



## Delta Fixation versus Interbody Fusion in Severe Spondylolisthesis

Ibrahim Najm Abed<sup>a</sup>, Walid Hemdan<sup>b</sup>, Abdelrahman Ahmed Momtaz<sup>c</sup>, Abdallah Wael Kamar<sup>c</sup>, Ahmad Wadhah Yahya<sup>D</sup>

<sup>a</sup> M.B.Ch. B, FIRM, Neuro Surgery, Doctorate of Board in Neurosurgery.

<sup>b</sup> Researcher in Neurosurgery.

<sup>c</sup> Researcher & General Practitioner in Neurosurgery.

<sup>D</sup> MRCS, medical content creator.

Corresponding author: Ahmad Wadhah Yahya

Email: dr.ayahya@yahoo.com

### Abstract

**Background:** When one vertebra moves or slips relative to the other, a condition known as spondylolisthesis has occurred. Controversy surrounds the best course of treatment for high-grade spondylolisthesis (HGS). In cases of symptomatic high-grade fall that have not responded to conservative treatment, the necessity of surgical stabilization is widely acknowledged. With severe spondylolisthesis being a common medical condition, this study set out to compare the radiographic and clinical results of patients treated with interbody fusion versus Delta fixation.

**Methods:** This clinical research study was conducted on twenty patients with severe spondylolisthesis attending to orthopedic clinic Benha university hospital. Patients were split into 2 groups in accordance with the surgical technique: group A, which had interbody fusion, and group B, which had Delta fixation. The sacroiliac joints and the patient's upper and lower limb neurology were assessed. The patient underwent magnetic resonance imaging (MRI) of the spine and X-rays of the lower back prior to the surgery.

**Results:** VAS at 1, 3 and 6 months was significantly lower in group A in comparison to group B (P=0.007, 0.042, 0.019). ODI at one and three months was significantly lower in group A in comparison to group B (P=0.006, 0.020). COMI at one, three and six months was significantly lower in group A in comparison to group B (P=0.001, 0.010, 0.005).

**Conclusions:** Delta fixation was superior to interbody fusion, providing shorter operative time, lower blood loss intraoperatively, significant improvement in pain, ODI and quality of life and COMI during the management of severe spondylolisthesis.

**Keywords:** Delta fixation, Interbody fusion, Severe, Spondylolisthesis

### Introduction:

Displacement or slippage of one vertebra relative to the lower one is called spondylolisthesis.

There is a 4% prevalence of spondylolisthesis, with high-grade spondylolisthesis (HGS) accounting for 15% of the total. Cases of HGS are more commonly reported in children than adults. Conservative treatments fail to alleviate high-grade spondylolisthesis, which necessitates surgical fixation <sup>[1]</sup>.

The Meyerding classification defines HGS as the displacement of more than half of a vertebral body from its neighboring one. A Belgian obstetrician named Herbiniaux described the first case of spondylolisthesis in 1782. The patient had a protrusion anterior to the sacrum that made vaginal delivery difficult. Spondylolisthesis is a common problem in neurosurgical



departments, affecting 4.2% to 11.2% of the population. However, HGS is an extremely rare occurrence, making up only 19% of all spondylolisthesis cases [2].

Because of this, there isn't a universally accepted method for treating it. When dealing with a patient diagnosed with HGS, neurosurgeons should keep a few things in mind. To start, almost everyone agrees that HGS patients should have surgery to fuse the space and stop the anterior displacement from getting worse. Second, in situ fusion is tolerated in cases where the spine is balanced to avoid neurological deficits that could occur in 5-45% of patients during slippage reduction [3].

The best way to treat HGS is a contentious matter. When conservative measures fail to alleviate symptoms of high-grade slip, surgical stabilization becomes the next logical step. With "in situ" fusion, low-dysplastic spondylolisthesis patients may see good results. For this particular kind of spondylolisthesis, a reduction is typically not required to achieve satisfactory neurologic and biomechanical recovery. An in situ fusion technique is relatively safe and reliable, as it is characterized by a low risk of neurologic injury and a high rate of arthrodesis [4].

