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Current trends in the management of degenerative lumbar spondylolisthesis

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- Degenerative spondylolisthesis (DS) is a common disease of the degenerative spine, often associated with lumbar canal stenosis. However, the choice between the different medical or surgical treatments remains under debate.
- Preference for surgical strategy is based on the functional symptoms, and when surgical treatment is selected, several questions should be posed and the surgical strategy adapted accordingly.
- One of the main goals of surgery is to improve neurological symptoms. Therefore, radicular decompression may be necessary. Radicular decompression can be performed indirectly through interbody fusion or interspinous spacer. However, indirect decompression has some limits, and the most frequent technique is a posterior decompression with fusion.
- Indeed, in cases of DS, associated fusion or dynamic stabilization are recommended to improve functional outcomes and prevent future destabilization. Risk factors for destabilization, such as anteroposterior and angular mobility, and significant disc height, have been discussed in the literature. When fusion is performed, osteosynthesis is often associated. It is essential to choose the length and position of the fusion according to the pelvic incidence and global alignment of the patient. It is possible to add interbody fusion to the posterolateral arthrodesis to improve graft area and stability, increase local lordosis and open foramina.
- The most common surgical treatment for DS is posterior decompression with instrumented fusion. Nevertheless, some cases are more complicated and it is crucial to consider the patient's general health status, symptoms and alignment when selecting the surgical strategy.

Keywords: degenerative spondylolisthesis; decompression; sagittal alignment

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Introduction

Degenerative spondylolisthesis (DS) is defined as the slippage of one vertebra on the vertebra below, without any lysis of the posterior arch, unlike isthmic lysis spondylolisthesis (Fig. 1).[1] Thus, DS is often responsible for lumbar canal stenosis[2] (Fig. 2). Different risk factors for DS have been suggested, including older age, female gender, larger body mass index and sagittal facet orientation. More recently, the relationship between sagittal alignment and DS occurrence has been highlighted in the literature.[3] Indeed, in the setting of DS, listhesis is often responsible for a local kyphosis, which is associated with loss of lumbar lordosis and can lead to anterior shift. Moreover, recent studies have confirmed the impact of sagittal malalignment on patient-reported outcomes. Therefore, analysis of the stenosis area and sagittal alignment is of utmost importance in DS.

Although it is a frequently occurring disease with a prevalence of 2.7% in men and 8.1% in women according to Jacobsen et al,[3] no therapeutic consensus exists on the different surgical and medical treatments, or on the choice between medical or surgical treatment. Medical treatment is based on the use of different painkillers, anti-inflammatory drugs, analgesic injections (epidural, foraminal or into the facets) and physiotherapy to prevent low back pain. When medical treatment is unsuccessful, surgery can be proposed. Recently, the Spine Patients Outcomes Research Trial group (SPORT) compared efficacy of surgical (decompression, or decompression and fusion) *versus* medical treatment and natural history of the disease.[4] Despite some bias, the results of the SPORT study demonstrated the superiority of surgical treatment at two and four years postoperatively, especially when radicular symptoms were more prominent than low back pain. However, unless there is a neurological deficit, most of the time the indications for surgical treatment are based on the degree of functional symptoms. When surgical treatment is selected, the surgeon must think about decompression, fusion and osteosynthesis.

