

## Evaluation of Lumbar Lordosis, Disc Height, and Foraminal Diameter One Year after Anterior Lumbar Interbody Fusion (ALIF) Performed Alone in Degenerative Lumbar Disc

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Received: 18 November 2022 / Accepted: 7 March 2023 / Published online: 19 June 2023

**BACKGROUND:** The most prevalent cause of low back pain is lumbar disc degeneration. Traditionally, treatment for discogenic low back pain was restricted to conservative therapy or surgical fusion. The primary justification for ALIF is that it may produce superior biomechanical and perioperative outcomes compared to other techniques.

**OBJECTIVE:** The aim of the study was to evaluate the role of anterior lumbar interbody fusion (ALIF) as a stand-alone procedure in patients with degenerative lumbar disc degeneration.

**PATIENTS AND METHODS:** This study was conducted on 40 consecutive adult patients with degenerative disc disease (DDD) of the lumbar spine admitted at the neurosurgery department of the Alexandria Main University Hospital. Back pain with or without mild sciatica was their primary complaint. Every patient was evaluated using the visual analogue scale (VAS) and Oswestry disability index (ODI) scales. All patients were operated upon by ALIF and the cage was inserted anteriorly through a paramedian incision for both single and double degenerative levels. Radiologically, the foraminal diameter, disc height, and lumbar lordosis were compared to the preoperative state.

**RESULTS:** Postoperative pain intensities were much lower than preoperative scores. Radiologically, the spine's biomechanics and sagittal balance improved, including lumbar lordosis, disc height, and foraminal diameter. Postoperatively, the minimal disc height was 1.15 cm and the maximal one was 1.50 cm with a median of 1.3 cm, while the minimal lumbar lordosis was 21 degrees and the maximal one was 51 degrees with a median of 31.5 degrees, and the minimal longitudinal foraminal diameter was 1.20 cm and the maximal one was 2.20 cm with a median of 1.80 cm.

**CONCLUSION:** The ALIF technique is a safe method for treating degenerative disc disease of the lumbar spine. The selection of patients who are candidates for ALIF is critical for achieving positive outcomes. In cases of only DDD in the form of black disc space, the stand-alone anterior approach is sufficient for fusion.

**KEYWORDS:** Degenerative lumbar disc, Disc height, Foraminal diameter, Lumbar lordosis, Sagittal balance, Stand-alone ALIF.

### INTRODUCTION

The most prevalent cause of low back pain is lumbar disc degeneration which is a target for many diagnostic and surgical procedures. There is no agreement on what intervertebral disc degeneration is, and/or how it differs from the natural processes of growth, aging, healing, and adaptive remodeling.<sup>1</sup> Degenerative disc disease (DDD) describes the normal deterioration of an intervertebral disc of the spine. Despite its name, DDD is neither a disease nor a gradual degenerative condition. In contrast, disc degeneration is frequently the result of natural daily stresses and mild injuries that cause the annulus fibrosus of spinal discs to gradually weaken and lose water. As the discs lose strength and water, they begin to collapse. This can cause back discomfort by putting pressure on the nerves in the spinal column.<sup>2</sup>

Disc degeneration affects the neurological system

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around the disc, which can trigger the nociceptors in the annulus fibrosus and induce nociceptive pain, also known as discogenic pain. Immunoreactive nerve fibers for substance P, calcitonin gene-related peptide, and vasoactive intestinal polypeptide are found in the outermost layers of a normal annulus fibrosus.<sup>3</sup>

Mechanical stimuli that are ordinarily harmless to disc nociceptors can under certain conditions elicit an increased response known as peripheral sensitization. Low pH caused by the presence of lactic acid increases both neurogenic and non-neurogenic pain mediators provoking pain.<sup>4</sup> Discogenic pain is caused not only by the structural breakdown of the disc, but also by nociceptive neurotransmitters and neuronal and vascular ingrowth in the outer annulus fibrosus, although this has not been conclusively demonstrated.<sup>5</sup>

