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Radiographic Outcomes and Clinical Complications of Expandable versus Static Spacers in Anterior Lumbar Interbody Fusion: A Retrospective Study

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Abstract

Objective: To compare radiographic outcomes of anterior lumbar interbody fusion (ALIF) with an expandable interbody spacer with integrated fixation (ESIF) versus a static interbody spacer with integrated anti-migratory blades (SSIB) without posterior fixation. **Methods:** This retrospective study compared 58 degenerative disc disease patients undergoing 1 - 2 level ALIF with either ESIF (n = 27) or SSIB (n = 31). Radiographic outcomes were compared between groups and against preoperative baselines at 2 weeks, 6 weeks, and at 3, 6, and 12 months. Significance was set at $p < 0.05$. **Results:** The anterior disc height (DH) showed a statistically significant difference between the two interbody groups out to 1 year postoperatively, with the ESIF group exhibiting a greater change from the preoperative measurements. Patients treated with ESIF also exhibited a significantly greater increase in middle DH compared to SSIB, which was maintained through 6 months. There were no other meaningful differences in measured radiographic parameters between the interbody groups. There were no intraoperative complications; however, there were 3 (9.7%) reoperations in the SSIB group within the first postoperative year and none in the ESIF group. **Conclusions:** Patients who underwent ALIF with ESIF showed greater increases in DH during the first postoperative year compared to those with SSIB.

Keywords

Anterior Lumbar Interbody Fusion, Expandable Spacers, Static Spacers, Indirect Decompression

1. Introduction

Anterior lumbar interbody fusion (ALIF) is a common procedure for treating degenerative disc disease (DDD), spondylolisthesis, and adjacent segment disease when conservative treatment has failed. The goal of ALIF is to restore spinal alignment, decompress nerves, and promote stability and fusion to improve clinical outcomes [1] [2]. ALIF is effective in restoring lumbar lordosis, intradiscal height, and foraminal height [3]-[5]. Traditionally, this technique utilizes static interbody spacers available in incremental size options, which may be under- or over-sized for the intervertebral space and result in less-than-optimal indirect decompression, height restoration, and alignment. The use of aggressive vertebral endplate preparation and forceful impaction of a static spacer may additionally lead to endplate damage and reduce the expected sagittal correction [6] [7]. Expandable spacer technology was designed to reduce the need for impaction and improve implant fit, which is achieved through vertical or angular expansion in the disc space, maximizing the possible sagittal correction.

Recent papers have shown good clinical and radiographic outcomes and lower subsidence rates when using expandable spacers compared to static spacers in transforaminal lumbar interbody fusion (TLIF) or lateral lumbar interbody fusion (LLIF) [3]. Given these positive outcomes from posterior and lateral approaches, it can be hypothesized that the use of expandable spacers in ALIF may also produce similar improvements in outcomes compared to static spacers, as they require less impaction and support a more optimal disc height restoration. However, clinical outcomes with expandable interbody spacers may depend on the specific implant design, which can vary with respect to endplate footprint, expansion direction (e.g., vertical and/or angular), and materials of construction, among other characteristics [8]. The procedural approach may also influence the ability of an expandable cage to restore disc height or sagittal alignment, since the approach can dictate the ligamentous releases and bony resections [9]. Thus, there is an unmet need to study clinical outcomes of expandable cages for ALIF procedures, particularly in a comparative manner to established static cages.

The purpose of this study was to compare the radiographic outcomes of patients treated with expandable and static ALIF spacers, each with integrated fixation, through 1 year postoperatively.

