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Special issue

Two-year follow-up of unilateral biportal endoscopy assisted extraforaminal lumbar interbody fusion: how to perform indirect decompression and fusion under endoscopy: a retrospective study in Japan

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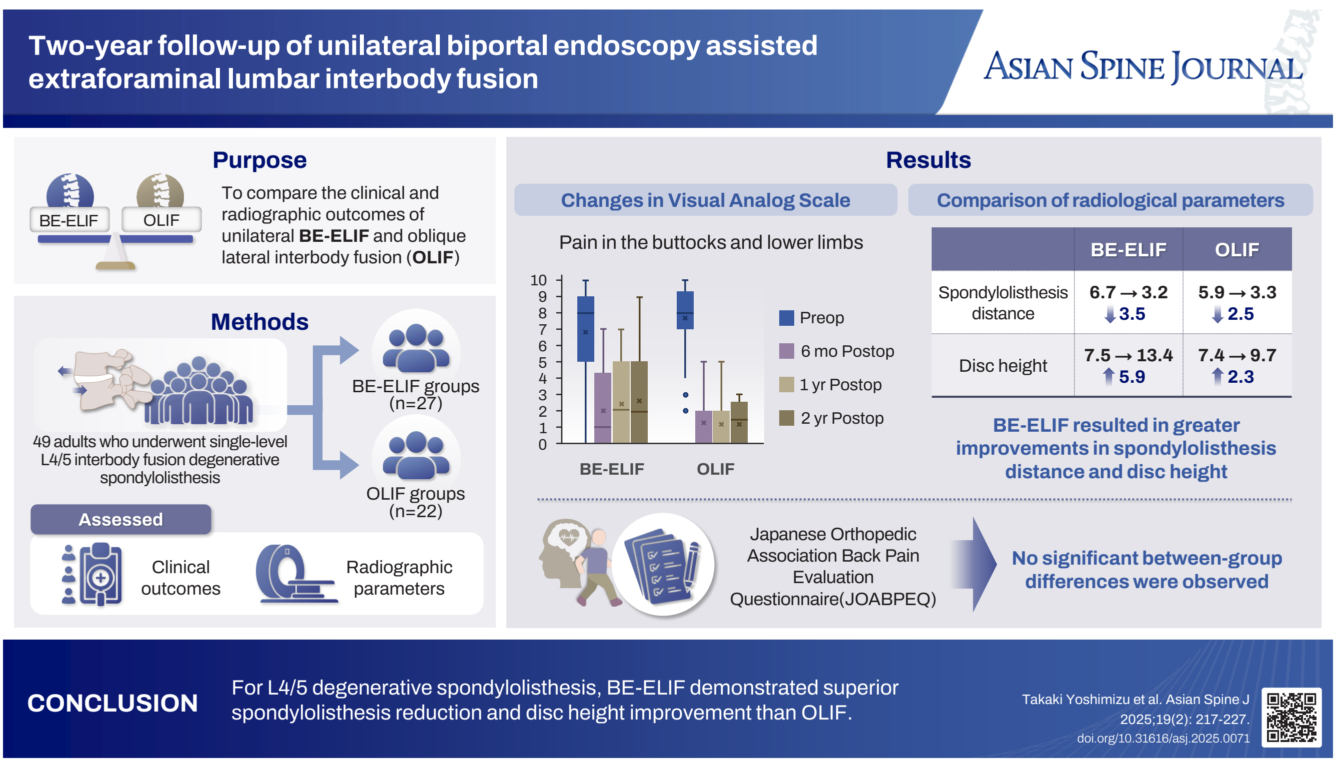

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Two-year follow-up of unilateral biportal endoscopy assisted extraforaminal lumbar interbody fusion: how to perform indirect decompression and fusion under endoscopy: a retrospective study in Japan

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Study Design: Retrospective study.
Purpose: To compare the clinical and radiographic outcomes of unilateral biportal endoscopy-assisted extraforaminal lumbar interbody fusion (BE-ELIF) and oblique lateral interbody fusion (OLIF).
Overview of Literature: OLIF is widely recognized for its strong realignment capability, achieved through placing a large interbody cage, and its favorable clinical outcomes with indirect decompression. ELIF, similar to OLIF, does not entail exposure of the spinal canal. At our hospital, BE-ELIF involves removing the superior articular processes on both sides, inserting two expandable cages, and performing indirect canal decompression. BE-ELIF is a lumbar interbody fusion technique that provides indirect decompression similar to OLIF. However, no studies have compared the efficacy of ELIF performed under unilateral biportal endoscopy with that of OLIF.
Methods: Forty-nine adults who underwent single-level L4/5 interbody fusion for degenerative spondylolisthesis were divided into BE-ELIF (n=27) and OLIF (n=22) groups based on the surgical approach used. Clinical outcomes were assessed using the Visual Analog Scale and the Japanese Orthopedic Association Back Pain Evaluation Questionnaire (JOABPEQ). Radiographic parameters, including distance of spondylolisthesis, disc height, segmental lordosis, lumbar lordosis, pelvic tilt, and sagittal vertical axis, were evaluated preoperatively and at final follow-up.
Results: OLIF provided significantly better relief of pain in lower limbs and buttocks at 1-year follow-up. No significant between-group differences were observed in JOABPEQ domains. BE-ELIF resulted in greater improvements in spondylolisthesis distance and disc height, while other parameters did not differ significantly between the two groups.
Conclusions: For L4/5 degenerative spondylolisthesis, BE-ELIF demonstrated superior spondylolisthesis reduction and disc height improvement than OLIF. Although BE-ELIF was associated with some inferior clinical outcomes, it provided satisfactory results, effective realignment, and a low complication risk.

