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ORIGINAL ARTICLE

The combined use of unilateral pedicle screw and contralateral facet joint screw fixation in transforaminal lumbar interbody fusion

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Abstract
Purpose This paper is to evaluate the efficacy and safety of transforaminal lumbar interbody fusion (TLIF) using unilateral pedicle screws along with contralateral translaminar facet joint screw (UPS+TFS) fixation in comparison with the method using bilateral pedicle screws fixation (BPS) in degenerative lumbar diseases.
Methods Forty patients with single-level lumbar diseases were divided into two groups randomly. One group was treated by TLIF with BPS fixation while the other group was treated by the new technique with UPS+TFS fixation. The preoperative and postoperative ODI, JOA, VAPS scores, mean operation time, mean operation blood loss, fusion rate and complications were collected for comparison under two surgical methods. In terms of complications, only two cases of superficial infection in the BPS group and one case of urinary tract infection in the other group was found.
Results The mean operation time and blood loss was significantly less in UPS+TFS group than in BPS group. The preoperation and postoperative ODI, JOA and VAPS at the intervals of 6 weeks, 3, 6 months and 1 year between the BPS and UPS+TFS group showed no significant disparities. Only one patient in UPS+TFS group was not fused with pseudoarthrosis formation.
Conclusions The clinical efficacy and safety of TLIF with UPS+TFS fixation were comparable to BPS fixation; however, the soft tissue injury and the corresponding operation cost were reduced with unilateral pedicle screw plus translaminar facet screw fixation.

Keywords Transforaminal lumbar interbody fusion · Bilateral pedicle screw · Unilateral pedicle screw · Translaminar facet joint screw · Lumbar degenerative disease

Introduction

Harms and Rolinger [1] first described the transforaminal lumbar interbody fusion (TLIF) with bilateral pedicle screws to treat the lumbar degeneration in 1982. Since that, it has been widely accepted and become a standard operation. The bilateral screws can provide the rigid fixation and increase the fusion rate. To implant the bilateral pedicle screws, bilateral paravertebral muscles have to be severed and this will cause the operation wound and blood loss. These disadvantages have stimulated the research of less invasive posterior fixation.

In 1984, Magerl [2] introduced the translaminar facet screw (TFS) fixation technique. To achieve a solid purchase, commonly available 4.5-mm cortical screws are inserted from each side of the spinous process of the upper vertebra. Passing through the lamina, they pierce the facet joints and end up in the base of the opposite transverse process of the lower vertebra. The translaminar facet screws minimize the operation invasion given the presence of the complete facet joints. Therefore, only one translaminar facet screw can be used to fix the spine segment in the transforaminal lumbar interbody fusion at most.

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Because of the advantages and disadvantages of the two fixation technique, we decided to combine these two techniques. In our new technique, we used the unilateral pedicle screws plus contralateral translaminar facet screw to fix the operational segment. This study is to confirm whether this new technique has the same effect as the transforaminal lumbar interbody fusion with bilateral pedicle screws.

Materials and methods

Patient characteristics

After appropriate approval was granted by Human Assurances Committee, 40 patients with single-level lumbar diseases who were treated with TLIF from July 2010 to February 2012 were divided into two groups randomly. One group was treated by the standard TLIF with bilateral pedicle screws (BPS) fixation (Fig. 1) another, while the other group was treated by the new technique with unilateral pedicle screws plus contralateral translaminar facet screw (UPS+TFS) (Fig. 2).

Surgical procedure

After induction of general endotracheal anesthesia, patients were positioned prone on a radiolucent Jackson table with the hips in maximum extension conducive to maintaining lumbar lordosis. After mark pedicles of vertebral arch of the operating level on the skin with the C-arm machine, a 4-cm paramedian incision which was about 2-cm lateral to the midline was made on the severe side in both groups. Through the posterior lumbar fascia, the sacrospinalis was split to expose the ipsilateral facet joint, transverse processes and vertebral plate. The pedicle screw insertion was performed on the ipsilateral side at first. Then the inferior and superior articular processes and part of the vertebral plate were removed with osteotomes and kerrison rongeurs. The underlying bone was kept for use as an autograft during the interbody fusion. The nerve root was decompressed by removal of ligamentum flavum and fatty tissue while fatty tissue surrounding the nerve root was preserved. A sharp-points knife was used to create a rectangular window on the annulus fibrosus. Disc materials and endplate were completely removed by pituitary rongeurs, rasps and curettes through this window and the cage with autogenous bone was implanted into the disc space.

