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The limited area decompression, intervertebral fusion, and pedicle screw fixation for treating degenerative lumbar spinal stenosis with instability

Follow-up at least 12 months an observational study

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Abstract

The aim of the study was to evaluate the clinical effect of the limited area decompression, intervertebral fusion, and pedicle screw fixation for treating degenerative lumbar spinal stenosis (DLSS) with instability. Hemilaminectomy decompression, intervertebral fusion, and pedicle screw fixation for treating DLSS with instability as the control group.

Follow-up of 54 patients (26 males and 28 females; average age, 59.74 ± 10.38 years) with DLSS with instability treated by limited area decompression, intervertebral fusion, and pedicle screw fixation (LIFP group), and 52 patients as control group with hemilaminectomy decompression, intervertebral fusion, and pedicle screw fixation (HIFP group). We assessed clinical effect according to the patients' functional outcome grading (good to excellent, fair, or poor), Oswestry Disability Index (ODI) and visual analogue scale (VAS) for low back pain and lower limb pain, which was administered preoperatively and at 3, 6, and 12 months postoperatively. Fusion status was assessed by radiologists at the last follow-up. Treatment satisfaction was assessed according to the subjective evaluations of the patients.

At the 12-month follow-up, 96.2% (52/54) and 90.3% (47/52) of group LIFP and HIFP belonged to good to excellent outcome categories, respectively, while 3.7% (2/54) and 9.6% (5/52) of group LIFP and HIFP belonged to fair respectively, neither group belonged to poor. Satisfaction rates of patients in group LIFP and group HIFP were 98.1% (53/54) and 92.3% (48/52), respectively. The patients' functional outcome grading and satisfaction rate in group LIFP were better than that in group HIFP. The VAS for low back and lower limb pain and the ODI improved significantly during the 12 months after surgery (all $P < .001$) in 2 groups. The VAS for low back and lower limb pain were no difference between two groups, however, the ODI of group LIFP was lower than that of group HIFP ($P < .001$). All patients achieved radiological fusion.

The limited area decompression, intervertebral fusion, and pedicle screw fixation had a satisfactory effect on patients with DLSS with instability.

Abbreviations: CT = computed tomography, DLSS = degenerative lumbar spinal stenosis, LSS = lumbar spinal stenosis, MRI = magnetic resonance imaging, ODI = Oswestry Disability Index, VAS = visual analogue scale, VAS back = visual analogue scale scores for low back pain, VAS leg = visual analogue scale scores for lower limb pain.

Keywords: decompression, degenerative lumbar spinal stenosis (DLSS), intervertebral fusion, oswestry disability index (ODI), treatment satisfaction, visual analogue scale (VAS)

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1. Introduction

Degenerative lumbar spinal stenosis (DLSS) is a spinal disease that is closely related to age and occurs with degeneration of the spine. It often causes neurogenic claudication, lower back pain and other symptoms, and potential for disability.[1–3] The quality of life of patients is significantly reduced, and the psychological and physical effects of patients are adversely affected.[4] According to the Framingham study,[5] the incidence of lumbar spinal stenosis (LSS) in the population is as high as 27.2%, most of which occurs between 50 and 60 years,[6] which has become one of the main causes of lumbar surgery in elderly patients.[1,2]

Surgical treatment is considered to be the best treatment after conservative treatment is ineffective.[7–9] There are many surgical methods for the treatment of DLSS. The traditional procedures include laminectomy, hemilaminectomy, and laminotomy, etc. Different surgical decompression ranges are different, and the treatment effects and complications are not the same.[10] Currently, there is no standard method for the treatment of DLSS.[3] The aim of this study was to evaluate the effect of the limited area decompression, intervertebral fusion, and pedicle screw fixation on the treatment of DLSS with instability.

2. Materials and methods

2.1. Patient population

This study was approved by Lanzhou University Second Hospital ethics committee. The limited area decompression, intervertebral fusion, and pedicle screw fixation were performed between June and December 2017. The patients who received our treatment met the following three inclusion criteria:

(1) clinical symptoms of LSS, such as intermittent claudication, low back pain, and radiating lower extremity pain, conservative treatment was ineffective;
(2) imaging findings on a cross-section of the spinal canal (magnetic resonance imaging/computed tomography [MRI/CT]) showing compression of the dural sac or nerve roots, such as thickening of the ligamentum flavum and hypertrophy of the joints; and
(3) lumbar instability (the diagnostic criteria for lumbar instability are overextension and flexion X-ray findings >3 mm translation and >10° angulation[11]).