The most characteristic sign of degenerative disc disease is a low-grade, chronic discomfort surrounding the degenerating disc that occasionally flares up into a more severe, potentially incapacitating agony. Pain flare-ups might be caused by recent exercise and aberrant tension on the spine, or they can occur without apparent

explanation. Episodes might persist from few days to several weeks before returning to mild pain levels or disappearing temporarily.<sup>6</sup>

Traditionally, treatment for discogenic low back pain was restricted to conservative therapy or surgical fusion. To accurately evaluate the efficacy of any treatment for discogenic low back pain, the natural history of such pain must be established in advance.<sup>7</sup> Typically, pharmacologic treatment consists of analgesics, nonsteroidal anti-inflammatory medications, and muscle relaxants, but the evidence for their efficacy is weak. In randomized trials, the differences in pain after a patient has taken nonsteroidal anti-inflammatory medications versus a placebo have generally been within the range of being barely noticeable.<sup>8</sup>

Numerous studies conducted since the early 1990s have demonstrated that lumbar fusion is superior to non-operative therapy or decompressive surgery alone in the management of intractable low back pain caused by degenerative lumbar diseases. Moreover, a number of researches on fusion rates have been conducted to compare the outcomes of posterior procedures and the factors that influence fusion with those of other techniques.<sup>9</sup>

In the 1950s, Doctor Cloward performed the first ALIF surgery to alleviate lower back discomfort caused by

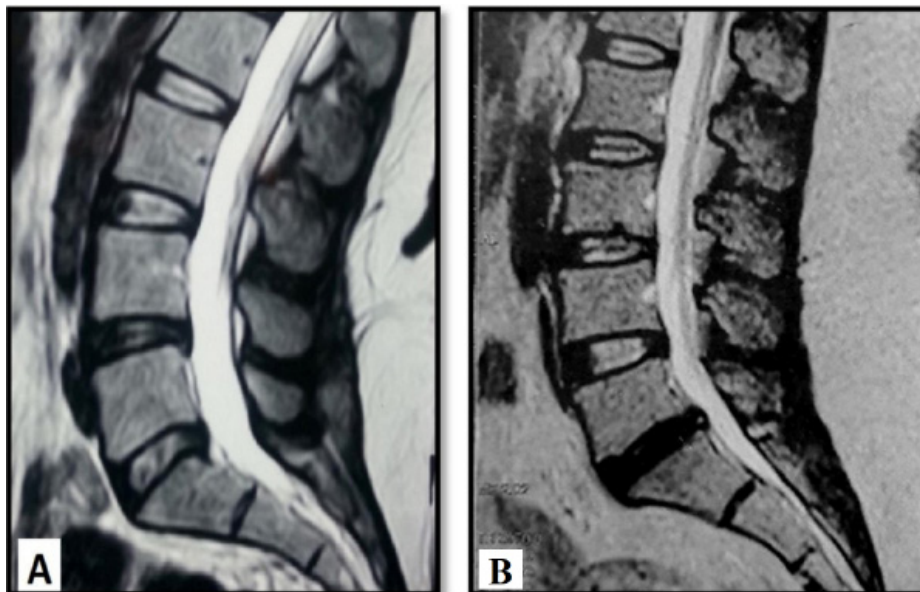
degenerative spine diseases. Due to the relatively high rate of nonunion (30-40%), the Cloward technique did not gain early favor.<sup>10</sup> Due to the introduction of new threaded titanium cages that held the disc space more securely and permitted a higher fusion rate, ALIF surgery has had a comeback in popularity.<sup>11</sup> The primary justification for ALIF is that it may produce superior biomechanical and perioperative outcomes compared to other techniques. The front and middle weight-bearing columns of a normal lumbar spine in the upright standing posture carry roughly 80% of the spinal load, while the posterior column supports around 20%.<sup>12</sup>

The aim of the study was to evaluate the role of anterior lumbar interbody fusion (ALIF) as a stand-alone procedure in patients with degenerative lumbar disc degeneration.

