Retrospective Study

Postoperative Longitudinal Outcomes in Patients with Residual Disc Fragments after Percutaneous Endoscopic Lumbar Discectomy

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Disclaimer: JH Baek and SH Yang are equally contributed as first author. A grant from the Korea Health Technology R&D Project supported this work through the Korea Health Industry Development Institute (KHIDI) funded by the Ministry of Health & Welfare, Republic of Korea (HC15C1320). Grant No. 0320160210 (2016-1062) from the Seoul National University Hospital also partially supported this study. The first author (CHK) is a consultant of RIWOspine GmbH. The other authors declare that they have no conflicts of interest concerning the materials/methods used in this study or the findings described in this paper. The institutional review board at the Seoul National University Hospital approved this study (H-1611-015-803).

Manuscript received: 01-06-2018
Revised manuscript received: 02-18-2018
Accepted for publication: 03-06-2018

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Background: Residual disc fragments are observed on immediate postoperative magnetic resonance imaging (MRI) in 2.8–15% of patients after percutaneous endoscopic lumbar discectomy (PELD). Considering the known postoperative longitudinal outcomes in patients with residual disc tissue, a 'watchful waiting' strategy may be preferable to immediate re-operation in patients with asymptomatic residual disc material.

Objectives: The aim of the present study was to compare the longitudinal clinical outcomes between PELD patients in whom the complete removal of disc fragments was achieved (complete group) and those in whom residual disc fragments were observed on postoperative MRI (residual group).

Study Design: Retrospective nested case-control study.

Methods: A total of 225 patients were included (complete group, n=187 and residual group, n=38). Clinical assessments were performed using the visual analog pain score for the leg (VAS-L, x/10) and back (VAS-B, x/10) and the Korean version of the Oswestry Disability Index (K-ODI, x/45). A linear mixed-effects model was used to analyze changes during the first 24 postoperative months.

Results: One month after surgery, significant improvements in the VAS-L, VAS-B and K-ODI values were observed and were maintained during the first 24 postoperative months. No differences in these changes were noted between the groups. Early re-operation (during the first 3 postoperative months) was performed in 3 patients in the residual group (7.9%) and in 4 patients in the complete group (2.1%) ($P = 0.10$).

Limitations: First, the study design was retrospective. Moreover, the number of patients was relatively small and therefore insufficient to achieve robust statistical power. Second, we did not explore the radiological outcomes in patients with asymptomatic residual disc material because follow-up MRI was only obtained to document symptom recurrence.

Conclusion: When residual disc tissue is observed in asymptomatic patients, a 'watchful waiting' strategy may be preferable to immediate re-operation. However, an increased early re-operation rate is expected for patients with residual disc tissue.

Key words: Discectomy, endoscopes, longitudinal studies, patient-reported outcome, percutaneous, reoperation, spine, residual disc

Pain Physician 2018: 21:E457-E466

Herniated lumbar disc (HLD) is one of the most common causes of lower back and leg pain (1). Surgical treatment is recommended when pain is intractable for longer than 6 weeks despite medication, injections or other interventions (2,3). The main goals of discectomy are the complete removal of the ruptured disc fragments, symptom improvement, and recurrence prevention (1,4,5). Open discectomy is currently the standard surgical treatment of choice; however, recent publications have shown that comparable outcomes can be achieved using percutaneous endoscopic lumbar discectomy (PELD) (2,4,6).

The most frequent and important question during discectomy may be 'How much disc material should be removed?' (1,6-11). In open surgery, the recurrence and re-operation rates are lower for the subtotal removal of disc material than those following limited discectomy (1,3,6-9,11,12). However, more patients experience progressive degeneration at the operated segment (and subsequent back pain) following subtotal discectomy than limited discectomy (3,6-12). Regardless, the high recurrence rate of limited discectomy remains a major drawback (6-11). PELD is a type of limited discectomy that was expected to exhibit a high recurrence rate; however, recent studies demonstrated that the recurrence rate for PELD was comparable to that of open discectomy (1,4,13). During PELD, the ruptured primary disc material and any loose fragments under the ruptured disc are removed (14). However, residual disc fragments were observed in 2.8–15% of patients in several studies in which immediate postoperative magnetic resonance imaging (MRI) was performed after PELD (6,14,15). Although the presence of a residual disc fragment with persistent compression is one cause of re-operation, not all residual disc fragments observed on immediate postoperative MRI are symptomatic. Additionally, residual disc fragments are not always associated with poor longitudinal clinical outcomes (9,10,14,16).

