# Spondylolysis and spondylolisthesis: operative treatment

Roxane Compagnon, Manon Bolzinger, Jérôme Sales De Gauzy

Department of Pediatric Orthopaedic Surgery, Children's Hospital, Toulouse University Hospital
330 Avenue de Grande-Bretagne 31026 Toulouse CEDEX

## Introduction

Surgical management is rarely indicated in children and adolescents with spondylolysis and spondylolisthesis when considering the high prevalence of these two entities in the general population. Abstention of treatment and conservative management are much more frequently employed management strategies. The focus of this chapter will be on the surgical strategies of L5-S1, the most frequent location of spondylolysis and spondylolisthesis.

Numerous surgical techniques have been described and the decision on which to employ remains controversial for both low-grade and high-grade spondylolisthesis. Different techniques, their results and their complications will be discussed, along with a management strategy based on the degree of vertebral translation and stability.

## Surgical techniques

### 1. Pars repair [15]

First described by Kimura in 1968, the goal of pars repair is to restore the continuity of the isthmus with a bone graft. This intervention has the theoretical advantage of conserving the mobility of the L5-S1 segment and requires a healthy L5-S1 intervertebral disc pre-operatively verified on MRI. The patient is placed prone, and a posterior midline approach is made. After the posterior arch is cleared, fibrous tissue at the level of the pars interarticularis is excised. The autologous bone graft, harvested from the iliac crest using the same incision, is placed.

In order to ensure the graft is held firm in place, multiple fixation techniques have been described [5]:

- Screw fixation through the superior articular process with an associated laminar hook (Morscher technique).
- Direct fixation of the isthmus (Buck repair) (figure 1): lag screw placement through the lamina is often difficult due to the laminar dysplasia.

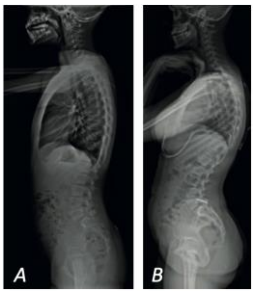


***Figure 1:*** *A) 10-year-old girl with symptomatic grade I spondylolisthesis resistant to conservative treatment. B) isthmic repair by Buck's technique. Results at 6-year follow-up.*

- Cerclage wire around the transverse and spinous processes (Scott repair).
- perforated screw with passage of a polyesther ligament with the strands placed around the L5 lamina (Bonnard's technique). The construct is combined with a Kirschner wire passing through the lamina and the pedicle in order to neutralize shearing forces.

Our preference is the combination of a pedicle screw and a sublaminar hook along with a short rod in between (figure 2). This construct may be undertaken with most commonly used spinal instrumentations and allows adequate compression of the grafted area. The increased stability renders post-operative immobilization unnecessary [5].

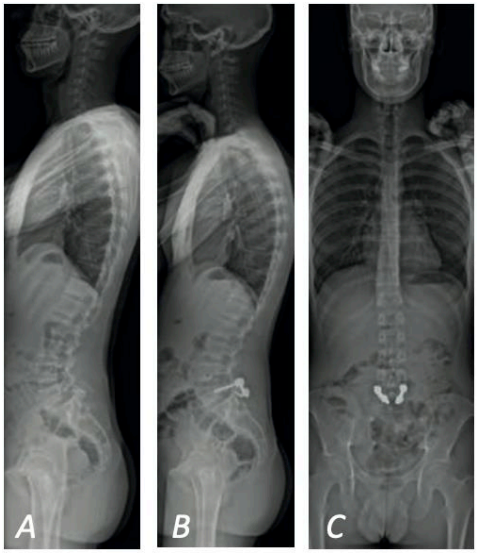


***Figure 2:*** *A) 18-year-old boy with symptomatic grade I spondylolisthesis resistant to conservative treatment. B,C) pars repair with pedicle screws and sublaminar hooks. Results at 1-year follow-up.*

These different instrumentation techniques were tested experimentally by Fan et al. [3], who confirmed increased stability with the screw-hook construct.

Return to full sporting activities is usually authorized 6 months postoperatively.

