L5 Pedicle Subtraction Osteotomy for High-Grade Isthmic Spondylolisthesis

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abstract

To the authors’ knowledge, this is the first article to present a pedicle subtraction osteotomy in the lumbar spine to correct and stabilize a high-grade isthmic spondylolisthesis, which poses many challenges with regard to treatment options and outcomes. The optimal surgical treatment for high-grade spondylolisthesis is controversial, but the goals of treatment are to stabilize the affected spinal levels and to decompress the neural elements. A pedicle subtraction osteotomy is a reconstructive procedure that addresses fixed sagittal imbalance by increasing lumbar lordosis through posterior spinal column shortening. The authors report a 46-year-old patient with chronic, progressively worsening back and leg radiculopathy accompanied by sagittal plane malalignment and for which a pedicle subtraction osteotomy was performed. The procedure yielded stabilization of the patient’s lumbar spondylolisthesis and sagittal plane alignment was restoration. At 3 months postoperatively, the patient’s pain had fully resolved and her motor and neurologic examination exhibited no deficits. At 24 months postoperatively, she was still symptom-free and ambulating without assistance. This report is the first documented successful pedicle subtraction osteotomy in the treatment of high-grade spondylolisthesis. This report indicates that certain patient populations may be amenable to pedicle subtraction osteotomy as a treatment option for pathology involving high-grade isthmic spondylolisthesis [Orthopedics. 2015; 38(4):e347-e351.]
Spondylolisthesis is an anterior translational displacement of one vertebra on another. In the adult, this occurs in the lumbar spine as a result of defects in the bony architecture, a trauma, or degeneration. Adult spondylolisthesis predominately presents in 2 patterns: the isthmic variety, which involves abnormalities of the pars-articularis, and the degenerative variety. Within the discussion of spondylolisthesis, a radiographic classification has been used to describe the degree of slippage (grades 1-5) by Meyerding. Grades 3 to 5 are described as more than 50% slippage and categorized as high-grade spondylolisthesis.

High-grade isthmic spondylolisthesis poses many challenges in regard to treatment options and outcomes. High-grade spondylolisthesis is usually accompanied by a significant amount of lumbosacral kyphosis due to the position of the L5 vertebra and the kyphotic angle produced. The optimal surgical treatment for high-grade spondylolisthesis is controversial. The goals of surgical treatment consist of stabilization of the affected levels and decompression of the neural elements. In high-grade spondylolisthesis, patients have secondary hyperlordosis in the upper lumbar spine, creating significant pain and cosmetic problems. The cosmetic problem that results from the posture and gait abnormalities can be an indication for surgery and should be taken into account when deciding on treatment options.

Surgical treatment options in isthmic spondylolisthesis consist of a direct repair of the pars intra-articularis, decompression of the neural elements alone, decompression of the neural elements in conjunction with an in situ posterior lateral fusion, decompression of the posterior lateral fusion with pedicular instrumentation, or decompression and reduction of the spondylolisthesis with instrumentation and interbody fusion. Low-grade spondylolistheses (grades 1-2) are commonly treated with anterior-posterior stabilization fusion, transforaminal lumbar interbody fusion, or instrumented fusion. In high-grade spondylolisthesis (grades 3-5), in situ fusion is currently recommended because reduction is associated with neurologic injury. In situ fusion has a high pseudoarthrosis rate. Other options to treat high-grade isthmic spondylolisthesis include L5 spondylectomy (a technically challenging procedure involving complete removal of the L5 vertebral body) or a fibular allograft strut through the L5 vertebral body into S1 combined with posterior stabilization. Each option has its limitations and contraindications. Most options, with the exception of reduction or spondylectomy, ultimately do not reduce the kyphosis or affect the sagittal balance.

A pedicle subtraction osteotomy (PSO) is a reconstructive procedure that increases lumbar lordosis through posterior spinal column shortening. Considered the “workhorse” procedure for correcting fixed sagittal imbalance, the procedure allows for a 3-column correction of the spine through an entirely posterior approach and it does so without lengthening the spinal column. Pedicle subtraction osteotomy has been extensively described at L3 and L4 to increase lumbar lordosis. Sacral PSO has been described to change pelvic incidence and in posttraumatic reconstruction.

