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Original Article

Novel Technique for Degenerative Lumbar Spine Fusion: Unilateral Pedicle Screw Fixation Combined with Contralateral Interbody Cage Fusion for Posterior Lumbar Interbody Fusion

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Abstract

Objective The common traditional surgical techniques for posterior lumbar interbody fusion (PLIF) and fixation are bilateral pedicle screw fixation with or without interbody cage fusion and unilateral pedicle screw fixation with ipsilateral cage fusion. However, the novel unilateral pedicle screw fixation combined with the contralateral interbody cage fusion technique may provide the benefits and avoid the hazards of those traditional techniques. This prospective randomized comparative clinical trial aims to compare pedicle screw fixation with contralateral interbody cage fusion and unilateral pedicle screw fixation with ipsilateral cage fusion in single-level PLIF and fixation.

Methods This comparative prospective study was conducted on 60 patients subjected to a single-level PLIF and unilateral pedicle screw fixation during the period from January 2022 to July 2022 to compare two different surgical modalities: group A (unilateral pedicle screw fixation with contralateral interbody cage fusion) and group B (unilateral pedicle screw fixation with ipsilateral cage fusion).

Results Operative time, blood loss, operative complications, and visual analog scale improvements showed insignificant differences between the two groups, while group A showed significant improvements in the Oswestry Disability Index and wider coronal disc heights contralateral to the screw, which is the side of the cages, during postoperative follow-up.

Conclusion Unilateral pedicle screw fixation with contralateral cage fusion during the PLIF and pedicle screw fixation procedure is preferred to maintain bilateral coronal disc heights and thus better clinical and mechanical results without affection of the preceding disc.

Keywords
- ► unilateral pedicle screw fixation
- ► lumbar spine fusion
- ► contralateral cage fusion

Introduction

Lumbar degenerative spinal diseases can be managed by surgical procedures and other options such as rest, medications, and physiotherapy.[1] Neural element decompression by laminectomy, facetectomy, foraminotomy, and ligamentous resection will affect the stability of the spine, so instrumentation and fusion may be required.[2] Pedicle screw fixation and internal fusion techniques are the most common surgical procedures for lumbar degenerative spine management.[3] Interbody fusion is the best method of fusion, as proven biomechanically and clinically.[4] Sufficient stability of

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the vertebral segment cannot be achieved by the interbody cage alone without screw fixation, which may lead to looseness or migration. Pedicle screws are mandatory to be added to cage fusion for three-column stiff fixation and better fusion.[5–7] Unilateral lumbar pedicle screw fixation with the ipsilateral interbody cage fusion technique was compared in many studies to bilateral pedicle screw fixation with the interbody cage fusion technique during posterior lumbar interbody fusion (PLIF). Both showed sufficient long-term follow-up effects, with different pros and cons.[8,9] No studies discussed or evaluated the position of the interbody cage in relation to unilateral lumbar pedicle screw fixation regarding fusion rate, stabilization, or outcome.[10]

This study aimed to compare the novel technique of unilateral pedicle screw fixation combined with contralateral interbody cage fusion in degenerative lumbar spine diseases to the traditional unilateral pedicle screw with ipsilateral interbody cage fusion during PLIF and pedicle screw fixation surgeries regarding clinical and radiological outcomes.

Patients and Methods

This comparative prospective study was done on patients who suffered from a single-level lumbar spine degenerative disease and were indicated for PLIF and pedicle screw fixation. All patients were routinely prepared at our outpatient clinic by magnetic resonance imaging (MRI) lumbar spine, computed tomography (CT), and X-ray (dynamic lateral flexion and extension, right and left oblique, and anteroposterior) views to assess segmental stability, facet joints condition, and fracture pars interarticularis. During the period from January 2022 to July 2022, 60 patients were operated on for PLIF and pedicle screw fixation at our institute after approval from the institutional review board (IRB #: 9181) and considering the code of ethics of the World Medical Association (Declaration of Helsinki) for studies on humans. The study is registered at clinicaltrial.gov (identifier NCT 05238662). Consents were obtained from all patients before surgeries for the procedures. Randomly, the patients were divided into two groups, A and B; group A included 30 patients operated on by unilateral pedicle screw fixation and contralateral interbody cage fusion, and group B included 30 patients operated on by unilateral pedicle screw fixation and ipsilateral interbody cage fusion. All surgeries were performed under general anesthesia in the prone position by the same team with at least 5 years' experience in spinal fusion surgeries. Measurements were requested from radiology department consultants, who were blinded to the study.

