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Surgical Management of Grade IV L5-S1 Spondylolisthesis Using Posterior Instrumented Fusion with Sacral Dome Osteotomy: A Case Report

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Abstract

Background: High-grade spondylolisthesis (HGSL) remains a complex surgical condition with no clear consensus on optimal management. Current controversy lies between in situ fusion vs reduction with fusion as *in-situ* fusion reduces neurological risk but may inadequately correct deformity and pelvic parameters. Recently, a posterior-only approach incorporating sacral dome osteotomy has been proposed to allow controlled shortening, facilitating deformity correction while minimising neural tension; however, supporting evidence remains limited. **Case Presentation:** A 27-year-old female presented with an 11-year history of chronic low back pain without neurological deficit. Imaging demonstrated grade IV L5-S1 spondylolisthesis with severe foraminal stenosis. Following multidisciplinary discussion, she underwent single-stage posterior instrumented fusion from L4 to S2, with decompression, sacral dome osteotomy, and partial reduction. Intraoperatively, complete neural decompression and controlled sacral dome resection enabled safe reduction of the slip from grade IV to grade II. The L5 nerve roots were protected throughout and stable fixation was achieved. At 3 month follow up she was mobilising independently with minimal pain and had returned to work with high satisfaction. Radiographs confirmed maintained alignment and stable instrumentation. **Conclusion:** This case demonstrates that posterior-only fusion with sacral dome osteotomy is an effective strategy for managing HGSL. Partial reduction combined with controlled shortening can achieve satisfactory clinical and radiographic outcomes while preserving neurological safety. These findings support the role of posterior shortening techniques as a viable operative approach. Further prospective studies are required to define their role in the surgical

management of HGSL.

Keywords

Spondylolisthesis, Sacral Dome Osteotomy, Spinal Fusion, Posterior Instrumentation

1. Introduction

High-grade spondylolisthesis (HGSL) is defined as over 50% vertebral translation relative to the caudal vertebra [1]. It most commonly occurs at L5-S1 and presents significant surgical challenges.

Despite numerous techniques, no consensus exists regarding optimal surgical management [2] [3]. Current strategies include in situ fusion, partial or complete reduction and anterior, posterior, or combined approaches [4]. The principal controversy lies between in situ fusion vs reduction with fusion [5]. While reduction improves anatomical alignment, it carries increased risk of neurological injury and instrumentation failure [6] and both strategies have been associated with deformity progression and non-union [5] [7].

Regardless of technique, surgical goals are restoration of the lumbosacral junction, correction of spinopelvic alignment and achievement of adequate decompression and stabilisation [8]. With a growing emphasis on spino-pelvic balance and sagittal alignment, there has been increasing interest in more novel single-stage, posterior-only, reduction and fusion with sacral dome-osteotomy, as first described by Reidler and Kebaish [6] [9] [10]. However, evidence remains limited, with only a small number of published series [11]-[13]

In summary, high-grade HGSL remains surgically challenging. Single stage posterior-only shortening techniques with sacral dome resection, described by Min *et al.* (2012), supported by Rivollier *et al.* (2020) and Ferrero *et al.* (2018), allow for improved alignment and acceptable outcomes in small series. More aggressive shortening via L5 partial spondylectomy, as reported by Obeid *et al.* (2016) and more recently by Guo and Li (2025), achieves greater correction while maintaining a posterior-only approach. However, evidence remains limited and no consensus exists on optimal technique [14].

The aim of this case study is therefore to present the management of a complex rare presentation of high-grade HGSL within a tertiary spinal centre, highlighting the decision-making process, technical considerations, and perioperative challenges encountered. By detailing our approach and outcomes, we aim to contribute to the limited body of literature, provide practical insights for surgeons managing similarly complex cases and support the role of carefully selected posterior-only shortening techniques in achieving satisfactory clinical and radiographic results.

