduction-head screws from L3 to S1. Through an L3-to-sacrum midline exposure, bilateral facetectomies, capsular releases, multilevel discectomies, and expandable interbody cage placement were performed. Importantly, bilateral 10 × 60 mm 3D-printed PML SI joint fusion implants were placed under fluoroscopic inlet and outlet views. Two 9 × 80 mm S2AI screws were then placed caudal to the PML SI fusion implants, creating a combined lumbopelvic and SI joint foundation. Contoured rods were passed proximally through the percutaneous towers and captured distally in the reduction heads. Two cross-links were added. Final imaging showed satisfactory correction, and no intraoperative complication was recorded.

At six months, radiographs showed more than 50% correction of the thoracolumbar curves. Full-length standing imaging at six months showed maintained proximal alignment without radiographic PJK or clinical PJF. Recorded VAS and ODI measures improved by more than 50% compared with baseline. At 12 months, there was no change in the radiographic findings, and clinical improvement was maintained, with lower VAS and ODI scores than preoperative values. Perioperative data included an operative time of approximately 4 hours, estimated blood loss of 500 mL, and a hospital length of stay of 2-4 days. No transfusion was required. There were no perioperative complications or reoperations. The patient was discharged home with home health services.



Figure 5: Preop AP lumbar X-rays with leftward 25–30-degree rotatory adult scoliosis



Figure 6: At 6 months post-op AP lumbar X-rays with correction of Preop adult lumbar scoliosis. Cement augmentation at UIV, UIV +1 and UIV -1.



Figure 7: At 6 months post-op Lateral lumbar X-rays with improved Lordosis. Cement augmentation at UIV, UIV +1 and UIV -1.

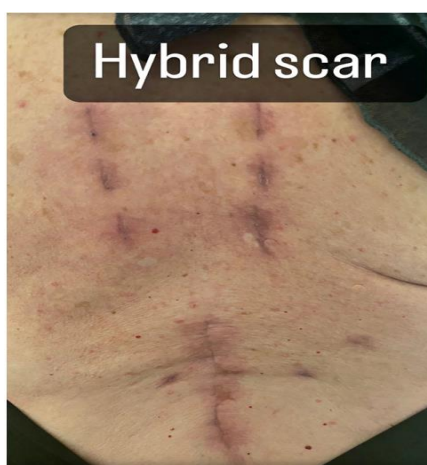


Figure 8: At 6 months post-op using junctional (hybrid) ladder technique, the proximal scars are insertion points for percutaneous screws with Cement augmentation and the midline scar for decompression and instrumentation. Optional Wiltse approach can be used here as well.

Discussion

The Junctional Ladder Technique is based on the premise that the proximal end of a long deformity construct should be treated as both a mechanical transition zone and a biologically vulnerable region. Proximal junctional kyphosis and proximal junctional failure are multifactorial complications rather than consequences of a single implant choice. Patient age, bone quality, sarcopenia, preoperative thoracic alignment, magnitude of sagittal correction, disruption of the posterior tension band, and the stiffness differential between fused and mobile spinal segments may all contribute to junctional stress [Kim et al., 2012; Lau et al., 2014; Maruo et al., 2013].

The Junctional Ladder concept does not attempt to eliminate all of these variables. Instead, it addresses modifiable technical factors at the proximal transition while preserving the corrective capacity required for complex adult spinal deformity reconstruction. A traditional continuous posterior exposure extending through the upper instrumented vertebra may detach or denervate portions of the multifidus, longissimus, and erector spinae muscles and may disturb the interspinous, supraspinous, and facet capsular structures near the UIV. These tissues contribute to dynamic stabilization and resist flexion at the proximal end of the construct. Their disruption may be particularly consequential in older adults with reduced muscle mass or poor bone quality.

The association between severe multifidus sarcopenia, lower vertebral Hounsfield units, and increased risk of PJK or PJF supports the clinical relevance of preserving the remaining muscular and osseous reserve whenever feasible [Pinter et al., 2023]. By using separate percutaneous proximal access sites rather than extending the open lumbar incision cephalad, the Junctional Ladder Technique is intended to limit injury to this posterior stabilizing envelope.

The technique also creates a functional gradient within the instrumentation strategy. Percutaneous corticocancellous screws with tower attachments are used at the lower-thoracic proximal levels, whereas modular reduction-head screws are retained in the open lumbar and lumbopelvic portion of the construct. This arrangement permits the surgeon to preserve proximal soft tissues without surrendering the ability to perform decompression, facetectomies, interbody reconstruction, rod contouring, derotation, compression, distraction, and gradual reduction in the region where these maneuvers are most often required. Sequential advancement of multiple reduction mechanisms may further distribute correction forces across the construct rather than concentrating force at a single screw-bone interface. This distributed reduction is a proposed mechanical advantage, although it was not directly measured in the present report and requires biomechanical validation.

The ladder analogy reflects the intended stepwise transition from the rigid corrected lumbar spine to the mobile lower thoracic spine. The proximal anchors remain pedicle-based and therefore provide reliable fixation, but their placement through limited exposures may reduce the additional biologic insult created by wide muscle stripping. This differs from strategies that soften the transition by changing the anchor type, adding ligamentous tethers, using transition rods, performing cement augmentation, or employing prophylactic vertebral reinforcement. These approaches are not necessarily mutually exclusive. In a high-risk patient, the Junctional Ladder Technique could potentially be combined with bone-health optimization, age-adjusted alignment goals, careful facet preservation, tethering, vertebral augmentation, or postoperative bracing. The present cases, however, evaluate only the feasibility of the hybrid exposure and instrumentation strategy and do not permit comparison with other junctional-protection methods.