The significant risk of neurological problems—up to 31%—is the primary justification for avoiding reduction maneuvers in spondylolisthesis. Combinations of surgical techniques such as posterior interbody fusion, posterolateral fusion (with or without instrumentation), front-and-back, or circumferential 360 fusion can be used to perform "in situ" spondylodesis. Surgery to stabilize the spine can be done using a number of different methods. Posterior pediculo-body fixation posterior interbody cage fixation, pedicle screw implantation, and transvertebral pedicle screw fixation are a few examples of procedures that can be utilized to improve mechanical stability. These procedures can be performed either alone or in combination with superior level fusion [5].



Initial stability is improved with delta fixation. The goal of developing Delta Fixation was to create a stable fixation method that required less manipulation of nerve roots and did not involve interbody cages. Thus, it is a less invasive and less expensive alternative to fusion cages for fixation [6].

The purpose of this study was to assess the radiographic and clinical outcomes of patients who were treated with Delta fixation versus interbody fusion for the management of severe spondylolisthesis.

### **Patients and Methods:**

This clinical research study was conducted on twenty patients with severe spondylolisthesis attending to neurosurgery clinic Benha university hospital. An informed written consent was obtained from the patient or relatives of the patients. The study was done after approval from the Ethical Committee Benha University Hospitals and registration of clinicaltrials.gov.

Inclusion criteria the following criteria were considered for this study: age (18+), the presence of Meyerding III or IV spondylolisthesis and sagittal balance (correct); chronic low back pain and/or radiculopathy; absence of general contraindications to surgery; and co-operative medical health.

Exclusion criteria were patients with isthmic spondylolisthesis, degenerative scoliosis spinal stenosis, and previous spine surgery.

### **Grouping:**

Surgical procedure determined which of two study groups a patient was placed in. Ten patients suffering from severe spondylolisthesis were assigned to either Group A, where Delta fixation was administered, or Group B, where interbody fusion was administered.

### **Preoperative assessment:**

Pain, weak muscles, sphincter incontinence, and instability were among the patient's detailed complaints recorded. Patients' demographic and clinical information included their age, sex,



symptoms, level of spondylolisthesis, medication, and pain prior to surgery. Paraspinal muscle spasm, flexion attitude at the hip and knee joints, significant step felt in the lower back on deep palpation of the spine, and increased lumbar lordosis were some of the signs we looked for. Assuming a bilateral angle of 40 degrees, the straight leg raising test was considered successful. We checked the patient's sacroiliac joints and evaluated their upper and lower limb neurology. Investigations: The preoperative spine MRI was performed, and the lumbar spine X-ray was taken in anteroposterior and lateral views.

### **Operative technique:**

The operating room protocol for both groups was the same: a standard posterior midline approach. Patients with severe spinopelvic sagittal imbalance were the only ones who underwent partial reduction. All patients underwent standard titanium screw procedures.

Using the transdiscal lumbosacral fixation technique, sacral screws were inserted into the S1 pedicle, subsequently passing through the endplate of S1, across the disc space, and ultimately terminating in the L5 body. In order to accomplish in situ fusion or partial listless reduction, the L5 body was manipulated with implanted screws. A conventional pedicle screw fixation was carried out on the pedicle group. A partial reduction or in situ fusion procedure was carried out. Everyone who needed it had interbody fusion (L5-S1 cages) performed.

The bone fragments that were removed were used to perform standard posterolateral fusion and decompression in both groups following the surgical approach. Also, bone substitute and/or autologous iliac crest graft alternatives. Rates of level instrumentation and reduction (partial vs. in situ) were compared between the two groups.

### **Postoperative protocol:**

The patient was scanned using routine radiography equipment, which comprised standing anteroposterior, lateral, and oblique views, before surgery and at every follow-up. At 6 months



after the operation, a computed tomography (CT) scan was performed. To detect neurological deficits, magnetic resonance imaging was employed.

The Oswestry Disability Index (ODI) was the primary measure employed in this research to evaluate the intensity of symptoms, with a range of 0 to 100. Scoring lower indicates less symptoms <sup>[7]</sup>. At every appointment, the Core Outcomes Measures Index (COMI) assessed the patient's health.<sup>[8]</sup>, The results were better with lower COMI scores (which could range from 0 to 10). The discomfort in the lower back and legs were assessed independently using a visual analogue scale (VAS), where zero represents no pain and ten is the highest level of pain <sup>[9]</sup>. At 1, 3, and 6 months post-op, standardized prospective assessments were performed both before and after the operation.

Major complications that required revision surgery or caused permanent neurological deficit after surgery were documented.

