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Comparison of Long-Term Follow-Up Outcomes Between Minimally Invasive and Open Surgery for Single-Level Lumbar Fusion

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ABSTRACT

AIM: To evaluate, and to compare the clinical outcomes of minimally invasive surgery (MIS), and open surgery for single-level lumbar fusion over a minimum of 10-year follow-up.

MATERIAL and METHODS: We included 87 patients who underwent spinal fusion at the L4 – L5 level between January 2004 and December 2010. Based on the surgical method, the patients were divided into the open surgery (n=44) and MIS groups (n=43). We evaluated baseline characteristics, perioperative comparisons, postoperative complications, radiologic findings, and patient-reported outcomes.

RESULTS: The mean follow-up period was > 10 years in both groups (open surgery, 10.50 years; MIS, 10.16 years). The operative time was longer in the MIS group (4.37 h) than that in the open surgery group (3.34 h) (p=0.001). Estimated blood loss was lower in the MIS group (281.40 mL) than in the open surgery group (440.23 mL) (p<0.001). Postoperative complications, including surgical site infection, adjacent segment disease, and pseudoarthrosis, did not differ between the groups. Plain radiographic findings of the lumbar spine did not differ between the two groups. Visual scores for back/leg pain and the Oswestry disability index did not differ between the two groups, preoperatively and at 6 months, 1, 5, and 10 years after surgery.

CONCLUSION: After a minimum of the 10-year follow-up, postoperative complications and clinical outcomes did not differ significantly between patients who underwent open fusion and MIS fusion at the L4 – L5 level.

KEYWORDS: Minimally invasive surgery, Open surgery, Patient-reported outcome measures, Spinal fusion, Treatment outcome

INTRODUCTION

Conservative treatments, including drug and physical therapy, were initially attempted for symptomatic lumbar degenerative disease. Surgical treatment is then indicated if symptoms do not improve despite conservative treatment. Lumbar interbody fusion provides stability for painful segments caused by degenerative diseases, such as low back pain and radiculopathy caused by disc herniation, spinal stenosis, and foraminal stenosis (12,13).

Open surgery is considered the gold standard for instrumented lumbar fusion with dependable improvements in clinical outcomes (11,14). However, postoperative complications may occur due to soft tissue damage during surgical field exposure, resulting in worse patient outcomes (6,17-19,21). Meanwhile, lumbar fusion via minimally invasive surgery (MIS) has been widely performed in recent years due to its various advantages, such as minimal blood loss, faster recovery, and less postoperative pain (8,10,16,18,23).

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Numerous reviews have compared the clinical outcomes of open and MIS lumbar fusion (10,14,16,18,23). However, to our knowledge, no long-term studies with a follow-up period of > 10 years have been reported. Therefore, we evaluated the clinical outcomes and complications of open and MIS lumbar fusions over a long-term follow-up period of > 10 years.

MATERIAL and METHODS

The Institutional Clinical Research Ethics Review Committee approved this study (GAIRB2021-004), and the need for informed consent was waived due to the retrospective nature of the study.

Patient Selection

We reviewed the data of 119 patients who underwent single-level fusion of L4–L5 at a single institution between January 2004 and December 2010. We excluded 32 patients based on the following exclusion criteria: unavailability of complete data; follow-up period of < 10 years; record of lumbar spine surgery at other levels; fusion without posterior screw fixation; and diagnosis associated with cancer, infection, or trauma.

Finally, 87 patients were enrolled and assigned to open surgery (n=44) and MIS (n=43) groups (Figure 1). All patients complained of persistent back and radiating pain despite at least six months of conservative treatment, including analgesia, physiotherapy, and activity modification.

Surgical Procedure

Four surgeons performed lumbar fusion using either posterior lumbar interbody fusion (PLIF) or transforaminal lumbar interbody fusion (TLIF) technique. Interbody fusion was accompanied by pedicle screw fixation in all patients. The surgical experience of the surgeons in open surgery was over 10 years, except for surgeon C (A, 18 years; B, 15 years; C, 5 years; and D, 25 years). Since MIS fusion using percutaneous screw fixation was recently introduced in our institute (i.e., in 2007), technical experience with percutaneous screw fixation was insufficient at the beginning of the introduction. However, the surgeons had sufficient experience with the MIS dilator (METRX or Caspar-type retractor) before introducing the percutaneous screw fixation system. The decision to perform open surgery or MIS was made at the operator's discretion after considering the benefits of each technique.