2. Case Presentation

A 27-year-old female first presented to our spinal clinic with a history of chronic lower back pain of approximately 11 years' duration, initially triggered during dancing activities. She had previously been seen by a spinal surgeon out of area and was offered surgical fusion. However, this was deferred due to coinciding with GCSE examinations.

Since then, she continued only conservative management by regular physiotherapy and yoga exercised which she gradually noticed she was unable to perform due to increasing lower back pain. She still didn't report any radicular symptoms, bowel or bladder dysfunction. The pain had stopped her from dancing or any other sporting activities, and she had to choose office work mainly due to back pain. She was extremely concerned that the progressive pain stops her from normal daily activities. She was an otherwise fit and well, non-smoking 27-year-old with no past medical history or regular medications.

On clinical examination, she had a normal sagittal balance with localised tenderness over lumbosacral region and otherwise normal sensation and power L2-S1 bilaterally with downgoing plantar reflexes. At the time, MRI of lumbosacral spine showed high-grade, Labelle type 6, dysplastic spondylolisthesis Meyerding grade 4 at L5-S1 with severe bilateral foraminal narrowing and neural impingement (Figure 1). Pre-operative radiographic measurements are shown in Table 1.

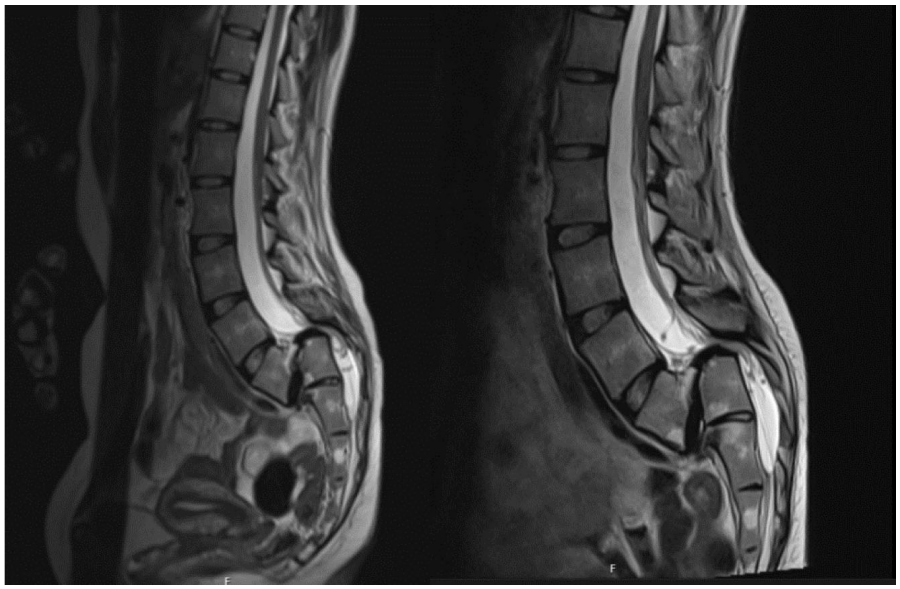

Figure 1. Pre-operative sagittal MRI.

Table 1. Pre and post op radiographic measurements.

	Pre-op	Post-op
Dub-LSA	40	62
% slip	70.7%	33%

Continued

PT	44	28
LL	66	58
Labelle classification (Labelle, Mac-Thiong, Roussouly, 2011)	Type 6—High grade Low SS/High PT (unbalanced pelvis)	Type 2—Low grade High PI/High SS

Legend: Dub-LSA = Dubousset lumbo-sacral angle. % slip = L5 Slip Percentage. PT = Pelvic Tilt. LL = Lumbar Lordosis.

She was subsequently discussed in the complex spine MDT that same week and the week following with the plan to proceed with an L4-S2 Fusion with L4/5 and L5/S1 decompression + Sacral dome resection and posterior reduction of L5/S1 following radiographs and computed tomography of the lumbosacral spine (Figures 2 and Figures 3).

