

## Pilot Study

# A Pilot Study of Full-Endoscopic Annulus Fibrosus Suture Following Lumbar Discectomy: Technique Notes and One-Year Follow-Up

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**Background:** An annulus fissure or defect will inevitably be left on the posterior annulus fibrosus after almost all kinds of lumbar discectomy, which may lead to unsatisfying postoperative pain relief and recurrence of the disc herniation.

**Objective:** The objective of this research is to introduce the technique of full-endoscopic annulus fibrosus suture following lumbar discectomy through the transforaminal or interlaminar approach, and to analyze the clinical outcome of full-endoscopic lumbar discectomy and annulus fibrosus suture.

**Study Design:** This study used a prospective cohort design.

**Setting:** The research was conducted in a hospital and outpatient surgery center.

**Methods:** A total of 50 patients with noncontained lumbar disc herniation treated with full-endoscopic lumbar discectomy and annulus fibrosus suture were treated in our department between January 2018 and November 2018. Full-endoscopic single-stitch suture via the transforaminal approach (Group T) or double-stitch suture via the interlaminar approach (Group I) was selected according to the level of lesion. Lumbar magnetic resonance imaging (MRI) was reexamined on the second day and 3 months after operation to evaluate the completeness of the discectomy and the adequacy of nerve decompression. Patients were followed up on the second day, 3 months, 6 months, and one year after operation to evaluate the relief of low back pain and leg pain, using a visual analog scale (VAS, 100-point scale). At 3 months, 6 months, and one year after operation, the patients were followed up for recovery of lumbar spine function, using the Oswestry Disability Index (ODI). At the one-year follow-up, the MacNab score was used to evaluate the clinical outcome, and the recovery of nerve root function (sensation, muscle strength, and reflex) was recorded.

**Results:** All operations were successfully completed, including 27 cases in Group T and 23 cases in Group I. There were no surgical complications and no recurrence of lumbar disc herniation. Lumbar MRI reexaminations of all patients showed that the herniated disc was completely removed and the nerves were fully decompressed. Postoperative low back pain and leg pain were significantly relieved, and the ODI score was significantly improved ( $P < .01$ ) in both groups. At the one-year follow-up, the excellent and good rates as measured by the MacNab score were 92.6% in Group T and 91.3% in Group I with no significant difference between the 2 groups ( $P > .05$ ). The impaired sensation and muscle strength in the low extremities of evolved nerve root of the 2 groups of patients recovered significantly at the one-year follow-up ( $P < .01$ ), but the tendon reflex did not recover significantly ( $P > .05$ ).

**Limitations:** This is an observational cohort study with relatively small sample sizes and short-term follow-up.

**Conclusions:** Full-endoscopic lumbar discectomy and annulus fibrosus suture through either the transforaminal or interlaminar approach are safe and effective minimally invasive spinal surgery techniques that can reduce the recurrence rate of lumbar disc herniation after full-endoscopic lumbar discectomy.

**Keywords:** Annulus fibrosus suture; full-endoscope; lumbar disc herniation; lumbar discectomy; minimally invasive spinal surgery

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**A**fter lumbar discectomy, an annulus fissure or defect will inevitably be left on the posterior annulus fibrosus. There is no exception for full-endoscopic lumbar discectomy, whether it is performed through the transforaminal approach or the interlaminar approach. Short-term postoperative crater-like bulged annulus fibrosus still causes mechanical stimulation to the nerve roots. Inflammatory mediators in the disc are released through the annulus rupture and continue to leak into the spinal canal, which can cause chemical radiculitis. If the annulus fissure fails to heal, it may cause the residual nucleus pulposus in the intervertebral disc to protrude into the spinal canal again, leading to the recurrence of the disc herniation. Ambrossi et al (1) studied the incidence of complications after the primary lumbar discectomy with 12 months' follow-up; 12% had symptomatic recurrence of disc herniation, of which 7.8% required revision surgery. Sherman et al (2) reported the results of 497 cases of lumbar discectomy: 15% of patients had complications within 40 days after surgery; at the 6-month follow-up, 137 (28%) of patients needed further treatment, of which 52 (11%) patients required revision surgery. Bron et al (3) also reported a high recurrence rate and persistent postoperative low back pain after lumbar discectomy. They believed that an annulus fissure should be effectively closed after lumbar discectomy, using techniques such as tissue engineering reconstruction and annulus repair. At present, the biological repair of annulus fibrosus is still in the laboratory research stage; methods under study include collagen modification, cell therapy, gene therapy, and tissue engineering reconstruction (3-7). Surgical repair of lumbar annulus fibrosus has been carried out in clinical practice, including various suture and closure techniques, and has achieved good results. But to our knowledge, the technique of repairing lumbar annulus fibrosus under full endoscope has not been reported. This study will detail the technical notes of full-endoscopic lumbar annulus suture and report the outcome after one year of follow-up.