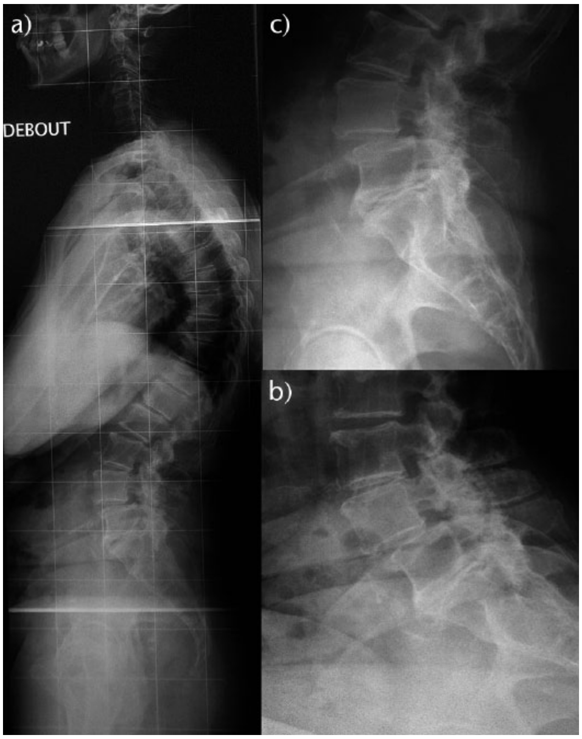

Fig. 1 L4-L5 degenerative spondylolisthesis: a) sagittal full spine radiograph; b) flexion radiograph; c) extension radiograph.

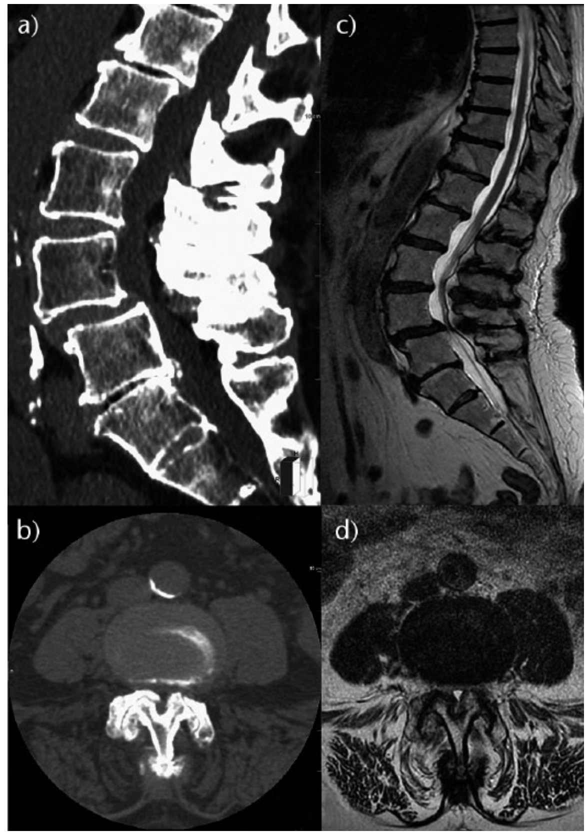

Fig. 2 Intracanal images of L4-L5 degenerative spondylolisthesis: a) and b) sagittal and axial CT slices; c) and d) sagittal and axial MRI slices.

Decompression

The main goal of surgical treatment in DS patients is to improve neurological symptoms.

Single decompression

As these symptoms are mainly due to lumbar canal stenosis, the main goal should be to perform a decompression. The most common surgical approach when performing decompression is a posterior approach with a laminectomy or lamino-arthrectomy. Nevertheless, fusion is often associated with decompression to avoid posterior instability.

Single anterior fusion for indirect decompression

Local instability and slipping increases radicular compression; therefore, some surgeons have suggested fixing the listhetic level without direct decompression – i.e. with fusion only.[5,6] Most frequently, this therapeutic strategy has been performed using an anterior lumbar interbody fusion (ALIF) with or without posterior instrumentation. With the improvement of mini-invasive surgery (MIS), this procedure has gained popularity with patients and surgeons alike. In a recent study of 39 patients, Takahashi et al[7] presented the long-term results of DS treatment using an ALIF. In their actuarial survivorship analysis, 76% of patients were satisfied at ten years and 60% at 20 years. More recently, Oliveira et al[8], in their series on 21 DS patients with lumbar spinal stenosis treated with transpsoas lateral lumbar interbody fusion (XLIF), confirmed that the foramina and central canal area were increased postoperatively. However, they also reported some cases with cage subsidence, loss of correction and recurrence of radicular pain. Ahmadian et al,[9] in a similar study without direct decompression on 31 patients in 2013, reported an improvement in low back pain measured using the Oswestry Disability Index (ODI), and in quality of life using the Short-Form 36, at two years. Marchi et al,[10] in a prospective study, corroborated these results with a significant improvement in ODI (54%) in 52 DS patients treated with standalone XLIF. However, they also described temporary psoas deficit and dysesthaesia in 19.2% and 9.2% of the patients, respectively. Moreover, although they obtained a high fusion rate at two years (86.5%), cage subsidence was reported in 17% of patients, with a revision surgery in 13%. Consequently, the literature does not define the limits of this indication and some questions remain unanswered regarding indirect decompression in DS patients and associated loss of lordosis and lumbar canal stenosis, multi-level spondylolisthesis and osteoporotic bone.

