12

Surgical Management of Low Back Pain and Degenerative Spinal Disorders

Vu H. Le and S. Samuel Bederman
University of California, Irvine, USA

1. Introduction

Low back pain is the second most common reason to seek a physician in the United States, third most common reason for a surgical procedure, and fifth most common cause for hospitalization (Andersson, 1997). The lifetime prevalence of low back pain is predicted to range from 60 to 80 percent (Hart, 1995; Van Tulder, 2002). The annual prevalence is estimated to be between 15 to 45 percent, with a point prevalence of 30 percent. Low back pain is the most common and most expensive cause of work-related disability in the United States (Atlas, 2000). Between 2002 and 2004, the estimated annual medical costs for all spine related conditions were approximately 193 billion dollars, with about 14 billion dollars in lost wages due to spine disorders (Bone and Joint Decade, 2005). It is a burden to both the individual and society, in terms psychosomatic impairment and socioeconomic impact. In fact, the presence of comorbidity adds to the burden and negatively impacts the patient's functional status (Fanuele et al, 2000).

Fortunately, the majority of these patients recover within 3 months. With conservative care, it has been estimated that about 60 percent recover in 6 weeks, and 80 to 90 percent recover within 3 months (Andersson, 1999). Therefore, only a minority warrants further workup and care that can potentially include surgery. Non-surgical treatment consists of medications, cognitive training, physical therapy, and local injections. Some studies have shown that intensive, structural cognitive behavior therapy including encouragement and daily physical therapy can produce equivalent results compared to fusion in non-specific chronic low back pain (Brox et al, 2006; Fairbank et al, 2005).

In contrast, Fritzell et al (2001) showed that non-intensive, non-structural therapy yielded less optimal results than surgery. What comprises a structural or non-structural non-operative therapy regimen still remains unanswered. Additionally, only a few non-surgical interventional therapies have been shown to be effective, while prolotherapy, facet joint injection, intradiscal steroid injection, and percutaneous intradiscal radiofrequency thermocoagulation have been proven to be ineffective (Chou et al, 2009). The relative merits of non-surgical treatment for these conditions are beyond the scope of this chapter.

The literature on surgical management for low back pain similarly elicits uncertainties due to non-specific diagnosis, but Glassman et al (2009) showed that with diagnostic specificity and stratification, the outcome of surgery depends on the underlying diagnosis. Functional improvement after surgery is not equal among diagnostic subgroups. Since surgery is a highly technical treatment modality, it is imperative to clearly define the pathological condition causing the symptoms rather than relying on simply a 'diagnosis' of low back pain, being a symptom rather than a clinical diagnosis or disease. Identifying a pathological condition allows surgeons to determine whether a surgical intervention can correct the problem and, in turn, improve the symptoms.

The aim of the chapter is to discuss current options of surgical treatment of degenerative spinal disorders presenting with predominantly axial low back pain. Although the perception of the benefits of surgery for axial spine pain stemming from degenerative changes remains controversial, our aim is to discuss the current literature on the relative merits of surgery for selected patient groups.

2. Differential diagnosis

There are many causes of axial low back pain. Generally, the history and physical can play a paramount role in illuminating the etiology. Patients exhibiting constitutional signs such as fevers and chills can insinuate infectious etiologies, whereas weight loss, night sweats, and personal or family history of cancer can imply malignancy. Obviously, any recent trauma warrants imaging to rule out fracture.

Other causes of axial low back pain are divided into non-structural and structural entities relating to the vertebral column. Non-structural causes, sometimes referred to as non-specific low back pain, are due to strain or sprain around the vertebral column, whereas structural reasons involve abnormalities within the vertebral column identified on imaging and can be considered as stable or unstable conditions. For this chapter, we will focus on structural degenerative causes of axial low back pain. Stable conditions include degenerative disc disease (DDD) and facet arthropathy, while degenerative and isthmic spondylolistheses and degenerative scoliosis are more unstable conditions. Before delving into specific causes, general surgical outcomes for low back pain will be discussed.

3. Surgical outcomes for low back pain

Most people with low back pain are successfully treated non-surgically through medications, modified activities, physical therapy, localized injections, and alternative therapies that are well described in other chapters of this book. However, there is a minority with persistent or increased pain, needing further workup and possibly surgery. There is a wealth of studies gauging the efficacy of surgical treatment for non-neurogenic axial low back pain. Systematic reviews of randomized controlled trials provide a strong level of evidence by setting inclusion and exclusion criteria when looking at the study methodologies, participants, interventions, and outcome measures. Yet, when it comes to comparing operative and non-operative results for axial low back pain, there can be conflicting results due to the lack of specificity in describing the cause of back pain since the outcomes from surgery differ between diagnostic subgroups. The shortcoming of these systematic reviews is their broad categorization of causes of back pain by combining the aforementioned causes as just degenerative disease. Also, differences in patient inclusion criteria, fusion technique, non-surgical treatment, and outcome measures make it hard to draw conclusions.

The general view of surgery for axial low back pain is met with skepticism. Mirza and Deyo (2007) systematically reviewed surgical compared to non-surgical treatment of discogenic back pain and concluded that surgery may not be more efficacious than structured cognitive behavior therapy. However, careful analysis of this study shows that the specific diagnostic indications for surgery are poorly defined. The population in this review was deemed to have low back pain for 12 months or longer without a specific diagnosis, and there was no established way of diagnosing discogenic pain. Furthermore, there was no uniform surgical technique, but rather an inclusion of a myriad of interventions, including one group that received flexible stabilization without fusion. Thus, due to its limitations, this study fails to accurately measure the effectiveness of surgery for axial low back pain.

Similarly, Chou et al (2009) systematically reviewed the benefits and harms of surgery for non-radicular back pain compared with non-operative measurements. They looked at different trials addressing fusion for chronic back pain mostly due to DDD, but not exclusively limited to DDD. Their conclusion is that fusion is no better than intensive rehabilitation with cognitive behavior emphasis, but slightly better than non-intensive non-surgical therapy. Again, a fault of the analysis is the inability to specify the specific causes of low back pain. It also combined various surgical techniques for undefined chronic back pain. This leads to the presumption that there is no role for surgery in axial low back pain when, in fact, the success of surgery depends on specific causes.

Glassman et al (2009) demonstrated that it is possible to stratify by specific diagnostic indication when looking at lumbar fusion for different diagnostic subgroups. In contrast to prior systematic reviews, they prospectively collected clinical outcome measures and reported on the impact of lumbar posterolateral fusion on different subgroups. Outcome measures such as the Oswestry Disability Index (ODI), Short Form-36 (SF-36), and numeric rating scales for back pain were used. Their findings showed that outcomes scores were not equal among diagnostic subgroups. In fact, the diagnostic subgroup that demonstrated the most significant improvement in ODI scores were the patients with spondylolisthesis, followed in decreasing order by scoliosis, disc pathology (i.e. DDD), postdiscectomy revisions, stenosis, and adjacent level degeneration. This was based on the percentage of patients in each subgroup to reach minimum clinically important difference, or an improvement of at least 10 points in ODI scores, during a 2-year follow-up.

Carreon et al (2008) provided another study looking at outcome measures while stratifying subgroups. They also used ODI and SF-36 to compare surgery with no surgery. The mean improvement in ODI in the surgical group was higher than the non-surgical group. Within this group, patients with spondylolisthesis had the greatest improvement, followed by those with DDD, then patients with chronic non-structural non-specific low back pain. This implies that non-specific etiologies, as displayed by the chronic low back pain group, can portend less success with surgery. On the other hand, more specific structural etiologies such as spondylolisthesis can benefit from surgical interventions.

4. Stable degenerative conditions

4.1 Degenerative disc disease

Degenerative disc disease (DDD) (Figure 1) stems from structural changes of the disc, which eventually leads to disc space narrowing, endplate osteophyte formation and sclerosis, and gas formation within the disc space. This is in contrast with internal disc disruption (IDD), which displays only abnormal discal properties without loss of disc height or endplate changes. The exact pathophysiology of DDD is not fully understood, and so its natural history is still unknown. Kirkaldy-Willis et al (1978) proposed a pathoetiology for this condition. They viewed each level of the lumbar vertebra as a three-joint complex consisting of a disc and two posterior joints. Stresses to one joint can affect the others. The process of degenerative disc disease starts with internal disruption, followed by resorption of the disc and endplate changes. With a degenerative disc and therefore more strain on the posterior facet joints, this eventually leads to advanced facet arthropathy and spondylosis. With minor repeated trauma, the degenerative interaction between the three-joint complex leads to more stresses on the adjacent levels, thus, potentially leading to a multilevel degenerative spine. In 10 to 39 percent of chronic low back pain cases, the intervertebral disc is suggested to be the source of pain (Schwarzer et al, 1995; Manchikanti et al, 2001). Despite this, it is still controversial as to how much DDD correlates to low back pain. As a result, there is a debate regarding its treatment. Clinical examination may show midline spinal tenderness and reduced range of motion, typically in flexion.

Fig. 1. Degenerative disc disease
Lateral radiograph of the lumbosacral spine depicting marked loss of disc spaces from L2 to S1. There are anterior osteophytes and endplate subchondral sclerosis.