Keywords: Lumbosacral region; Spondylolisthesis; Unilateral biportal endoscopic spine surgery; Extraforaminal lumbar interbody fusion; Indirect decompression

Introduction

Endoscopic interbody fusion is a minimally invasive interbody fusion technique that reduces surgical invasiveness compared with conventional methods [1]. Unilateral biportal endoscopic spine surgery (UBE) is a highly flexible and maneuverable procedure, making it well-suited for fusion procedures [2-7]. Most UBE-based fusion techniques are derived from the transforaminal lumbar interbody fusion (TLIF) approach, which involves direct decompression.

Lateral lumbar interbody fusion (LLIF) has been widely reported to improve lower limb symptoms through indirect decompression [8]. This technique enables the insertion of a large cage via a ventral approach, facilitating effective indirect decompression. However, LLIF risks damaging vital organs, such as ureters, intestinal tract, and vasculature, which are rarely affected in posterior approaches [9,10].

Extraforaminal lumbar interbody fusion (ELIF), first described by Baek and Lee [11], entails the insertion of a cage from the lateral part of the foramen, with or without resection of the superior articular process (SAP) [12]. ELIF is a fusion technique that does not involve direct canal decompression or dura mater exposure. At our hospital, we perform lumbar interbody fusion using the ELIF approach with UBE assistance (BE-ELIF), where two expandable cages are inserted from both sides to achieve indirect spinal canal decompression. The BE-ELIF technique, presented in this paper, is a complete

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indirect decompression fusion procedure similar to LLIF.

This study compared the 2-year follow-up outcomes of BE-ELIF with oblique lateral interbody fusion (OLIF), a type of LLIF. The objective was to examine the technical aspects of performing indirect decompression endoscopically using UBE and evaluate the efficacy of the procedure.

Materials and Methods

Ethics statement

This study was approved by the Institutional Review Board (IRB) of Seirei Hamamatsu General Hospital (IRB no., 3895). Written informed consent was obtained from all participants.

Inclusion and exclusion criteria

This retrospective study included 49 adult patients who underwent single-level interbody fusion for L4 lumbar degenerative spondylolisthesis between 2017 and 2022. Patients were followed up for at least 2 years after initial surgery and were divided into the BE-ELIF group (n=27) and the OLIF group (n=22) (Table 1). The inclusion criterion was a diagnosis of single-segment L4 degenerative spondylolisthesis. Exclusion criteria included additional direct decompression, history of spinal surgery, concomitant lumbar spinal stenosis at other levels, and imbalance of coronal alignment.

BE-ELIF utilized a titanium (Ti) expandable cage, whereas OLIF employed a Ti-coated polyetheretherketone (PEEK) cage. The expansion height range of the expandable cage is shown in Table 1.

For BE-ELIF, a bone graft composed of autograft from the SAP supplemented with demineralized bone matrix (DBM) and or β-tricalcium phosphate (β-TCP) was used. For OLIF, a mixture of autograft from the iliac bone and DBM was used.

Table 1. Demographic data

Characteristic	BE-ELIF	OLIF	*p*-value
No. of patients	27	22	
Sex			0.12
Male	10	13	
Female	17	9	
Age (yr)	66.1±10.7	68.7±9.2	0.38
Body mass index (kg/m^2)	23.2±3.3	25.0±2.3	0.028*
Meyerding classification			0.54
I	23	20	
II	4	2	
Degree of spondylosis (%)	17.3±5.6	14.9±7.0	0.19
Operating time (min)[a)]	181.7±44.3	102.7±20.7	<0.001*
Postoperative hospitalization (day)	9.5±3.6	10.7±3.7	0.28
Cage-size			
Width (mm)	12±0.7	50±4.8	<0.001*
Length (mm)	30±2.25	18±0.0	<0.001*
Footprint (mm^2)	720±83.6	900±86.3	<0.001*
Height (mm)	8±0.6 (min) 15±0.3 (max)	10±1.2	
No. of bone graft			
SAP+DBM	4		
SAP+β-TCP	11		
SAP+DBM+β-TCP	12		
Iliac bone+DBM		22	

Values are presented as number or mean±standard deviation.
BE-ELIF, biportal endoscopy-assisted extraforaminal lumbar interbody fusion; OLIF, oblique lateral interbody fusion; SAP, superior articular process; DBM, demineralized bone matrix; β-TCP, β-tricalcium phosphate.
*$p<0.05$ (statistical significance between the two groups). [a)]Operating time counts the period from skin incision to wound closure and includes the time to change positions in OLIF.

Surgical technique for biportal endoscopy-assisted extraforaminal lumbar interbody fusion

Portal creation

Two skin incisions were made on the cephalocaudal transverse process, 2 cm lateral from the outer pedicle line. For a right-side approach, the surgeon stood on the right, utilizing the cranial portal for instrumentation and the caudal portal for endoscopy; the roles were reversed for a left-side approach (Fig. 1A, B).

Soft tissue dissection

Dissection was performed using a radiofrequency device from the dorsal side of the transverse process to the lateral and dorsal surfaces of the SAP. The facet joint capsule was evaporated, and the SAP and facet joint were identified (Fig. 1C).

Superior articular process partial resection

The upper portion of the SAP was resected using a chisel or drill, with the cutline-plane aligned with the cephalic margin of the pedicle. The lateral part of the facet joint was completely resected, while the medial part, namely, the inferior articular process, was preserved (Fig. 1D, E).

