SURGICAL TREATMENT OF PATIENTS WITH DEGENERATIVE GRADE I LUMBAR SPONDYLOLISTHESIS COMBINED WITH SPINAL STENOSIS USING MINIMALLY INVASIVE BILATERAL DECOMPRESSION

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Objective. To analyze clinical and radiological outcomes of minimally invasive bilateral decompression through a unilateral approach in the treatment of patients with degenerative grade I spondylolisthesis combined with lumbar spinal stenosis.
Material and Methods. A total of 28 patients with degenerative grade I lumbar spondylolisthesis combined with spinal stenosis at one or several levels with clinical manifestations of neurogenic intermittent claudication and low back pain were operated on using the method of bilateral microsurgical decompression through a unilateral approach. The minimum follow-up period was 1 year. Clinical outcomes was assessed using VAS, Oswestry and MacNab questionnaires. Central stenosis of the spinal canal was graded according to Shizas classification based on MRI data, and the degree of segment stability according to Hanley and progression of spondylolisthesis in a neutral position were assessed by a functional lumbar spondylograms before surgery and in the long-term period.
Results. The average hospital stay was 3.07 ± 0.26 days. The average duration of the operation was 145.07 ± 44.67 minutes. When assessing pain by VAS questionnaire, a significant decrease in the median value of the intensity of pain was noted: in the leg — from 7.0 [7.0; 8.0] to 1.0 [1.0; 2.0], in the back — from 5.0 [4.0; 5.0] to 1.0 [1.0; 2.0]. The ODI questionnaire showed a decrease in the median indicator of disability from 60.0 [56.0; 64.0] to 15.0 [12.0; 19.0]. Assessment of radiological outcomes showed a slight increase in the parameters of anteroposterior translation (on average +0.42 mm) and segmental rotation (on average +1.03 degrees) of the operated segment during functional tests, and a slight increase in spondylolisthesis (on average by 1.42 %), which in general did not affect clinical outcomes.
Conclusion. Retrospective analysis of minimally invasive bilateral decompression through unilateral approach in patients with degenerative grade I lumbar spondylolisthesis combined with spinal stenosis without segmental instability provided the evidence of significant clinical efficacy of the method with a low risk of iatrogenic segment instability in the late postoperative period.
Keywords: degenerative spondylolisthesis, lumbar spinal stenosis, neurogenic intermittent claudication, bilateral microsurgical decompression through unilateral approach.
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Degenerative spondylolisthesis is acquired displacement of a suprajacent vertebra with respect to the subjacent one, which does not involve any damage to the interarticular portion of the vertebral arch [1]. In older patients, this process is often associated with lumbar spinal stenosis [1]. According to Wang et al. [2] and Jacobsen et al. [3], the prevalence of degenerative spondylolisthesis is 2.8–8.4 % of the total number of cases of degenerative diseases of the lumbar spine.

There are many approaches to surgical treatment of grade I degenerative spondylolisthesis; they can be classified into the decompression and decompression/stabilization interventions [1]. Some surgeons prefer to perform spinal fusion when patients have no radiological signs of spinal instability to minimize the risks of instability development during the postoperative period [4]. As minimally invasive spinal surgery methods are mastered, more and more data demonstrate that decompression only is effective for treating patients with degenerative stenosis of the lumbar spine, including that combined with spondylolisthesis.

Today, there are conflicting opinions in foreign and Russian research literature [5–9] regarding the feasibility and effectiveness of decompression surgeries as a potential alternative to decompression/stabilization interventions. The aim of the present study was to analyze the clinical and radiological outcomes of minimally invasive bilateral decompression performed through the unilateral approach in treatment of patients with grade I degenerative spondylolisthesis combined with lumbar spinal stenosis.

Material and Methods

A retrospective analysis of the outcomes of surgical treatment in 28 patients who had undergone minimally invasive bilateral decompression through the unilateral approach for grade I degenerative lumbar spondylolisthesis at a single level combined with lumbar spinal stenosis at one or several levels (for the period between 2011 and 2019) was performed. Table 1 summarizes patients' characteristics.