However, no previous study has explored the postoperative longitudinal outcomes of patients with residual disc tissue (6). Considering the known postoperative longitudinal outcomes, a 'watchful waiting' strategy may be preferable to immediate re-operation in patients with asymptomatic residual disc tissue (14,15,17). The aim of the present study was to compare the longitudinal clinical outcomes between patients who underwent PELD and achieved complete removal of the disc fragments (complete group) and those in whom residual disc fragments were observed on postoperative MRI (residual group).

Methods

Since 2005, all clinical and radiological data were prospectively recorded using an electronic medical recording system (IRB No. 0507-509-153). Informed consent was obtained from all patients. After approval by our institutional review board (IRB No. 1611-015-803), the medical records, including imaging results, were retrospectively reviewed for patients who underwent PELD from 2009 to 2017.

We selected patients with the following criteria from the database: 1) single-level HLD, 2) age less than 60 years, 3) absence of spinal stenosis at any level, 4) absence of a psychological diagnosis, such as depression and Parkinson's disease, and 5) a follow-up period longer than 6 months. A total of 225 patients were included in the present study. The preoperative and postoperative management protocols were the same in all patients. All patients reported intractable radicular leg pain that was non-surgically treated for longer than 6 weeks. All patients exhibited symptomatic HLD verified by MRI (14,18). Clinical assessments were performed using patient-reported outcome (PRO) questionnaires that included a Korean version of the Oswestry Disability Index (K-ODI, x/45) (19) and visual analogue pain scores for the back (VAS-B, x/10) and leg (VAS-L, x/10) (20). All included patients completed the questionnaires preoperatively (20). The surgical procedures and principles used to select the surgical approach were the same for all patients (4,14,18,21,22). A percutaneous endoscopic transforaminal approach and discectomy (PETD) was selected for patients with an HLD at L4-5 or above, whereas a percutaneous endoscopic interlaminar approach and discectomy (PEID) was preferred for all patients with an HLD at L5-S1 (21). PEID was selected for patients with high-grade superior or inferior migrated HLD at any level, an HLD exhibiting high-grade (> 50%) canal compromise or a high iliac crest (21-23). Postoperatively, the patients were encouraged to ambulate, and MRI was performed within 24 hours after the operation. All patients were discharged on the day following the operation if their symptoms had improved. However, discharge was postponed if symptoms persisted or if symptomatic residual disc tissue was identified on MRI. Re-operation was considered when persistent pain was intractable in patients with residual disc material on postoperative MRI. Patients chose between close follow-up and re-operation during their hospital stay. Patients were scheduled to visit the clinic at 1, 3, 6, and 12 months after the operation and yearly thereafter. Additionally, patients were encouraged to visit an outpatient clinic any time they experienced intractable pain. Patients completed the same PRO questionnaires during every visit. MRI was not routinely performed in patients without recurrent symptoms. The median follow-up period was 23 months (range, 6–88 months).

Surgical Method

The surgical procedures were performed as previously described (4,14,21,22). All operations were performed with the patient in the prone position and under general anesthesia. Intraoperatively, spontaneous electromyography (EMG) was monitored in all patients. For PETD, an 18-gauge needle was inserted into the neural foramen from the side, and a guide wire was introduced after the stylet was removed. All procedures were performed under fluoroscopic guidance and with EMG monitoring. The working channel was inserted over the dilator and along the guide wire after an incision (8 mm in diameter) was made in the skin. An endoscope (Vertebris system; Richard Wolf, Knittlingen, Germany) was introduced into the neural foramen after the obturator was removed. The ruptured disc fragments were identified as over or under the annulus in all cases and removed using forceps. All graspable loose disc fragments were removed using forceps or flexible forceps. Decompression of the nerve root was indirectly confirmed by visualizing the free movement of the traversing nerve root or epidural fat, the ability of a probe to freely pass into the epidural space, and the removal of the expected ruptured disc and loose fragments based on the preoperative MRI (4,14,18,22).

