



# Current Practice in Neurosciences

## Low-grade degenerative spondylolisthesis: To fuse or not to fuse?

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Ramakrishna Easwaran, Vedantam Rajshekhar<sup>1</sup>

Neuro One Hospital, Trichy, <sup>1</sup>Department of Neurological  
Sciences, Christian Medical College, Vellore, Tamil Nadu,  
India

## Introduction

Decompression of the neural structures is a part of every operation for degenerative spinal stenosis (DSS) or degenerative spondylolisthesis (DSO). Whether to additionally fuse or not has been, and continues to be, the subject of debate and discussion. The earlier recommendations on whether “to-fuse-or-not-to fuse” had been based mostly on expert opinions or on retrospective case series. Now evidence is available from prospective randomized trials comparing “decompression-alone versus decompression + fusion” head-to-head. In this article, old and new evidence are presented and evaluated, to formulate clinical practice guidelines.

## Natural History Studies

A typical patient with DSO presents with low backache alone (62%), leg pain alone (7%), low backache and leg pain (31%), positive straight leg raising test (12%), and L5 sensory impairment (13%), as was found in an observational study.<sup>[1]</sup>

Matsunaga *et al.*<sup>[2]</sup> reported on 145 nonsurgically managed patients with DSO followed up for a minimum of 10 years. There was no correlation between changes in clinical symptoms and progression of spondylolisthesis. A total of 84 (76%) of 110 patients who had no neurological deficits at initial examination remained without neurological deficit after 10 years of follow-up. Twenty-nine (83%) of the 35 patients who had neurological symptoms and refused surgery experienced neurological deterioration.

This contrasts with the experience of Johnsson *et al.*,<sup>[3]</sup> who followed-up 32 untreated patients with clinical symptoms and myelographically confirmed spinal stenosis (nine of them with DSO) for an average of 49 months. About 75% of the patients had spinal claudication. In the follow-up survey, the same number of patients had claudication, but the symptoms were milder. In estimation by visual analog scale (VAS), symptoms in 70% of the cases were unchanged, 15% showed improvement, and 15% worsened. No proof of severe deterioration was found after 4 years.

## Is Surgery Needed in Patients with DSO/DSS?

On the basis of natural history studies, the benefit of surgery in patients with DSO/DSS can be questioned. There is, however, evidence from prospective trials to state categorically that any operation is preferable to nonoperative management in DSO. The outcome of the subgroup of patients with DSO in the SPORT trial was reported.<sup>[4]</sup> This multicenter study used rigorous and independent assessment outcome measures. There were 304 patients in the randomized cohort and 303 patients in the observational cohort. In both cohorts combined, 372 patients underwent surgery within the first 2 years and 235 received nonsurgical treatments such as physical therapy (42%), epidural steroid injections (45%), nonsteroidal antiinflammatory drugs (51%), and opioids (34%). Surgical procedures done were decompression-alone (5%), decompression + fusion (21%), and decompression + fusion + instrumentation (74%). The 2-year results of this trial are given in Table 1.

Hence, the conclusion was that patients with DSO and DSS treated surgically showed significantly greater improvement in pain and function during a period of 2 years than patients treated nonsurgically. The study was not designed or powered to perform subgroup analysis of the various types of surgery.

**Table 1: Results of the SPORT trial at 2 years<sup>[4]</sup>**

2-year follow-up result	Number	Improvement in back pain	Improvement in leg pain	SF-36 score <sup>§</sup>	Oswestry Disability Index change <sup>¶</sup>
Nonsurgical	235	16%	17%	12	-7.5
Surgical	372	31%	41%	30	-24

<sup>§</sup>The SF-36 scores range from 0 to 100, with higher scores indicating less severe symptoms.

<sup>¶</sup>The Oswestry Disability Index ranges from 0 to 100, with lower scores indicating less severe symptoms. The more negative the change in score, the greater the improvement

## Observation Studies in Decompression Surgery

The twin aims of surgery in DSO are to relieve pain and prevent progressive worsening or recurrence of symptoms. Decompression procedures have become progressively more focused and less invasive over the years.