Clinical manifestations involved axial pain in all patients, neurogenic intermittent claudication of caudogenic type in 21.4 % of patients (n = 6), and that of radicular type in 35.7 % of patients (n = 10), and a combination of these symptoms in 42.9 % of patients (n = 12). Lower extremity sensory disorders were diagnosed in 21.4 % of cases (n = 6); motor disorders, in 14.3 % of cases (n = 4).

In patients with multilevel stenosis, decompression at the adjacent levels was performed along with decompression at the level affected by spondylolisthesis (Table 1).

The inclusion criteria were as follows: age > 45 years; grade I degenerative lumbar spondylolisthesis according to the Meyerding's classification; concomitant symptomatic degenerative lumbar stenosis; no segmental instability (anteroposterior translation of suprajacent vertebra < 4 mm; segmental rotation < 10°); clinical signs of caudogenic- or radicular-type neurogenic intermittent claudication or radicular compression syndromes with sensory and motor disorders when conservative therapy had no effect for at least one year.

The exclusion criteria were as follows: clinically significant foraminal stenosis; degenerative scoliosis (Cobb angle from frontal radiographic images > 10°); patients who had previously undergone surgery on these functional spinal units; and inflammatory spondylodiscitis.

In these patients, the minimal number of diagnostic procedures included MRI (at least 1.5 T), which assessed whether a patient had central stenosis of the spinal canal (grade B–D according to the Schizas classification) and lateral stenosis at the level of spondylolisthesis. When identifying indications for surgery involving adjacent segments, such factors as the presence or absence of central (grade C–D according to the Schizas classification), lateral, foraminal degenerative stenosis, or their combination, were also taken into account.

Static spondylograms (lateral view) of patients in the standing position were used to assess the spondylolisthesis degree during the preoperative period (anterior slippage of a vertebral body with respect to the subjacent one by no more than 25 %). The degree of segmental instability was evaluated on the basis of functional spondylograms (lateral view) using the Hanley's criteria: the segment was considered stable if the difference in anteroposterior slippage of vertebrae was less than 4 mm and segmental rotation angle during flexion and extension was less than 10° (Fig. 1) [10].

Surgical procedure. All the patients underwent microsurgical bilateral decompression through unilateral approach using the technique proposed by McCulloch et al. [11] and Young et al. [12]. A midline incision above the spinous processes was made. The skin incision was 2.5 to 7.5 cm long depending on the number of operated segments. Next, the paramedian access to the interarch space at the operated level was ensured (from the side where clinical symptoms were more pronounced); the multifidus muscles were not skeletonized. A Caspar wound retractor was installed. The caudal portion of the cranial vertebral arch was resected ipsilaterally using microsurgical instruments and a high-speed drill, up to the site where the yellow ligament is attached. The medial portion of the facet joint was resected up to 1/6–1/5 (up to the level of the vertebral pedicle), and the cranial portion of the caudal vertebral arch was resected to leave 3–4 mm. The hypertrophied yellow ligament was then removed layerwise. The base of the spinous process of the vertebra was then resected. The operating table was tilted 10–20° away from the surgeon; the wound retractor was tilted 25–40° toward the surgeon in order to perform contralateral decompression. The medial portion of the facet joint and the hypertrophied contralateral yellow ligament were resected. At the final stage of the surgery, a drain was installed through a contraperture. The surgery was performed using a binocular surgical magnifier with headlights (3.5 magnification; focal length, 420 mm).

In the postoperative period, the achieved degree of dilatation of the central portion of the spinal canal was assessed using the MRI data (according to the Schizas classification), and so were the changes in the sagittal dimension of the lateral portion of the spinal canal.

Control radiographs of the lumbar spine recorded in a neutral position and during functional tests were used to assess the degree of spondylolisthesis progression and changes in the degree of segmental stability.