For PEID, the endoscope was introduced to the ligamentum flavum (LF) after the dilator and working channel were inserted. An oblique trajectory was chosen in cases with a highly migrated disc herniation based on the direction and amount of migrated disc material (22). A small hole was created in the LF. The working channel and endoscope were inserted into the spinal canal through the hole, and the hole was then enlarged (24). The ruptured disc was visualized after the neural tissue was gently retracted using the working channel. The ruptured disc was removed first in all cases, and the loose fragments under the ruptured disc were then removed. The decompression of the nerve root was confirmed directly from the axilla and shoulder side of the nerve root. The working channel and endoscope were withdrawn after the PEID or PETD was completed, and the skin subsequently closed using 3-0 nylon sutures.

Classification of Postoperative MRI Results

Pfirrmann et al (25) proposed the following practical grading system using MRI to score lumbar nerve root compression caused by HLD: Grade 0 (normal), the nerve root is not compromised; Grade 1 (contact), visible contact is observed between disc material and the nerve root, with no dorsal deviation; Grade 2 (deviation), the nerve root is displaced dorsally by disc material; and Grade 3 (compression), the nerve root is compressed between disc material and the wall of the spinal canal and may appear flattened or be indistinguishable from disc material. Patients were assigned to either the 'complete group (Grade 0 or 1)' or the 'residual group (Grade 2 or 3)' based on the postoperative MRI results assessed by an independent researcher without access to patient information (14,25).

Statistical Analysis

The primary endpoint was VAS-L. The secondary endpoints were VAS-B and K-ODI. The residual disc factors analyzed included location, an HLD exhibiting high-grade (> 50%) canal compromise (15), the presence of a migrated disc herniation (yes vs. no) (15,22) and the surgeon's experience (6,23,26). Other factors known to influence clinical outcomes include age, gender, body mass index (BMI, kg/m2), the duration of symptoms, the presence of weakness (less than manual motor power grade IV-/V), smoking status, disc morphology (protrusion vs. extrusion/sequestration) (27), Pfirrmann grade at the index level (grade 1–3 vs. 4–5) (28,29), the presence of Modic change (yes vs. no) (30), and surgical method (PETD vs. PEID) (3,14). These factors were analyzed, and the results were compared between the two study groups. Comparisons between continuous and non-continuous values were performed using Mann-Whitney U tests (or t-tests) and Chi-square tests, respectively.

A linear mixed-effects model (LMM) was used to assess changes that occurred in the VAS-L, VAS-B and K-DOI values during the first 24 postoperative months. The fixed effects included group, time, the interaction between group and time, and factors with *P*-values less than 0.2 in the univariate analysis. The random effect was subjects. A post hoc analysis using a stepdown Bonferroni method was performed with the following significant interaction effects: the time trend in each group, testing the changes between preoperative and postoperative (1, 3, 6, 12 and 24 months) time points for the groups that showed significant temporal trends, and group differences at each time point. Specifically, the least squares means for VAS-L, VAS-B and K-ODI were estimated using adjusted 99% confidence intervals in the LMM.

Surgical failure was recorded for the following: persistent symptoms after surgery and symptomatic recurrent HLD. Recurrent HLD was defined as a re-herniation at the same level and side after a transient symptom-free period of at least 2 weeks in patients in whom complete removal of the herniated disc material was achieved based on immediate postoperative MRI (6). Re-operation performed within 3 months after initial PELD was defined as an 'early re-operation'. Event-free time (i.e., time without surgical failure) was calculated using a Kaplan-Meier survival analysis, and a log-rank test was used for comparisons between groups. All statistical analyses were performed using SPSS (version 23.0, IBM, SPSS, NY, USA). Statistical significance was defined as $P < 0.05$ (two-sided).

