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Clinical Study

Degenerative lumbar scoliosis in elderly patients: dynamic stabilization without fusion versus posterior instrumented fusion

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Abstract

BACKGROUND CONTEXT: Posterolateral fusion with pedicle screw instrumentation is currently the most widely accepted technique for degenerative lumbar scoliosis in elderly patients. However, a high incidence of complications has been reported in most series. Dynamic stabilization without fusion in patients older than 60 years has not previously been compared with the use of posterior fusion in degenerative lumbar scoliosis.

PURPOSE: To compare dynamic stabilization without fusion and posterior instrumented fusion in the treatment of degenerative lumbar scoliosis in elderly patients, in terms of perioperative findings, clinical outcomes, and adverse events.

STUDY DESIGN: A retrospective study.

PATIENT SAMPLE: Fifty-seven elderly patients were included. There were 45 women (78%) and 12 men (22%) with a mean age of 68.1 years (range, 61–78 years). All patients had degenerative de novo lumbar scoliosis, associated with vertebral canal stenosis in 51 cases (89.4%) and degenerative spondylolisthesis in 24 patients (42.1%).

OUTCOME MEASURES: Clinical (Oswestry Disability Index, visual analog scale, Roland-Morris Disability Questionnaire) and radiological (scoliosis and lordosis corrections) outcomes as well as incidence of complications.

METHODS: Patients were divided into two groups: 32 patients (dynamic group) had dynamic stabilization without fusion and 25 patients (fusion group) underwent posterior instrumented fusion. All the patients' medical records and X-rays were reviewed. Preoperative, postoperative, and follow-up questionnaires were obtained to evaluate clinical outcomes.

RESULTS: At an average follow-up of 64 months (range, 42–90 months), clinical results improved similarly in both groups of patients. Statistically superior scoliosis and final lordosis corrections were achieved with posterior fusion (56.9% vs. 37.3% and −46.8° vs. −35.8°, respectively). However, in the dynamic group, incidence of overall complications was lower (25% vs. 44%), and fewer patients required revision surgery (6.2% vs. 16%). Furthermore, lower average values of operative duration (190 vs. 240 minutes) and blood loss (950 vs. 1,400 cc) were observed in the dynamic group than in the fusion group.

CONCLUSIONS: In elderly patients with degenerative lumbar scoliosis, pedicle screw–based dynamic stabilization was less invasive with shorter operative duration, less blood loss, and lower adverse event rates than instrumented posterior fusion. Scoliosis curve reduction and lumbar lordosis were superior after fusion; however, dynamic stabilization achieved satisfying values of both these parameters, and these results were stable after an average follow-up of more than 5 years. Furthermore, there was no difference between the two techniques in terms of functional clinical outcomes at the last follow-up.

Keywords: Degenerative lumbar scoliosis; Dynamic stabilization; Posterior instrumented fusion

FDA device/drug status: Investigational (Dynesys System [Zimmer Spine]).

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EVIDENCE & METHODS

Context
Posterior dynamic stabilization (PDS) has been suggested as an alternative to rigid fixation and fusion for a variety of degenerative lumbar conditions. The authors report their experience using one such system for adults with degenerative scoliosis.

Contribution
In a retrospective review of outcomes in unmatched groups treated with either a PDS or a rigid fusion, the authors found similar clinical outcomes. Correction of deformity was superior with fusion, but less morbidity and need for revision was noted in the PDS group.

Implications
PDS is currently used at many centers in Europe, though less widely accepted in the US. Whereas early positive reports were published from company sponsored studies, these results have not been reproduced by independent (non–industry-funded) studies that suggested that PDS is perhaps inferior to fusion. This study provides further data on assigning the potential role of PDS for lumbar degenerative conditions. Unfortunately, as the groups were neither randomized nor well-matched, this study cannot resolve the question of when, if ever, this new technique may be a better choice than standard decompression alone with fusion.

Introduction

Degenerative lumbar scoliosis, also described as de novo or primary degenerative scoliosis [1], is a frequent disease in the elderly population. Its incidence is reported to be from 6% to 68% [2–5] and increases with age [6]. Two different studies [3,7] followed adults without a previous scoliosis and reported 7 [7] and 12 years [3] later, respectively, the development of a de novo scoliosis; the incidence was quite similar in both series: 36.7% [7] versus 34.4% [3].

Degenerative curves are located at thoracolumbar or lumbar levels and must be distinguished from degenerated preexisting idiopathic scoliosis. The degenerative curves in question develop de novo after skeletal maturity with no history of scoliosis. Decreased bone density was initially considered to be the cause of de novo lumbar scoliosis [2]. At present, asymmetric degenerative changes of the disc, vertebral body wedging, and facet joint arthritis are held to be the predominant causes [1,3,8,9]; disc degeneration appearing to be the starting point [3,8]. In the adult population, lateral end plate osteophytes longer than 5 mm and asymmetric tilt of a disc space greater than 3° are risk factors for development of de novo scoliosis [3].

Lumbar de novo scoliosis is frequently associated with degenerative spondylolisthesis and stenosis [6,10–12]. Moreover, progression of degenerative scoliosis can lead to decreased lumbar lordosis [6,8,13].

In elderly patients, medication for painful symptoms associated with degenerative scoliosis should be limited to short-term use [11]. Although nonsurgical procedures have unproven long-term efficacy in these patients [14], surgical treatment should be considered only after their failure.

The most frequent indication for surgical treatment is neurogenic claudication, followed by severe pain refractory to nonoperative procedures and progressive neurologic deficit [11,15]. Moreover, progression of scoliosis alone without other symptoms rarely warrant surgery in elderly patients [10].

Decompression alone has been proposed: it obtained satisfying results in patients with mild degenerative scoliosis and stabilizing osteophytes [16]. However, many authors [1,10,17,18] presented poor results, related to the progression of deformity.

