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Original Article

Comparison of clinical and radiological outcomes after automated open lumbar discectomy and conventional microdiscectomy: a prospective randomized trial

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Abstract: Objective: Microdiscectomy (MD) is the gold standard for surgical discectomy. As a minimally invasive discectomy, automated open lumbar discectomy (AOLD) is designed to preserve annular integrity and disc height as well as effectively remove herniated disc and degenerated disc material. However, there have been no prospective clinical studies comparing their effectiveness. The study was designed to compare clinical and radiological outcomes after AOLD with those of MD. Methods: Seventy-eight patients were evaluated for unilateral leg pain with the presence of disc herniation on magnetic resonance imaging (MRI) scans at a single attributable level. Sixty-two patients were enrolled; 33 patients (53%) were randomly assigned to the AOLD group and the remaining 29 patients (47%) were assigned to the MD group. Follow-up assessment was performed for 19 of the AOLD patients and 17 of the MD patients. The average follow-up period was 20 months. Clinical and functional outcomes were assessed using VAS and ODI scores. Change of disc height (DH), instability, and disc degeneration were assessed from radiographs, while Modic change and reherniation were assessed using MRI scans. Results: Postoperative VAS scores for leg pain and ODI scores for function were significantly improved in both groups. Postoperative VAS for back pain tended to decrease in the MD group but the decrease was statistically insignificant (P = 0.081). The postoperative VAS for back pain was significantly reduced in the AOLD group (P = 0.012). Patients from the MD group showed greater DH reduction than the AOLD group (P = 0.049). The MD group experienced greater disc degeneration and Modic change than the AOLD group. Follow-up MRI revealed 2 cases of reherniation in the AOLD group; 1 case was symptomatic, the other was asymptomatic. Conclusions: AOLD showed comparable clinical and radiological outcomes to conventional MD. AOLD preserves the central disc and removes only the loose degenerative disc fragments that are the main cause of reherniation by small annulotomy. Our results suggest that preservation of the central disc prevents loss of disc height and segmental instability, which is related to postdiscectomy back pain.

Keywords: Microdiscectomy, automated open lumbar discectomy, lumbar spine, disc herniation, prospective randomized study, reherniation

Introduction

When conservative treatment of symptomatic lumbar disc herniation with radiculopathy fails, lumbar microdiscectomy is the gold standard for treatment [1-3]. A recent modification to lumbar discectomy involves the use of a microendoscope instead of an operating microscope for visualization. This modification in technique is less invasive in its muscle splitting than conventional microdiscectomy, but clinical outcomes are similar for both techniques [4, 5]. Percutaneous endoscopic lumbar discectomy (PELD) uses a rigid operating spinal endoscope that allows direct visualization and excision of contained and non-contained herniated disc fragments [6]. With advanced modification [7-10], percutaneous endoscopic discectomy is reliable and comparable to conventional microdiscectomy. However, this modified technique involves a steep learning curve, and in cases of high-grade migration, it is technically limited [11, 12].

Debate remains surrounding the degree of discectomy required to prevent reherniation and improve long-term clinical outcome, but many researchers support minimally invasive discectomies [13-16]. Spengler [17] introduced a limited discectomy that removes extruded disc

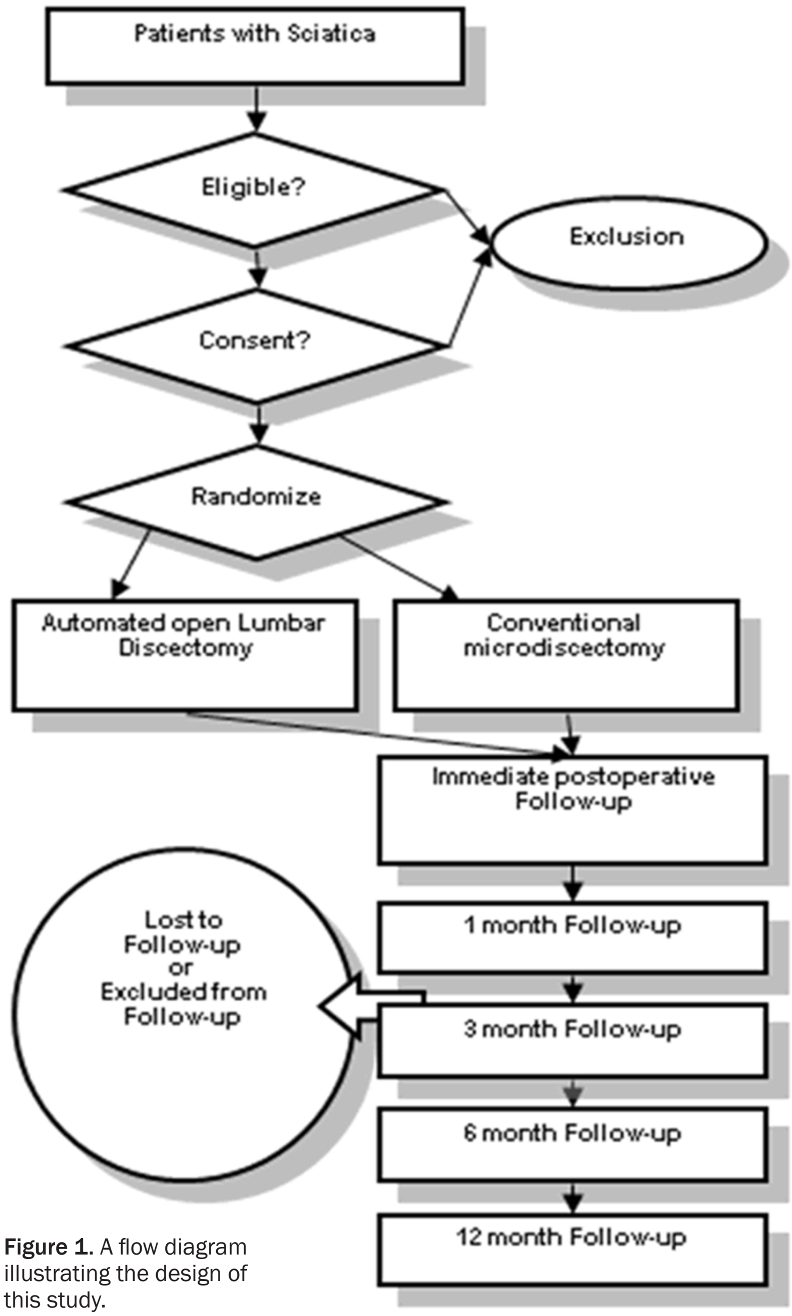

Figure 1. A flow diagram illustrating the design of this study.

