*Original Article*

# Comparison of Spinal Alignment between XLIF, TLIF, PLIF, and PLF in the Treatment of Single Level Spondylolisthesis: A Retrospective Study

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***Background***: Most lumbar spinal fusion procedures are performed to increase fusion potential, correct a deformity, and decompress spinal nerve roots. Nowadays, there are several spinal fusion techniques such as extreme lateral lumbar interbody fusion (XLIF), transforaminal lumbar interbody fusion (TLIF), posterior lumbar interbody fusion (PLIF), and posterolateral fusion (PLF). However, there are no studies directly comparing their capacity to alter lumbar lordosis, segmental lordosis, intervertebral disc height, foraminal height, and the grade of slip for treating single level spondylolisthesis in Thailand.

***Objective***: To compare which lumbar interbody technique amongst XLIF, TLIF, PLIF, and PLF, is the most effective in restoring spinal alignment in cases such as lumbar lordosis, increased segmental lordosis, increased intervertebral disc height, increased foraminal height, and a reduced slip grade in spondylolisthesis patients.

***Materials and Methods***: The medical records and radiographs of single level spondylolisthesis patients treated in Siriraj hospital between 2002 and 2017 were retrospectively reviewed. Clinical data and radiographic parameters such as lumbar lordosis, segmental lordosis, intervertebral disc height, foraminal height, and grade of slip, including preoperative and postoperative data were collected and analyzed. An inter-observer/intra-observer reliability test for all parameters was also performed.

***Results***: Two hundred forty patients including 192 females and 48 males with a mean age of 60.1 years were included in the present study. There was no statistically significant difference in demographic data except in younger patients in the PLF group and those with shorter length of stays in the XLIF group. The present study results indicated that there was a statistically significant increase in lumbar lordosis, increased foraminal height, and decreased slip grade in the XLIF group when compared to other three groups as TLIF, PLIF, and PLF.

***Conclusion***: All spinal fusion techniques could improve lumbar spinal alignment, however, XLIF is superior to other procedures, especially in lumbar lordosis, foraminal height restoration, and slip grade.

***Keywords***: Lumbar spondylolisthesis; Extreme lateral lumbar interbody fusion; Transforaminal lumbar interbody fusion; Posterior lumbar interbody fusion; Posterolateral fusion; Lumbar lordosis

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Spondylolisthesis occurs when one vertebra slips forward or backward over to the adjacent vertebrae. This can have a congenital, acquired, or idiopathic cause. Spondylolisthesis most frequently occurs at the L5-S1 region while L4-5 is the second most common location. For most patients with degenerative spondylolisthesis, back pain and other symptoms improve with conservative treatment. However, patients who have persistent back pain or severe slippage of the vertebrae may need surgery to relieve symptoms and be able to return to sports and activities[1,2].

Lumbar spinal fusion is a common surgical procedure for the management of degenerative spine disorders and spinal deformities. Interbody fusions have the advantage of removing the disc that is the source of pain and thus leading to a higher rate of successful fusion. Lumbar interbody fusion is an accepted treatment method for a variety of spinal disorders, including trauma, infections, and neoplastic conditions[3,4]. The loss of lumbar lordosis after a lumbar spine fusion can lead to chronic lower back pain, and therefore, restoration of adequate lumbar

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lordosis is important. A primary consideration for all spinal fusion procedures is the restoration of normal anatomy, including lumbar lordosis, disc height, and foraminal height. Failure to restore these parameters can result in permanent loss of local lordosis and sagittal balance, potentially leading to poor long-term outcomes[5-9].

Nowadays, several techniques can be used to fuse the spine such as 1) extreme lateral lumbar interbody fusion (XLIF), 2) transforaminal lumbar interbody fusion (TLIF), 3) posterior lumbar interbody fusion (PLIF), and 4) posterolateral fusion (PLF). XLIF is a minimally invasive procedure performed through the side of the body using an expandable retractor. Once the disc is removed, a large implant filled with bone graft is placed inside to restore disc height and to correct sagittal and coronal plane imbalance[10]. Meanwhile, TLIF is a minimally invasive procedure for the paramedian, or a muscle-sparing approach performed through a tubular retractor docked unilaterally on the facet joint. Discectomy, endplate preparation, and interbody devices with graft are completed through the tube[11]. PLIF is a traditional midline longitudinal incision with a wide laminectomy that includes removal of the intervertebral disc. A cage made of allograft bone or posterior lumbar interbody cages with bone graft is inserted into the disc space[12]. PLF is also a midline longitudinal incision. The laminectomy, medial facetectomy, foraminotomy, and bone graft are placed along the edges of the back part of the spine[13].