2. Methods

2.1. Study Design

This institutional review board-exempt, retrospective, comparative study involved patients who had previously undergone ALIF surgery between the L3 - S1 levels from February 2014 to May 2019 at a single institution, using either a standalone expandable interbody spacer with integrated fixation (ESIF) [Magnify S®, Globus Medical, Inc., Audubon, PA] or a static interbody spacer with integrated anti-migratory blades (SSIB) [ROI-A, Zimmer Biomet, Warsaw, IN]. All patients were required to have postoperative follow-up visits through 1 year. The study

included 58 patients treated at 88 levels with a diagnosis of DDD at 1 or 2 contiguous levels with or without grade 1 spondylolisthesis or retrolisthesis. An additional 68 patients were excluded due to missing postoperative visits. Surgical notes and postoperative follow-up radiographic chart notes were used to assess radiographic outcomes and complications.

2.2. Implant Description

The ESIF body and screws are manufactured predominantly from titanium alloy. It is designed for controlled height restoration through continuous in situ vertical expansion (up to 4 mm) and is available in several footprints and fixed lordotic angulation options of 8˚ and 15˚. The SSIB is manufactured from a radiolucent, medical-grade PEEK body with tantalum radiological position markers. The anterior fixation blades are made from surgical titanium alloy and are deployed through an inline tamping system. The SSIB is provided in several footprints with fixed heights in 2 mm increments from 10 - 16 mm and fixed lordotic angulations of 6˚, 10˚, and 14˚.

2.3. Surgical Technique

The access surgical procedures using ESIF and SSIB were equivalent. The anterior exposure was performed by an experienced access general surgeon. A left longitudinal periumbilical incision was used, followed by retroperitoneal exposure. Once the anterior spine was exposed, an intraoperative X-ray image confirmed the level. Anterior discectomy was then performed through removal of disc material and cartilaginous endplate, taking care to preserve the subchondral bone. In cases of a very collapsed disc space, a Cobb elevator was used to identify the interspace and then carefully distract using distraction trials at the edges of the disc space to ensure the other side of the disc could be prepared. Disc was removed posteriorly to the posterior longitudinal ligament. Angled curettes were used to clean out disc at the edges of the disc space. This was followed by placement of trials. An intraoperative radiograph was then taken with the trial in place. The appropriate size implant was then chosen. Allograft bone was placed within the window of the spacer, and the implant was subsequently inserted into the disc space. For ESIF only, the spacer was vertically expanded and then backfilled with more allograft. Integrated fixation was then placed through the anterior aspect of the spacer (*i.e.*, hydroxyapatite-coated titanium alloy screws, one screw on the superior endplate and two screws on the inferior endplate for ESIF, and blades for SSIB). Intraoperative anterior-posterior and lateral radiographs were performed to document the position of the spacer. Layered closure was then performed by the access surgeon. Intraoperative neuromonitoring was utilized during the entire procedure.

2.4. Measurements

Demographic, perioperative, and postoperative data were recorded and examined

retrospectively. Radiographic parameters included anterior, middle, and posterior disc height, neuroforaminal height, lumbar lordosis, segmental lordosis, and intervertebral angles. The radiographic measurements were conducted by two different observers using a consensus approach. Lumbar lordosis (LLs L1 - S1) was measured from the superior endplate of L1 to the superior endplate of S1. Segmental lordosis was measured from the superior endplate of the upper instrumented vertebra to either the inferior endplate of the lower instrumented vertebra or, for L5 - S1 segments, the superior endplate of S1. The intradiscal anterior height was measured from the most anterior bony prominences at the instrumented surgical level. The middle height was measured from the middle points at each of the instrumented levels. The posterior height was measured from the most posterior bony prominence of the surgical level. The foramen was measured from the superior pedicle to the inferior pedicle. All measurements were taken using Surgimap® (Nemaris Inc., New York, NY) using the Lumbar Lordosis, Angle, and Line measurement tools.

2.5. Statistical Analysis

Statistical analysis was performed with Excel (Microsoft, Inc., Richmond, VA). Descriptive statistics were recorded as mean and standard deviation, or frequency and percentage, where applicable. The chi-square test was used to check for significant differences in categorical variables between the two groups. Unpaired t-tests were used to compare if outcomes were significantly different between the two groups. Statistical significance was set at $p < 0.05$.