fragments and any loose pieces in the disc space. Spengler's method has been popularized for lumbar microdiscectomy and is referred to as conventional microdiscectomy (MD). Automated open lumbar discectomy (AOLD) was first introduced by James C. Thomas during the 6th annual meeting of International Intradiscal Therapy Society (IITS) in 1993 [18]. AOLD using the Micro II™ nucleotome kit (Clarus Medical, LLC, MN, USA) has been developed for minimally invasive discectomy, enabling surgeons to selectively decompress the herniated disc via an annular hole that is less than 3 mm in diameter preserving most of the posterior spinal structure. The automated nucleosome is blunt at its tip and prevents the surgeon from using pituitary forceps or rongeurs, both of which carry the risk of causing annular penetration and subsequent damage to the great vessels [19].

The purpose of this study was to compare the clinical and radiological outcomes of AOLD and MD. We assumed greater disc height preservation in the AOLD group, but the effectiveness of decompression and prevention of reherniation using the AOLD technique compared with the MD technique remains to be studied. This study attempts to determine whether AOLD is an effective minimally invasive surgical option for discectomy in terms of preserving disc height and preventing reherniation.

Materials and methods

Patient population

Patients deemed eligible for this study presented with unilateral leg pain with the presence of disc herniation as determined by magnetic resonance imagining (MRI) and pain that persisted for 4-8 weeks after conservative treatment involving rest, analgesia and physical therapy. Patients with progressive neurologic deficit underwent emergency operations. The exclusion criteria were as follows: age older than 69 years, previous surgery, severe lumbar stenosis, spondylosis, spondylolisthesis, extraforaminal far lateral disc herniation, foraminal spur or bony compression, met-

Table 1. Summary of patients' demographics and clinical characteristics

	Overall	Discectomy		
		AOLD group	MD group	*P*
Number of patient	40	21	19	
Gender (males/females)*	27/13	14/7	13/6	0.906§
Average age (years)	42.7±11.5	42.0±13.0	43.4±9.8	0.712
Smoking (yes/no)*	11/29	5/16	6/13	0.583§
Preop. Sx duration (weeks)	4.6±4.9	5.1±4.8	3.9±5.0	0.483
Mean FU duration (months)				
Clinical FU	20.1±5.9	21.6±6.8	18.3±4.1	0.075
Radiographic FU	17.8±5.2	19.1±5.4	16.4±4.8	0.130
Discectomy level*				
L3-4/L4-5/L5-S1	1/14/25	0/6/15	1/8/10	0.334§
Heniation type*				
Contained/non-contained	10/30	6/15	4/15	0.583§

AOLD, automated open lumbar discectomy; MD, microdiscectomy, Preop. Sx, preoperative symptom; FU, follow-up. Mean value ± standard deviation, *The incidence of each grade, respectively. *P* values determined by independent two-sample t-test and §chi-square test.

abolic bone disease, patients receiving worker's compensation, and patients who have coexisting lumbar spinal disease. We received informed consent from all patients included in the study, and these patients were divided into 2 groups by complete randomization using repeated fair coin tossing. The design of this study is represented as a flow diagram in **Figure 1**.

Between April 2008 and April 2009, 78 patients were evaluated for unilateral leg pain with the presence of disc herniation on MRI at a single attributable level. Of these 78 patients, 16 were excluded and 62 (79%) were enrolled. Thirty-three (53%) of the 62 patients were randomly assigned to the AOLD group and the remaining 29 (47%) patients were assigned to the MD group. During the follow-up period, 1 patient underwent a total knee arthroplasty and 1 patient experienced heavy trauma that interfered with the clinical outcome. Both patients were excluded from analysis. Among the 62 patients enrolled, 36 patients kept both clinical and radiological follow-up appointments. Clinical follow-up using a telephone survey was used for 4 patients. Twelve patients did not participate in follow-up assessment. The study group was composed of 27 (67.5%) men and 13 (32.5%) women, with a mean age of 42.7 (11.5) years (range, 21-69 years). The affected spinal levels were L3-4 in 1 (2.5%) case, L4-5 in 14 (35%) cases and L5-S1 in 25 (62.5%) cases. The mean duration of follow-up was 20.1 (5.9) months (range, 12-35 months). The patients' demographic and clinical data are summarized in **Table 1**.

Surgical techniques

AOLD: A small skin incision of 2-2.5 cm was made at the corresponding lumbar level and the paraspinal muscles were split. A Magana retractor was placed after exposing the lamina. Using an operating microscope, a partial laminectomy and foraminotomy was performed. The ligamentum flavum was removed and the affected disc was exposed by gentle retraction of the thecal sac and traversing nerve root. By inserting a round annulotome (diameter: 2.5 mm) through the posterior longitudinal ligament (PLL) and posterior annulus (**Figure 2**), a small hole was created. The Micro II™ nucleotome kit (Clarus Medical, LLC, MN, USA), which has a blunt tip with a small side opening, was inserted through this hole and the automated aspiration of the nucleus material was performed as previously described (**Figures 2**, **3**) [19]. In cases where the posterior annulus was hard, a CO_2 laser was used to make a small annulotomy to facilitate removal of loose central disc fragments. However, if the annulotomy could be performed using a cutter, the laser was not used. After confirming adequate decompression and release of the nerve root using the microprobe, each layer of the wound was closed after meticulous hemostasis (**Figure 4**).

