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Original Article

Spine-pelvis sagittal parameters and clinical efficacy before and after short-segment reduction and fusion surgery in patients with degenerative lumbar spondylolisthesis

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Abstract: Objective: To study the spine-pelvis sagittal parameters before and after surgery as well as the clinical efficacy in patients with degenerative lumbar spondylolisthesis (DLS). Methods: One hundred and two DLS patients admitted to the hospital underwent the short-segment (less than three segments) reduction and fusion surgery from January 2013 to January 2016 and received the follow-up. And the clinical results were retrospectively analyzed. The Japanese Orthopedics Association (JOA) score and visual analogue score (VAS) were respectively evaluated before surgery and at 1, 6 and 12 months post-surgery; patients' function improvements and pain relief conditions were digitalized and these patients were then divided into three groups (excellent group, good group and moderate and poor group) according to the clinical efficacy. The spine-pelvis sagittal parameters before surgery and at 1, 6 and 12 months post-surgery in 102 patients measured with the whole spine lateral side X-ray photograph in standing position were recorded and compared, including the changes of lumbar lordosis (LL), sacral slope (SS), pelvic tilt (PT), pelvic incidence (PI) and sagittal vertical axis (SVA). Results: Among the 102 patients, in terms of the evaluation about clinical efficacy, there were 79 excellent cases, 11 good cases, 7 moderate cases and 5 poor cases, and the excellent and good rate reached 88.20%. The comparisons of general data before surgery among the three groups (excellent group, good group, moderate and poor group) were not statistically significant (all $P>0.05$). And with respect to the parameters including PI, PT, SS, LL and SVA in all the patients, there was no statistically significant difference between the data before and at 1 month post-surgery (all $P>0.05$). However, when compared with the parameters before surgery, those at 6 and 12 months post-surgery were decreased (all $P<0.05$). Moreover, when compared the JOA and VAS scores before surgery with those at each observation time point after surgery, there were statistically significant differences (all $P<0.05$), and with statistically significant differences at 1, 6 and 12 months post-surgery. Conclusion: The short-segment reduction and fusion surgery can significantly improve the clinical symptoms of DLS patients and the spine-pelvis parameters.

Keywords: Degenerative lumbar spondylolisthesis, reduction and fusion surgery, spine-pelvis sagittal parameters, Japanese Orthopedics Association score, visual analogue score

Introduction

Degenerative lumbar spondylolisthesis (DLS), occurring more frequently in people over 40 years old, refers to the forward movement of upper vertebra relative to the next vertebra, which usually affects the fourth and fifth lumbar vertebra. As China has gradually become an aging society, the incidence of DLS increases by degrees, which is one of the common causes of low back and leg pain in middle-aged and elderly people [1]. Currently, the reduction and fusion surgery is the gold standard for the treatment of DLS [2]. The auto-regulations of spine and peripheral muscles are closely related to the changes of spine-pelvis parameters in DLS patients after surgery. In this study, we retrospectively analyzed the imaging data of 102 DLS patients to observe the correlation between the pre-surgical and postsurgical changes of spine-pelvis sagittal parameters and the improvement degrees of postsurgical clinical symptoms in elderly patients with DLS.