Technique for open lumbar fusion

The operative level was confirmed by using a mobile C-arm radiography machine. Subperiosteal dissection was performed after a midline incision was made to expose the appropriate surgical anatomy. After confirming the entry point for pedicle screw insertion as suggested by Magerl, bilateral pedicle screws were inserted. Bilateral laminectomy was performed for PLIF, and facetectomy accompanied by partial laminectomy was performed for TLIF. Discectomy and endplate preparation were carefully performed, followed by the insertion of autologous bone and cages for interbody fusion into the disc space. Finally, the contoured rods were secured to the pedicle screws.

Technique for MIS lumbar fusion

After checking the desired operative level using a C-arm radiography machine, a skin incision was made at the midline for PLIF and at 3–5 cm lateral to the midline for TLIF. After inserting a Caspar-type or tubular-type retractor, bilateral partial laminectomy (PLIF) or facetectomy (TLIF) was performed. Discectomy, endplate preparation, and cage and bone graft insertion were performed serially. Under fluoroscopic guidance, the lateral edge of the pedicle ellipse was used as the entry point for the pedicle screw insertion. Pedicle screws and rods were percutaneously inserted under C-arm guidance.

Data Analysis

General patient characteristics such as age, sex, diagnosis, surgeon, body mass index, bone mineral density, symptom duration, and follow-up period were retrospectively examined. Perioperative indicators, including operative time, estimated blood loss (EBL), amount of blood transfusions, postoperative ambulatory time, and length of hospital stay, were also reviewed.

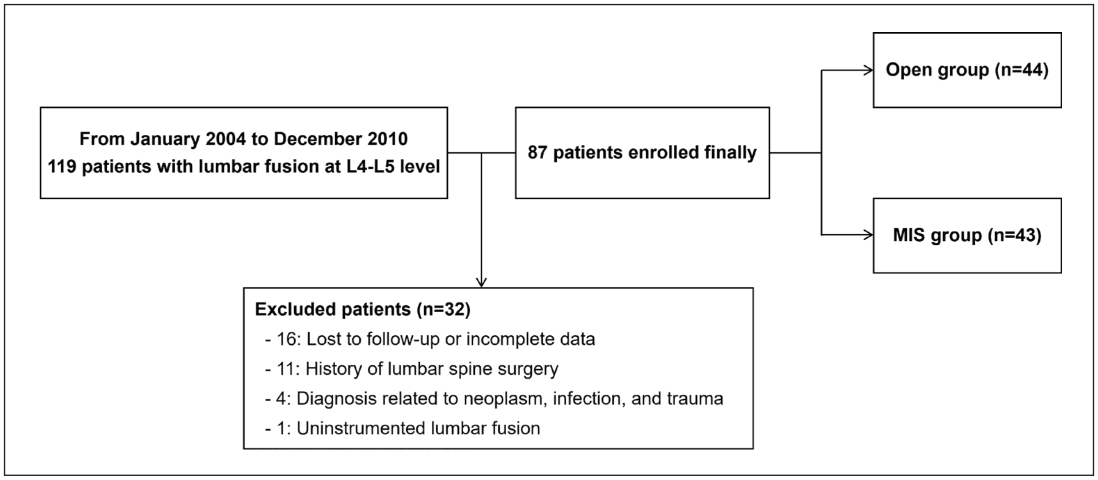

Figure 1: Patient selection. **MIS:** Minimally invasive surgery.

EBL was calculated by measuring the total amount of fluid collected through suction and subtracting it from the amount of irrigation fluid used throughout the surgery. Additional blood loss absorbed by the surgical gauze was calculated using the method proposed by Ali Algadiem et al. (1).