## PATIENTS AND METHODS

This study was conducted retrospectively on 40 consecutive adult patients with degenerative disc degeneration (DDD) of the lumbar spine who were hospitalized at the neurosurgery department of the Main University Hospital of Alexandria, between March 2018 and March 2019 and followed up until March 2020.

All patients were submitted to a comprehensive medical history and neurological assessment. Visual analogue



**Fig 1:** (A) Preoperative MRI lumbosacral spine (LSS) T2-weighted scan (sagittal view) of a 29 years female patient complaining of low back pain and mild left sciatica, showing degenerated L4-L5 disc and contained disc bulge at L4-L5. (B) Preoperative MRI LSS T2-weighted scan (sagittal view) of a 33 years female patient complaining of low back pain, showing degenerated L5-S1 disc.

scale (VAS) and Oswestry disability index (ODI) were employed to evaluate the pain. Plain X-ray, computed tomography (CT) scan and magnetic resonance imaging (MRI) of the lumbar spine were done for all patients (**Fig. 1**), while percutaneous discography was done only if necessary to establish that the source of the pain is the DDD. Dual-energy X-ray absorptiometry (DEXA scan) was done only if osteoporosis was suspected.

All patients provided written informed consent regarding the nature of the disease, the cause of back pain, the nature of the surgery and type of anesthetic, the anticipated length of hospitalization, and the potential risks and complications of the procedure.

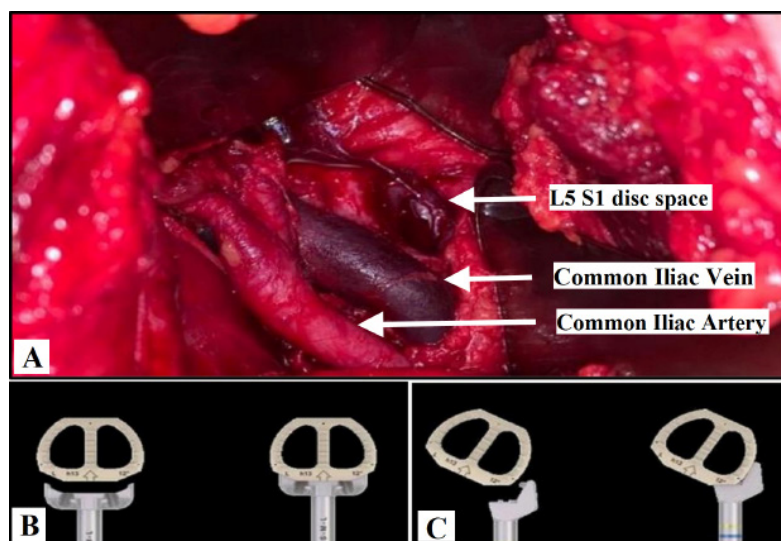
Under general anesthesia the patient was positioned supine on an operating table that allows for bending and extension of the lumbosacral region when necessary.

A left paramedian longitudinal incision approximately 2 cm from the midline was required to expose the L5-S1 disc level, and an anterior approach guided by the fluoroscopic C-arm was done to determine the level. For lumbar levels above L5-S1, the same incision was made 4 finger widths (about 10 cm) from the midline and an anterolateral approach (also guided by the fluoroscopic C-arm) was employed.