**2. Posterolateral fusion (PLF) [15] (figure 3)**

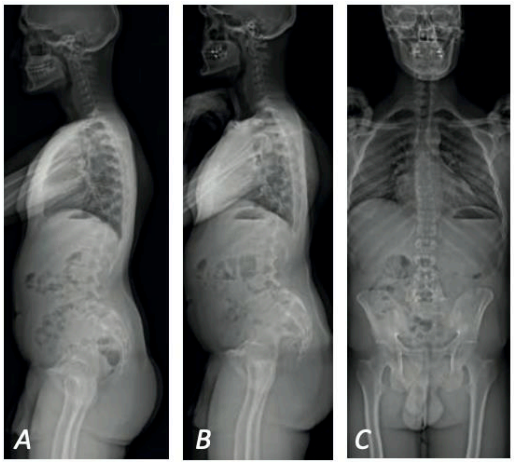


***Figure 3:*** *A) 15-year-old boy with symptomatic, unstable, grade III spondylolisthesis. B,C) L4-S1 posterolateral fusion. Results at 6-year follow-up. No further translation of L5 over S1 was observed.*

Posterolateral fusion is undergone according the Wiltse's technique with the aim of in-situ L5-S1 and sometimes L4-S1 fusion without reduction or instrumentation. Laminectomy or exploration of the spinal canal are not necessary. A posterior midline incision is made centered on L5-S1. Subcutaneous dissection is done approximately 5cm lateral to the midline. After incision of the aponeurosis and passage between the multifidus and longissimus muscles, the L5 transverse process, the lateral portions of the L5-S1 facet joints, and the sacral ala are exposed. A rongeur is used to excise the fibrous tissue at the level of the pars interarticularis (isthmic hook) since it can be a source of localized and radiating radicular pain. Decortication of the L5 transverse processes, lateral portion of the L5-S1 facet joint, and sacral ala is carried out. Finally, cortical and cancellous bone grafts harvested from the iliac crest through the same incision are placed. Immobilization with a thermoformed back brace, crafted prior to the intervention, is prescribed for a period of 3 months.

**3. Closed reduction and fusion [15].**

This technique is used in high-grade spondylolisthesis. The goal is to achieve progressive reduction of the lumbosacral kyphosis followed by fusion in the reduced position. This technique is highly constringent and requires a cooperative child and family. Reduction is achieved through bipolar traction and support with a hammock. The hammock is fashioned out of a 20cm-wide piece of cloth with the superior ends passing directly over the anterosuperior iliac spines. The hammock is then progressively tightened by adding a weight on both sides. The weight is then progressively increased until half of the child's weight is reached and until the buttocks are suspended in the air. Reduction may be obtained within the first 24 to 48h. Radiographs are obtained to confirm the reduction of the lumbosacral kyphosis. A cast is then fashioned in the reduced position and includes both thighs. Circumferential (anterior and posterior) fusion is then performed while the patient is still in the cast, through a window that is created beforehand. The cast is left in place until consolidation is achieved. This technique is no longer commonly used due to its constringent nature.

**4. Surgical reduction and fusion [15] (figure 4).**

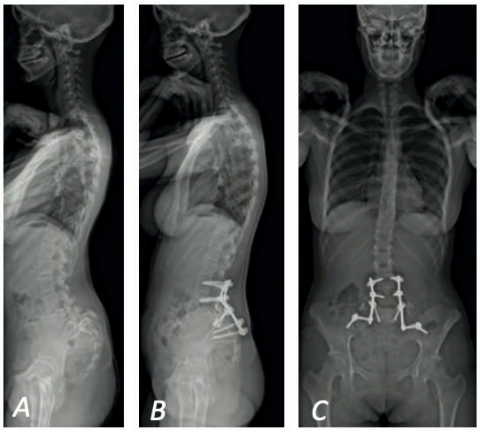


***Figure 4****: A) grade IV spondylolisthesis. B,C) surgical correction with reduction with L5-S1 anterior and L4-S1 posterior fusion. Postoperative results at 1-year follow-up.*