Postoperative complications were categorized into perioperative and long-term complications. Perioperative complications included postoperative neurological deficits, cerebrospinal fluid (CSF) leakage, epidural hematoma, and surgical site infection (SSI). Adjacent segment disease (ASD) and pseudoarthrosis are long-term complications.

SSI is defined as an infection within one year of surgery if an artificial substance is inserted, according to the US Centers for Disease Control and Prevention criteria (3). ASD is defined as radiographic changes in the adjacent segments of previous spinal fusion levels, accompanied by new clinical symptoms. (7) Two independent observers assessed fusion status using the method described by Brantigan and Steffee (BSF scale) (2,4). Pseudoarthrosis is generally defined as BSF-1 and BSF-2.

Plain radiographs were analyzed preoperatively and at 1, 5, and 10 years postoperatively, and the corrected disc height, range of motion (ROM), and segmental angles of adjacent levels were evaluated. The corrected disk height was calibrated using the method proposed by Son et al. (20). The segmental angle of the adjacent level was evaluated in a neutral supine position. The ROM at the adjacent level was assessed using dynamic radiography.

Clinical outcomes were evaluated before and at 6 months and 1, 5, and 10 years after surgery using the visual analog scale (VAS) for back/leg pain and the Oswestry Disability Index (ODI).

Statistical Analyses

An independent t-test was used to analyze continuous variables. The χ^2 test and Fisher's exact test were used to analyze continuous variables. In all analyses, a p-value of < 0.05 was considered statistically significant. Data analysis was performed using SPSS version 23.0 for Windows (SPSS Inc., Chicago, IL).

RESULTS

Baseline Characteristics

There was no significant difference in the baseline characteristics between the open surgery and MIS groups. Common diagnoses were stenosis and listhesis in both groups. The mean follow-up period for both groups was > 10 years (open, 10.50 years; MIS, 10.16 years). The duration of the symptoms was 7.75 and 8.05 months in the open surgery and MIS groups, respectively (Table I).

Table I: Baseline Characteristics

	Open (n=44)	MIS (n=43)	p-value
Age, years	47.45 ± 10.75	52.26 ± 14.19	0.078
Sex			0.236
Male	24 (54.5%)	18 (41.9%)	
Female	20 (45.5%)	25 (58.1%)	
Diagnosis			0.472
Disc herniation (Large/recurrent)	9 (20.5%)	6 (14.0%)	
Stenosis	17 (38.6%)	22 (51.2%)	
Listhesis	18 (40.9%)	15 (34.8%)	
Surgeon			
A	28 (63.6%)	32 (74.4%)	0.327
B	4 (9.1%)	5 (11.6%)	
C	3 (6.8%)	0 (0.0%)	
D	9 (20.5%)	6 (14.0%)	
Smoking, yes	11 (25.0%)	7 (16.3%)	0.315
Alcohol, yes	12 (27.3%)	9 (20.9%)	0.489
BMI, kg/m²	23.86 ± 3.13	25.01 ± 3.73	0.138
BMD, T-score	-1.56 ± 1.67	-1.60 ± 1.79	0.962
Follow-up period (range), years	10.50 (10.0–14.0)	10.16 (10.0–13.0)	0.083
Symptom duration, months	7.75 ± 18.58	8.05 ± 13.87	0.931

***BMD:** Bone mineral density, **BMI:** Body mass index, **MIS:** Minimally invasive surgery.*

Perioperative Comparison

The EBL and operative time differed significantly between the groups. The operative time was longer in the MIS group (4.37 h) than that in the open surgery group (3.34 h) (p=0.001). However, EBL was lower in the MIS group (281.40 mL) than in the open surgery group (440.23 mL) (p<0.001). There were no significant differences between the groups with respect to transfusion, ambulation, or length of hospital stay (Table II).

Postoperative Complications

Two perioperative complications occurred in the open group: CSF leakage and voiding difficulty due to the Foley catheter insertion. Three perioperative complications occurred in the MIS group: postoperative aggravation of asthma and voiding difficulty due to the Foley catheter insertion. In the case of CSF leakage, the dura was torn during laminectomy, and postoperative magnetic resonance imaging revealed fluid collection in the paraspinal muscles. Nevertheless, it resolved without other complications with conservative treatment, including bed rest.