To avoid ALIF and MIS XLIF complications such as nerve root deficit and wall dehiscence, Silvestre et al[11] developed another technique for anterior interbody fusion through a retroperitoneal MIS approach. In this series, 20 of the 179 patients had postoperative complications (residual pain in the scar, damage of the sympathetic plexus, neurological deficit, iliac vein lesions), but no wall dehiscence or retrograde ejaculation were reported. Sato et al,[12] in a recent series of 20 patients, corroborated these results with significant improvement in lumbar and radicular pain, but also reported one neurological and one iliac vessels deficit.

Indirect decompression with interspinous spacer

Another way to perform indirect decompression is to use an interspinous spacer. In a 2010 literature review on interspinous spacers, Kabir et al[13] concluded that there were good biomechanical results but that clinical results were not so promising. Anderson et al,[14] in a randomized prospective study on 75 DS patients with neurogenic claudication, compared medical treatment *versus* the interspinous spacer and observed that improvement in functional symptoms was better with interspinous spacers. Nevertheless, Eismont et al,[5] in a recent literature review, did not corroborate these results, especially on long-term outcomes.

Posterior decompression

Posterior decompression is the most common way to treat DS and it could be associated with posterior fusion. Patients are operated on in the prone position or genupectoral position. Through a median posterior approach, spinous processes, laminae and facets are exposed. First, laminectomy is performed and the ligamentum flavum is removed. An oblique facetectomy is then performed to decompress the nerve roots. At the end of surgery, it is important to assess root decompression in the central, lateral and foraminal area.

Stabilization

Epstein[15] and Mardjetko et al[16] highlighted the efficiency of posterior decompression to improve neurological symptoms. Once posterior decompression is achieved, it is necessary to analyze whether stabilization should be performed. The aims of stabilization are to prevent instability secondary to decompression and to fix preoperative instability. In the literature, some authors reported that results after posterior decompression in DS patients were improved with associated fusion. In their series of 50 DS patients, Herkowitz and Kurz[17] corroborated these results. They observed better outcomes in cases of decompression and fusion than in decompression alone. Bridwell et al[18] and Zdeblick[19] in prospective studies and Mardjetko et al[16] in a meta-analysis reported comparable results.

However, occurrence of postoperative instability after decompression in DS patients is not always observed and the association between postoperative instability and poor outcomes is controversial. Charafeddine et al,[20] Herno et al,[21] Epstein[15] and more recently Martin et al[22] concluded that postoperative instability was not always associated with poor outcomes, contrary to Johnsson et al,[23] Herkowitz and Kurz,[17] Bassewitz and Herkowitz[24] and Mullin et al.[25] It is more likely that poor outcomes are mostly due to significant postoperative slippage and other risk factors of postoperative instability. In 2013, Blumenthal et al[6] identified three main risk factors for postoperative instability in grade I DS: preoperative listhesis > 2 mm; disc height > 6.5 mm; and sagittal facets. In this study, the presence of any of these three factors was associated with revision surgery for poor outcomes in 75% of the patients. Another important point to reflect on when considering preventing revision surgery in DS patients is global and local sagittal alignment.

Types of stabilization

Two types of stabilization technique exist: dynamic stabilization (ligamentoplasty) and fusion (arthrodesis).