Non-surgical management may include such modalities as physical therapy, medications, and interventional injection treatments. According to Cochrane reviews, long-term bedrest and back braces are not recommended (Hagen et al, 2004; van Duijvenbode et al, 2008). Interventional modalities such as epidural injections and intervertebral disc injections and manipulation have yet to be proven effective by randomized controlled trials. Acetaminophen and non-steroidal anti-inflammatory drugs are the most commonly used medications. Non-surgical options for this condition are discussed elsewhere in this book.

Surgical options for DDD may include fusion or motion-preservation strategies, such as artificial disc replacement. There have been only a handful of high quality randomized controlled studies assessing the effectiveness of surgery for DDD. Because the diagnosis of DDD is still controversial, these studies are still non-specific in terms of diagnostic categorization. In a meta-analysis of randomized trials comparing fusion to conservative treatment for DDD, surgery led to improved functional scores compared to non-surgical treatment (Ibrahim et al, 2008). However, the difference in functional improvement was not statistically significant. Meanwhile, disc replacement can be an option for isolated disc pathology, without arthrosis of the facet joints or spinal instability. There has been little research comparing total disc replacement versus conservative care, however, some studies have shown non-inferiority of disc replacement to fusion (Blumenthal et al, 2005; Zigler et al, 2007). Surgical options for these conditions will be discussed in more detail later in the chapter.

4.2 Facet arthropathy

Along the spectrum of degenerative changes, facet arthrosis results from increased load to the posterior elements due to abnormal load sharing from disc derangement and repetitive minor trauma over time as discussed by Kirkaldy-Willis. Similar to other synovial joints, like the hip, knee, and shoulder, degenerative arthropathy of the facet joints can lead to joint space narrowing, osteophyte and cyst formation, joint effusions, and mechanical pain. Facetogenic pain is typically worse with extension and may be relieved with rest. Patients often get relief of their back pain with leaning on a walker or shopping cart. It is the same degenerative process that may be implicated in spinal stenosis whereby the osteophyte formation, cyst formation, disc bulging, and redundancy of the ligamentum flavum from disc height loss all cause encroachment on the neural elements.

Conservative management, in addition to physical therapy and medications, consists of intra-articular facet injection and medial branch block. Medial branches of the dorsal rami are usually blocked at the junction between the superior articular facet and transverse process. In patients who respond to medial branch blocks, medial branch neurotomy via radiofrequency ablation presents as an effective non-surgical treatment for facet arthropathy (Dreyfuss et al, 2000). Once the diagnosis is confirmed with positive blocks, but the pain still recurs, then surgical options include posterior fusion and facet replacement (discussed later in the chapter).

5. Unstable degenerative conditions

5.1 Degenerative scoliosis

5.1.1 Introduction

Scoliosis is defined as an abnormal curvature of the spine of more than 10 degrees (Figure 2). In adults, scoliosis can be a result of untreated scoliosis that existed before skeletal maturity or can develop after skeletal maturity, otherwise known as de novo scoliosis. An example of de novo scoliosis is degenerative scoliosis, which is caused by a continuum of degenerative changes as described in DDD and facet arthropathy, leading to central canal and foraminal narrowing. Adult scoliosis has detrimental effects on the health status of the affected person. Berven et al (2003) illustrated that compared with control subjects, adults with scoliosis have more pain, lower self-image, less functional capacity, and lower mental health scores. They also concluded that radiographic parameters do not necessarily correlate well with the patient's self-assessment of health status.

Fig. 2. Degenerative Scoliosis

Figure 2a shows an anteroposterior (AP) radiograph of the lumbosacral spine showing degenerative lumbar scoliosis with the apex at the L2-3 level. Notice the degenerative disc disease from L1-L5 and the rotational deformities of the vertebral bodies based on the asymmetric pedicles. Figure 2b shows postoperative AP radiograph with posterior instrumentation and lateral interbody fusions for deformity correction. Note that the lumbar spine now sits in line with the mid-sacrum.

5.1.2 Natural history

Progression of the curve is common, but the extent of it is unknown so continual observation is important. Chin et al (2009) demonstrated that women older than 69 years of age with levoscoliosis and lateral listhesis of more than 5mm might progress rapidly. Deviren et al (2002) showed that increasing age and curve magnitude correlate to decreased curve flexibility. Also, the degree of axial back pain associates with increasing age. Pritchett and Bortel (1993) studied 200 patients older than 50 years of age with adult scoliosis and found that certain factors might predict curve progression. In general, those with significant curves with rotation can progress rapidly.

5.1.3 Diagnostic imaging

Full-length standing radiographs are required to fully assess the overall spinal balance. Cobb angles are determined for the structural curve, which is usually the largest curve, and any compensatory curve. Coronal balance is determined with a plumb line from the middle of C7 vertebral body on posteroanterior (PA) radiograph. This should intersect the midsacrum. Sagittal balance is measured using a plumb line from the center of C7 on the lateral radiograph. This line should typically fall within 2 to 4 centimeters from the the posterior margin of the lumbosacral disc. If it falls anterior to the posterior margin of the disc then positive sagittal imbalance is present, while negative sagittal imbalance is when the line falls posterior to the disc. Global sagittal imbalance has the most significant impact on pain and function compared to other radiographic parameters (Glassman et al, 2005). The evaluation of the flexibility of the main structural curve and its compensatory curve is done through various specialized radiographs. Obliquities such as pelvic tilt and shoulder asymmetry should also be noted. Flexibility and obliquity assessment dictate which level to fuse and instrument when performing surgery. Any radicular or neurogenic pain should merit obtaining magnetic resonance imaging (MRI).

5.1.4 Clinical diagnosis

While axial back pain is common in scoliosis, Smith et al (2008) showed that neurological symptoms and deficits are also frequently found in these patients. The incidences of back pain and radiculopathy were found to be 99 percent and 85 percent, respectively. Neurogenic symptoms typically arise from the concave side of the curve from asymmetric disc collapse and resultant neural foraminal stenosis. In addition to axial pain and neurogenic symptoms, spinal imbalance can manifest in late presentation. With the patient standing up without hip or knee bending, coronal balance can be evaluated with a plumb line from the C7 spinous process. Normally this plumb line should intersect the gluteal cleft in a balanced spine. Gross sagittal balance can be determined by evaluating the relationship of the pinna of the ear to the greater trochanter of the femur.

5.1.5 Treatment

Non-operative treatment aims to control pain and function. This includes modalities such as medications, physical therapy, activity modification, orthotics, and injections. Numerous studies have shown that conservative treatment does not lead to improved pain and function compared with surgery (Bridwell et al, 2009; Smith et al, 2009; Glassman et al, 2010). In a non-randomized, prospective study looking at 123 patients with a 2-year follow-up, Glassman et al (2010) questioned the cost-effectiveness of non-operative treatment when the average cost over 2 years was $10,815 US.

Thus, surgical management has been preferred. Like other spinal conditions, surgery is only entertained after conservative treatment has failed and the patient is presenting with refractory pain limiting function, progressive deformity or neurologic deficits. Smith et al (2009) have shown that surgery can lead to better outcomes in back pain, leg pain, disability, and health status after 2 years compared to non-operatively treated patients. This is in the face of greater pre-operative back pain, leg pain, and functional disability. Grubb et al (1994) also showed that pain relief was associated with a solid fusion, and surgically managed patients demonstrated improved standing and walking.

While the goal of adolescent idiopathic scoliosis is to prevent progression of deformity and subsequent sequelae such as pain and neurological symptoms, the objectives of surgical care for degenerative scoliosis are to improve current pain and neurologic symptoms, and to restore normal spinal balance, particularly in the sagittal plane; all while maintaining as many mobile segments as possible. Although surgery has been shown to be more effective than non-surgical treatment, there is no consensus regarding the optimal approach and the levels to be included. This is due to the variety of clinical presentations and extent of disease and lack of clear evidence-based literature on approaches. The number of levels to involve in a fusion has been debated. Cho et al (2008) demonstrated that short fusion is a viable method in patients with small Cobb angles and good global balance. In their study, the average Cobb angle in patients receiving short fusion (average was 3 levels) was 16 degrees. Careful assessment of the global alignment must be performed to prevent progression of deformity prior to performing instrumented fusion. The inclusion of L5-S1 is also debatable. While stopping the fusion at L5 reduces perioperative complications and chances of pseudoarthrosis, the theoretical advantages of including this segment include complete sagittal balance correction and obviating future revisions due to degenerative changes at the L5-S1 level (Bridwell et al, 2003). Some clear indications to extend fixation to the sacrum include spondylolisthesis, stenosis requiring decompression, and degenerative disc changes at the L5-S1 level.

Combined anterior and posterior approaches provide presumed circumferential fusion and generous sagittal correction. However, they are associated with high perioperative complication rates as shown in Berven et al's retrospective study (2003). Despite achieving good sagittal correction, 32 percent of the patients developed perioperative complications including infections, dural tears, pneumonia, and acute renal failure. Overall, 40 percent needed repeat surgery for various causes including revision of fusion, hardware complications, and infection. With recent advances in instrumentations and techniques, circumferential fusion and deformity correction can be performed through a posterior-based approach. Interbody fusion can be done through the posterior lumbar interbody fusion (PLIF) and transforaminal lumbar interbody fusion (TLIF) techniques via a posterior-based approach. Crandall and Revella (2009) demonstrated equivalent results between these posterior-based interbody fusion approaches and anterior-based interbody fusion technique. Another recent technique to lessen the perioperative complication rates is the lateral lumbar interbody fusion through a minimally invasive trans-psoas approach (Figure 2). Although it has a steep learning curve, this method can provide lower complication rates, lower blood loss, and shorter hospital stay (Mundis et al, 2010).