Epstein<sup>[5]</sup> reported on the outcomes in 320 patients with DSO followed up for at least 10 years after decompressive procedures. Of these 320 patients, fusions were performed in only 30 during the first surgery (9.3%). A second fusion was required in another nine, and two underwent tertiary fusions. Good-to-excellent outcomes were observed in more than 80% of patients with DSO.

In a retrospective study, 49 patients undergoing decompression-alone for DSO without hypermobility in flexion-extension radiographs with a mean age of 68.7 years were followed up for a mean period of 3.73 years.<sup>[6]</sup> The mean Prolo Scale score increased from 4 before operation to 8 at last follow-up, indicating significant improvement. Excellent and good results were demonstrated in 73.5% of the patients. Only 10% of the patients underwent a second instrumentation-assisted lumbar fusion when decompression-alone failed to resolve symptoms. The authors recommended the “decompression-alone” strategy in elderly patients with DSO. The recent tendency to make the decompression operation less invasive by using tubular retractors and microendoscopic means has permitted a Japanese group to conclude that the results of decompression are superior to fusion.<sup>[7]</sup>

Postdecompression increase in olisthesis does occur but might not be always symptomatic. Such an occurrence was detected in 83% of 23 cases of DSO followed up for 18 months in one study.<sup>[8]</sup> In a 11-year follow-up study of 50 patients undergoing decompression-alone for DSS, those with preoperative slip and those whose slip increased after surgery had documented clinical progression and needed re-operation.<sup>[9]</sup>

Because lumbar spondylosis is a progressive disease, it is easy for the decompressionist to lay the blame for worsening on aging changes. But studies have shown that degeneration with progression of spondylolisthesis is worse at the laminectomized levels.<sup>[10]</sup> Bone regrowth after pure decompression (which was symptomatic in 40% of patients) is less in those undergoing primary fusions.<sup>[11]</sup>

## Fusion Surgery

The aim of spinal fusion in DSO is to obtain a stable spine and a pain-free patient without limitation of back mobility. Before 1990s, fusion was done without any metallic instrumentation, using only autograft or allograft. Then came the era of instrumented fusion with metallic or nonmetallic implants in addition to bone graft. For details on the fusion procedures, see the review article by Mobbs *et al.*<sup>[12]</sup>

Even if there is minimal benefit of fusion surgery over decompression surgery alone, why not offer it to everyone? The reason is that there are many unresolved issues and drawbacks of fusion surgery which are discussed below.

### Is solid bony fusion needed for good outcome?

The difference in the outcome of those who achieve a solid bony fusion and those who have only pseudarthrosis is a matter of debate. In an early prospective study, the results were excellent or good in 9 of the 25 patients who developed pseudarthrosis following arthrodesis for DSO.<sup>[13]</sup> However, in a prospective randomized study of 47 patients undergoing noninstrumented fusion, with an average follow-up of 7.75 years, the clinical outcome was excellent or good in 86% of patients with a solid arthrodesis, but only in 56% of patients with a pseudarthrosis ( $P = 0.01$ ).<sup>[14]</sup>

In a randomized trial comparing pedicle screw instrumented and noninstrumented fusion for single-level DSO that recruited 75 patients, the clinical outcome at 2 years was excellent or good in 76% of the patients in whom instrumentation was placed and in 85% of those in whom no instrumentation was placed, and this difference was not statistically significant ( $P = 0.45$ ).<sup>[15]</sup> Successful arthrodesis occurred in 82% of the instrumented

versus 45% of the noninstrumented cases ( $P = 0.0015$ ). Overall, successful fusion did not influence patient outcome ( $P = 0.435$ ).

### Is instrumentation necessary in spinal fusion?

Despite its popularity with spine surgeons, there is no consensus on the use of instrumentation in lumbar fusion. Currently, transpedicular screw instrumentation that provides three-column stabilization has supplanted all other previously used instrumentations. The purported reasons for performing instrumented fusion are summarized in Table 2.