The 10-point Visual Analog Scale (VAS) was used for objective assessment of clinical outcomes. Lower back and leg pain intensity was assessed before surgery and one year after it. Patients' ability to work and objectified symptoms of neurogenic intermittent claudication before surgery and 1 year after it were assessed using the Oswestry questionnaire (0–100 %). The modified MacNab scale was used to perform subjective assessment of the outcomes of surgical treatment.

Statistical analysis of the results was conducted using Microsoft Excel and Statistica 8.0 software. Nonparametric Wilcoxon test was used to assess significance of differences between the samples; $p < 0.05$ was assumed to be the lower bound of the confidence interval. Data distribution within the groups was presented as median values and 25th–75th percentiles in the format Me (25 %; 75 %) for the non-normal distribution and as mean value with standard deviation in the format M ± SD for normal distribution.

Results

The average length of hospital stay (including the preoperative period) was 3.07 ± 0.26 days.

Table 1
Characteristics of patients with grade I degenerative spondylolisthesis combined with lumbar spinal stenosis

Parameters	Value
Number of patients, n	28
Female/male, n (%)	23/5 (82.1/17.9)
Mean age, years	69.66 ± 8.98 (from 51.3 to 80.6)
Minimal follow-up period	1 year
Level of spondylolisthesis	L4 vertebra (78.5 %)
	L3 vertebra (21.5 %)
Stenosis grade according to the Schizas classification, n (%)	
B	4 (14.3)
C	17 (60.7)
D	6 (21.4)
Number of levels at which an intervention was performed, n (%)	
1	7 (25.0)
2	15 (53.6)
3	6 (21.4)

One year after the surgery, the intensity of patients reported statistically significant decrease in leg and back pain assessed according to the VAS, and their working capacity evaluated using the Oswestry questionnaire was improved (Table 2, Fig. 2, 3).

Assessment of the subjective outcomes of surgical treatment according to the modified MacNab scale at follow-up (the follow-up duration being 1 year) revealed excellent and good outcomes in 89.21 % of patients; satisfactory outcomes, in 3.57 % of patients; and poor outcomes, in 7.14 % of patients.

Assessment of radiological outcomes one year after the surgery showed spondylolisthesis progression by an average of 1.42 % ($p < 0.05$) (control lumbar radiographs in the neutral position) and a slight increase in anteroposterior slippage by 0.42 mm and an increase in segmental rotation angle by 1.03° ($p < 0.05$; Table 3) (radiographs taken during functional tests). However, these radiographic changes had no effect on clinical results or treatment effectiveness.

During the postoperative period, repeated surgery (decompression + stabilization) to treat segmental instability was performed in 2 (7.14 %) patients. In one case, a patient had had an old compression fracture of the L4 vertebral body and osteoporosis. The surgery was performed at the level of the L4–L5 segment. Severe degeneration and cicatrization occurring during decompression caused injury to the dura mater and liquorrhea, which made it impossible to properly complete the decompression. Therefore, no clinical improvement was observed during the early postoperative period, and repeated interventions involving decompression and stabilization were required. Overall, intraoperative injury to the dura mater with liquorrhea was observed in 2 (7.14 %) patients, including the one described above. In such cases, the defect was closed using the Tachocomb® sponge, and the outcome was favorable. In the second case, a patient developed recurrent lower limb pain 23.5 months after the surgery at the L4–L5 level. MRI revealed bilateral synovial cysts in facet joints at the level of surgical intervention. Taking into account the signs of segmental instability, the patient was subjected to a decompression/stabilization intervention.

During the postoperative period (the duration of follow-up was at least 1 year), MR images of all the patients (except for two patients who had undergone repeated surgery) showed no signs of dural sac and nerve root compression in the central canal (grade A1-A4 according to the Schizas classification). In the group of patients preoperatively having lateral stenosis, the sagittal size of the lateral recess was increased to at least 4 mm.

