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Clinical Study

Adjacent segment pathology following posterior lumbar interbody fusion for lumbar degenerative spondylolisthesis: a comparison between minimally invasive and conventional open approach

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ABSTRACT

BACKGROUND CONTEXT: The minimally invasive (MI) approach in posterior lumbar interbody fusion (PLIF) minimizes the muscle stripping posterior exposure of the lumbar spine; therefore, it is hypothesized that such benefits would reduce adjacent segment pathology (ASP) development.
OBJECTIVE: This study aimed to estimate the incidence of ASP following MI PLIF.
STUDY DESIGN: Retrospective study.
PATIENT SAMPLE: A total of 100 patients who had undergone single level PLIF at the L4/5 level for lumbar degenerative spondylolisthesis were retrospectively studied (MI PLIF group: 68 patients; conventional open PLIF [O PLIF] group; 32 patients; average follow up period: 100.5 months).
OUTCOME MEASURES: Incidence of ASP.
METHODS: Patients were considered to have operative ASP (OASP) if adjacent segments mani fested degenerative lesions that caused clinically significant symptoms requiring surgery. Survival curves were estimated for each group using the Kaplan–Meier method. The study was not exter nally funded. The authors have no conflicts of interest to declare.
RESULTS: Four (5.9%) of the 68 patients in the MI PLIF group and 6 (18.8%) of the 32 patients in the O PLIF group experienced OASP during the follow up period. Kaplan–Meier analysis pre dicted a disease free OASP survival rate of 98.5% (95% confidence interval [CI], 95.5%–100%) in the MI PLIF group and 90.6% (95% CI, 81.1%–100%) in the O PLIF group at 5 years, and 93.7% (95% CI, 86.8%–100%) in the MI PLIF group and 71.8% (95% CI, 52.9%–97.5%) in the O PLIF group at 10 years. MI PLIF achieved a significantly higher survival rate in OASP than did O PLIF (p=.04). O PLIF was associated with a 3.97 times higher risk (odds ratio 3.97, 95% CI, 1.02–15.48; p=.04) of developing OASP in our cohort.
CONCLUSIONS: Following MI PLIF, the rate of OASP was predicted to be 1.5% at 5 years and 6.3% at 10 years. MI PLIF had a lower incidence of OASP and more favorable clinical outcomes than did O PLIF.

Keywords: lumbar degenerative spondylolisthesis; Adjacent segment pathology; Posterior lumbar interbody fusion; Mini mally invasive lumbar interbody fusion; MI PLIF; Long term surgical outcomes; Adjacent segment disease

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Introduction

Posterior lumbar interbody fusion (PLIF) is a fusion technique that can accomplish the decompression of the dural sac and the nerve roots and improve sagittal alignment by restoring load-bearing anterior column support [1]. With the development of pedicle screws (PS) and interbody fusion implants, PLIF offers the benefits of immediate postoperative biomechanical stability and a high fusion rate [2]; however, the strong mechanical stability of PLIF may increase the mechanical stress to the adjacent segment and then accelerates the postoperative degenerative process of the adjacent segments [3].

Adjacent segment pathology (ASP) is defined as symptomatic or imaging-based findings in a segment adjacent to a previously operated spinal motion segment [4]. Although biomechanical factors appear to play a key role in ASP development, approach-related factors may also influence the development of ASP [5]. In comparative studies on ASP development after PLIF and anterior lumbar interbody fusion (ALIF), Min et al. reported that the ASP rate with ALIF was lower than in PLIF, suggesting that conventional posterior midline approach might be a risk factor for ASP [6].

Recently, a minimally invasive (MI) approach has gained popularity in PLIF for the minimization of approach-related morbidity that is associated with a conventional open approach. MI-PLIF minimizes iatrogenic muscle injury and allows the surgeon to perform the operation as effectively as conventional open PLIF (O-PLIF) [7 9]. The MI approach in PLIF minimizes the muscle-stripping posterior exposure of the lumbar spine; therefore, it is hypothesized that such benefits would reduce ASP development.

To our knowledge, no long-term follow-up studies have evaluated and compared the ASP rate between MI-PLIF and O-PLIF. This study aimed to evaluate the operative results and ASP rate after MI-PLIF and O-PLIF.