In the standard BPS group, an equivalent paramedian incision on the other side was needed. Similar to the prior side, the following procedures were sequentially performed, i.e., splitting the sacrospinalis, exposing the articular process and transverse process, inserting the pedicle screws, resecting the articular process and removing the ligamentum flavum using the osteotomes and kerrison rongeurs.

But in the UPS+TFS group, if patients have some nerve root compression symptoms at the other side before operation, further decompression to the other side would be needed. The contralateral ligamentum flavum and the osteophyte which proliferated on the medial margin of the contralateral lamina and zygapophyseal joint were grinded

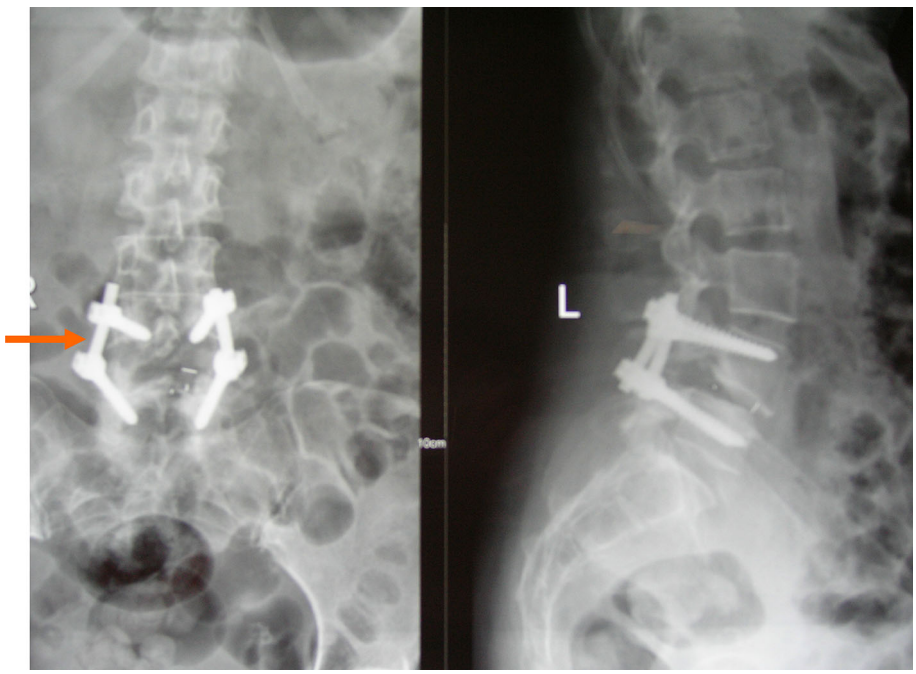

Fig. 1 *Plain film* showed standard TLIF with BPS fixation

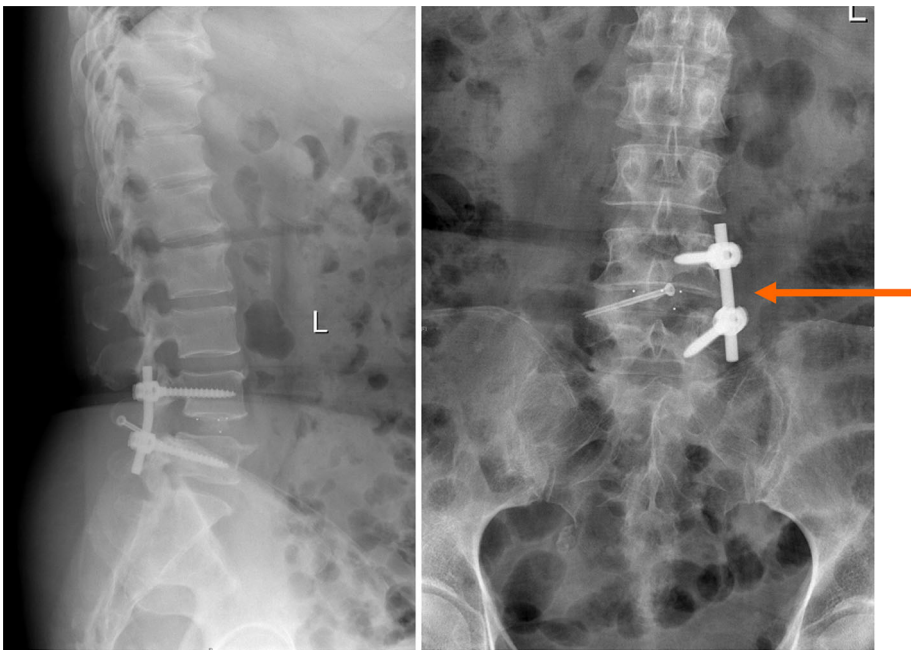

Fig. 2 *X-ray* showed TLIF with UPS+TFS fixation

and removed by using high-speed drills and kerrison rongeurs through the same paramedian incision. The contralateral nerve root was also considered to be decompressed if 1 cm nerve root could be seen.

After the decompression was finished, the last step was to insert translaminar facet screw. At first, we inserted the 1.5 mm K-wire from the base of spinous process of the upper vertebra through the contralateral lamina, across the facet joint and into the base of the opposite transverse process of the lower vertebra. Then the 3.2 mm core drill was used to enlarge the hole along the K-wire. Eventually the 4.0 mm cannulated screw was inserted.

All of the above procedure was accomplished; one or two rods were mounted and secured with locking caps according to the manufacturer's specifications. The wound was rinsed with the saline and the drain was placed as needed. Closing the fascia and the subcutaneous tissues and the skin alternately was the last step during the course of the whole operation. Patients wearing a lumbar corset were able to leave the bed as soon as the drain was pulled off one or 2 days after the surgery.

Clinical assessment