Case report. A 66-year-old patient M. was complaining of lumbar pain (VAS score 5) radiating to both legs, transient numbness and weakness in legs, mostly on the right side (VAS score 8), which increased during walking a distance up to 200 m; the ODI was 56 %. Preoperative MRI revealed degenerative antelisthesis of the L3 vertebra and development of stenosis (predominantly lateral and central stenosis, grade C according to the Schizas classification; Fig. 4).

Follow-up examination 14.2 months after the surgery revealed positive changes: pain in leg and lower back significantly regressed (up to VAS score 1), and the Oswestry Disability Index (ODI), a parameter assessing the patient's working capacity, significantly increased (by 10 %). Control MR images confirmed the complete decompression of the central (grade A2-3 according to the Schizas classification) and lateral portions of the spinal canal (Fig. 5). Comparison of the radiographs recorded in the neutral position before and after treatment showed a slight increase in spondylolisthesis degree (+2.2 mm; 2.6 %; Fig. 6). Assessment of segmental stability in functional spondylograms revealed a decrease in anteroposterior translation parameters (-1.03 mm) and segmental rotation angle (-0.2°; Fig. 7, 8).

Discussion

In 1991, McCulloch [11] modified the method of microsurgical fenestration previously described by Young et al. [12] by developing a method of microsurgical bilateral decompression through the unilateral approach. The unilateral approach allows one to preserve the spinous process of the vertebra, its ligaments, the facet joint, and the vertebral arch on the contralateral side, thus reducing postoperative

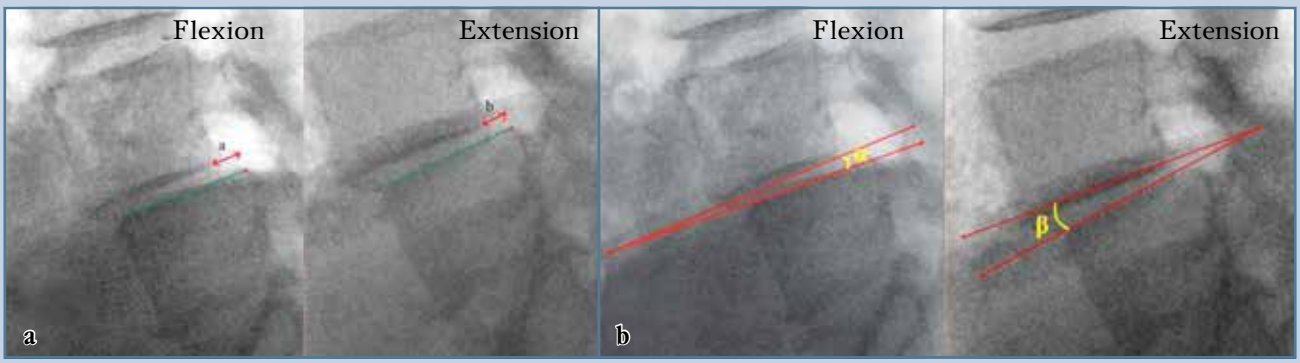

Fig. 1
Assessment of segmental instability degree according to functional spondylograms: **a** – anterior slippage of the vertebrae; **b** – segmental rotation angle

instability and cicatrization during the postoperative period.

Grade I degenerative spondylolisthesis is considered stable in most cases as degenerative changes naturally restabilize the segment. The probability of progression is ⩽ 30 %, and no additional stabilization is needed in most cases [6, 13, 14].

Open decompression/stabilization surgery allows one to perform complete decompression of nerve elements and rigid fixation of the functional spinal unit. However, this type of surgery still has drawbacks associated with injury to the adjacent tissues, significant blood loss volume, long-term rehabilitation, and high cost of implants. After evaluating the effectiveness of the two treatments, a conclusion was drawn that in patients with severe degenerative spondylolisthesis (grade II and higher), there is no doubt that stabilization surgery is more effective than decompression one, but in case of grade I spondylolisthesis it is unclear whether additional artificial ankylosis offers any advantages [15, 16]. In addition, a decompression only broadens the list of indications for surgical treatment in older patients, including those with complicated general somatic status.