Until now, there have been no studies comparing the restoration of lumbar lordosis using all spinal fusion techniques in degenerative spondylolisthesis in Thailand. Therefore, the present study was conducted to evaluate the restoration of spinal alignment parameters, including lumbar lordosis, intervertebral disc height, foraminal height, and grade of slip in all spinal fusion techniques.

## Materials and Methods

### Subjects

All medical records and radiographic data of spondylolisthesis patients underwent spinal fusion surgeries including XLIF, TLIF, PLIF or PLF at the Department of Orthopedic Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University, Thailand between 2002 and 2017 were retrospectively reviewed. The present study was reviewed and approved by the Siriraj Ethics Committee (Si 412/2019). The inclusion criteria were 1) single level spondylolisthesis patients older than 50 years undergoing XLIF, TLIF, PLIF or PLF, 2) availability of preoperative and postoperative radiographic studies on standing L-S spine AP, lateral lumbar lateral flexion, and extension, and 3) a minimum clinical follow-up of 12 months. The exclusion criteria were 1) patients with incomplete data, 2) previous history of spinal surgery, and 3) non-union after spinal fusion. All clinical data from medical records including demographic data, underlying medical conditions, length of stay, and operative details were collected and analyzed.

### Radiographic measurement

Radiographic analyses included measurements of standing lateral preoperative and postoperative lumbar lordosis, segmental lordosis, intervertebral disc height, foraminal height as shown in Figure 1. The postoperative measurements were taken using radiographs obtained at the 12-month follow-up visit. The lumbar lordosis angle was determined by the angle formed by the superior endplate line of L1 vertebra and the superior endplate line of the S1 vertebra. Segmental lordosis was measured between the superior or endplate of the vertebra to the superior endplate below or adjacent vertebrae using the Cobb method. The intervertebral disc height was measured as the distance between the inferior endplate to the superior endplate at the middle vertebral body line. The foraminal height was measured as the distance between the inferior pedicle wall above the index disc space to the superior pedicle wall from below. Finally, the slip length was measured as the distance between posterior vertebra body line from the level below. All radiographic parameters were measured using an image viewer computer system (Sectra IDS7 version 15.1.28.6; Sectra AB., Linkoping, Sweden). All measurements were evaluated by two independent orthopedic residents. The intra-observer and inter-observer measurement reliability of these different parameters were performed by measurement on two separate periods with at least one-month interval between measurements and each observer.

### Statistical analysis

Data were described as mean plus/minus standard deviation (SD) for continuous data with normal distribution and as number and percentage for categorical data. An analysis of variance (ANOVA) test was used to assess for statistically significant differences among three or more independent data groups. For non-parametric data, the Wilcoxon signed