The exclusion criteria were:

(1) central lumbar disc herniation causing spinal stenosis;
(2) spinal stenosis caused by tumors, inflammation, or other diseases, as determined by preoperative and postoperative pathological examinations;
(3) history of mental illness or alcoholism; and
(4) inadequate accurate follow-up data. If it meets any of the above, it will be excluded.

2.2. Surgery and clinical follow-up

These operations were performed by the same spine surgery team, which consisted of a chief physician, an attending physician, and 2 residents. The key parts of the operation were completed by the chief physician and the attending physician; the residents assisted with implementation of the operation.

The shortest follow-up of the patients who met the inclusion criteria was more than 12 months. The visual analogue scale (VAS) scores for low back pain (VAS back) and lower limb pain (VAS leg), and the Oswestry Disability Index (ODI) score (range: 0–50 points, where lower scores denote better functional status), were recorded preoperative and at 3, 6, and 12 months after surgery. Patients level of satisfaction (unsatisfied, satisfied, or very satisfied) with the surgical results was investigated. The fusion status was assessed by radiologists. Computed tomography is performed when radiological fusion is suspected or considered to have not been achieved.

We refer to the table of Takaso et al[12] (Table 1), and according to the functional outcomes at follow-up, the three grades of Good to excellent, Fair and Poor were used to evaluate the effect of surgical treatment.

2.3. Surgical procedure

The surgical procedure was divided into the following steps:

(1) General anesthesia was induced with the patient in the prone position. Then, a median incision was made in the back to reveal the level of the bilateral articular processes, with the integrity of the supraspinous and interspinous ligaments being retained.
(2) Using a gun-type rongeur to bite off the ligamentum flavum at the end of the lower lumbar vertebral lamina, gradually bite the ipsilateral lower articular process of the vertebral body, the ligamentum flavum was removed at the lower end of the upper lumbar vertebral lamina, then use a bone knife to cut the attachment point of the ligamentum flavum on the inner side of the articular process on the next vertebral body, and the ligamentum flavum was carefully separated from the dura mater, excision of free ligamentum flavum. The dura mater was separated and pushed to the inside, exposing the intervertebral space.
(3) The nerve roots and spinal cord were protected and a sharp knife was used to cut the fiber ring. Nucleus pulposus extraction with nucleus pulposus forceps. Then, the intervertebral space was cleaned with a reamer and curette to treat the

Table 1

Clinical and functional outcome.

Rating	Description
Good to excellent	A patient with a good to excellent outcome had absent or occasional mild back and leg pain. Additionally, it was required that good to excellent patients be able to ambulate more than one mile or 20 minutes, and that they not restrict themselves from their usual activities
Fair	A fair result implied persistent mild back or leg pain with occasional moderate pain, and less than one mile or 20 minutes of ambulation endurance. These patients also acknowledged some mild restrictions in their customary physical activity.
Poor	A poor result implied little to no pain relief from surgery, major activity limitations, or both. A repeat operation for any reason was considered a poor result, regardless of the ultimate level of function.

