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Surgical treatment of symptomatic degenerative lumbar spondylolisthesis by decompression and instrumented fusion

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Abstract Degenerative spondylolisthesis is characterized by the slippage of one vertebral body over the one below, with association of intervertebral disc degeneration and degenerative arthritis of the facet joints, which cause spinal stenosis. The aim of this study was to evaluate the clinical and radiographic results of 22 patients with symptomatic degenerative spondylolisthesis, operated on by decompressive laminectomy and instrumented posterolateral fusion associated with interbody fusion (PLIF). Mean age at surgery was 64 years (range, 57–72). Clinical results were evaluated on a questionnaire at the last follow-up visit concerning postoperative low back and leg pain, restriction of daily life activities, and resumption of sports activity. Lumbar spine radiographs were used to evaluate the status of fixation devices, the reduction of the spondylolisthesis, the lumbar sagittal balance and the presence of spinal fusion. No intraoperative or postoperative complications were encountered. There were no superficial or deep infections, fixation device loosening, or hardware removal. Mean follow-up time was 4 years (range, 3–6 years). Clinical outcome was excellent or good in 19 patients and fair in 3 patients. Preoperatively, mean forward vertebral slipping on neutral lateral radiographs was 5 mm, while postoperatively it decreased to 3 mm. Preoperatively, mean sagittal motion was 3 mm and angular motion was 8°, while postoperatively these values decreased to 1 mm and 1°, respectively. This study demonstrated that spinal decompression followed by transpedicular instrumentation associated with PLIF technique is a valid surgical option for the treatment of degenerative spondylolisthesis with symptomatic spinal stenosis. Clinical outcome, intended as relief of pain and resumption of activity, was improved significantly and fusion rate was high.

Key words Degenerative spondylolisthesis • Interbody fusion • Pedicle instrumentation • Spinal fusion

Introduction

Spondylolisthesis is a disorder that usually affects the lumbar spine and is defined as the slippage of one vertebral body over the one below. Spondylolisthesis can be caused by many pathological entities, and all types of spondylolistheses are classified according to the Marchetti and Bartolozzi etiopathological classification (Fig.1) [1].

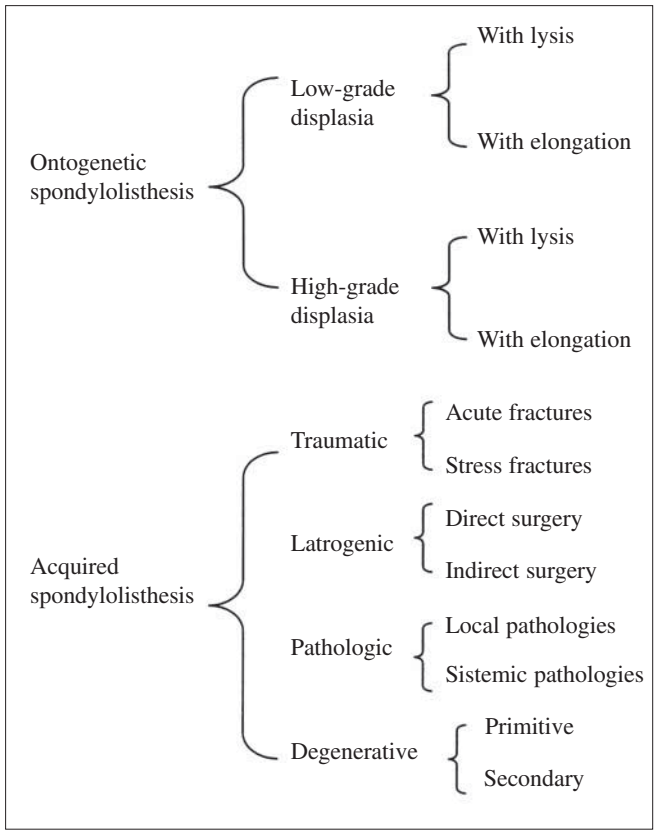

Fig. 1 The Marchetti and Bartolozzi etiopathological classification of spondylolistheses [1]

Degenerative spondylolisthesis represents a distinct entity characterized by intervertebral disc degeneration and degenerative arthritis of the facet joints, and it differs from all other spondylolistheses in that the pars interarticularis remains intact [2–4]. Both intervertebral disc degeneration with loss of disc height and enlargement of the facet joints cause spinal stenosis, which may affect the vertebral canal, the foramina or the lateral recess [3]. Hypertrophy of the ligamentum flavum also contributes to spinal stenosis. Degenerative spondylolisthesis influences the mechanics of the lumbar spine, producing instability of one or more segments [3]. As a result, rotational vertebral subluxation may occur, with the coexistence of degenerative scoliosis.