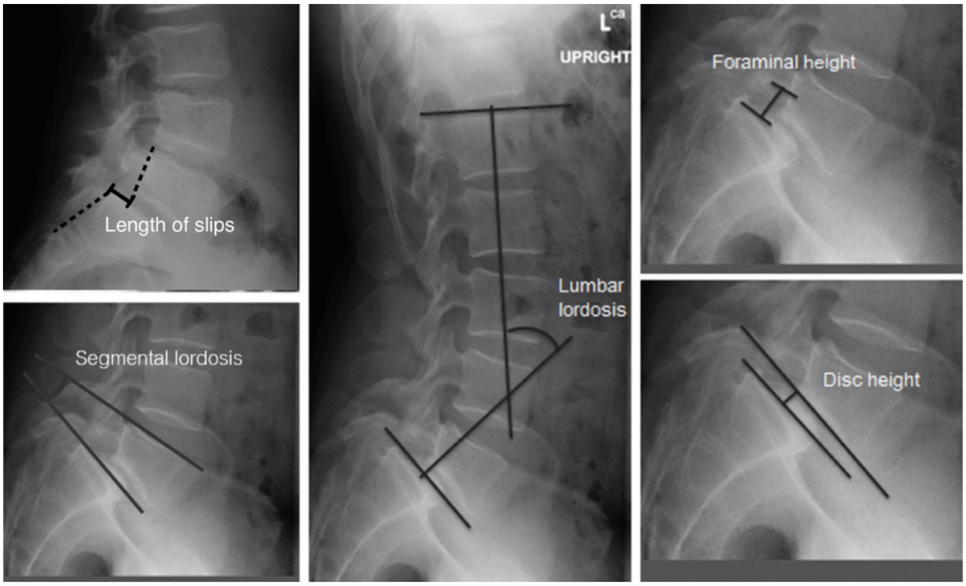


**Figure 1.** Lateral preoperative radiographs demonstrating measurement of the length of slips, lumbar lordosis, segmental lordosis, foraminal height and disc height.

**Table 1.** Demographic and operative data

| Parameters | XLIF (n=60); n (%) | TLIF (n=60); n (%) | PLIF (n=60); n (%) | PLF (n=60); n (%) | p-value |
|---|---|---|---|---|---|
| Age (year) | 63.15±10.43 | 62.90±7.95 | 63.88±8.86 | 58.50±9.77 | 0.007 |
| Sex | | | | | |
| Male | 9 (15.0) | 10 (16.7) | 15 (25.0) | 14 (23.3) | 0.439 |
| Female | 51 (85.0) | 50 (83.3) | 45 (75.0) | 46 (76.7) | |
| BMI (kg/m$^2$); mean±SD | 25.19±1.78 | 25.01±1.92 | 25.10±1.84 | 25.38±2.17 | 0.778 |
| LOS (day); median (min-max) | 7 (5 to 9) | 8 (3 to 13) | 7 (5 to 10) | 8 (6 to 11) | <0.001* |
| Operative time (minute); mean±SD | 169.05±21.43 | 173.35±18.40 | 171.65±20.38 | 169.45±22.40 | 0.639 |
| Blood loss (mL); median (min-max) | 80 (40 to 120) | 80 (40 to 250) | 80 (40 to 150) | 80 (40 to 700) | 0.288 |
| Level | | | | | |
| L3/L4 | 2 (3.3) | 0 (0.0) | 5 (8.3) | 4 (6.6) | <0.001 |
| L4/L5 | 57 (95.0) | 55 (91.7) | 9 (15.0) | 13 (21.7) | |
| L5/S1 | 1 (1.7) | 5 (8.3) | 46 (76.7) | 43 (71.7) | |
| Slip grade | | | | | |
| 1 | 60 (100) | 60 (100) | 57 (95.0) | 60 (100) | |
| 2 | 0 (0.0) | 0 (0.0) | 3 (5.0) | 0 (0.0) | |
| Disease | | | | | |
| HT | 41 (68.3) | 42 (70.0) | 44 (73.3) | 42 (70.0) | 0.944 |
| DM | 19 (31.7) | 20 (33.3) | 18 (30.0) | 13 (21.7) | 0.505 |

XLIF=extreme lateral lumbar interbody fusion; TLIF=transforaminal lumbar interbody fusion; PLIF=posterior lumbar interbody fusion; PLF=posterolateral fusion; LOS=length of stays; BMI=body mass index; HT=hypertension; DM=diabetes mellitus; SD=standard deviation

rank test was used. All analyses were performed using PASW Statistics, version 18.0 (SPSS Inc., Chicago, IL, USA). A p-value of less than 0.05 was considered statistically significant.

## Results

Two hundred forty patients were enrolled in the present study. Demographic data, body mass index (BMI), operative time, blood loss, length of stay, and

**Table 2.** Inter-observer and intra-observer reliability

| Variable | Inter-observer correlation (95% CI) | Intra-observer correlation (95% CI) |
|---|---|---|
| Pre-operation | | |
| Lumbar lordosis | 0.975(0.954 to 0.987) | 0.880(0.785 to 0.935) |
| Segment lordosis | 0.997(0.994 to 0.998) | 0.992(0.986 to 0.996) |
| Disc height | 0.995(0.991 to 0.997) | 0.936(0.883 to 0.966) |
| Foraminal height | 0.992(0.984 to 0.996) | 0.921(0.856 to 0.958) |
| Slip | 0.999(0.999 to 1.000) | 0.961(0.928 to 0.979) |
| Post-operation | | |
| Lumbar lordosis | 0.991(0.983 to 0.995) | 0.833(0.706 to 0.908) |
| Segment lordosis | 0.992(0.985 to 0.996) | 0.983(0.969 to 0.991) |
| Disc height | 0.980(0.962 to 0.989) | 0.854(0.741 to 0.920) |
| Foraminal height | 0.996(0.992 to 0.998) | 0.959(0.923 to 0.978) |
| Slip | 0.896(0.812 to 0.944) | 0.906(0.830 to 0.949) |