Discectomy and endplate removal

Following venous plexus hemostasis, the disc and endplate were removed using ring curettes and shavers (Fig. 1F–H).

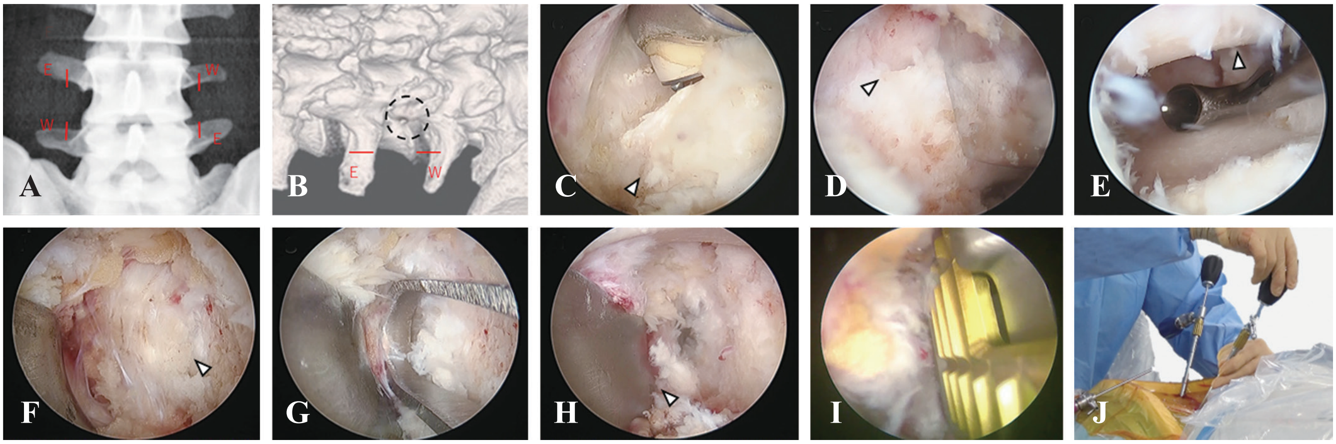

Fig. 1. Endoscopic visualization of the left-side approach. **(A)** Portal position of bilateral approach. E, endoscopic portal; W, working portal. **(B)** Endoscopic visual field location on three-dimensional computed tomography images. **(C)** Dissection around the superior articular process (△). **(D)** After identifying facet joint (△), superior articular process was cut using a chisel under fluoroscopy. **(E)** The superior articular process was resected down to the facet joint. The top of the screen presents the inferior articular process articular surface (△). **(F)** The disc (△) in the lateral half of the foramen was exposed. **(G)** Disc curettage. **(H)** The dura mater and the traversing nerve root were protected by the inferior articular process, and the exiting nerve root was protected by the retractor (△). **(I)** An expandable cage was inserted and slides onto the retractor. **(J)** Two cages on both sides were expanded simultaneously under fluoroscopy.

Insertion of the first cage

The first cage was inserted when sufficient space was available to avoid exiting nerve irritation. The exiting nerve root was protected using a retractor before cage insertion. Expandable cages were used for all patients. If insufficient space existed for safe cage insertion, the approach was modified to access the opposite side before inserting the first cage, and a paddle distractor was used to lift and open the space for cage insertion (Fig. 1I).

Bone grafting, Second cage insertion

Bone grafting was performed on the contralateral side of the first cage, using crushed excised SAPs from both sides, supplemented with DBM and or β-TCP as needed. Iliac bone harvesting was not performed in any of the patients. The second cage was inserted after bone grafting. Both first and second cages were expanded simultaneously, and the end plates were lifted while fitting each cage (Fig. 1J).

Screw insertion

Screws were inserted percutaneously under fluoroscopic or navigational guidance. Only four skin incisions were required for insertion of all cages and screws.

Clinical evaluation items

Clinical outcomes were assessed using the Visual Analog Scale (VAS) scores for back pain, buttock and lower limb pain, and buttock and lower limb numbness, evaluated preoperatively and postoperatively at 6 months, 1 year, and 2 years. A ≥50% improvement in VAS score was considered effective, and the effectiveness rates were compared between the two groups. Additionally, the effectiveness rate for each domain of the Japanese Orthopedic Association Back Pain Evaluation Questionnaire (JOABPEQ) was calculated pre- and postoperatively and compared between groups.

Radiographical evaluation items

The following radiographic parameters were evaluated: distance of spondylolisthesis (DS), disc height (DH), segmental lordosis (SL), lumbar lordosis (LL), sacral slope (SS), pelvic incidence (PI), pelvic tilt (PT), and sagittal vertical axis (SVA). The degree of change in these parameters before and after surgery was compared between the two groups.

Interbody fusion was evaluated using computed tomography (CT) scans performed during the 2-year follow-up period. Successful fusion was determined by the presence of bone formation between vertebral bodies with continuous cephalocaudal endplates, facet joint fusion, and anterior or lateral cross-linking of the vertebral body bony spar.

Statistical analysis

Statistical analyses were performed using the JMP statistical software (SAS Institute Inc., Cary, NC, USA). Continuous variables were expressed as mean±standard deviation, while categorical variables were expressed as frequency (percentage). Normally distributed continuous variables were analyzed using the independent *t*-

test and paired t-test, while the Mann-Whitney U test was used for non-normally distributed variables. Categorical variables were analyzed using the chi-square test. A p-value <0.05 was considered indicative of statistical significance.