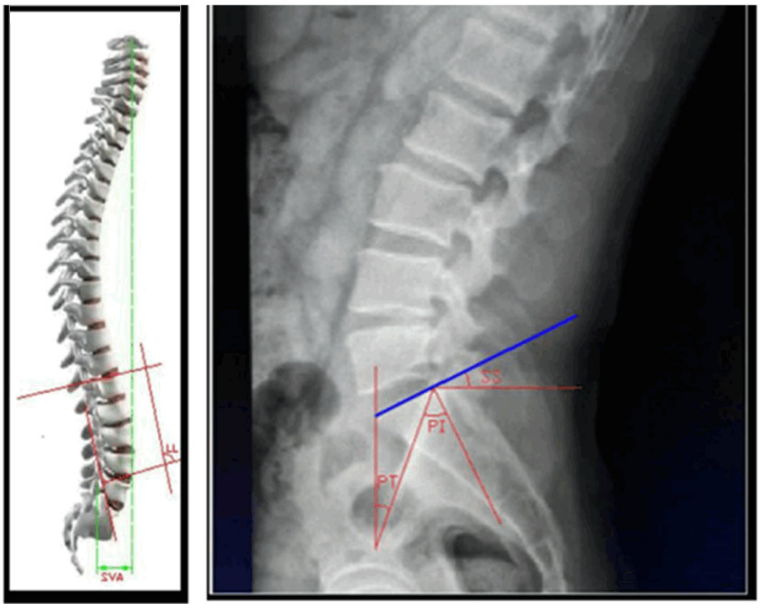


Figure 1. The measurement on PI, PT, SS and SS, SVA.

Clinical data

General data

The included 102 DLS patients aged from 32 to 75 years old (52±28 years old, 67 males and 35 females) admitted to the hospital from January 2013 to January 2016, underwent the short-segment (less than 3 segments) reduction and fusion surgery and received postsurgical follow-up. Among them, there were 74 cases of single segmental spondylolisthesis, 21 cases of double-segmental spondylolisthesis and 7 cases of three-segmental spondylolisthesis.

Inclusion criteria

Patients aged from 30 to 80 years old, with completed clinical data, conformed to the diagnostic criteria of DLS described in the *Applied Orthopaedics and Fractures* [3], with less than three diseased segments and completed follow-up records which lasted no less than half a year met the requirement of this study.

Exclusion criteria

Patients had the history of spinal surgery; patients complicated with lumbar spondylolysis or isthmic spondylolisthesis [4]; patients suffered from concurrent pelvic lesions, discrepancy in length of both lower extremities and other malformations; patients complicated with metabolic bone disease, infectious diseases, tumor and other diseases; patients had the medical history of idiopathic or degenerative scoliosis; patients were difficult to bear surgeries.

Information extraction

General information of patients (gender, age, basic health status, injured area, time form injury to surgery, etc.) were extracted. Before and after surgery, patients' pelvis sagittal parameters were measured and the Japanese Orthopedics Association (JOA) and VAS scores were also recorded.

Measurement of pelvis sagittal parameters

At each observation time point before and after surgery, the lateral full spine X-ray radiographs were shot in standing position in patients. And the lumbar lordosis (LL), sacral slope (SS), pelvic tilt (PT), pelvic incidence (PI) and sagittal vertical axis (SVA) were measured on the X-ray radiographs. See **Figure 1**. All the imageological findings were measured and processed by the Surgimap Spine software [5].

JOA and VAS scores in patients before surgery and at 1, 6 and 12 months post-surgery

JOA, as a 29 points scoring system for low back pain, can estimate patients' subjective pain degree [6]. It ranges from 0 to 29, scores less than 10 points regarded as poor, 10-15 as moderate, 16-24 as good and 25-29 excellent. VAS scoring system applies a vernier gauge with the length of ten centimeters on which "0" to "10" rating scales are marked to present "1-10" degrees. Zero means painless; 1 to 3 points indicate mild pain; 4 to 6 show moderate pain; 7 to 9 present severe pain and 10 expresses extreme pain. The higher the number, the more severe the degree of pain will be [7]. During the measurement of this study, patients were clearly informed of the scoring standard, and were required to find their own pain degrees on the scale and marked. After

Table 1. Patients' general data among three groups

Groups	Spondylolysis classification (first stage/second stage)	Spondylolysis segments (2/3)	Gender (males/females)	Age (years old)
Excellent group	31/48	42/37	49/30	52±28
Good group	7/4	6/5	9/2	49±30
Moderate and poor group	7/5	4/8	9/3	56±21
P	0.928	0.391	0.092	0.163