Selection of the UIV remains a major determinant of construct design. The Junctional Ladder Technique may allow a reconstruction to terminate at an appropriate lower-thoracic neutral vertebra rather than extending routinely into the upper thoracic spine solely because of concern for junctional complications. Prior comparisons of upper- and lower-thoracic UIV selection indicate that longer proximal extension does not eliminate PJK or PJF and may increase operative exposure, blood loss, implant burden, and the number of mobile segments sacrificed (Ha et al., 2013; O'Shaughnessy et al., 2012). Nevertheless, this technique should not be interpreted as justification for selecting an otherwise unsuitable lower-thoracic UIV. Curve pattern, thoracic kyphosis, shoulder balance, coronal and sagittal stability, adjacent-level degeneration, vertebral morphology, bone quality, and the planned magnitude of correction must remain central to level selection.

The two illustrative cases also emphasize that proximal transition management cannot be separated from global alignment. Excessive or abrupt sagittal correction may increase junctional loading even when the proximal musculature is preserved. Conversely, inadequate correction may leave persistent disability and compensatory posture. The goal is therefore not maximal radiographic normalization in every patient, but a balanced correction appropriate to age, flexibility, pelvic parameters, and functional demands. In both cases, the rods were contoured and reduced through multiple fixation points, allowing correction to be developed progressively. The maintained proximal alignment at six months suggests that this method can coexist with meaningful coronal and sagittal correction, but the study does not establish that the degree of correction was optimal or that the technique independently reduced junctional stress.

The distal foundation is another important component of long-segment reconstruction. Constructs extending to the sacrum are exposed to substantial cantilever forces and may require pelvic fixation to protect the lumbosacral junction. In both cases presented, bilateral PML SI joint fusion implants were combined with S2AI screws, creating a broad lumbopelvic and SI joint foundation. This configuration is conceptually complementary to the Junctional Ladder: the proximal strategy seeks a gradual, muscle-preserving transition, whereas the distal strategy seeks stable load transfer across the pelvis and treatment of coexisting SI joint pathology when clinically indicated. The SI fusion component should remain clearly distinguished from the proposed proximal PJK-mitigation mechanism. The goal of the SI fusion implants is to protect the S2AI screws from early loosening, provide a fusion across the sacroiliac joint which provides a solid foundation for the long constructs, and reduce distal junctional failure.

The clinical and radiographic findings in these two patients are encouraging. Both experienced greater than 50% improvement (VAS 5-6-point reduction) in the recorded pain and disability measures, substantial coronal correction, and maintained proximal alignment without radiographic PJK or clinical PJF at the available six-month follow-up. These observations demonstrate technical feasibility and support further investigation, but they cannot establish causation or preventive efficacy. The improvements reflect the complete reconstructive procedure, including decompression, interbody fusion, deformity correction, pelvic fixation, rehabilitation, and postoperative care. Similarly, the absence of an early junctional complication may reflect patient selection, alignment targets, bone quality, surgical execution, or chance in addition to the proximal exposure strategy.

Future study should evaluate the Junctional Ladder Technique in a larger consecutive cohort with standardized standing full-length radiographs, formal proximal junctional angle measurements, age-adjusted sagittal alignment analysis, bone-density assessment, and prospectively collected patient-reported outcomes.

Comparative groups could include conventional open lower-thoracic fixation, other hybrid constructs, or alternative junctional-protection strategies. Important endpoints should include operative time, blood loss, length of stay, wound complications, proximal muscle morphology, PJK, PJF, revision surgery, pseudarthrosis, implant failure, and long-term functional outcomes. Advanced imaging or postoperative MRI-based analysis of multifidus preservation could help determine whether the biologic premise of the technique is achieved. Until such data are available, the Junctional Ladder Technique should be presented as a reproducible, hypothesis-generating strategy for preserving proximal soft tissues while maintaining deformity-correction capability, rather than as a proven method of preventing PJK or PJF.

Limitations

This report is limited by its retrospective design, two-case sample, single-surgeon experience, incomplete long-term imaging, absence of a control group, and incomplete standardized outcome data. Although available records include approximate operative time, estimated blood loss, length of stay, and perioperative complication data, these measures were retrospectively collected and are insufficient for comparative conclusions.

Conclusion

The Junctional Ladder Technique combines percutaneous lower-thoracic fixation with open modular lumbar and lumbopelvic reconstruction to preserve proximal soft tissues while maintaining deformity-correction capability. In two illustrative cases, correction was maintained at six months without observed PJK or PJF. Bilateral SI joint fusion using the PML technique may provide a complementary distal strategy fixation in appropriately selected patients. Comparative prospective study with longer follow-up is required before claims of PJK prevention can be made.

Declarations

Competing interests: The author originated the Junctional Ladder Technique and the PML SI fusion technique. Author is a consultant for SI-BONE (California), Zavation Medical (St. Louis, Missouri), Spine Art (California), and Spine Wave (Connecticut).

Funding: No external funding was received.

Data availability: De-identified clinical data are available from the corresponding author subject to patient privacy and institutional requirements.

Author contributions: B.O. conceived the technique, performed the procedures, collected and interpreted the clinical data, and drafted the manuscript.

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