We performed decompression at the adjacent levels in patients having severe degenerative central (grade C-D according to the Schizas classification) and lateral stenosis, foraminal stenosis accompanied by radicular pain, radiculopathy of a nerve root that passes or exits the segment at this level or a combination of the aforementioned conditions according to the MRI data as we believe that treating spondylolisthesis at a single level may cause incomplete resolution of neurogenic intermittent claudication of caudogenic type resulting from the maximally narrowed central canal. In patients with lateral foraminal stenosis accompanied by radicular pain, residual radicular pain will persist during the postoperative period. Furthermore, because of progression of degenerative changes, patients might require reoperation at the adjacent levels in future. The risk of such interventions was reduced in our case series.

The opinions regarding this issue currently available in the literature are conflicting. Adilay and Guclu [17] compared two groups of patients operated on to treat multilevel spinal stenosis and measured the anteroposterior dimension of the spinal canal: if the difference between the maximally narrowed level and the adjacent levels was > 3 mm and the size of the adjacent segments was > 9 mm, they used single-level decompression and vice versa. Thus, evidence was obtained that pain intensity was higher and working capacity was lower in patients who had undergone multilevel decompression, but the risk of requiring a reoperation to treat spinal stenosis progression in the adjacent segments was lower than that in the single-level decompression group.

A number of studies show that additional stabilization in patients with grade I spondylolisthesis does not improve the clinical outcomes. In particular, Forsth et al. [18] analyzed the clinical outcomes

Table 2
Assessment of the clinical outcomes of microsurgical bilateral decompression through the unilateral approach (n = 28)

Questionnaire	Follow-up period	Outcome	p-value
VAS: leg pain, score	Preoperatively	7.0 [7.0; 8.0]	<0.05
	One year later	1.0 [1.0; 2.0]	
VAS: back pain, score	Preoperatively	5.0 [4.0; 5.0]	<0.05
	One year later	1.0 [1.0; 2.0]	
ODI, %	Preoperatively	60.0 [56.0; 64.0]	<0.05
	One year later	15.0 [12.0; 19.0]	

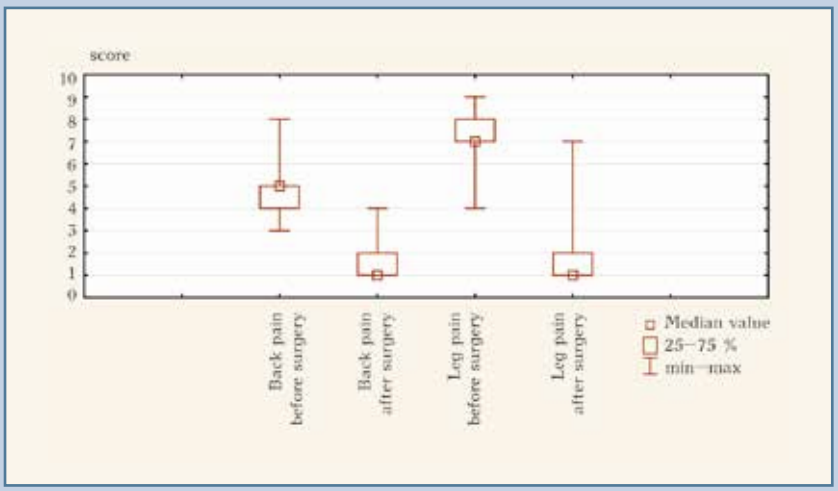

Fig. 2
Changes in the VAS score (back and leg pain): before and one year after the surgery