3. Results

3.1. Patient Demographics and Operative Data

In total, 126 patients were screened (61 in SSIB and 65 in ESIF), of which 30 in SSIB and 38 in ESIF were excluded for missing follow-up data. The remaining fifty-eight patients were included in this study, including 27 patients in the ESIF group and 31 patients in the SSIB group. The ESIF group was 57 ± 12 years old on average and 48.1% female, and the SSIB group was 53 ± 13 years old and 41.9% female. The average body mass index (BMI) was 28.0 ± 3.8 kg/m^2 for the ESIF group and 29.5 ± 5.0 kg/m^2 for the SSIB group. There were no significant differences in age, sex, race, smoking status, or BMI between the two groups (**Table 1**).

Among the 88 total operative levels, 38 (44%) levels were at L4 - 5 and 48 (56%) levels were at L5 - S1. There were no significant differences in surgical data between the two groups. There were 54.8% (17/31) and 40.7% (11/27) single-level procedures in the SSIB and ESIF groups, respectively. Mean operative time was similar for each group, with 205.5 ± 56.1 minutes for the SSIB group and 227.7 ± 63.8 minutes for the ESIF group. The fluoroscopy time was 14.0 ± 10.2 seconds and 12.7 ± 7.9 seconds in the SSIB and ESIF groups, respectively ($p > 0.05$). The SSIB group had a length of stay of 4.0 ± 1.9 days, and the ESIF group was 4.0 ± 1.4 days (**Table 2**).

Table 1. Demographic data.

	SSIB (N = 31)	ESIF (N = 27)	p-value
Sex			
Female (%)	13 (41.9)	13 (48.1)	0.64
Male (%)	18 (58.1)	14 (51.9)	
Age (mean ± SD) (range)	53 ± 13 (25 - 83)	57 ± 12 (34 - 74)	0.34
BMI (mean ± SD) (range)	29.5 ± 5.0 (21.9 - 40.7)	28.0 ± 3.8 (22.4 - 34.2)	0.89
Race/Ethnicity			
White (%)	25 (80.6)	20 (74.1)	0.54
African-American (%)	6 (19.4)	6 (22.2)	
Hispanic (%)	0 (0.0)	1(3.7)	
Smoking History			
Never (%)	14 (45.2)	15 (55.6)	0.62
Current (%)	6 (19.4)	3 (11.1)	
Past (%)	11 (35.5)	9 (33.3)	

ESIF: expandable interbody spacer with integrated fixation; SSIB: static spacers with integrated anti-migratory blades; SD: standard deviation.

Table 2. Intraoperative data.

	SSIB	ESIF	p-value
Total Levels	45	43	
Number of Operative Levels			
1 (%)	17 (54.8)	11 (40.7)	0.31
2 (%)	14 (45.2)	16 (59.3)	
Operative Levels			
L3 - 4 (%)	1 (2.2)	1 (2.3)	0.57
L4 - 5 (%)	17 (37.8)	21 (48.8)	
L5 - S1 (%)	27 (60.0)	21 (48.8)	
Operative Time (min) (mean ± SD)	205.5 ± 56.1	227.7 ± 63.8	0.33
Fluoroscopy Time (sec) (mean ± SD)	14.0 ± 10.2	12.7 ± 7.9	0.69
Length of Stay (days) (mean ± SD)	4 ± 1.9	4 ± 1.4	0.93

ESIF: expandable interbody spacer with integrated fixation; SSIB: static spacers with integrated anti-migratory blades; SD: standard deviation.

3.2. Radiographic Outcomes

It was identified that there were statistically significant differences in the preoperative measurements of anterior and posterior disc heights between interbody groups (Table 3). Radiographic changes from baseline for the ESIF and SSIB groups at each postoperative follow-up visit are summarized in Table 4.

Table 3. Preoperative radiographic parameters.