MD: A skin incision of 2.5-3 cm was made. By using a periosteal elevator, the paraspinal muscles were split and a Caspar retractor was placed. All procedures, including partial laminectomy, foraminotomy, and removal of the ligamentum flavum, were performed using operating microscopic guidance. A CO_2 laser (Sharplan 30C, Lumenis, Yokneam, Israel) was used to perform the annulotomy, and pituitary forceps were used for subsequent removal of the central disc. Extracted disc material was limited to the central disc pieces in the disc

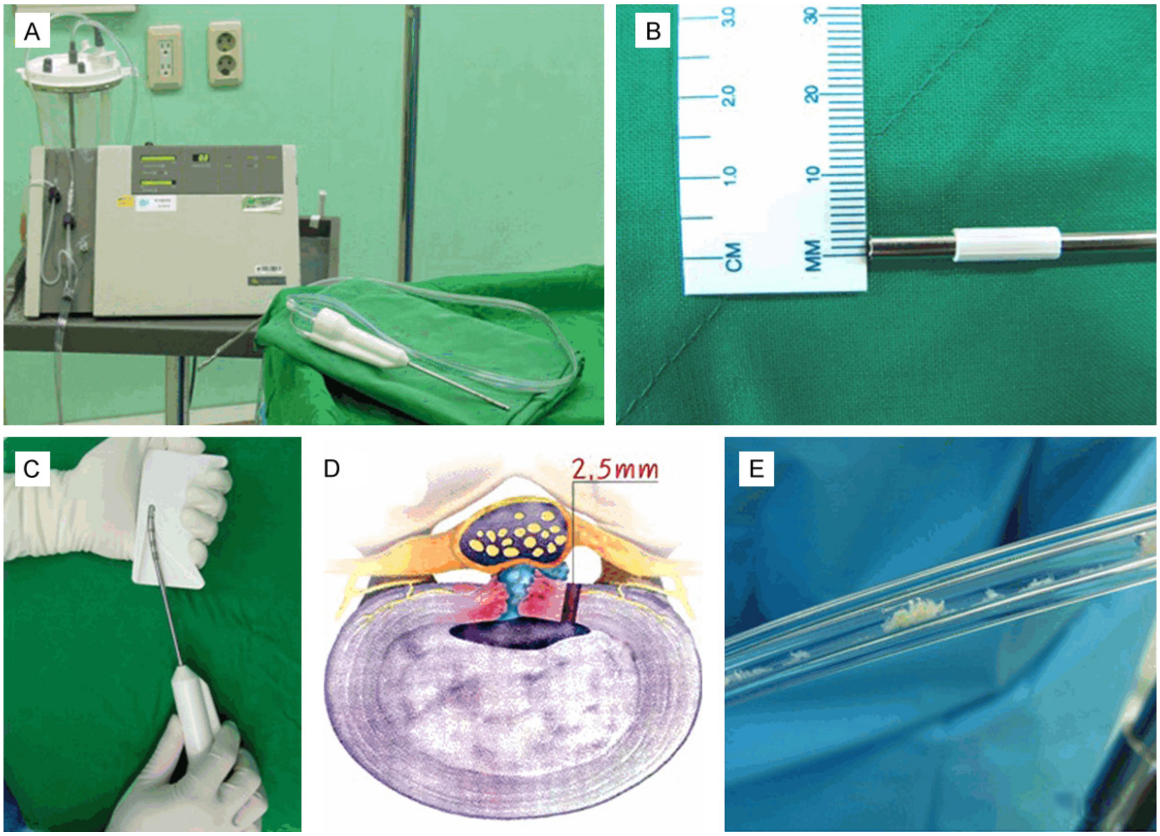

Figure 2. Photograph of the Micro II™ nucleotome kit (A). A round annulotome, which is 2.5 mm in diameter is used for annulotomy (B). The blunt tip of the nucleotome is flexible (C). The upward exploration of the posterior annulus or exploration deep within the nucleus on the contralateral side can be achieved without retraction of the nerve root via small annulotomy (D). Photograph showing loose central disc fragments aspirated with the nucleotome (E).

space and inner-annular fragments. The endplates were preserved without requiring curettage. After confirming adequate decompression and release of the nerve root by using the microprobe, each layer of the wound was closed after meticulous hemostasis. (**Figure 5**).

Clinical evaluation

Clinical outcomes were assessed by using a visual analogue scale (VAS; 0-10, with 0 reflecting no pain) and functional outcomes were scored according to the Oswestry Disability Index (ODI; 0-100%). Additionally, operating time, complications, and the estimated amount of blood loss were evaluated. Patients were asked to answer a questionnaire about their clinical and functional outcomes during their regular follow-up appointments at 1, 3, 6, and 12 months post surgery. Preoperative and postoperative clinical evaluations were performed by nurses or non-physician staff members who were not aware of patients' surgical details.

Radiological evaluation

Follow-up dynamic lumbar radiographs were evaluated for all patients during their regular visit to the outpatient clinic. Follow-up MRIs were obtained 12 months after the operation for 28 (77.8%) of the 36 patients. An independent observer who was not in charge of the surgeries conducted all radiographic assessments using a program with a built-in picture-archiving communication system (PiView; INFINITT Co. Ltd., Seoul, South Korea). Factors included in the radiologic evaluation included change in disc height, degree of instability assessed from dynamic radiographs, the degree of disc degeneration, Modic endplate change [20], and reherniation as assessed by MRI. Disc height index (DHI) was measured using Inoue's method [21] from standing lateral radiographs (**Figure 6**). Instability was defined as more than 10° of angular motion between adjacent vertebral bodies. All measurements were repeated 1 month later to account for intra-observer reliability. The average of the 2 measurements