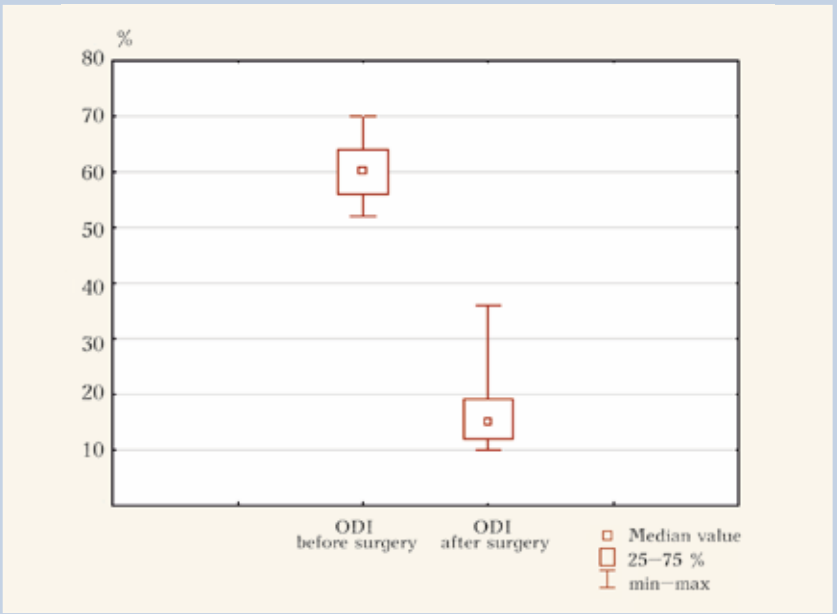

Fig. 3
Changes in the Oswestry Disability Index score before and one year after the surgery

in 5390 patients who had been operated on to treat lumbar spinal stenosis and spondylolisthesis (4259 patients, decompression without artificial ankylosis; 1131 patients, with artificial ankylosis). Duration of the follow-up period was two years. A conclusion was drawn that there were no significant differences between the two surgical groups in terms of the studied parameters, regardless whether the patients had spondylolisthesis or not.

An objective of performing a minimally invasive intervention is to ensure adequate decompression of neural structures with minimal injury to the adjacent soft tissues, to resect bone and soft tissue structures of the spinal canal, while preserving the stability of a spinal motion segment as much as possible. This is especially important for elderly patients with comorbidities, since this procedure allows one to reduce the volume of blood loss and length of stay and ensure quicker patient activation and rehabilitation. In our study, the mean length of hospital stay was extremely short (3.07 days), being consistent with the similar experience of some other researchers [19, 20].

An analysis of clinical outcomes in the operated patients (the minimal follow-up duration being 1 year) revealed that the VAS score for back and leg pain intensity decreased significantly (mean reduction was by 3.39 and 5.54 points, respectively). The ODI score decreased by an average of 44.51 %. These facts allow us to infer that this method is effective, including for patients who preoperatively had severe back pain in some cases being more intensive than leg pain). Our results are consistent with those reported by other authors, who have shown that the outcomes were significantly improved during the follow-up period from 7 months to 5.4 years [22–24]. Joung et al. [12] assessed the clinical outcomes in operated patients according to the ODI score (follow-up duration being at least three years) and revealed that disability in these patients was significantly reduced (by 33.33 %). Musluman et al. [24] analyzed the outcomes of surgical treatment in 84 patients with grade I degenerative spondylolisthesis (the mean follow-up being 4.4 ± 2.3 years) and found that the back pain VAS score was reduced by a mean value of 1.63 points, while the Oswestry index decreased from 43.1 ± 12.4 % (mean, 26.8 ± 9.5). This proves that decompression is effective according to such criteria as pain alleviation and the Oswestry index, but differs from our findings. In two cases the clinical outcomes could be followed up for a long period (up to 110 months). The patients with the extreme follow-up period had clinical signs of neither segmental instability nor increased inten-

Table 3
Assessment of the long-term radiographic outcomes of microsurgical bilateral decompression through the unilateral approach (n = 28)