Parameter	SSIB (mean ± SD)	ESIF (mean ± SD)	p-value
Lumbar Lordosis (˚)	52.5 ± 13.1	50.1 ± 12.2	0.467
Segmental Lordosis (˚)	18.9 ± 8.9	18.0 ± 7.7	0.620
Anterior Disc Height (mm)	13.4 ± 5.2	16.4 ± 5.5	0.012
Middle Disc Height (mm)	10.7 ± 3.7	11.3 ± 3.6	0.42
Posterior Disc Height (mm)	8.1 ± 2.7	6.9 ± 1.9	0.026
Foramen Height (mm)	19.6 ± 4.6	20.5 ± 4.3	0.347

Note: Lumbar lordosis is averaged across patients; others are averaged across treated levels. ESIF: expandable interbody spacer with integrated fixation; SSIB: static spacers with integrated anti-migratory blades.

Table 4. Change in radiographic parameters.

Mean ± Std	2 Weeks			6 Weeks			3 Months			6 Months			1 Year		
Parameter	SSIB	ESIF	p-value	SSIB	ESIF	p-value	SSIB	ESIF	p-value	SSIB	ESIF	p-value	SSIB	ESIF	p-value
Lumbar Lordosis (˚)	2.9 ± 11.0	−2.6 ± 6.6	1	2.3 ± 9.2	−0.8 ± 6.5	0.78	3.6 ± 10.3	−1.0 ± 6.0	0.74	2.7 ± 8.4	−1.8 ± 6.8	0.51	3.7 ± 11.5	−0.2 ± 5.9	0.57
Segmental Lordosis (˚)	0.4 ± 9.7	1.5 ± 6.8	1	1.4 ± 8.2	0.5 ± 6.8	1	0.4 ± 9.7	−0.8 ± 7.8	1	0.1 ± 7.4	−0.7 ± 6.9	1	0.6 ± 8.3	0.5 ± 6.0	1
Anterior Disc Height (mm)	4.3 ± 6.6	7.7 ± 6.2	**<0.0001**	6.1 ± 6.3	8.5 ± 6.1	**<0.0001**	5.6 ± 6.8	7.0 ± 5.6	**<0.0001**	5.6 ± 5.7	6.7 ± 6.1	**<0.0001**	5.8 ± 6.2	6.2 ± 6.1	**0.02**
Middle Disc Height (mm)	3.4 ± 4.6	6.2 ± 4.6	**<0.0001**	4.4 ± 4.6	6.7 ± 5.1	**0.001**	3.8 ± 4.8	5.9 ± 4.1	**0.001**	4.0 ± 4.1	5.0 ± 4.9	**0.02**	4.3 ± 4.8	4.8 ± 4.8	0.74
Posterior Disc Height (mm)	2.4 ± 3.7	3.4 ± 3.0	1	2.7 ± 3.3	3.3 ± 4.3	1	2.2 ± 3.6	3.1 ± 3.2	1	2.1 ± 3.2	2.4 ± 4.0	1	2.4 ± 3.1	2.8 ± 4.0	0.99
Foramen Height (mm)	2.2 ± 4.8	3.4 ± 5.0	0.80	2.1 ± 4.7	3.4 ± 4.6	0.57	1.3 ± 4.5	2.6 ± 3.8	0.57	2.5 ± 4.2	2.3 ± 5.2	1	2.0 ± 4.8	2.6 ± 5.1	0.95

ESIF: expandable interbody spacer with integrated fixation; SSIB: static spacers with integrated anti-migratory blades.