Results

After the postoperative MRIs were reviewed, 187 patients were assigned to the complete group, and 38 patients were assigned to the residual group (Table 1). The characteristics of the groups did not differ significantly, except for the presence of migration. Preoperatively, migration of disc material was observed in 126 patients (56%). Postoperative MRI revealed that residual disc tissue was observed in 30/126 (23.8%) patients with migration and 8/99 (8.1%) patients without migration ($P = 0.02$). Preoperatively, high-grade canal-compromising disc herniation was observed in 100/225

Table 1. *Characteristics of the included patients.*

		Complete (n = 187)	Residual (n = 38)	*P*-value
Age (year)	(mean ± SD)	38.8 ± 10.6	41.2 ± 9.6	0.20
Female	(Proportion, %)	95 (50.8%)	15 (39.5%)	0.20
BMI (kg/m^2)		24.1 ± 3.6	25.2 ± 3.7	0.08
Duration of symptoms (months)		4.8 ± 5.3	3.1 ± 3.1	
OP method	PETD	90 (48.1%)	21 (55.3%)	0.42
	PEID	97 (51.9%)	17 (44.7%)	
Weakness (yes)		38 (20.3%)	10 (26.3%)	0.41
Smoking (yes)		49 (26.2%)	12 (31.6%)	0.50
Disc type	Protrusion	73 (39%)	10 (26.3%)	0.14
	Extrusion/sequestration	114 (61%)	28 (73.7%)	
High canal compromise		85 (45.5%)	15 (39.5%)	0.50
Migration (yes)		96 (51.3%)	30 (78.9%)	0.02
Pfirrmann grade	1–3	94 (50.3%)	16 (42.1%)	0.36
	4–5	93 (49.7%)	22 (57.9%)	
Levels	L1–2	3	0	0.42
	L3–4	5	2	
	L4–5	110 (58.8%)	27 (71.1%)	
	L5–S1	69 (36.9%)	9 (23.7%)	
Modic change	Type 1	2		
	Type 2	33	6	
	Type 3	8	1	
K-ODI		22.1 ± 7.6	22.1 ± 8.2	0.98
VAS-B		6.5 ± 1.9	6.7 ± 2.3	0.56
VAS-L		6.9 ± 1.6	6.7 ± 1.7	0.49

Abbreviations: K-ODI, Korean version of Oswestry Disability Index; VAS-B, visual analogue pain scale of the back; VAS-L, visual analog pain scale of the leg; PETD, percutaneous endoscopic transforaminal approach and discectomy; PEID, percutaneous endoscopic interlaminar approach and discectomy (PEID)

Table 2. *Adjusted VAS-L, VAS-B, and K-ODI.*

Time	Preop	1 mo	3 mo	6 mo	12 mo	24 mo
VAS-L (x/10)	6.7	2.4	1.8	1.3	1.0	0.7
99% CI	6.3–7.1	1.9–2.8	1.3–2.3	0.7–1.8	0.4–1.7	0.01–1.5
VAS-B (x/10)	6.6	2.5	2.3	1.8	1.7	1.5
99% CI	6.1–7.0	2.0–2.9	1.8–2.8	1.3–2.4	1.0–2.4	0.7–2.2
K-ODI (x/45)	21.9	10.5	8.3	5.9	5.6	4.6
99% CI	20.3–23.4	8.9–12.1	6.5–9.9	4.0–7.8	3.3–7.7	2.1–7.1

All values are calculated for a BMI = 24.23 kg/m^2.
Abbreviations: CI, confidence interval; K-ODI, Korean version of Oswestry Disability Index; VAS-B, visual analog pain scale of the back; VAS-L, visual analog pain scale of the leg

(44.4%) patients. Postoperative MRI revealed that residual disc tissue was present in 15/100 (15.0%) patients with high-grade canal-compromising disc herniation and in 23/125 (18.4%) patients without (*P* = .50). Residual disc tissue was observed in 21/111 (18.9%) patients after PETD and 17/114 (14.9%) patients after PEID. No difference was observed between these groups (*P* = 0.42).