Patients and methods

Patient population

From January 2001 to January 2014, 160 consecutive patients underwent single level PLIF with cages and PS for lumbar degenerative spondylolisthesis at 2 institutions. The following exclusion criteria were applied: (1) additional laminectomy other than at the L4/5 level (n=42), (2) PLIF other than at the L4/5 level (n=13), (3) previous lumbar spine surgery (n=3), and (4) never visited our hospital postoperatively and could not be located (n=2). The remaining 100 patients were retrospectively reviewed and separated into the MI-PLIF group and O-PLIF group. Informed consent was obtained from all patients. This study was approved by both institutional ethics review boards.

Surgical procedures

MI-PLIF was performed only at A institution, while O-PLIF was performed at both A and B institutions. At A institution, the selection of surgical procedures was made as per the patient's choice after he and/or she was informed of the risks and benefits of the surgical procedures because MI-PLIF was a new procedure. All the patients underwent surgery in the prone position. In MI-PLIF, under fluoroscopic guidance, 2 paramedian 3-cm skin incisions that were placed 3 cm from the midline centered over the L4/5 disc space were made bilaterally. After fascial incision, the cleft between the multifidus and longissimus muscles was bluntly dissected, and expandable tubular retractors (X-tube or QUADRANT, Medtronic Sofamor Danek, Memphis, TN) were docked on the facet joint. Thereafter, all the procedures were performed through the retractors. Decompression of the neural element was performed through total facetectomy and complete discectomy. After PS insertion under fluoroscopy and slip reduction, interbody cages filled with local bone were inserted [9].

In O-PLIF, a posterior midline skin incision (at about 10 cm) was made, followed by subperiosteal dissection of the paravertebral muscles freed from the spinous processes and lamina to the lateral aspect of the L3 L4 and L4 L5 facet joints by using the conventional technique. Decompression (laminotomy and facetectomy) and discectomy were performed, followed by PS insertion using muscle retractors and PLIF with interbody cages, similar to that for MI-PLIF.

Outcome measures

Symptomatic ASP (SASP) is defined as clinical symptoms that are associated with degenerative lesions, such as spinal stenosis, radiculopathy, segmental instability, or deformity, at the L3/4 and/or L5/S1 level. Operative ASP (OASP) is defined as SASP requiring revision surgery. The criteria for reoperation of SASP were progressive back pain and/or neurologic claudication after the failure of a minimum of 3 months of conservative treatment. Patients were followed-up every 6 months postoperatively. Patients who could not visit our hospital were evaluated via telephone interview. The endpoint was defined as the time of a revision surgery because of OASP.

Radiographic ASP is defined as radiographical changes that occur at the adjacent segment, such as loss of disc height [10], increase in the antero- or retro-listhesis >3 mm on a neutral lateral radiograph, and decrease in the intervertebral angle of flexion of >5° on a flexion lateral radiograph [11,12] at the L3/4 or L5/S1 level at 5 years postoperatively. Fusion status was evaluated using anteroposterior and dynamic lateral plain radiographs with Ito's method at the final follow-up [13].

Preoperative lumbar disc degeneration was evaluated using sagittal plane T2-weighted lumbar spine magnetic resonance imaging as per the Pfirrmann classification system [14].

Postoperative lumbar lordosis (LL), pelvic incidence (PI), PI-LL, and L4/5 intervertebral angle as segmented lordosis were measured on neutral standing lateral radiographs at the first erect radiograph after the surgery (postoperative 1 2 weeks).

Facet joint violation with PS was evaluated using postoperative lumbar spine computed tomography imaging as per the classification described by Shah [15].

Clinical outcomes were evaluated using Japanese Orthopedic Association (JOA) scores preoperatively and at 5 years postoperatively. The score comprises 9 points that are assigned to subjective symptoms, 6 to clinical signs and 14 to the restriction of activities of daily living, giving a total score of 29 points. The rate of improvement in the JOA score was evaluated using Hirabayashi's method [16].

Radiographic parameters and clinical outcomes were evaluated by a reviewer who was blinded to the patient treatment group.