In a recent retrospective study comparing surgical outcomes between decompression alone, decompression with limited fusion, and decompression with full curve fusion, Transfeldt et al (2010) showed that decompression alone had the lowest rate of complications followed by decompression and limited fusion, while the decompression and full curve fusion group had the highest rate of complications. On the other hand, post-surgical satisfaction questionnaire showed that the group with the full curve correction had the highest satisfaction rate, while the decompression alone group had the lowest satisfaction rate. Therefore, in spite of higher complication rates associated with full curve correction, patients subjectively prefer global curve balance through full curve correction.

5.2 Isthmic spondylolisthesis

5.2.1 Introduction

Spondylolisthesis is the slippage of one vertebral body on another. Isthmic spondylolisthesis is a common condition encountered in adolescents and adults and involves a defect of the pars interarticularis, which is the junction where the lamina and inferior facet meet with the pedicle and superior facet (Figure 3). This leads to a disconnect between the anterior and posterior elements of the vertebra, leading to slippage (olisthesis). The most common level is at the L5-S1 level (Figure 3), with the pars defect commonly discovered on L5 (Figure 4). The reason for this could be due to the fact that as one goes caudad on the lumbar spine, the pars

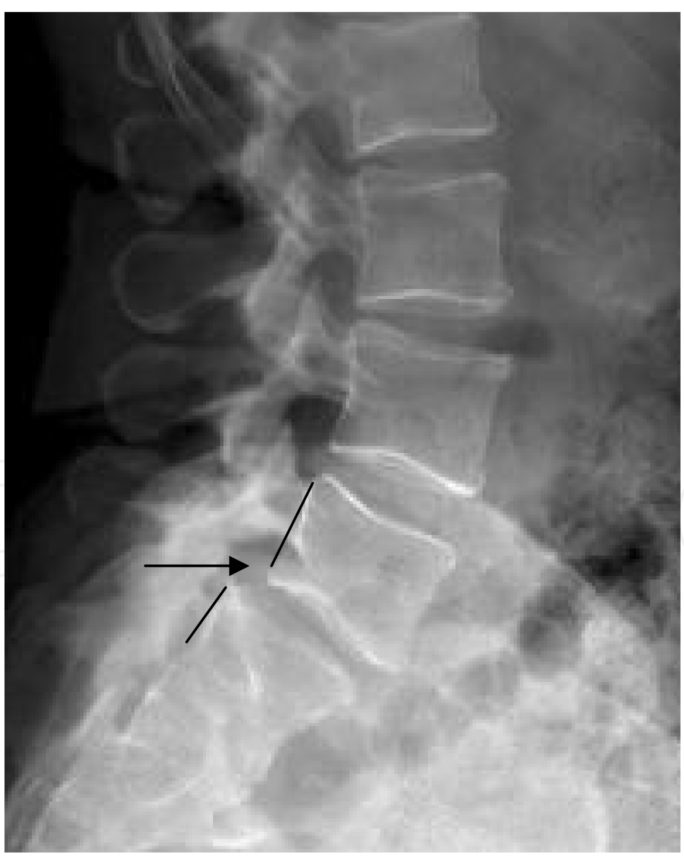


Fig. 3. Isthmic spondylolisthesis.
Lateral radiograph of the lumbar spine showing less than 25% spondylolisthesis at the L5-S1 level.. Notice the posterior cortices of L5 and S1 vertebral bodies do not line up.

get thinner. This, coupled with the fact that the L5-S1 junction endures a lot of stresses, places this level at a high risk for isthmic spondylolisthesis. Contrary to degenerative spondylolisthesis (DS), the isthmic subtype is more common in males. The incidence of pars defect is estimated to be 4 to 6 percent in the general population (Meyerding, 1932; Boxall et al, 1979; Taillard, 1976). In their prospective study, Frederickson et al (1984) reported an incidence of 4.4 percent of pars defect and 2.6 percent of spondylolisthesis at the age of 6. At adulthood, the incidence of pars defect is 5.4 percent while spondylolisthesis is 4 percent.

Fig. 4. Pars defect.
Sagittal reformat cut on computed tomography showing disruption of L5 pars interarticularis.

5.2.2 Natural history

In a 45-year follow up, Beutler el al (2003) showed that subjects with unilateral pars defects did not develop slippage. In those with bilateral pars defects without initial slippage, half showed no further slippage while the other half slipped a mean of 24 percent. Also, progression of the spondylolisthesis slowed with each decade and there was no association of slip progression and low back pain. Saraste (1987) showed that risk factors for low back symptoms were slippage greater than 25 percent, pars defect at the L4 level, and early disc degeneration.

5.2.3 Diagnostic imaging

Just like in DS, the lateral standing radiographs can depict spondylolisthesis and often the pars defect. If the pars defect cannot be seen on the lateral view, 30-degree oblique lateral views can be obtained. Computed tomography (CT) can provide the best bony details if still suspecting pars defect (Figure 4). Bone scan can aid in detecting stress fracture or reaction.

5.2.4 Clinical diagnosis

Most people with isthmic spondylolisthesis are asymptomatic. Back pain is generally worsened by activities and relieved with rest. This pain can be caused by lumbar hyperlordosis, which is associated with tight hamstrings. Occasionally, a step-off deformity of the spinous processes can be palpated adjacent to the level of the spondylolisthesis. Neurologic symptoms are usually in a radicular and dermatomal distribution due to impingement of the exiting nerve root, which is frequently L5 for the L5-S1 level. The site of impingement is at the site of the pars defect where the body forms hypertrophic fibrocartilaginous tissue or Gill lesion in an attempt to heal the defect.

5.2.5 Treatment

Most people with symptomatic isthmic spondylolisthesis improve with non-surgical treatment. This includes nonsteroidal anti-inflammatory drugs, activity modification (not including prolonged bedrest), and physical therapy. Radicular symptoms can be treated with epidural or transforaminal injections. Indications for surgery include failure of conservative therapy, progressive instability and/or neurological function, and intractable back or leg pain specific to the spondylolisthetic level. Surgical management of isthmic spondylolisthesis shows favorable outcomes compared to non-surgical treatment. In a prospective, randomized study comparing posterolateral fusion with an exercise program, Moller and Hedlund (2000) demonstrated that the surgical group had better functional outcome based on the Disability Rating Index and pain reduction.

The general basis of surgery for this condition is stabilization of the spondylolisthesis with or without decompression of affected neural structures. Since decompression alone fails to stabilize the spondylolisthesis, the options include decompression and non-instrumented posterior fusion, decompression and instrumented posterior fusion, decompression with posterior fusion augmented with anterior column support in the form of interbody fusion, and direct pars repair.

Controversy exists about non-instrumentated versus instrumentated posterior fusion. In a 5-year prospective randomized study comparing the two techniques, Bjarke et al (2002) showed that patients with non-instrumented posterior fusion had better clinical outcomes than their counterparts, and there was no difference in fusion rates between the two groups. Moller and Hedlund (2000) also echoed similar findings in that instrumentation does not add to the fusion rate nor improve clinical outcomes. Proponents of instrumentation claim that it can attain slip reduction and can restore sagittal alignment. Pertaining to reduction, Poussa et al (2006) showed that patients receiving in situ fusion had better outcome scores compared to the group that had reduction and fusion. Moreover, the reduction group had more neurologic complications and pseudoarthroses than the in situ fusion group. Hence, instrumentation and slip reduction have not been shown to have clear superiority over non-instrumentation and in situ fusion.

The addition of anterior support with interbody fusion theoretically provides circumferential fusion sites. Multiple studies have shown positive effects of anterior support with interbody fusion in high-grade spondylolisthesis (Helenius, 2006; Molinari, 1999, Shufflebarger, 2005). These include better functional outcomes and fusion rates. On the other hand, the use of interbody fusion is debatable for low-grade spondylolisthesis. Stand-alone interbody fusion without posterior instrumentation is discouraged in this condition due to high rates of failure such as cage migration (Button et al, 2005).

The theoretical advantage of direct repair of the pars defect relates to its ability to preserve motion compared with fusion, possibly leading to decreased degeneration in the adjacent segment. Although direct repair has been proven to be successful with low-grade spondylolisthesis in the short-term period (Morelos, 2004), it has not been shown to be as effective in the long-term period as initial improvement in functional outcomes declined with time and the adjacent segment degeneration phenomenon was comparable to those who received posterior fusion (Schlenzka et al, 2006). However, the method of direct repair shown in Schlenzka et al's study involved cerclage wiring, whereas today's fixation typically involves screws/hooks and/or rods (Figure 8). As a result, it is unknown whether today's technology could prove otherwise and long term follow up studies are needed.

5.3 Degenerative spondylolisthesis

5.3.1 Introduction

Degenerative spondylolisthesis (DS) is a condition generally found in females older than 40 years of age. The usual level of involvement is L4-L5, with L4 slipping anterior to L5 (Figure 5). The cause of this is presumed to be a result of structural degenerative changes in disc and ligaments, more importantly the facet capsules. In a review of magnetic resonance imaging (MRI) in 140 subjects, Boden et al (1996) suggested that more sagitally oriented facets might be the cause of DS.

