Clinical Study

Restoration of the spinopelvic sagittal balance in isthmic spondylolisthesis: posterior lumbar interbody fusion may be better than posterolateral fusion

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Abstract

BACKGROUND CONTEXT: More and more orthopedic surgeons recognize the importance of the sagittal balance of the spine.

PURPOSE: To analyze the pre- and postoperative sagittal and deformity parameters of low-grade isthmic spondylolisthesis and evaluate the effect of posterolateral fusion (PLF) and posterior lumbar interbody fusion (PLIF) on spinopelvic sagittal balance.

STUDY DESIGN: Nonrandomized controlled prospective study with a historical control.

PATIENT SAMPLE: A total of 99 patients with low-grade L5–S1 isthmic spondylolisthesis were treated surgically; 36 patients (mean age, 60.2±5.2 years) received the PLF operation, and 63 patients (mean age, 57.1±6.9 years) chose the PLIF operation. The healthy control group was composed of 60 volunteers (mean age, 44.5±8.4 years).

OUTCOME MEASURES: The pre- and postoperative spinopelvic and deformity parameters.

METHODS: All patients had radiographs that allowed measurement of spinopelvic parameters before and after the operation. All the spinopelvic and deformity parameters were measured. Two radiologists measured the parameters with the Cobb method.

RESULTS: All of the preoperative spinopelvic parameters showed no difference between the PLIF and PLF groups in this study (p>0.05). In both of the operation groups, the preoperative pelvic incidence, pelvic tilt (PT), sacral slope, lumbar lordosis (LL), and L5 incidence (L5I) were significantly higher than in the control group (p<0.01); the height of the intervertebral disc (HOD) was significantly lower than the controls. There were no significant differences in PT among PLIF, PLF, and control groups after the operation (p>0.05). LL increased in the PLIF group and decreased in the PLF group. The slip degree (SD) and L5I were restored significantly in both groups. The HOD of the PLIF group increased 5.04 mm, the postoperative HOD of the PLF group had no significant change. In both PLIF and PLF groups, the correction of SD was correlated with the change of LL (r=0.398, p=0.007; r=0.365, p=0.022). The restoration of HOD in the PLIF group correlated with the change of LL (r=0.334, p=0.011). No significant differences could be found between the short-term clinical outcomes of the PLF and PLIF.

CONCLUSION: Either PLF or PLIF would lead a great change in spinopelvic parameters and deformity parameters. The decrease of PT may be an important role for the short-term surgical outcome. The PLIF could increase the LL and form a more reasonable sagittal alignment. From the point of the sagittal spinopelvic balance, the PLIF may be better than the PLF for patients with isthmic spondylolisthesis.

Keywords: Spondylolisthesis; Pelvic parameters; Surgery; Pelvic incidence; Sagittal balance; Surgical outcome

FDA device/drug status: Not applicable.


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Introduction

With the development of pedicle screw–based instrumentation, spine surgery has had great progress. But some orthopedic surgeons did not focus attention on the sagittal balance of the spine. Many patients suffered from low back pain that resulted from the fixed sagittal imbalance. Some of them had to maintain a forward bending position. The authors report the results of a small series of patients treated using interbody or posterolateral fusion and followed prospectively.

Context

In low-grade isthmic spondylolisthesis, debate persists regarding the optimal type of surgical intervention and specifically whether interbody fusion is necessary (in light of its ability to restore spinopelvic parameters to a greater extent). The authors report the results of a small series of patients treated using interbody or posterolateral fusion and followed prospectively.

Contribution

The authors report that among their 99 patients (63 PLIF and 36 PLF), lumbar lordosis and sagittal alignment were restored to a greater extent following interbody fusion. The fusion rate was also higher among those who underwent PLIF. At two-year follow-up, however, no significant difference was appreciated in clinical outcome between the two groups.

Implications

This study reinforces findings documented in other studies, particularly an increased capacity on the part of interbody techniques to restore spinopelvic parameters and an increased rate of radiographic fusion among patients receiving PLIF. At the same time, clinical outcomes were comparable between the two groups over the course of this study. This finding may call into question the rationale behind a procedure (interbody fusion) that is both more expensive and carries a greater risk of complications. Readers should appreciate that, even though this investigation was conducted prospectively, the small sample size and potential for selection bias in assigning patients to the treatment groups results in this work presenting no better than Level III evidence.