Posterolateral fusion with pedicle screw instrumentation in addition to decompression is currently the most widely accepted technique [1,10,11,19–21]. However, the incidence of complications resulted high, ranging from 20% to 80% [1,17,20,21]: factors appearing to play important roles include older than 65 years, medical comorbidities, blood loss, and number of levels fused. In one study, excessive intraoperative blood loss was found to be the most significant risk factor for early postoperative complications [20]. The arthrodesis can increase operative time and blood loss and consequently the incidence of complications, especially in elderly patients [19,22,23]. In patients older than 75 years undergoing spinal fusion, one large cohort study reported a complication rate 1.9 times greater than that of age-matched patients who had surgery without fusion [22].

The purpose of this study was to consider dynamic stabilization without fusion, using Dynesys implants (Zimmer Spine, Minneapolis, MN, USA) as an alternative to fusion in elderly patients with degenerative lumbar scoliosis, as reported in a previous study [24]. The Dynesys device was introduced by Dubois et al. [25] in 1994. In vitro study demonstrated that Dynesys stabilized unstable spine segments sufficiently to be considered as a potential option to replace fusion [26]. This was confirmed in patients with degenerative spondylolisthesis treated by decompression and Dynesys instrumentation instead of arthrodesis; the dynamic stabilization device remained stable in most patients and prevented progression of spondylolisthesis [27,28]. Especially, the purpose of the present study was to reduce the incidence of complications after posterior fusion, such as adjacent segment degeneration, which generally occurs proximal to posterior instrumentation, and has been reported primarily after short lumbar fusion [20,21]. In a recent study, Cahill et al. [29] suggested that the adjacent problems at the proximal end of a scoliosis construct may be completely eliminated with the use of a transition rod at the most proximal level. The hypothesis of our study was that the choice of a dynamic system could lead to similar results, permitting to perform a short stabilization

with a decreased risk of junctional problems. For this reason, in this series, the comparison was made between dynamic stabilization without fusion and posterior instrumented fusion in elderly patients with degenerative lumbar scoliosis, considering deformity correction, clinical outcome, and rate of adverse events including adjacent segment degeneration.

Materials and methods

A retrospective database review was performed to identify all patients affected by degenerative lumbar de novo scoliosis (Aebi's classification type I [1]), who had been surgically treated by dynamic fixation (Dynesys system) without fusion or rigid fixation with fusion at our department between January 2002 and December 2005.

Inclusion criteria were minimum age at surgery of 60 years; Cobb angle more than 10° before surgery; proximal fusion level no higher than T11; no improvement after conservative treatment; and minimum 3-year follow-up.

Exclusion criteria were fixed sagittal imbalance; scoliosis Cobb angle more than 40° before surgery; and no previous lumbar fusion or stabilization surgery.

An independent spine surgeon reviewed all the selected patients' medical records and X-rays. Inpatient and outpatient charts were used for collecting demographic data, preoperative data (location of pain, neurologic symptoms, previous surgeries), perioperative data (blood loss, surgical duration, hospital stay, and any medical- and surgical-related complications), and postoperative data, including revision surgeries. Clinical outcome was assessed by means of the Oswestry Disability Index (ODI), Roland-Morris Disability Questionnaire (RMDQ), and separate visual analog scale (VAS) for back and leg pain, completed by patients preoperatively, in the early postoperative period, and at the last follow-up. Radiographic evaluation included preoperative computed tomography and magnetic resonance imaging of the lumbar spine, as well as preoperative, postoperative, and follow-up standing plain radiographs. Overall lumbar measures from the radiographs included Cobb angle of the lumbar curve, lumbar lordosis (T12–S1), and thoracolumbar junction alignment (TLJA) (T10–L2), apical vertebral lateral displacement, and anterior vertebral translation (AVT) measurements for spondylolisthesis. Instrumentation loosening or breakage and degenerative alterations of adjacent levels were also investigated, as well as the presence or absence of fusion.

The clinical and radiologic results were analyzed using *t* test. Results are expressed as the mean (range), with a p value $<.05$ considered as being statistically significant.

Preoperative patient data

One hundred eleven consecutive patients were assessed for eligibility: 54 were excluded. Reasons were previous spinal fusion or instrumentation (n=16), scoliosis Cobb angle >40° (n=9), fixed sagittal imbalance (n=5), proximal fusion level higher than T11 (n=17), and younger than 60 years (n=7).

Fifty-seven elderly patients were included. There were 45 women (79%) and 12 men (21%), with a mean age of 68.1 years (range, 61–78 years). All 57 patients presented a degenerative lumbar de novo scoliosis, associated in 51 cases (89.4%) with stenosis of the vertebral canal. Twenty-four patients (42.1%) also had degenerative spondylolisthesis (four patients had spondylolisthesis at two levels): the mean slippage was 17.2% (range, 10–27%). Nineteen patients (33.3%) had undergone previous spine surgery, including 17 decompressions and 11 discectomies (12 patients had had one previous operation, five patients two previous operations, and two patients three previous operations). At the time of surgery, all 57 patients reported leg pain; 47 (82.4%) also had neurogenic claudication; and 42 (73.6%) had back pain. All patients had failed to respond to conservative treatment conducted for at least 12 months (Table 1).

Among these 57 patients, 32 cases (dynamic group) had dynamic stabilization (Dynesys implants) and 25 patients (fusion group) had posterior instrumented fusion (titanium instrumentation in all cases). The choice of surgical strategy (dynamic instrumentation without fusion vs. instrumented fusion) was made according to surgeon's preferences.

Surgical treatment

All surgeries were performed by four experienced spine surgeons of our department. Preventive antibiotics were routinely started 12 hours before surgery and continued for an average of 9 days (range, 8–11 days). The patients were treated under general anesthesia in the prone position.