## METHODS

### Patients

Fifty patients who met the inclusion criteria were treated with full-endoscopic lumbar discectomy and annulus fibrosus suture between January 2018 and November 2018 in our department.

Inclusion criteria: 1) lumbar disc herniation with

consistent clinical symptoms, signs, and imaging; 2) no significant lumbar instability; 3) imaging suggestion of a soft noncontained herniation, including extrusion and sequestraton; 4) no obvious calcification or ossification around the annulus fissure; 5) no obvious annulus fibrosus defect after discectomy (< 10 mm).

Exclusion criteria: 1) clinical symptoms and signs are inconsistent with imaging; 2) combined segmental lumbar instability; 3) annulus fibrosus around the annulus fissure is obviously calcified or ossified; 4) annulus fibrosus has an obvious defect (> 10 mm) after discectomy.

### Interventions

Approval to conduct the study was granted by the ethics committees of the Fourth Medical Center of Chinese PLA General Hospital. The Institutional Review Board approved informed consent document and protocols were provided to all the patients, which described details of the surgery including the mechanism of treatment, predictive outcome, potential risks, and side effects.

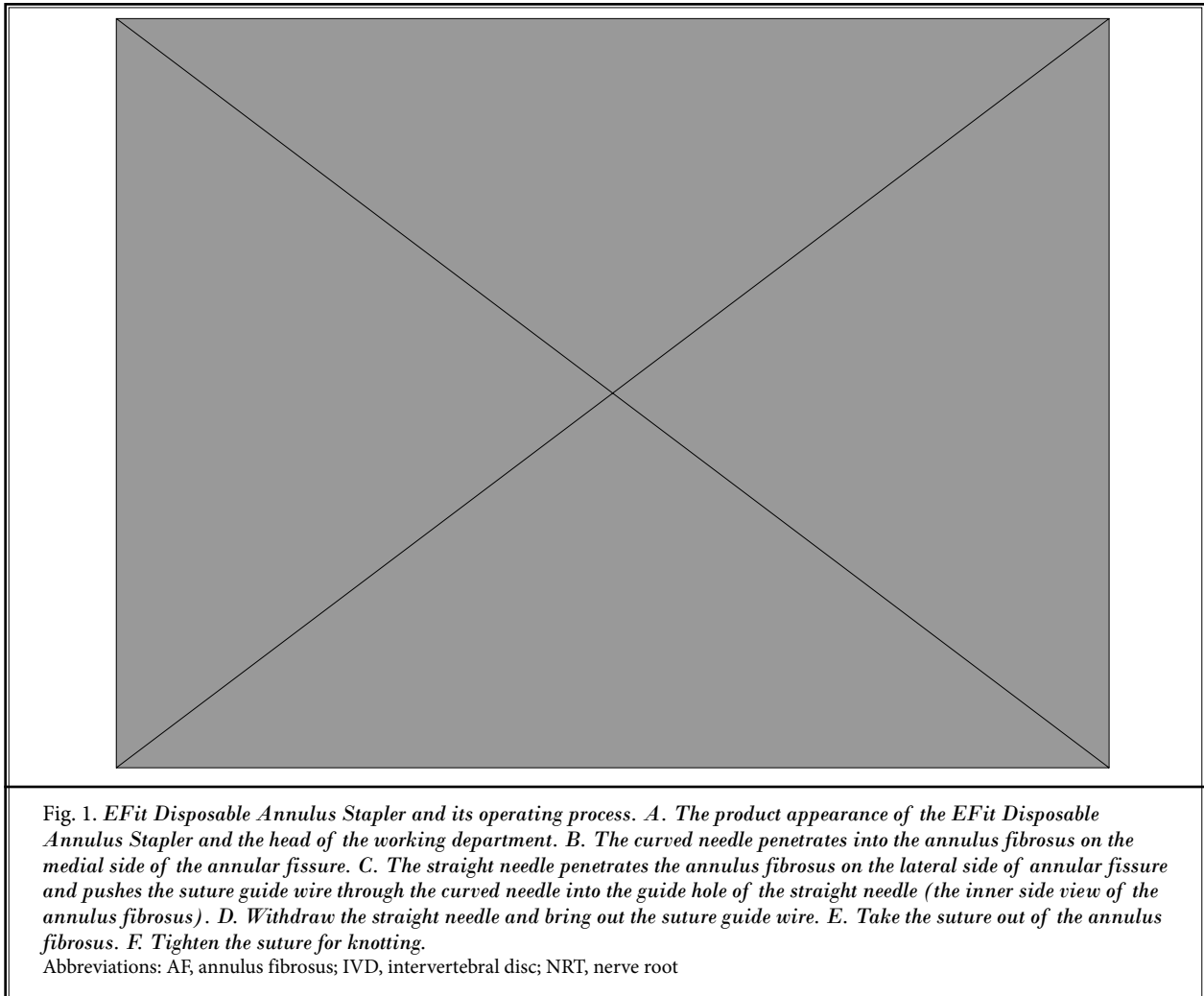
### Surgical Tools

An EFit Disposable Annulus Stapler (Beijing 2020 Medical Science & Technology Co. Ltd., China) and full-endoscope equipment were required for this study.

The EFit Disposable Annulus Stapler (Fig. 1A-F) has a variety of models that can be used for annulus suture after traditional open lumbar discectomy, microscopic lumbar discectomy, or full-endoscopic lumbar discectomy. The EFit Disposable Annulus Stapler for full-endoscopic annulus suture has a 5-mm-diameter working part. The size parameters of the EFit Disposable Annulus Stapler for a full-endoscopic annulus suture are as follows: the diagonal diameter of the working part is 5.3 mm, the distance between the 2 puncture needles is 4 mm, the diameter of the puncture needle is 1.6 mm, and the suture is a 3-0 nonabsorbable polyester thread. Therefore, a full-endoscopic system with a working channel greater than 5.5 mm must be selected for use. Currently, Wolf, Spinendos, and JoiMax companies have corresponding full-endoscopic systems that can be used. The Lusta full-endoscopic system (Spinendos GmbH, Germany) was used in this study.

### Surgical Procedures

1. Single-stitch suture technique for full-endoscopic annulus repair through the transforaminal approach:
  - 1) Case report: A 23-year-old man with low back pain and radiating pain in his right leg for more