Degenerative spondylolisthesis occurs more commonly at the L4-L5 level and the displacement rarely exceeds 30% [5]. It affects persons older than 50 years, and it is more frequent in women due to an increased ligamentous laxity and in black persons due to a higher incidence of L5 sacralization [6–9]. Another risk factor for degenerative spondylolisthesis is the more horizontal sagittal facet joint orientation. This anatomical variation is more common at the L4-L5 facet joints [6–8]. The L5-S1 level can also be affected by degenerative spondylolisthesis, particularly in cases of increased pelvic incidence (defined as the angle between the line perpendicular to the sacral plate and the line connecting the midpoint of the sacral plate to the bi-coxofemoral axis) [10–13].

Degenerative spondylolisthesis is a slowly progressive pathology, which explains why it is generally asymptomatic. There can be four clinical manifestations of degenerative spondylolisthesis as a result of spinal stenosis and instability: low back pain, radiculopathy, neurogenic claudication, and cauda equina syndrome [5, 8].

The optimal treatment for degenerative spondylolisthesis is still controversial. Initially, conservative treatment is recommended; in fact, conservative treatment is effective and only 10%–15% of patients need to undergo a surgical operation [4, 5, 8]. Surgery aims to reduce pain and to stabilize the spine in order to prevent progression of the pathology. Surgical options include decompression alone, decompression and non-instrumented spinal fusion, and decompression associated with instrumented spinal fusion [7, 8, 14–22].

The aim of this study was to evaluate the clinical and radiographic results of a series of patients with symptomatic degenerative spondylolisthesis who were operated on by decompressive laminectomy and instrumented posterolateral fusion associated with interbody fusion.

Materials and methods

Between 1998 and 2003, 22 patients were treated. There were 14 women and 8 men with a mean age of 64 years (range, 57–72). None of the patients had a history of trauma, infection or neoplasm of the spine.

Preoperative assessment

All patients had a clinical diagnosis of degenerative spondylolisthesis associated with spinal tenosis. Twenty patients complained of low back pain, while unilateral or bilateral radicular pain was present in 14 patients. Neurogenic claudication, characterised by pain, weakness and burning sensation along one or both legs after walking a short distance, was the clinical expression of spinal stenosis, which was present in all patients. On inspection, loss of the lumbar lordosis was presented in 9 patients.

Preoperative imaging consisted of plain radiography, computed tomography (CT) and magnetic resonance imaging (MRI) in all patients. Plain radiographs of the lumbar spine included anteroposterior, lateral and oblique (left and right) views. On lateral view radiographs, the grade of spondylolisthesis was determined, by measuring the ratio between the displacement and the total width of the vertebral endplate: grade 1, up to 25%; grade 2,