The goal of reduction and fusion in spondylolisthesis is the restoration of sagittal balance with correction of the lumbosacral kyphosis rather than reduction of the translated vertebrae. An L5 laminoarthrectomy is realized through a posterior approach, and the L5-S1 root are located. The L5 roots must be protected throughout the procedure due to the risk of compression within the foramen or stretching after reduction is achieved, with the risk a permanent postoperative deficit. L4-L5 pedicular screws are then placed. At the level of the pelvis, fixation may be achieved with S1-S2 screws, iliac screws, or by trans-sacral rods as per the Jackson technique. Under fluoroscopy, the sacral dome is resected passing by both sides of the dural sac using an osteotome. The rods are bent beforehand and positioned allowing for a progressive reduction of the lumbosacral kyphosis. At the end of correction, the L5-S1 roots must be checked for entrapment. The iliac bone grafts are finally placed in front of the L5-S1 space, and posterolaterally between L4, L5 and S1. In order to increase stability, an intersomatic cage may be placed at the level of L5-S1, which also aids in restoring the L5-S1 intervertebral disc height. Postoperatively, in order to release the L5 root, the patient's hips and knees must be kept in flexion with the support of a pillow. Extension is allowed progressively over the following days, and then a cast brace or rigid lumbar brace with inclusion of the thighs is prescribed for at least 3 months.

**5. Trans-sacral screw fixation [15] (figure 5).**

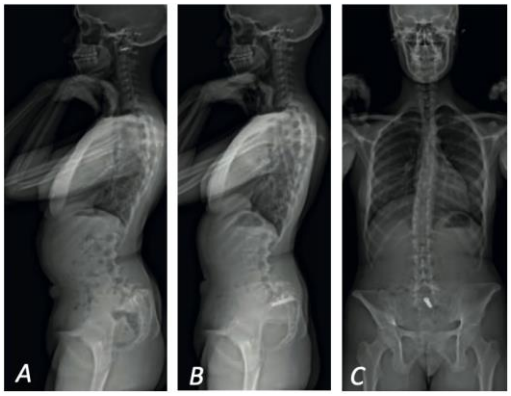


***Figure 5****: A) 18-year-old girl with Spondyloptosis. B,C) circumferential fusion through a posterior approach with placement of a trans-sacral screw. Postoperative radiographs at 3-month follow-up.*

Trans-sacral screw fixation is indicated in high-grade spondylolisthesis. The patient is placed on cushions in the prone position, allowing partial reduction of the intervertebral translation and lumbosacral kyphosis. An L5-S1 laminoarthrectomy is carried out. The nerve roots and the dural cul de sac are retracted in order to expose the posterior aspect of the S2 vertebra. Under fluoroscopic control, a Kirschner wire is placed through S2 at its midline in the direction of the posterosuperior corner of L5. A perforated drill bit is used over the guidewire and the dedicated screws are placed (Medicalex®); The proximal end of the screw is curtailed allowing for the attachment of the posterior aspect of the S2 vertebra after adequate compression has been achieved. The protruding dome of S1 is resected in order to liberate the S1 vertebra and the L5 nerve root is checked for entrapment. L5-S1 discectomy is then carried out, and debridement of the L5 and S1 endplates is achieved using an osteotome and a curette. Finally, the iliac bone grafts are placed anteriorly in the L5-S1 intervertebral space and posteriorly around the posterolateral area.

**6. Lumbosacral fusion without instrumentation by anterior approach [15].**

Lumbosacral fusion without instrumentation using an anterior approach is indicated in high-grade spondylolisthesis as a complement to L5-S1 posterolateral fusion. The patient is placed supine in a hyperlordotic position. A Pfannenstiel incision is made, and the anterior aspect of L5 is reached by subperiosteal dissection. Using an osteotome, the middle third of L5 is resected. The L5-S1 intervertebral disc and the sacral dome are accessed and the L5-S1 disc is excised. An autologous graft harvested from either the tibia or the iliac crest is then placed. Postoperative immobilization is prescribed for 4 months.