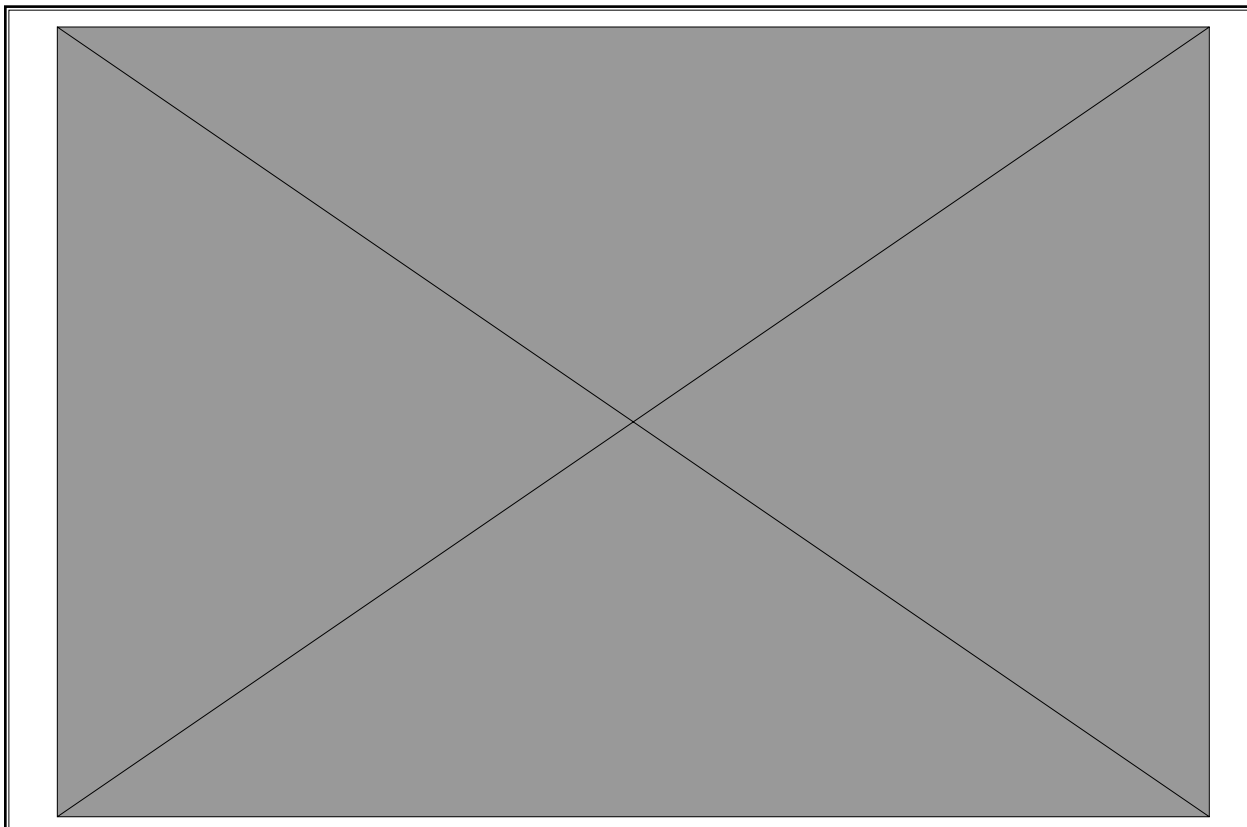


than 4 months. Preoperative magnetic resonance imaging (MRI) showed that the L4-5 intervertebral disc extruded from the right side (Fig. 2A).

- 2) Anesthesia: local anesthesia (0.5% lidocaine).
- 3) Posture: prone position.
- 4) Full-endoscopic lumbar discectomy through the transforaminal approach: a) We punctured through the right posterolateral approach under fluoroscopic guidance, established skin-right L4-5 intervertebral foramen pathway, and enlarged the intervertebral foramen with