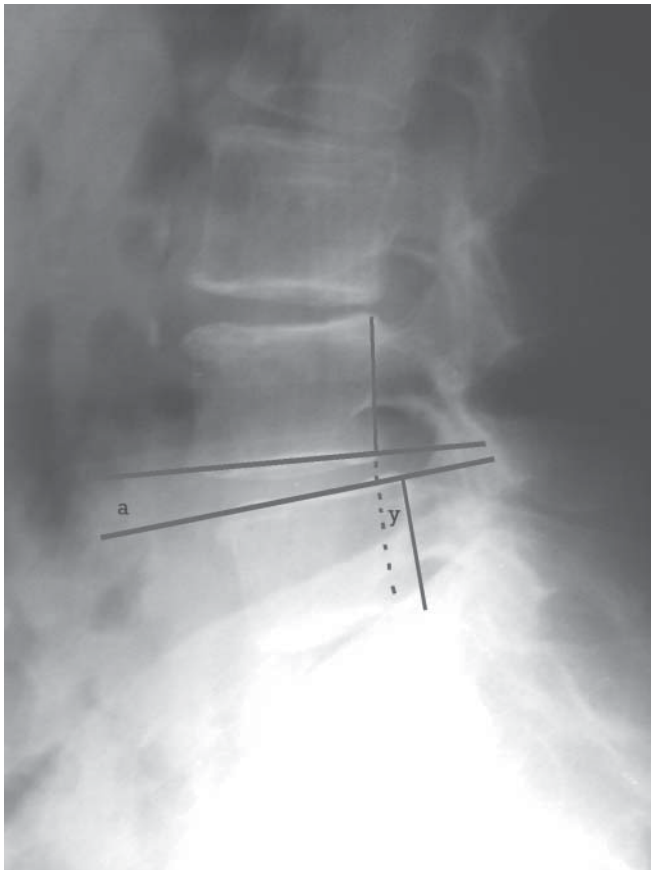

Fig. 2 A lateral radiograph of the lumbar spine of a patient with degenerative spondylolisthesis. Two lines were drawn: one was tangent to the lower endplate of the upper vertebra and the other was tangent to the upper endplate of the subadjacent vertebra. The angle *a* indicates the angle between the two vertebrae. The change in angle *a* between maximal flexion and maximal extension states indicates the angular displacement between the two vertebrae. The distance *y* is the amount of forward vertebral slippage on the subadjacent vertebra. The change in distance *y* between maximal flexion and maximal extension states indicates the sagittal displacement between the two vertebrae

up to 50%; grade 3, up to 75%; and grade 4, up to 100%. Spondylolisthesis was classified as grade 1 in 15 patients and as grade 2 in 7. In this series, 13 patients presented degenerative spondylolisthesis at the L4-L5 level, the L3-L4 level was involved in 5 patients, and the L5-S1 level in 4. To quantify spinal segmental instability, lateral radiographs in maximal flexion and maximal extension were obtained. Two lines were drawn: a line tangent to the lower endplate of the upper vertebra and a line tangent to the upper endplate of the subadjacent vertebra (Fig. 2); the angle a between the lines indicated the angular displacement between the two vertebrae. Then, two more lines were drawn and flush with the posterior aspect of the vertebrae; the distance y between these two lines, at the level of the lower tangent, indicated the forward vertebral slippage. Sagittal motion was determined as the change in y on radiographs taken in maximun flexion and maximum extension.

CT demonstrated the presence of stenosis at the level of spodylolisthesis in all patients, while signs of stenosis at the adjacent levels were evident in 14 patients. MRI showed involvement of the cauda equina and of the nerves; severe disk degeneration was present in all cases with dehydration and black disc at the level of the spondylolisthesis. Besides, in 14 cases a compression of the dural sac by the degenerated disk was visible.

All patients had been treated conservatively for a mean period of 4 months. Conservative treatment had consisted of nonsteroidal anti-inflammatory drugs, cortisone, and different types of physical therapy, such as heat, lumbar massages, application of ultrasounds, and aerobic exercise. In 4 patients, epidural steroid injections had been performed.

Indications for surgery included presence of symptoms refractory to conservative treatments and severe radiculopathy. The level of spinal decompression and the extent of spinal fusion were planned preoperatively according to clinical symptoms and imaging results. Thirteen patients received bilateral decompressive laminectomy of one level; 7 patients had this treatment at 2 levels and 2 patients were thus treated at 3 levels. Enlargement of the nerve foramina was performed in those patients who complained of radiculopathy. The spinal fusion level was L4-L5 in 10 cases, L3-L5 in 5 cases, L5-S1 in 3 cases, L4-S1 in 3 cases, and L3-L4 in 1 patient. Instrumented posterolateral fusion was associated with posterior interbody lumbar fusion (PLIF) in all cases.

Surgical technique

All patients were operated under general anesthesia in prone position. A longitudinal median skin incision was performed over the lumbar segments involved. After exposure of the spinal processes, the laminas and the transverse processes, the entry point for pedicle screw placement was individuated. The pedicle screw entry point of a lumbar vertebra was placed at the distal part of the superior articular process in correspondence to the transverse process; a minimal part of cortical bone at that point was removed. Under fluoroscopic control, every pedicle was cannulated with a K-wire placed oblique on the sagittal plane; tapping was then performed and a screw was inserted. In all cases, 5.5 mm length diameter polyaxial screws (XIA TITANIUM, Stryker SPINE, Kalamazoo, MI, USA) of 40–55 mm length were used.

When all screws were inserted, decompressive laminectomy was initiated. Since decompression can cause profuse bleeding, this was done as the second surgical step, in order to facilitate screw insertion. Once the cauda equina was freely moved, decompression was extended laterally, removing the osteophytes that reduce the foraminal canal space, and one-third to two-thirds of the superior articular process. The degenerated disc was removed and two previously modelled rods were placed into the screws in slight distraction, in order to restore the anterior column height and the foraminal height. An additional increase of the intervertebral and foraminal heights was reached by inserting an interbody cage. A polyetheretherketone (PEEK) cage (XIA TITANIUM, Stryker SPINE, Kalamazoo, MI, USA) filled with homologous cancellous bone graft was inserted into the intervertebral space, according to the PLIF technique, and a slight compression was applied to the rods. Only in cases of residual

foraminal stenosis was the foraminal canal completely opened, removing all the facets and osteophytes.