Inclusion Criteria

Patients with unstable degenerative lumbar spine disease affecting a single spinal unit after failure of conservative treatment for at least 3 months.

The Criteria of Unstable Lumbar Spinal Segment

The decision on each case was taken in the round meeting of the team of neurosurgery after a detailed discussion of the clinical condition of the patient and the imaging findings including dynamic X-ray, CT, and MRI of the lumbar spine. Segmental instability criteria can be summarized as endplate sclerosis, intradiscal gas vacuum sign, traction or/and claw osteophytes, osteoarthritis of the facet joints, flexion-extension sagittal translation > 4 mm, flexion-extension sagittal angulation > 10 degrees, annular tear in MRI, and clinical Gowers' sign.[11,12]

Exclusion Criteria

Recurrent lumber surgeries (as a prospective design, cannot predict the surgical situation), fractures, infections, tumors, spondylolisthesis (as unilateral fixation may be not sufficient in all cases), and osteoporosis according to bone mineral density less than 160 Hounsfield units in the CT spine,[13] bony canal stenosis with a transverse diameter less than 11 mm (as contralateral cage insertion is difficult in such cases with aiming to keep fact joint integrity), and incomplete medical records.

Interventional Procedures

All patients underwent detailed general and neurological medical histories and examinations. All patients were operated under general anesthesia in the prone position. The common steps for both groups were a skin incision of approximately 10 cm in length at the operative site, which was confirmed by fluoroscopy, bilateral laminectomy, bilateral discectomy, endplate preparation for cage insertion, filling the cage with fragments of autologous bone derived from laminectomy, and unilateral pedicle screw insertion under X-ray guide. The upper screw insertion was done with precautions regarding facet joint injuries. The cages were of the straight type, with a fixed length of 26 mm, a fixed width of 10 mm, and variable heights of 8, 10, 12, 14, and 16 mm. In group A, a limited medial facetectomy for cage insertion was done contralateral to screw insertions. In group B, a facetectomy was done on the side where the cage and screws were inserted.

The Following Data were Used for Comparison

1. Measure the operative time, intraoperative blood loss by the visual method, and radiation exposure shots in both groups.
2. Measure the disc height at the operative site and the preceding one (the disc height was measured in the CT spine sagittal cut passing the spinous processes by means of anterior and posterior measures and in the CT coronal cut, right and left sides), the functional spine unit angle (by the CT sagittal cut passing the spinous process), the lumbar lordotic angle (by the CT sagittal cut passing the spinous process), cage subsidence,[14] and fusion rate[15] in both groups.
3. Clinical evaluation by the visual analog scale (VAS)[16] for both low back pain and leg pain and the Oswestry Disability Index (ODI).[17]
4. Complications.

All patients were followed for at least 6 months. Radiological analysis was done by an independent radiologist who was