Among the patient characteristics evaluated, BMI, disc type and the presence of migration were considered confounding variables in the LMM. The LMM analysis revealed no difference in VAS-L between the groups according to time (*P* = 0.61). Similarly, no differences in VAS-B (*P* = 0.12) or K-ODI (*P* = 0.84) were noted between the groups. The adjusted means for VAS-L, VAS-B and K-ODI are presented in Table 2 and Fig. 1. All clinical values were significantly reduced at 1 month after the operation, and these improvements were maintained throughout the follow-up period (Fig. 1).

Surgical failure occurred in 14 patients (6.2%) (Table 3). Re-operation was performed in 11 patients (4.8%), and early re-operation was performed in 64% (7/11) of re-operated patients. Patients in the residual group exhibited trends for higher re-operation (*P* = 0.09) and early re-operation rates (*P* = 0.10) than patients in the complete group. The restricted mean event-free time was 82.7 ± 1.6 months (95% CI, 79.6–86.0) in the complete group and 65.0 ± 5.0 months (95% CI, 78.3–85.0) in the residual group (*P* = 0.17) (Fig. 2).

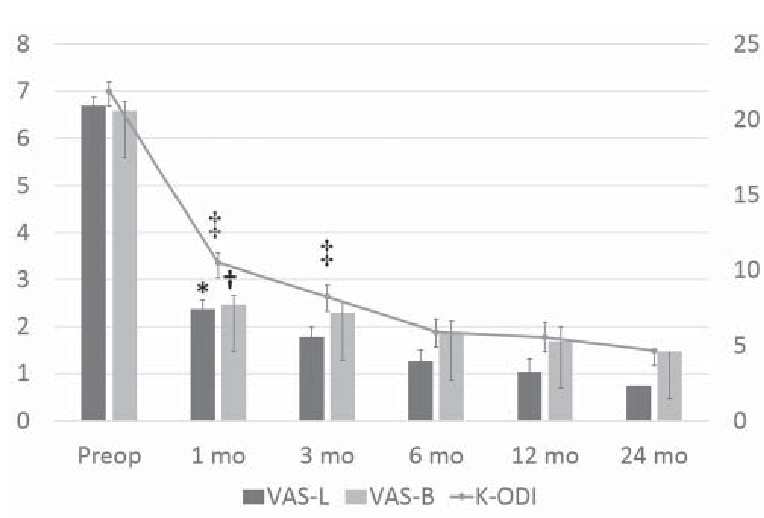

Fig. 1. ***Changes in VAS-L, VAS-B and K-ODI values over time.***
Graph presenting the changes in clinical parameters assessed throughout the postoperative period. Bar graph values are presented on the left Y-axis, and line graph values are presented on the right Y-axis. Standard errors are marked. VAS-L and VAS-B values were significantly lower at 1 month postoperatively (*P* < 0.001), and this improvement was also maintained during the follow-up period. K-ODI values decreased significantly after 1 month (*P* < 0.001), further decreased at 3 months postoperatively (*P* = 0.04), and were maintained at this lower level throughout the follow-up period. '*', '†' and '‡' indicate a significant decrease in VAS-L, VAS-B and K-ODI values relative to the previous time point, respectively.
Abbreviations: K-ODI, Korean version of the Oswestry Disability Index; VAS-B, visual analog pain scale of the back; VAS-L, visual analog pain scale of the leg.

Illustrative Case

A 38-year-old male patient presented with right leg pain that began 2 months prior to his visit. MRI revealed high-grade canal compromise

Table 3. *Summary of surgical failure.*

	Overall (n = 225)	Complete group (n = 187)	Residual group (n = 38)	*P*-value
Surgical failure	14 (6.2%)	10 (5.3%)	4 (10.5%)	0.26
Re-operation	11 (4.8%)	7 (3.7%)	4 (10.5%)	0.09
Early re-operation	7 (3.1%)	4 (2.1%)	3 (7.9%)	0.10

and a high-grade inferior migrated disc herniation (Fig. 3a and b). The preoperative VAS-L, VAS-B and K-ODI values were 6/10, 0/10 and 17/45, respectively. He underwent PEID, and a large amount of disc material was removed. Postoperative MRI showed that the migrated disc material was incompletely removed (Fig. 3c), although the VAS-L, VAS-B and K-ODI values improved (4/10, 1/10 and 17/45, respectively) at 1 month postoperatively. Follow-up MRI performed 6 months after the operation revealed that the residual disc material was completely resorbed (Fig. 3d). His symptoms further improved. The VAS-L, VAS-B and K-ODI values were 2/10, 0/10 and 12/45, respectively, at 24 months postoperatively.