Results

Clinical evaluations

In the BE-ELIF group, the mean preoperative VAS score for low back pain was 4.48, which improved to 2.04 at 6 months post-surgery, corresponding to an effectiveness rate of 64%. At 1 and 2 years, the VAS scores and effectiveness rates were 2.00 and 62%, and 2.34 and 72%, respectively. In the OLIF group, the preoperative VAS score was 4.22, which improved to 1.84 at 6 months post-surgery, corresponding to an effectiveness rate of 75%. At 1 and 2 years, the VAS scores and effectiveness rates were 1.76 and 78% and 1.76 and 65%, respectively. No significant between-group differences were observed in any of the assessments.

For pain in the buttocks and lower limbs, the mean postoperative VAS score in the BE-ELIF group was 6.81, improving to 2.00 at 6 months post-surgery, with an effectiveness rate of 72%. At 1 year and 2 years, the corresponding values were 2.37 and 65% and 2.65 with 65%, respectively. In the OLIF group, the preoperative VAS score of 7.64 improved to 1.21 at 6 months post-surgery, corresponding to an effectiveness rate of 89%. At 1 and 2 years, the VAS scores and effectiveness rates were 1.14 and 90%, and 1.19 and 85%, respectively. The effectiveness rate at 1 year postoperatively was significantly higher in the OLIF group.

In the BE-ELIF group, the preoperative mean VAS score for numbness in the buttocks and lower limbs was 6.93, which improved to 2.19 at 6 months post-surgery with an effectiveness rate of 64%. At 1 and 2 years, the VAS scores and effectiveness rates were 2.25 and 62%, and 2.31 and 72%, respectively. In the OLIF group, the preoperative VAS score was 5.00, which improved to 1.30 at 6 months post-surgery, representing an effectiveness rate of 75%. At 1 and 2 years, the VAS scores and effectiveness rates were 0.95 and 78%, and 1.23 and 65%, respectively. The preoperative numbness was greater in the BE-ELIF group than in the OLIf group. However, there was no significant between-group difference regarding the effectiveness rate of surgery at each assessment (Table 2, Fig. 2).

In the JOABPEQ evaluation, there were no significant between-group differences with respect to any of the assessments from 6 months to 2 years after surgery (Table 3, Fig. 3).

Table 2. VAS scores at preoperative, 6 months, 1 year, and 2 years postoperative effectiveness

Condition	BE-ELIF		OLIF		p-value[a)]	p-value[b)]
	VAS	Effectiveness %	VAS	Effectiveness %		
Low back pain						
Preoperative	4.48±3.0		4.22±3.0		0.78	
6 mo FU	2.04±1.9	64	1.84±2.0	75	0.60	0.63
1 yr FU	2.00±2.1	62	1.76±1.9	78	0.68	0.26
2 yr FU	2.34±2.8	72	1.76±1.5	65	0.97	0.61
Pains in buttocks and lower limb						
Preoperative	6.81±2.9		7.64±2.3		0.29	
6 mo FU	2.00±2.6	72	1.21±1.7	89	0.45	0.15
1 yr FU	2.37±2.5	65	1.14±1.5	90	0.13	0.043*
2 yr FU	2.65±2.9	65	1.19±1.3	85	0.13	0.11
Numbness in buttocks and lower limb						
Preoperative	6.93±2.8		5.00±2.8		0.013*	
6 mo FU	2.19±2.8	64	1.30±1.9	75	0.35	0.41
1 yr FU	2.25±2.9	62	0.95±1.4	78	0.15	0.15
2 yr FU	2.31±3.0	72	1.23±1.7	65	0.41	0.48

Values are presented as number or mean±standard deviation or effectiveness % unless otherwise stated.
VAS, Visual Analog Scale; BE-ELIF, biportal endoscopy-assisted extraforaminal lumbar interbody fusion; OLIF, oblique lateral interbody fusion; FU, follow-up.
*$p<0.05$. [a)]p-value for VAS. [b)]p-value for Effectiveness (%).

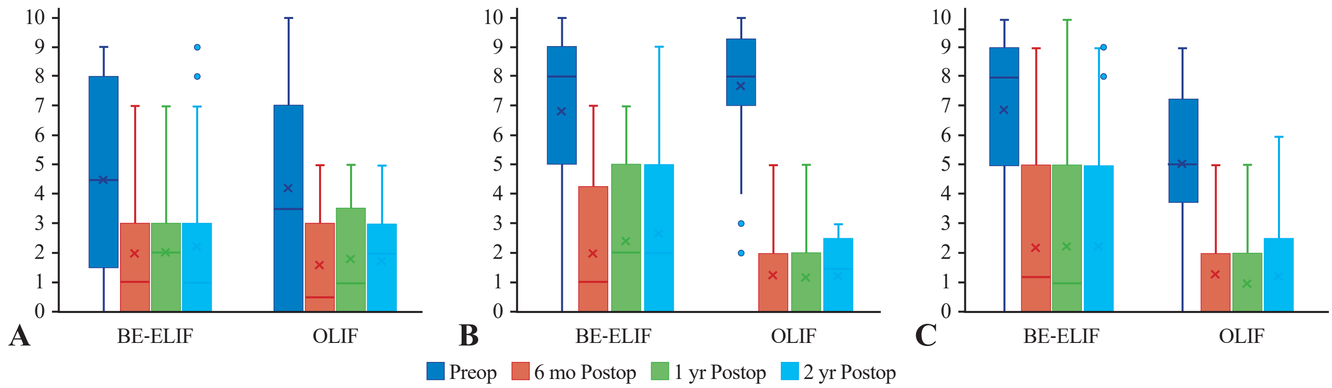

Fig. 2. Changes in Visual Analog Scale (VAS) for low back pain **(A)**, pain in the buttocks and lower limbs **(B)**, and numbness in the buttocks and lower limbs **(C)**. BE-ELIF, biportal endoscopy-assisted extraforaminal lumbar interbody fusion; OLIF, oblique lateral interbody fusion;Preop, preoperative; Postop, postoperative.