a modified foraminoplasty (8) so that the large-channel full-endoscope could enter the spinal canal for operation (Fig. 2B). b) The herniated disc (HD) was exposed under the full-endoscope, the posterior longitudinal ligament and the annulus fibrosus were incised in the direction of the

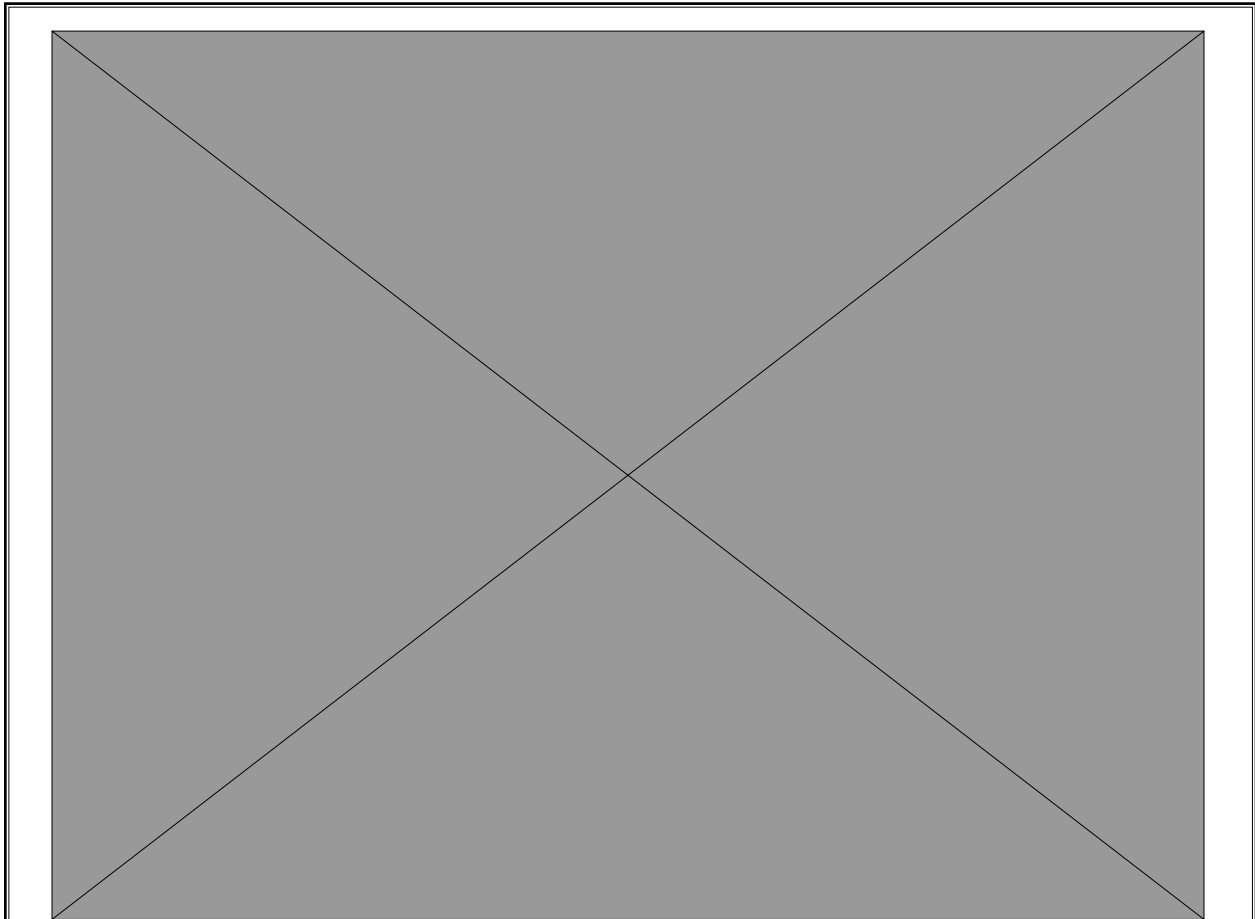
annulus rupture, and the HD was exposed and removed. c) The free and loose nucleus pulposus in the intervertebral disc is was removed. d) The annulus fissure was sufficiently exposed for suture (Fig. 2C).