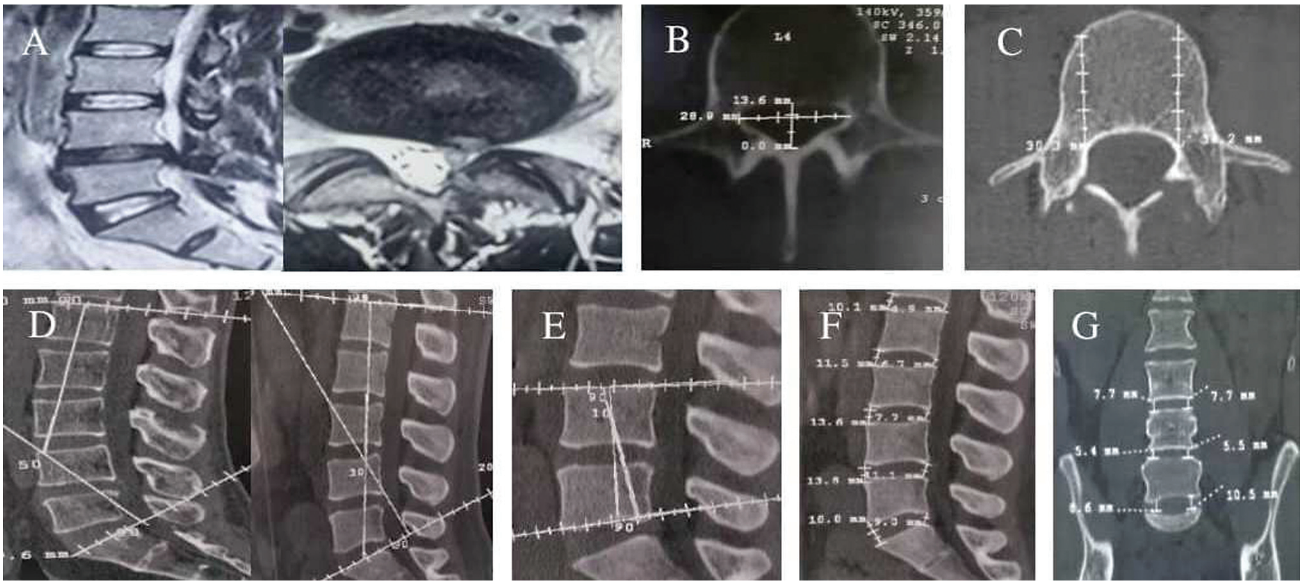

Fig. 1 Preoperative imaging evaluation. (**A**) Magnetic resonance imaging (MRI) T2 lumber spine sagittal and axial cuts. (**B** and **C**) Axial computed tomography (CT) to measure spinal canal dimensions, pedicle width, and vertebral body length. (**D**) Sagittal CT at the level of spinous processes; measures the lumber lordosis angle. (**E**) Sagittal CT at the level of spinous processes; measures the segmental lordosis angle. (**F**) Sagittal CT at the level of spinous processes; measures anterior and posterior disc heights. (**G**) Coronal CT at height part of iliac bone to measure right and left disc heights.

blinded to the study. The clinical data were analyzed by the neurosurgical team at our neurosurgery department. ►**Figs. 1**–**3** show the preoperative, intraoperative, and postoperative notes.

Statistical Analysis

The data were analyzed using IBM SPSS Statistics for Windows, Version 23 (IBM Corp., Armonk, New York, United States). Quantitative data are presented as means and standard deviation, and qualitative data are presented as numbers and percentages. The *t*-test was used to compare two groups of normally distributed variables. Mann–Whitney *U* test was used to compare two groups of nonnormally distributed variables. The Wilcoxon sign rank test was used to compare pairs of nonnormally distributed variables. The Friedman test was used to compare nonnormally distributed variables that are measured at several points in time. Percent of categorical variables were compared using chi-square tests or Fisher's exact tests when appropriate. The tests were two-sided. A *p*-value of < 0.05 was considered statistically significant.