To the authors’ knowledge, the novelty of PSO to correct deformity and stabilize a high-isthmic spondylolisthesis has not been previously published in the literature. The authors present a patient with persistent pain, deformity, and failed attempts at multiple conservative treatments with a high-grade isthmic spondylolisthesis who was successfully treated with a PSO.

Case Report

A 46-year-old woman presented with a 3-year history of atraumatic onset, progressively worsening back and leg pain. Leg pain was located equally in the bilateral buttocks, posterolateral thighs, lateral calves, and dorsal aspect of the feet in an L5 distribution. She had no bowel or bladder dysfunction. Her back pain was severe, sharp, and stabbing and was combined with paresthesias and weakness in her feet. History revealed an accident during dance class as a child followed by several weeks of severe back pain. She attempted epidural steroid injections, physical therapy, nonsteroidal anti-inflammatory medications, and opioid pain medications. She was unable to lie supine at any time.

Physical examination showed weakness in bilateral tibialis anterior (4/5) and extensor hallucis longus (2/5) muscles. She had decreased sensation in an L5 distribution.

Lumbar radiographs (Figure 1) showed a grade 4 congenital spondylolisthesis that appeared to be immobile on flexion-extension. Preoperative measurements included lumbar lordosis of 41° (L1-S1), L5-S1 angle of -19° (kyphosis), L1 to L5 angle (compensatory lordosis, 60.8°), pelvic incidence of 58°, pelvic tilt of 39.3°, and sacral slope of 33°. A preoperative computed tomography (CT) scan (Figure 2) showed arthrodasis of the L5-S1 disk space, no evidence of pars interarticularis defect, and severe stenosis at L5-S1. Magnetic resonance imaging showed severe central and foraminal stenosis at L5-S1.

Figure 1: Lateral lumbar radiograph of the patient on presentation showing grade 4 congenital spondylolisthesis.

Figure 2: CT scan showing arthrodasis of the L5-S1 disk space.
Several surgical options were discussed, including laminectomy alone to decompress the neural elements and relieve the leg pain. Posterior in situ fusion was considered but this would not correct the sagittal plane malalignment. Options to correct the patient’s sagittal plane malalignment were considered. Because the patient appeared to be arthrodesed at L5-S1, she was not a candidate for an anterior lumbar interbody fusion or transforaminal lumbar interbody fusion at L5-S1. Therefore, a PSO at L5 was considered to address the patient’s sagittal plane deformity.

After providing informed consent, the patient was placed supine on a Jackson table. The spine was exposed subperiosteally and segmental instrumentation was placed 2 levels above and below the planned osteotomy. In this case, the L3 and L4 pedicles were instrumented along with bilateral S1 pedicles, and iliac bolts were placed. Morselized bone was harvested from bilateral iliac crests prior to placement of iliac crest bolts. Then, a midline laminectomy of L5 and S1 was performed and the pars interarticularis of L4 and L5 were osteotomized. Due to the high-grade nature of the slip and the congenital nature of the spondylolisthesis, the patient had central stenosis and an S1 laminectomy was indicated. The L5 pedicles were skeletonized. Care was taken to identify the L4-L5 disk and the S1 superior endplate. The L5 pedicles were decencellated with curettes. The L5 pedicles were resected with an osteotome, and then the L5 vertebral body was decancellated with osteotomes and a high-speed burr. A temporary rod was placed from L4 to S1. A temporary rod was placed unilaterally from L4 to S1. The anterior L5 cortex was osteotomized unilaterally, and then the temporary rod was placed on the contralateral side and the osteotomy was completed. The osteotomy was closed and final rods were put into place. The bone graft from the osteotomy, along with iliac crest autograft harvested prior to placing the iliac bolts, was laid over the decorticated transverse processes and sacral alar. Operative time was 150 minutes. Intraoperative blood loss was 525 mL. Postoperatively, the patient was placed in a custom lumbosacral orthosis with leg extensions.