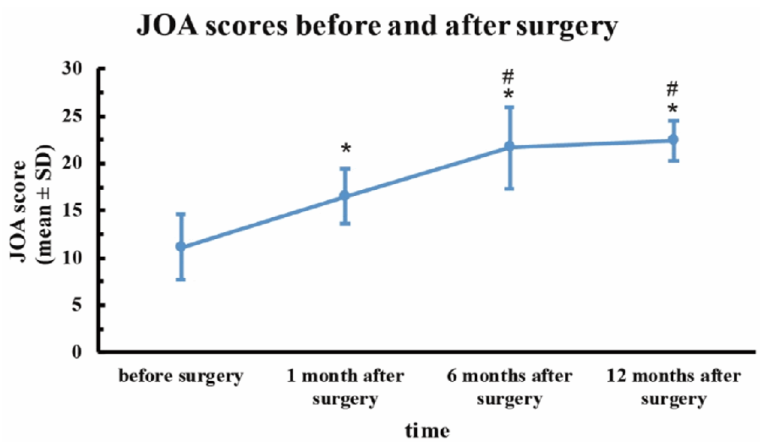


Figure 2. Changes of JOA scores at each observation time point before and after surgery. Compared with scores before surgery, *P<0.05; compared with scores 1 month after surgery, #P<0.05.

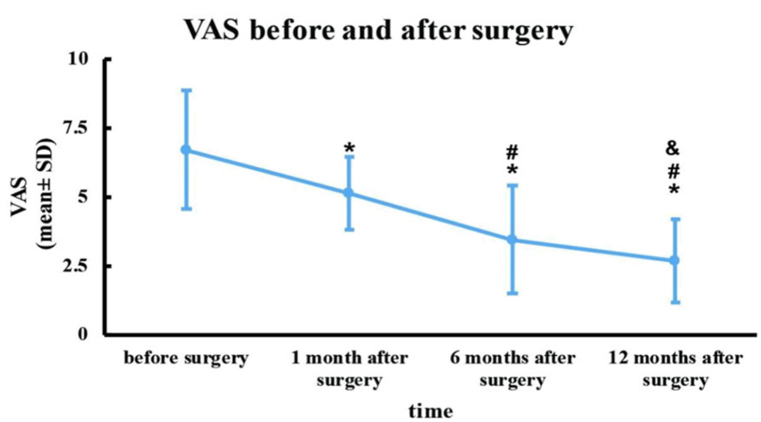


Figure 3. Gradually decrease of VAS scores at each observation time point before and after surgery. Compared with scores before surgery, *P<0.05; compared with scores 1 month after surgery, #P<0.05; compared with scores 6 months after surgery, &P<0.05.

that, physicians should score according to patients' marked locations.

Grouping according to therapeutic effects

The experimental subjects were divided into three groups (excellent group, good group, moderate and poor group) according to the patients' JOA scores 12 months after surgery. Patients scored from 25 to 29 points were classified as excellent group, 16 to 24 as good group and 0 to 15 as moderate and poor group.

Main observation indexes

The main observation indexes were the excellent and good rates of surgical treatment, changes of JOA and VAS scores before and after surgery and changes of the spine-pelvis sagittal parameters.

Statistical analysis

SPSS19.0 statistical software was used to analyze the obtained data statistically. The measurement data were expressed by mean ± standard deviation. When excellent group, good group and moderate and poor group were compared, the testing was done with the analysis of variance and post testing with the Bonferroni. And comparisons before and after treatment in single groups were conducted by using the paired t-test. The significant level was $\alpha=0.05$.

Results

Comparison of patients' general data among three groups before surgery

Before surgery, there were no statistically significant differences in the comparison of gen-