Using pedicle screw instrumentation with interbody spacers and bone graft, the outcome measures were significantly improved in a set of 36 patients of DSO with mean age of 65 and followed up for a mean of 2 years.<sup>[16]</sup> The outcome was rated as good or excellent by 91%. Mean preoperative slip reduced from 20.2 to 1.7% (92% correction,  $P < 0.001$ ). There were no device-related procedural complications. Dickman<sup>[17]</sup> obtained 96% fusion rates with pedicle screws in 104 cases followed up for a mean of 20 months. The rate of progression of the spondylolisthesis was least with instrumented fusion, intermediate with noninstrumented fusion, and highest with decompression-alone in a study of 44 patients with DSO followed for minimum of 2 years.<sup>[18]</sup>

### Complications of fusion surgery

The fear of higher complications in the elderly stems from the report of Deyo in 1992 showing 18% complication rate in those over 75 years.<sup>[19]</sup> It must be remembered that this report studied all types of lumbar surgery and not specifically fusions. However, major complications of fusions were rare (2%) in another study.<sup>[20]</sup>

Percutaneous options are now available for placing pedicle screws that reduce the magnitude of surgery.<sup>[21]</sup> Unilateral pedicle screw instrumented fusion has been proved to be as effective as bilateral procedure in a randomized trial.<sup>[22]</sup> Transforaminal posterior lumbar interbody fusion (TLIF) with instrumentation has been advocated as a less invasive procedure.<sup>[23]</sup> Laparoscopic or minimally invasive anterior lumbar interbody fusion approaches also reduce the blood loss and give comparably good results.<sup>[24]</sup> The replacement of autograft with allografts or cages helps shorten operating time, reduces blood loss, and avoids donor-site morbidity. A Japanese study showed no differences in the outcome of lumbar fusion across ages, with elderly people being no more vulnerable to complications than younger ones.<sup>[25]</sup>

### Degeneration at the adjacent level

The rate of adjacent-level disease was 18 out of 125 instrumented fusion levels in a follow-up of 3–4 years.<sup>[26]</sup> Next-segment disease included spondylolisthesis (39%), canal stenosis due to disc herniation and/or facet hypertrophy (33%), stress fracture of the adjacent vertebral body (28%), and scoliosis (17%). Postmenopausal women and smokers had increased risk.

Although these figures raise concern, we must remember that the radiological degeneration at an adjacent level may have no bearing on the clinical outcome.<sup>[27,28]</sup> In contrast, in a Japanese study of 37 patients with L4-5 DSO, with more than 10-year follow-up, the adjacent segment degeneration occurred in 40.5% and re-operation was required in 8.1%.<sup>[29]</sup> Epstein's review in 2015 suggested that the incidence of postoperative adjacent segment disease (ASD) is greater following either open or minimally invasive surgery (MIS) instrumented lumbar fusions (e.g., TLIF/PLIF), whereas decompressions with

**Table 2: Purported reasons for instrumentation in lumbar spinal fusion**

Immediate stabilization
Quicker ambulation and return to work
Better relief of pain
Correction of spondylolisthesis
Correction of kyphosis or scoliosis
To maximize the chances of fusion
Use in situations where fusion chances are lower (osteoporosis, smokers)
Minimize the chances of recurrence of spondylolisthesis or stenosis

Note: Adapted with permission from *Progress in Clinical Neurosciences*, Vol. 23.<sup>[34]</sup>

noninstrumented fusions led to a much smaller 5.6% risk of ASD. Dynamic stabilization did not protect against ASD.<sup>[30]</sup>

**Cost and complications of instrumentation**

There is no denying of the cost of implants such as titanium pedicle screws (especially the percutaneous variety) and cages. Intraoperative and postoperative complications of pedicle screws are seen in around 1.5% of patients.<sup>[31]</sup> A higher re-operation rate was noted in patients undergoing instrumented fusion as compared to those with noninstrumented fusion in a randomized trial.<sup>[32]</sup> A literature review by Epstein in 2018 showed lower complication rate for lumbar laminectomy (4.3%) as compared to MIS/TLIF/other fusions (8.3%).<sup>[33]</sup> The 5-year re-operation rate was 10.6% for laminectomy and 18.6% for fusions.

**To Fuse or Not to Fuse?**

We can conceptualize the debate by examining the arguments put forth by the nonfusion and fusion camps. Tables 3 and 4 summarize the arguments of both the camps.