The patients were arranged to achieve a series of regular follow up after the operation. The mean follow up in the BPS group was 28.5 ± 6.5 months (range 20–40 months) and it was 26.9 ± 8.4 (range 18–45 months) in the UPS+TFS group. An ODI questionnaire, a JOA questionnaire and a VAPS questionnaire [10] were completed before surgery with an interval of 6 weeks, 3, 6 months and 1 year, respectively, in the follow-ups. The plain X-ray films and three-dimensional CT scans were obtained in both groups to evaluate the outcomes on the imageology in each follow-up. Additional data were collected including operating time and estimated blood loss during surgery.

Statistical analysis

Statistical analysis was performed using the Stata software. The Wilcoxon Ranksum and T test were used for statistical analysis of the differences in non-categorical variables between the UPS+TFS group and BPS group. A p value less than 0.05 was considered statistically significant.

Results

The mean operation time in the BPS group was 128.8 ± 18.2 min (range 120–170 min), but it was 96.3 ± 18.4 min (range70–135 min) in the UPS+TFS group. The mean operation time in the UPS+TFS group had a significant decrease than that in the BPS group. The mean blood loss in the BPS group was 161 ± 55.9 ml (range 80–300 ml), and the average blood loss in the UPS+TFS group was 116.5 ± 36.5 ml (range 60–200 ml). Consistent with the average operation time, the mean blood loss in the UPS+TFS group also had a significant reduction than that in the BPS group.

We collected and counted the follow-up data (Table 1). The preoperative ODI, JOA and VAPS in the BPS and UPS+TFS group were 24.8, 11.6, 6.95 and 29.5, 10.5, 6.7,

Table 1 The average ODI, JOA and VAPS scores in BPS and UPS+TFS group, respectively, before surgery and at 6-week, 3-, 6-month and 1-year follow-up

	Preoperation	6 weeks	3 months	6 months	1 year
ODI (BPS)	24.8	7.6	2.85	2.2	2.1
ODI (UPS+TFS)	29.5	8.8	2.7	2.4	1.8
JOA (BPS)	11.6	24.4	27.25	27.65	28.35
JOA (UPS+TFS)	10.5	23.9	26.9	27.6	28.1
VAPS (BPS)	6.95	2.15	1.15	0.95	0.25
VAPS (UPS+TFS)	6.7	2.1	0.8	0.6	0.4