Figure 2. Pre-operative sagittal CT.

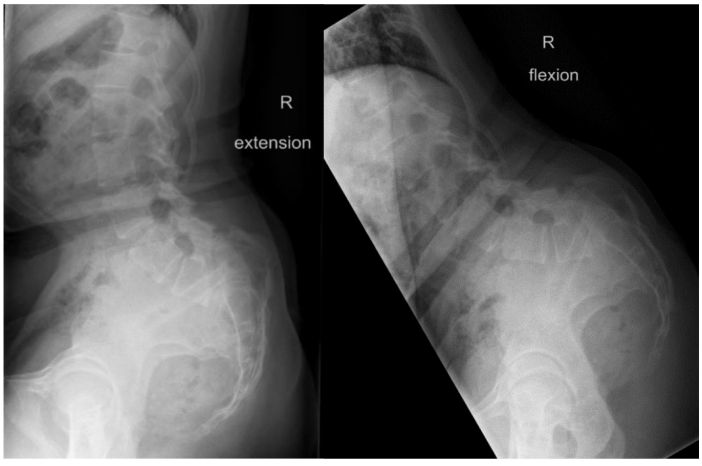

Figure 3. Pre-operative sagittal flexion-extension radiographs.

Based on high grade of slippage, patient's age and fear of progression to spondyloptosis, it was decided to reduce the grade of slippage ideally to grade II - III. It was also thought that by reducing the grade of slippage and sufficient posterior decompression, we can address the foraminal narrowing and as such there was no need for interbody fusion. To avoid excessive neural traction, complete reduction of spondylolisthesis was avoided.

3. Operation and Technical Note

The procedure was performed using neuromonitoring and with the assistance of navigation system. The patient was positioned prone with all pressure points inspected and appropriately padded. Under fluoroscopy, the L4-S2 region was identified and marked. Skin was then incised down to the lumbodorsal fascia. Cobb periosteals and monopolar electrocautery were used to create a subperiosteal dissection, dissecting the soft tissues off the spinous processes, lamina, medial facets and transverse processes from L4 to S1 bilaterally. Once adequate exposure was obtained, X-rays were taken to confirm spinal levels.

Intraoperative navigation was used throughout with the array based on the right iliac bone. Under navigation, pedicle screws were inserted in L4, L5 and S1 along with bilateral S2AI screws. Complete removal of the L5 lamina was then performed, along with flavectomy at L4/5 and L5/S1. The L5 nerve roots were thoroughly decompressed and exposed laterally until exiting from the foramen. The L5/S1 disc was then exposed bilaterally between the S1 and L5 roots and excised.

Osteotomy of the sacral dome was performed from both sides in an anteromedial direction using standard straight osteotomes along with a Sonopet device, after which the upper part of the sacrum, together with attached disc fragments, was removed piece by piece.

A lateral radiograph confirmed that sufficient osteotomy had been achieved. Rotation was measured under navigation, and a Bendini system was used to contour the rods. These were firmly fixed first to the S1 and S2AI screws, and then sequentially to the L4 and L5 screws, thereby reducing the slipped L5 onto the osteotomized surface of S1.

The L5 nerve roots were continuously visualized to ensure that they were not stretched. The space between the endplates of L5 and S1 was supported with synthetic bone chips (DBX) plus autologous bone graft. Adequate L5 nerve root decompression was achieved, and reduction from grade IV to grade II was accomplished. Final X-rays were satisfactory.

The wound was then copiously irrigated with antibiotic solution. No evidence of dural tears was seen, and a drain was placed over the thecal sac and brought out through a separate stab incision.

The fascia was closed with continuous 1-0 Stratafix, subcutaneous tissues were closed with inverted 2-0 Vicryl sutures, and the skin was closed with 2-0 Monocryl.