Initially, in cases with associated stenosis of the vertebral canal, patients' hips were flexed at an angle of 90° to facilitate decompression of the stenotic levels. Stenosis was treated by wide laminectomy: the decompression was extended to the lateral recess, and foraminotomy was performed without interrupting the isthmus. After decompression, the patients' position was modified to obtain the maximum lumbar lordosis, and stabilization was performed.

Dynesys implants were used for dynamic fixation. Dynesys implants consist of titanium alloy pedicle

Table 1
Preoperative patient data

	All cases	Dynamic group	Fusion group
Age (y)	68.1	68.4	67.6
Female gender, %	79	78	80
Comorbidities	1.8±0.8	1.8±0.7	1.9±0.6
Degenerative spondylolisthesis, %	42.1	43.7	90.6
Stenosis, %	89.4	90.6	88.0
Previous spinal surgery, %	33.3	34.4	32.0
Leg pain, %	100	100	100
Back pain, %	71.9	84.4	76.0
Claudication, %	82.4	84.4	80.0

screws, polyethylene-terephthalate cords, and polycarbonate urethane spacers, which fit between the pedicle screw heads (Fig. 1). The pedicle screws used in lumbar or thoracolumbar vertebrae were 6 mm in diameter, whereas 7.2-mm diameter screws were used in the sacrum. The pedicle entry point was lateral, at the basis of the transverse process. The screws were inserted as deep as possible. So as not to compromise the bone purchase of the screws, given their conical core, we avoided removing and reinserting them in the same hole. Each polycarbonate urethane spacers were cut to the desired length and threaded with a polyester cord, which was stretched between and fixed to two adjacent screw heads. Larger spacers were used on the concave side and shorter on the convex side of the scoliosis curve.

In the fusion group, different titanium alloy systems were used with rigid rods 5.5 mm in diameter, screws 6 mm in diameter for lumbar or thoracolumbar vertebrae, and screws 7.5 mm in diameter for the sacrum. Iliac screws were also implanted in some patients who had severe osteopenia (Fig. 2). No circumferential fusion was performed at the lumbosacral level in any of these aging patients to limit blood loss and operative duration. Allograft banked bone (one femur head for every patient) and autograft bone (spinous processes and laminae obtained from decompression procedure) were used in all 25 patients of the fusion group. Redon drains were applied and maintained for a mean of 3.9 days (range, 3–4 days).

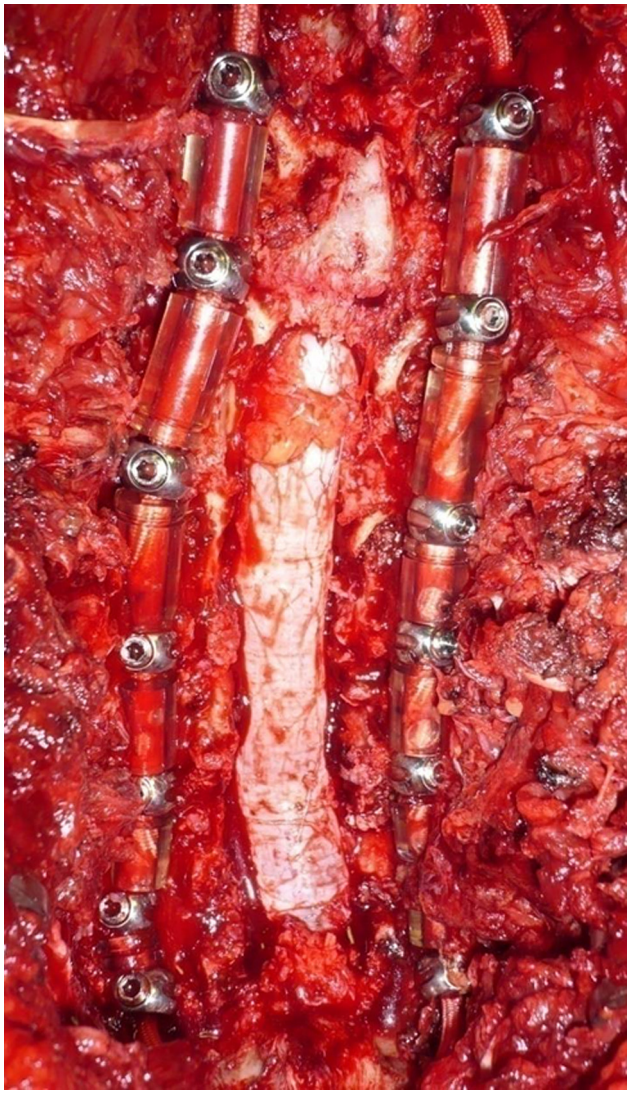

Fig. 1. Dynesys implants used for dynamic fixation, combined as in this case with decompressive laminectomy.

The dynamic group included 25 women (78%) and 7 men (22%), with a mean age of 68.4 years (range, 61–78 years), treated with dynamic stabilization without fusion (Dynesys system). Average body mass index (BMI) was 26.4 (range, 20–36). There were 1.8±0.7 comorbidities per patient, including diabetes mellitus in 15, heart disease in 7, arterial hypertension in 20, liver disease in 8, and pulmonary disease in 7 patients. All 32 patients had degenerative lumbar de novo scoliosis (with an average Cobb angle of 17.2°), associated in 29 cases (90.6%) with vertebral canal stenosis. Fourteen patients (43.7%) also presented with degenerative spondylolisthesis, at L2–L3 level in one case, L3–L4 in seven cases, L4–L5 in three cases, and L5–S1 in three cases (three patients had spondylolisthesis at two levels): the mean slippage was 18.9% (range, 12–27%). Eleven patients (34.4%) had previously undergone lumbar spinal surgery, including 10 decompressions and 6 discectomies (seven patients had had one previous operation, three had had two operations, and one patient had had three).