Criteria	Before surgery	After surgery	p-value
Radiographs in a neutral position: anterolateral slippage, %	12.22 [8.35; 15.84]	14.12 [9.40; 17.11]	p < 0.05
Flexion-extension radiographs: anterolateral translation upon flexion-extension, mm	2.12 [1.67; 2.38]	2.27 [1.84; 2.74]	p < 0.05
segmental rotation angle, degrees	3.77 [2.22; 4.68]	4.89 [2.57; 5.25]	p < 0.05

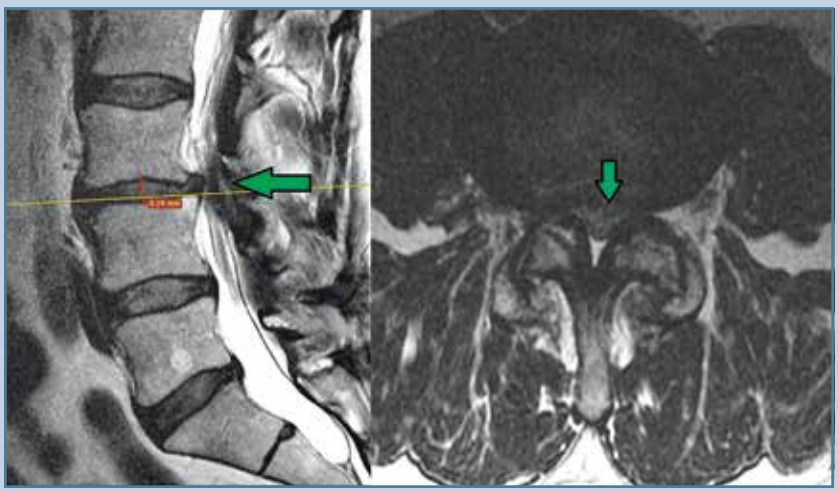

Fig. 4
Preoperative MR image of the 66-year-old patient M.

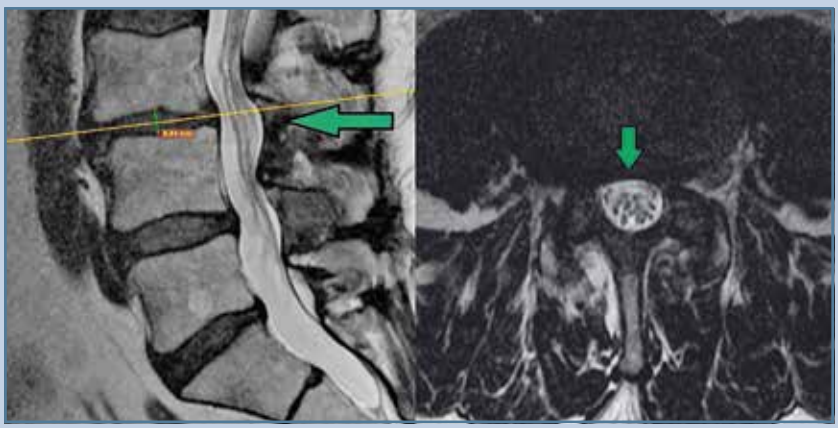

Fig. 5
Control MR image of the 66-year-old patient M. 14.2 months after the surgery

sity of vertebrogenic pain. This fact confirmed that degenerative changes were not progressing at the level of operated segments.

Evaluating the degree of segmental stability is an important aspect during preoperative planning and assessment of surgical outcomes. There is no consensus in the literature regarding which criteria for vertebra slippage should be considered the threshold ones when analyzing the functional spondylograms [25–27]. We used the criteria proposed by Hanley due to their lower values. When functional spondylograms were evaluated, anteroposterior vertebra slippage and segmental rotation angle increased by an average of 0.42 mm and 1.03° during flexion and extension, respectively. These findings are similar to those reported by other authors [4, 27]. Spondylolisthesis degree in the neutral position increased by an average of 1.42 %, which is actually statistically insignificant. According to Toyoda et al. [23], progression of degenerative spondylolisthesis for the follow-up periods of at least 5 years was 2.4 ± 4.7 %. Mori et al. [27] evaluated the increase in spondylolisthesis degree in control spondylograms by dividing all their observations into two groups: the cases where the slippage increased by less than 5% and more than 5%. According to their findings, the slippage by more than 5 % was considered significant and regarded as a potential risk for segmental instability.