5.3.2 Natural history

Matsunaga et al (1990) studied the natural course of DS by observing 40 patients from 5 to 14 years. Slip progression was seen in 12 (30 percent) of the patients, but this did not correlate well with clinical symptoms. Meanwhile, 4 of the 28 patients who did not show progressive slip displayed clinical deterioration. Therefore, there is a lack of correlation between progressive slip and clinical symptoms. Also, the study infers that there is no correlation between degenerative changes, such as intervertebral disc narrowing, spur formation, subcartilaginous sclerosis, or ossification of ligaments, and slip progression, hence, suggesting that these anatomic changes may act to stabilize the spine.

5.3.3 Diagnostic imaging

Since DS is a dynamic condition involving instability of the spine, the preferred radiological imaging study is a lateral radiograph, in the standing position. Dynamic flexion and extension views can be added for further inspection of the instability. In a study by Boden and Wiesel (1990) looking at dynamic flexion and extension views, 90 percent of asymptomatic volunteers had 1 to 3mm of translation, therefore, it was considered that anything more than 4mm is abnormal. Slippage is graded based on the percentage of antero-posterior displacement on the vertebral body. Grade 1 equates to less than 25 percent of displacement on the caudad vertebral body; grade 2 is up to 50 percent; grade 3 is up to 75 percent; and grade 4 is up to 100 percent. Additionally, supine views are not helpful

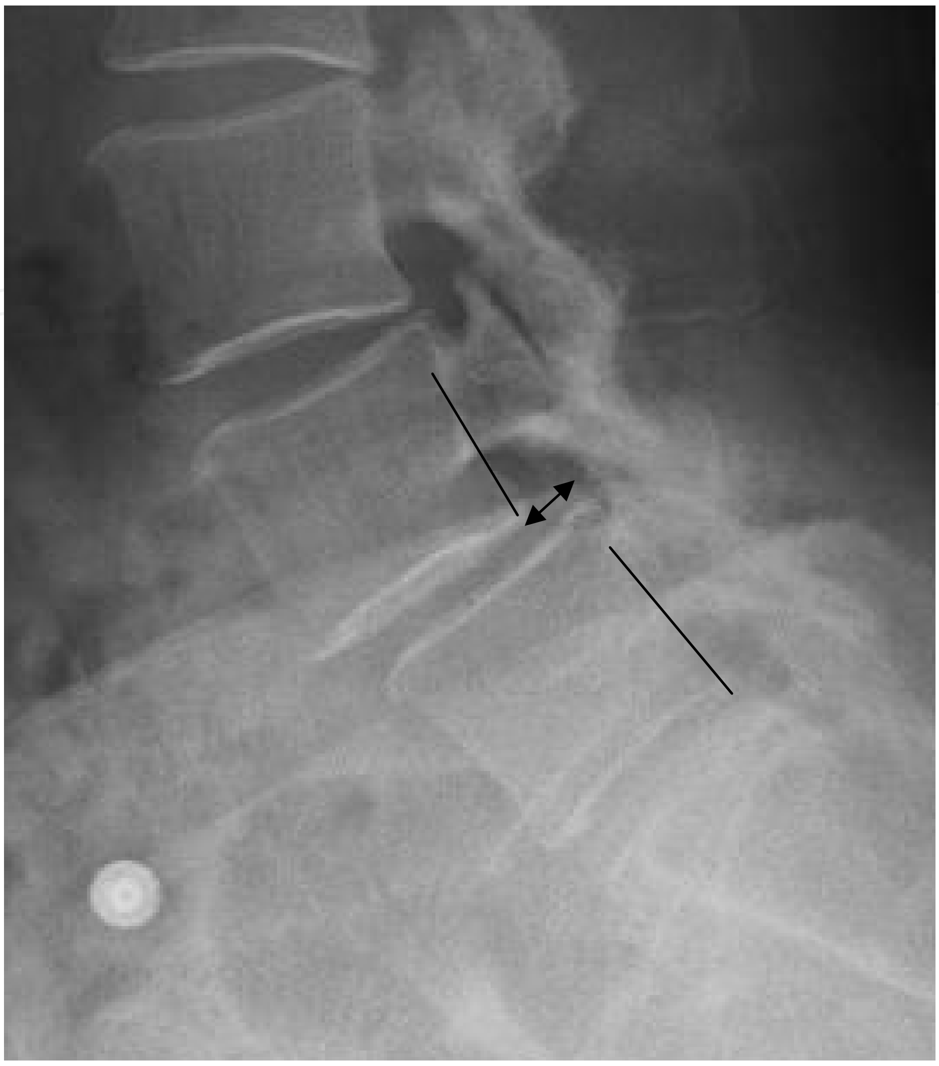


Fig. 5. Degenerative spondylolisthesis.
Lateral radiograph of the lumbosacral spine showing grade 1 spondylolisthesis at the L4-5 level. Notice the posterior cortices of L4 and L5 vertebral bodies do not line up. The percentage of displacement is approximately 20-25 percent of the vertebral body of L5.

since this position may reduce the slippage. Although MRI portrays a static condition, a study by Chaput et al (2007) showed that large (>1.5mm) facet effusions are highly predictive of DS at L4-L5.

5.3.4 Clinical diagnosis

Axial back pain in DS is frequently associated with back extension, whereas back pain in discogenic back pain is classically related to sitting and flexion. Other features of the condition can mimic spinal stenosis and lead to neurogenic claudication. The predominant symptom is pain, radiating from the buttock to the legs, and commonly involves bilateral legs. The neurogenic symptoms do not resemble radicular symptoms in affecting a specific dermatome, but may be diffuse in nature. If there are associated radicular signs, L5 is the most commonly involved root. Also, neurogenic claudication must be differentiated with vascular claudication when diagnosing DS.

5.3.5 Treatment

Generally, a comprehensive course of non-surgical treatment is the first line unless the patient exhibits any sign of neurological deterioration. This is defended by Matsunaga et al's (2000) study showing that 76 percent of his sample size remained without neurological deficit at the 10 year follow up. Those who have failed conservative treatment and display increased or persistent pain, with or without neurologic symptoms, may be considered for surgery. The Spine Patient Outcomes Research Trial (SPORT) depicts the benefits of surgical treatment in patients with DS associated spinal stenosis. They followed 607 subjects for 4 years and rated their progress with outcome measures including, SF-36 and ODI. Despite their high cross over rate between surgical and non-surgical treatment groups, their conclusion was that patients with DS treated with surgery showed better improvement in pain and function during the 4 year follow up. Another shortcoming of this study was that it did not compare different types of surgical techniques. However, there are numerous studies that offer insights into the optimal surgical treatment.

The surgical options include decompression alone, decompression with posterior non-instrumented fusion, decompression with posterior instrumented fusion, and decompression with posterior fusion and anterior column support. Several papers have clearly shown that posterior non-instrumented fusion in conjunction with decompression leads to better clinical outcome than decompression alone in DS patients (Herkowitz, 1991; Mardjetko, 1994). As far as whether or not to add instrumentation to the fusion is still debatable. Fischgrund et al (1997) demonstrated in a prospective, randomized study comparing instrumented fusion with non-instrumented fusion, that fusion rate at 2 years was better in the instrumented group compared to the non-instrumented group. In spite of this, clinical outcome was similar for both groups. As a result, it is up to the physician's discretion to determine when it is appropriate to place instrumentation in this setting of spinal instability. Similarly, there is no convincing data to support the routine use of anterior column support, such as interbody fusion, in addition to posterior fusion. The purported advantages of this would be restoration of disc height and neuroforaminal space, circumferential fusion leading to higher likelihood to fuse, and better sagittal alignment restoration.

6. Surgical methods

Surgical treatment for degenerative lumbar conditions causing axial low back pain can be considered in two broad categories: fusion procedures and motion-preservation techniques. For stable conditions causing low back pain, fusing two vertebrae together will eliminate the pain arising from their articulation. In an attempt to preserve motion, like in the hip or knee, and prevent accelerated degeneration at the adjacent level, motion-preservation strategies have been developed. For more unstable conditions, such as spondylolisthesis or scoliosis, fusion surgery with or without correction of the deformity, is considered the best surgical option.

6.1 Lumbar fusion

Spinal fusion is the surgical attempt at bonding two vertebrae together to stop the motion between them and restore the normal anatomical relationships. Fusion procedures are most commonly performed for those who are considered candidates for surgery. There are a variety of fusion techniques that may include the use of instrumentation, the location of fusion (interbody, intertransverse, interspinous, etc.), the approach (posterior, anterior, lateral), and the type of graft material used (e.g. autograft, allograft, osteogenic biologics) or a combination. A detailed account of all of these techniques is beyond the scope of this chapter.

The most commonly employed fusion technique is the posterior approach using pedicle screw-rod instrumentation and fusion across the transverse processes or facet joints (Figure 6). Pedicle screw placement is a technically demanding procedure, but it is the most commonly used technique to stabilize the spine. A retrospective study showed that the rate of screw misplacement can reach 6.7 percent, but no major neurological compromise was observed (Jutte and Castelein, 2002). Therefore, pedicle screw fixation is safe and has an acceptable complication rate despite pedicle breach. Spinal fixation can also be performed with a variety of other instrumentation, such as screws alone, hooks, plates, or wires. Non-instrumented fusions remain a viable option, however, they fail to stabilize the spine during the healing process and are associated with higher rates of failure of fusion (pseudarthrosis).