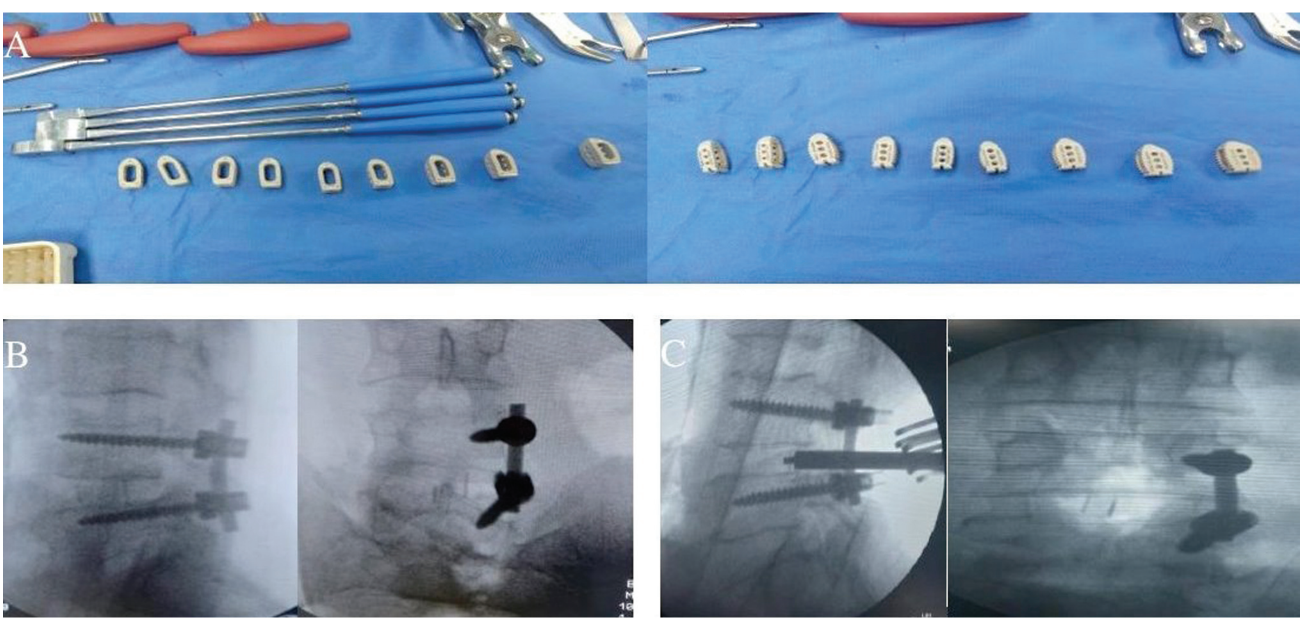

Fig. 2 Intraoperative images. (**A**) Different cage sizes and instrumentation. (**B**) Intraoperative X-ray lateral and posteroanterior views of ipsilateral cage and screws fusions. (**C**) Intraoperative X-ray lateral and posteroanterior views of contralateral cage and screws fusions.