Discussion

The aim of the present study was to compare the longitudinal clinical outcomes between PELD patients in whom disc fragments were completely removed (complete group) and those in whom residual disc fragments were observed on postoperative MRI (residual group). Residual disc tissue was observed in 16.9% (38/225) of patients, and 1.3% (3/225) of patients were symptomatic. One-fourth of patients with migrated HLD showed residual disc tissue on MRI. After surgery, VAS-L, VAS-B and K-ODI values were similarly improved in both groups. Surgical failure occurred in 14 patients (6.2%). Re-operation was performed in 11 patients (4.8%), and early re-operation was performed in 64% (7/11) of re-operated patients. Patients in the residual group exhibited trends for higher re-operation and early re-operation rates than patients in the complete group.

Amount of Disc Material Removed During PELD

To prevent recurrence, the amount of disc material removed must be sufficient to decompress the neural

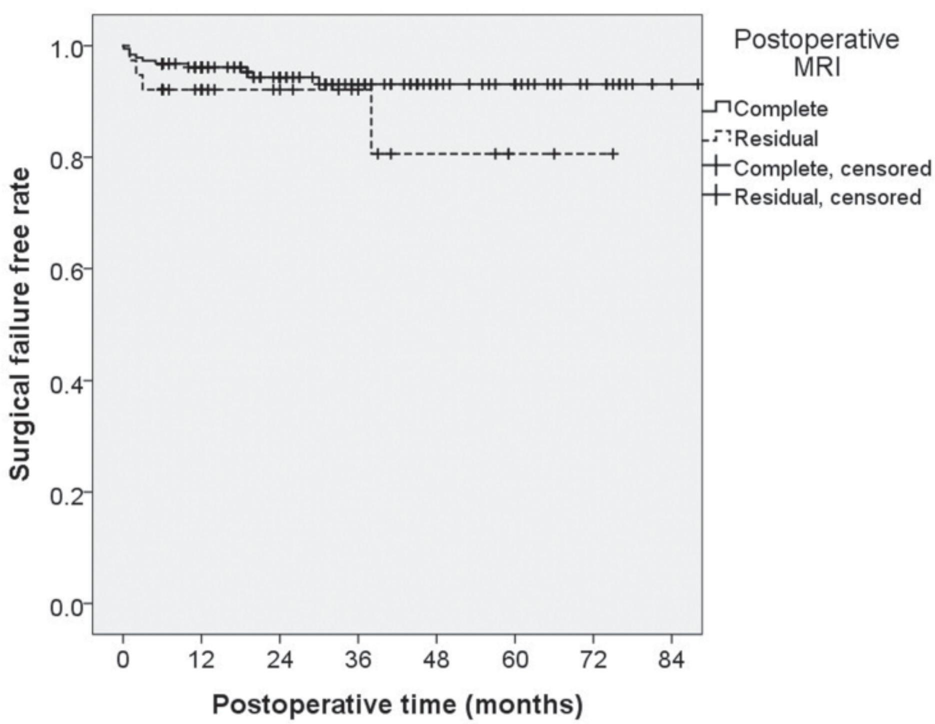

Fig. 2. *Surgical failure-free time.* Graph depicting the surgical failure-free rate at different postoperative time points in the complete and residual groups. The restricted mean event-free time was 82.7 ± 1.6 months (95% CI, 79.6–86.0) in the complete group and 65.0 ± 5.0 months (95% CI, 78.3–85.0) in the residual group. This difference was not significant (log-rank test, *P* = 0.17). Although the surgical failure rate did not differ significantly between the groups, the failure rate was higher in the residual group (10.5%, 4/38) than in the complete group (5.3%, 10/187).