Table 3. Japanese Orthopedic Association Back Pain Evaluation Questionnaire scores: preoperative and postoperative effectiveness at 6 months, 1 year, and 2 years

Condition	BE-ELIF	OLIF	*p*-value
Low back pain			
Preop score	43 (29–71)	43 (14–67.5)	0.53
6 mo Postop effectiveness	70.8 (17/24)	76.5 (13/17)	0.69
1 yr Postop effectiveness	82.6 (19/24)	75.0 (12/16)	0.56
2 yr Postop effectiveness	79.2 (17/24)	84.2 (16/19)	0.67
Lumbar function			
Preop score	50 (25–83)	58 (35.3–81.0)	0.47
6 mo Postop effectiveness	60.0 (15/25)	55.6 (10/18)	0.77
1 yr Postop effectiveness	64.0 (16/25)	66.7 (12/18)	0.86
2 yr Postop effectiveness	70.8 (17/24)	47.0 (8/17)	0.12
Walking ability			
Preop score	43 (29–71)	29 (14–67.5)	0.24
6 mo Postop effectiveness	80.1 (21/26)	85.0 (17/20)	0.71
1 yr Postop effectiveness	76.9 (20/26)	88.8 (16/18)	0.31
2 yr Postop effectiveness	88.8 (24/27)	76.2 (16/21)	0.24
Social life function			
Preop score	46 (32–51)	40.5 (30–51)	0.40
6 mo Postop effectiveness	63.0 (17/27)	61.9 (13/21)	0.94
1 yr Postop effectiveness	51.9 (14/27)	70.0 (14/20)	0.21
2 yr Postop effectiveness	55.6 (15/27)	84.2 (18/22)	0.053
Mental health			
Preop score	39.5 (26.25–55)	42 (33.0–49.75)	0.93
6 mo Postop effectiveness	70.8 (16/26)	76.5 (11/22)	0.42
1 yr Postop effectiveness	82.6 (14/26)	75.0 (6/20)	0.11
2 yr Postop effectiveness	79.2 (14/26)	84.2 (18/22)	0.23

Values are presented as median (interquartile range) or effectiveness % (number/total numbers) unless otherwise stated.
BE-ELIF, biportal endoscopy-assisted extraforaminal lumbar interbody fusion; OLIF, oblique lateral interbody fusion; Preop, preoperative; Postop, postoperative.

Radiological evaluations

The DS showed significant improvement in both groups. In the BE-ELIF group, the preoperative DS was 6.7±2.2 mm, which decreased to 3.2±2.0 mm at the final evaluation, reflecting a reduction of 3.5±1.6 mm. In the OLIF group, the preoperative DS was 5.9±2.5 mm, which decreased to 3.3±2.2 mm, with a reduction of 2.5±1.9 mm. The improvement in DS was significantly greater in the BE-ELIF group (Table 4).

In the BE-ELIF group, the preoperative DH was 7.5±1.7 mm, increasing to 13.4±2.3 mm at the final evaluation, representing an increase of 5.9±2.0 mm. In the OLIF group, the preoperative DH was 7.4±2.1 mm, which increased to 9.7±1.6 mm at the final evaluation, representing an increase of 2.3±1.3 mm. The increase in DH was significantly greater in the BE-ELIF group, resulting in a significantly higher DH at the final evaluation.

No significant differences were observed with respect to the values or the extent of change before and after surgery for SL, LL, SS, PT, PI, and PI–LL.

In the BE-ELIF group, the preoperative SVA was 51.3±40.4 mm, which decreased to 44.8±37 mm at the final evaluation, reflecting a difference of 7.1±25.9 mm. In the OLIF group, the preoperative DS was 31.1±30.7 mm, which decreased to 24.9±28.6 mm at the final evaluation, with a difference of 4.2±24.0 mm. Although the extent of change was greater in the BE-ELIF group, the preoperative value tended to be higher in BE-ELIF, resulting in a significantly greater SVA at the final evaluation.

There was no significant between-group difference regarding fusion rate (78% [21/27] for BE-ELIF and 68% [15/22] for OLIF, p=0.45).

Table 4. Comparison of radiological parameters between the BE-ELIF and OLIF groups

Variable	BE-ELIF	OLIF	*p*-value
Distance of spondylolisthesis			
Preop	6.7±2.2	5.9±2.5	0.14
Postop	3.2±2.0	3.3±2.2	0.96
Δ	3.5±1.6	2.5±1.9	0.009*
Disc height			
Preop	7.5±1.7	7.4±2.1	0.91
Postop	13.4±2.3	9.7±1.6	<0.001*
Δ	5.9±2.0	2.3±1.3	<0.001*
Segmental lordosis			
Preop	13.3±6.7	13.8±5.0	0.65
Postop	12.4±5.3	12.7±5.6	0.77
Δ	–0.9±4.1	–1.1±3.7	0.84
LL			
Preop	39.9±10.3	37.9±10.6	0.34
Postop	40.8±10.1	41.1±9.1	0.92
Δ	0.94±4.4	3.2±4.9	0.15
Sacral slope			
Preop	29.8±9.2	29.9±5.4	0.95
Postop	29.9±7.3	30.7±5.5	0.56
Δ	–0.6±4.0	0.83±4.3	0.33
Pelvic tilt			
Preop	23.4±9.6	20.9±8.3	0.39
Postop	23.7±9.5	19.5±7.2	0.30
Δ	0.07±4.5	–1.4±4.9	0.34
PI			
Preop	53.2±12.4	50.7±7.4	0.45
Postop	53.5±12.1	50.2±8.3	0.55
Δ	–0.5±3.9	–0.5±4.4	0.95
PI–LL			
Preop	13.6±11.8	5.7±22.02	0.33
Postop	12.7±11.1	8.1±11.3	0.25
Δ	–1.0±6.0	2.4±15.5	0.91
Sagittal vertical axis			
Preop	51.3±40.4	31.1±30.7	0.063
Postop	44.8±37.5	24.9±28.6	0.028*
Δ	–7.1±25.9	–4.2±24.0	0.63