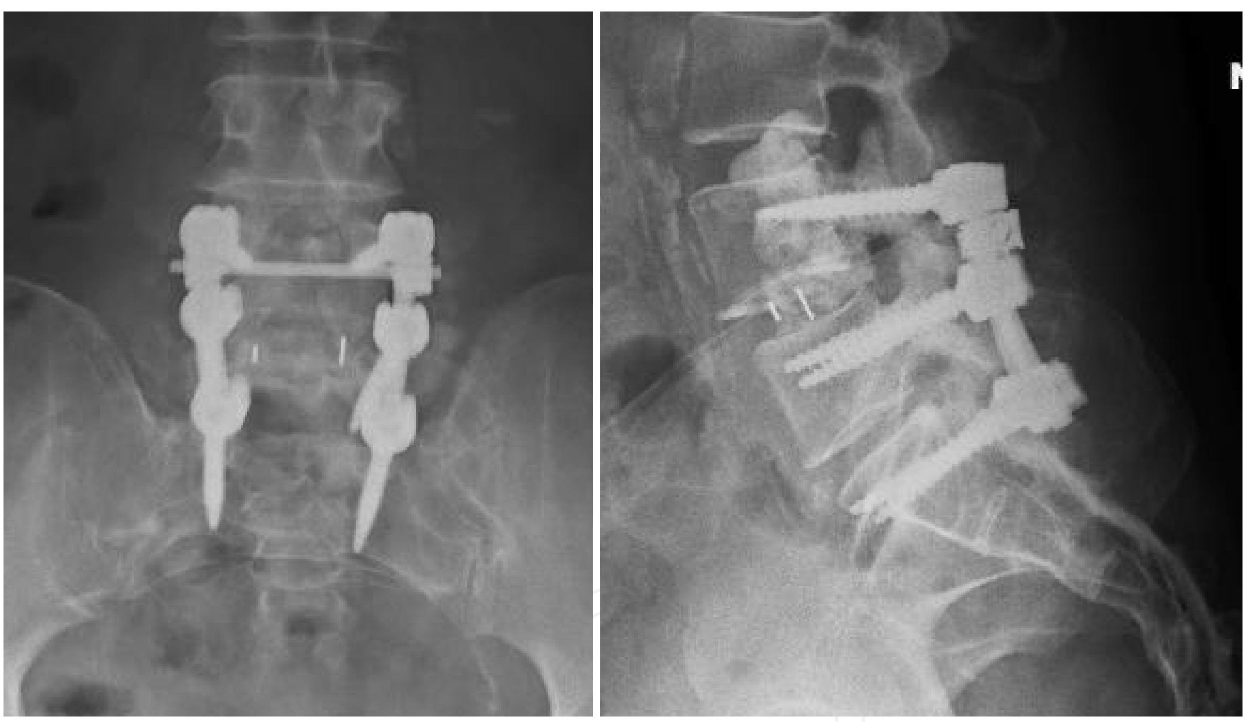


Fig. 6. Posterior and anterior fusion through posterior-based approach.
AP and lateral radiographs of two-level fusion with posterior pedicle screw-rod construct and TLIF at L4-5. (identified by radio-opaque vertical lines).

Anterior fusions through the disc spaces improve our ability to restore the normal anatomy of the anterior column of the spine by restoring normal disc height and curvature. Generally accepted indications for interbody fusions include degenerative disc disease, disc collapse with resultant neuroforaminal stenosis, and the need to restore sagittal and coronal balance. Interbody fusion creates a bond between two vertebral bodies through the disc space and can be done in combination with posterior fusion or as a stand-alone technique. Anterior fusion can be approached via several different routes: posterior, lateral or directly anterior. The posterior approach, most commonly done in association with a posterior fusion and/or decompression, is performed through a posterolateral approach into the disc space similar to removing a herniated disc fragment. There are two commonly used methods for interbody fusion done through a posterior approach: the posterior lumbar interbody fusion (PLIF) and the transforaminal lumbar interbody fusion (TLIF). PLIF is performed bilaterally and uses the same approach as disc fragment removal. A laminotomy or laminectomy is created to allow exposure of the nerve roots, which are carefully retracted and mobilized. Once the disc is identified, a window is created in the disc, the disc material is removed and the vertebral endplates are denuded of cartilage until there is bleeding bone. A prosthetic cage or structural allograft bone filled with bone graft is inserted into the disc space on both sides. TLIF involves resection of the facet and unroofing the neuroforamen on one side only to get to the posterolateral corner of the intervertebral disc. The traversing nerve root requires less retraction with the TLIF since the approach is slightly more lateral than PLIF. Once inside the disc, it is prepared in a similar way as PLIF. A prosthetic cage or structural allograft filled with bone graft is inserted into the disc space only from one side and placed in a central position inside the disc space (Figure 6). The difference between the two is that TLIF entails less neural manipulation to get to the vertebral disc and is done with a unilateral approach so it is more widely practiced. They both take advantage of the commonly used posterior approach to establish access to the anterior column of the spine.

Anterior lumbar interbody fusion (ALIF) approaches the spine directly anteriorly through the abdomen either through a trans-peritoneal or retroperitoneal approach. The rectus abdominus is retracted laterally which makes this approach truly muscle-preserving. The advantage over a posterior interbody approach (i.e. PLIF or TLIF) is ease of clearing out the disc for fusion, the ability to place a large graft for better restoration of normal anatomical height and better fusion rates, and obviating the need to retract the thecal sac or nerve roots. The potential risks include vascular injury, ileus, and retrograde ejaculation in males.

The lateral trans-psoas approach, is a relatively new procedure that has been gaining in popularity (Figure 7). The patient is placed in the lateral position, and with the use of fluoroscopy and nerve monitoring, a safe corridor through the retroperitoneum and psoas muscle is created to access the disc. While the obvious advantages are that it avoids the need for a posterior approach and can correct spinal instabilities or deformities, it cannot be used to access the L5-S1 disc space.

6.2 Motion-preservation techniques

The technology for motion-preservation techniques are developing at an exponential rate and include a wide range of options such as simple as direct pars repair (Figure 8) (for isthmic spondylolisthesis), interspinous spacers, to more complex devices such as disc replacement, facet replacement, and posterior dynamic stabilizations (Figure 9). Because they are relatively novel concepts, there is a lack of long-term clinical studies demonstrating their effectiveness and safety. While disc replacement is indicated primarily for discogenic pathology, facet replacement aims to treat posterior degeneration and dynamic stabilization intends to limit, but not abolish motion in an unstable spine. The purported benefits of

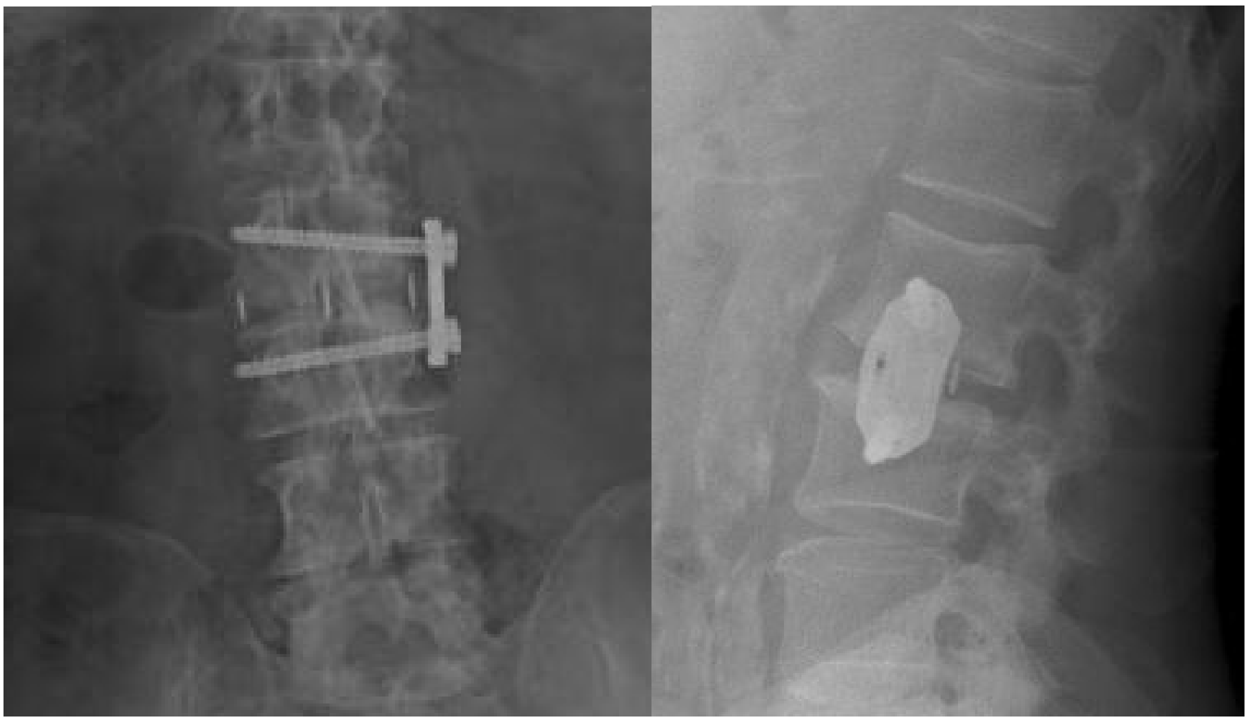


Fig. 7. Lateral lumbar interbody fusion.
AP and lateral radiographs of the lumbar spine showing lateral trans-psoas interbody fusion at the L2-L3 level with a side plate and interbody fusion mass as depicted by the white markers.