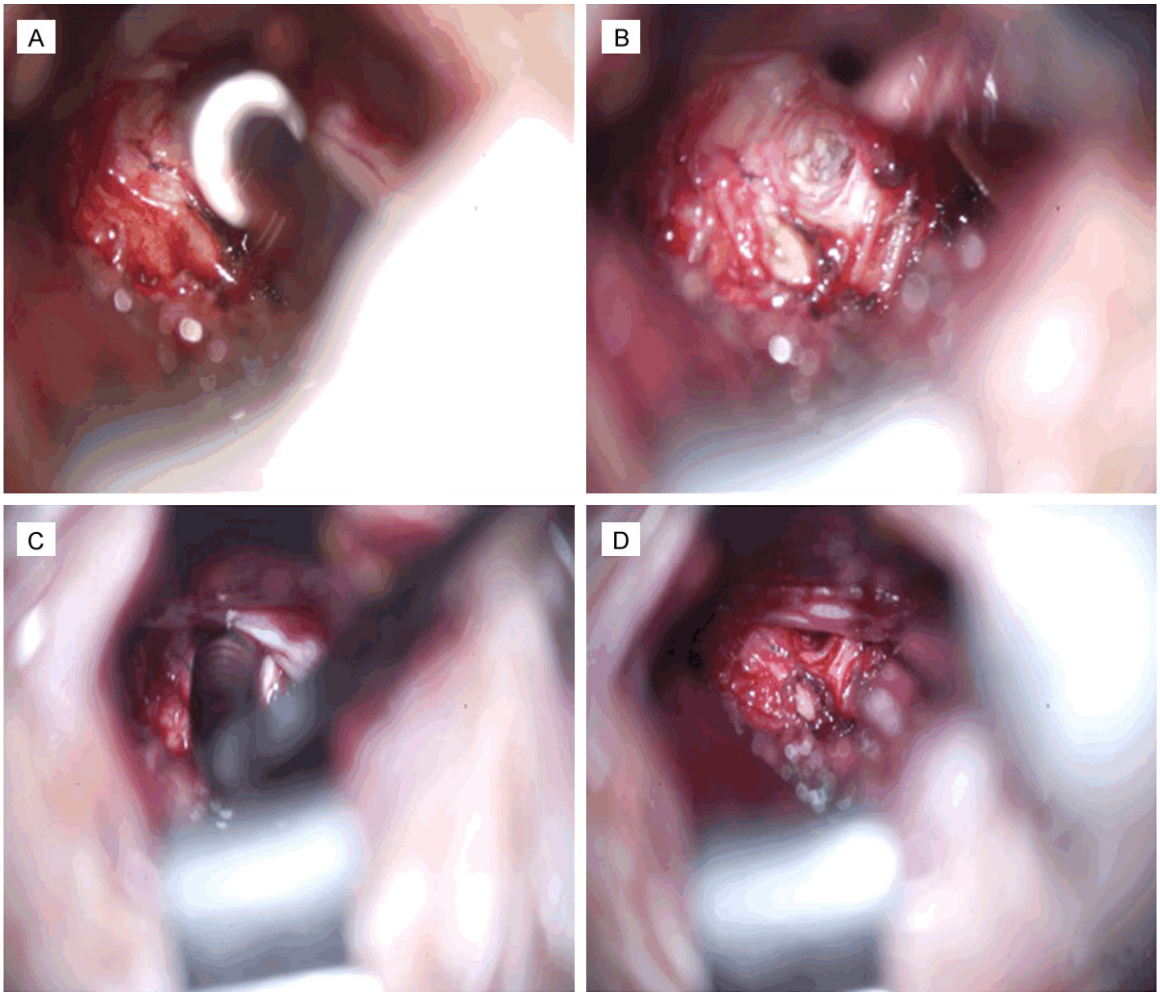

Figure 3. Intraoperative microscopic photograph (upper left: medial cranial view, upper right: medial caudal view, lower left: lateral cranial view, lower right: lateral caudal view, arrowhead in (C, D) Magana retractor). A round annulotome (*) is inserted in the posterior annulus (A) to make a small round annulotomy (black arrow) (B). A flexible nucleotome (white arrow) is inserted into the disc space without a nerve root retractor (C). After discectomy, the nerve root is decompressed. Note the small annulotomy (black arrow) behind the root (D).

was used for assessment. The degree of disc degeneration was assessed from T2-weighted sagittal MRI and was rated between grade I and grade V using the classification system of Pfirrmann and colleagues [22] (**Table 2**). Type 1 Modic changes were hypointense on T1-weighted imaging (T1WI) and hyperintense on T2-weighted imaging (T2WI), type 2 Modic changes were hyperintense on T1WI and isointense or slightly hyperintense on T2WI, and type 3 Modic changes were hypointense on both T1WI and T2WI.

Statistical analysis

All data were entered into SPSS statistical program (version 14.0K; SPSS Inc., Chicago, IL). Statistical tests included analysis of variance using the Chi-square test, independent *t*-test, matched 2-sample *t*-test, Mann-Whitney *U* test, and Wilcoxon sign-ranked test. Results were considered statistically significant if $P < 0.05$.

Results

Clinical results

Tables 3-5 show the scores for pre- and postoperative VAS and ODI. Overall VAS for back and leg pain and ODI for function decreased significantly postoperatively (**Table 3**). For the MD group, postoperative VAS for back pain tended to decrease but the difference was not statistically significant ($P = 0.081$). However, the decrease in postoperative VAS for back pain was significant for the AOLD group ($P = 0.012$)