Values are presented as number or mean±standard deviation unless otherwise stated.
BE-ELIF, biportal endoscopy-assisted extraforaminal lumbar interbody fusion; OLIF, oblique lateral interbody fusion; Preop, preoperative; Postop, postoperative; LL, lumbar lordosis; PI, pelvic incidence.
*$p<0.05$.

Illustrated case

A 72-year-old woman with progressively worsening back and buttock pain for 2 years underwent BE-ELIF (Fig. 4). Her preoperative VAS scores indicated severe pain, with a score of 7 for both low back pain and buttocks/lower limb pain, and a score of 0 for numbness. Preoperative JOABPEQ scores revealed significant impairment, with scores of 29 for low back pain, 8 for lumbar function, 64 for walking ability, 51 for social life, and 40 for mental health. Radiographic examination revealed Meyerding classification grade II degenerative spondylolisthesis, and MRI confirmed spinal stenosis. She underwent BE-ELIF using two expandable cages.

Two years after surgery, MRI and CT showed indirect decompression and bone formation. VAS scores for pain and numbness were 0. JOABPEQ showed significant improvement in low back pain (72), lumbar function (92), and walking ability (86), while there were limited changes in social life functions (70) and mental health (50).

Discussion

The first report of fusion surgery using UBE was published by Heo et al. [2], who performed direct decompression of the spinal canal using the TLIF approach. Many subsequent studies have also described direct decompression techniques that outline TLIF-compliant methods [3-5]. UBE-TLIF has been shown to result in less bleeding, reduced inflammation, and faster recovery compared to conventional TLIF and posterior lumbar interbody fusion (PLIF) [6,7].

In contrast, the usefulness of the LLIF approach, which entails the insertion of a large cage and indirect decompression, has been widely reported. LLIF has been shown to effectively achieve indirect decompression, as evidenced by improvements in disc and foramen height and area, as well as segmental lordosis, compared to the posterior approach [8]. Moreover, due to the strong corrective power of the large cage, fusion surgery with LLIF and anterior lumbar interbody fusion is less likely to result in adjacent segmental disease compared to TLIF and PLIF, which involve direct decompression [13].

Cao et al. [14] compared OLIF, a type of LLIF, with TLIF performed under UBE conditions. The results showed that OLIF has distinct advantages over UBE-assisted TLIF in terms of postoperative restoration of lumbar sagittal parameters and faster achievement of interbody fusion. This suggests that achieving the same results as OLIF in UBE-assisted interbody fusion may