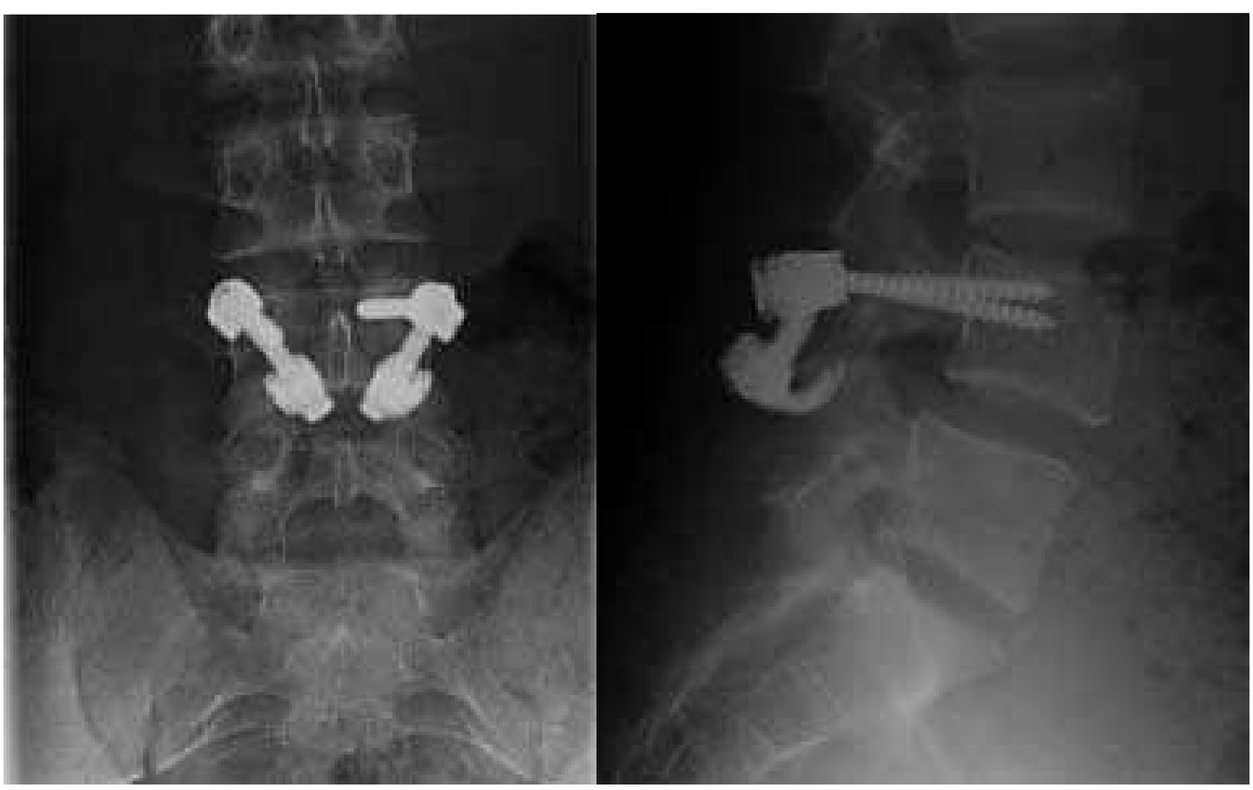


Fig. 8. Pars repair.
AP and lateral radiographs of the lumbar spine showing pars repair of L4 with pedicle screws, hooks, and rods.

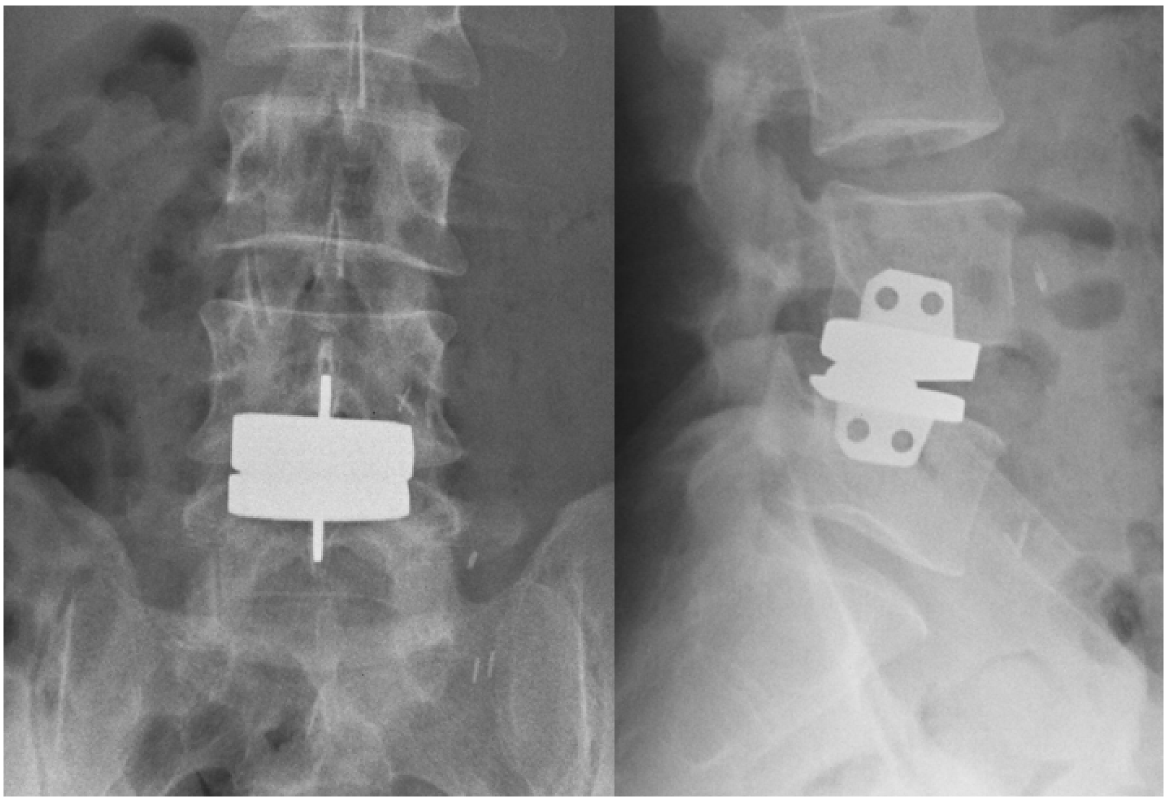


Fig. 9. Artificial total disc replacement.
AP and lateral radiographs of an artificial disc replacement at L4-5.

lumbar disc replacement, facet replacement, and dynamic stabilization are to maintain normal motion of the lumbar spinal segment and therefore to potentially decreasing the risk of degeneration at the adjacent segments. Mid-term outcomes of single level total disc replacement showed sustained improved outcome measures at an average follow up of 44.9 months in the treatment of DDD (Scott-Young et al, 2011). However, complications reported in literature such as implant subsidence, loosening, early wear, displacement, malposition, and the difficulty with revision surgery, have limited its widespread use.

7. Conclusion

Surgical treatment for low back pain remains controversial largely due to confusion in terminology and the inability of literature to stratify the results based on specific diagnostic indication. Low back pain should be viewed as a symptom, not a disease or diagnosis. When considered only as a diagnosis, study results are mixed and confounded due to the many different causes. Therefore, it is imperative to elucidate the conditions causing low back pain whether structural or non-structural. When stratified into diagnostic subgroups, results of surgery differ. For example, surgery is beneficial for more structural abnormalities, in particular those with more instability such as spondylolisthesis and degenerative scoliosis, as opposed to non-structural conditions which are better treated with non-surgical modalities. While the preferred method of treatment for these degenerative conditions is a non-surgical approach, there are many patients who are candidates for surgery. Although the traditional surgical strategy for structural degenerative conditions is fusion, motion-sparing techniques are showing promise, however, long-term studies are needed. More unstable degenerative conditions benefit more from fusion procedures with correction of deformities. Only with a more refined diagnostic ontology and a better understanding of the pathomechanical processes, can we hope to determine the best treatments available for patients suffering from these conditions.