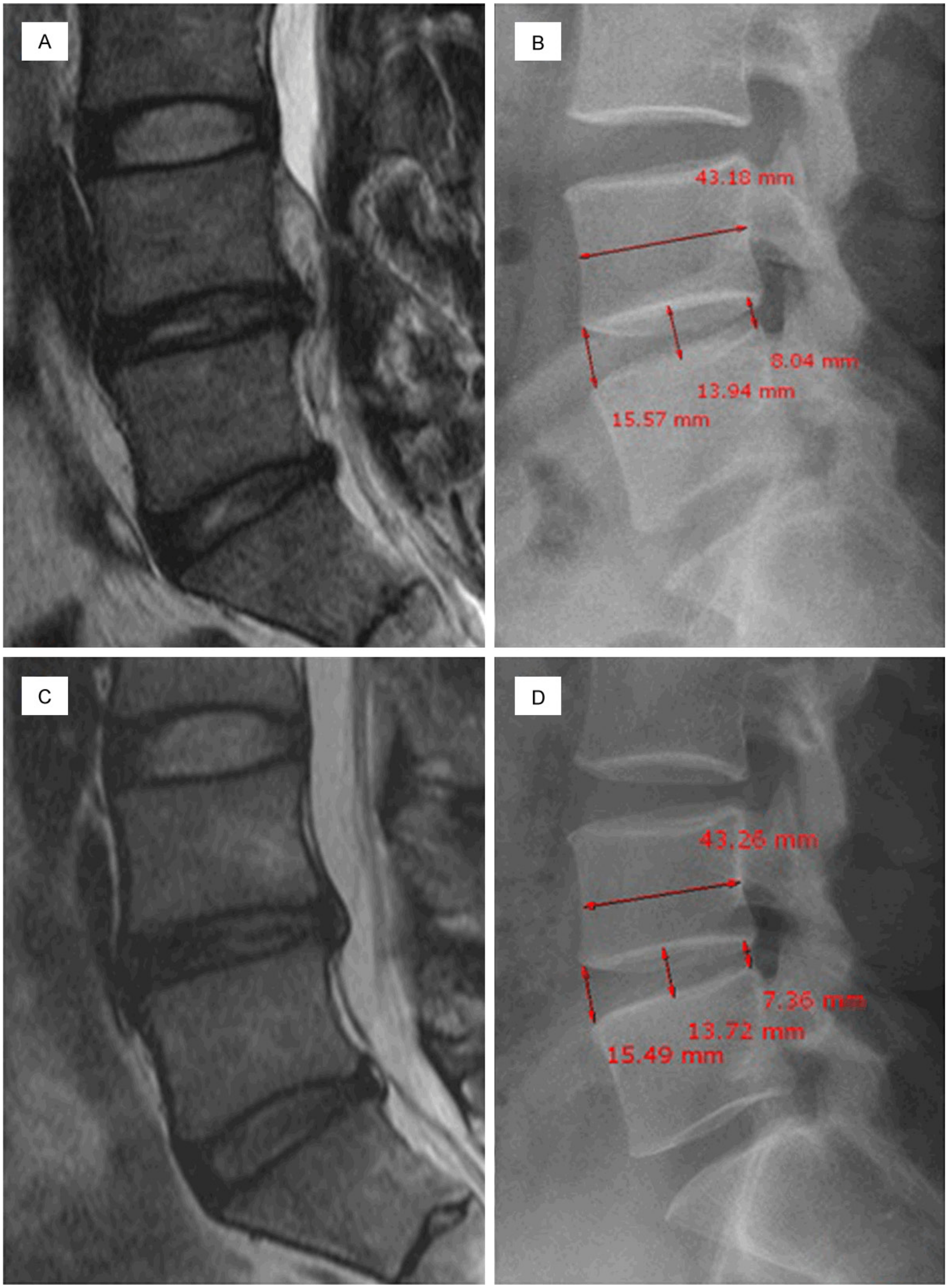

Figure 4. Illustration of an automated open lumbar discectomy (AOLD). A 30-year-old male patient presented with radiating pain down his right leg that persisted for 4 weeks. Preoperative MRI (A) showed an upward migration of a herniated disc at the L4-5 level. Preoperative disc height index (DHI) on standing lateral radiograph (B) was 0.289. AOLD was performed. Follow-up MRI and radiography (C, D) at 21 months after operation showed complete removal of herniation without any recurrence and preserved disc height (DHI = 0.282).

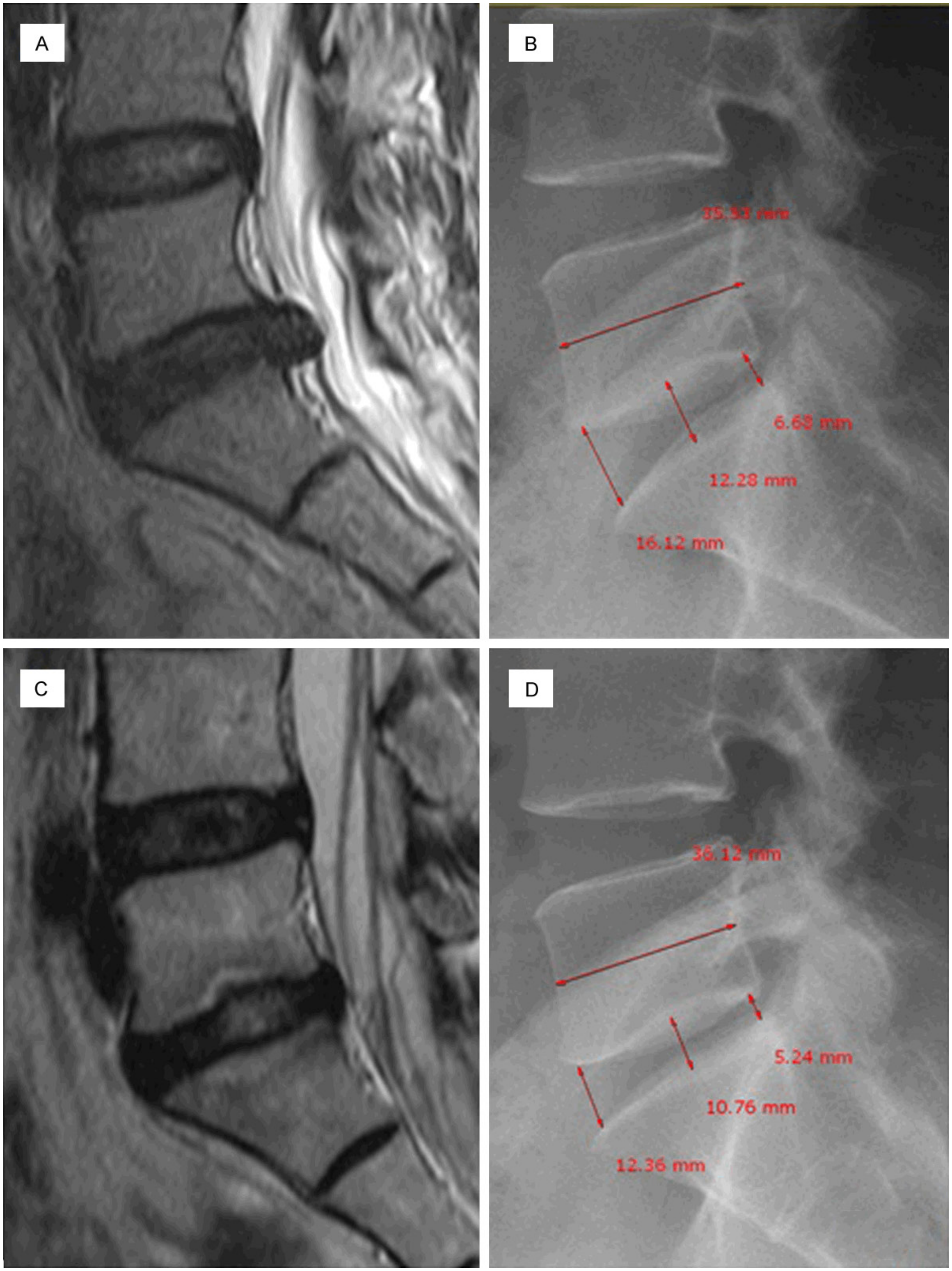

Figure 5. Illustration of conventional microdiscectomy (MD). A 39-year-old female patient presented with radiating pain down her left leg that persisted for 2 weeks. Preoperative MRI (A) showed disc extrusion at the L5-S1 level. Preoperative DHI on standing lateral radiograph (B) was 0.329. Follow-up MRI and radiography (C, D) at 19 months after operation showed complete removal of herniation without any recurrence, but decreased disc height (DHI = 0.262). Note the endplate Modic change on follow-up MRI.