## Results

**1. Low-grade spondylolisthesis.**

The most frequently utilized techniques are PLF and pars repair. Clinically, pars repair has satisfactory results in the majority of the reported series with 80 to 90% of the studies

reporting good results, ranging between 56 and 100% [5]. Return to physical exercise at the previous level is observed in the majority of patients. However, the isthmus may not consolidate in all patients. Furthermore, incertitude persists on the long-term effects of these interventions on the L5-S1 disc. After a 15-year follow-up, Schlenzka et al. found identical results between PLF and pars repair for both symptoms and lumbar mobility [19].

**2. High-grade spondylolisthesis (superior to 50%).**

Multiple series have shown good results with in-situ fusion, all of which were carried out with long-term follow-up; 10 years for Seitsalo et al. [18] and 17 years for Lamberg et al. [11]. Circumferential fusion has been shown to provide better results than isolated posterior or anterior fusion [2,11]. No significant advantages were found between fusion with or without reduction. Alzakri et al. [1] and Mac-Thiong et al. [14] reported better results after restoration of the pelvic sagittal balance. Contrarily, Poussa et al. found improved results after in-situ fusion compared to reduction and fusion [16]. Longo et al. found identical clinical outcomes and no significant differences in terms of neurological complications in a systematic review comparing in-situ fusion (101 patients) to reduction and fusion (165 patients) [12], and the only difference found was the risk of non-union, with higher rates non-union in non-instrumented cases. No advantages were found for fusion with reduction. In a recent study, Joelson et al. confirmed the good clinical and functional outcomes after a 30-year follow-up in patients treated with circumferential fusion without reduction [8]. Nevertheless, these patients reported a deteriorated self-image compared to the general population and related it to their lumbosacral deformity [9].

## Complications

In a series with over 600 patients, Fu et al. reported complication rates exceeding 10% [4]. In 50% of these patients, neurological deficits were noted mostly at the level of L5 root, with cauda equina syndrome also being reported. Damage to the L5 nerve root is estimated at around 10 to 50%. The deficit is most often temporary, although it can rarely be permanent. The risk of neurological damage is increased in patients in who had undergone reduction [12]. Nonetheless, this complication may also arise in patients treated by posterolateral fusion without reduction, and especially in high-grade spondylolisthesis [12,17].

Perioperatively, the L5-S1 roots must be protected. Perioperative monitoring of the L5-S1 roots has been proposed, although no objective results have been reported in the literature [12]. As was previously discussed, patients must be placed with hips and knees in flexion over a cushion in the postoperative period. Progressive extension is allowed in the days following surgery.

Other complications include a 3% risk of infection, with no significant differences between reduction and in-situ fusion [4].

The risk of non-union is higher in patients treated by in-situ fusion (18%) compared to surgical reduction (5.5%) [12].

Complications specific to the anterior approach include vascular complications secondary to the proximity of the aorto-bi-iliac bifurcation and the ilio-cava venous confluence, and neurovegetative complications (reduced fertility) due to the proximity of the hypogastric plexus.

## Indications

Operative treatment remains controversial. This is true for both the indications for surgical management and the surgical technique to use. The most essential element is the analysis of sagittal balance in order to assess the stability of the deformity [7,10,14,20].

Two factors are essential: sacral slope and pelvic incidence.

- In patients with a horizontal sacrum, the deformity is generally stable due to the vertical orientation of the sacral plate, thereby conferring sufficient lumbar lordosis that is harmonious with the pelvic incidence. This is true even in patients with high pelvic incidence.
- In patients with a vertical sacrum, the deformity is generally unstable due to the horizontal orientation of the sacral plate, thereby limiting the lumbar spine's ability to increase lordosis and to adapt to the pelvic incidence.

As a result, if pelvic incidence is high, the slippage of L5 over S1 will usually progressively increase and may even rotate around the anterosuperior corner of S1 in an attempt to increase lordosis. This is characterized by lumbosacral kyphosis with an L5-S1 angle <90° (as described by Dubousset). In the majority of cases, this leads to a decompensated sagittal alignment and a progressive translation of L5 over S1 leading to spondyloptosis.