The fusion group included 20 women (80%) and 5 men (20%), whose mean age was 67.6 years (range, 62–77 years), treated with posterior instrumented fusion. Average BMI was 27.1 (range, 22–38). There were 1.9±0.6 comorbidities per patient, including diabetes mellitus in 10, heart disease in 5, arterial hypertension in 18, liver disease in 5, and pulmonary disease in 9 patients. All 25 patients had degenerative lumbar de novo scoliosis (with an average Cobb angle of 19.2°), associated in 22 cases (88.0%) with vertebral canal stenosis. Ten patients (40%) also presented with degenerative spondylolisthesis, at L2–L3 level in one case, L3–L4 in five cases, and L4–L5 in four cases (one patient had spondylolisthesis at two levels): the mean slippage was 16.0% (range, 10–25%). Eight patients (32.0%) had previously undergone lumbar spinal surgery, including seven decompressions and five discectomies (five patients had had one previous operation, two had had two operations, and one patient had had three surgeries).

Perioperative data

Dynamic group

All 32 patients had dynamic stabilization alone without fusion (Figs. 1 and 3). Three levels were stabilized in 18 patients (56.2%: L1–L4 in 3, L2–L5 in 10, and L3–S1 in 5); four levels were stabilized in six patients (18.7%: L1–L5 in

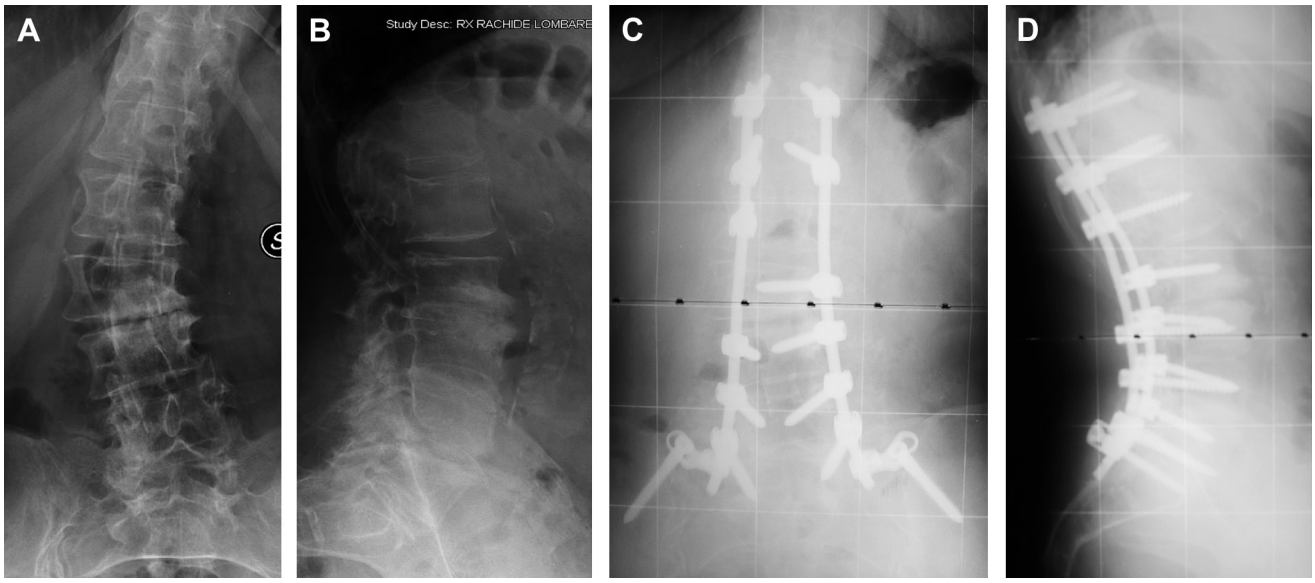

Fig. 2. A 67-year-old woman. (A, B) Degenerative lumbar scoliosis with good sagittal balance, associated with stenosis of the vertebral canal. Treatment: T12–S1 posterior instrumented fusion with iliac screws and decompressive laminectomy. (C, D) Four-year postoperative radiographs showing stable scoliosis correction, with maintained sagittal balance.

three and L2–S1 in three), five levels in three patients (9.4%: T12–L5 in two and L1–S1 in one), six levels in four patients (12.5%: T12–S1), and seven levels were stabilized in one patient (3.1%: T11–S1).

In 29 patients (90.6%), the stabilization was combined with wide decompressive laminectomy of two levels in four cases (13.3%: L2–L3 in one, L3–L4 in one, and L4–L5 in two), three levels in 10 cases (33.3%: L2–L4 in three and L3–L5 in seven), four levels in seven cases (23.3%: L2–L5 in six and L3–S1 in one case), five levels in six cases (20.0%: L1–L5 in two and L2–S1 in four), and six levels in three cases (10.0%: T12–L5 in two and L1–S1 in one). If present, the associated spondylolisthesis was always included in the stabilization construct.

Mean operating time was 190 minutes (range, 120–330 minutes), mean hospital stay was 6.8 days (range, 6–9 days), and mean blood loss was 950 cc (range, 200–1,600 cc). Patients were returned to the upright position at 2.6 days postoperatively (range, 2–4 days) with a lumbar orthosis, which was prescribed for 1 month.