CI=confidence interval

co-morbidities are shown in Table 1. There were 192 females and 48 males, and the average age was 60.1 years with a range of 30 to 89 years. There were 60 patients in each group of spinal fusion techniques. The most treated segments of spondylolisthesis were the L4-5 and L5-S1 region, which had slip grade I. There was no statistically significant difference between XLIF, TLIF, PLIF, and PLF groups based on gender, BMI, operative time, blood loss, and comorbidities. However, the length of stay in hospital in the XLIF group at 6.68±0.87 days ($p<0.001$) was shorter than the TLIF, PLIF, and PLF group and in younger patients in the PLF group.

The intra-observer reliability of all measurements showed an excellent reliability with intraclass correlation coefficient (ICC) of more than 0.9, while pre-operative lumbar lordosis, post-operative lumbar lordosis, and post-operative disc height showed good reliability with ICC range from 0.833 to 0.880. The inter-observer reliability also showed an excellent reliability for all pre-operative and post-operative radiographic measurements with an ICC of more than 0.9, except good reliability in post-operative slip with an ICC of 0.896 (data shown in Table 2).

Data of all radiographic parameters such as lumbar lordosis, segmental lordosis, intervertebral disc height, foraminal height, and grade of slip in each patient group are shown in Table 3 and 4. In Table 3, all preoperative radiographic parameters did not show statistically significant difference in the four groups of patients. At 12 months post-operation, all four surgical techniques displayed an increase in all spinal parameters when compared to pre-operative parameters ($p<0.001$) (data shown in Table 4).

In addition, data in Table 5 shows that XLIF had a superior radiological outcome when compared to other surgical techniques, especially in achieving better results for the 12-months post-operative lumbar lordosis at 40.67±6.12 ($p=0.005$), 12-month post-operative foraminal height was 15.86±2.23 mm ($p<0.001$), and 12-month post-operative slip 2.42±0.98 mm ($p=0.017$). For foraminal height, XLIF shows statistically significant difference in multiple comparison (post-hoc test) when compared to PLIF and PLF ($p<0.05$). The present study results indicated that XLIF was superior to other techniques in increasing lumbar lordosis, foraminal height, and decrease slip ($p<0.05$). XLIF was similar to other techniques in post-operative disc height ($p=0.172$).

## Discussion

Spinal sagittal balance and lumbar lordosis correction have become significant goals in spinal surgery as they have a great impact on clinical outcomes[5,8]. At present, several spinal surgery techniques ranging from the traditional such as the PLF or PLIF to the new novel minimally invasive procedures such as the TLIF or XLIF are done. The present study's aim was to compare these techniques in terms of lumbar lordosis correction, disc height restoration, and restoration in slip grade in single level spondylolisthesis patients.

The present study showed that at 12 months after operation, there were more increased lumbar lordosis, foraminal height, and less slip in the XLIF group when compared to the PLIF, TLIF, and PLF groups ($p<0.05$).

Lumbar lordosis in the present study was higher (7.22±8.80°) when compared to the other studies such as Sharma et al[14], which had an improvement of 2.8°, Acosta et al[15], which had an improvement of 2.9°, and Sembrano et al[16], which had an improvement of 2.5°. In addition, Malham et al[17] reported a direct comparison of ALIF and XLIF lordosis of 4.7° versus 2.1°, respectively. This high-level of correction of lumbar lordosis corresponds to study by Mobbs et al[18] in which systematic reviews demonstrated that regional lumbar lordosis significantly improved from 35.8 to 43.3. This may be due to the anterior placement of interbody implants that was preferred by the present study surgeon. Furthermore, the XLIF cage had a higher profile and greater width, which is important for correcting lumbar lordosis.