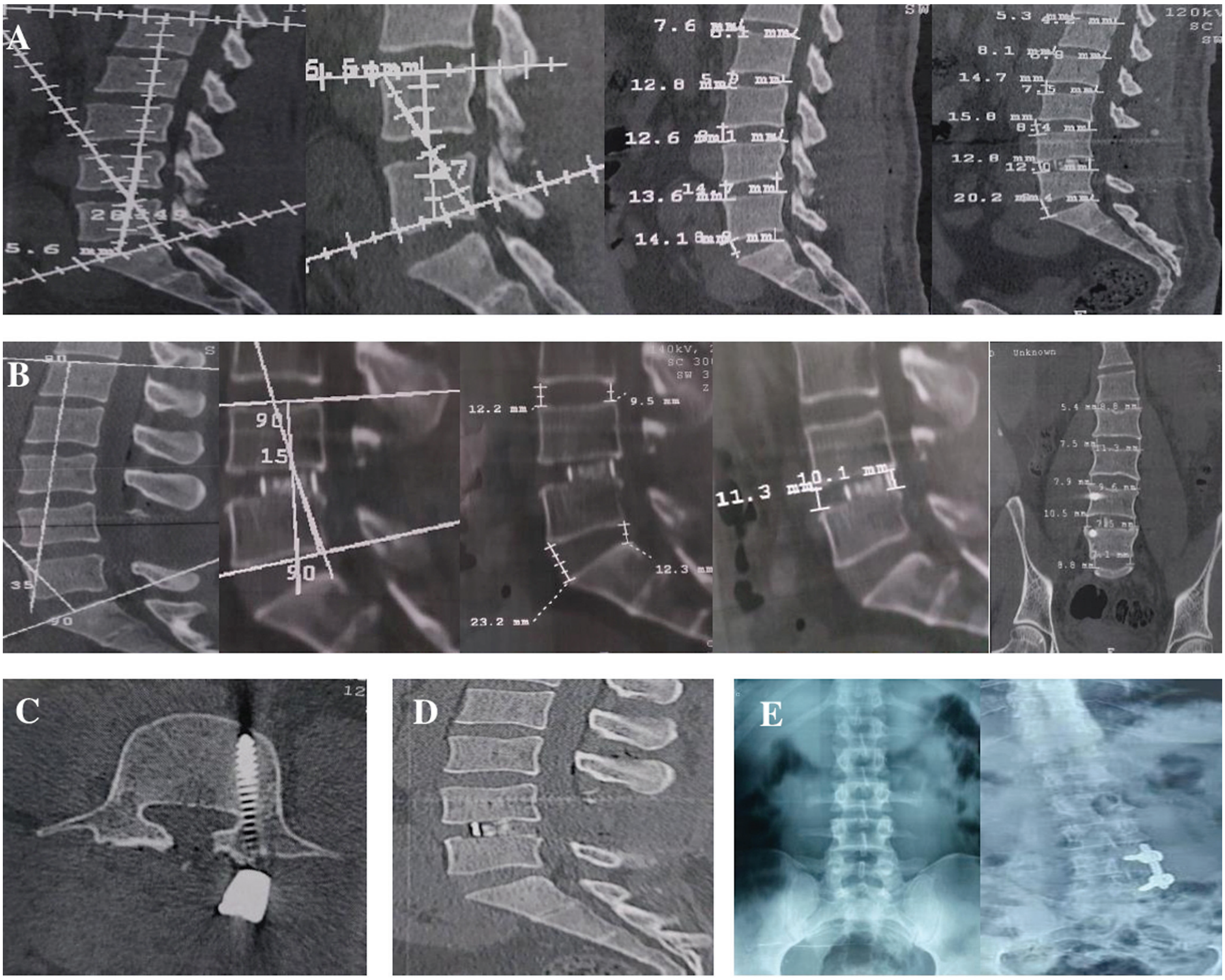

Fig. 3 Postoperative images. (**A**) Wrong measurements, not through spinous processes cuts. (**B**) Right measurements at spinous processes cuts. (**C**) Screw passing the pedicle to the vertebral body. (**D**) Interbody fusion. (**E**) Complicated case by scoliosis with the convex head toward the cage and the screws.

Results

There were no significant differences between the two groups regarding age, sex, body mass index, spinal level affection, operative time, intraoperative blood loss, intraoperative radiation shots, or postoperative wound infection. Five patients in group B suffered postoperative lumber scoliosis with statistical significance (►**Table 1**). ►**Table 2** represents the detailed clinical and imaging data of the studied groups.

❖ Clinical comparative data used in this study were: back pain (VAS), leg pain (VAS), and ODI score.

- There was no significant difference between the studied groups regarding preoperative clinical data.
- There were significant improvements in clinical data in the studied groups after 6 months of surgery.
- Group A presented a significant improvement in ODI score in comparison with group B after 6 months of surgery.

❖ Imaging comparative data included measurements of segmental lordosis, lumber lordosis, operated disc height, and preceding disc height in sagittal and coronal plans.

- There was no significant difference between the studied groups regarding preoperative imaging data.
- The segmental lordotic angle of the operated level and lumber lordotic angle showed significant changes in both groups after 6 months from surgery in comparison to preoperative measurements.
- Sagittal disc heights (mean anterior and posterior heights at the level of the spinous processes) of the operated and preceding discs showed no significant differences in both groups after 6 months in comparison between the groups or in comparison to preoperative heights.
- The coronal disc heights of the operated disc levels within postoperative 48 hours; measurements showed significant change in group A contralateral to screws insertion, which were the sides of cage insertion in this group in comparison to preoperative mean right and left coronal measurements. After 6 months from surgery, measurements showed a significant increase in contralateral (screws relation) heights in group A and a significant decrease in group B.