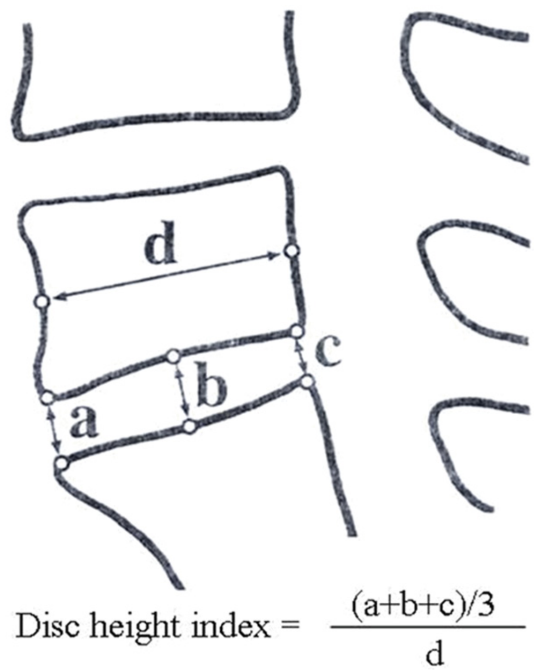

Figure 6. Radiographic measurements of lumbar disc height. a. Anterior disc height, b. Middle disc height, c. Posterior disc height, d. Sagittal diameter of the overlying vertebral body. Disc height index = [(a + b + c)/3]/d.

(**Table 4**). Postoperatively, VAS for leg pain and ODI scores were significantly reduced for both groups. The pre- and postoperative clinical and functional outcomes were similar for both surgical methods (**Table 5**).

Radiological results

Final dynamic standing radiographs were obtained for 36 of the patients 17.9 months (range, 7-28 months) after operation. Disc height was reduced in patients from both groups after operation (**Table 6**). In terms of the ratio of pre- to postoperative DHI (postoperative DHI/preoperative DHI), the MD group demonstrated a greater reduction than the AOLD group (0.917 and 0.959, respectively, P = 0.049). Postoperative newly developed segmental instability at the affected segment occurred in 2 patients from the MD group. Four patients (2 AOLD, 2 MD) had a preoperative angular motion that was greater than 10°, and the range of motion for these 4 patients did not change significantly postoperatively. Postoperative MRI was obtained for 28 patients 19.3 months (range, 13-25 months) after operation. **Table 6** shows the Modic change and disc degeneration for both pre- and postoperative periods. In terms of Modic change, 2 (15.4%) of the 13 AOLD patients and 4 (36.4%) of the 11 MD patients changed from a normal endplate signal to type 1 Modic change (P = 0.357). The MD group showed greater signs of disc degeneration than the AOLD group, but the difference was statistically insignificant.

Complications

Follow-up MRI revealed radiological reherniations in 2 patients from the AOLD group (**Figure 7**). One patient had radiating pain that was tolerable with conservative treatment. The other patient remained asymptomatic. Additionally, there was 1 patient from the AOLD group with suspicious discitis with aggravated low back pain and signal changes at the affected intervertebral disc and endplate on MRI. A percutaneous endoscopic exploration into the affected disc space was performed, but there was no definitive pus within the intervertebral disc, and no positive bacterial growth in the culture obtained from the specimen. The patient recovered after 3 weeks of empiric antibiotic treatment and was discharged without any further complications.

Operative data

Patients in the AOLD group spent a mean of 85.5 (24.8) min in surgery (range, 35-125 min), whereas, patients in the MD group spent a mean time of 82.6 (23.7) min in surgery (range, 50-125 min). The estimated amount of blood loss during surgery was 106.8 (32.8) ml (range, 50-200 ml) for the AOLD group and 117.45 (56.2) ml (range, 50-250 ml) for the MD group. The time spent in surgery and amount of blood loss during surgery were not statistically significantly different between the AOLD and MD groups (time in surgery: P = 0.789 and blood loss: P = 0.260).

Discussion

The chief issue for current methods of lumbar microdiscectomy is to keep the balance between successful decompression and the prevention of complications such as reherniation and instability.

Inflammation from prolonged neuroischemia of the microvasculature of the nerve root by mechanical compression and neurochemical factors contributes to sciatic pain in cases of lumbar disc herniation, while pure compression of a uninflamed nerve produces only sensory

Table 2. Grades of lumbar disc degeneration on T2-weighted sagittal magnetic resonance images according to the classification system proposed by Pfirrmann et al.

Grade	Structure	Distinction of Nucleus and Annulus	Signal intensity	Height of Intervertebral disc
I	Homogeneous, bright white	Clear	Hyperintense or isointense	Normal
II	Inhomogeneous with or without horizontal bands	Clear	Hyperintense or isointense	Normal
III	Inhomogeneous, grey	Unclear	Intermediate	Normal to slightly decreased
IV	Inhomogeneous, grey to black	Lost	Intermediate to hypointense	Normal to Moderately decreased
V	Inhomogeneous, black	Lost	Hypointense	Collapsed disc space

Table 3. Preoperative and postoperative overall clinical and functional outcomes

	Preoperative	Postoperative	*P*
VAS (back)	2.77±1.90	1.60±1.80	0.003
VAS (leg)	7.89±1.78	2.16±2.18	< 0.0001
ODI (%)	60.04±14.07	13.03±11.40	< 0.0001

VAS, Visual Analogue Scale; ODI, Oswestry Disability Index. Mean value ± standard deviation. *P* values determined by matched two-sample t-test.

and motor changes without pain [23, 24]. Therefore, a microsurgical decompression by laminectomy with foraminotomy and fragment excision that permits the nerve root to recover from neuroischemia and perineural inflammation can be sufficient to relieve sciatic pain associated with lumbar disc herniation.