Estimated blood loss was 750 mL. The Cell Saver was used to autotransfuse 415 mL. Postoperatively, the patient was instructed to maintain bed rest for 72 hours, with head elevation at 30 degrees and knee flexion at 45 degrees, use a back brace with hip extension, and keep the drain under gravity.

4. Follow-Up and Outcomes

Post operatively, the patient remained neurologically intact with stable recovery. At 6-Week Follow-Up she was mobilising with one crutch, walking around 5,000 steps daily with good pain control, no neurological deficits other than occasional transient bilateral foot pain without progression.

On examination she had full strength (5/5) in both lower limbs, was able to stand toe and heel and straight leg raise with normal dermatomal sensation and myotomal function. Radiographs confirmed satisfactory alignment and instrumentation (Figure 4).

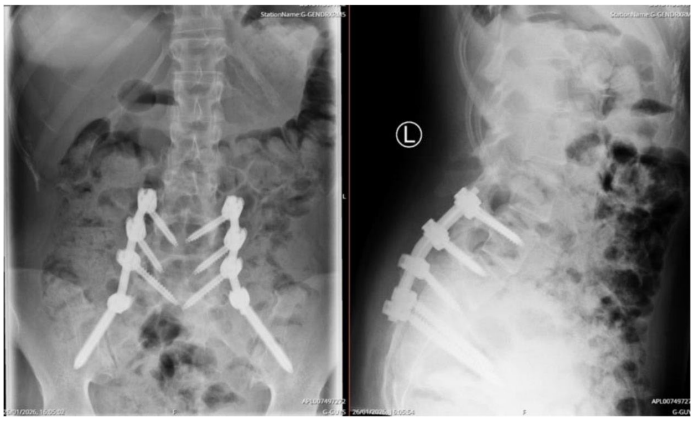

Figure 4. Immediate post-operative coronal and sagittal radiograph.

Three month follow up showed continued improved postoperative recovery, good mobilisation of over 5,500 steps a day full return to work and no neurological deterioration with good patient satisfaction and metal work positioning (Figure 5).

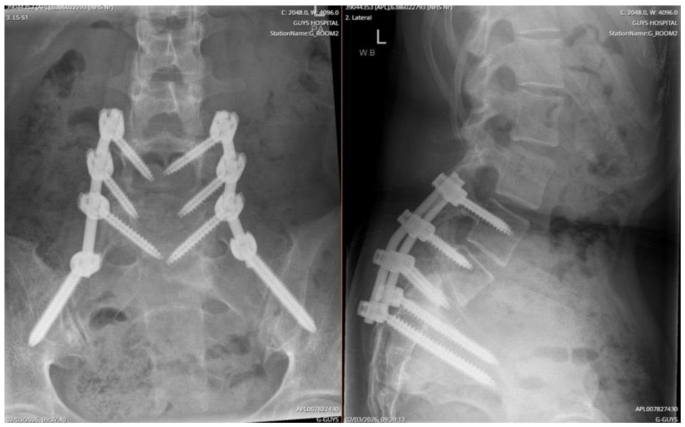

Figure 5. 3-month post-operative coronal and sagittal radiographs.

The patient attended regular physiotherapy sessions with progressive improvement. At 5 months post-op she managed 30k steps a day on holiday and returned to office work. She managed 5l-8k steps a day, Home Exercise Programme and yoga exercises.

5. Discussion

High-grade spondylolisthesis remains a technically demanding and controversial topic in spinal surgery due to the need to balance deformity correction, neural preservation, and achieve adequate fusion [5]. The ongoing controversy between in situ fusion and reduction with fusion continues to underpin surgical decision-making [4].

In situ fusion offers the advantage of reduced neurological risk but may inadequately address sagittal imbalance and lumbosacral kyphosis, especially in younger, active individuals. In contrast, reduction techniques allow for restoration of anatomical alignment and improvement in spinopelvic parameters, but carry an increased risk of neurological injury, particularly L5 nerve root stretch, as well as potential instrumentation failure [7] [15]. In this context, the use of posterior-only reduction with sacral dome resection represents a strategy aimed at balancing these competing priorities. By facilitating controlled shortening at the lumbosacral junction, this technique permits deformity correction while minimising neural tension.