**Studies Showing Superiority of Fusion**

Retrospective case series provide only low quality of evidence. A meta-analysis of such studies up to 1993 indicated success rates of 69, 86, and 90% for decompression, noninstrumented fusion, and instrumented fusion, respectively.<sup>[35]</sup>

Long-term follow-up results of fusion are also available. In a minimum 5-year follow-up study of instrumented posterolateral fusion (PLF) for DSO, 83% were satisfied with the result.<sup>[20]</sup> There was no pseudarthrosis, stenosis, or progression of spondylolisthesis at the operated level. In a study that specifically measured patient relevant outcomes, 93% fusion was achieved and 93% of patients were satisfied with the result of instrumented fusion for DSO.<sup>[36]</sup> In a 11-year follow-up study, patients with DSO had a lower incidence of re-operation after fusion surgery than after decompression-alone (17 versus 28%,  $P = 0.002$ ).<sup>[37]</sup> In a Japanese study of 37 patients followed up for 10 years, the degree of slip significantly improved from an average of 17.0% before surgery to 9.7% at the last follow-up. Mean Japanese Orthopaedic

**Table 3: Arguments favoring decompression surgery in DSO**

<b>Arguments FOR performing nonfusion surgery (decompression alone)</b>	<b>Arguments AGAINST performing fusion surgery (decompression + reduction, fusion instrumentation)</b>
Symptoms are due to nerve root compression alone and it is sufficient to relieve the compression	Spinal instability is a poorly defined entity
Decompression does not destabilize the spine significantly	No proof that fusion gives better results
DSO is low-grade and does not progressively worsen to higher grades	Fusion surgery has more complications, a steep learning curve, and is poorly tolerated by the elderly. Convalescence is longer
Postdecompression progression of slip on radiographs may not be clinically symptomatic	A good postoperative X-ray does not equate to asymptomatic patient. On the contrary, even those with pseudarthrosis at a fusion site might be asymptomatic
Nonfusion surgery is simple, has low complication rate with shorter convalescence, and is cheap	Even patients with radiologically successful fusion might have progression of spondylolisthesis
Literature evidence favoring decompression-alone strategy	Higher risk of adjacent-level degeneration
	Higher cost and complications of instrumentation. No proof that instrumentation improves the clinical outcome. Instrumentation failure occurs
	Morbidity at iliac bone donor site is high

Note: Reproduced with permission from *Progress in Clinical Neurosciences*, Vol. 23.<sup>[34]</sup>

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**Table 4: Arguments favoring fusion surgery in DSO**

Arguments AGAINST performing nonfusion surgery (decompression alone)	Arguments FOR performing fusion surgery (decompression + reduction, fusion instrumentation)
Decompression adds to biomechanical weakening caused by the existing and ongoing degeneration leading to worsening of symptomatic instability	Pain is not only due to static nerve compression but mainly due to dynamic instability. Successful fusion relieves symptoms better and prevents further progression
Root pain may be relieved for some time after decompression but disabling back pain due to instability persists and root pain recurs	Recent advances make fusion surgery safe, simple, and patient-friendly. Increased experience reduces the complication rate
Surgeon hesitates to do the required degree of decompression for fear of inducing further instability. Inadequate lateral canal decompression is a common cause of failed back surgery syndrome	While adjacent-level degeneration does occur after fusion, it is overestimated and not clinically relevant
Should the patient ultimately need a fusion, it is two operations: greater cost and longer convalescence	Literature evidence favoring fusion surgery
Not fusing an unstable or potentially unstable spine may be a ground for litigation	Use of instrumentation increases chance of good fusion
	Increased cost of instrumentation is offset by a quicker return to occupation Alternatives are available now to rigid fixation

Note: Reproduced with permission from *Progress in Clinical Neurosciences*, Vol. 23.<sup>[34]</sup>

Association (JOA) score significantly improved (13.4 before surgery and 24.5 at the last follow-up).<sup>[29]</sup>

A systematic review, published in 2007, of 12 out of 13 randomized trials and comparative observational studies reported a beneficial effect with fusion.<sup>[38]</sup> An overall statistically significant benefit for clinical outcome was reported for fusion in comparison with decompression-alone ( $P < 0.05$ ). Instrumented spinal fusion was associated with a significantly increased probability of solid fusion ( $P < 0.05$ ). However, no conclusions could be drawn about the clinical benefit of instrumented spinal fusion. It must be admitted that these reviewers have commented on the low methodological quality of the studies in general.