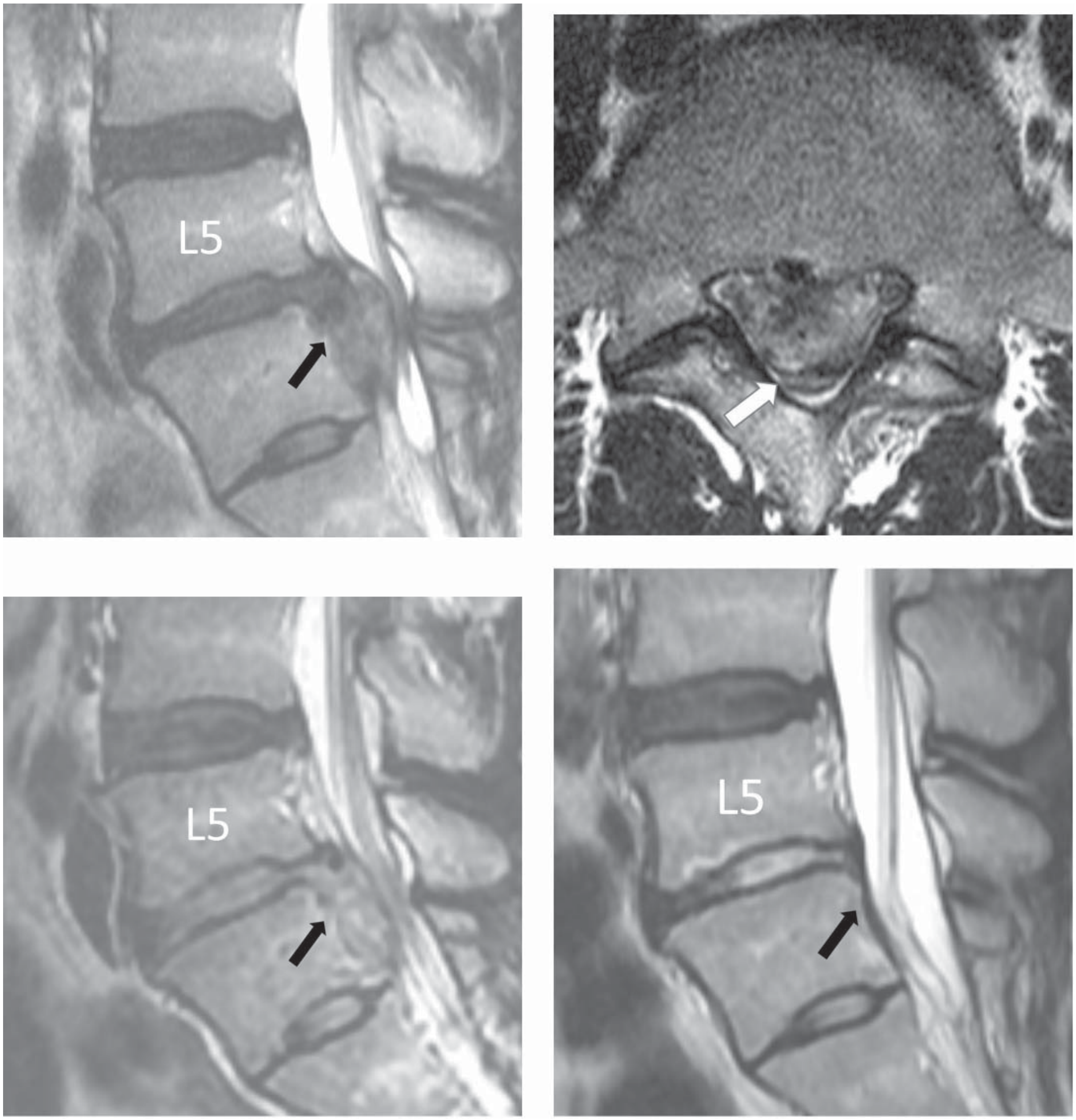

Fig. 3. *Illustrative case.*
Preoperative sagittal (a) and axial (b) T2-weighted magnetic resonance imaging (MRI) showing a herniated lumbar disc (HLD) (arrow) that migrated inferiorly from L5-S1. The HLD occupied greater than 50% of the spinal canal, and the dura was severely compressed posteriorly (b, arrow). Immediate postoperative MRI demonstrated that decompression was achieved; however, residual disc remained at S1 (c, arrow). Follow-up MRI (d) performed 6 months after the operation revealed that the disc material was completely resorbed (arrow).

tissue without leaving residual disc fragments inside the spinal canal (14). Subtotal discectomy is supported because its recurrence and re-operation rates are lower than those of limited discectomy (3,8,10,11,31). However, the complications associated with subtotal discectomy are not minor and include decreased disc height, the occurrence of Modic changes, and subsequent increased back pain and decreased functional status (7,8,10). However, the advantages of limited discectomy revealed in these studies are offset by its higher recurrence rate than subtotal discectomy (3,8,10,11,31).