**1. Spondylolysis and low-grade spondylolisthesis (translation <50%)**

Stable forms

Operative treatment in stable forms is rarely indicated and is recommended only in patients who remain symptomatic after conservative treatment has been attempted. As previously mentioned, pars repair and PLF have similar outcomes. Our preference is operative treatment of these patients with a direct pars repair by pedicular screws and sublaminar hooks.

Unstable forms

Unstable forms are rarely encountered in patients with low-grade spondylolisthesis. Nevertheless, knowledge of these forms is still important. In our institution, surgery is absolutely indicated in order to avoid further slippage of L5 over S1. L5-S1 PLF is sufficient to ensure stability. In fact, fusion between L5 and S1 will modify the lumbosacral alignment, with the superior endplate of L5 becoming the new base upon which the lumbar spine will adapt its lordosis.

**2. High-grade spondylolisthesis (translation >50%)**

Stable forms

Various studies have shown that conservative management with close follow-up is possible in stable forms [2,6,13]. However, after an 18-year follow-up, Harris and Weinstein [6] showed that patients who had been previously operated were more active. As such, in both symptomatic and asymptomatic patients, surgical intervention is preferred [2]. Our preference in this case is to operate with in-situ fusion without reduction.

Unstable forms

Surgery is absolutely indicated in these unstable forms with large displacement in order to avoid progressive translation of L5 over S1 and to relieve pain, a very complaint.

Circumferential fusion is necessary in these patients. However, the question of reduction is controversial. As was previously discussed, the goal is reduction of the lumbosacral kyphosis rather than the translation of L5 over S1.

Our attitude actually depends on the amount of translation. It must be taken into consideration that the per-operative prone position often allows partial reduction of the translation and, more significantly, the L5-S1 kyphosis. In grade III spondylolisthesis, reduction with posterior fusion and intersomatic L5-S1 cage placement may be indicated. In spondyloptosis, in-situ fusion with trans-sacral screws is preferred. In grade IV, choosing between the two techniques may be difficult.

**3. Spondylolisthesis by isthmic elongation**

This particular type of spondylolisthesis is rare but must be mentioned. The isthmus is elongated but not fractured and translation is generally moderate (grades I or II). Progression of slippage of L5 over S1 may be responsible for poorly tolerated lumbar spinal stenosis requiring laminoarthrectomy along with L5-S1 fusion and instrumentation.

## Conclusion

Surgical management of spondylolisthesis must be suggested with care. It is rarely indicated in forms with low translation, with PLF or pars repair both providing good results in symptomatic patients not responding to conservative treatment. Surgery is more formally indicated in forms with a large displacement where circumferential fusion is indicated. Reduction of the deformity remains controversial.

## References

1. Alzakri A, Labelle H, Hresko MT, Parent S, Sucato DJ, Lenke LG, Marks MC, Mac-Thiong JM. Restoration of normal pelvic balance from surgical reduction in high- grade spondylolisthesis. Eur Spine J. 2019;28(9):2087- 2094.