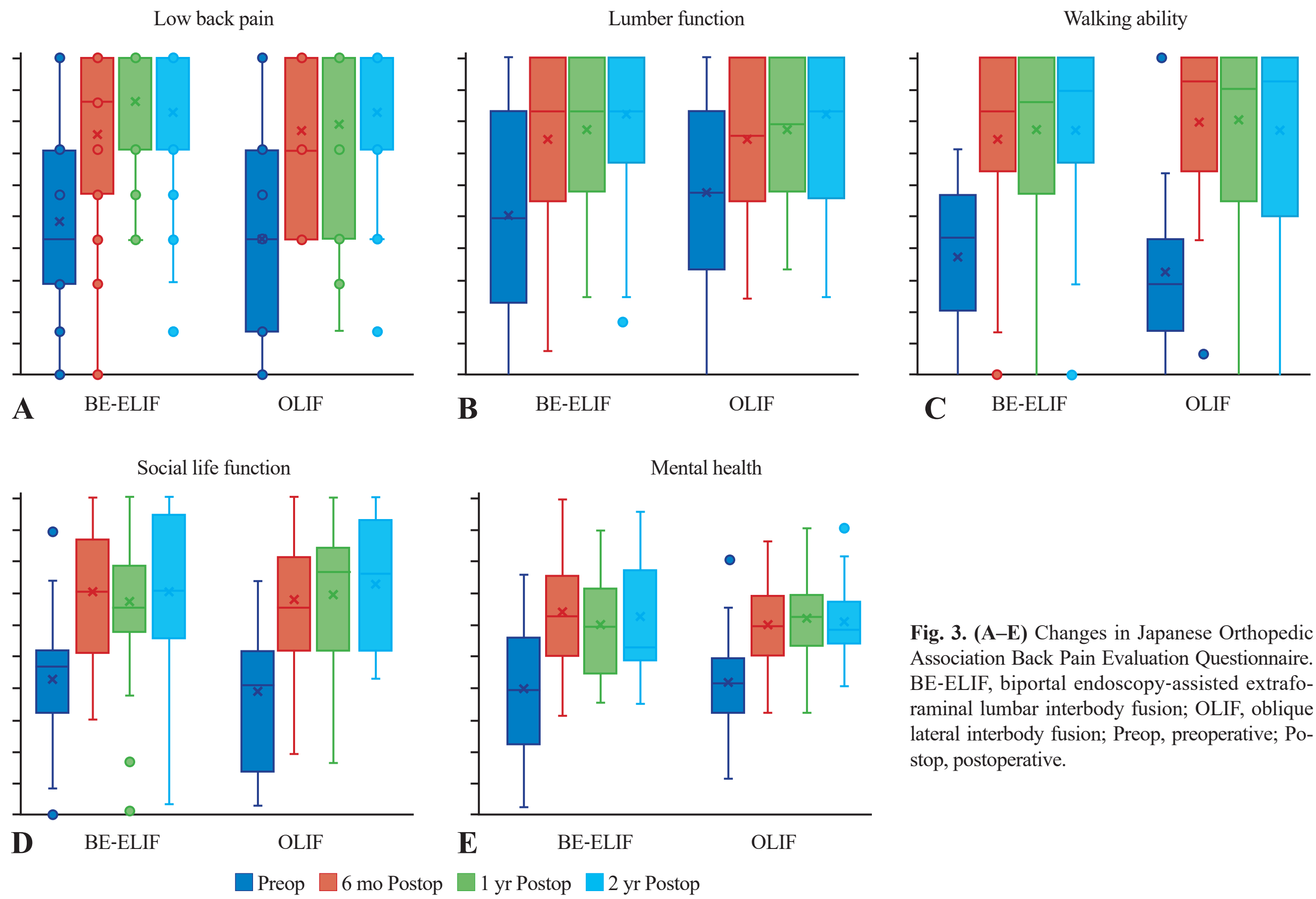

Fig. 3. (A–E) Changes in Japanese Orthopedic Association Back Pain Evaluation Questionnaire. BE-ELIF, biportal endoscopy-assisted extraforaminal lumbar interbody fusion; OLIF, oblique lateral interbody fusion; Preop, preoperative; Postop, postoperative.

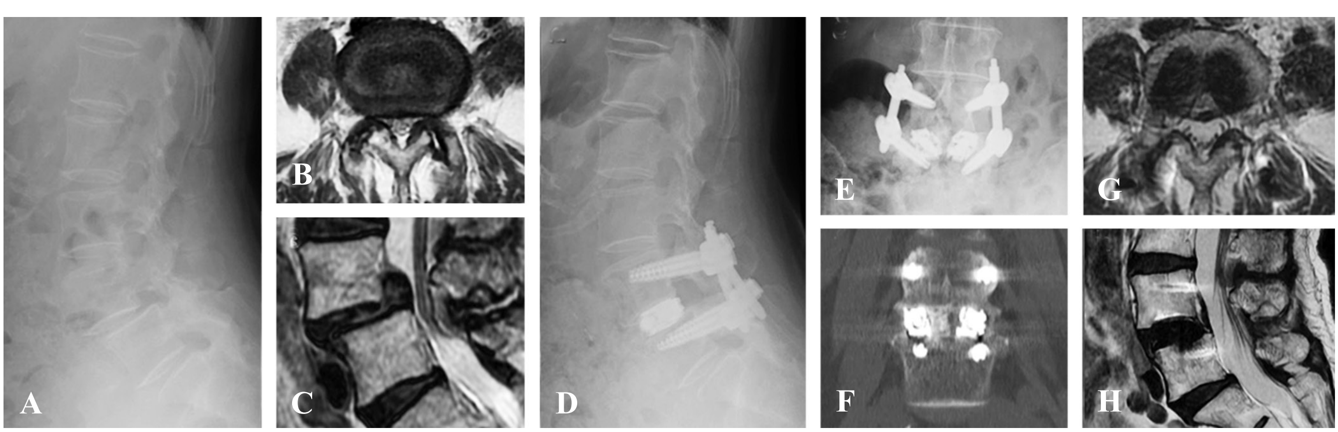

Fig. 4. Illustrated case images. **(A)** Radiological images of Meyerding grade II degenerative spondylolisthesis at L4. **(B)** Preoperative magnetic resonance imaging (MRI) revealed bilateral spinal canal to the lateral recess stenosis. **(C)** Axial MRI image demonstrated stenosis at L4/5 due to spondylolisthesis. **(D)** Radiological images of lateral view at 2 years post-surgery showing restored disc height and corrected spondylolisthesis. **(E)** Radiological images of anteroposterior view showed that two cages were inserted symmetrically. **(F)** Computed tomography imaging at 2 years postoperatively showed bone formation between the interbody, cross-linked with endplates. **(G)** Postoperative MRI slice of axial showed that canal and lateral recess was decompressed indirectly. Lamina and inferior articular process were preserved. **(H)** Postoperative MRI slice of sagittal showed enlarged spinal canal associated restoration of disc height and reduction of spondylolisthesis.

necessitate indirect decompression using a different approach from TLIF.

The ELIF approach we adopted was first reported by Baek and Lee [11] as a method of inserting the cage entirely from the lateral side of the SAP. This approach allows for posterior interbody fusion while only exposing the exiting nerve root and not the abdominal cavity, dura mater, or traversing nerve root. Lee et al. [12] modified the method by Baek and Lee [11] by partially excising the upper part of the SAP and widening the

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space medially. Furthermore, Kang et al. [15] reported the results of UBE-assisted ELIF. According to their report, UBE-assisted ELIF is recommended for degenerative spondylolisthesis, spondylolisthesis, and stenosis with instability. However, when canal decompression is necessary, unilateral laminotomy for bilateral decompression (ULBD) should be added. You et al. [16] reported favorable outcomes in 12 patients who underwent ULBD combined with BE-EFLIF.