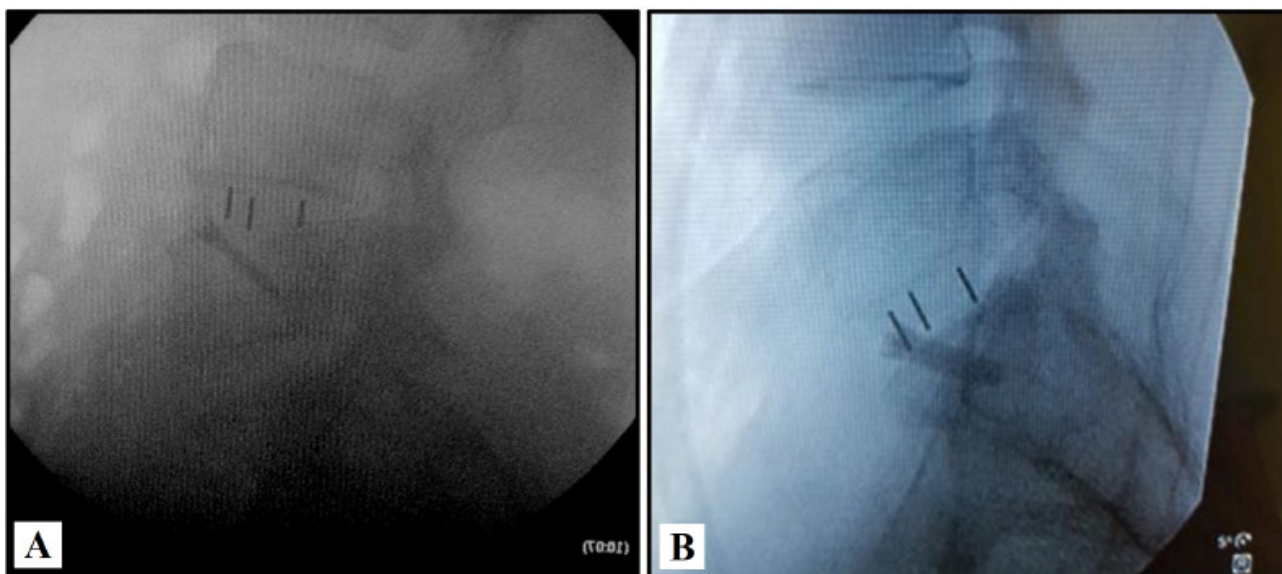
The operating system for the ALIF approach is the anterior thoracolumbar interbody fusion cage for arthrodesis, with four Homan retractors positioned at the two adjacent levels to secure the peritoneum and major blood vessels, and to make disc space identification easier. The anterior longitudinal ligament was then incised in cases with an L5-S1 disc (anterior ALIF), or the pre-psoas alone was addressed in patients above L5-S1, without cutting the anterior longitudinal ligament

(anterolateral ALIF) (**Fig. 2**). Curettage of the disc space was performed in conjunction with the cartilaginous end plate till the appearance of the annulus fibrosus without incising it. The ALIF cage was then installed according to disc size with screws securing it to the neighboring levels. As a substitute for bone, the cage was filled with hydroxyapatite paste to facilitate fusion. C-arm fluoroscopic pictures were collected intraoperatively to confirm that the cages were correctly positioned (**Fig. 3**).

On the first postoperative day, all patients were evaluated clinically with a neurological examination, and radiologically with a plain x-ray to ensure proper placement of the cage and dilatation of the stenotic foramen. After two weeks, the patients were re-evaluated to guarantee the procedure's efficacy and discogenic pain alleviation.



**Fig 2:** (A) Intraoperative image showing the disc space of L5-S1 and the great vessels (common iliac artery and vein). (B) The cage applicator used in the ALIF procedure for L5-S1 disc. (C) The cage applicator used in the ALIF procedure for L4-L5 disc.



**Fig 3:** (A) Intraoperative C-arm image (lateral view) showing correctly placed cage in L4-L5 disc. (b) Intraoperative C-arm image (lateral view) showing correctly placed cage in L5-S1 disc.



At the two-month, six-month, and one-year postoperative visits, the pain scores were assessed for all patients. After 1 year, a plain x-ray was required to ensure the success of the treatment. During the follow-up phase, CT scans

and MRIs of the spine were ordered only if neurological deficits manifested or if back discomfort worsened. (Fig. 4).



**Fig 4:** Postoperative CT scan bone window (lateral view) showing the process of the bone fusion between adjacent levels, and the impacted cage.