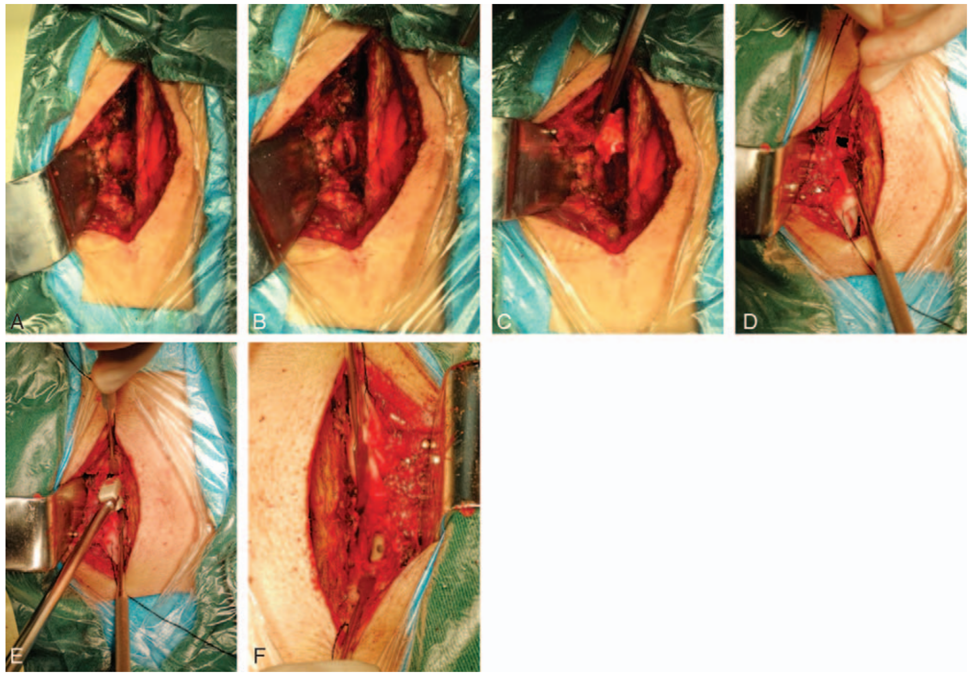

Figure 1. Key steps of Surgical procedure. (A) Exposure of articular process. (B) Determine the range of decompression. (C) Excision of bone and ligamentum flavum in decompression area. (D) Removal of nucleus pulposus and preparation of bone graft bed. (F) Implantation of spinal cage. (E) Prepare for insertion of internal fixator.

upper and lower cartilage endplates, and the bone graft bed was prepared.

(4) A model was used to evaluate the size of the intervertebral space, and to determine the maximum height of the implantable cage, which was then filled with decompressed broken bone. The granular bone cut during decompression was implanted; then, the cage was implanted into the intervertebral space.

Figure 2. Boxed area represents decompression area.

(5) Pedicle screws were inserted according to the number of narrow or unstable phases.
(6) According to the physiological curvature of the spine at the surgical site, a connecting rod was pre-bent, implanted, and locked with a screw.
(7) Saline was used to wash the surgical field, followed by drainage and layer-by-layer suturing.

During the operation, the sagittal{sagittal judgment standard: lumbar lordosis= pelvic incidence+9°(±9)}[13] and coronal positions were balanced by X-ray fluoroscopy. Whether it's a single-level surgery, two-level surgery or three-level surgery, it is done through a median dorsal incision. In our surgery, the decompression site is used as the entrance of intervertebral fusion to achieve decompression and fusion. Figure 1 shows the key steps of the surgical procedure. Figure 2 shows the unilateral decompression area. Our decompression position is more centerline and less decompression area than transforaminal lumbar interbody fusion described by Harms and Rolinger.[14]

Principle of decompression (Fig. 3):

(1) Imaging examination shows that lumbar spinal stenosis is mainly unilateral, if symptoms are unilateral, unilateral decompression should be selected, if symptoms are bilateral, decompression should be taken from the serious side.
(2) Imaging examination showed total spinal stenosis, bilateral symptoms were equally severe, choose bilateral decompression (cage is placed from one side).