—The Editors

Method

Patient selection and surgical procedure

A total of 99 patients with low-grade L5–S1 isthmic spondylolisthesis were treated surgically in our institute.
Thirty-six patients (mean age, 60.2±5.2 years) received the PLF operation, and 63 patients (mean age, 57.1±6.9 years) received the PLIF operation. There were 60 healthy volunteers (mean age, 44.5±8.4 years) who participated in our study as the control group. The study started in 2009 and ended in 2013. The study was approved by the institutional review board.

Patients who received the PLIF or PLF had to satisfy the following criteria: (1) have a diagnosis of low-grade isthmic L5–S1 spondylolisthesis (Meyerding grade I or II); and (2) have an indication for surgery (each patient had at least one side neurological symptoms). The study excluded patients with any previous spine surgery or significant lower limb discrepancy (ie, >20 mm). The inclusion criteria of the control group were as follows: (1) age of 18 or older; (2) no evidence or history of spine problems; (3) no marked lower limb length discrepancy (ie, >20 mm).

To avoid bias, all the patients had the PLIF or PLF with L5–S1 monosegment instrumentation and nerve root decompression. The facets were kept unless they interfered with the nerve root decompression. The pedicle screws for instrumentation were made from titanium alloy, and the cage was polyetheretherketone (Medtronic Sofamor Danek, Memphis, TN, USA). One wedge-shaped cage was placed in the L5-S1 segment in each subject of the PLIF group [18–20]. The size of the cage was fit for the intervertebral space. After placing the cage, the segment was compressed. The follow-up time was at least 2 years.

**Imaging evaluation**

In our study, each subject had a standing lateral radiograph from the T10 vertebra to the femoral head before and after the operation. The subject stood in a comfortable position with the hips and knees fully extended. The arms of the subject could rest on the support facility. The spinopelvic parameters and deformity parameters were measured by the radiologists using the Cobb method. The spinopelvic parameters included PI, PT, SS, LL, and lumbar 5 incidence (L5I) (Fig. 1), and the deformity parameters were height of the intervertebral disc (HOD), slip degree (SD), and lumbosacral angle (LSA) (Fig. 2) (Table 1).

![Fig. 1](https://example.com/f1.jpg)  
**Fig. 1.** Sagittal spinopelvic parameters are based on standing lateral radiographs. (Left) The measurement of pelvic incidence (PI), sacral slope (SS), and pelvic tilt (PT). (Right) The measurement of L5 incidence (L5I).
Clinical outcome

The X-ray films were examined by radiologists, and the fusion rates were calculated. The life quality of the patients was measured with the medical outcomes study item short form health survey (SF-36). Every patient completed the SF-36 form before and after the operation.

Statistical analysis

The parameters of the control, PLF, and PLIF groups were analyzed with the statistical software SPSS for Windows version 12.0 (SPSS, Inc., Chicago, IL, USA). The preoperative and postoperative parameters of the patients were tested with paired Student t test. Analysis of variance was used to analyze the statistics of the PLF, PLIF, and control groups. Every group was compared with each other by the Student-Newman-Keuls test. If the statistics were heterogeneity of variance, we used the Wilcoxon rank sum test and Kruskal-Wallis test. To analyze the correlation between spinopelvic parameters and the change of deformity, Pearson correlation analysis was used. The scores of the SF-36 were compared with independent t test. All the data were presented as mean ± standard deviation. The statistically significant level for all was set at 0.05.

Table 1

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI (pelvic incidence)</td>
<td>The angle subtended by a line perpendicular to the upper sacral plate at its midpoint and the line connecting this midpoint to the middle axis of the femoral heads (Fig. 1, Left).</td>
</tr>
<tr>
<td>PT (pelvic tilt)</td>
<td>The angle between the vertical line and the line joining the middle of the sacral plate and the axis of the femoral heads. It is positive when the hip axis lies in front of the middle of the sacral plate (Fig. 1, Left).</td>
</tr>
<tr>
<td>SS (sacral slope)</td>
<td>The angle between the sacral plate and the horizontal line (Fig. 1, Left).</td>
</tr>
<tr>
<td>LL (lumbar lordosis)</td>
<td>The angle between a line joining the center of the upper endplate of L5 to the axis of the femoral heads and a line perpendicular to the upper endplate of L5 (Fig. 1, Right).</td>
</tr>
<tr>
<td>L5I (L5 incidence)</td>
<td>The angle between a line joining the center of the upper endplate of L5 to the axis of the femoral heads and a line perpendicular to the upper endplate of L5 (Fig. 1, Right).</td>
</tr>
<tr>
<td>SD (slip degree)</td>
<td>The interval between two extended lines of the posterior aspect of upper and lower vertebral body (Fig. 2, Left).</td>
</tr>
<tr>
<td>LSA (lumbosacral angle)</td>
<td>The angle between inferior endplate of L5 and superior endplate of S1 (Fig. 2, Middle).</td>
</tr>
<tr>
<td>HOD (height of the intervertebral disc)</td>
<td>The mean value of the foremost intervertebral disc height and the most posterior one (Fig. 2, Right).</td>
</tr>
</tbody>
</table>
Preoperative statistics

As we expected, no significant difference can be found between the parameters of the PLF and PLIF groups (Table 2). Except for the HOD, the parameters of the patients with spondylolisthesis were significantly higher than the control group. Unlike other parameters, the HOD of the patients was obviously lower than the control group.