Fusion group

All 25 patients were treated by posterior instrumented fusion (Fig. 2). Three levels were fused in 13 patients

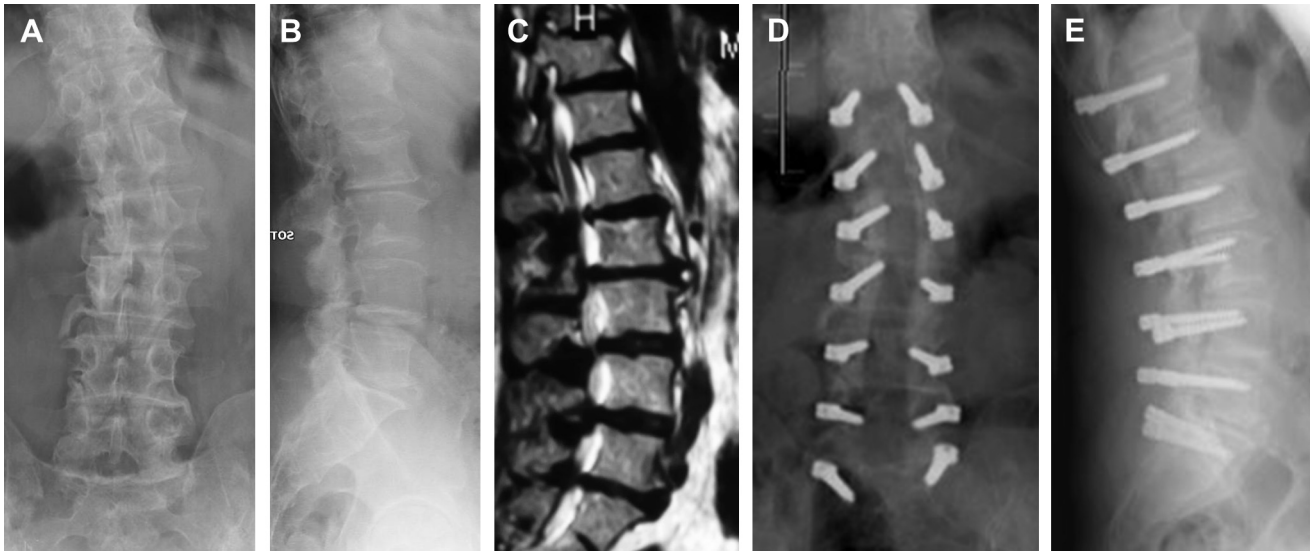

Fig. 3. A 71-year-old man. (A–C) Degenerative lumbar scoliosis associated with stenosis of the vertebral canal: good sagittal balance. Treatment: T12–S1 dynamic fixation and L2–L5 decompressive laminectomy. (D, E) Three-year and 9-month postoperative radiographs showing stable scoliosis correction, with maintained sagittal balance.

(52%: L1–L4 in three, L2–L5 in five, and L3–S1 in five), four levels in five patients (20.0%: L1–L5 in one and L2–S1 in three), five levels in two cases (8%: T12–L5 in one and L1–S1 in one), six levels in four patients (16.0%: T12–S1), and seven levels in one patient (4%: T11–S1). In 22 patients (88.0%), fusion was combined with wide decompressive laminectomy of two levels in three cases (13.6%: L2–L3 in one, L3–L4 in one, and L4–L5 in one), three levels in four cases (18.2%: L2–L4 in one and L3–L5 in three), four levels in six cases (27.3%: L2–L5 in four and L3–S1 in two), five levels in four cases (18.2%: L1–L5 in two and L2–S1 in two), and six levels in five cases (22.7%: T12–L5 in two and L1–S1 in three). If present, the associated spondylolisthesis was always included in the arthrodesis.

Mean operating time was 240 minutes (range, 180–360 minutes), mean hospital stay was 9.5 days (range, 6–11 days), and mean blood loss was 1,400 cc (range, 500–2,500 cc). Patients were returned to the upright position at 3.1 days postoperatively (range, 2–5 days) with a lumbar orthosis, which was prescribed for 1 month.

In conclusion, the two groups of patients were well matched according to age (68.4 vs. 67.6 years, p=.15), gender (female, 78% vs. 76%; p=.20), BMI (26.4 vs. 27.1, p=.10), comorbidities (18±0.7 vs. 19±0.6, p=.21), scoliosis Cobb angle (17.2° vs. 19.2°, p=.16), canal stenosis (90.6% vs. 88%, p=.15) and associated spondylolisthesis (43.7% vs. 40%, p=.1), previous treatment (34.4% vs. 32%, p=.6), instrumentation (4.9 vs. 4.8, p=.1), and laminectomy levels (3.5 vs. 3.3, p=.15).

Results

At an average follow-up of 64 months (range, 42–90 months), all patients included in the study had radiographs and completed questionnaires.

Clinical outcome

In the dynamic group, the mean preoperative ODI score was 51.6% (range, 28–80), mean postoperative score was 27.2 (range, 0–66), and final follow-up score was 27.7 (range, 0–70) (p<.05), with a mean final improvement of 51.6% (range, 12–100%) (p<.05) (Table 2). In the fusion group, the mean preoperative ODI score was 52.7 (range, 30–80), mean postoperative score was 29.2 (range, 0–70), and final follow-up score was 30.2 (range, 0–70) (p<.05), with a mean final improvement of 48.2 (range, 10–100%) (p<.05).

In the dynamic group, the mean preoperative RMDQ score was 12.4 of 24 (range, 7–22), mean postoperative score was 6.0 (range, 0–19), and final follow-up score was 6.3 (range, 0–20) (p<.05), with a mean final improvement of 58.8% (range, 9.1–100%) (p<.05). In the fusion group, the mean preoperative RMDQ score was 13.2 of 24 (range, 8–22), mean postoperative score was 6.4 (range, 0–18), and final follow-up score was 6.8 (range, 1–20) (p<.05), with a mean final improvement of 54.2% (range, 10–100%) (p<.05).