The present study findings for XLIF are consistent with a recent study by Watkins et al[19]

**Table 3.** Pre-operative radiographic data of different surgical techniques

| Variable | XLIF (n=60); mean±SD | TLIF (n=60); mean±SD | PLIF (n=60); mean±SD | PLF (n=60); mean±SD | p-value |
|---|---|---|---|---|---|
| Pre-operation value | | | | | |
| Lumbar lordosis (°) | 33.45±9.42 | 31.80±9.26 | 31.35±8.89 | 32.83±10.57 | 0.615 |
| Segmental lordosis (°) | 13.55±6.48 | 12.92±5.96 | 14.17±6.08 | 14.60±7.09 | 0.503 |
| Disc height (mm) | 9.37±3.44 | 9.66±3.58 | 9.80±3.54 | 9.51±3.91 | 0.925 |
| Foraminal height (mm) | 13.66±2.76 | 13.84±2.56 | 13.84±2.77 | 13.19±3.04 | 0.535 |
| Slip (mm) | 5.30±4.81 | 5.08±4.82 | 5.62±5.49 | 4.99±3.67 | 0.886 |

XLIF=extreme lateral lumbar interbody fusion; TLIF=transforaminal lumbar interbody fusion; PLIF=posterior lumbar interbody fusion; PLF=posterolateral fusion; SD=standard deviation

**Table 4.** Radiographic data comparing pre-operative outcomes and post-operative results after 12 months of each surgical technique

| Parameters | Pre-operative; mean±SD | 1-year post-operative; mean±SD | Mean difference ±SD | 95% CI | p-value |
|---|---|---|---|---|---|
| XLIF | | | | | |
| Lumbar lordosis | 33.45±9.42 | 40.67±6.12 | 7.22±8.80 | 4.94 to 9.49 | <0.001* |
| Segmental lordosis | 13.55±6.48 | 15.87±4.86 | 2.32±4.52 | 3.48 to 3.97 | <0.001* |
| Disc height | 9.37±3.44 | 13.40±1.51 | 4.03±3.19 | 4.86 to 9.80 | <0.001* |
| Foraminal height | 13.66±2.76 | 15.86±2.23 | 2.20±2.34 | 2.80 to 7.28 | <0.001* |
| Slip | 5.30±4.81 | 2.42±0.98 | –2.84±5.06 | –1.57 to –4.40 | <0.001* |
| TLIF | | | | | |
| Lumbar lordosis | 31.80±9.26 | 37.37±7.18 | 5.70±10.93 | 2.85 to 8.54 | <0.001* |
| Segmental lordosis | 12.92±5.96 | 14.75±5.45 | 1.85±4.32 | 0.72 to 2.97 | <0.001* |
| Disc height | 9.66±3.58 | 13.35±1.46 | 3.65±3.19 | 2.82 to 4.48 | <0.001* |
| Foraminal height | 13.84±2.56 | 15.25±2.24 | 1.43±2.31 | 2.09 to 4.77 | <0.001* |
| Slip | 5.08±4.82 | 3.09±1.34 | –1.96±4.67 | -0.74 to -3.22 | <0.001* |
| PLIF | | | | | |
| Lumbar lordosis | 31.35±8.89 | 35.67±8.63 | 4.32±11.32 | 1.39 to 7.24 | 0.003* |
| Segmental lordosis | 14.17±6.08 | 16.83±3.83 | 2.67±4.51 | 3.83 to 4.58 | <0.001* |
| Disc height | 9.80±3.54 | 13.24±2.12 | 3.44±3.21 | 4.27 to 8.31 | <0.001* |
| Foraminal height | 13.84±2.77 | 14.69±2.09 | 0.85±2.17 | 1.41 to 3.02 | 0.004* |
| Slip | 5.62±5.49 | 2.88±1.86 | –2.74±5.23 | –1.39 to –4.06 | <0.001* |
| PLF | | | | | |
| Lumbar lordosis | 32.83±10.57 | 36.52±9.72 | 3.68±12.08 | 0.56 to 6.80 | 0.015* |
| Segmental lordosis | 14.60±7.09 | 16.95±4.77 | 2.35±5.71 | 0.87 to 3.83 | 0.002* |
| Disc height | 9.51±3.91 | 12.64±2.95 | 3.12±3.43 | 2.24 to 4.01 | <0.001* |
| Foraminal height | 13.19±3.04 | 13.44±2.99 | 0.25±1.62 | –0.16 to 0.67 | 0.316 |
| Slip | 4.99±3.67 | 3.33±2.00 | –1.65±3.54 | –2.57 to –0.74 | <0.001* |