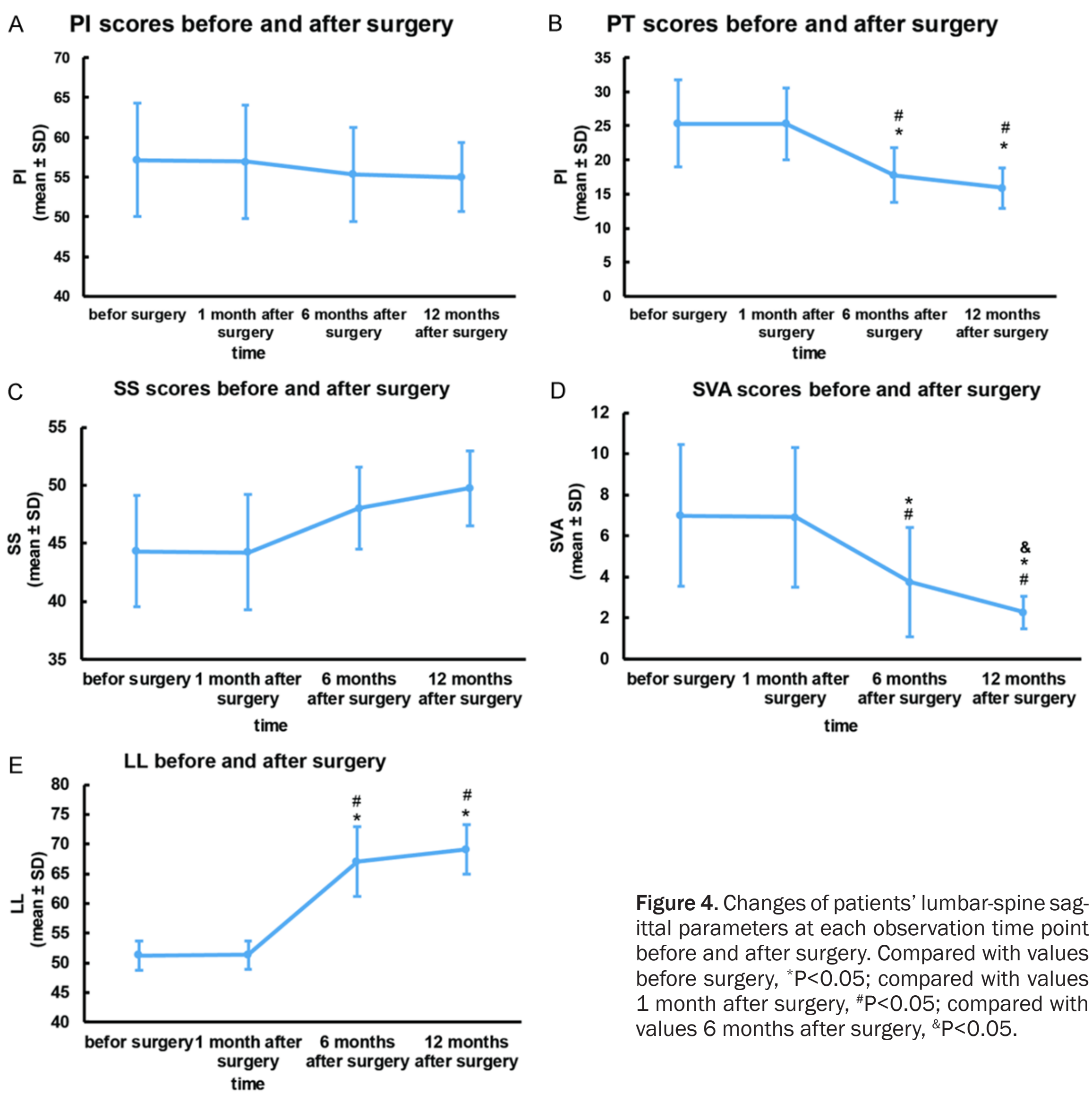


Figure 4. Changes of patients' lumbar-spine sagittal parameters at each observation time point before and after surgery. Compared with values before surgery, *P<0.05; compared with values 1 month after surgery, #P<0.05; compared with values 6 months after surgery, &P<0.05.

eral data including gender, age and spondylolysis classification in patients among three groups. And these general data were comparable (P>0.05). See **Table 1**.