- 5) Full-endoscopic annulus suture: a) First, we pierced the curved needle of the EFit Disposable Annulus Stapler into the posterior longitudinal ligament and annulus fibrosus medial to the annulus fissure. b) We closed the posterior longitudinal ligament and the medial annulus to the lateral annulus (Fig. 2D). c) We inserted the straight needle into the annulus fibrosus lateral to the annulus fissure. d) According to the EFit Disposable Annulus Stapler operating procedures, we threaded the suture through the annulus fibrosus on both sides, pulled it out,



**Fig. 2. Full-endoscopic lumbar annulus fibrosus suture through a transforaminal approach. A. Preoperative T2-weighted axial lumbar MRI showed L4-5 disc herniation. B. The L4-5 intervertebral foramen is enlarged through the right transforaminal approach to allow the large working-channel endoscope to enter the spinal canal. C. The fissures and medial dorsal aspect of the posterior longitudinal ligament are exposed under full-endoscopy. D. Insert the curved needle into the posterior longitudinal ligament and pull it laterally to cover the annulus fibrosus lateral to the annular fissure. E. The suture knot, fissures of the annulus fibrosus, and their relationship with nerve roots are exposed under full-endoscopy. F. Postoperative lumbar T2-weighted axial MRI on the second day after operation showed that the herniated disc was completely removed and the posterior annulus fibrosus was flattened.**  
 Orientation of endoscopic field of vision: left-caudal; right-cephalad; upper-dorsal; lower-ventral.  
 Abbreviations: AF, annulus fibrosis; MRI, magnetic resonance imaging; NRT, nerve root; PLL, posterior longitudinal ligament

- and tied it. e) We cut off the extra sutures after confirming that the sutures were correct and reliable. f) We explored the suture quality of the annulus fibrosus and confirmed the decompression of the nerve root (Fig. 2E).
2. Double-stitch suture technique for full-endoscopic annulus repair through the interlaminar approach:
    - 1) Case report: A 32-year-old man with low back pain and left leg pain for more than 6 months. Preoperative lumbar MRI showed a left downward sequestration HD of axilla type at the L5/S1 level, and the left S1 nerve root was significantly compressed (Fig. 3A, Fig. 3B).
      - 2) Anesthesia: general anesthesia with tracheal intubation.
      - 3) Posture: prone position.
      - 4) Full-endoscopic lumbar discectomy through the interlaminar approach:
        - a) The ligamentum flavum was opened under the full-endoscopy to expose the intracanal nerve tissue. The HD removal approach was selected according to the HD position (9). The HD in the axilla of the S1 nerve root was removed.
        - b) The shoulder HD lateral to the left S1 nerve root was exposed and removed.
        - c) The loose and free nucleus pulposus tissue in the intervertebral disc was removed.