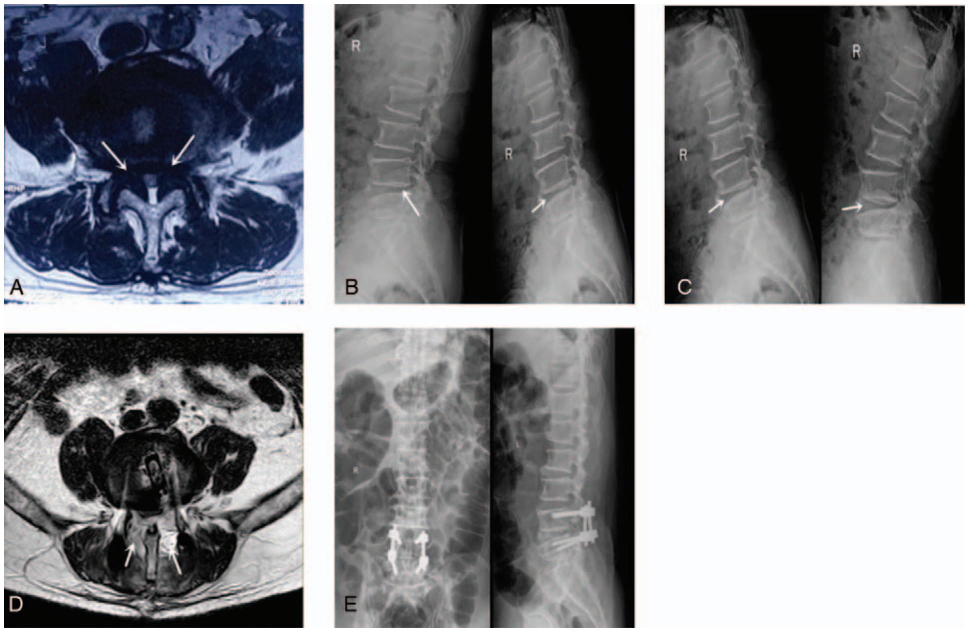

Figure 3. A 75-year-old DLSS patient, male. (A) Preoperative L4/5 segmental cross-section MRI, bilateral lateral recess stenosis. (B) Preoperative lumbar spine X-ray, showing L4/5 intervertebral space narrowing. (C)The instability of the L4/5 segment was found in overextended flex X-ray films. (D) Postoperative L4/5 segmental cross-sectional MRI, marked as surgical decompression area. (E) Postoperative lumbar spine X-ray film.

2.4. Statistical analysis

Values are expressed as means ± standard deviation. The paired-sample *t*-test was used to compare low back pain and lower limb pain VAS scores, and the ODI score, between before and at 12 months after the surgery. A P value $< .001$ was considered significant. Statistical tests were performed using SPSS software (ver. 22.0; SPSS Inc., Chicago, IL).

3. Results

3.1. Patient demographics and surgical details

The study initially included 58 patients, of whom 4 were lost to follow-up. One patient died from esophageal cancer at 7 months after the surgery, two died from cardiovascular disease at 5 and 9 months after surgery, and 1 died in a car accident 6 months after surgery. There were 54 patients (26 males and 28 females; mean age, 59.74±10.38 years) with a minimum follow-up time >12 months. A total of 86 segments were surgically treated; 21 cases were single-segment (L4–L5: 16 cases, L5–S1: 5 cases), 27 involved two segments (L2–L4: 1 case, L3–L5: 12 cases, L4–S1: 14 cases), and 4 involved 3 segments (L3–S1). In HIFP group, 52 of 53 patients (23 males and 29 females; mean age, 61.40±9.55 years) were followed up. The preoperative VAS low back score of group LIFP and group HIFP were 8.04±0.84 and 7.79±0.89, the preoperative VAS lower extremity score of group LIFP and group HIFP were7.48±0.90 and 7.37±0.92, and the preoperative ODI score of group LIFP and group HIFP were 38.22±1.80 and 38.40±1.91, respectively. The mean operation time in group LIFP and group HIFP were 99.57±21.26 min and 112.04±25.89 min, respectively. The mean bleeding volume in group LIFP and group HIFP were 93.20±22.32 ml and 108.46±28.91 ml, respectively. There were no complications, such as a dural tear or postoperative wound infection. No blood transfusions were performed during or after surgery (Table 2).

3.2. Patients' functional outcome grading and satisfaction rate

At the 12-month follow-up, 96.2% (52/54) and 90.3% (47/52) of group LIFP and HIFP belonged to good to excellent outcome categories, respectively, while 3.7% (2/54) and 9.6% (5/52) of group LIFP and HIFP belonged to fair respectively, neither group belonged to poor. Satisfaction rates of patients in group LIFP and group HIFP were 98.1% (53/54) and 92.3% (48/52), respectively. The patients' functional outcome grading and

Table 2

Patient demographics and surgical details.

	Grouping	
Demographic	**LIFP**	**HIFP**
No. of cases	54	52
Mean age (years)	59.74±10.38	61.40±9.55
Male/female	26/28	23/29
Total levels	86	84
Single-level surgery		
L4-L5	16	15
L5-S1	5	7
Two-level surgery		
L2-L4	1	2
L3-L5	12	13
L4-S1	14	13
Three-level surgery		
L3-S1	4	2
VAS (back)	8.04±0.84	7.79±0.89
VAS (leg)	7.48±0.90	7.37±0.92
ODI	38.22±1.80	38.40±1.91
Operating time	99.57±21.26min	112.04±25.89min
Blood loss	93.20±22.32ml	108.46±28.91ml

HIFP = hemilaminectomy decompression, intervertebral fusion, and pedicle screw fixation, LIFP = limited area decompression, intervertebral fusion, and pedicle screw fixation, ODI = Oswestry disability index, VAS = visual analog scale.