Statistical analyses

The incidence of OASP was calculated using life-table methods. Survival curves were estimated for each group using the Kaplan Meier method and compared statistically using the log-rank test. Multivariate Cox proportional-hazards model was also used to adjust for confounding variables of the major patient demographic parameters, such as age, sex, and body mass index (BMI). Comparisons of the mean values of the groups were performed using Welch's *t* test. Categorical variables were analyzed with Fisher's exact test. Ordinal data were analyzed using the Mann Whitney *U* test. For all the analyses, a p value <.05 was considered significant. Statistical analyses were performed using the statistical package R, version 3.6.1 (available at http://www.r-project.org).

Results

The cohort was separated into 68 patients who underwent MI-PLIF and 32 patients who received O-PLIF. The mean follow-up duration of the MI-PLIF and O-PLIF groups was 98.8 months (range: 30 184 months) and 104.0 months (range: 60 204 months), respectively (p=.56). MI-PLIF was performed between March 2004 and January 2014 (mean: 2009, median: 2009), while O-PLIF was conducted between January 2001 and November 2012 (mean: 2007, median: 2009). The detailed characteristic data of the 2 groups are summarized in Table 1. No significant differences were observed in the age, sex, and BMI of the 2 groups. Moreover, there were no significant differences in preoperative disc degeneration at the L3/4 and L5/S1 levels, postoperative PI-LL, postoperative segmental lordosis at the L4/5 level, fusion status, and facet violation in the 2 groups.

SASP and OASP

In the MI-PLIF and O-PLIF groups, 7 (10.3%) and 10 (31.2%) patients, respectively, experienced SASP during the follow-up period (p=.01). Among them, 3 patients in the MI-PLIF group and 4 patients in the O-PLIF did not undergo revision surgery, with symptoms managed by conservative treatment. Thus, in the MI-PLIF group, there were 4 patients (5.9%) with OASP during the follow-up period, including 3 patients at the L3/4 level and 1 at the L5/S1 level. In the O-PLIF group, there were 6 patients (18.8%) with OASP, including 5 at the L3/4 level and 1 at both the L3/4 and L5/S1 level. In the Kaplan Meier analysis, the estimated OASP-free survival rate was 98.5% [95% confidence interval (CI), 95.5% 100%] in the MI-PLIF group and 90.6% (95% CI, 81.1% 100%) in the O-PLIF group at 5 years; the rate was 93.7% (95% CI, 86.8% 100%) in the MI-PLIF group and 71.8% (95% CI, 52.9% 97.5%) in the O-PLIF group at 10 years. The log-rank test revealed a significant difference in the survival rates of the 2 groups (p=.04) (Figure). Cox proportional-hazards model (Table 2) showed that O-PLIF was a possible risk factor for OASP (Odds ratio 3.97, 95% CI, 1.02 15.48; p=.04).

Radiographic findings and clinical outcomes

At 5 years, the radiographs and clinical charts of 8 patients from the MI-PLIF group and 3 patients from the O-PLIF group were missing. These patients who required

Table 1.
Demographic data of the MI PLIF and O PLIF groups

	MI PLIF group (n 68)	O PLIF group (n 32)	p value
Age at surgery (years)	60.2 (range: 39–74)	63.3 (range: 47–77)	.08
Sex (male/female)	19/49	5/27	.21
BMI (kg/m^2)	24.0 (range: 16.0–35.6)	23.2 (range: 17.3–29.9)	.26
Preoperative L3/4 Pfirmann classification (I/II/III/IV/V)	0/0/18/50/0	0/2/10/20/0	.20
Preoperative L5/S1 Pfirmann classification (I/II/III/IV/V)	0/3/20/33/12	0/1/15/14/2	.08
Postoperative PI–LL (degrees)	5.1 (range: −14–25)	8.7 (range: −12–29)	.09
Postoperative segmented lordosis (degrees)	6.2 (range: 0–13)	6.1 (range: 0–12)	.89
Nonunion	6 (8.8%)	4 (12.5%)	.72
Shah's classification (Grade 1/2/3)	50/17/1	23/9/0	.89

BMI, body mass index; MI PLIF, minimally invasive posterior lumbar interbody fusion; O PLIF, conventional open posterior lumbar interbody fusion; PI–LL, pelvic incidence–lumbar lordosis.