Postoperative change of the spinopelvic and deformity parameters

The two different operations can reduce the PT of the patients with spondylolisthesis. The PT of the PLIF group decreased 4.92° after the operation. In the PLF group, the PT improved 3.89°. In correspondence with the PT, after the surgical treatment, the SS increased 4.64° in PLIF group and 3.98° in PLF group. The LL increased 5.09° in PLIF group, whereas the LL decreased 8.80° in the PLF group (Figs. 3 and 4). The SD and L5I restored significantly in both groups. The HOD of the PLIF group increased 5.04 mm, and the postoperative HOD of the PLF group showed no notable difference with the preoperative HOD. The LSA increased 6.11° after the operation in the PLIF group. Without the cage, the LSA decreased 2.38° in the PLF group (Table 3).

Postoperative statistics

Most of the parameters of the patients received a restoration after the surgical treatment. Compared with the control group, the postoperative PT in the PLIF and PLF groups showed no significant difference. As the PT decreased, the postoperative SS and L5I of the two groups were still higher than the control. The LL changed differently after the operation, the postoperative LL of the PLF showed no more difference with the control. The postoperative HOD and LSA of the PLIF group were significantly higher than the control group (Table 4).
**Correlation between the change of spinopelvic parameters and the deformity parameters**

In both PLIF and PLF groups, the correction of SD was correlated with the change of LL ($r = -0.398$, $p = .007; r = 0.365$, $p = .022$). The restoration of HOD in the PLIF group correlated with the change of LL ($r = 0.334$, $p = .011$). Other improvements of deformity parameters showed no significant correlation with the changes in spinopelvic parameters (Tables 5 and 6).

**Clinical outcome**

The fusion rate of the PLIF group was higher than the PLF group. The fusion rate of the PLIF group was 62/63, and the PLF group was 32/36. There were no significant differences between the preoperative SF-36 of the PLF and PLIF groups ($p = .715$). The situation was the same 6 months after the operation ($p = .737$). After 2 years, there were still no obvious differences between the two groups ($p = .055$). The details of the SF-36 are provided in Table 7.

**Table 3**

Pre- and postoperative parameters of the PLIF and PLF groups

<table>
<thead>
<tr>
<th>Variables</th>
<th>PLIF (Pre)</th>
<th>PLIF (Post)</th>
<th>PLF (Pre)</th>
<th>PLF (Post)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI, deg.</td>
<td>64.32±10.43</td>
<td>64.04±9.56*</td>
<td>63.65±9.26</td>
<td>63.74±9.26*</td>
</tr>
<tr>
<td>PT, deg.</td>
<td>20.76±6.36</td>
<td>15.84±5.45*</td>
<td>20.61±4.15</td>
<td>16.72±4.64*</td>
</tr>
<tr>
<td>SS, deg.</td>
<td>43.56±7.63</td>
<td>48.20±7.43*</td>
<td>43.04±8.42</td>
<td>47.02±8.63*</td>
</tr>
<tr>
<td>LL, deg.</td>
<td>58.73±10.45</td>
<td>63.82±11.13*</td>
<td>59.80±7.26</td>
<td>51.00±6.23*</td>
</tr>
<tr>
<td>L5I, deg.</td>
<td>32.13±9.02</td>
<td>26.68±8.75*</td>
<td>31.98±5.02</td>
<td>27.18±4.55*</td>
</tr>
<tr>
<td>HOD, mm</td>
<td>7.94±4.21</td>
<td>12.98±3.69*</td>
<td>8.13±2.84</td>
<td>8.24±2.46</td>
</tr>
<tr>
<td>SD, mm</td>
<td>18.07±5.87</td>
<td>6.34±4.02*</td>
<td>17.61±4.50</td>
<td>7.13±3.32*</td>
</tr>
<tr>
<td>LSA, deg.</td>
<td>10.87±5.46</td>
<td>16.98±2.84*</td>
<td>9.78±3.54</td>
<td>7.40±3.42*</td>
</tr>
</tbody>
</table>

HOD, height of the intervertebral disc; LL, lumbar lordosis; LSA, lumbar 5 incidence; PLF, posterolateral fusion; PLIF, posterior lumbar interbody fusion; PT, pelvic tilt; SD, slip degree; SS, sacral slope.