In the present case, reduction from Meyerding grade IV to grade II was achieved, demonstrating that meaningful correction and reduction can be obtained without complete anatomical realignment. This supports that sub-total reduction may be sufficient to restore functional alignment while mitigating the risks associated with more aggressive correction. Sacral dome osteotomy, as originally described by Min *et al.* (2012), plays a central role in this approach by removing the mechanical obstruction at S1 and allowing posterior translation of L5 without the need for excessive distraction. This effectively converts a high-shear deformity into a shortened, more stable construct, thereby reducing stress on both neural elements and instrumentation.

The operative strategy employed in this case is consistent with previously reported series, which have demonstrated improvements in lumbosacral alignment, acceptable neurological safety profiles and satisfactory functional outcomes [11]-[13]. In this case, the absence of postoperative neurological deficit suggests that shortening techniques may reduce nerve root strain compared to previously documented reduction manoeuvres.

Alternative approaches, such as L5 partial spondylectomy, have been described for more severe deformities, including spondyloptosis, and allow for greater degrees of correction [10] [14]. However, these techniques are associated with increased operative complexity, greater blood loss, and the need for more extensive stabilisation. In comparison, sacral dome resection represents a less invasive shortening strategy that preserves more native anatomy while still enabling sub-

stantial deformity correction.

Contemporary management of HGSL increasingly emphasises the importance of spinopelvic alignment, including parameters such as pelvic incidence, sacral slope, and pelvic tilt [6] [15]. Although this patient did not demonstrate gross sagittal imbalance preoperatively, restoration of a more physiological lumbosacral relationship remains critical to reducing the risk of adjacent segment degeneration, mechanical failure, and long-term disability [16].

Clinically, the patient demonstrated a favourable postoperative course, with no neurological deficits, progressive mobilisation, and return to work by three months, alongside high levels of patient satisfaction. These findings are consistent with existing literature reporting good functional recovery following posterior-only shortening techniques, even in the absence of complete anatomical reduction [12] [13] [17]. The transient bilateral foot pain reported at six weeks is likely attributable to temporary nerve root irritation, a recognised postoperative phenomenon, and its resolution without progression further supports the safety profile of this approach.

This report provides a detailed single-centre experience of a growing surgical strategum to a complex and controversial spinal pathology. Given that much of the current evidence is derived from small series in specialised units, there remains a need to demonstrate that these technically demanding approaches are reproducible and translatable across tertiary spinal centres. By reporting our experience, we provide further external validation that this approach can be safely implemented with favourable clinical and radiographic outcomes. In doing so, this case adds incrementally to the growing body of evidence, helping to refine surgical decision-making and strengthen the foundation for future comparative and prospective studies in the management of HGSL.

6. Conclusion

This case demonstrates the surgical management of HGSL via a single stage, posterior fusion with sacral dome osteotomy with satisfactory radiographic and clinical outcomes while maintaining neurological safety. Partial reduction was sufficient when combined with adequate decompression and stable fixation. However, given the single-case design and absence of longer-term outcome data, these findings should be cautiously interpreted. Given the ongoing lack of consensus and the reliance on small retrospective series, further prospective studies with larger cohorts are required to better define optimal surgical strategies and clarify the role of such techniques in this patient population.

7. Limitations

This report is limited by its single-case design and short 3-month follow-up duration. Although early clinical recovery and radiographic alignment were satisfactory, longer-term follow-up is required to assess fusion status, hardware durability, adjacent segment changes and sustained functional outcomes. As such, this

case should reflect feasibility of a posterior-only shortening and partial reduction strategy in a carefully selected patient, rather than establishing broader efficacssy or generalisable findings.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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