Reports of reherniation rates in the literature range from 2 to 10.4% [25-27]. To prevent recurrent disc herniation, extensive removal of the nucleus pulposus and endplate curettage were thought to be important [28]. However, this method of subtotal discectomy had unsatisfactory outcomes in terms of postoperative back pain due to instability, as well as increased risk of injury to the anterior spinal structures [29-31].

Fountas et al. reported that the degree of disc removal during MD did not influence clinical outcome or risk of complications such as reherniation and instability [32]. Fragmentectomy removes only the free disc fragments and tissue that can be easily mobilized from the disc space [15]. Comparing fragmentectomy and MD, Faunlauer and colleagues reported that the fragmentectomy group showed less reherniation and better clinical outcome. According to Faunlauer et al., only 2% of fragmentectomy patients experience reherniation compared with 7% of MD patients [25]. Fakouri et al. reported that 4.17% of fragmentectomy patients and 5.56% of MD patients experienced reherniation, a difference that is statistically insignificant (P = 1.00) [13]. Barth et al. also found that the incidence of reherniation in fragmentectomy patients (12.5%) was not significantly different (P = 1.00) from the incidence in MD patients (10.5%) [15, 16]. They demonstrated fragmentectomy causes significantly less postoperative disc degeneration such as, loss of disc height and endplate changes than MD after a 2-year prospective follow-up period. Results of the present study correspond with these previous findings. Although the clinical and functional outcomes were not significantly different between AOLD and MD groups, AOLD was shown to better preserve disc height than MD. The purpose of the AOLD technique is to preserve the central disc minimizing postoperative instability, and to remove only the loose degenerative disc fragments that cause reherniation.

Many authors suggest that postoperative loss of disc height leads to intervertebral instability [33, 34]. In the present study, disc height decreased in both AOLD and MD groups postoperatively, but the loss was greater for the MD group. However, segmental instability was observed in only 2 patients from the MD group. This low incidence of segmental instability may be due to the relatively short follow-up period of this study. We think a longer follow-up period will clarify the effect of disc height loss on instability. Kim et al. reported that biomechanical stress related to segmental range of motion affects the development of reherniation [35]. They demonstrated that a segmental range of motion that is greater than 10° is more vulnerable to reherniation. In the present study, there was 1 case (4.7%) of symptomatic reherniation from the AOLD group and 2 cases of newly developed instabilities in the MD group. We are unable to demonstrate the relationship between instability and reherniation from the

Table 4. Comparison of preoperative and postoperative clinical and functional outcomes in AOLD and MD groups

	AOLD			MD		
	Preop.	Postop.	*P*	Preop.	Postop.	*P*
VAS (back)	2.75±1.83	1.62±1.94	0.012	2.80±2.04	1.63±1.54	0.081
VAS (leg)	7.85±1.76	2.52±2.14	< 0.0001	7.93±1.87	1.50±1.91	< 0.0001
ODI	58.42±16.47	12.95±11.32	< 0.0001	62.20±10.17	11.80±10.80	< 0.0001

AOLD, automated open lumbar discectomy; MD, microdiscectomy; VAS, Visual Analogue Scale; ODI, Oswestry Disability Index; Preop., preoperative; Postop., postoperative. Mean value ± standard deviation. *P* values determined by matched two-sample t-test.

Table 5. Comparison of preoperative and postoperative clinical and functional outcomes between AOLD and MD groups

	Preoperative			Postoperative		
	AOLD	MD	*P*	AOLD	MD	*P*
VAS (back)	2.75±1.83	2.80±2.04	0.940	1.62±1.94	1.63±1.54	0.982
VAS (leg)	7.85±1.76	7.93±1.87	0.893	2.52±2.14	1.50±1.91	0.120
ODI	58.42±16.47	62.20±10.17	0.410	12.95±11.32	11.80±10.80	0.745

AOLD, automated open lumbar discectomy; MD, microdiscectomy; VAS, Visual Analogue Scale; ODI, Oswestry Disability Index; Preop., preoperative; Postop., postoperative. Mean value ± standard deviation. *P* values determined by matched two-sample t-test.

Table 6. Comparison of preoperative and postoperative radiologic outcomes between AOLD and MD groups

	AOLD			MD		
	Preop.	Postop.	*P*	Preop.	Postop.	*P*
DHI	0.295±0.037	0.283±0.033	0.007	0.262±0.035	0.240±0.035	0.001
Instability*	2	2	ND	2	4	ND
Modic change*			0.558§			0.087§
Normal	13	11		11	7	
Type 1	1	3		0	4	
Type 2	2	2		1	1	
Type 3	0	0		0	0	
DD*			0.522§			0.528§
I/II/III/IV/V	2/9/2/2/0	0/10/3/2/0		0/7/4/1/0	0/4/6/1/1	

DHI, disc height index; DD, disc degeneration; Preop., preoperative; Postop., postoperative; ND, not determined. Mean value ± standard deviation. *The incidence of each grade, respectively. *P* values determined by matched two-sample t-test and §chi-square test.

results of the present study. To date, it appears that preservation of the central disc prevents loss of disc height and segmental instability and does not increase the risk of reherniation when compared to other published reports.

The amount of disc material removed during surgery does not predict the potential for reherniation, but large annular defects does provide an opportunity for remaining disc material to herniated [29]. Carragee et al. demonstrated that reherniation occurs more often when there is a large or massive annular defect [29, 36]. To reduce the material left behind, Carragee and colleagues performed a subtotal discectomy and compared the result with limited discectomy. They found that the rate of reherniation was not statistically different for the 2 techniques. Thus, we suggest that a small annular incision during surgical discectomy is an important factor for reherniation, not the amount of disc material removed.