In the dynamic group, the mean leg pain VAS decreased from a preoperative score of 67.5 (range, 30–100) to a mean postoperative score of 40.1 (range, 2–90) and 41.6 (range, 2–90) at the last follow-up (p<.05), with a mean final improvement of 51.1% (range, 10–96.4%) (p<.05). The mean back pain VAS decreased from a preoperative score of 66.7 (range, 30–100) to a postoperative score of 33.1 (range, 2–75) and 33.8 (range, 2–79) at the last follow-up (p<.05), with a mean final improvement of 57.4% (range, 20–97.0%) (p<.05). In the fusion group, the mean leg pain VAS decreased from a preoperative score of 65.3 (range, 35–100) to a postoperative score of 38.4 (range, 0–80) and 40.0 (range, 5–85) at the last follow-up (p<.05), with a mean final improvement of 50.2% (range, 15–100%) (p<.05). The mean back pain VAS decreased from a preoperative score of 68.1 (range, 38–100) to a postoperative score of 31.5 (range, 0–75) and 32.5 (range, 5–85) at the last follow-up (p<.05), with a mean improvement of 58.9% (range, 25–100%) (p<.05).

None of the differences in ODI, RMDQ, or VAS between dynamic and fusion group patients was statistically significant.

Radiologic outcome

In the dynamic group, the average scoliosis Cobb angle was 17.2° (range, 12°–38°) before surgery, 11.0° (range,

Table 2
Clinical outcome

	Preoperative	Follow-up	Percent of correction	p Value
Dynamic group				
ODI (mean–range)	51.6 (28–80)	27.7 (0–70)	51.6 (12–100)	<.05
RMDQ	12.4 (7–22)	6.3 (0–20)	58.8 (9.1–100)	<.05
VAS "leg score"	67.5 (30–100)	41.6 (2–90)	51.1 (10–96.4)	<.05
VAS "back score"	66.7 (30–100)	33.8 (2–79)	57.4 (20–97)	<.05
Fusion group				
ODI (mean+standard deviation)	52.7 (30–80)	30.2 (0–70)	48.2 (10–100)	<.05
RMDQ	13.2 (8–22)	6.8 (1–20)	54.2 (10–100)	<.05
VAS "leg score"	65.3 (35–100)	40.0 (5–85)	50.2 (15–100)	<.05
VAS "back score"	68.1 (38–100)	32.5 (5–85)	58.9 (25–100)	<.05

ODI, Oswestry Disability Index; RMDQ, Roland-Morris Disability Questionnaire; VAS, visual analog scale.

4°–26°) after surgery, and 11.3° (range, 4°–26°) at the last follow-up ($p<.05$), with a mean final correction of 37.3% (range, 13.3–61.5%) ($p<.05$) (Tables 3 and 4). In the fusion group, the average scoliosis Cobb angle was 19.2° (range, 14°–38°) before surgery, 8.1° (range, 4°–18°) after surgery, and 8.3° (range, 4°–18°) at the last follow-up ($p<.05$), with a mean final correction of 56.9% (range, 37.5–73.3%) ($p<.05$). In conclusion, both the early and final Cobb angle corrections were better in the fusion group than in the dynamic group ($p<.05$).

In the dynamic group, lumbar lordosis was −30.6° (range, 3° to −39°) before surgery, −36.8° (range, −12° to −57°) after surgery, and −35.8° (range, −10° to −55°) at the last follow-up ($p<.05$), with a mean final improvement of 6.4% (range, 0–17%) ($p<.05$). In the fusion group, lumbar lordosis was −28.8° (range, 5° to −40°) before surgery, −47.1° (range, −18° to −56°) after surgery, and −46.5° (range, −15° to −56°) at the last follow-up, with a mean final improvement of 29% (range, 19–37%) ($p<.05$). In conclusion, the percentages of lumbar lordosis correction were better at early and final controls in the fusion group than in the dynamic group ($p<.05$), as were the actual values of lumbar lordosis observed at early and final follow-ups ($p<.05$).

In the dynamic group, TLJA (T10–L2) was −2.8° before surgery (range, −25° to 23°), −0.2° (range, −18° to 25°) after surgery, and −0.4° (range, −18° to 25°) at the last follow-up. In the fusion group, TLJA was −1.9° before surgery (range, −20° to 28°), −0.3° (range, −20° to 25°) after surgery, and −0.5° (range, −20° to 25°) at the last follow-up.

In the dynamic group, apical vertebra lateral listhesis was 1.2 cm (range, 0.2–2.0 cm) before surgery, 0.8 cm (range, 0.2–1.1 cm) after surgery, and 0.8 cm (range, 0.3–1.2 cm) at the last follow-up ($p<.05$), with a mean final correction of 30.7% (range, 0–44.4%) ($p<.05$). In the fusion group, apical vertebra lateral listhesis was 1.3 cm (range, 0.3–2.2 cm) before surgery, 0.5 cm (range, 0.2–0.9 cm) after surgery, and 0.5 cm (range, 0.2–1.0 cm) at the last follow-up ($p<.05$), with a mean final correction of 63.0% (range, 50.0–75.0%) ($p<.05$).

In the patients in the dynamic group with associated spondylolisthesis, AVT was 19.5% (range, 12–27%) before surgery, 16.7% (range, 0–25%) after surgery, and 17.5% (range, 0–27%) at follow-up ($p<.05$), for a 14.9% mean correction (range, 0–100%) ($p<.05$). In the patients in the fusion group with associated spondylolisthesis, AVT was 15.7% (range, 10–25%) before surgery, 10.0% (range, 0–20%) after surgery, and 10.0% (range, 0–20%) at follow-up ($p<.05$), with a mean final correction of 36.3% (range, 21.4–100%) ($p<.05$).