Changes of JOA scores in 102 patients after surgical treatment

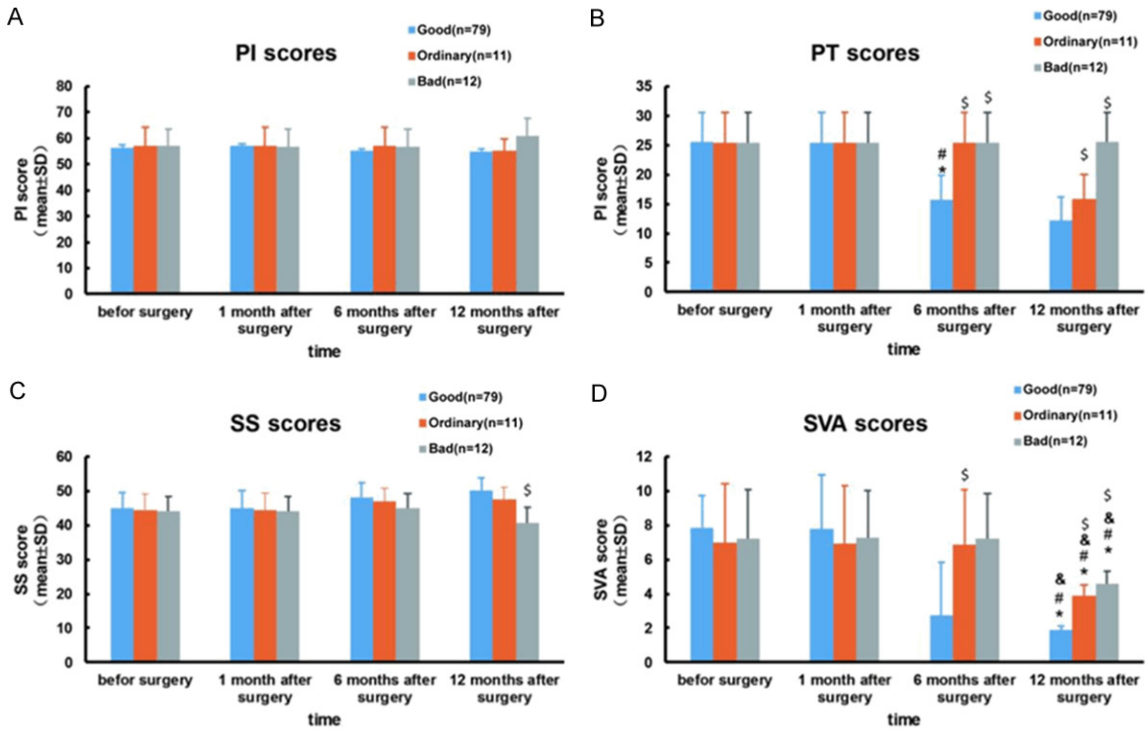
The JOA scores at each observation time point were compared before and after surgery in 102 patients, with statistical significance. (all P<0.05); comparisons among at 6 and 12 months post-surgery and1 month post-surgery were significant (P=0.023, P=0.097). See **Figure 2**.

Changes of VAS scores in 102 patients after surgical treatment

The VAS scores at each observation time point was compared before and after surgery in 102 patients, with statistical significance (P=0.019, P=0.017). See **Figure 3**.

Changes of spine-pelvis sagittal parameters in 102 patients at each observation time point before and after surgery

The spine-pelvis sagittal parameters at each observation time point were compared before and after surgery in 102 patients. The compari-



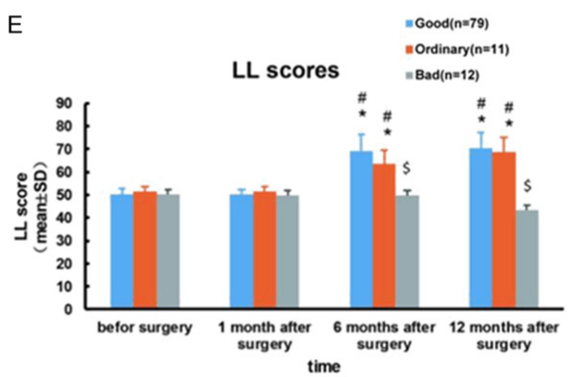


Figure 5. Changes of sagittal parameters at each observation time point before and after surgery in three groups. When compared the values 1 month after surgery with those before surgery, there were no significant differences; when compared the values 6 and 12 months after surgery with those before surgery, there were statistically significant differences; compared with values before surgery in the same group, *P<0.05; compared with values 1 month after surgery in the same group, #P<0.05; compared with values 6 months after surgery in the same group, &P<0.05; compared with excellent group, $P<0.05.