To favour posterolateral spinal fusion, the cancellous bone of the transverse processes and the remaining part of the articular processes was exposed and covered with homologous bone graft. Closure was routine. An aspiration drainage was used to avoid formation of postoperative haematoma.

Postoperative management

Drainage was removed 24 hours after surgery. Sitting was permitted on the first postoperative day, while standing and walking started 2 days after surgery. Rehabilitation began immediately and consisted of passive and active movements of the legs. After the first postoperative month, leg muscles were strengthened by static exercises and electrostimulation, while flexion-extension movements of the spine were avoided. Exercises without weight-bearing, such as bicycle and swimming, were permitted 6–8 weeks after surgery. An orthopaedic brace was used only by some patients who felt insecure when going out during the first 2 postoperative months.

All patients were examined clinically and radiographically at 1 and 3 months, at 1 year, and then yearly (Fig. 3). To evaluate clinical results, each patient was asked to fill out a questionnaire at the latest follow-up visit; questions concerned postoperative low back pain and leg pain (scored on a visual analogic scale from 0 to 10), restriction of daily life activities, and resumption of sports activity. The clinical result was considered to be excellent, good, fair or poor according to the criteria on Table 1. At

Table 1 Criteria used to assess clinical outcome

Excellent	Near complete relief of back or leg pain Resumption of unrestricted activities of daily life Resumption of sports activity
Good	Occasional back or leg pain Resumption of unrestricted activities of daily life Resumption of sports activity
Fair	Intermittent discomfort in the back or lower limb Significant restriction of activities of daily life Significant restriction of sports activity
Poor	Marked discomfort in the back or lower limb Significant restriction of activities of daily life Significant restriction of sports activity

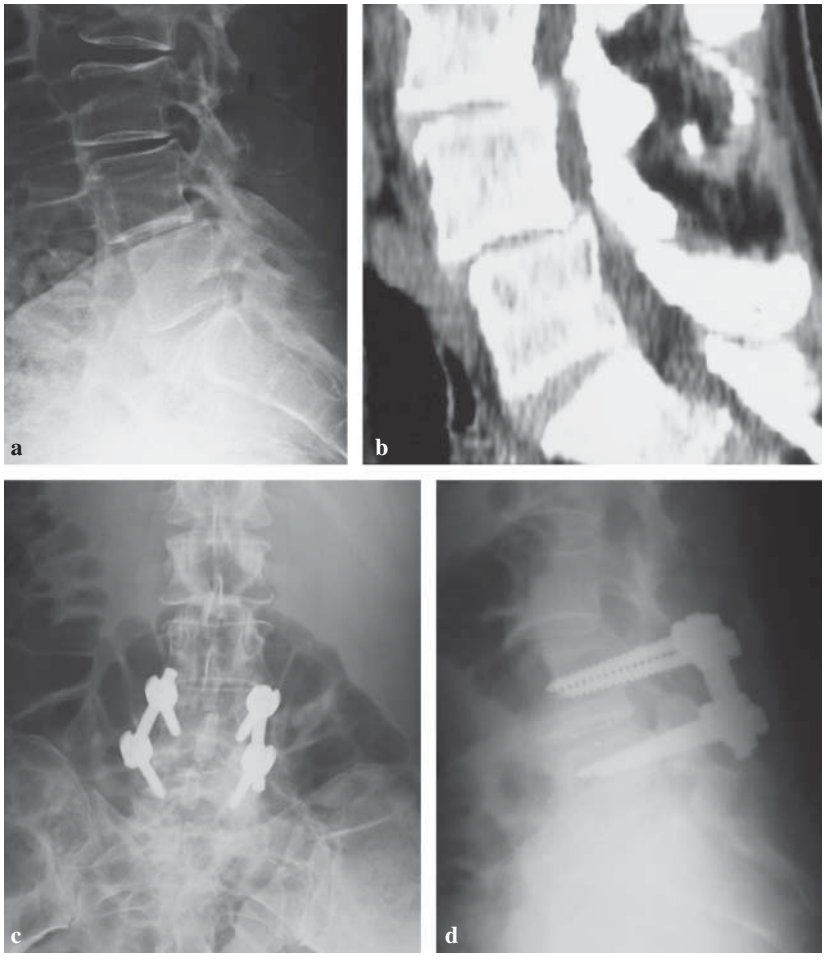

Fig. 3a-d *A 64-year-old woman with degenerative spondylolisthesis.* **a** Preoperative lateral radiograph showing listhesis of L4 over L5 with the pars interarticularis intact. **b** Preoperative computed tomogram showing spinal stenosis at the level of spondylolisthesis. **c**, **d** Radiographs at the 4-year follow-up demonstrating reduction of the deformity

the last control, lateral radiographs in maximal flexion and maximal extension of the lumbar spine, as well as standard anteroposterior and lateral views were obtained. These exams permitted to evaluate the status of the fixation devices, the reduction of the spondylolisthesis, the lumbar sagittal balance and the presence of spinal fusion.