*Fig. 3. Full-endoscopic annulus fibrosus suture through the interlaminar approach. A-B. Preoperative T2-weighted lumbar MRI showed L5S1 disc herniation, and the left S1 nerve root was significantly compressed. C. Using the double-stitch suture technique, the anchor sutures are sutured on the relatively healthy annulus fibrosus medial and lateral to the annular fissure. D. Pull and tie the bilateral anchor sutures. E-F. Postoperative T2-weighted lumbar MRI 3 months after surgery showed that the nerve was decompressed sufficiently and the posterior edge of the disc was flat. Orientation of endoscopic view: left-cephalad side; right-caudal side; upper-medial side; lower-lateral side. Abbreviations: LF, ligamentum flavum; IVD, intervertebral disc; MRI, magnetic resonance imaging; NRT, nerve root*

5) Full-endoscopic annulus suture: a) The annulus fissure was sufficiently exposed; anchoring sutures were performed on the relatively healthy annulus fibrosus and posterior longitudinal ligament on both sides of the annulus fissure (Fig. 3C). b) A bilateral anchoring suture was knotted. c) We checked the suture quality of the annulus fibrosus and confirmed the decompression of the nerve (Fig. 3D).

### Outcome Assessment

The lumbar MRI was reexamined on the second day and 3 months after surgery to evaluate the HD resec-

tion and the nerve decompression (Fig. 2F, Fig. 3E, Fig. 3F).

Patients were followed up 2 days, 3 months, 6 months, and one year after surgery to evaluate the relief of pain symptoms, using a visual analog scale (VAS, 100-point scale). At 3 months, 6 months, and one year after surgery, the patients were followed up for recovery of lumbar spine function using the Oswestry Disability Index (ODI). At the one-year follow-up, the MacNab score of lumbar spine function was evaluated, and the recovery of nerve root function (sensory, muscle strength, and tendon reflex) was recorded.

## Statistical Analysis

SPSS Version 26 (IBM Corporation, Armonk, NY) was used for statistical analysis. One-way analysis of variance (ANOVA) was performed on VAS scores of low back pain and leg pain and ODI scores before surgery, 2 days, 3 months, 6 months, and one year after surgery. Multiple comparisons at different time points were performed using the least significant difference (LSD) test. The qualitative data of nerve root function status before and one year after surgery were compared by chi-square test. The comparison of MacNab function scores between the 2 groups at the one-year follow-up was performed by chi-square test.  $P < .01$  was considered statistically significant.

Table 1. Summary of demographic data and preoperative parameters in each group.

Index	Group T	Group I	P Value
Gender			.522*
Women	14	14	
Men	13	9	
Age (y)	57.9 ± 9.1	54.0 ± 6.5	.034#
Level			.000*
L3-4	8	0	
L4-5	19	11	
L5S1	0	12	
HD location			.383*
Shoulder	3	6	
Ventral	12	9	
Axilla	12	8	
HD type			.408*
Protrusion	17	17	
Sequestration	10	6	
VAS of back pain	24.81 ± 12.82	26.1 ± 13.1	.867#
VAS of leg pain	74.81 ± 9.76	77.0 ± 9.3	.685#
ODI	74.15 ± 9.18	76.3 ± 9.7	.722#
Nerve root function			.623*
Sensation			
Normal	10	7	
Abnormal	17	16	
Muscle strength			.509*
Normal	21	16	
Abnormal	6	7	
Tendon reflex			.001*
Normal	25	12	
Abnormal	2	11	

\*, chi-square test; #, *t* test

Abbreviations: HD, herniated disc; ODI, Oswestry Disability Index; VAS, visual analog scale