Complications

No neurologic complications were observed in any of the 57 patients, and there was no case with pseudoarthrosis in the fusion group (Table 5). In the dynamic group, eight overall complications (25.0%) occurred. Six patients (18.7%) had minor complications. These included two cases of ileus (6.2%) and two urinary tract infections (6.2%), which resolved after medical treatment. Another patient (3.1%) had transient postoperative delirium, which spontaneously resolved after 3 days. One patient (3.1%) developed dyspnea after surgery, requiring 5 days of recovery in the intensive care unit for complete resolution.

Two patients (6.2%) had major complications that required revision surgery. One patient (3.1%) developed severe postoperative sciatica, resistant to medication without neurologic deficit, because of a misplaced screw on L5: revision surgery for replacement of the screw was performed 5 days after the first operation, with complete resolution of the sciatica. Another patient (3.1%) developed persistent leg pain, resistant to medication without neurologic deficit, 28 months after surgery, because of disc degeneration at the lower junctional level: revision surgery was performed 32 months after the first operation, with decompression and extension of fixation from L5 to S1.

No screw loosening or breakage was observed at follow-up. However, asymptomatic radiolucent lines up to 2 mm around the thread of pedicle screws in the sacrum without

Table 3
Radiologic data

	Preoperative	Follow-up	Percent of correction	p Value
Dynamic group				
Scoliosis (mean–range)	17.2° (12–38)	11.3° (4–26)	37.3 (13.3–61.5)	<.05
Lordosis	−30.6° (3/−39)	−35.8° (−10/−55)	6.4 (0–17)	<.05
TLJA	−2.8° (−25/23)	−0.4° (−18/25)	NA	NA
AVLL (cm)	1.2 (0.2/2)	0.8 (0.3/1.2)	30.7 (0–44.4)	<.05
AVT (%)	19.5 (12–27)	17.5 (0–27)	14.9 (0–100)	<.05
Fusion group				
Scoliosis	19.2° (14–38)	8.3° (4–18)	56.9 (37.5–73.3)	<.05
Lordosis	−28.8° (5/−40)	−46.5° (−1/−56)	29.0 (19–37)	<.05
TLJA	−1.9° (−20/28)	−0.5° (−20/25)	NA	NA
AVLL (cm)	1.3 (0.3/2.2)	0.5 (0.2/1.0)	63.0 (50–75)	<.05
AVT (%)	15.7 (10–25)	10.0 (0–20)	36.3 (21.4–100)	<.05

TLJA, thoracolumbar junction alignment (T10–L2); NA, not available; AVLL, apical vertebra lateral listhesis; AVT, anterior vertebral translation.

Table 4
Radiologic outcome

Percent of correction	Dynamic group	Fusion group	p Value
Scoliosis (°)	37.3 (13.3–61.5)	56.9 (37.5–73.3)	<.05
Lordosis (°)	6.4% (0–17)	29.0% (19–37)	<.05
AVLL (cm)	30.7 (0–44.4)	63.0 (50–75)	<.05
AVT (%)	14.9 (0–100)	36.3 (21.4–100)	<.05

AVLL, apical vertebra lateral listhesis; AVT, anterior vertebral translation.

screw loosening were found in five patients (15.6%) at the last follow-up.

In the fusion group, 11 overall complications (44.0%) occurred. Seven patients (28.0%) had minor complications. These included four cases of ileus (16.0%) and one urinary tract infection (4.0%), which resolved after medical treatment. Two patients (8.0%) had postoperative dyspnea, which resolved after medical treatment.

Major complications occurred in four patients (16.0%). Three patients (12.0%) developed adjacent segment disease requiring revision surgery after 15, 18, and 21 months, respectively. In one, who developed sagittal imbalance, the salvage surgery consisted of new instrumentation and pedicle subtraction osteotomy. In the second patient, who had proximal junctional kyphosis, the arthrodesis was extended up to T2. In the third patient, who had L5–S1 disc degeneration, the arthrodesis was extended to S1. Another patient (4%), who developed paraparesis 3 days after surgery because of a hematoma, was treated on the fourth day after surgery by surgical drainage but without neurologic recovery.

Discussion

The surgical treatment of degenerative lumbar scoliosis in elderly patients presents demanding aspects. Important concerns include the older age of patients, their frequent medical comorbidities, and senile osteoporosis. Most patients with degenerative scoliosis are women, in whom osteoporosis may be severe after the menopause [1].

Table 5
Complications

Complications	Dynamic group, n (%)	Fusion group, n (%)
Overall	8 (25.0)	11 (44.0)
Minor	6 (18.7)	7 (28.0)
Ileus	2 (6.2)	4 (16.0)
Urinary tract infection	2 (6.2)	1 (4.0)
Transient delirium	1 (3.1)	—
Dyspnea	1 (3.1)	2 (8.0)
Major	2 (6.2)	4 (16.0)
Misplaced screw	1 (3.1)	—
Lower junctional disc degeneration	1 (3.1)	1 (4.0)
Sagittal imbalance	—	1 (4.0)
Proximal junctional kyphosis	—	1 (4.0)
Paraparesis (hematoma)	—	1 (4.0)

The main goals of surgery in these cases are pain relief and improvement in quality of life. Some correction of the deformity is desirable, but this is not the most important issue. In contrast, it is essential to limit the aggressiveness of the surgical procedure as much as possible [10,11]. Posterolateral fusion with pedicle screw instrumentation in addition to laminectomy [1,10,11,19–21] is one of the most commonly used procedures, achieving both decompression and stabilization of the spine. Short posterior fusion extended within the deformity has been proposed for cases with a small Cobb angle or minimal lateral vertebral listhesis [21] as well as for patients with no coronal and sagittal imbalance [30]. Longer posterior fusion has been proposed for patients with a large Cobb angle [21]. Posterior lumbar interbody fusion has been combined with posterior fusion in some patients [20]. In any event, as the posterior elements are removed for decompressive laminectomy and the pedicles represent the strongest points of anchorage in elderly patients, especially those who have osteopenia, the use of pedicle screw fixation is recommended by many authors [1,10]. Unfortunately, a high incidence of complications has been reported in older patients with degenerative scoliosis after posterior fusion procedures [19,20,31–33]. Notably, age has been correlated with an increased incidence of complications [31], with an 80% rate of overall complications in patients older than 65 years [19] and a 20% rate of major complications in patients older than 80 years [31]. Furthermore, excessive blood loss and the number of levels fused have been found to be associated with higher complication rates [20].