son results were presented as follows: the PI values at each observation time point before and after surgery were approaching with no statistically difference (P=0.092) (**Figure 4A**); the PT value at 1 month post-surgery was compared with that before surgery without statistically significant difference (P=0.172), but the PT values at 6 and 12 months post-surgery were decreased than those before surgery with statistically significant differences (P=0.018 and 0.014 respectively) (**Figure 4B**); the SS values at each observation time point before and after surgery were close and there were no statistically significant differences (P=0.374, P=0.197 and P=0.069 respectively) (**Figure 4C**); the SVA value at 1 month post-surgery was compared with that before surgery and the difference was not statistically significant (P=0.272), but the SVA values at 6 and 12 months post-surgery were decreased than those before surgery and there were statistically significant differences (P=0.015 and P=0.029 respectively), and the SVA value at 12 months post-surgery was lower than that at 6 months post-surgery, indicating statistically significant differences (P=0.042) (**Figure 4D**); the LL value at 1 month post-surgery was compared with that before surgery and the difference was not statistically significant (P=0.398), but were increased at 6 months and 12 months post-surgery and the differences were statistically significant (P=0.023 and P=0.042 respectively) (**Figure 4E**).

Parameters including PI, PT, SS, LL and SVA

The results of grouping analysis demonstrated that the improvement of parameters such as

PT and SVA in excellent group were better and earlier than those in good group and moderate and poor group. The PI values at each observation time point before and after surgery in three groups were close and there was no statistically significant difference (P=0.092, P=0.073, P=0.089 respectively) (**Figure 5A**). In the excellent group, the PT values at 6 months post-surgery were compared with those before surgery and at 1 month post-surgery, showing that differences reached statistically significance (P=0.039 and P=0.024 respectively); at 6 months post-surgery, the comparison of PT values between excellent group and good group and moderate and poor group manifested that the differences were statistically significant (P=0.008 and 0.028 respectively); at 12 months post-surgery, the comparison of PT value between moderate and poor group and excellent group showed that the difference was statistically significant (P=0.041) (**Figure 5B**). At 12 months post-surgery, when compared the SS value in moderate and poor group with that in excellent group, there was found statistically significant difference (P=0.031, P=0.039, P=0.027 respectively) (**Figure 5C**). At 6 months post-surgery, there was statistically significant difference in SVA values between the good group and excellent group (P=0.019), and when compared the SVA values at 12 months post-surgery with those before surgery in three groups, we could conclude that all the differences were statistically significant (P=0.017, P=0.008 and P=0.023 respectively); at 12 months post-surgery, the SVA values in good group and moderate and poor group were compared with those in excellent group, and the differences were statistically significant (P=0.041 and 0.001 respectively) (**Figure 5D**). When compared the LL values at 6 months post-surgery with those before surgery in three groups, we obtained that all the differences were statistically significant (P=0.003, P=0.036 and P=0.047 respectively). Moreover, the LL values at 6 months post-surgery were compared with those at 1month post-surgery in three groups, and the comparison results confirmed that all the differences reached statistically significance (P=0.040, P=0.029 and P=0.031 respectively). Besides, at 6 months post-surgery, the LL value in moderate and poor group was compared with that in excellent group, and the results displayed that the difference was statistically significant (P=0.026). And it was obvious that all the differences were statistically significant when compared the LL values at 12 months post-surgery in three groups with those before surgery (P=0.022, P=0.032 and P=0.006 respectively). In addition, when compared the LL values at 12 months post-surgery in three groups with those at 1 month post-surgery, we found statistically significant differences (P=0.031, P=0.011 and P=0.042 respectively). At 12 months post-surgery, the comparison of LL value between moderate and poor group and excellent group attested that there was statistically significant difference (P=0.017) (**Figure 5E**).