In a prospective clinical follow-up study of 50 patients with DSO, the patients who had a concomitant noninstrumented fusion were significantly better at 3 years with respect to relief of back and leg as compared to those undergoing decompression-alone.<sup>[13]</sup>

The other nonrandomized but prospective studies have shown a similar superiority of fusion over decompression.<sup>[39]</sup> A Korean nonrandomized study reported in 2018 prospectively compared 71 patients who had undergone decompression-alone with 65 who had undergone fusion for grade I DSO.<sup>[40]</sup> The fusion group had significantly longer operating time, blood loss, and length of hospital stay. VAS and Oswestry Disability Index (ODI) scores for back pain were not significantly different between the two groups at postoperative 1, 3, and 6 months. However, at the 12 and 24 months follow-up, the fusion group had lower VAS scores than the decompression group. The authors concluded that although both decompression-alone and decompression with fusion improved functional outcomes for grade I DSO, fusion showed better results than decompression alone after 1 and 2 years postoperatively. According to their results, decompression with fusion appeared to be the first option for grade I DSO.

### Studies Showing No Superiority of Fusion

In a Japanese nonrandomized study, prospectively collected data were analyzed retrospectively at 2 years.<sup>[41]</sup> Patients with single-level spinal stenosis at L4/5 due to grade

IDSO were divided into three groups: conservatively treated, decompression and pedicle screw fusion, and midline preserving decompression. The surgically treated patients had alleviation of symptoms, while the conservative group showed no improvement. There was no significant difference in the degree of clinical improvement between the decompression group and the fusion group.

In a Canadian multicenter nonrandomized prospective study, 46 patients with symptomatic DSO undergoing only MIS midline preserving decompression were compared to 133 patients undergoing decompression + instrumented fusion.<sup>[42]</sup> The patients who underwent decompression-alone were patients with grade 1 DSO with leg-dominant symptoms that were relieved by rest, no mechanical back pain, and no dynamic instability on radiographs (<5 mm change in standing flexion-extension radiograph). At 2 years there was no significant difference between the two groups in health-related quality-of-life.

### Recent Randomized Trials

#### Swedish Spinal Stenosis Study

The Swedish Spinal Stenosis Study was reported in the New England Journal of Medicine in April 2016.<sup>[43]</sup> In this randomized trial, 113 patients with DSS were randomly assigned to undergo decompression + fusion surgery, whereas 120 were assigned to decompression-alone. The patients who had DSO were equally represented in both the groups, 67 in the fusion group and 68 in the decompression group. The primary outcome measure was the ODI at 2 years. The secondary outcome measures were European Quality of Life 5 dimensions (EQ-5D), VAS, Zurich Claudication Questionnaire (ZCQ), and 6-min walk test.

Overall, both the decompression-alone group and the fusion group showed significant improvement (decrease) in ODI score at 2 years compared to their preoperative status, but there was no difference in the outcome between the two groups. The ODI score of patients with DSO also improved significantly in both the groups but there was no difference in outcome between the two groups. No difference was seen between the two groups even when the preoperative vertebral slip was 7.4 mm or greater. There was no difference between the two groups in any of the secondary outcome measures.

A group of 138 patients participating early in this trial completed 5 years of follow-up. There was some increase in ODI score (indicating clinical worsening) in both groups over time but the patients were still significantly better off than before surgery. Once again, no significant difference was noted between the decompression-alone and fusion groups, with or without DSO in any of the primary or secondary outcome measures at 5 years.

The incidence of dural tears, wound infection, systemic complications were no different in the two groups. However, the investigators admitted that the study was not powered enough to study the complication rate. The cost of surgery, length of hospitalization, and the operative blood loss were significantly more in the fusion group.