SSI was diagnosed in three patients in the open surgery group and one in the MIS group. All the SSI cases were treated with antibiotics. There was no significant difference in the incidence of ASD between both groups. Pseudoarthrosis, including BSF grades 1 and 2, was found in five cases in each group (Table III).

Radiologic Findings

Corrected disc height, segmental angle, and ROM at adjacent levels were not significantly different between the two groups throughout the follow-up period. Postoperative corrected disc height decreased at the L3 – L4 level in both groups at 10 years postoperatively. The segmental angle also gradually decreased in both groups postoperatively. However, the segmental angle at the L5 – S1 level significantly decreased in the open surgery group but did not change in the MIS group (Table IV).

Patient-Reported Outcomes

Patient-reported clinical outcomes, including the ODI and VAS scores for back/leg pain, did not differ between the open surgery and MIS groups, preoperatively and at 6 months, 1, 5, and 10 years after surgery (Table V and Figure 2).

DISCUSSION

The advantages and disadvantages of open and MIS lumbar fusion have been thoroughly discussed and well-established in spinal surgery (5,8,18).The open approach is advantageous for

Table II: Comparison of Perioperative Outcomes

	Open (n=44)	MIS (n=43)	p-value
Operative time (hours) (mean±SD)	3.34 ± 1.28	4.37 ± 1.41	**0.001***
Estimated blood loss (mL) (mean±SD)	440.23 ± 141.94	281.40 ± 116.00	**<0.001***
Transfusion (number of patients)	9	6	0.422
Ambulation (days) (mean±SD)	1.57 ± 0.62	1.40 ± 0.49	0.157
Hospital stay (days) (mean±SD)	11.64 ± 3.88	12.42 ± 3.09	0.302

Statistically significant difference (p<0.05). **MIS: Minimally invasive surgery.*

Table III: Postoperative Complications

	Open (n=44)	MIS (n=43)	p-value
Perioperative complications	2 (4.5%)	3 (7.0%)	1.000
Neurological deficit	0	0	
CSF leakage	1	0	
Cardiovascular	0	0	
Pulmonary	0	1	
Urinary	1	2	
Epidural hematoma	0	0	
Surgical site infection	3 (6.8%)	1 (2.3%)	0.616
ASD	14 (31.8%)	15 (34.9%)	0.822
Pseudoarthrosis (BSF-1,2)	5 (11.4%)	5 (11.6%)	1.000

__ASD:__ Adjacent segment disease, __BSF:__ Brantigan and Steffee scale, __CSF:__ Cerebrospinal fluid, __MIS:__ Minimally invasive surgery.

Table IV: Radiological Findings

	Open (n=44)	MIS (n=43)	p-value
Corrected disc height (mm)			
L3-L4	(mean ± SD)		
Preoperative	26.21 ± 4.98	27.06 ± 3.59	0.364
1-year	27.23 ± 4.55	28.42 ± 10.97	0.579
5-year	24.65 ± 3.78	25.21 ± 3.67	0.269
10-year	24.71 ± 4.65	23.55 ± 6.79	0.656
L5-S1			
Preoperative	25.06 ± 5.79	25.06 ± 5.79	0.356
1-year	25.06 ± 8.16	27.47 ± 15.19	0.439
5-year	24.86 ± 5.96	27.03 ± 4.95	0.673
10-year	26.04 ± 4.65	26.18 ± 5.81	0.954
Segmental angle, (°)	**Open (n=44)**	**MIS (n=43)**	**p-value**
L3-L4	(mean ± SD)		
Preoperative	10.45 ± 7.94	8.79 ± 5.20	0.250
1-year	13.13 ± 7.96	12.42 ± 5.99	0.693
5-year	19.07 ± 6.43	13.65 ± 4.37	0.108
10-year	13.20 ± 8.64	12.0 ± 4.71	0.693
L5-S1			
Preoperative	16.45 ± 5.51	15.63 ± 6.50	0.524
1-year	17.32 ± 5.61	17.94 ± 8.45	0.738
5-year	18.60 ± 6.76	25.71 ± 25.62	0.306
10-year	15.10 ± 6.71	20.09 ± 7.70	0.631
Range of motion, (°)	**Open (n=44)**	**MIS (n=43)**	**p-value**
L3-L4	(mean ± SD)		
Preoperative	9.05 ± 4.58	8.19 ± 4.02	0.356
1-year	6.93 ± 6.21	6.68 ± 5.92	0.874
5-year	7.69 ± 4.84	7.13 ± 4.50	0.747
10-year	2.29 ± 7.80	4.67 ± 4.80	0.236
L5-S1			
Preoperative	7.41 ± 6.58	6.88 ± 5.70	0.692
1-year	7.68 ± 8.05	7.25 ± 8.42	0.852
5-year	4.00 ± 7.02	4.63 ± 6.58	0.807
10-year	0.57 ± 3.74	6.44 ± 7.09	0.068