### Statistical analysis:

For the purpose of statistical analysis, we utilized SPSS v26, which was developed by IBM Inc. and is located in Armonk, NY, USA. For quantitative data, which were shown as means and standard deviations (SD), an unpaired Student's t-test was used to compare the two groups. Using repeated measures ANOVA tests, we compared the same participants across time and conditions. When necessary, we used chi-square or Fisher's exact tests to examine the data. The frequency and percentage (%) of qualitative variables were provided. Statistical significance was determined when the two-tailed P value was less than 0.05.

## Results

An insignificant difference was observed among both groups in relation to sex, age and presentation. **Table 1**

**Table 1: Baseline characteristics of the studied groups**

	Group A (n=10)	Group B (n=10)	P value
--	-------------------	-------------------	---------



	<b>Age (years)</b>	54.2± 14.2	51.9± 8.02	0.661
<b>Sex</b>	<b>Male</b>	6 (60%)	7 (70%)	0.205
	<b>Female</b>	4 (40%)	3 (30%)	
<b>Presentation</b>	<b>L5-S1 developmental spondylolisthesis with lysis</b>	5 (50%)	6 (60%)	0.653
	<b>L5-S1 developmental spondylolisthesis with pars interarcularis elongation</b>	5 (50%)	4 (40%)	

Data presented as mean ± SD or frequency (%). L: lumbar, S: sacral.

An insignificant difference was found among both groups in relation to preoperative spinopelvic parameters (SS and PT)

**Table 2: Preoperative spinopelvic parameters by x-ray of the studied groups**

	<b>Group A (n=10)</b>	<b>Group B (n=10)</b>	<b>P value</b>
<b>Preoperative SS</b>	50.6± 6.24	45.8± 4.8	0.070
<b>Preoperative PT</b>	22.5± 6.79	23.5± 5.87	0.729

Data presented as mean ± SD, SS: Sacral slope, PT: pelvic tilt.

A significantly shorter operative time and lower intraoperative blood loss were observed in Group A in comparison to Group B (P<0.001, <0.001).

**Table 3: Operative data of the studied groups**

	<b>Group A (n=10)</b>	<b>Group B (n=10)</b>	<b>P value</b>
<b>Operative time (min)</b>	141.7± 28.1	237.8± 58.1	<0.001*
<b>Intraoperative blood loss(ml)</b>	289.4± 57	708.6± 166.67	<0.001*

Data presented as mean ± SD., \*: statistically significant as p value <0.05

In both groups, VAS was significantly lower at 1, 3 and 6 months compared to baseline (p<0.05), was significantly lower at 3 and 6 months compared to VAS at 1 month (P<0.05) and was significantly lower at 6 months in comparison to VAS at 3 months (P<0.05). Group A exhibited a significantly lower VAS level than group B at 1, 3, and 6 months (P=0.007, 0.042, 0.019). **Table 4**



**Table 4: Visual analogue scale (VAS) of the studied groups**

		Group A (n=30)	Group B (n=30)	P value
VAS	Baseline	8.8± 1.32	8.5± 1.18	0.598
	1 months	3.8± 0.79	5.1± 1.1	<b>0.007*</b>
	3 months	2.4± 0.52	3.2± 1.03	<b>0.042*</b>
	6 months	0.8± 0.79	1.9± 1.1	<b>0.019*</b>
	P value within group	<b>P1&lt;0.001*, P2&lt;0.001*, P3&lt;0.001*, P4&lt;0.001*P5&lt;0.001*, P6&lt;0.001*</b>	<b>P1&lt;0.001*, P2&lt;0.001*, P3&lt;0.001*, P4&lt;0.001*P5&lt;0.001*, P6=0.014*</b>	

Data presented as mean ± SD., \*: statistically significant as p value <0.05, VAS: visual analogue scale, P1: p value between baseline and 1 month, P2: p value between baseline and 3 months, P3: p value between baseline and 6 months, p4: p value between 1 month and 3 months, p5: p value between 1 month and 6 months, p6:p value between 3 and 6 months.