One criticism leveled against this study is that the patients did not undergo flexion-extension radiographs in the preoperative or postoperative evaluation. The authors defended not using dynamic radiography as it is prone to measurement errors, as it has low reproducibility and is vitiated by the normal movement that occurs in the lumbar spine. The study showed no difference in the outcome between those with <7.4 mm slip and those with >7.4 mm slip. Nevertheless, it is unclear whether patients with such dynamic slip would have any advantage in undergoing fusion instead of decompression-alone. It is also unclear whether there would have been any difference if the SF-36 physical component summary score had been used as an endpoint, instead of measuring the disability by ODI as the primary endpoint.

#### American study

In contrast to this, in the same issue of the New England Journal of Medicine, the very next article was a report on another prospective randomized trial of patients with DSO.<sup>[44]</sup> A total of 66 patients with symptomatic "stable" DSO (7–14 mm of slip) of mean age 67 years underwent randomization. "Stable" DSO was defined as those in whom there was no change in the degree of listhesis in the supine and standing lateral radiographs.

The rate of follow-up was 89% at 1 year, 86% at 2 years, and 68% at 4 years. The fusion group had a greater increase in SF-36 PCS scores at 2 years after surgery than did the decompression-alone group (15.2 versus 9.5,  $P = 0.046$ ). The increases in the SF-36 PCS scores in the fusion group remained greater than those in the decompression-alone group at 3 years and at 4 years ( $P = 0.02$  for both years). The ODI scores at 2 years after surgery did not differ significantly between the study groups ( $-17.9$  in the decompression-alone group and  $-26.3$  in the fusion group,  $P = 0.06$ ). More blood loss and longer hospital stays occurred in the fusion ( $P < 0.001$ ). The cumulative rate of reoperation was 14% in the fusion group and 34% in the decompression-alone group ( $P = 0.05$ ).

This study favoring fusion in DSO has been criticized for the high drop-out rate and high re-operation rate. This study also did not specifically study patients with flexion-extension instability.

#### Japanese study

A prospective, randomized, controlled trial of 85 Japanese patients with L4-5 DSO followed up for 5 years was reported in 2018.<sup>[45]</sup> They were randomized into three groups, viz., decompression-alone, decompression + fusion, or decompression + instrumented fusion. The JOA and VAS scores significantly improved postoperatively, and these outcomes were maintained at 5 years postoperatively in each group. There were no significant differences between the three groups at 1 and 5 years postoperatively. The two fusion groups showed higher blood loss, longer operative time longer, and longer postoperative hospital stay than the decompression group. The authors concluded that additional fusion or instrumentation for low-grade (<30%) DSO did not result in superior results compared to decompression alone at 1 and 5 years postoperatively.

#### Future Studies

A Norwegian Degenerative Spinal Stenosis-Degenerative Spondylolisthesis (NORDSTEN-DS) trial has started recruiting patients in a randomized manner to study the difference in outcome after midline preserving decompression on the one hand and decompression + PLF with pedicle screws.<sup>[46]</sup> It is planned to report the outcome at 2, 5, and 10 years. Hopefully this trial would give Level I evidence for answering this vexatious question.

#### Conclusions

In spite of lack of solid evidence, spine surgeons continue to widely perform and ardently recommend instrumented fusion surgery for DSO as is evident from an article in 2018, which proposes instrumented fusion as the standard of care for DSO.<sup>[22]</sup> Another systematic review in 2017 conceded that the studies by-and-large point to no significant differences between decompression and instrumented PLF (Level 3 evidence) but recommended fusion for those with clear evidence of instability.<sup>[47]</sup>

From the evidence available to us, we can reach the following conclusions:

1. The natural history of low-grade DSO is benign. Those with neurological symptoms are more likely to progress without surgical therapy. However, not all patients worsen
2. Despite radiological progression, many patients do not have progressive symptom worsening and some indeed have improvement in symptoms. Having said that, it must be admitted that the course of the individual patient is difficult to predict. Current level of disablement in daily activities should guide choice of management
3. Any form of surgery is likely to result in better outcome as compared to natural history or conservative management of symptomatic DSO
4. Clinical result in terms of symptom relief, reduction of disablement, and improvement in physical activity is more important than a perfect radiological result in the treatment of DSO
5. Decompression of neural structures is the most important intervention needed to relieve neurogenic leg symptoms. The midline preserving and less invasive procedures carry an advantage of lesser postoperative pain and early ambulation
6. 70–80% of patients who undergo decompression alone for low-grade DSO do not require fusion at a later stage. There is data to show that decompressive surgery does contribute to an increase in olisthesis over time in some patients, but this may often be asymptomatic. Bone regrowth is also likely to happen in some