Dynamic stabilization was created by Graf in the 1980s to increase rigidity in order to avoid instability, but also to avoid adjacent segment disease.[26] Graf hypothesized that as biomechanical constraints were normalized, bone and soft-tissue healing would be improved. Initially developed to treat chronic low back pain, indications for this technique were extended to DS and lumbar spinal stenosis to prevent postoperative instability after decompression. In 2000, Konno and Kikuchi[27] confirmed these results on early postoperative outcomes but without long-term follow-up. More recently, Schaeren et al[28] and Hoppe et al[29] reported results of long-term follow-up studies at four and seven years, respectively. In Schaeren et al's series,[28] 47% of the patients developed a radiological adjacent segment disease. In Hoppe et al's series,[29] 18% of the patients developed inferior adjacent segment disease and 28% superior adjacent segment disease. They concluded that these results were similar to posterolateral arthrodesis. Similarly to Schaeren et al and Hoppe et al, we have noted that it is not rare to observe a loss of mobility at long-term follow-up with dynamic stabilization; therefore, the advantage at long-term follow-up seems theoretical.

Another advantage of fusion is to prevent occurrence of articular cysts;[30] indeed, several authors evoked the role of micro-mobility in the development of articular cysts.[31,32] Arthrodesis can be posterolateral, anterior or circumferential. However, as posterolateral arthrodesis

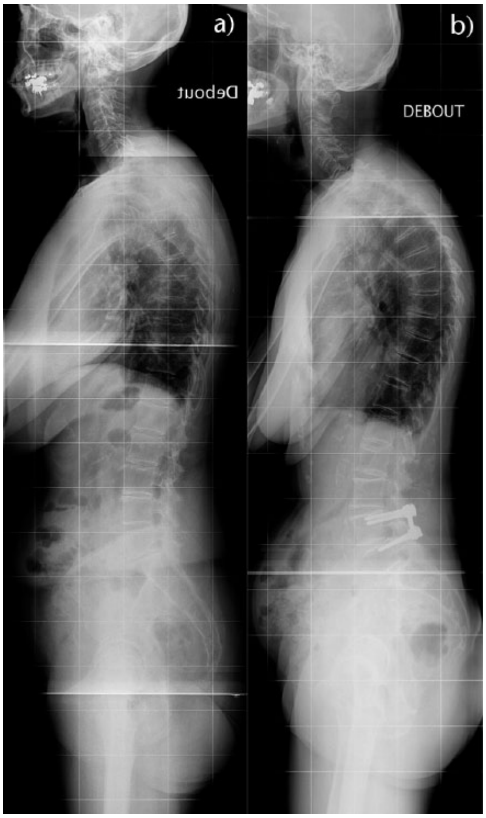

Fig. 3 Full spine standing radiographs: fusion for L4-L5 degenerative spondylolisthesis: a) *in situ* fusion; b) instrumented fusion.

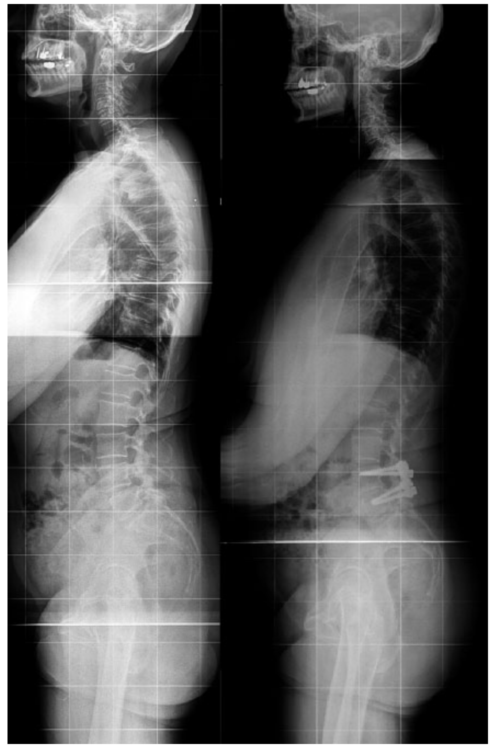

Fig. 4 Preoperative and one-year postoperative radiographs of L4-L5 degenerative spondylolisthesis treated by decompression and instrumented posterolateral fusion.

can be performed at the same time as decompression, this is the most common procedure.