Previous studies demonstrated that maintained annulus competence was associated with a low recurrence rate (3,31). Although PELD is a type of limited discectomy, its recurrence rate may differ from that of previously employed types of limited discectomy because it produces only small defects in the annulus as a result of the use of small instruments and high magnification (3,4,31-33). Ruetten et al. performed a randomized controlled trial that compared PELD and open discectomy. The recurrence rate was 6.2% after PELD and 5.7% after open discectomy, and the difference was not significant (4). Similarly, in the present study, surgical failure occurred in 6.2% of patients.

Postoperative Longitudinal Outcomes of Patients with Residual Disc Material

Residual disc fragments were observed on immediate postoperative MRI in 2.8–15% of patients who underwent PELD (6,14,15). Choi et al. showed that herniated disc material was incompletely removed in 283/10,228 (2.8%) patients (6). Revision surgeries were performed in all patients regarded as having a 'symptomatic residual disc' (6). However, the present study produced different results. Although residual disc tissue was observed in 16.9% (38/225) of patients, symptomatic residual disc material was observed in only 1.3% (3/225) of patients. Although residual disc fragments with persistent compression were one cause of re-operation, not all of the residual disc tissue observed on immediate postoperative MRI was symptomatic (9,10,14,16). The 2-year postoperative radiological outcomes after open discectomy revealed recurrent HLD in 23–51% of patients (7,16). However, radiological recurrent HLD did not correlate with lower back pain, sciatica, performance status, overall outcomes or pain-related drug use (7,16). Similar outcomes may be expected for patients with an 'asymptomatic residual disc after PELD'. Considering the known postoperative longitudinal outcomes, a 'watchful waiting' strategy may be preferable to immediate re-operation in patients with asymptomatic residual disc material (14,15,17). In the present study, we demonstrate that leg pain, back pain and functional status are not dependent on the presence or absence of residual disc tissue on immediate postoperative MRI. Therefore, a 'watchful waiting' strategy may be preferable in patients with asymptomatic residual disc tissue (34). However, early re-operation was associated with the presence of residual disc tissue, as demonstrated in the present and previous studies (6). If complete surgery is achieved, the re-operation rate might be reduced by 1–2% (6). To improve surgical outcomes following PELD, a variety of surgical techniques, such as a transforaminal approach, an extraforaminal technique, an outside-in technique and an interlaminar approach, are recommended to perform PELD properly, particularly for patients with migrated disc herniation (6,15,22,35).

Limitations

First, the study design was retrospective. Moreover, the number of patients was relatively small and therefore insufficient to achieve robust statistical power. Second, we did not explore the radiological outcomes in patients with asymptomatic residual disc tissue because follow-up MRI was planned to document the recurrence of symptoms. Finally, our results suggest that a 'watchful waiting' strategy may be preferable to immediate re-operation in patients with asymptomatic residual disc tissue. However, the strategy was not randomized, and a definitive conclusion could not be obtained from the present study. A further prospectively randomized controlled trial may be required.

Conclusion

No differences in the postoperative longitudinal outcomes were noted between the patients with asymptomatic residual disc tissue and those in whom complete removal of the disc fragments was achieved. When asymptomatic residual disc tissue is observed on immediate postoperative MRI, a 'watchful waiting' strategy may be preferable to immediate re-operation for patients and surgeons. Nonetheless, 1.3% of patients undergo early re-operation as a result of residual disc fragments. A variety of surgical techniques may be employed to completely remove the herniated disc fragment, particularly in patients with migrated disc herniation.

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