Postoperative changes in lumbar lordosis were similar between groups at 2 weeks (−2.9˚ ± 11.0˚ vs −2.6˚ ± 6.6˚, p = 1.00), 6 weeks (2.3˚ ± 9.2˚ vs −0.8˚ ± 6.5˚, p = 0.78), 3 months (3.6˚ ± 10.3˚ vs −1.0˚ ± 6.0˚, p = 0.74), 6 months (2.7˚ ± 8.4˚ vs −1.8˚ ± 6.8˚, p = 0.51), and 1 year (3.7˚ ± 11.5˚ vs −0.2˚ ± 5.9˚, p = 0.57). Segmental lordosis changes also showed no significant differences at any timepoint (2 weeks: 0.4˚ ± 9.7˚ vs 1.5˚ ± 6.8˚, p = 1.00; 6 weeks: 1.4˚ ± 8.2˚ vs 0.5˚ ± 6.8˚, p = 1.00; 3 months: 0.4˚ ± 9.7˚ vs −0.8˚ ± 7.8˚, p = 1.00; 6 months: 0.1˚ vs −0.7˚ ± 6.9˚, p = 1.00; 1 year: 0.6˚ ± 8.3˚ vs 0.5˚ ± 6.0˚, p = 1.00).

Postoperative changes in anterior disc height were greater in the ESIF group at all follow-ups: 2 weeks (7.7 ± 6.2 mm vs 4.3 ± 6.6 mm), 6 weeks (8.5 ± 6.1 mm vs 6.1 ± 6.3 mm), 3 months (7.0 ± 5.6 mm vs 5.6 ± 6.8 mm), 6 months (6.7 ± 6.1 mm vs 5.6 ± 5.7 mm) (all $p < 0.0001$), and 1 year (6.2 ± 6.1 mm vs 5.8 ± 6.2 mm, $p = 0.02$). Middle disc height changes were also higher through 6 months ($p \leq 0.02$), with no difference at 1 year (4.8 ± 4.8 mm vs 4.3 ± 4.8 mm, $p = 0.74$). Changes in posterior disc height and foramen height were comparable between groups at all timepoints.

3.3. Complications

Complications reported included ileus, retrograde ejaculation, unresolved back pain, subsidence, and infection. There were 19 total cases of ileus: 4 (12.9%) cases with the SSIB group and 15 (55.6%) cases with the ESIF. All instances of ileus were resolved before discharge and were considered temporary. There was 1 (3.7%) case of retrograde ejaculation when using the expandable spacer, which was ongoing at the final visit. There were 3 (9.7%) cases of reoperation for the static spacer cohort: one patient had continued back pain and underwent subsequent subarticular and foraminal decompression, one patient had revision surgery approximately 5 months postoperatively due to subsidence of the interbody spacer, and there was one case of infection, which resulted in reoperation for wound debridement. A consolidated view of the study's complication profile can be seen in Table 5.

Table 5. Complications profile.

Complications [patient count (%)]	SSIB (N = 31)	ESIF (N = 27)	p-value
Did not need reoperation			
Temporary Ileus*	4 (12.9%)	15 (55.6%)	<0.0001
Retrograde Ejaculation	0 (0.0%)	1 (3.7%)	0.47
Required reoperation			
Infection	1 (3.2%)	0 (0.0%)	1.00
Subsidence	1 (3.2%)	0 (0.0%)	1.00
Unresolved Back Pain	1 (3.2%)	0 (0.0%)	1.00

*Resolved before discharge. ESIF: expandable interbody spacer with integrated fixation; SSIB: static spacers with integrated anti-migratory blades.

4. Discussion

ALIF is a well-established option for treating symptomatic lumbar degenerative disc disease that has failed conservative management. Traditionally, surgeons place allografts or manufactured static interbody spacer implants (SSIB in this study) after discectomy to promote fusion and restore disc height and segmental

lordosis. The restoration of disc height and lordosis provides indirect decompression, relieving impingement of nerve roots and associated symptoms. More recently, expandable spacers (ESIF) have entered the market. The primary differentiating feature of the ESIF is the ability to expand in situ, allowing for a smaller insertion footprint, continuous rather than discrete height selection, and minimized impaction during placement. This study evaluated clinical data from a single surgeon's practice to assess whether these perceived advantages translate into measurable radiographic or safety differences between ESIF and SSIB in ALIF procedures.