respectively. And these preoperative scores of the two groups exhibited no significant differences. The same time point postoperative ODI, JOA and VAPS at 6 weeks, 3, 6 months and 1 year between the BPS and UPS+TFS group also had no significant difference, respectively. But all of the postoperative ODI, JOA and VAPS showed a significant improvement in contrast with the preoperative scores. These results revealed that both two techniques had good efficacy for treating degenerative lumbar diseases. And the surgery efficacy in the UPS+TFS group was the same as that in the BPS group. Besides these, some other phenomenon was found from the data that the scores showed a better trend at the next follow up than that at the previous one. All of the scores at 3-, 6-month and 1-year follow-up showed a significant improvement than that at 6-week follow-up. But the scores at 6-month follow-up had no significant difference in contrast with that at 3-month follow-up. The ODI at 1-year follow-up also had no significant difference than that at 3 and 6 months follow up (Fig. 3). But the JOA and VAPS showed a significant improvement than that at 3 and 6 months (Figs. 4, 5).

Besides the questionnaires, plain films and three-dimensional CT scans were taken at each follow-up in both groups. Through the last time radiological examination, there was no screws breakage, loosen and misplacement in both groups. The fusion of the vertebral body was confirmed through the three-dimensional CT. The criteria [3] for radiologic bony fusion required the presence of at least 3 preconditions of the following: trabecular structure appearing in the bone graft, bony bridging anterior to the cage, the lack of radiolucent lines around the graft, and bony continuity between the upper and lower endplates. According to this principle, 19 of 20 patients in the UPS+TFS group were classified as fused (Fig. 6) and all of the patients in the BPS group was considered fused. There were no significant differences between two groups.

Other complications included two cases of superficial infection in the BPS group and one case of urinary tract infection in the other group. All cases were treated with antibiotics and patients recovered well.

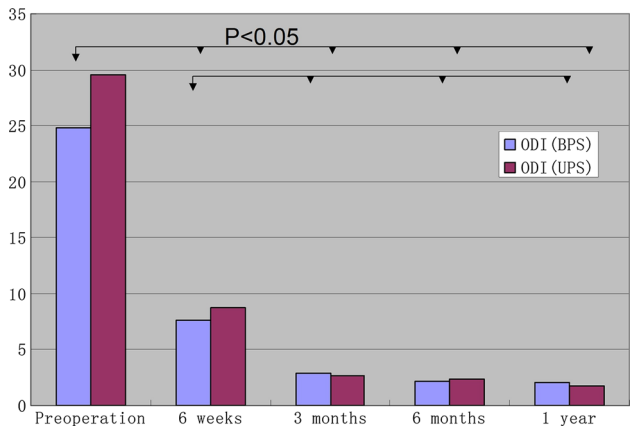

Fig. 3 The ODI showed no significant difference between two groups at pre-operation and each time follow up. But all of the postoperative ODI showed a significant improvement in contrast with the preoperative scores. All of the scores at 3-, 6-month and 1-year follow-up showed a significant improvement than that at 6-week follow-up. The ODI at 3-, 6-month and 1-year follow-up had no significant difference with each other

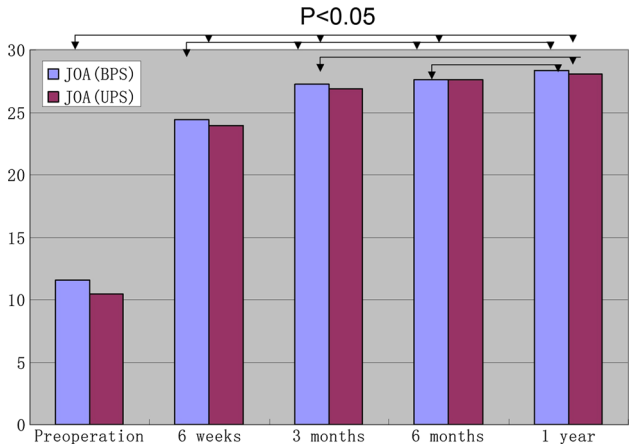

Fig. 4 The JOA showed no significant difference between two groups at preoperation and each time follow-up. But all of the postoperative JOA showed a significant improvement in contrast with the preoperative scores. All of the scores at 3-, 6-month and 1-year follow-up showed a significant improvement than that at 6-week follow-up. The JOA at 6-month follow-up had no significant difference with that at 3-month follow-up. But the JOA at 1-year follow-up showed a significant improvement than that at 3 and 6 months

Discussion

The etiology of lumbar degeneration diseases is complicated. The disc degeneration and bone hyperplasia are two of the contributing factors. The disc degeneration includes the disc hernia and the loss of the normal architecture as well as function of the disc which would result in the loss of the disc height and anterior column stability. Furthermore, the stability would transfer additional stress to the posterior column and induce the abnormal segment motion. Besides, the bone hyperplasia of laminar and facet joints would cause spinal canal stenosis that compresses the spinal cord and nerve root with the disc hernia together. At last, spine instability and spinal cord and nerve root compression produce a number of symptoms such as low back pain, leg pain, disability, etc. So the treatment of symptomatic lumbar degeneration diseases is to decompress the spinal cord and nerve root and reconstruct the disc height and spine stability.