Postoperative radiographs were reviewed, including full-length anteroposterior and lateral (Figure 3), lumbar flexion, and lumbar extension views, and indicated a successful arthrodesis. Postoperative measurements included a lumbar lordo-

**Figure 2:** Preoperative sagittal computed tomography image showing arthrodesis of the L5-S1 disk space.

**Figure 3:** Postoperative full-length anteroposterior (A) and lateral (B) radiographs showing successful arthrodesis and postoperative measurements, including lumbar lordosis (L1-S1 angle) of 44°, L5-S1 angle of -1.4°, L1-L5 angle of 46°, and pelvic tilt of 30°.
In the current case, the patient had an arthrodesis at L5-S1 (Figure 2), so the caudal half of the L5 body was stable relative to the S1 body. In the event that the patient had active hypermobility at L5-S1, another technique (eg, transforaminal lumbar interbody fixation) could have been performed to stabilize the L5 segments before PSO. Minor degrees of slip (<25%) usually do not have significant local kyphosis and sagittal imbalance. Therefore, such patients are commonly treated with instrumented (accepting whatever reduction occurs on the operative table) fusion in situ, unless there is demonstrable instability on flexion-extension lateral radiographs. However, with a more marked deformity in higher-grade spondylolisthesis, especially in the presence of increased lumbosacral kyphosis and extreme spondylolisthesis, some degree of reduction is necessary to realign the lumbar spine over the sacrum in a position that will permit a solid fusion with acceptable sagittal alignment.

Studies on in situ fusion for high-grade slips have reported pseudoarthrosis rates ranging from 0% to 60% and slip progression rates as much as 25%, not to mention the unaddressed effects on gait disturbances and persistent cosmetic deformity. These data have led many to advocate reduction of high-grade slips, not only to address these issues, but also to save motion segments. Although there is some concern about the neurologic risk with PSO, in situ fusions for high-grade slips have also been associated with adverse neurologic outcomes.

The PSO has the advantage of obtaining correction through all 3 columns strictly from a posterior approach without lengthening the anterior column, thereby maximizing the healing potential while avoiding stretch on the major vessels and viscera anterior to the spine. The expected correction from PSO is 30° per level. That degree of correction is significantly more than what would be expected from an interbody technique, where average interbody grafts afford approximately 10° to 15° per level of correction. The patient was not a candidate for a less complex osteotomy technique (eg, Ponte or Smith-Peterson osteotomy) because she had an arthrodesed disk space at L5-S1.

The patient had an excellent clinical outcome consistent with the prior lit-
Case Report

should have particular caution releasing lateral to midline. Therefore, surgeons facing the L5 pedicles are relatively large; there is especially difficult at the L5 level due to the vertebra. Body decancellation and osteotomy is parallel to the L5 superior endplate (cranially) and appropriately converging "deep" in the wound due to the anterolisthesis. In vivo due to the posterior vertebra body cortex and anterolisthesis. In addition, the L5 vertebral body decancellation and osteotomy closure. The L5 is particularly wide and, therefore, the lateral cortex is difficult to identify. Using intraoperative fluoroscopy is essential to determine that the osteotomy direction is parallel to the L5 superior endplate (cranially) and appropriately converging caudally. Surgeons should have significant experience with spinal osteotomy techniques at other levels (e.g., L2 or L3) to learn the appropriate techniques of vertebrectomy and osteotomy closure. The L5 is particularly wide and the L5 pedicles are relatively large; therefore, dissecting across the midline and release of the posterior vertebral body cortex are particularly technically challenging. In this location, the vessels are lateral to midline. Therefore, surgeons should have particular caution releasing the anterior vertebral body cortex because the common iliac veins are frequently directly apposed to the vertebral bodies. To the authors’ knowledge, this report represents the first documented successful PSO in the treatment of high-grade spondylolisthesis. This report indicates that certain patient populations may be amenable to PSO as a treatment option for pathology involving high-grade isthmic spondylolisthesis. All risk factors should be taken into account because this procedure is associated with complications and morbidities.

REFERENCES