Table 3

Follow-up at 6 and 12 months after surgery.

			Six months follow-up				Twelve months follow-up			
Grouoping	n	Follow-up	Good to excellent	Fair	Poor	Satisfaction	Good to excellent	Fair	Poor	Satisfaction
LIFP	54		79.6%(43/54)	20.3%(11/54)	0%	90.7%(49/54)	96.2%(52/54)	3.7%(2/54)	0%	98.1%(53/54)
HIFP	52		65.8%(34/52)	34.6%(18/52)	0%	86.5%(45/52)	90.3%(47/52)	9.6%(5/52)	0%	92.3%(48/52)

HIFP = hemilaminectomy decompression, intervertebral fusion, and pedicle screwfixation, LIFP = limited area decompression, intervertebral fusion, and pedicle screw fixation.

satisfaction rate in group LIFP were better than that in group HIFP. (Table 3).

3.3. Clinical outcomes

The VAS for low back and lower limb pain and the ODI improved significantly during the 12 months after surgery (all $P < .001$) in 2 groups. The VAS for low back and lower limb pain were no difference between 2 groups, however, the ODI of group LIFP was lower than that of group HIFP ($P < .001$). (Table 4). All patients achieved radiological fusion at the last follow-up.

4. Discussion

Frequent low back pain, neurogenic claudication, and lower extremity pain are the most common clinical symptoms in patients with LSS. These symptoms are usually related to compression of the nerve root or dural sac.[6] Spondylolisthesis and loss of spinal stability due to degenerative changes in the spine also occur in elderly patients,[15–17] and are an important cause of low back pain and neurological deficits in patients.[18] Decompressing the nerve root or dural sac and restoring stability of the spine are key to treatment. In this study, we applied the limited area decompression, intervertebral fusion, and pedicle screw fixation for DLSS with instability, and satisfactory results were obtained at the 12-month follow-up.

Surgical treatment of LSS aims to adequately decompress the nerve roots and dural sac without compromising spinal stability.[15,19] A laminectomy, the classical surgical procedure for treating LSS, is necessary to remove the spinous processes, the laminae on both sides, the ligamentum flavum, and part of the articular process during decompression, which can damage the posterior structure of the spine.[19–21] In addition to a laminectomy, bilateral fenestration and unilateral fenestration with undercutting contralateral decompression result in different degrees of damage to the posterior spinal structure.[22] However, a meta-analysis[23] showed that the success rate of these three surgical methods is only 64%, with the main reason for failure being postoperative iatrogenic spinal instability. Traditional decompression poses a threat to spinal stability. Lauryssen et al[24] reported that traditional decompression methods destabilize the spine and increase the pressure on the intervertebral discs. The spine structure should be preserved as much as possible to preserve stability in the surgical treatment of LSS, under sufficient decompression conditions.

Among patients with DLSS, especially those with instability, small facet joint hyperplasia and hypertrophy of the ligamentum flavum are the main causes of spinal stenosis, due to biomechanical changes and compensatory activities of the body.[15,22,25] The ligamentum flavum is divided into 2 layers, being mainly attached to the edge of the upper and lower lamina.[26] The ligamentum flavum and the superior articular process form the posterior wall of the lateral recess; therefore, hypertrophy of the ligamentum flavum is likely to cause stenosis of the lateral recess.[25,27] The entire root process of the lower lumbar nerve roots travels via an inclined duct, increasing susceptibility to intervertebral foramen stenosis.[25] During the operation, we resected the part of the ligamentum flavum and some of the articular processes that form the lateral recess, which enlarged the lateral recess and relieved the nerve root compression. It is important to retain as much of the spinal structure as possible during surgery, and we retained the integrity of the supraspinous ligament and interspinous ligament when it was exposed. Kakiuchi et al[28] conducted a retrospective study with a 12-year follow-up and reported that the continuity of the lamina and spinous processes has important implications for the outcome of the procedure. Hindle et al[29] showed that the supraspinous ligament and interspinous ligament play an important role in maintaining spinal stability early after spinal surgery, even in cases of pedicle screw fixation. Reducing damage

Table 4

VAS and ODI score changes during follow-up.