## RESULTS

### Patient's Demographic Characteristics

Fifty patients with noncontained lumbar disc herniation treated with full-endoscopic lumbar discectomy and annulus fibrosus suture were included in this study, including 28 women and 22 men. The average age was 56.1 years (range, 46-78 years). There were 8 cases of L3-4 level, 30 cases of L4-5 level, and 12 cases of L5-S1 level. According to the location of the HD to the transversing nerve root, 20 cases were axillary type with HD medial to the transversing nerve root, 21 cases were ventral type with HD anterior to the transversing nerve root, and 9 cases were shoulder type with HD lateral to the transversing nerve root. Thirty-four cases were extrusion type and 16 cases were sequestration type. Preoperative neurological impairment included 33 cases of impaired sensation, 13 cases of weakened muscle strength, and 13 cases of weakened or disappeared tendon reflexes. Fifty patients were divided into a single-stitch suture group via a transforaminal approach (Group T) and a double-stitch suture group via an interlaminar approach (Group I). Our case grouping strategy was as follows: L5-S1 level HD was selected for an interlaminar approach, L3-4 level HD was selected for a transforaminal approach, and surgical approach for L4-5 level HDs was selected based on the patient's selection. There were no significant differences between the 2 groups in terms of age, gender, location of HD, type of herniation, preoperative low back pain VAS score, leg pain VAS score, ODI, impairment of nerve root sensation, and motor function before surgery (Table 1).

### Postoperative Outcomes

All operations were successfully completed, including 27 cases (including 8 cases of L3-4 and 19 cases of L4-5) in Group T and 23 cases (including 11 cases in L4-5 and 12 cases in L5S1) in Group I. The operation time was 30 to 60 minutes, with an average of 43.2 minutes. No intraoperative conversion to other surgical procedures occurred. There were no complications such as nerve injury or dura tear during operation; no postoperative infection, cerebrospinal fluid leakage, recurrence of disc herniation, or nerve root function aggregation after operation occurred. Postoperative lumbar MRI of all patients showed complete removal of the HD and sufficient nerve decompression. All patients in both groups provided complete follow-up data (Table 2). All patients had significant relief of low back pain and leg

Table 2. Changes in the quantitative indices at various time points after full-endoscopic lumbar discectomy and annulus fibrosus suture in each group (mean ± standard deviation).

Indices	Preoperative	1 day Postoperative	3 months Postoperative	6 months Postoperative	1 year Postoperative	F value
VAS of back pain						
Group T	24.81 ± 12.82	11.48 ± 10.99 a	8.15 ± 8.33 a	6.30 ± 7.41 a	6.30 ± 9.67 ab	16.276*
Group I	26.09 ± 13.05	10.43 ± 8.25 a	7.83 ± 6.00 a	6.09 ± 5.00 a	4.78 ± 5.11 ab	26.584*
VAS of leg pain						
Group T	74.81 ± 9.76	2.59 ± 4.47 a	4.07 ± 6.94 a	0.74 ± 2.67 a	0.74 ± 2.67 a	807.200*
Group I	76.96 ± 9.26	4.78 ± 5.11 a	3.91 ± 5.83 a	2.17 ± 4.22 a	1.74 ± 3.88 a	702.248*
ODI						
Group T	74.15 ± 9.18	/	28.37 ± 4.74 a	19.26 ± 3.73 a	14.22 ± 4.05 ac	591.512*
Group I	76.26 ± 9.71	/	27.39 ± 5.77 a	20.43 ± 5.75 a	14.17 ± 5.15 ac	394.204*

\*, ANOVA,  $P < .01$ ; a, LSD test,  $P < .01$ , compared to preoperative; b, LSD test,  $P < .01$ , compared to one day postoperative; c, LSD test,  $P < .01$ , compared to 3 months postoperative.

pain, and ODI scores improved significantly ( $P < .01$ ). At the one-year follow-up, impaired sensation and muscle strength of the involved nerve root were significantly recovered ( $P < .01$ ), but tendon reflexes were not significantly recovered ( $P > .05$ ) (Table 3). At the one-year follow-up, the excellent and good rates of the MacNab score were 92.6% in Group T and 91.3% in Group I with no significant difference between the 2 groups ( $P > .05$ ) (Table 4).