XLIF=extreme lateral lumbar interbody fusion; TLIF=transforaminal lumbar interbody fusion; PLIF=posterior lumbar interbody fusion; PLF=posterolateral fusion; SD=standard deviation; CI=confidence interval

**Table 5.** Comparison of post-operative radiographic data after 12 months using different surgical techniques

| Variable | XLIF (n=60); mean±SD | TLIF (n=60); mean±SD | PLIF (n=60); mean±SD | PLF (n=60); mean±SD | p-value |
|---|---|---|---|---|---|
| Post-operation value (12 months) | | | | | |
| Lumbar lordosis (°) | 40.67±6.12 | 37.37±7.18 | 35.67±8.63 | 36.52±9.72 | 0.005* |
| Segmental lordosis (°) | 15.87±4.86 | 14.75±5.45 | 16.83±3.83 | 16.95±4.77 | 0.043* |
| Disc height (mm) | 13.40±1.51 | 13.35±1.46 | 13.24±2.12 | 12.64±2.95 | 0.172 |
| Foraminal height (mm) | 15.86±2.23[a,d] | 15.25±2.24 | 14.69±2.09[b] | 13.44±2.99[c] | <0.001* |
| Slip (mm) | 2.42±0.98 | 3.09±1.34 | 2.88±1.86 | 3.33±2.00 | 0.017* |

XLIF=extreme lateral lumbar interbody fusion; TLIF=transforaminal lumbar interbody fusion; PLIF=posterior lumbar interbody fusion; PLF=posterolateral fusion; SD=standard deviation

a p<0.05 when comparing with PLIF, b p<0.05 when comparing with XLIF, c p<0.001 when comparing with XLIF, d p<0.001 when comparing with PLF and Sembrano et al[16] in which they reported mean segmental lordosis improvement of 2.2° and 3.2° after LLIF. The authors reported an improvement of 2.32±4.52°, however, the present study results were not statistically significant. This strongly suggests that XLIF also has the capacity to improve segmental lumbar lordosis.

In the authors' study, XLIF does not show significant improvement for disc height compared to other techniques, which contrast to the study by Watkins et al[19]. Their study showed that lateral approaches led to greater improvement in disc height than the transforaminal approach. They explained the result as an outcome of their surgical technique in which greater discectomy and a larger interbody graft was inserted.

The present study showed that all four surgical techniques significantly reduced the grade of spondylolisthesis with significant difference in the XLIF group. In fact, reduction in listhesis may indirectly decompress the spinal nerve and improve sagittal alignment.

The present study is the first report that compares XLIF and PLF in term of restoration in spinal alignment. In the recent meta-analysis study of Said et al, it was demonstrated that PLF have similar clinical outcomes compared to PLIF except lower fusion rate[20]. PLF also is a famous procedure that most orthopedic surgeon prefer to perform spinal fusion in Thailand. The present study demonstrated higher correction in spinal alignment in XLIF comparing to PLF. However, the authors' previous study also reported high rate of complications in XLIF procedure, which align to the recent review by Epstein et al[21,22].

The limitation of the present study is its retrospective design with difficulty in history comparison. Other limitations include a small sample size compared to the other studies, and the fact that the present study data were collected from only one center. However, the strength of the present study is that it is the first study in Thailand to compare postoperative radiographic parameters in different spinal fusion techniques.

## Conclusion

A primary consideration for all spinal fusion procedures is the restoration of normal anatomy, including lumbar lordosis, disc height, and foraminal height. Failure to recognize these during surgical planning may lead to poor surgical outcomes. Although all spinal fusion techniques could improve lumbar lordosis, the present study data demonstrated that XLIF is superior to the other procedures, especially in the aspect of increasing lumbar lordosis and foraminal height restoration.

## What is already known on this topic?

There are many reports about spinal alignment in various spinal fusion techniques but no study compares XLIF with PLF in correction spinal alignment.

## What this study adds?

This study reported the superiority of XLIF technique comparing to the other technique, especially PLF, which most of spinal surgeon in Thailand used in spondylolisthesis patients.

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## Conflicts of interest

There are no conflicts of interest.

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