Characteristics	Grouping	n	Preoperative	Three months	Six months	Twelve months
VAS (back)	LIFP	54	8.04 ± 0.84	3.30 ± 0.83	2.26 ± 0.73	1.39 ± 0.59*
	HIFP	52	7.79 ± 0.89	3.60 ± 0.79	2.37 ± 0.79	1.52 ± 0.54*
VAS (leg)	LIFP	54	7.48 ± 0.90	3.24 ± 1.11	2.17 ± 0.94	1.22 ± 0.66*
	HIFP	52	7.37 ± 0.92	3.48 ± 1.07	2.37 ± 1.01	1.19 ± 0.62*
ODI	LIFP	54	38.22 ± 1.80	15.63 ± 2.79†	10.22 ± 2.85†	5.56 ± 2.20*,†
	HIFP	52	38.40 ± 1.91	18.15 ± 3.98	11.73 ± 2.62	6.79 ± 2.15*

HIFP = hemilaminectomy decompression, intervertebral fusion, and pedicle screw fixation, LIFP = limited area decompression, intervertebral fusion, and pedicle screw fixation, ODI = Oswestry disability index, VAS = visual analog scale.

3, 6, 12 months: postoperatively 3, 6, 12 months.

* Compared between 12 months after operation and before operation, $P < .001$.

† Compared with Group HIFP, $P < .001$.

to the posterior structure of the spine not only increases spinal stability, but also facilitates early recovery of the patient.[30]

Loss of spinal stability is one of the main causes of lower back pain. Studies have shown that external fixation effectively alleviates the pain caused by spinal instability,[18] but is only a temporary fix. Regular efforts should be made to restore stability of the spine.[22,31,32] Pedicle screw fixation and intervertebral fusion restore intervertebral displacement, maintain balance between the spine and the pelvis, provide immediate spinal stability, relieve symptoms, prevent progressive slippage, and increase the fusion rate.[15] When the spine undergoes a degenerative change, it is often accompanied by a loss of height of the intervertebral space,[33] resulting in wrinkles in the soft tissue of the spinal canal, such as the posterior longitudinal ligament and the ligamentum flavum, thus decreasing the volume of the spinal canal and compression of the dural sac. We used the maximum height of the implantable cage as a guide to restore the height of the intervertebral space during fusion, so that the soft tissue in the spinal canal, such as the posterior longitudinal ligament and the ligamentum flavum, was stretched, which increased the volume of the spinal canal.

There is no standard method to surgically treat DLSS.[3] In recent years, minimally invasive techniques have become increasingly popular among surgeons and patients due to the minimal amount of tissue damage, small skin incisions, and good aesthetic results. However, because minimally invasive surgery requires specialized equipment and technical experience, as well as certain surgical indications, it is not routinely performed. Minimally invasive techniques cannot solve the problem of simultaneous pedicle screw fixation, intervertebral fusion, and spinal canal decompression in patients with DLSS with instability. Therefore, immediate spinal stabilization and spinal canal decompression are not performed. The surgeon's goal in DLSS is not to restore the spinal structure to that of a 30-year-old, but rather to achieve an age-appropriate treatment outcome so that the independence of older patients is ensured.[10] With the continuous development of spinal surgery technology, treatment of DLSS with instability not only achieves a stable spine and spinal canal decompression, but also restores the patient's quality of life.

In this study, the limited area decompression, intervertebral fusion, and pedicle screw fixation for DLSS with instability stabilized the spine and decompressed the spinal canal, resulting in satisfactory therapeutic results. However, this study had several limitations. First, the study was carried out in a single institution and the operation was performed by a team of spine surgeons. Second, the sample size was small, and the follow-up time was short. Future studies should include more patients and a longer follow-up to validate our results.

5. Conclusion

The final conclusion would be that LIFP and HIFP groups had similar clinical outcomes. The advantage of LIFP is not clear, but is non-inferior to the current surgical treatment HIFP. The LIFP can stabilize the spine and decompressed the spinal canal, is a therapeutic option for DLSS with instability. The early clinical effect of this operation is satisfactory, but its long-term effect needs further observation.

Author contributions

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Funding acquisition: Yonggang Wang.
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Supervision: Xuewen Kang.
Validation: Enhui Ren, Liang Yang, Yonggang Wang, Xuchang Hu, Yong Yang.
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Writing – original draft: Fengguang Yang.
Writing – review & editing: Yonggang Wang, Xuewen Kang.
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