The study was approved by the Ethics Committee of the Faculty of Medicine of Alexandria University institutional review board (IRB) No.: 00012098, FWA No.: 00018699). Additionally, the study was performed according to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) statement. Written informed consent was obtained from all our participants

## RESULTS

The present study was conducted on 40 patients with degenerative lumbar disc disease who underwent ALIF. The VAS of back pain decreased dramatically during the 2 month, 6 month, and 1 year follow up intervals after ALIF compared to the preoperative state. The mean preoperative VAS was  $6.78 \pm 0.862$  and the median was 7. After 2 months the mean was  $1.8 \pm 0.992$  and the median was 1, after 6 months, the mean was  $0.65 \pm 0.834$  and the median was 0 and after 1 year, the mean was  $0.25 \pm 0.588$  and the median was 0.

Mild sciatic pain was present in 13 patients out of 40 and the ODI decreased in the 2 month, 6 month, and 1 year follow up periods compared to the preoperative state. The mean for mild sciatic pain in the preoperative period was  $7.60 \pm 11.15$  and the median was 0. After 2 months postoperatively, the mean was  $0.85 \pm 4.07$  and the median was 0, after 6 months, the mean was  $0.58 \pm 3.64$  and the median was 0, while after 1 year, the mean was  $0.55 \pm 3.48$  and the median was 0.

Thirty patients had single level affection and 10 patients

had double level affection. Eleven out of the 30 single level patients had L4-L5 disc, and 19 patients of the single level had L5-S1 disc. Among the 10 patients who had double level affection, 2 patients had L3-L4/L4-L5 and 8 patients had L4-L5/L5-S1. Thirty patients out of 40 had only black disc, and 10 patients had black disc with contained bulge.

The minimal disc height preoperatively was 0.5 cm and the maximal one was 1.37 cm with a median of 1.10 cm. Postoperatively, the minimal disc height was 1.15 cm and the maximal one was 1.50 cm with a median of 1.3 cm. The minimal lumbar lordosis preoperatively was 15 degrees and the maximal one was 49 degrees with a median of 23 degrees. Postoperatively, the minimal lumbar lordosis was 21 degrees and the maximal one was 51 degrees with a median of 31.5 degrees. The minimal longitudinal foraminal diameter preoperatively was 0.7 cm and the maximal one was 1.90 cm with a median of 1.20 cm. Postoperatively, the minimal longitudinal foraminal diameter was 1.20 cm and the maximal one was 2.20 cm with a median of 1.80 cm. (Tables 1-3).

We had few complications in this study that included superficial wound infection in 2 patients, cage subsidence in 1 patient (reoperated again with larger cage), intraoperative bleeding from common iliac vein tributary in 1 patient (compression was done with packing which was then removed after 3 days) and peritoneal tears in 4 patients (sutured intraoperatively). No lymphocele or retrograde ejaculation or impotence or bowel injury or pseudoarthrosis was reported.

**Table 1: Relation between preoperative and postoperative lumbar lordosis**

	Preoperative	Postoperative	t	p
<b>Lumbar lordosis (in degrees)</b>				
Minimum – Maximum	15 – 49	21 – 51		
Mean $\pm$ standard deviation.	$25.675 \pm 8.106$	$27.90 \pm 7.40$	-7.816	<0.001*
Median	23.00	31.50		

t= Paired t test.

**Table 2: Relation between preoperative and postoperative disc height**

	Preoperative	Postoperative	t	P
<b>Disc height (in cm)</b>				
Minimum – Maximum	0.50 – 1.37	1.15 – 1.50		
Mean ± standard deviation	1.232 ± 1.121	1.311 ± 0.083	-0.443	0.660
Median	1.10	1.30		

t= Paired t test.