### DISCUSSION

The clinical significance of lumbar annulus fibrosus suture includes: 1) closing the annulus fissure reduces the short-term postoperative recurrence of disc herniation; 2) closing the annulus fissure reduces the mechanical stimulation of nerves by the ruptured and bulged annulus and reduces postoperative residual symptoms of low back pain and leg pain; 3) closing the annulus fissure lessen the inflammatory medias in the intervertebral disc to release and enter the epidural space reduces the inflammatory mediators in the epidural space released from the intervertebral disc, reduces the inflammatory stimulation of the nerve, and reduces the occurrence of chemical radiculitis; 4) closing the annulus fissure promotes the scar healing process of ruptured annulus fibrosus. Yasargil et al (10) first reported the technique and clinical results of using a 7-0 suture for annulus fissure repair under a microscope in 1977 without postoperative recurrence of disc herniation, neurological impairment, or postoperative radiculopathy found. Cauthen (11) observed 254 patients with lumbar disc herniation who underwent lumbar discectomy. If an annulus suture is not performed, the recurrence rate after 2 years is 21%. If a single-stitch suture is used, the recurrence rate can be reduced to 10%. With a 2-stitch suture, the recurrence rate can be reduced to 5%. Bai-

Table 3. Changes in nerve root function at one-year follow-up after full-endoscopic lumbar discectomy and annulus fibrosus suture in each group (number).

Indices	Preoperative	One year Postoperative	X2 Value
Sensation			
Group T			21.333*
Normal	10	26	
Abnormal	17	1	
Group I			12.738*
Normal	7	19	
Abnormal	16	4	
Muscle strength			
Group T			6.750*
Normal	21	27	
Abnormal	6	0	
Group I			8.256*
Normal	17	23	
Abnormal	6	0	
Tendon reflex			
Group T			0.000
Normal	25	25	
Abnormal	2	2	
Group I			0.354
Normal	12	14	
Abnormal	11	9	

\*, Chi-square test,  $P < .01$ .

Table 4. MacNab scores at one-year follow-up in each group (number).

Approaches	Excellent	Good	Fair	Poor
Group T	9	16	2	0
Group I	8	13	2	0

chi-square test,  $X^2 = 0.049$ ,  $P = .98$



ley et al (12) used the “X-close” annulus repair device to suture the annulus fissure after lumbar discectomy and compared the recurrence rate after lumbar discectomy to that of the nonsutured group. The outcome of the 3-month follow-up (1.0% vs 5.9%;  $P = .019$ ) and 6-month follow-up (2.0% vs 6.9%;  $P = .046$ ) showed that an annulus suture can significantly reduce the recurrence rate; however, the difference at the 24-month follow-up (6.7% vs 12.1%;  $P = .13$ ) was not significant. Parker et al (13) reported the clinical results of using the “Barricaid” annular closure device. That multicenter prospective cohort study proposed that this annulus closure device can reduce the recurrence rate after lumbar discectomy; maintain disc height; and improve one-year leg pain, back pain, and low back disability. Trummer et al (14) reported the effect of the use of the “Barricaid” annular closure device on the degeneration of the facet joint after lumbar discectomy. At the 12-month follow-up, degeneration of facet joints in patients with the “Barricaid” annular closure device was significantly lighter than that in the control group. Kamaric et al (15) found that implanting a “Barricaid” annular closure device after lumbar discectomy can promote restoration in disc height lost.

## CONCLUSION

The safety and efficacy of full-endoscopic annulus suture following lumbar discectomy have not been reported in the literature. In this study, 50 patients

with lumbar disc herniation underwent full-endoscopic lumbar discectomy and annulus suture through the transforaminal approach or interlaminar approach. No recurrence of herniated disc occurred within one year after operation. Postoperative low back pain, leg pain, and ODI scores were significantly improved in both groups of patients. The excellent and good rates of the MacNab score at the one-year follow-up were 92.6% in Group T and 91.3% in Group I. There was no significant difference between the 2 groups ( $P > 0.05$ ). The authors previously reported the follow-up results of the same techniques of full-endoscopic lumbar discectomy, but without annulus suture. The total 5-year recurrence rate for full-endoscopic lumbar discectomy through the transforaminal approach was 3.7% (5 of 134) (8). The total one-year recurrence rate for full-endoscopic L5/S1 lumbar discectomy through the interlaminar approach was 1.4% (1 of 73) (9). Of course, this study is a small sample and a prospective observational study. Without a control group, it is not yet possible to determine whether full-endoscopic annulus suture can significantly reduce the recurrence rate of disc herniation and improve the postoperative clinical outcome, but this study shows that full-endoscopic lumbar discectomy and annulus suture is a safe, reliable, and effective surgical technique. It can provide a safety and efficacy basis for further large-scale, prospective, randomized controlled studies in order to derive higher-level evidence-based medical evidence.

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