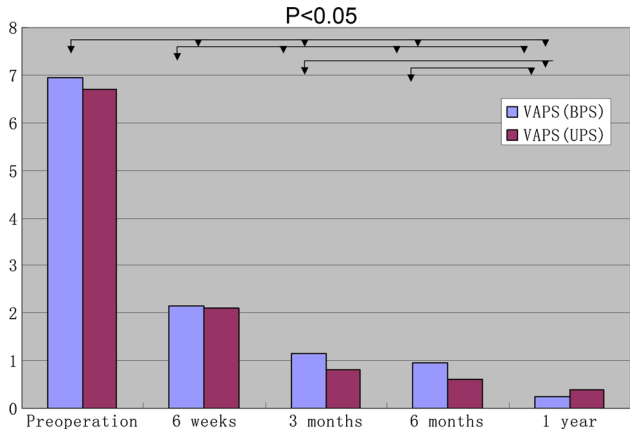

Fig. 5 Like JOA, The VAPS showed no significant difference between two groups at preoperation and each time follow up. But all of the postoperative VAPS showed a significant improvement in contrast with the preoperative scores. All of the scores at 3-, 6-month and 1-year follow-up showed a significant improvement than that at 6-week follow-up. The VAPS at 6-month follow-up had no significant difference with that at 3-month follow-up. But the VAPS at 1-year follow-up showed a significant improvement than that at 3 and 6 months

Transforaminal lumbar interbody fusion was designed to address the loss of disc height and abnormal motion with the cage. Apart from that, it decompressed the spinal canal by removing the facet joints and ligamentum flavum and supported the immediately rigid fixation with the use of pedicle screws. The bilateral pedicle screws supported the rigid stability and raised the fusion rate. Compared with the former surgery such as anterior lumbar interbody fusion (ALIF) and posterior lumbar interbody fusion (PLIF), it reduced the invasion and complications to patients. Therefore, since it was first introduced in 1982, it became more and more popular in the following decade and now it has become the standard operation for lumbar degeneration diseases. But this technique is not free from complications. It was reported that the pedicle screws would increase the local back pain because of the long incision, muscle stripping and denervation, the adjacent facet joints destroying or at least abutting and much higher in profile [4–11].

Almost at the same time, Magerl introduced another minimally invasive posterior internal fixation technique to the spine. He inserted a 4.5-mm cortical screw from each

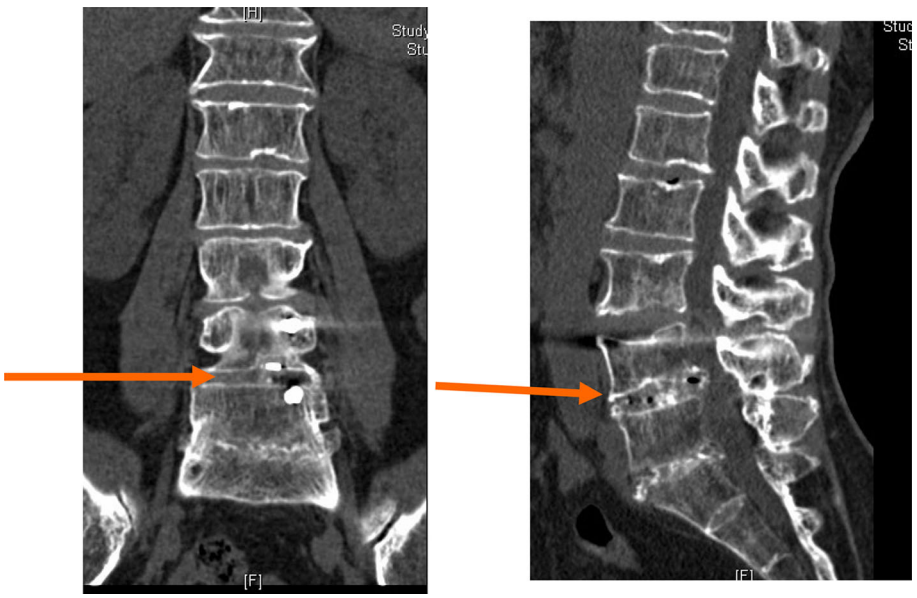

Fig. 6 Three-dimensional CT showed solid fusion between the verterbral body in TLIF