2. Crawford CH 3rd, Larson AN, Gates M, Bess RS, Guillaume TJ, Kim HJ, Oetgen ME, Ledonio CG, Sanders J, Burton DC. Current Evidence Regarding the Treatment of Pediatric Lumbar Spondylolisthesis: A Report From the Scoliosis Research Society Evidence Based Medicine Committee. Spine Deform. 2017 Sep;5(5):284-302.
3. Fan J, Yu GR, Liu F, Zhao J, Zhao WD. A biomechanical study on the direct repair of spondylolysis by different techniques of fixation. Orthop Surg. 2010 ;2(1):46-51.
4. Fu KM, Smith JS, Polly DW Jr, Perra JH, Sansur CA, Berven SH, Broadstone PA, Choma TJ, Goytan MJ, Noordeen HH, Knapp DR Jr, Hart RA, Donaldson WF 3rd, Boachie-Adjei O, Shaffrey CI. Morbidity and mortality in the surgical treatment of six hundred five pediatric patients with isthmic or dysplastic spondylolisthesis. Spine. 2011, 15;36(4):308-12.
5. Gagnet P, Kern K, Andrews K, Elgafy H, Ebraheim N. Spondylolysis and spondylolisthesis: A review of the literature. J Orthop. 2018,17;15(2):404-407.
6. Harris IE, Weinstein SL. Long-term follow-up of patients with grade-III and IV spondylolisthesis: treatment with and without posterior fusion. J Bone Joint Surg Am. 1987;69:960–969.
7. Hresko MT, Labelle H, Roussouly P, Berthonnaud E. Classification of high-grade spondylolisthesis based on pelvic version and spine balance: possible rationale for reduction. Spine. 2007,15;32(20):2208-13.
8. Joelson A, Danielson BI, Hedlund R, Wretenberg P, Frennered K.Sagittal Balance and Health-Related Quality of Life Three Decades After in Situ Arthrodesis for High-Grade Isthmic Spondylolisthesis. J Bone Joint Surg Am. 2018 Aug 15;100(16):1357-1365.
9. Joelson A, Diarbakerli E, Gerdhem P, Hedlund R, Wretenberg P, Frennered K. Self-Image and Health-Related Quality of Life Three Decades After Fusion In Situ for High-Grade Isthmic Spondylolisthesis. Spine Deform. 2019 Mar;7(2):293- 297.
10. Jouve JL. Spondylolyse et spondylolisthesis lombosacré de l'enfant et de l'adolescent. In : Cahiers d'enseignement de la SOFCOT. Paris : Expansion Scientifique Publications ; 2001. P.171-92
11. Lamberg T, Remes V, Helenius I, Schlenzka D, Seitsalo S, Poussa M. Uninstrumented in situ fusion for high-grade childhood and adolescent isthmic spondylolisthesis: long-term outcome. J Bone Joint Surg Am. 2007 Mar;89(3):512-8.
12. Longo UG, Loppini M, Romeo G, Maffulli N, Denaro V Evidence-based surgical management of spondylolisthesis: reduction or arthrodesis in situ. J Bone Joint Surg Am. 2014 Jan 1;96(1):53-8.
13. Lundine KM, Lewis SJ, Al-Aubaidi Z, Alman B, Howard AW. Patient outcomes in the operative and nonoperative management of high-grade spondylolisthesis in children. J Pediatr Orthop. 2014 Jul-Aug;34(5):483-9.
14. Mac-Thiong JM, Hresko MT, Alzakri A, Parent S, Sucato DJ, Lenke LG, Marks M, Labelle H. Eur Spine J. 2019 Sep;28(9):2060-2069.
15. Morin C, Sales de Gauzy J, Jouve JL. Orthopédie Pédiatrique Rachis et Thorax. Editions Elsevier Masson. 2016.
16. Poussa M, Remes V, Lamberg T, Tervahartiala P, Schlenzka D, Yrjönen T, Osterman K, Seitsalo S, Helenius I. Treatment of severe spondylolisthesis in adolescence with reduction or fusion in situ: long- term clinical, radiologic, and functional outcome. Spine (Phila Pa 1976). 2006 Mar 1;31(5):583-90; discussion 591-2.
17. Schoenecker PL, Cole HO, Herring JA, Capelli AM, Bradford DS. Cauda equina syndrome after in situ arthrodesis for severe spondylolisthesis at the lumbosacral junction. J Bone Joint Surg Am. 1990 ;72 : 369-77

18. Seitsalo S, Osterman K, Hyvärinen H, Schlenzka D, Poussa M. Severe spondylolisthesis in children and adolescents. A long-term review of fusion in situ. J Bone Joint Surg Br. 1990 Mar;72(2):259-65.
19. Schlenzka D, Remes V, Helenius I, Lamberg T, Tervahartiala P, Yrjönen T, Tallroth K, Osterman K, Seitsalo S, Poussa M. Direct repair for treatment of symptomatic spondylolysis and low-grade isthmic spondylolisthesis in young patients: no benefit in comparison to segmental fusion after a mean follow- up of 14.8 years. Eur Spine J. 2006 Oct;15(10):1437-47.
20. Violas P, Lucas G. L5S1 spondylolysthesis in children and adolescents. Orthop Traumatol Surg Res. 2016 Feb;102(1 Suppl):S141-7.