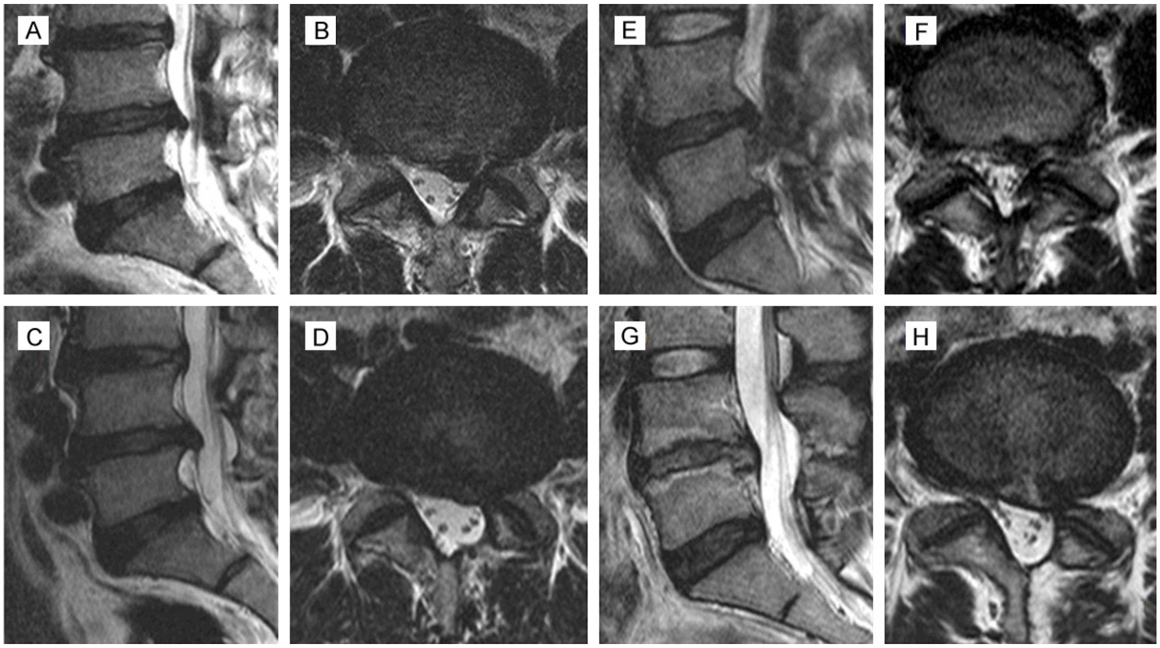

Figure 7. Case illustrations of recurrent disc herniation. *Case 1.* A 54-year-old male underwent AOLD for disc herniation at the L4-5 level (A, B). At 14 months after operation, follow-up MRI showed recurrent disc herniation (C, D), but he did not experience any back or leg pain. *Case 2.* A 29-year-old female underwent AOLD for downward-migrated disc herniation at the L4-5 level (E, F). At 11 months after operation, recurrent radiating pain developed and MRI showed recurrent disc herniation (G, H). Percutaneous endoscopic discectomy was recommended but was declined as conservative treatment involving oral analgesics and a nerve root block kept the pain at a tolerable level and the pain has decreased with time.

To the best of our knowledge, there is no available clinical study that addresses the relation between the size of annular incision and reherniation. Biomechanical analyses of the effects of specific methods of annular incision have been previously reported. The technique used to incise the annulus during discectomy has been shown to affect subsequent healing strength of the annulus and the biomechanical stability of the segment. Specifically, the box incision led to significantly weaker healing than did the slit incision [37]. Natarajan et al. compared 4 incision methods (square, circular, cross, and slit) using finite element analysis [38]. They reported a subsequent increased external load transfer to the facet joint that was much larger for combined annulotomy with nucleotomy than for annular incision alone. The circular incision produced the smallest external load transfer. These studies provided the theoretical background to support the hypothesis that a small round annulotomy will preserve annular integrity and reduce the risk of reherniation [19]. Pituitary forceps are often used to remove intradiscal degenerated disc material in MD. However, it is difficult to use pituitary forceps through an annular window that is less than 3 mm in diameter. The Micro II™ nucleotome kit allows the surgeon to remove tissue that can be easily mobilized from the disc space less invasively than conventional fragmentectomy.

An even less invasive option for disc decompression that uses an automated probe to remove the nucleus pulposus for percutaneous discectomy was first described by Onik et al. [39]. This technique is called automated percutaneous lumbar discectomy (APLD). APLD has been shown to be favorable in some patient subgroups such as the elderly, patients who have underwent previous surgery and patients with discogenic low back pain [40]. However, the eligible lesion for APLD is limited to contained disc herniation. APLD is not suitable for uncontained extrusion or sequestrated or migrated fragments, rather these fragments can be easily removed by open surgery. AOLD has advantages in removal of uncontained disc fragments over APLD. However, it is difficult to remove hard degenerated discs and large fragments that cannot be aspirated using a nucleotome. Therefore, whether the herniation is contained or not, indication for AOLD is a disc that is soft enough to be removed with the nucleotome kit. In the present study, AOLD showed comparable clinical and radiological outcomes to conventional MD for the appropriate lumbar disc herniation. Follow-up MRI revealed radiological reherniations in 2 cases from the AOLD group. These cases of reherniation might be due to remaining large fragments in the intervertebral disc space. The short-term follow-up period in the present study limits our ability to draw definitive conclusions. However, the study does demonstrate acceptable early clinical outcomes after minimally invasive discectomy by using a nucleotome probe via a small annular incision.

We performed MD with CO_2 laser-equipped microscopes. Lasers have been shown to be more precise than scalpel use in spine surgery [41]. Lasers reduce the size of the annular incision required repair a herniated disc, which helps to reduce nerve root injury. Because we used pituitary forceps for the central discectomy, the annular incision discectomies were larger than those of AOLD.

There are some limitations of this study. One is the relatively large number patients for whom we have no follow-up data. Although we were able to contact some patients via telephone interviews, it is not sufficient to support the sincerity of the present cohort. Another is the relatively short follow-up period that limits the conclusions we can make from our results. To our knowledge, this is the first study to compare the surgical outcomes of AOLD and MD using a randomized trial. We plan to perform further follow-up assessments for this cohort.

Conclusion

AOLD showed comparable clinical and radiological outcomes to conventional MD. It is useful for preserving the central disc minimizing postoperative instability and for removing only the loose degenerative disc fragments, which are the main cause of reherniation. Our results suggest that preservation of the central disc prevents loss of disc height and segmental instability, which is related to postdiscectomy back pain. Further follow-up with these patients is required to draw definitive conclusions.

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Disclosure of conflict of interest

None.

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