side of the spinous process of the upper vertebra, through the lamina, across the facet joints and into the base of the opposite transverse process of the lower vertebra. It had proved that bilateral translaminar facet joint screws achieved the same stability as did bilateral pedicle screws biomechanically in vitro experiments in many literatures [12–15]. Besides these biomechanical results, some clinical results have also been encouraging. The result of Magerl [16] showed one pseudoarthrosis in 36 patients. Jocobs et al. [17] described its effectiveness on 43 patients and reported a pseudoarthrosis rate of 9 %. Heggeness et al. [18] showed the 17 solid fusion in all of the 18 patients, and there was also only one case of pseudoarthrosis because of the single translaminar facet screw. These results indicated the fusion rate of TFS being as high as that of PS which was showed from 90 to 100 % in the literatures [16–18].

TFS need the integrated facet joints, but TLIF need to remove facet joint to create the approach to decompress the nerve root and insert the cage. Because of this contradiction, TFS could not support the posterior fixation in the traditional TLIF technique. Now with the development of operation technology, the bilateral nerve roots could be decompressed from the single transforaminal approach. By this method, another facet joint was preserved, rendering one insertion of TFS possible. In view of this improvement, unilateral pedicle screw plus contralateral translaminar facet screw began to be used in the new TLIF technique. After that, some literatures began to compare UPS+TFS with BPS in biomechanically and it was proved that UPS+TFS had the same stability and supported the same stiffness in all directions such as flexion–extension, lateral bending and axial rotation comparing with BPS [12–15].

Though this new fixation system was proved to be stable in biomechanically, up to now, whether this technique is as effective as the traditional TLIF in clinically was still open to further research. Jang et al. [19] showed that the UPS+TFS had the advantages over conventional TLIF of reduced estimated blood loss and diminished soft tissue injury. He found that the fusion rate in his study was 22 out of 24 fusion sites and the satisfactory outcomes in the last follow up were 21 out of 23 patients. The result of this study may be consistent with ours. But his study only introduced this minimal invasive technique while did not compare it with the conventional TLIF. In our study, we divided patients into two groups randomly; one group received the traditional TLIF with BPS fixation and the other group with the UPS+TFS fixation. In the UPS+TFS group, only one 4-cm paramedian incision was needed to insert not only the cage but also the pedicle screws and translaminar facet screw. But in the BPS group, two 4-cm paramedian incisions were needed to remove the facet joints and insert the cage and pedicle screws. So in the UPS+TFS group, contralateral muscle and soft tissue and facet joint were protected. Through the data collection during surgery, the operating time and estimated blood loss in the UPS+TFS group were less than those in the BPS group. This result proved that the new technique could minimize the invasion to patients.

There was no significant difference between two groups not only in ODI but also in JOA and VAPS before operation and every same time follow up and there was a better trend at the next follow up than that at the previous follow up. There was only one case of pseudoarthrosis in the UPS+TFS group because of severe osteoporosis. All cases in the BPS group achieved the solid fusion. It was proved that two operation techniques had the same clinical effectiveness on releasing the symptoms and achieving fusion. But because of less invasion to patients, it seemed that the UPS+TFS fixation had a more promising prospect than BPS fixation though no significant difference was found.

At last, the cost of the internal fixation material was reduced because two pedicle screws were replaced with a 4.5 mm cortical screw in the UPS+TFS group.

Conclusions

In summary, TLIF with unilateral pedicle screws plus translaminar facet screw fixation could reduce soft tissue injury and operation cost without the reduction of the clinical efficacy in contrast with TLIF using bilateral pedicle screws fixation. In this regard, the former approach might be adopted to treat the lumbar degenerative diseases in the future.

Compliance with ethical standards

Conflict of interest There is no actual or potential conflict of interest in relation to this article.

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