Radiographic analyses focused on disc height, neuroforaminal height (as indicators of indirect decompression), and segmental and lumbar lordosis (as measures of sagittal alignment) from preoperative to 1-year follow-up. Lumbar and segmental lordosis remained statistically similar between groups across all timepoints, with mean changes from baseline ranging from −0.2% to 3.7% at 1 year, indicating that both implant types maintained sagittal parameters effectively. Both groups demonstrated increased disc heights postoperatively; however, ESIF produced significantly greater improvements in anterior and middle disc heights through 6 months, consistent with prior studies comparing expandable and static devices [9] [10]. Neuroforaminal height increased in both groups without statistically significant differences, suggesting that either implant type can help achieve adequate indirect decompression.

The observed ability of ESIF to effect increased postoperative disc height changes relative to SSIB, while not demonstrating a similar ability with respect to angular alignment measures, may relate to specific design attributes of the ESIF being studied. The ESIF device is designed for continuous vertical expansion but not angular expansion. Lordotic angle options were fixed in both the ESIF and SSIB devices being studied. It is possible that other device designs, particularly those differing in the mode or modes of expansion, may impact radiographic outcomes differently than measured in this study. Caution is warranted in generalizing the current study results across a diverse set of expandable ALIF implant designs.

Complication rates were evaluated based on whether reoperation was required. Complications which did not necessitate reoperation were higher in the ESIF than SSIB group due to a higher incidence of temporary ileus, all of which resolved before discharge. It is difficult to pinpoint the exact reason for more ileus occurrence in the ESIF group over SSIB as all surgical techniques were similar for both groups. It is recommended that this finding be evaluated further in larger cohorts of patients. Although in this study temporary ileus and retrograde ejaculations were observed more often in ESIF as compared to SSIB, these types of complications are often related to the anterior approach procedure, occurring with prolonged retraction of the peritoneal sac and injury to the left common iliac vein [11]-[13]. When looking at complications requiring reoperation, all instances in this study occurred in the SSIB group. Reoperations were performed for implant subsidence, unresolved back pain, and infection. Even though findings are based

on a small sample size, the presence of subsidence only in the SSIB group and not in the ESIF group may be due to the unique in-situ expansion mechanism of ESIF that allows for a low starting height while inside the disc space, preventing the need for forceful impaction that has been shown to damage the vertebral end plates in prior studies [14]-[17].

Limitations of this study include a small sample size, which may have minimized the study's sensitivity and the ability to detect changes in the smaller posterior disc and foraminal heights or in the global and segmental lordosis. A further limitation is that the effectiveness of expandable versus static spacers in providing improvements for patients as measured through patient-reported outcomes of pain and function was not available for the cohorts in this study. Another important outcome not captured in this study was the evaluation of the fusion rate between the spacer types. This study was also non-prospective and non-randomized, which may have introduced selection bias and differences in unmeasured confounding variables. The serial radiographic comparisons focused exclusively on the differences between implant groups in accordance with the study objective, which does not fully account for multiple comparisons or potential mixed effects with time and should be interpreted with appropriate caution. Future long-term (>1 year follow-up) multi-center randomized trials are needed to improve generalizability and measure radiographic improvement durability, fusion rates, and clinical outcomes.

5. Conclusion

ALIF is a common technique to provide intervertebral support and promote spinal fusion. The use of expandable interbody spacers in ALIF is newer compared to static spacers, and there is a paucity of literature supporting anecdotal evidence of the benefits of using expandable over static spacers, particularly for providing indirect decompression and minimizing damage to vertebral endplates. The purpose of this study was to assess these claims. The data in this study suggest that both static (SSIB) and expandable (ESIF) interbody spacers increased the intervertebral heights as compared to preoperative. ESIF demonstrated significantly greater anterior disc height compared with SSIB at 1 year. Reoperations were only observed in the SSIB group, and there were no intraoperative complications for either cohort.

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Conflicts of Interest

The authors declared the following potential conflicts of interest with respect to

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