Osteosynthesis

Associated osteosynthesis aims at decreasing mobility of the operated level to improve fusion, correcting a deformity and creating immediate stability while a bone graft is consolidating (Figs 3 and 4). As a matter of fact, osteosynthesis seems logical in cases of DS, particularly if a large decompression is performed. In 2000, Guigui et al,[3] comparing two groups of patients (fusion alone *versus* fusion and osteosynthesis), concluded that three parameters were highly associated with pseudarthrosis: disc height, local sagittal mobility and angular mobility. In a prospective randomized study, Fischgrund et al[34] emphasized these findings: 82% of patients with decompression and instrumented fusion were fused at last follow-up *versus* 48% in the groups without instrumentation. They confirmed the role of angular segmental hypermobility in pseudarthrosis. Nevertheless, instrumentation was not necessarily associated with better clinical outcomes; patients who obtained fusion and those with pseudarthrosis had similar clinical scores at two-year follow-up. Thomsen et al[35] and France et al[36] corroborated these results.

Interestingly, in another study with longer follow-up (seven years on average), Fischgrund[37] obtained better functional outcomes in patients with fusion *versus* those with pseudarthrosis. He concluded, similarly to Guigui et al,[3] that osteosynthesis was recommended in cases where there were sagittal and angular hypermobility, loss of disc height and a large bone resection for decompression. Although the literature does not provide strong recommendations on the usefulness of instrumentation, the association of decompression and posterolateral instrumented fusion became the standard of use in DS surgical treatment.

Fusion length and position

Numerous risk factors for DS have been discussed in the literature (female gender, obesity, age, sagittal facets). More recently, the role of sagittal alignment was highlighted: DS patients had on average higher pelvic incidence than asymptomatic subjects.[38] Based on these findings, one explanation of the physiopathology of DS might be that high pelvic incidence is associated with large lumbar lordosis and pelvic tilt; those two factors, while increasing constraints on facets and shearing forces

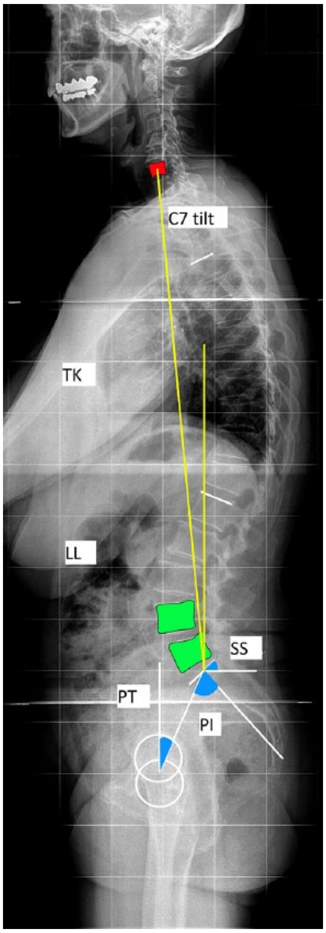

Fig. 5 Sagittal alignment parameters (PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope; LL, lumbar lordosis; TK, thoracic kyphosis; C7 tilt: C7 sagittal tilt).