***MIS:** Minimally invasive surgery.*

ensuring the surgeon's visibility given the wide operative field; however, it might further destabilize the posterior ligamentous complex. The MIS approach has disadvantages, such as a narrow operative field and increased radiation exposure, but it can minimize damage to the supporting structures. In addition, with the recent development of MIS instruments, the shortcomings of a narrow operative field have been addressed and overcome. Therefore, MIS has become a popular surgical method for lumbar fusion.

Seng et al. analyzed the 5-year outcomes of MIS and open surgery for TLIF (18). There were no significant differences between the open surgery and MIS groups in clinical outcomes, including ODI, VAS, neurogenic symptom score, and 36-Item Short Form Survey (SF-36) at 6 months, 2 years, and 5 years after surgery. The MIS group had less EBL, earlier ambulation, shorter hospitalization, and reduced morphine use but a longer fluoroscopy time. Likewise, a meta-analysis of the two techniques performed by Miller et al. showed similar

Table V: Patient-Reported Outcomes

	Open (n=44)	MIS (n=43)	p value
Preoperative			
VAS for back pain	7.48 ± 1.11	7.02 ± 1.46	0.105
VAS for leg pain	7.70 ± 1.30	7.40 ± 1.38	0.286
ODI	52.50 ± 10.28	49.16 ± 11.10	0.149
Postoperative 6 months			
VAS for back pain	3.68 ± 1.14	3.30 ± 1.35	0.160
VAS for leg pain	2.75 ± 0.84	3.12 ± 1.64	0.195
ODI	24.14 ± 5.00	22.98 ± 8.08	0.669
Postoperative 1-year			
VAS for back pain	3.00 ± 1.06	2.95 ± 1.34	0.858
VAS for leg pain	2.14 ± 1.25	2.88 ± 1.95	0.138
ODI	20.27 ± 5.53	21.35 ± 8.76	0.497
Postoperative 5-year			
VAS for back pain	2.52 ± 1.59	3.21 ± 1.91	0.072
VAS for leg pain	2.25 ± 1.78	3.02 ± 2.14	0.070
ODI	20.32 ± 11.76	22.37 ± 12.23	0.427
Postoperative 10-year			
VAS for back pain	2.41 ± 1.70	2.63 ± 1.95	0.579
VAS for leg pain	1.70 ± 2.00	2.12 ± 2.20	0.362
ODI	19.91 ± 12.46	19.30 ± 12.25	0.819