At 1, 3, and 6 months, ODI was significantly lower in both groups in comparison to baseline (p<0.05), at 3 and 6 months compared to ODI at 1 month (P<0.05), and at 6 months compared to ODI at 3 months (P<0.05). ODI was significantly lower in group A in comparison to group B at 1 and 3 months (P=0.006, 0.020). **Table 5**

**Table 5: Oswestry disability index (ODI) of the studied groups**

		Group A (n=30)	Group B (n=30)	P value
ODI	Baseline	63.5± 6.8	64.1± 4.68	0.821
	1 months	24.6± 3.06	31± 5.66	<b>0.006*</b>
	3 months	15.6± 3.84	22.3± 6.7	<b>0.020*</b>
	6 months	9.4± 5.32	11± 6.63	0.348
	P value within group	<b>P1&lt;0.001*, P2&lt;0.001*, P3&lt;0.001*, P4&lt;0.001*P5&lt;0.001*, P6&lt;0.001*</b>	<b>P1&lt;0.001*, P2&lt;0.001*, P3&lt;0.001*, P4&lt;0.001*P5&lt;0.001*, P6=0.002*</b>	

Data presented as mean ± SD., \*: statistically significant as p value <0.05, ODI: Oswestry disability index, P1: p value between baseline and 1 month, P2: p value between baseline and 3 months, P3: p value between baseline and 6 months, p4: p value between 1 month and 3 months, p5: p value between 1 month and 6 months, p6:p value between 3 and 6 months.

**Table 6** shows that in both groups, COMI was significantly lower at 1, 3 and 6 months in comparison to baseline (p<0.05), was significantly lower at 3 and 6 months in comparison to COMI at 1 month (P<0.05) and was significantly lower at 6 months in comparison to COMI at 3 months (P<0.05). COMI at 1, 3 and 6 months was significantly lower in group A compared to group B (P=0.001, 0.010, 0.005). In group A, we did not see any complications, but in group B, they resolved after antibiotic therapy. Revision surgery was necessary for one patient in group A who experienced radicular leg pain due to an S1 pedicle screw misplacement. We found that one temporary L5 neurological impairment in group B was able to resolve.



**Table 6: Core outcomes measures index (COMI) of the studied groups**

		<b>Group A (n=30)</b>	<b>Group B (n=30)</b>	<b>P value</b>
<b>(COMI)</b>	<b>Baseline</b>	8.9± 1.1	8.3± 1.16	0.251
	<b>1 months</b>	5.1± 0.88	6.9± 1.2	<b>0.001*</b>
	<b>3 months</b>	3.3± 1.06	5.1± 1.66	<b>0.010*</b>
	<b>6 months</b>	1.2± 1.23	2.7± 0.82	<b>0.005*</b>
	<b>P value within group</b>	<b>P1&lt;0.001*, P2 &lt;0.001*, P3&lt;0.001* P4&lt;0.001*P5&lt;0.001*, P6&lt;0.001*</b>	<b>P1&lt;0.016 *, P2 &lt;0.001*, P3&lt;0.001* P4&lt;0.012*P5&lt;0.001*, P6&lt;0.001*</b>	

Data presented as mean ± SD., \*: statistically significant as p value <0.05, P1: p value between baseline and 1 month, P2: p value between baseline and 3 months, P3:p value between baseline and 6months,p4:p value between 1months and 3months,p5: p value between 1months and 6months ,p6:p value between 3months and 6 months, COMI: Core Outcomes Measures Index.

## Discussion

In spondylolisthesis, surgical stabilization is necessary for symptomatic high-grade slips that do not respond to conservative treatment. In situ fusion is a safe and effective treatment for high-grade spondylolisthesis. It can realign the spine even if the pelvis is dislocated. High-grade spondylolisthesis can be treated with in situ fusion through a variety of surgical procedures, such as posterior side fusion (with or without instruments), posterior-anterior body fusion, and a variety of other procedures <sup>[10]</sup>.

Results from both clinical and radiological studies have demonstrated the superiority of circumferential fusion. In order to achieve circumferential fusion, there are several methods, including posterior interbody cage and pedicle screw fixation, posterior trans sacral interbody fusion, and posterior pediculobody fixation. The former two approaches include implanting a cortical bone graft and pedicle screws. These methods can be done either in combination with superior level fusion or on their own <sup>[11]</sup>.

This form of spondylolisthesis has shown promising clinical results and a high fusion rate when treated with "in situ" fusion. Multiple surgical methods for achieving "in situ" fusion have been detailed. Grob et al. <sup>[12]</sup> proposed fixation of the pediculo-body by way of two cancellous screws implanted among the S1 pedicle and the L5 vertebral body. There were further accounts of this technique from Zagra et al. <sup>[13]</sup> achieving a positive result in the long run.