8. References

Andersson, G. (1997). The epidemiology of spinal disorders, In: The Adult Spine: Principles and Practice, Frymoyer J et al, pp93-141, Raven Press, ISNB 978-0781703291, New York, USA

Andersson, G. (1999). Epidemiologic features of chronic low back pain. *Lancet*, 354, 1999, pp. 581-585

Atlas, SJ; Chang, Y; Kammann, E; Keller, RB; Deyo, RA & Singer, DE. (2000). Long-term disability and return to work among patients who have a herniated lumbar disc: the effect of disability compensation. *J Bone Joint Surg Am*, 82(1), Jan 2000, pp. 4-15

Berven, SH; Deviren, V; Smith, JA; Hu, S & Bradford, D. (2003). Management of fixed sagittal plane deformity: outcome of combined anterior and posterior surgery. *Spine*, 28, 2003, pp. 1710-1715

Berven, S; Deviren, V; Demir-Deviren, S; Hu, S & Bradford, D. (2003). Studies in the modified Scoliosis Research Society Outcomes Instrument in adults: validation, reliability, and discriminatory capacity. *Spine*, 28, 2003, pp. 2164-2169

Beutler, WJ; Fredrickson, BE; Murtland, A; Sweeney, CA; Grant, WD & Baker, D. (2003). The natural history of spondylolysis and spondylolisthesis: 45-year follow-up evaluation. *Spine,* 28. 2003, pp. 1027-1035

Bjarke Christensen, F; Stender Hansen, E; Laursen, M; Thomsen, K & Bünger, CE. (2002). Long-term functional outcome of pedicle screw instrumentation as a support for posterolateral spinal fusion: randomized clinical study with a 5-year follow-up. *Spine,* 27, 2002, pp. 1269-1277

Blumenthal, S; McAfee, PC; Guyer, RD, Hochschuler, S; Geisler, F; Holt, T; Garcia, R; Regan, J & Ohnmeiss, D. (2005). A prospective, randomized, multicenter Food and Drug Administration investigational device exemptions study of lumbar total disc replacement with the CHARITE artificial disc versus lumbar fusion: Part I. Evaluation of clinical outcomes. *Spine,* 30, 2005, pp. 1565-1575

Boden, SD; Riew, KD; Yamaguchi, K; Branch, T; Schellinger, D & Wiesel, S. (1996) Orientation of the lumbar facet joints: Association with degenerative disc disease. J Bone Joint Surg Am. 78, 1996, pp. 403-411

Boden, SD & Wiesel, SW. (1990). Lumbosacral segmental motion in normal individuals: Have we been measuring instability properly?. *Spine*, 5, 1990, pp. 571-576

Bone and Joint Decade. US Bone and Joint Decade Web site. (2005). The Burden of Musculoskeletal Diseases in the United States. Accessed December 28, 2005. Available from: http://www.usbjd.org/index.cfm

Boxall, D; Bradford, DS & Winter RB. (1979). Management of severe spondylolisthesis in children and adolescents. *J Bone Joint Surg,* 61A, 1979, pp. 479-495

Bridwell, KH; Edwards, CC & Lenke, LG. (2003). The pros and cons to saving the L5-S1 motion segment in a long scoliosis fusion construct. *Spine,* 28, 2003, pp. S234-S242

Bridwell, KH; Glassman, S; Horton, W; Shaffrey, C; Schwab, F; Zebala, L; Lenke, L; Hilton, J; Shainline, M; Baldus, C & Wooten, D. (2009). Does treatment (nonoperative and operative) improve the two-year quality of life in patients with adult symptomatic lumbar scoliosis: A prospective multicenter evidence-based medicine study. *Spine,* 34, 2009, pp. 2171-2178

Brox, J; Reikeras, O; Nygaard, O; Sorensen, R; Indahl, A; Holm, I; Keller, A; Ingebrigtsen, T; Grundnes, O; Lange, J & Friis, A. (2006). Lumbar instrumented fusion compared with cognitive intervention and exercises in patients with chronic back pain after previous surgery for disc herniation: a prospective randomized controlled study. *Pain*, 122, 2006, pp. 145–155

Button, G; Gupta, M; Barrett, C; Cammack, P & Benson, D. (2005). Three- to six-year follow-up of stand-alone BAK cages implanted by a single surgeon. *Spine J,* 5, 2005, pp. 155-160

Carreon, L; Glassman, S & Howard, J. (2008). Fusion and nonsurgical treatment for symptomatic lumbar degenerative disease: a systematic review of Oswestry Disability Index and MOS Short Form-36 outcomes. *Spine J,* 8, 2008, pp. 747-755

Chaput, C; Padon, D; Rush, J; Lenehan, E & Rahm, M. (2007) The significance of increased fluid signal on magnetic resonance imaging in lumbar facets in relationship to degenerative spondylolisthesis. *Spine,* 32, 2007, pp.1883-1887

Chin, K; Furey, C & Bohlman, H. (2009). Risk of progression in de novo low-magnitude degenerative lumbar curves: natural history and literature review. *Am J Orthop,* 38, 2009, pp. 404-409

Cho, K; Suk, S; Park, S; Kim, J; Kim, S; Lee, T; Lee, J & Lee, JM. (2008). Short fusion versus long fusion for degenerative lumbar scoliosis. *Eur Spine J,* 17, 2008, pp. 650-656

Chou, R; Atlas, S; Stanos, S & Rosenquist, R. (2009). Nonsurgical Interventional Therapies for Low Back Pain: A Review of the Evidence for an American Pain Society Clinical Practice Guideline. *Spine,* 34, 2009, pp. 1078-1093

Chou, R; Baisden, J; Carragee, E; Resnick, D; Shaffer, W & Loeser, J. (2009). Surgery for low back pain: a review of the evidence for an American Pain Society Clinical Practice Guideline. *Spine,* 34, 2009, pp. 1094-1109

Crandall, DG & Revella, J. (2009). Transforaminal lumbar interbody fusion versus anterior lumbar interbody fusion as an adjunct to posterior instrumented correction of degenerative lumbar scoliosis: Three year clinical and radiographic outcomes. *Spine*, 34, 2009, pp. 2126-2133

Deviren, V; Berven, S; Kleinstueck, F; Antinnes, J; Smith, JA & Hu, S. (2002). Predictors of flexibility and pain patterns in thoracolumbar and lumbar idiopathic scoliosis. *Spine*, 27, 2002, pp. 2346-2349

Dreyfuss, P; Halbrook, B; Pauza, K; Joshi, A; McLarty, J & Bogduk, N. (2000). Efficacy and validity of radiofrequency neurotomy for chronic lumbar zygapophysial joint pain. *Spine*, 25, 2000, pp. 1270-1277

Fairbank, J; Frost, H; Wilson-MacDonald, J; Yu, L; Barker, K & Collins, R. (2005). Randomised controlled trial to compare surgical stabilisation of the lumbar spine with an intensive rehabilitation programme for patients with chronic low back pain: the MRC spine stabilisation trial. *BMJ,* 330, 2005, pp. 1233

Fanuele, JC; Birkmeyer, NJ; Abdu, WA; Tosteson, TD & Weinstein, JN. (2000). The Impact of Spinal Problems on the Health Status of Patients: Have We Underestimated the Effect?. *Spine*, 25, 2000, pp. 1509-1514

Fischgrund, JS; Mackay, M; Herkowitz, HN; Brower, R; Montgomery, DM & Kurz, LT. (1997). Degenerative lumbar spondylolisthesis with spinal stenosis: a prospective, randomized study comparing decompressive laminectomy and arthrodesis with and without spinal instrumentation. *Spine,* 22, 1997, pp. 2807-2812

Fredrickson, BE; Baker, D; McHolick, WJ; Yuan, H & Lubicky, J. (1984). The natural history of spondylolysis and spondylolisthesis. J *Bone Joint Surg*, 66A, 1984, pp. 699-707

Fritzell, P; Hagg, O; Wessberg, P & Nordwall, A. (2001). Swedish Lumbar Spine Study Group. 2001 Volvo Award Winner in Clinical Studies: lumbar fusion versus nonsurgical treatment for chronic low back pain: A multicenter randomized controlled trial from the Swedish Lumbar Spine Study Group. *Spine,* 26, 2001, pp. 2521–2532

Glassman, SD; Berven, S; Bridwell, KH; Horton, W & Dimar, J. (2005). Correlation of radiographic parameters and clinical symptoms in adult scoliosis. *Spine*, 30, 2005, pp. 682-688

Glassman, S; Carreon, L; Djurasovic, M; Dimar, J; Johnson, J; Puno, R & Campbell, M. (2009). Lumbar fusion outcomes stratified by specific diagnostic indication. *Spine J*, 9, 2009, pp. 13-21

Glassman, SD; Carreon, LY; Shaffrey, CI; Polly, D; Ondra, S; Berven, S & Bridwell, K. (2010). The costs and benefits of nonoperative management for adult scoliosis. *Spine,* 35, 2010, pp. 578-582

Grubb, S; Lipscomb, H & Suh, P. (1994). Results of surgical treatment of painful adult scoliosis. *Spine,* 19, 1994, pp. 1619-1627

Hagen, K; Hilde, G & Jamtvedt, G. (2004). Bed rest for acute low-back pain and sciatica. Cochrane Database Syst Rev CD001254

Hart, LG; Deyo, RA & Cherkin DC.(1995). Physician office visits for low back pain. Frequency, clinical evaluation, and treatment patterns from a U.S. national survey. *Spine,* 20, 1995, pp.11–19

Hanson, DS; Bridwell, KH; Rhee, JM & Lenke, LG. (2002). Correlation of pelvic incidence with low- and high-grade isthmic spondylolisthesis. *Spine,* 27, 2002, pp. 2026-202

Helenius, I; Lamberg, T & Osterman, K. (2006). Posterolateral, anterior, or circumferential fusion in situ for high-grade spondylolisthesis in young patients: A long-term evaluation using the Scoliosis Research Society questionnaire. *Spine,* 31, 2006, pp. 190-196

Herkowitz, H & Kurz, L. 1991. Degenerative lumbar spondylolisthesis with spinal stenosis: A prospective study comparing decompression with decompression and intertransverse process arthrodesis. *J Bone Joint Surg Am*, 73, 1991, pp. 802-808

Hicks, J; Singla, A; Shen, F & Arlet, V. (2010) Complications of pedicle screw fixation in scoliosis surgery; a systematic review. *Spine,* 35, 2010, pp. E465-470

Ibrahim, T; Tleyjeh, IM & Gabbar O. (2008) Surgical versus non-surgical treatment of chronic low back pain: A meta-analysis of randomised trials. *Int Orthop,* 32, 2008, pp. 107-113