***MIS:** Minimally invasive surgery, **ODI:** Oswestry Disability Index, **VAS:** Visual analogue scale.*

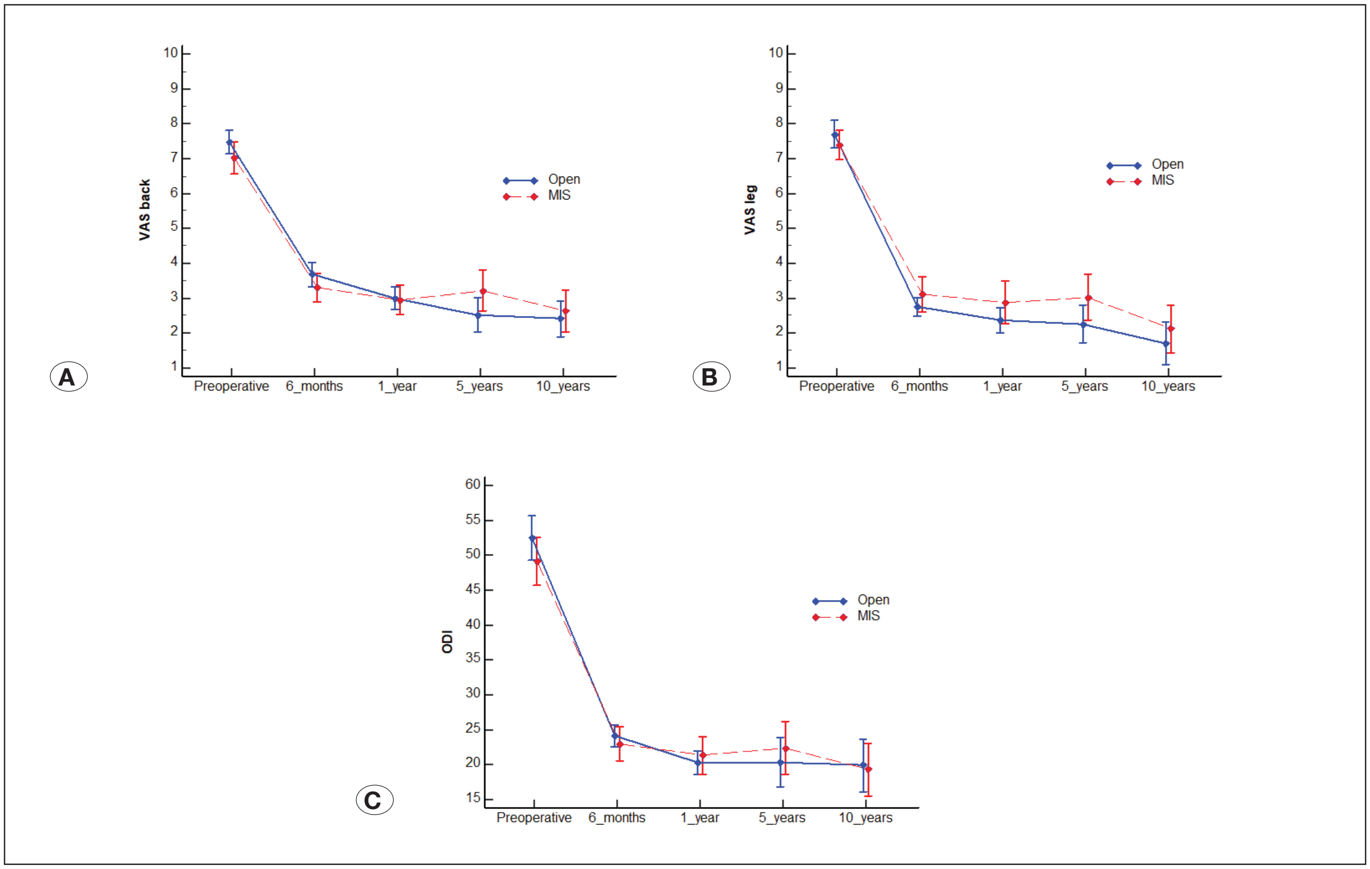

Figure 2: Graph of the VAS score for back pain **(A)**, VAS score for leg pain **(B)**, and ODI **(C)** with time. **MIS:** Minimally invasive surgery, **ODI:** Oswestry Disability Index, **VAS:** Visual analog scale.

results, in which the MIS group had less EBL, shorter hospital stay, and longer fluoroscopy time, and at the 1-year minimum follow-up, the VAS did not differ between the two groups, but the ODI was lower in the MIS group than in the open surgery group (12).

In our study of evaluating the 10-year follow-up outcomes, patient-reported outcomes did not differ between the open surgery and MIS groups in the short- and long-term periods. In the perioperative period, the MIS group had less EBL and a longer operative time. However, there were no differences in the time to first ambulation and length of hospital stay between the two groups.