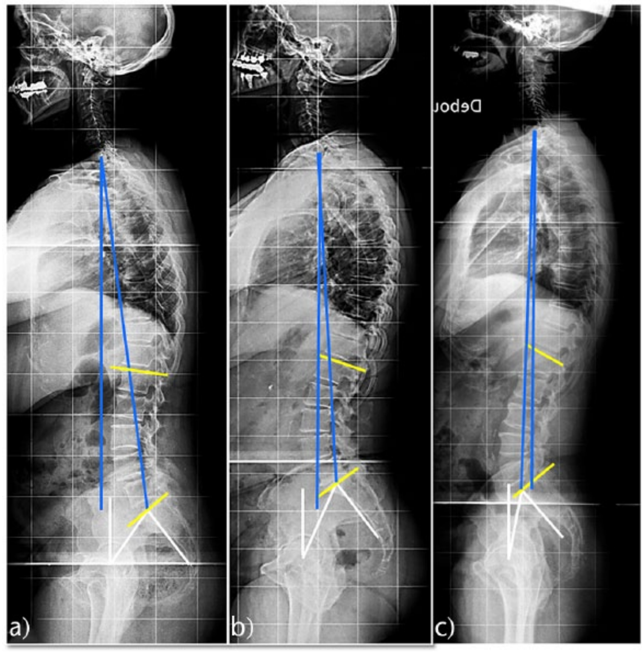

Fig. 6 Comparison of sagittal standing radiographs in (a) a patient with spondylolisthesis in anterior tilt, (b) a patient with spondylolisthesis and compensated alignment by pelvic retroversion and (c) an asymptomatic subject. (Patient A: high pelvic incidence, severe loss of lumbar lordosis, strong pelvic retroversion, anterior C7 tilt. Patient B: high pelvic incidence, moderate loss of lumbar lordosis, pelvic retroversion, C7 in balance behind the femoral heads. Patient C: lower pelvic incidence, lumbar lordosis adapted to pelvic incidence, no pelvic retroversion, C7 in balance behind sacrum).

on discs, could cause a deterioration of a spinal functional unit and therefore lead to the development of a DS. However, although high pelvic incidence is often associated with DS this is not always the case, since some DS patients have a small pelvic incidence.[38]

Consequently, it is essential to analyze global sagittal alignment to treat DS patients (Fig. 5). In a recent study, Ferrero et al[38] described the sagittal alignment of 654 DS patients: 24% had anterior malalignment (C7 sagittal tilt > 10.7° on average) and 76% did not have anterior malalignment, but more than 50% of them had pelvic retroversion. In the groups of DS patients with anterior malalignment, large pelvic incidence was associated with a lack of lumbar lordosis. Moreover, in each group, lumbosacral lordosis was decreased: < 46% of total lordosis *versus* 66% in asymptomatic patients, and pelvic retroversion was higher than in asymptomatic subjects (Fig. 6).

Consequently, position and length of fusion are linked to global sagittal alignment and its main parameters: pelvic incidence, pelvic tilt and lumbar lordosis. Based on this knowledge, principles of arthrodesis (length, position, type) aim at correcting local kyphosis and sagittal malalignment, and obtaining a harmonious shape of the spine. Indeed, persistence of a kyphotic area and/or anterior malalignment can be responsible for pseudarthrosis, implant failure and poor clinical outcomes. In the case of lumbar kyphosis, adjacent segment disease may be observed and this requires an extension of the fusion, sometimes with correction osteotomy. Thus, short fusion could be performed in DS patients with global sagittal alignment. However, in cases of anterior malalignment and significant lack of lordosis, correction osteotomy with a longer fusion might be necessary.

In any case, the greatest challenge is perhaps not only to choose the best therapeutic strategy, but to adapt it to each patient's specificity and general health status. Indeed, DS is a degenerative disease and comorbidities are frequent in this population. Another key point is that degenerative discs rarely require extension of the fusion to treat or prevent low back pain: given that DS is a degenerative pathology, disc degeneration is not rare in this population and would require long fusion with poor influence on final outcomes.

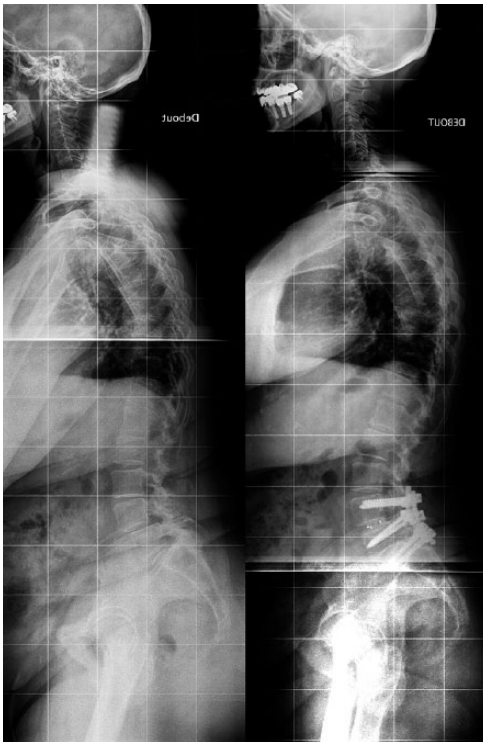

Fig. 7 Preoperative and one-year postoperative full spine radiographs of a degenerative spondylolisthesis patient treated with L4-L5 transforaminal interbody fusion.