Less invasive than posterolateral fusion with posterior fixation, pedicle screw–based dynamic stabilization without fusion might be a useful alternative to fusion in elderly patients with degenerative lumbar scoliosis. A previous series of degenerative scoliosis patients with associated lumbar stenosis has shown that it can prevent progression of scoliosis and postoperative instability, even after wide laminectomy [24]. In that report, operative duration was short, blood loss was low, and there was no screw loosening or breakage at follow-up. The present study confirms the impression of shorter procedure with limited blood loss. Compared with the control arthrodesis procedure, the mean operating time resulted shorter using dynamic fixation (190 vs. 240 minutes; $p<.05$), and blood loss was reduced (950 vs. 1,400 cc; $p<.05$). The overall complication rate was lower in the dynamic fixation group reflecting both a lower incidence of minor complications (18.7% vs. 28%) and an even markedly lower incidence of major complications (6.2% vs. 16%).

A frequent complication observed in elderly patients after posterior fusion is adjacent segment disease, which generally occurs proximal to posterior instrumentation and has been reported primarily after short lumbar fusion [20,21]. Proximal adjacent disease appears to develop more frequently when stopping fusion from T11 to L1 compared with extending it to T10 [20,34]. In older patients, the

advantage for a short posterior fusion is obvious, even if the instrumentation should not stop at a junctional zone or adjacent to a rotatory subluxation, spondylolisthesis, or a segment with significant spinal stenosis because this may lead to spinal instability. In a recent study, Cho et al. [21] compared the results of short posterior fusion, within the deformity, versus long fusion, extended above the upper end vertebra, for degenerative lumbar scoliosis in patients whose mean age was 65.5 years. In that series, there was a trade off in complications between short and long fusions. Whereas all cases of proximal adjacent segment disease developed in the short fusion group, long fusion induced excessive intraoperative blood loss, which was closely related to the development of perioperative complications [21].

In our series, elderly patients received a short instrumentation in both groups, extended up to T11 at most. In the fusion group (n=25), three patients (12%) were reoperated after a mean of 18 months for adjacent segment disease: in the first patient, the salvage surgery consisted of pedicle subtraction osteotomy; in the second, the arthrodesis was extended up to T2; and in the third, the arthrodesis was extended to S1. In the dynamic group, only one patient (3.1%) required subsequent surgery for adjacent segment disease, a distal junctional disc degeneration 32 months after surgery. At present, there is no consensus on whether dynamic instrumentation protects adjacent levels more than fusion. A study concluded that dynamic stabilization can prevent degeneration of the adjacent segment [35]. However, the results of the study of Schnake et al. [27] after Dynesys instrumentation in cases with degenerative spondylolisthesis did not support this theory: the authors found signs of adjacent degeneration in 29% of the patients after 2 years. Although longer follow-up studies are necessary for definitive conclusions, the theoretical protective effect of dynamic stabilization against adjacent segment degeneration is consistent with our findings, with a 5-year minimum follow-up.

In our series, dynamic fixation provided substantial stability by preserving against further scoliosis progression or translation of associated spondylolisthesis, despite use of decompressive laminectomy. By applying asymmetric spacers, larger on the concave side and shorter on the convex side of scoliosis, it was possible to obtain some reduction of the scoliosis Cobb angle, albeit less than with fusion constructs. There was no case of screw loosening or breakage during follow-up. In five of the patients (15.6%), asymptomatic radiolucent lines up to 2 mm did appear around the thread of pedicle screws in S1 at the last follow-up; however, a screw mobilization or a loss of scoliosis correction was not observed, and the patients were asymptomatic: so we did not classify these cases as unstable.

In this series, posterior fusion corrected scoliosis better than dynamic fixation (56.9% vs. 37.3%). However, in de novo scoliosis patients, the goal of treatment is less the amount of correction of the curve, than its stability over time. The same could be said for final lumbar lordosis. Although the value of final lordosis tended to be better in the fusion group, dynamic fixation maintained a stable and satisfying lumbar lordosis at follow-up. The patient's position on the operating table was always assessed to maintain or to increase the lumbar lordosis. All cases included in this study presented preoperatively a satisfying sagittal balance. In cases of sagittal imbalance, it is very difficult to achieve normal lumbar lordosis by dynamic stabilization or posterior fusion alone: different surgical techniques such as corrective osteotomy should be considered preoperatively in these patients.

Finally, it is important to underline that, at a mean follow-up of 64 months (Table 3), dynamic fixation achieved clinically significant improvement in ODI, RMDQ, and VAS scores that were quite similar to those obtained by fusion, with no statistically significant differences between the two groups.

Conclusions

The present series must be interpreted in the context of its limitations (the retrospective nature of the review and the fact that patients were not randomized). However, this series is consecutive with no statistical differences between the two groups, according to age, BMI, comorbidities, scoliosis Cobb angle, canal stenosis with associated spondylolisthesis, previous treatment, instrumentation, and laminectomy levels.

In elderly patients with degenerative scoliosis, pedicle screw–based dynamic stabilization was less invasive with shorter operative duration, less blood loss, and lower adverse event rates than instrumented posterior fusion, obtaining similar results in terms of functional clinical outcomes at the last follow-up.

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