Kang et al. [15] and You et al. [16] described inserting the cage from one side. However, we propose that bilateral cage insertions can provide enhanced corrective power, potentially alleviating symptoms, even in patients with cauda equina syndrome. Another advantage is the removal of the SAP from the degenerated and hardened facet joints on both sides, facilitating correction through facet manipulation. Our BE-ELIF technique utilizes two cages for this concept.

We advocate for the use of expandable cages for indirect decompression of the posterior region. Previous studies have demonstrated that expandable cages are more effective in recovering disc height and achieving local lordosis angles than static cages [17,18]. Consistent with these findings, our results showed that BE-ELIF is superior to OLIF in terms of disc height recovery and spondylolisthesis correction. The expandable cages used in BE-ELIF have a lower initial height compared to those used in OLIF, which reduces the load on the end plate during insertion. However, the maximum expansion height of the BE-ELIF cage is significantly greater than that of the OLIF cage, enabling better disc height recovery. Furthermore, using two expandable cages in BE-ELIF facilitates disc height recovery and spondylolisthesis correction via ligamentotaxis. We consider this approach useful for achieving optimal disc height recovery and indirect decompression.

However, one disadvantage of expandable cages is the risk of subsidence due to endplate overload caused by the lifting mechanism. Chang et al. [18] reported a higher incidence of subsidence when an expandable cage was inserted with unilateral facetectomy compared to posterior column osteotomy. In our procedure, the SAP is bilaterally excised to the articular surface, allowing for facet manipulation on both sides, which reduces the risk of subsidence. Additionally, Grant et al. [19] observed that the dorsolateral endplate is stiffer than the median part. In the ELIF approach, the cage is naturally installed in that position, which may contribute to a lower incidence of subsidence and a higher fusion rate. This is attributed to a more concentrated application of bone healing, enhancing compression forces during the fusion and healing process [20].

The fusion rates were not significantly different between BE-ELIF and OLIF. However, a notable difference was observed regarding the fusion sites. In BE-ELIF, 14 of the 21 fused patients exhibited continuous upper and lower end plates due to bone formation between the interbody space, while the remaining seven cases demonstrated cross-linking on the lateral sides of the vertebral body spar or facet joints. However, all 15 OLIF cases showed lateral cross-linking of the vertebral body or fusion of facet joints. Despite the OLIF cage having a larger footprint than the BE-ELIF cage, the latter was effective in promoting bone formation between vertebral bodies. This suggests that the BE-ELIF cage size is sufficient for bone fusion and that other factors may also contribute to this outcome. Possible explanations include the clear dissection of the intervertebral disc and end plate from both sides, as well as the ease of positioning the cage on the harder portion of the end plate. Although the exact reason for the difference in bone fusion sites remains unclear, it is an intriguing finding worthy of further investigation.

To determine whether indirect decompression was performed sufficiently, it is important to evaluate improvement in symptoms affecting the buttocks and lower limbs. In this study, both techniques demonstrated postoperative improvement in lower limb pain, although BE-ELIF showed slightly lower effectiveness at 1 year follow-up. Additionally, numbness in the buttocks and lower limbs after BE-ELIF was approximately one point worse than OLIF at each follow-up; however, there was no significant between-group difference with respect to the effectiveness rate. Both procedures resulted in a significant relief from lower limb symptoms over time through indirect decompression. Furthermore, while there were no significant differences in the JOABPEQ scores for each period and domain, BE-ELIF displayed a higher effectiveness rate than OLIF in certain items.

Notably, BE-ELIF was slightly inferior to OLIF in terms of improvement in lower limb symptoms despite BE-ELIF's superior correction of disc height and spondylolisthesis. This suggests that differences in the approaches and cage contact areas may influence the recovery of lower limb symptoms. In addition, BE-ELIF was expected to have an advantage over OLIF in alleviating lower limb pain due to the removal of the SAP and direct decompression of the foramen. However, this expected benefit was not observed. It is possible that the results might have differed if the study had targeted a different disease entity, as the current study was limited to patients with degenerative disorders.

There are certain anatomical features that can make OLIF challenging or even contraindicated, such as retrorenal colon, high iliac crest, and rising psoas sign. Moreover, OLIF carries the risk of serious surgical complications, including vascular and intestinal damage, although these are rare [9,10]. Considering this, BE-ELIF offers a distinct advantage by providing satisfactory outcomes for patients with indirect decompression while avoiding the risks associated with OLIF.

As with OLIF, one limitation of BE-ELIF is that direct decompression is still necessary in cases with ossification of the ligaments or strong bony spar of the lateral recess. Other limitations of BE-ELIF include longer surgical times and higher costs associated with the use of expandable cages. Furthermore, long-term and multi-level pathology data for BE-ELIF remain limited, highlighting the need for further research.

Conclusions

BE-ELIF demonstrates satisfactory outcomes comparable to OLIF, particularly in its significant realignment potential, sufficient indirect decompression, minimal invasiveness, and low risk.

Key Points

- Biportal endoscopy-assisted extraforaminal lumbar interbody fusion (BE-ELIF) is an extraforaminal lumbar interbody fusion performed under unilateral biportal endoscopy without exposing the spinal canal.
- The procedure involves the insertion of two expandable cages from both sides to increase the corrective force and ensure indirect decompression.
- Compared to oblique lateral interbody fusion, BE-ELIF demonstrated superior correction of spondylolisthesis and restoration of disc height in patients with L4 degenerative spondylolisthesis.
- BE-ELIF provides satisfactory outcomes and safe and effective indirect decompression without exposing dura.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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