Interbody fusion

As explained above, interbody fusion might be possible to perform indirect decompression. Nevertheless, it is equally possible to associate interbody fusion with posterolateral arthrodesis by posterolateral interbody fusion or transforaminal interbody fusion (TLIF) (Fig. 7). Advantages of interbody fusion are to increase the graft area, improve immediate and long-term stability, open foramina and improve local lordosis. In return, interbody fusion may increase perioperative morbidity with longer operative time, blood loss and neurological complications.

Many studies compare decompression with posterolateral fusion and decompression with posterolateral fusion associated with interbody fusion in DS patients. The advantages of associated interbody fusion for clinical outcomes remain in question. For example, in a 2014 literature review (evidence-based recommendations), Matz et al[39] concluded that it was impossible to give recommendations on the value of interbody fusion associated with posterolateral fusion for DS treatment.

Recent literature reviews offer some advice on interbody fusion indications: DS with Modic 1 endplate degeneration, DS with instability (anteroposterior mobility above 4 mm or angular sagittal mobility above 10°) and lack of lordosis. Another indication for interbody fusion is a significant postoperative increase in lumbar lordosis. In such cases, ALIF is recommended to improve the graft area and avoid postoperative loss of correction.[39]

MIS in DS patients

Nowadays, with improvement in MIS techniques, it is possible to treat DS patients using this method. Most of the time, this procedure involves MIS, TLIF and percutaneous screws. In a prospective study in 2010, Wang et al[40] compared treatment of DS patients with MIS procedure *versus* open posterior standard approach (decompression with posterior instrumented fusion and TLIF in each group). They obtained similar clinical outcomes at two years in 85 patients. Advantages of MIS surgery are reduced blood loss and length of stay. In a recent meta-analysis comparing MIS and open surgery at two-year follow-up, Goldstein et al[41] corroborated these findings with the same advantages and similar outcomes between each group for perioperative complications, functional outcomes (assessed with ODI), pseudarthrosis rate and revision surgery rate. Price et al,[42] in a prospective study on 452 patients and Mummaneni et al,[43] in a literature review, obtained the same results for complications, clinical and radiological outcomes. Nevertheless, the authors highlighted the length of the learning curve.

Another possibility when carrying out MIS surgery is to perform bilateral decompression without fusion through a unilateral MIS approach. In their series, Toyoda et al[44] obtained 64% improvement in functional scores at six years. Similarly, Jang et al,[45] in a retrospective study, observed an ODI improvement from 59 to 26 at three-year follow-up. However, slippage worsened in 50% of the patients, especially in cases with preoperative instability. Therefore, MIS release seems effective in stenosis associated with spondylolisthesis, but it should not be performed in cases of hypermobility at the listhetic level or in cases of misalignment.

Conclusion

Simple decompression or indirect decompression might be proposed in cases of symptomatic DS, but the most common surgical treatment for DS patients includes posterior decompression with instrumented posterolateral fusion. However, some cases are more complicated; differences exist between patients in terms of their general health status and sagittal alignment. These factors are important to consider when planning a therapeutic strategy, and they influence short- and long-term results.

One should remember:

1) that decompression without fusion is not recommended in cases of instability (anteroposterior and

angular), significant disc height and large bone resection for decompression;
2) that instrumented fusion is the standard of care with good long-term outcomes;
3) it is of the utmost importance that global, spinal and local sagittal alignment must be analyzed to determine the length and position of fusion. Nevertheless, surgical planning also needs to take into account patient comorbidities.

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