Discussion

As a common disease in spine surgery, lumbar spondylolisthesis can be divided into five categories, including pathological, traumatic, degenerative, isthmic and hypoplastic, among which the DLS is more common in middle-aged and elderly women [8]. And as China has gradually become an aging society, the cases of lumbar and leg pain caused by DLS are growing. The lumbar degenerative lesions are often accompanied by the lumbar spondylolisthesis, scoliosis or instability, and the spine-pelvic sagittal parameters may have a change due to the spondylolisthesis [9]. According to the changes in human standing posture, the spine-pelvic sagittal position will keep balance in the continuous adjustment. But the spine-pelvic sagittal position will lose its balance when the conditions of DLS patients become worse. And in order to adapt to such changes, the body has to continue the spine-pelvic compensation constantly [10]. The posterior pelvic rotation is the only compensatory way of the pelvis. The hyperextension of the hip joint makes the pelvis present a horizontal position and also makes the femoral head in front of the sacral plateau, so as to compensate for the body anteversion caused by the lumbar lordosis [11]. The ability of posterior pelvic rotation is determined by the PI. As the rise of PI value, the space of the posterior pelvic rotation will be enlarged and the risk of spondylolisthesis will also increase [12]. The compensatory degree of pelvis is reflected by the PI value, and the two are positively correlated [13]. The measurement of PI values in healthy volunteers manifested that the PI values in normal and healthy people were lower [14]. If the PI value is too high, it may manifest the pelvis overcompensation and cause the lumbosacral pain [15]. The SS values are used to reveal the condition of sacrum anteversion which is negatively correlated with the posterior pelvis rotation. Generally, the SS value will relatively reduce if the range of the posterior pelvic tilt becomes greater [16]. In this retrospective analysis, the PI and SS values in excellent group and good group were significantly improved, and the improvement of values in excellent group was better than those in good group. A study has shown that the rise of PT values can help compensate for the uneven spines and correct the posterior pelvic tilt. But the lumbago will be aggravated and the quality of life will be declined after the increase of PT [17]. Therefore, reducing the PT values can improve the clinical efficacy of patients.

The analysis about the results of this retrospective analysis was presented as follows. JOA and VAS scores at 1 month post-surgery were compared with those before surgery and there were statistically significant differences; JOA and VAS scores at each post-surgical observation time point were also compared with those before surgery and the differences were statistically significant. For patients with unbalanced lumbar spondylolisthesis, the reduction and fusion surgery was helpful to correct the spine-pelvic sagittal parameters (PI, PT, SS, SVA and LL) closer to the normal range, and the balance of spine-pelvic sagittal parameters would be gradually improved to achieve the satisfactory clinical efficacy by the regulating effects of muscles and ligaments around the spine after surgery [18].

In addition, JOA, VAS scores and SVA values in excellent and good groups were declined when compared with those before surgery and the decline degree in excellent group was obviously greater than that in good group, which revealed that the surgical efficacy would be better if the parameters of spine-pelvic sagittal could be corrected and be closer to the normal range of physiological value. Treating the DLS with the reduction and fusion surgery and correcting the spine-pelvic sagittal parameters to the normal physiological values could reduce the pain degree of patients and meanwhile improve their qualities of life [19]. In this retrospective analysis, the PI, and PT values in excellent group and good group were decreased when compared with those before surgery while the LL and SS values were increased, which were conducive to improve the pelvic sagittal balance of patients with DLS, thereby greatly improving the postsurgical degree of spondylolisthesis and the quality of life in patients [20].

To sum up, the changes of the parameters in this experiment indicate that the reduction and fusion surgery have positive significance on correcting the spine-pelvic sagittal parameters, reducing the occurrence of degenerative lesions and improving the quality of life in excellent and good group.

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Disclosure of conflict of interest

None.

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