* $p<.05$. Postoperative parameters were different from the preoperative parameters.

**Table 4**

Postoperative parameters of the control, PLIF, and PLF groups

<table>
<thead>
<tr>
<th>Variables</th>
<th>Normal Control</th>
<th>PLIF</th>
<th>PLF</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI, deg.</td>
<td>42.13±8.93</td>
<td>64.04±9.56*</td>
<td>63.74±9.26*</td>
</tr>
<tr>
<td>PT, deg.</td>
<td>14.47±5.32</td>
<td>15.84±5.45</td>
<td>16.72±4.64</td>
</tr>
<tr>
<td>SS, deg.</td>
<td>27.60±5.14</td>
<td>48.20±7.43*</td>
<td>47.02±8.63*</td>
</tr>
<tr>
<td>LL, deg.</td>
<td>52.43±7.38</td>
<td>63.82±11.13*</td>
<td>51.00±6.23*</td>
</tr>
<tr>
<td>L5I, deg.</td>
<td>18.67±5.04</td>
<td>26.68±8.75*</td>
<td>27.18±4.55*</td>
</tr>
<tr>
<td>HOD, mm</td>
<td>9.52±1.39</td>
<td>12.98±3.69</td>
<td>8.24±2.46</td>
</tr>
<tr>
<td>SD, mm</td>
<td>—</td>
<td>6.34±4.02</td>
<td>7.13±3.32</td>
</tr>
<tr>
<td>LSA, deg.</td>
<td>6.82±3.76</td>
<td>16.98±2.84*</td>
<td>7.40±3.42*</td>
</tr>
</tbody>
</table>

HOD, height of the intervertebral disc; LL, lumbar lordosis; LSA, lumbar 5 incidence; PLF, posterolateral fusion; PLIF, posterior lumbar interbody fusion; PT, pelvic tilt; SD, slip degree; SS, sacral slope.

* $p<.05$. Spinopelvic and deformity parameters of the controls were different from the postoperative parameters of the patients.

1 $p<.05$. Postoperative parameters of the PLF group were different from the PLIF group.
Table 5
Correlation between the change of spinopelvic parameters and the deformity parameters in PLIF group

<table>
<thead>
<tr>
<th>Deformity parameters/pelvic parameters</th>
<th>SD, mm</th>
<th>LSA, degree</th>
<th>HOD, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT, deg.</td>
<td>r = 0.288, p = .076</td>
<td>r = 0.143, p = .385</td>
<td>r = 0.097, p = .559</td>
</tr>
<tr>
<td>LL, deg.</td>
<td>r = 0.365, p = .022</td>
<td>r = 0.262, p = .107</td>
<td>r = 0.199, p = .225</td>
</tr>
<tr>
<td>L5I, deg.</td>
<td>r = 0.160, p = .332</td>
<td>r = 0.017, p = .916</td>
<td>r = −0.006, p = .972</td>
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HOD, height of the intervertebral disc; LL, lumbar lordosis; LSA, lumbo-sacral angle; L5I, lumbar 5 incidence; PLIF, posterior lumbar interbody fusion; PT, pelvic tilt; SD, slip degree.

Statistically significant correlation coefficient (p < .05).

Discussion

As the connection of the trunk and the lower limbs, the importance of the spinopelvic region in regulating sagittal balance was demonstrated by recent studies [4, 21–23]. Some studies reported that the PI of patients with spondylolisthesis was significantly higher than that of healthy people [6, 7, 24, 25]. Our study proved the result once again. Either the PI in the PLIF group or the PI in the PLF group was higher than in the control group. There existed a direct linear correlation between the PI and SS, PT, and LL. A high PI required a correspondingly high LL to maintain sagittal balance [10, 26]. In our study, we could find the same situation from the parameters measured from the patients with spondylolisthesis. The PT, SS, and LL were significantly higher than in the control group.

The contemporary surgical management of isthmic spondylolisthesis concentrated on decompression and instrumentation. Reduction for the high-grade spondylolisthesis was accepted by most scientists, but reduction for the low-grade spondylolisthesis was still in controversy [27–30]. The patients in our study were symptomatic and unresponsive to a prolonged course of conservative treatment. We believe the most important short-term clinical effect was decompression. All the patients in our study received sufficient decompression for the nerves during the operation.