Table 1 Demographic, pathological, and operative data of the studied groups

Parameters	Group A, $n = 30$	Group B, $n = 30$	p
Age	49 ± 12	48 ± 10	0.36
Sex			0.4
-Male	18 (60%)	19 (63%)	
-Female	12 (40%)	11 (37%)	
BMI	22 ± 5	23 ± 3.5	0.19
Level			0.2
-L4–5	18 (60%)	15 (50%)	
-L5-S1	12 (40%)	15 (50%)	
Operative time (min)	130 ± 35	140 ± 30	0.12
Intraoperative blood loss (mL)	310 ± 130	300 ± 120	0.38
Radiation shots	3–5	3–5	–
Complications			
-Infection	2 (6.7%)	2 (6.7%)	1
-Scoliosis	1 (3.3%)	5 (16.6%)	0.045

Abbreviations: BMI, body mass index; L, lumbar; S, sacral.

Table 2 Clinical and imaging data of the studied groups

Parameters	Group A, $n = 30$	Group B, $n = 30$	p
Back pain (VAS)			
-Preoperative	4 ± 2	4.2 ± 1.9	0.34
-Postoperative (6 mo)	1.6 ± 1.2	2 ± 1.5	0.13
p-Value	**0.0001**	**0.0001**	
Leg pain (VAS)			
-Preoperative	5 ± 2.2	5 ± 1.8	0.5
-Postoperative (6 mo)	1 ± 1	1.2 ± 1	0.22
p-Value	**0.0001**	**0.0001**	
ODI score			
-Preoperative	19 ± 3	18 ± 2	0.07
-Postoperative (6 mo)	3 ± 1	6 ± 2	**0.0001**
p-Value	**0.0001**	**0.0001**	
Operative level segmental lordotic angle			
-Preoperative	17.5 ± 5	16.6 ± 3.5	0.21
-Postoperative (6 mo)	14 ± 5	14 ± 6	0.5
p-Value	**0.0044**	**0.022**	
Lumbar lordotic angle			
-Preoperative	42 ± 10	40 ± 16	0.28
-Postoperative (6 mo)	35 ± 15	33 ± 15	0.3
p-Value	**0.018**	**0.04**	
Disc height (mean anterior and posterior height in mm) Operated disc			
-Preoperative	11.5 ± 3.5	11.6 ± 2.6	0.45
-Postoperative (6 mo)	12.6 ± 2.8	12.5 ± 3	0.45
p-Value	**0.09**	**0.1**	

(*Continued*)

Table 2 (*Continued*)

Parameters	Group A, $n = 30$	Group B, $n = 30$	p
Preceding disc			
-Preoperative	10.2 ± 3	10.5 ± 4.5	0.38
-Postoperative (6 mo)	10 ± 3	10.3 ± 4.2	0.38
p-Value	**0.52**	**0.87**	
Disc height (coronal height in mm) Operated disc			
-Preoperative (average RT and LT) -Postoperative (within 48 h)	8.5 ± 2	9 ± 1.8	0.41
Ipsilateral to screws	9.5 ± 2.3	10.2 ± 3	0.413
Contralateral to screws	9.8 ± 1.8	9.2 ± 1.8	0.3
p-Value	**0.049**	**0.19**	
-Preoperative (average RT and LT) -Postoperative (6 mo)	8.5 ± 2	9 ± 1.8	0.411
Ipsilateral to screws	9.3 ± 2	10 ± 2.8	0.37
Contralateral to screws	9.4 ± 1.6	8.2 ± 1.8	0.032
p-Value	**0.015**	**0.002**	
Preceding disc			
-Preoperative and postoperative (within 48 h)	9.1 ± 1.6	9.3 ± 1	0.64
-Postoperative (6 mo) Ipsilateral to screws	9 ± 1	8.8 ± 1.6	0.63
Contralateral to screws	9.3 ± 0.8	9.2 ± 1.2	0.76
p-Value	**0.83**	**0.51**	
Cage subsidence (6 mo)			
-Grade 0	3 (10%)	5 (16.7%)	0.22
Fusion (6 mo)	30 (100%)	30 (100%)	1

Abbreviations: LT, left; ODI, Oswestry Disability Index; RT, right; VAS, visual analog scale.

- The coronal disc heights of the preceding disc, cage subsidence, and fusion rates showed no significant differences between the groups after 6 months.