It is believed that minimally invasive surgeries increase the risk of intraoperative complications (injury to the dura mater accompanied by liquorrhea; injury to nerve elements) due to pronounced degenerative changes in the spine and distorted anatomical landmarks; in addition, there exists a risk of wound infection [6, 14, 21]. However, the rate of such complications is minimized as the surgeon becomes more experienced and his/her skills are mastered, which we could actually see from our experience. In the present study, the rate of complications was not higher than the mean figures reported by other authors.

Fig. 6
Lumbar spondylograms of the 66-year-old patient M. in a neutral position before and 14.2 months after the surgery

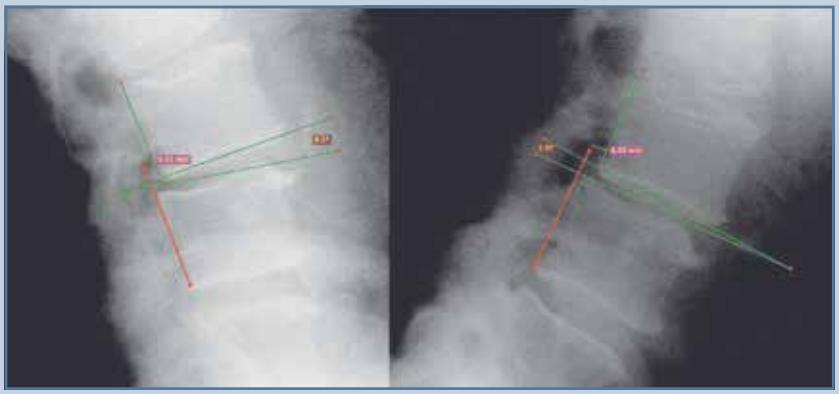

Fig. 7
Lumbar spondylograms (frontal view) of the 66-year-old patient M. before the surgery: anteroposterior slippage, 1.54 mm; segmental rotation angle, 4.9°

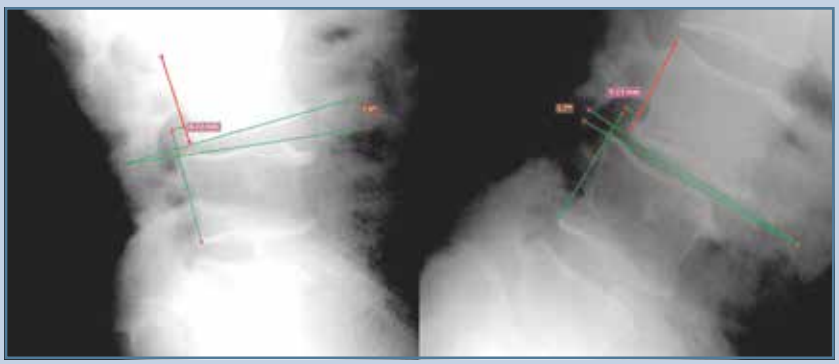

Fig. 8
Functional lumbar spondylograms of the 66-year-old patient M. 14.2 months after the surgery: anteroposterior slippage, 0.51 mm; segmental rotation angle, 4.7°

Conclusions

A retrospective analysis of a case series showed the favorable clinical and radiological outcomes of minimally invasive bilateral decompression through the unilateral approach in surgical treatment of patients with grade I degenerative spondylolisthesis combined with lumbar spinal stenosis without segmental instability, namely significant regression of pain in lower back and legs; improved parameters of working capacity in patients with slightly decreased segmental stability, and low probability of reoperation. These findings suggest that the proposed technique is effective, but further studies with a higher level of evidence are needed to confirm the conclusions made.

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