Jutte, P & Castelein, R. (2002). Complications of pedicle screws in lumbar and lumbosacral fusions in 105 consecutive primary operations. *Eur Spine J,* 11, 2002, pp. 594-598

Kirkaldy-Willis, WH; Wedge, JH; Yong-Hing, K & Reilly, J. (1978). Pathology and pathogenesis of lumbar spondylosis and stenosis. *Spine,* 3, 1978, pp. 319-328

Manchikanti, L; Singh, V; Pampati, V; Damron, K; Barnhill, R; Beyer, C & Cash, K. (2001). Evaluation of the relative contributions of various structures in chronic low back pain. *Pain Physician,* 4, 2001, pp. 308-316

Mardjetko, S; Connolly, P & Shott, S. (1994). Degenerative lumbar spondylolisthesis: A meta-analysis of literature, 1970-1993. *Spine,* 19(20 Suppl), 1994, pp. 2256S-2265S

Matsunaga, S; Sakou, T; Morizono, Y; Masuda, A & Demirtas, A. (1990). Natural history of degenerative spondylolisthesis: Pathogenesis and natural course of the slippage. *Spine,* 15, 1990, pp. 1204-1210

Matsunaga, S; Ijiri, K & Hayashi, K. (2000). Nonsurgically managed patients with degenerative spondylolisthesis: A 10- to 18-year follow-up study. *J Neurosurg*, 93, 2000, pp.194-198

Meyerding, H. (1932) Spondylolisthesis: surgical treatments and results. *Surg Gyn Obstet*, 54, 1932, pp. 371-377

Mirza, SK & Deyo, RA. (2007). Systematic review of randomized trials comparing lumbar fusion surgery to nonoperative care for treatment of chronic back pain. *Spine,* 32, 2007, pp. 816-823

Molinari, RW; Bridwell, KH; Lenke, LG; Ungacta, FF & Riew, KD. (1999). Complications in the surgical treatment of pediatric high-grade, isthmic dysplastic spondylolisthesis: A comparison of three surgical approaches. *Spine*, 24, 1999, pp. 1701-1711

Möller, H & Hedlund, R. (2000). Surgery versus conservative management in adult isthmic spondylolisthesis: A prospective randomized study. Part 1. *Spine,* 25, 2000, pp. 1711-1715

Möller, H & Hedlund, R. (2000) Instrumented and noninstrumented posterolateral fusion in adult spondylolisthesis: A prospective randomized study. Part 2. *Spine,* 25, 2000, pp. 1716-1721

Morelos, O & Pozzo, AO. (2004). Selective instrumentation, reduction and repair in low-grade isthmic spondylolisthesis. *Int Orthop,* 28, 2004, pp. 180-182

Mundis, G; Akbarnia, B & Phillips, F. (2010). Adult deformity correction through minimally invasive lateral approach techniques. *Spine,* 35, 2010, pp. S312-321

Poussa, M; Remes, V; Lamberg, T; Tervahartiala, P; Schlenzka, D; Yrjonen, T; Osterman, K; Seitsalo, S & Helenius, I. (2006). Treatment of severe spondylolisthesis in adolescence with reduction or fusion in situ: long-term clinical, radiologic, and functional outcome. *Spine,* 31, 2006, pp. 583-590

Pritchett, JW & Bortel, DT. (1993). Degenerative symptomatic lumbar scoliosis. *Spine*, 18, 1993, pp. 700–703

Saraste, H. (1987). Long-term clinical and radiological follow-up of spondylolysis and spondylolisthesis. *J Pediatr Orthop,* 7, 1987, pp. 631-638

Schlenzka, D; Remes, V; Helenius, I; Lamberg, T; Tervahartiaia, P, Yrjonen, T; Tallroth, K; Osterman, K; Seitsalo, S & Poussa, M. (2006). Direct repair for treatment of symptomatic spondylolisthesis in young patients: no benefit in comparison to segmental fusion after a mean follow-up of 14.8 years. *Eur Spine J,* 15, 2006, pp. 1437-1447

Schwarzer, AC; Aprill, CN; Derby, R; Fortin, J; Kine, G & Bogduk, N. (1995). The prevalence and clinical features of internal disc disruption in patients with chronic low back pain. *Spine,* 20, 1995, pp. 1878-1883

Scott-Young, M; Lee, M; Nielsen, D; Magno, C; Kimlin, K & Mitchell, E. (2011). Clinical and Radiological Mid-Term Outcomes of Lumbar Single-Level Total Disc Replacement. *Spine,* September, 2011

Shufflebarger, HL & Geck, MJ. (2005). High-grade isthmic dysplastic spondylolisthesis: Monosegmental surgical treatment. *Spine,* 30, 2005, pp. S42-S48

Shufflebarger, H; Suk, SI & Mardjetko, S. (2006). Debate: Determining the upper instrumented vertebra in the management of adult degenerative scoliosis: stopping at T10 versus L1. *Spine,* 31, 2006, pp. S185-S194

Smith, JS; Fu, KM; Urban, P & Shaffrey, C. (2008) Neurological symptoms and deficits in adults with scoliosis who present to a surgical clinic: Incidence and association with the choice of operative versus nonoperative management. *J Neurosurg Spine,* 9, 2008, pp. 326-331

Smith, JS; Shaffrey, CI; Berven, S; Glassman, S; Hamill, C; Horton, W; Ondra, S; Schwab, F; Shainline, M; Fu, K & Bridwell, K. (2009). Spinal Deformity Study Group: Improvement of back pain with operative and nonoperative treatment in adults with scoliosis. *Neurosurgery,* 65, 2009, pp. 86-93

Smith, JS; Shaffrey, CI; Berven, S; Glassman, S; Hamill, C; Horton, W; Ondra, S; Schwab, F; Shainline, M; Fu, K & Bridwell, K. (2009). Spinal Deformity Study Group: Operative versus nonoperative treatment of leg pain in adults with scoliosis: A retrospective review of a prospective multicenter database with two-year follow-up. *Spine,* 34, 2009, pp. 1693-1698

Swank, S; Lonstein, JE; Moe, JH; Winter, RB & Bradford, DS. (1981). Surgical treatment of adult scoliosis. A review of two hundred and twenty-two cases. *J Bone Joint Surg Am,* 63, 1981, pp. 268-287

Taillard, W. (1976). Etiology of spondylolisthesis. *Clin Orthop*, 115, 1976, pp. 30-39

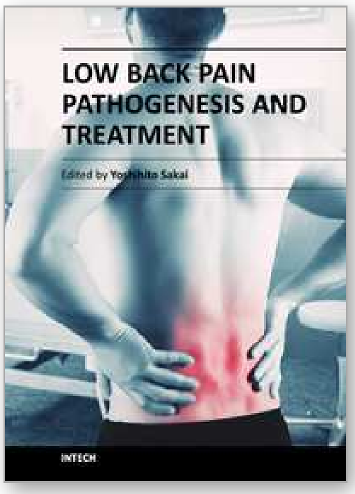
Transfeldt, E; Topp, R; Mehbod, A & Winter, R. (2010). Surgical Outcomes of Decompression, Decompression With Limited Fusion, and Decompression With Full Curve Fusion for Degenerative Scoliosis With Radiculopathy. *Spine.* 35, 2010, pp. 1872-1875

van Duijvenbode, IC; Jellema, P & van Poppel, MN. (2008). Lumbar supports for prevention and treatment of low back pain. Cochrane Database Syst Rev CD001823

van Tulder, M; Koes, B & Bombardier, C. (2002). Low back pain. *Best Pract Res Clin Rheumatol,* 16, 2002, pp. 761–775

Weinstein, JN; Lurie, JD; Tosteson, TD; Zhao, W; Blood, E; Tosteson, A; Birkmeyer, N; Herkowitz,H; Longley, M; Lenke, L; Emery, S & Hu, S. (2009). Surgical compared with nonoperative treatment for lumbar degenerative spondylolisthesis. *J Bone Joint Surg*, 91-A, 2009, pp. 1295-1304

Zigler, J; Delamarter, R; Spivak, JM; Linovitz, R; Danielson, G; Haider, T; Cammisa, F; Zuchermann, J; Balderston, R; Kitchel, S; Foley, K; Watkins, R; Bradford, D; Yue, J; Yuan, H; Herkowitz, H; Geiger, D; Bendo, J; Peppers, T; Sachs, B; Girardi, F; Kropf, M & Goldstein, J. (2007). Results of the prospective, randomized, multicenter Food and Drug Administration investigational device exemption study of the ProDisc-L total disc replacement versus circumferential fusion for the treatment of 1-level degenerative disc disease. *Spine,* 32, 2007, pp. 1155-1162



Low Back Pain Pathogenesis and Treatment

Edited by Dr. Yoshihito Sakai

ISBN 978-953-51-0338-7

Hard cover, 244 pages

Publisher InTech

Published online 14, March, 2012

Published in print edition March, 2012

Low back pain is a common disorder which affects the lumbar spine, and is associated with substantial morbidity for about 80% of the general population at some stages during their lives. Although low back pain usually is a self-limiting disorder that improves spontaneously over time, the etiology of low back pain is generally unknown and the diagnostic label, "non-specific low back pain", is frequently given. This book contains reviews and original articles with emphasis on pathogenesis and treatment of low back pain except for the rehabilitative aspect. Consisting of three sections, the first section of the book has a focus on pathogenesis of low back pain, while the second and third sections are on the treatment including conservative and surgical procedure, respectively.