Discussion

The location of lumbar vertebrae between thoracic and sacral rigid segments subjected this area to many biomechanical stresses and degenerative insults.[18] Multiple articles and meta-analyses discussed the advantages and disadvantages of bilateral and unilateral fixation with lumbar spine fusion in the treatment of degenerative spinal diseases during PLIF. In general, unilateral fixation and fusion showed better operative time, less blood loss, less cost, less stress on adjacent spinal segments, fewer potential complications of screw insertion, and less radiation exposure with equivalent clinical outcomes; however, there are conflicts about fusion rates and stability. The unilateral fixation showed delayed fusion but good fusion after 1 year. Adjacent segment disease was more pronounced with bilateral fixation than unilateral fixation. Unilateral fixation and fusion are less stable than bilateral options regarding resistance to axial rotation, lateral flexion, and cage migration. Mechanical studies on unilateral and bilateral fixation and fusion documented greater range of motion and less stabilization with unilateral fusion.[9,19,20]

Unilateral fixation results in asymmetry, and so the cage should be inserted in an oblique direction inside the disc space to cross the midline to provide support to the contralateral side to increase stability and fusion and to prevent cage migration.[21] The weakest portion of the vertebral endplate is the central region, so it is optimal to insert the cage in the periphery endplate, especially in the posterior and lateral positions, to decrease subsidence. Cage surface area does not impact rigidity, and cage positions in the sagittal plane do not affect stability. There are no published studies discussing the effect of cage position in unilateral screw fixation of the lumbar spine on stability.[10] The destructive effect of the pedicle screws inside the vertebral body on the subchondral trabecular bone may lead to cage subsidence when inserted ipsilateral to the screw.[22] Castellvi et al[23] documented that cage position in the coronal plane with pedicle screw fixation is documented that, cage position with pedicle screw fixation is recommended to be close to the midline in coronal plane to increase lateral pending stability, and the anterior sagittal plane to increases stability in flexion and lateral pending stability but, the method of posterior fixation is not identified in their study. In contrast, Faundez et al[24] found that sagittal cage positions did not affect flexion and bending mechanics in cadaveric studies without specifying the type of fixation, whether unilateral or bilateral.

The results of this study showed no significant difference between groups regarding operative data or postoperative clinical improvements except for ODI, which was in favor of group A (contralateral cage). Postoperative scoliosis or lumber spine tilting was recorded in 5 patients (16.7%) in group B with statistical significance. Choi et al[25] found that 6 patients (23.1%) in the unilateral fixation group and 1 patient (3.7%) in the bilateral fixation group suffered postoperative scoliosis with convexity toward the screw side in the unilateral fixation group, which was significant.

The incidence of scoliosis may be due to the stress on the contralateral side of the unilateral cage and screw, which is less common with bilateral fixation. In our study, postoperative scoliosis was recorded only in one patient in group A with contralateral cage fusion, possibly due to contralateral support by the cage and the presence of the cage away from the screws, which cause subchondral bone destruction, and also away from the weak central part of the endplates as mentioned above.

Sagittal disc heights of the operated and preceding discs showed no significant differences in both groups after 6 months in comparison between the groups or in comparison to preoperative heights. This indicates the effect is equivalent on adjacent segment disease and cage subsidence between the groups.

The coronal disc heights of the operated disc levels during the postoperative 48 hours showed a significant change in group A contralateral to screw insertion (sides of cage insertion) in comparison to preoperative mean right and left coronal measurements. After 6 months of surgery, the measurements showed a significant increase in contralateral (sides of cages) heights in group A and a significant decrease in group B. These results are a very important clue to evaluating the support effect of the contralateral cage with unilateral fixation by supporting mechanical action on the contralateral side and also protecting the contralateral facets for a better clinical outcome.

Conclusion

Interbody cage position relative to unilateral lumbar pedicle screw fixation during PLIF was not evaluated before, in spite of a lot of studies discussing the validity of this type of fixation. According to our results, contralateral cage insertion is better clinically and mechanically in comparison to ipsilateral insertion, with the benefits of unilateral fixation whenever previously compared with bilateral fixation.

Conflict of Interest
None declared.

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