**Table 3: Relation between preoperative and postoperative foraminal diameter**

	Preoperative	Postoperative	t	P
<b>Foraminal diameter (in cm)</b>				
Minimum – Maximum	0.70 – 1.90	1.20 – 2.20		
Mean ± standard deviation	1.188 ± 0.278	1.787 ± 0.224	-12.760	<0.001*
Median	1.20	1.80		

t= Paired t test.

## DISCUSSION

Since the invention of ALIF in the 1950s, the technology made little development until the 1980s.<sup>13</sup> In the current study, the body mass index (BMI) ranged from 22 to 26 and the waist circumference was 93 cm for males and 79 cm for females on average. The decision of all included candidates not to be fat was vital for a simple surgical procedure and positive outcome. These results were consistent with those of the majority of previous investigations. In 2014, Fischer and colleagues conducted a retrospective cohort analysis on adult patients who had anterior lumbar spine surgery in 2009. Medical records for all patients with a preoperative diagnosis of lumbar DDD or spondylolisthesis were reviewed and a survey was sent to them. The risk factor of BMI larger than 30 was associated with a poorer response on three complaints compared to patients with a BMI less than 30. Patients with a BMI of 30 were more likely to complain of pain around their anterior incision (30% versus 13%), decreased bowel function after surgery (22% versus 8%) and “daily” or “often” difficulties with bowel habits (36% versus 8%).<sup>14</sup>

In the current study, pain scores dropped and quality of life increased in DDD patients who received ALIF. These results concurred with those of the majority of earlier research. Norotte and Barrios performed a stand-alone ALIF on 65 patients with L5-S1 degenerative discopathy utilizing a polyetheretherketone (PEEK) cage loaded with hydroxyapatite nanoparticles and no bone graft in 2018. From 12 to 24 months of follow-up, clinical outcomes progressively improved and stabilized. Two years after surgery, VAS scores indicated a significant reduction in pain ( $p < .001$ ).<sup>15</sup>

Correction of lumbar lordosis is crucial for maintaining lumbopelvic characteristics in our current investigation. The minimum preoperative lumbar lordosis was 15

degrees, while the maximum was 49 degrees, with a mean of 23 degrees. The minimum postoperative lumbar lordosis was 21 degrees and the maximum was 51 degrees, with a mean of 31.5 degrees. These results were consistent with those of the majority of previous investigations. Rothrock et al. conducted a comprehensive analysis of the literature in 2018 to locate articles containing the degrees of lumbar lordosis correction accomplished by lumbar interbody fusion techniques. Regarding ALIF, 21 studies were discovered, with a mean correction of  $4.67 \pm 4.24$  degrees and median correction of 5.20 degrees.<sup>16</sup>

In the current study, disc height restoration was crucial for relieving back pain caused by disc space compression. The minimum preoperative disc height was 0.5 cm and the maximum was 1.37 cm, with a mean of 1.10 cm. Postoperatively, the minimum disc height was 1.15 centimeters and the maximum was 1.50 cm, with a mean of 1.30 cm. These results align well with those of the majority of previous studies. Norotte and Barrios reported in 2018 that stand-alone ALIF utilizing hydroxyapatite nanoparticles without an autologous bone graft is a safe and effective therapy option for L5-S1 degenerative disease. Immediately postoperatively, the anterior disc height was restored from  $4.1 \pm 3.2$  mm at baseline to  $9.5 \pm 1.6$  mm ( $p < .001$ ). The 2-month and 24-month follow-ups revealed a small decline (17.9%) in the height of the disc.<sup>15</sup>

In the current study, the postoperative foraminal diameter relative to the preoperative foraminal diameter was essential for indirect root decompression via the anterior method. The minimum longitudinal foraminal diameter preoperatively was 0.70 cm and the maximum was 1.90 cm, with a mean of 1.20 cm. The minimum longitudinal foraminal diameter postoperatively was 1.20 cm and the maximum was 2.20 cm, with a mean of 1.80 cm. Comparable to other studies' findings, Kapustka et al. documented 51 patients treated with ALIF, and 72% of

these patients showed improvement in their foraminal diameter (width and longitudinal height).<sup>17</sup>