We anticipated a difference in patient-reported outcomes at the 6-month follow-up due to greater surgical damage to the supporting structures caused by the open surgery approach. However, patient-reported short-term outcomes did not differ between the two groups. This may be because the difference in the structural damage following single-level fusion is relatively small between the two approaches.

In addition, there were no differences in the time to first ambulation or length of hospital stay. The similarity in the time to the first ambulation may have resulted from the minimal difference in pain between the groups or the surgeons' post-operative treatment plan. The influence of surgical methods on the duration of hospital stay could not be accurately evaluated because of factors such as comorbidities, postoperative complications, and the patient's discharge plan.

Mummaneni et al. compared open and MIS fusion for spondylolisthesis and reported no differences in the 90-day return to work, hospital stay, and patient-reported outcomes between open surgery and MIS techniques for single-level fusion (14). However, patients who underwent two-level MIS fusion showed greater improvements in the numeric rating scale for leg pain at 12 months than those who underwent open surgery. This may be because the damage to the supporting structures is greater in two-level fusion than in single-level fusion.

In the present study, the open surgery group showed a higher incidence of SSI than the MIS group, with three cases noted in the open surgery group and one in the MIS group; however, the difference was not statistically significant. Several studies have reported that risk factors for SSI after spinal surgery include increased EBL, multilevel surgery, longer operative time, and cerebrospinal fluid (CSF) leakage (9,15,22). Compared with the MIS group, the open surgery group showed shorter operative time, more blood loss, and more transfusions. These results may be related to the higher incidence of SSI in the open surgery group. In the perioperative comparison, the MIS group showed an increased operative time of approximately one hour compared to the open surgery group. We believe that the increased operative time was caused by the learning curve of the new percutaneous screw fixation technique.

This study showed no differences in the outcomes between the two groups. However, recently, many have preferred MIS over open procedures, although the indications for both procedures are slightly different. As surgical techniques and instruments for MIS are continuously being developed, the advantages of MIS, including less damage to soft tissue, less blood loss, and rapid recovery after surgery, have become more emphasized. Further, with the increase in elderly patients and patient preferences, MIS is in greater demand, and patient satisfaction is also increasing. Therefore, additional studies on MIS development are needed.

Study Limitations

Our study had several limitations. First, the sample size was relatively small, and the data were analyzed retrospectively. This is because there were few participants due to the long follow-up period of more than 10 years from the beginning of the introduction of MIS. Further studies will provide more reliable results if sufficient data can be collected. Second, lumbar interbody fusion techniques include both PLIF and TLIF. As there may be differences in outcomes based on the choice of surgical technique, it is necessary to divide the patients into groups for each technique and separately evaluate the groups. However, due to the small overall sample size, we could not separate them and thus analyze both surgical techniques together, which may have negatively impacted the data quality. Third, there may be a selection bias in the surgical approach, as the surgical method for the open and MIS procedures was decided according to the judgment and preference of each surgeon. Lastly, in the present study, the evaluation of perioperative parameters with fluoroscopy time, analgesic usage, and items of patient-reported outcomes, such as SF-36, was lacking. Further analyses are required to supplement these findings in future studies.

CONCLUSION

This study, with a long-term follow-up of more than 10 years, showed no difference in patient-reported outcomes, including VAS for back/leg and ODI, between the MIS and open surgery groups. When comparing perioperative outcomes, the MIS group had less EBL and longer operative time than the open surgery group; however, there were no differences in the time to first ambulation and length of hospital stay. In addition, postoperative complications did not differ between the two groups. Thus, comparing MIS and open surgery results can help surgeons select the optimal surgical method for lumbar fusion.

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AUTHORSHIP CONTRIBUTION

Study conception and design: SS

Data collection: SS, TSJ

Analysis and interpretation of results: SS, TSJ

Draft manuscript preparation: TSJ

Critical revision of the article: SS, BRY

Other (study supervision, fundings, materials, etc...): SS, TSJ, SGL, WKK, WSK

All authors (TSJ, SS, SGL, WKK, BRY, WSK) reviewed the results and approved the final version of the manuscript.

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