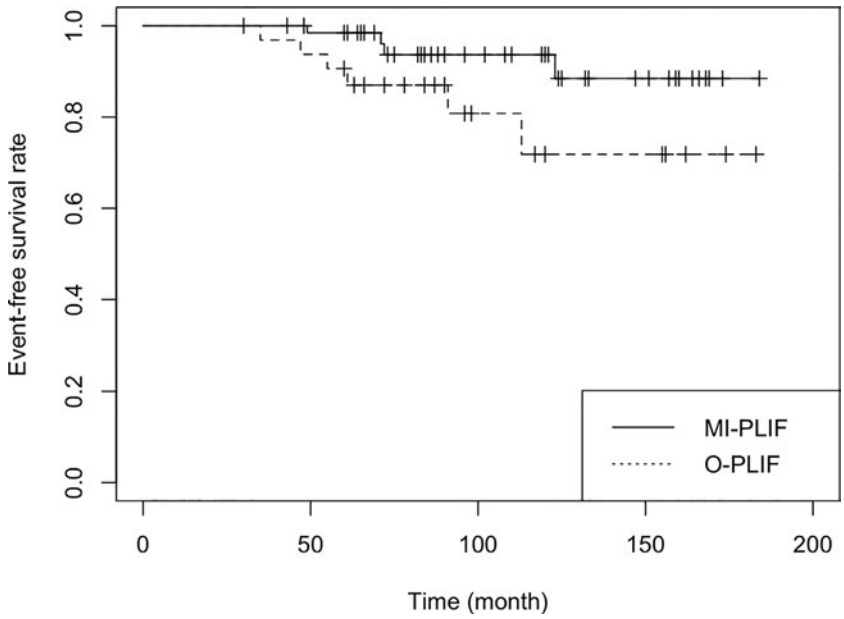

Figure. Kaplan−Meier survivorship curve of MI PLIF versus O PLIF. MI PLIF, minimally invasive posterior lumbar interbody fusion; O PLIF, conventional open posterior lumbar interbody fusion.

revision surgery during the first 5 years were excluded; the remaining 59 patients in the MI-PLIF group and 26 patients in the O-PLIF group were included in the analyses.

At 5 years after the surgery, the incidence of radiographic ASP was not significantly different between the 2 groups (Table 3). Although not statistically significant, the MI-PLIF group (8.5%) had a lower incidence of decrease in the L3/4 intervertebral angle of flexion as compared to the O-PLIF group (19.2%), p=.27.

The average JOA scores in the MI-PLIF group and the O-PLIF group were 14.5 (range: 5 23) versus 11.1 (range: 5 22) (p<.01), respectively, before the surgery and 25.9 (range: 16 29) versus 22.2 (range: 11 29), respectively, (p<.01) at 5 year postoperatively. In both the groups, the JOA scores improved significantly after the surgery (p<.01). The MI-PLIF group had a significantly higher improvement rate than the O-PLIF group (79.8% [range: 20 100] versus 61.1% [range: 42 100], p<.01).

Discussion

The short-term benefits of MI-PLIF, such as less perioperative blood loss, reduced postoperative pain, shorter hospitalization, and quicker recovery, have been reported [17].

Table 2.
Multivariate Cox proportional hazards model for the risk of operative adjacent segment pathology

	Hazard ratio	95% confidence interval	p value
Surgical approach (O PLIF vs. MI PLIF)	3.97	1.02−15.48	.04
Age (years)	1.00	0.92−1.08	.94
Sex (male vs. female)	2.54	0.59−10.84	.20
BMI (kg/m^2)	0.87	0.69−1.10	.24

BMI, body mass index; MI PLIF, minimally invasive posterior lumbar interbody fusion; O PLIF, conventional open posterior lumbar interbody fusion.

Table 3.
Radiographic characteristics of the MI PLIF and O PLIF groups 5 years after the surgery

	MI PLIF group (n59)	O PLIF group (n 26)	p value
Loss of L3/4 disc height (%)	11.8 (range: −18.7−48.4)	13.0 (range: −17.5−39.7)	.75
Loss of L5/S1 disc height (%)	9.6 (range: −28.4−74.1)	7.7 (range: −15.6−45.8)	.79
Increase of L3 antero or retro listhesis	1 (1.7%)	0 (0%)	1
Increase of L5 antero or retro listhesis	1 (1.7%)	2 (7.7%)	.22
Decrease of L3/4 intervertebral angle of flexion	5 (8.5%)	5 (19.2%)	.27
Decrease of L5/S1 intervertebral angle of flexion	9 (15.3%)	6 (23.1%)	.37

MI PLIF, minimally invasive posterior lumbar interbody fusion; O PLIF, conventional open posterior lumbar interbody fusion.