Mobbs et al. investigated the strategy linked to ALIF-associated problems for 227 patients. The range of operative blood loss was 30 to 900 mL, with a mean of 103 mL. The average duration of surgery was 78 minutes. The average hospital stay duration was 5.2 days. In 6.6% of patients, an intraoperative vascular damage necessitating primary repair with sutures occurred. There were two incidences of retroperitoneal hematoma following surgery, 3 patients (1.3%) had incisional hernia necessitating revision surgery, 7 patients (3.1%) had prolonged ileus (>7 days) treated conservatively, 4 patients described retrograde ejaculation and 6.6% of individuals experienced sympathetic dysfunction. There were five (2.2%) occurrences of superficial wound infection that were treated with oral antibiotics, whereas there were no cases of deep wound infection that required reoperation or intravenous medication. This series contained no fatalities. They concluded that ALIF is a safe operation when performed by a mixed team of vascular surgeons and spine surgeons, with a rate of complications that is acceptable. Their series demonstrates that the team approach reduces operating times and hospital stays, with fast management of intraoperative vascular damage and minimal blood loss.<sup>18</sup>

In the current study, two patients had superficial wound infection (treated conservatively); one patient had cage subsidence (the patient was re-operated with a larger cage) and one patient had intraoperative bleeding from a common iliac vein tributary (compression was performed with packing, which were removed after three days); and four patients had peritoneal tears (sutured intraoperatively).

Lee et al. evaluated the outcomes of anterior, posterior, and transforaminal lumbar interbody fusion at a single lumbar level in patients with degenerative spinal illness in 2017. A total of 77 patients with degenerative spinal stenosis and spondylotic spondylolisthesis participated in the study. According to surgical approach, patients were split into 3 groups: anterior lumbar interbody fusion (ALIF, n = 26), transforaminal lumbar interbody fusion (TLIF, n = 21), and posterior lumbar interbody fusion (PLIF, n = 30). Several radiologic characteristics, including fusion rates, were measured. ALIF was associated with improved segmental lordosis repair, TLIF was connected with better visual analogue scale after surgery, while PLIF had the lowest rate of cage subsidence. Therefore, it is difficult to determine which of the three surgical techniques is superior because each has its own benefits.<sup>19</sup>

In 2019, Moura et al. investigated the efficacy of ALIF implants with posterior stabilization. Over the course of four

years, 64 consecutive patients were operated on by the same surgeons. They concluded that instrumented ALIF combined with posterior stabilization was a successful treatment option for single level and multilevel degenerative disc disease of the L3 to S1 segments, even in the presence of significant risk factors for nonunion and previous lumbar surgeries and instabilities, assuring very satisfactory clinical functional and radiographic outcomes with a low incidence of complications in the medium term.<sup>20</sup>

## CONCLUSION

The ALIF method is a safe therapy for the treatment of degenerative disc disease of the lumbar spine. Selection of patients who qualify for ALIF is critical for positive outcomes. In cases of only DDD in the form of black disc space, the stand-alone approach is sufficient for fusion.

## List of abbreviation

ALIF: Anterior lumbar interbody fusion.

BMI: Body mass index.

CT: Computed tomography.

DDD: Degenerative disc disease.

DEXA: Dual energy X-ray absorptiometry scan.

IRB: Institutional review board.

LSS: Lumbosacral spine.

MRI: Magnetic resonance imaging.

ODI: Oswestry disability index.

PEEK: Polyetheretherketone.

PLIF: Posterior lumbar interbody fusion.

STROBE: Strengthening the Reporting of Observational Studies in Epidemiology.

TLIF: Transforaminal lumbar interbody fusion.

VAS: Visual analogue scale.

## Disclosure

The authors report no conflict of interest in the materials or methods used in this study or the findings specified in this manuscript.

## Funding

The authors received no financial support for the research, authorship, and/or publication of this paper.

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