Statistical analysis was performed to compare preoperative and postoperative clinical results by chi-square test. For the test, $p<0.05$ was set as significant.

Results

No intraoperative or postoperative complications were encountered in this series. There were no superficial or deep infections, fixation device loosening or hardware removal. Mean follow-up time was 4 years (range, 3–6 years).

Clinically, there was a statistically significant ($p<0.001$) improvement in low back pain and leg pain after surgery. In fact, the mean pain score was 7 (range, 5–8) preoperatively, while it reduced to a mean value of 1 (range, 0–1) at last available follow-up. All patients stated subjectively that their condition had improved compared to the preoperative one, and most of them had resumed unrestricted daily life activities. Clinical outcome was excellent or good in 19 patients and fair in 3 patients.

Postoperative radiographs showed that spondylolisthesis was reduced on the sagittal plane. In fact, preoperatively, mean forward vertebral slipping on neutral lateral radiographs was 5 mm, while postoperatively it had decreased to 3 mm. Fusion occurred in all cases: preoperatively, on lateral flexion-extension radiographs, mean sagittal motion was 3 mm and angular motion was 8°, while postoperatively these values had decreased to 1 mm and 1°, respectively.

Discussion

Degenerative changes of the lumbar spine are quite common in the elderly. Degenerative spondylolisthesis is a pathological entity with a slow progression, which may remain quiescent for many years and which becomes symptomatic when severe spinal stenosis is present. Patients present with chronic low back pain, leg pain and neurogenic claudication [3, 5, 7, 15].

Although most patients with degenerative spondylolisthesis and spinal stenosis respond to conservative treatment, when this becomes insufficient to control symptoms, surgery is indicated. It is widely accepted that the first surgical step consists of spinal decompression, and in severe cases, where decompression is quite wide, spine fusion is needed [3, 7, 15]. However, great controversy remains regarding the use of instrumentation in spinal fusion. Another point of disagreement is the connection between fusion rate and clinical outcome. In fact, a good clinical outcome can be achieved even without solid bone fusion [4].

Several studies reported better results using instrumentation to obtain spinal fusion. Fischgrund et al. [14] studied 68 patients with symptomatic degenerative spondylolisthesis who were divided into 2 groups according to whether or not they underwent instrumentation after spinal decompression. The study found that transpedicular instrumentation improved the fusion rate after posterolateral fusion. However, they found no significant difference in terms of clinical outcome between the two groups. Bridwell et al. [19] reported 49 patients with degenerative spondylolisthesis associated with spinal stenosis, who were operated on by decompression, decompression and fusion, or decompression and instrumentated fusion. They stated that the instrumentated fusion group had an improved fusion rate and significantly higher functional results.

In the current study, all patients had degenerative spondylolisthesis associated with spinal stenosis, and all underwent spinal decompression followed by instrumented spinal fusion. We believe that pedicle screw devices offer many advantages both to the surgeon and to the patient. In fact, it is possible to restore spinal alignment and to maintain it until arthrodesis becomes solid. Pedicular instrumentation permits slight distraction between the posterior spinal elements, which contributes to spinal decompression. Besides, the use of an interbody cage provides anterior column support and in the same time it increases intervertebral and neuroforaminal height, reducing nerve root compression. This way, part of the decompression is produced by the instrumentation, permitting in many cases to respect the facet joint, leaving intact a wide surface for a solid arthrodesis.

At a mean follow-up time of 4 years, clinical results were good or excellent in 86% of the patients. Radiographically, fusion was achieved in all cases and this was documented by the minimal sagittal and angular motion between the vertebrae. No failure of fixation devices occurred.

In summary, this study demonstrated that spinal decompression followed by transpedicular instrumentation associated with PLIF technique is a valid surgical option for the treatment of degenerative spondylolisthesis with symptomatic spinal stenosis. In fact, clinical outcome, intended as relief of pain and resumption of activity, was improved significantly and fusion rate was high.

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