However, it is unclear whether there are any long-term clinical advantages of MI-PLIF over O-PLIF, especially in terms of ASP development. The major findings of this study were as follows: (1) in the MI-PLIF group, the rate of OASP was 1.5% at 5 years and 6.3% at 10 years, (2) the rate of SASP and OASP was significantly lower in the MI-PLIF group than in the O-PILF group, and (3) the clinical outcomes at 5 years postoperatively were superior in the MI-PLIF group than in the O-PILF group. The prevalence of OASP with PLIF using the conventional open approach was 5.9% to13.6% at ≤5 years [6,18,19] and 9.9% to22.2% at 10 years [10,12,19,20]. Although, some differences may be present in the study design, the rate of OASP in the MI-PLIF group was lower than those reported previously. In summary, our results suggest that MI-PLIF is more effective in preventing ASP development.

The reason for a lower rate of SASP and OASP in the MI-PLIF group remains debatable. There are several possible factors that could influence the development of ASP following spinal fusion surgeries [5,21 24]. This study included only L4/5 single level PLIF without additional decompression procedures other than those at the L4/5 level. There was no significant difference in age, sex, BMI, preoperative degeneration of adjacent discs, and postoperative spinopelvic parameters in the 2 groups. Regarding adjacent superior segment facet joint violation with PS, a possible factor related to ASP, there was no significant difference in the violation rate of the groups. In this study, the 2 groups only differed in the type of approach; therefore, the lower approach-related soft tissue damage in MI-PLIF may have contributed to the lower prevalence of SASP and OASP.

The multifidus muscle (MF) is an important muscle for lumbar segmental stability [25,26]; therefore, damage to the MF potentially affects adjacent level stability in lumbar fusion surgeries [27]. Anatomically, each MF muscle comprises several bundles that originate from the spinous process, spread caudolaterally for 2 to5 segments, and then insert into the mammillary processes of the facet joints and the iliac crest [28]. The MF is innervated only by the medial branch of the dorsal ramus, with no intersegmental nerve supply [29]. In the open approach, in order to expose the L4 PS entry point, disruption of the MF attachments to the L3 spinous process and L4 facet joint were required. These MFs potentially act as a stabilizer of the L3-4 segment. Moreover, to achieve proper lateral-to-medial screw trajectory for PS insertion, prolonged forceful retraction of the paraspinal muscles is required that leads to paravertebral muscle damage [30] and injury of the medial branches of the dorsal ramus because these branches are relatively fixed because they run beneath the fibro-osseous mamilloaccessory ligament [29]. However, in the MI approach, lateral-to-medial trajectory of screw insertion can be easily achieved without detachment and forceful retraction of the MF, resulting in less MF damage [9]. Although less invasiveness to the MF in the MI approach contributes to lower prevalence of ASP after lumbar fusion surgery [31], definitive determination of the impact of MF damage on ASP requires further study.

There are certain limitations of the present study. First, our sample size was relatively small and employed a retrospective design. In the posterior approach, the transforaminal lumbar interbody fusion procedure has recently been replaced by PLIF as a boomerang-shaped cage has become popular. In this study, only PLIF procedures with bilateral facet joint resection (conventional and minimally invasive approach) were included, which resulted in a small sample size necessitating a long sampling period. Although the sample size limited the results of the statistical analysis, we believe it did not invalidate the main findings of our study. Second, the assignment of patients into MI-PLIF and O-PLIF groups was not randomized; therefore, it may include a selection bias. Third, although multivariate Cox regression analysis was conducted in order to examine the contribution of the MI approach, with the adjustment of confounding variables of major patient demographics, other factors might have been stronger confounding factors. Further prospective, large-sized studies are needed to confirm our results.

Conclusion

The rate of OASP was 1.5% at 5 years and 6.3% at 10 years in the MI-PLIF group. The MI-PLIF group had a lower incidence of OASP and favorable clinical outcomes as compared to the O-PLIF group. The MI approach in PLIF potentially lowers the risk of ASP development.

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Declarations of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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