Decompression was not the only factor that would influence the therapy effect. The clinical outcome of surgical treatment was correlated with the sagittal alignment of the spine [10, 31–33]. Once, the PLF was the gold standard for the treatment of the isthmic spondylolisthesis. Although studies showed no difference could be found in the short-term clinical outcome between the PLF and PLIF, the advantage of the PLIF had made itself more and more popular [14–16]. Our study described the effect of the PLF and PLIF on the spinopelvic alignment, to compare PLF with PLIF.

We reported that the postoperative PT after the PLIF operation would decrease [17]. Lafage and Kim’s studies [34, 35] reported the improvement of PT had correlation with health-related quality of life. PT was highly correlated with patient self-reported function (Oswestry Disability Index, 12-Item Short Form Health Survey, and Scoliosis Research Society Questionnaire) [25, 34, 35]. Several studies proved the postoperative low back pain was correlated with abnormal PT [22, 36]. In this study, we found the PT of the patients with isthmic spondylolisthesis decreased after the PLF. Both operations could reduce the PT. After the operation, there were no differences in PT among the PLF, PLIF, and control groups. The PT of the patients had been restored to the physiologic status after the surgery. We speculated the same PT may be one of the reasons for the same surgical outcome of PLF and PLIF. More work needs to be done to prove our hypothesis.

The LL of the PLF and PLIF groups changed differently in this study. This may be the most important difference between the two operations. There was no doubt that LL played an important role in sagittal balance. The LL would decrease with the increasing age, which would lead the C7 plumb line forward [37, 38]. Gottfried et al. [39] reported the LL would decrease after the PLF operation, the muscle of the back had to suffer the extra burden. Research also showed low LL was correlated with low back pain [40].

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The relationship between the SS and LL was detailed in previous studies; the LL was strongly correlated to the SS (r = 0.86) [4, 41]. There were two different formulas of theoretically ideal LL. The formula described by Schwab et al. [25] was $LL = PI + 9^\circ$, the other formula described by Lafage et al. was $LL = ([PI \times 0.5481 + 12.7] \times 1.087 + 21.61)$. 

Table 6
Correlation between the change of spinopelvic parameters and the deformity parameters in the PLF group

<table>
<thead>
<tr>
<th>Deformity parameters/pelvic parameters</th>
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HOD, height of the intervertebral disc; LL, lumbar lordosis; LSA, lumbo-sacral angle; L5I, lumbar 5 incidence; PLIF, posterolateral fusion; PT, pelvic tilt; SD, slip degree.

Statistically significant correlation coefficient (p < .05).
The SS increased in both operation groups. According to the change of SS, the ideal LL should increase. Kepler et al. [43] evaluated the surgical outcome with a visual analog scale; they found the patients with low LL had more probability to suffer low back pain.

The PLIF increased LL in this study, which meant the patients in the PLIF group may have better sagittal balance. Although no significant differences can be found between the postoperative LL of the PLF group and the LL of the control group, the postoperative LL may not be enough for the patients with spondylolisthesis. Boissiere et al. [44] described the LL index (ratio LL/PI). They suggested the LL index should be at least >0.5. The short-term clinical outcome of the PLF and PLIF were the same, but the follow-up time was only 2 years. We need a long period of follow-up for the surgical outcome of spondylolisthesis. The long-term efficacy of the two operations was still unknown, and the patients who received PLIF may get a better result.

In our study, the change of LL was correlated with the change of SD and HOD in the PLIF group, and negatively correlated with the change of SD in the PLF group. The reduction in the PLIF group would increase LL, on the contrary, the reduction would decrease LL. At the same time, the restoration of the HOD increased the LL. Park et al. [45] regarded the restoration of HOD as an important step in surgical treatment. They suggested the HOD should be restored without the damage of nerve root. This phenomenon indicated the importance of LL, and revealed the potential superiority of the PLIF operation.

After the operation, the L5I decreased significantly in the PLF and PLIF groups, but the postoperative L5I was still higher than in the control group. The relative position of the L5 and S1 was an important factor for surgical outcome [46]. After the fusion, the L5 and S1 united together as a new sacrum, the character of the L5I was the same as the PI. The reduction of the L5I would reduce the shearing force between the L4 and the L5, which was positive for avoiding adjacent segment degeneration.

Conclusion

There is no doubt that the sagittal spinopelvic parameters of the patients with spondylolisthesis would change significantly with surgical treatment. The decrease of PT may be an important factor for the short-term surgical outcome. The PLIF could increase the LL and form a more reasonable sagittal alignment. For patients with ischmic spondylolisthesis, the PLIF may be superior to the PLF in the reconstruction of sagittal spinopelvic balance.

References