Bartolozzi et al. <sup>[14]</sup> was a titanium cage implanted during an in situ interbody fusion, as described by Bohlman and Cook <sup>[15]</sup> method involving pedicle screw fixation and a transacral approach. Here, we present a new "in situ" fusion method that is based on a tweak to the Grob technique. The change was made to achieve better mechanical stability with a one-level six-screw fixation.

Logroscino et al <sup>[16]</sup> Three hundred and ten patients with L5-S1 spondylolisthesis who had "in situ" fusion performed an evaluation. All patients were found to have a proven low-dysplastic developing L5-S1 spondylolisthesis. For patients in group A, the operation involved instrumenting the L5-S1 pedicle and fixing them with transsacral screws. For patients in group B, the procedure was performed using an alternate approach called posterolateral interbody fusion (PLIF).

In comparison to the traditional interbody fusion group, they demonstrated that this surgical technique is highly reliable, has a shorter operating time, and reduces intraoperative blood loss, all of which led to better clinical outcomes and a quicker return to normal daily life.

Compared to group B, group A in the present study exhibited substantially less intraoperative blood loss and a considerably shorter operating time ( $P < 0.001$ ,  $< 0.001$ ). The VAS of group A was significantly lower than that of group B at 1, 3, and 6 months ( $P = 0.007$ ,  $0.042$ , and  $0.019$ , respectively). The ODI at 1 and 3 months was significantly lower in group A in comparison to group B ( $P = 0.006$ ,  $0.020$ ). Between groups A and B, COMI was significantly lower at 1, 3, and 6 months ( $P = 0.001$ ,  $0.010$ ,  $0.005$ ).

In Gupta et al <sup>[17]</sup> reported a case study that sought to evaluate the effectiveness of delta fixation for high-grade spondylolisthesis and discovered that posterior transdiscal (pediculobody) fixation, in conjunction with three-column stabilization, resulted in a higher rate of mechanical stability and fusion, as well as being more rapid and requiring fewer procedures <sup>[18]</sup>. There is less blood loss, perioperative anesthetic complications, and operating time with this procedure



compared to interbody fusion approaches, but the postoperative outcomes are the same <sup>[19]</sup>. They determined that delta fixation with transdiscal pedicle screws is a viable alternative for people with long-standing high-grade spondylolisthesis with adequate sagittal balance.

Abdu WA et al. <sup>[20]</sup> In its entirety, this surgical operation was detailed in an article titled "Pedicular transvertebral screw fixation of the lumbosacral spine in spondylolisthesis.". Here was the original description of the procedure: From L4 to sacrum, perform routine midline exposure. Following posterior decompression, the sacral promatory is used to obliquely insert pedicle screws in the S1 pedicles in an anterior-medial direction. The next step, guided by fluoroscopy, is to insert pedicle screws anteriorly into the body of L5 vertebral, from the L5-S1 disc space. Also, two screws are fastened to the pedicles of L4 and L5 via rods and plates, and they are connected to S1 and L5. After harvesting the iliac crest bone graft, it is utilized for postero-lateral fusion between L4 and S1. While this method is most often used to treat L5-S1 listhesis, it has also been applied to treat L4-L5 HGS in this case report.

### **Conclusions:**

Delta fixation was superior to interbody fusion, providing shorter operative time, lower blood loss intraoperatively, significant improvement in pain, ODI and quality of life and COMI during the management of severe spondylolisthesis.

As a result, it is advisable to conduct larger multicentre cohorts with a larger sample size in order to verify the current findings.