7. Addition of discectomy at the level of decompression does not necessarily lead to worse outcome in DSO 1
8. There is hardly any difference between the various fusion procedures for DSO in terms of outcome. Additional instrumentation enhances the likelihood of fusion but may not necessarily improve the outcome 2
9. Fusion operations, especially with instrumentation, take longer time, entail more blood loss, and require longer stay in hospital and carry a higher cost 3
10. Systemic complications of surgery for DSO do not depend on the type of surgery but have to do more with the age and co-morbidities 4
11. There is no significant difference in the outcome of low-grade “stable” DSO at 2 and 5 years treated by midline preserving decompression or decompression + instrumented fusion. At best, fusion may offer only a marginal clinical benefit (Level II evidence) 5
12. Adjacent level disease is more common with fusion, but this may not be symptomatic 6
13. Re-operation for progressive or symptoms is less likely when fusion has been done primarily but instrument-related complications may need re-operations 7
14. The jury is still out on the choice of procedure for DSO patients with predominant back pain and those with “mobile” spondylolisthesis. 8

### Our Protocol 17

#### RE 19

Our current protocol is based not only on the literature but also on our personal experience over three decades. Till the year 2000, we performed laminofacetectomy and stand-alone iliac block autograft PLIF for DSO. Although the patients had good relief of claudication, the disablement caused by donor-site morbidity made us switch over (for the next 5 years) to pedicle screw instrumented fusion with interbody cages or with chip bone grafts got from the laminofacetectomy. Unlike with isthmic spondylolisthesis, we never intentionally tried to correct the vertebral slip during surgery; any correction of the slip was incidental. From 2005 we performed bilateral open paraspinous transmuscular placement of pedicle screws<sup>[34]</sup> and this helped reduce the immediate postoperative back pain and allow early mobilization. Persistent root-related symptoms (leg pain, paresthesia) were seen and we attributed it to excessive root manipulation needed for placing the interbody cage. From 2010, we placed pedicle screws, performed midline preserving laminofacetectomies and flavectomy. Discectomy was needed only occasionally. This generally gave good results in spite of not trying to achieve bony fusion. However, we have had some mishaps during all the years of pedicle screw placement (intra or postoperative fat embolism, screw misplacement causing cerebrospinal fluid leak or root injury, hardware failure, and postoperative respiratory complications). From 2017 onwards we have often confined ourselves to unilateral placement of pedicle screws and decompression for patients with unilateral leg symptoms. From 2018, we have come back to performing midline preserving laminofacetectomy alone for DSO presenting purely as neurogenic claudication, especially in the elderly. We continue to perform instrumented decompression for patients who have long history of disabling back pain, especially when there is dynamic instability. 20

#### VR 42

We have been consistently conservative in our approach to DSO over the years.<sup>[48]</sup> Till the mid-1990s, we had performed laminectomy for grade 1 listhesis. Inter-transverse process *in situ* fusion (after decompression) with iliac bone graft was used for higher grades of listhesis. In the late 1990s, we started using coronal hemilaminectomy for decompression. The surgery is done with an operating microscope. This has been our workhorse for nearly 15 years or so and we have not had to perform fusion for worsening instability in any patient. But the caveat is that we do not have a 100% follow-up rate. Since the last few years, we have resorted to a microscopic unilateral approach for bilateral stenosis going from the side which is more symptomatic or more stenosed on imaging. This midline sparing approach is presently the surgery of choice for patients with DSO with grade 1 listhesis, provided the mobility is <3 mm on dynamic standing radiographs. Even in elderly patients with grade 2 listhesis and a collapsed disc space, we only resort to minimally invasive decompression without fusion. We do perform instrumented decompression using TLIF in selected cases with >3 mm movement of the listhesis with a preserved disc space when back pain is the predominant symptom. 43

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