**Financial support and sponsorship:** Nil

### **References:**

1. Li N, Scofield J, Mangham P, Cooper J, Sherman W, Kaye AD. Spondylolisthesis. *Orthop Rev (Pavia)*. 2022;14:36-45.



2. Kunze KN, Lilly DT, Khan JM, Louie PK, Ferguson J, Basques BA, et al. High-Grade Spondylolisthesis in Adults: Current Concepts in Evaluation and Management. *Int J Spine Surg.* 2020;14:327-40.
3. Delgado-Fernández J, Frade-Porto N, Blasco G, González-Tarno P, Gil-Simoes R, Rivas PP, et al. Long term outcome and fusion rate of transdiscal fixation for L5-S1 high grade spondylolisthesis. *Clin Neurol Neurosurg.* 2021;208:68-98.
4. Xue X, Wei X, Li L. Surgical Versus Nonsurgical Treatment for High-Grade Spondylolisthesis in Children and Adolescents: A Systematic Review and Meta-Analysis. *Medicine (Baltimore).* 2016;95:70-90.
5. Vanti C, Ferrari S, Guccione AA, Pillastrini P. Lumbar spondylolisthesis: STATE of the art on assessment and conservative treatment. *Arch Physiother.* 2021;11:19-35.
6. Hadgaonkar S, Katkade SM, Bhilare P, Shyam A, Sancheti PK. Efficacy of less Invasive modified O-arm navigated delta fixation in osteoporotic high-grade spondylolisthesis: "a LIMO delta technique". *Eur Spine J.* 2023;32:1393-400.
7. Koivunen K, Widbom-Kolhanen S, Perna K, Arokoski J, Saltychev M. Reliability and validity of Oswestry Disability Index among patients undergoing lumbar spinal surgery. *BMC Surg.* 2024;24:13-9.
8. Mannion AF, Vila-Casademunt A, Domingo-Sabat M, Wunderlin S, Pellisé F, Bago J, et al. The Core Outcome Measures Index (COMI) is a responsive instrument for assessing the outcome of treatment for adult spinal deformity. *Eur Spine J.* 2016;25:2638-48.
9. Okifuji A, Mitsunaga R, Kida Y, Donaldson GW. The visual time analog scale: simple, novel measurement approach to assess pain in patients with chronic pain. *Pain Manag.* 2021;11:357-68.
10. Saleh I, Librianto D. Surgical treatment of spondylolisthesis using long arm screw: A literature review. *Ann Med Surg (Lond).* 2022;73:10-32.



11. Kothari A, Khurjekar K, Hadgaonkar S, Singh N, Kulkarni HG, Sancheti P, et al. Delta fixation vs interbody fusion in cases of high-grade spondylolisthesis. *J Spinal Surg.* 2017;4:30-2.
12. Grob D, Humke T, Dvorak J. Direct pediculo-body fixation in cases of spondylolisthesis with advanced intervertebral disc degeneration. *Eur Spine J.* 1996;5:281-5.
13. Zagra A, Giudici F, Minoia L, Corriero AS, Zagra L. Long-term results of pediculo-body fixation and posterolateral fusion for lumbar spondylolisthesis. *Eur Spine J.* 2009;1:151-5.
14. Bartolozzi P, Sandri A, Cassini M, Ricci M. One-stage posterior decompression-stabilization and trans-sacral interbody fusion after partial reduction for severe L5-S1 spondylolisthesis. *Spine (Phila Pa 1976).* 2003;28:1135-41.
15. Bohlman HH, Cook SS. One-stage decompression and posterolateral and interbody fusion for lumbosacral spondyloptosis through a posterior approach. Report of two cases. *J Bone Joint Surg Am.* 1982;64:415-8.
16. Logroscino CA, Tamburrelli FC, Scaramuzzo L, Schirò GR, Sessa S, Proietti L. Transdiscal L5-S1 screws for the treatment of adult spondylolisthesis. *Eur Spine J.* 2012;1:28-33.
17. Gupta S, Khan SM, Dasari V, Jain S, Singh PK, Gupta S. Delta Fixation for High-Grade Spondylolisthesis: Technique, Indications and an Adult Case Report. *J Pharm Res Int.* 2021:30-50.
18. Lamartina C, Zavatsky JM, Petruzzi M, Specchia N. Novel concepts in the evaluation and treatment of high-dysplastic spondylolisthesis. *Eur Spine J* 2009;18:133-42.
19. Weinstein JN, Lurie JD, Tosteson TD, Zhao W, Blood EA, Tosteson AN, et al. Surgical compared with nonoperative treatment for lumbar degenerative spondylolisthesis: four-year results in the Spine Patient Outcomes Research Trial (SPORT) randomized and observational cohorts. *JBJS.* 2009;91:1295-304.



- 
20. Abdu WA, Wilber RG, Emery SE. Pedicular transvertebral screw fixation of the lumbosacral spine in spondylolisthesis: a new technique for stabilization. *Spine*. 1994;19:710-5.