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บทความต้นฉบับ/Original Article

# The Percentage of Postoperative Slip Reduction in Single Level Low-Grade Lumbar Spondylolisthesis Impact on Clinical, Radiologic Outcome and Complication

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## Abstract

**Introduction:** Reduction of spondylolisthesis is intended to restore the original morphology of the spinal canal, foramina, and alignment, potentially leading to neural decompression and reduced shear forces on the spine. However, the optimal extent of reduction during surgical management remains debated due to concerns about complications, particularly neurological deficits. This study aimed to evaluate the correlation between the postoperative slip reduction (Total or partial reduction) in 1 level spondylolisthesis and clinical outcomes, radiologic outcomes, and complications.

**Methods:** We conducted a retrospective analysis of 98 patients who underwent single-level trans-foraminal lumbar interbody fusion or posterior lumbar interbody fusion with or without polyetheretherketone (TLIF/PLIF ± PEEK) with intraoperative reduction in low-grade spondylolisthesis at the Neurological institute of Thailand between 2015 and 2020. Patients were divided into a total reduction group (n = 64) and a partial reduction group (n = 34). Both groups were followed for over 24 months, and outcomes were compared.

**Results:** Surgical complications were similar across both groups, with no statistically significant differences ( $p > 0.05$ ) in postoperative motor deficits, adjacent segment disease, pseudarthrosis, intraoperative blood loss, length of hospital stay, infection rates, or dural tears. The only significant difference noted was in operative time, which was longer in the partial reduction group. Postoperative spinal MRI findings showed no significant differences in disc or facet degeneration between the groups.

However, there was a trend toward reduced pseudarthrosis and adjacent segment disease, as well as slower degeneration of facet joints and discs in the total reduction group, although these findings did not reach statistical significance, likely due to insufficient follow-up duration.

**Conclusion:** Total reduction does not lead to better outcomes than partial reduction. However, it also does not increase the rate of complications. Total reduction of spondylolisthesis potentially improves fusion rates, reduces adjacent segment disease, slows facet and disc degeneration, although this difference was not statistically significant.

**Keywords:** Slip reduction, Low-grade spondylolisthesis, Lumbar interbody fusion, Clinical outcome, Radiographic outcome.

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## บทคัดย่อ

**ความเป็นมา:** การแก้ไขการเคลื่อนของกระดูกสันหลังในผู้ป่วยโรคกระดูกสันหลังเคลื่อน มีวัตถุประสงค์เพื่อปรับโครงสร้างของช่องไขสันหลัง ช่องเส้นประสาท และแนวกระดูกให้ใกล้เคียงปกติ ซึ่งช่วยลดแรงเฉือนที่กระทำต่อกระดูกสันหลังและลดการกดทับเส้นประสาท อย่างไรก็ตามระดับการแก้ไขที่เหมาะสมในระหว่างผ่าตัดยังเป็นที่ยกเถียงกันอยู่ เนื่องจากมีความกังวลเกี่ยวกับภาวะแทรกซ้อนทางระบบประสาทและทางศัลยกรรม งานวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาความสัมพันธ์ระหว่างการแก้ไขการเคลื่อนของกระดูกสันหลังหลังผ่าตัดในผู้ป่วยโรคกระดูกสันหลังเคลื่อนระดับเอวกับผลลัพธ์ทางคลินิก ภาพถ่ายรังสีและภาวะแทรกซ้อน

**วิธีการดำเนินการวิจัย:** ทำการศึกษาแบบย้อนหลัง (retrospective study) ในผู้ป่วยจำนวน 98 ราย ที่เข้ารับการผ่าตัดเชื่อมกระดูกสันหลังระดับเดียวด้วยวิธี transforaminal lumbar interbody fusion หรือ posterior lumbar interbody fusion และมีการแก้ไขระดับการเคลื่อนในระหว่างการผ่าตัด ในผู้ป่วยโรคกระดูกสันหลังเคลื่อนระดับเอวที่สถาบันประสาทวิทยา ระหว่างปี พ.ศ. 2558-2563 โดยแบ่งออกเป็น 2 กลุ่ม คือกลุ่มที่ได้รับการแก้ไขจนปกติ (total reduction) จำนวน 64 ราย และกลุ่มที่มีการแก้ไขบางส่วน (partial reduction) จำนวน 34 ราย โดยทั้งสองกลุ่มได้รับการติดตามมากกว่า 24 เดือน และนำข้อมูลทางคลินิก ภาพถ่ายรังสี และภาวะแทรกซ้อนมาเปรียบเทียบกัน

**ผลการวิจัย:** อัตราการเกิดภาวะแทรกซ้อนไม่แตกต่างกันอย่างมีนัยสำคัญทางสถิติระหว่างสองกลุ่ม ไม่ว่าจะเป็นภาวะแทรกซ้อนทางระบบประสาท โรคข้อกระดูกสันหลังระดับข้างเคียงเสื่อม (adjacent segment disease) ภาวะกระดูกไม่ติด การเสียเลือดระหว่างผ่าตัด ระยะเวลาอนโรพยาบาล การติดเชื้อ หรือการฉีกขาดของเยื่อหุ้มไขสันหลัง ความแตกต่างที่พบอย่างมีนัยสำคัญทางสถิติเพียงอย่างเดียวคือ ระยะเวลาการผ่าตัดที่นานกว่าในกลุ่มที่มีการแก้ไขบางส่วน (partial reduction) ส่วนภาพถ่ายรังสีไม่พบความแตกต่างอย่างมีนัยสำคัญทางสถิติในเรื่องการเสื่อมของหมอนรองกระดูกหรือข้อต่อกระดูก อย่างไรก็ตามมีแนวโน้มที่กลุ่มที่ได้รับการแก้ไขจนปกติ (total reduction) เพิ่มอัตราการเชื่อมกระดูก ลดอัตราการเกิดโรคข้อกระดูกสันหลังระดับข้างเคียงเสื่อม (adjacent segment disease) รวมถึงการเสื่อมของข้อต่อกระดูกและหมอนรองกระดูกที่ซ้ำกว่า แม้ว่าไม่แตกต่างกันอย่างมีนัยสำคัญทางสถิติซึ่งอาจเป็นเพราะระยะเวลาติดตามผลที่ยังไม่เพียงพอ

**สรุป:** การแก้ไขการเคลื่อนของกระดูกสันหลังจนปกติ (total reduction) ไม่ทำให้ผลลัพธ์ทางคลินิกดีกว่าแบบบางส่วน (partial reduction) แต่ก็ไม่ได้เพิ่มภาวะแทรกซ้อนเช่นกัน อย่างไรก็ตาม การแก้ไขจนปกติ (total reduction) อาจช่วยเพิ่มอัตราการเชื่อมกระดูก ลดโรคข้อกระดูกสันหลังระดับข้างเคียงเสื่อม (adjacent segment disease) และชะลอการเสื่อมของข้อต่อและหมอนรองกระดูก แม้ผลดังกล่าวจะยังไม่มีความสำคัญทางสถิติ

**คำสำคัญ:** การแก้ไขความเคลื่อน, โรคกระดูกสันหลังเคลื่อนระดับเอว, การเชื่อมกระดูกสันหลัง, ผลลัพธ์ทางคลินิก, ผลการภาพถ่ายรังสี

## Background

Lumbar spondylolisthesis is a common spinal disorder in adults, affecting approximately 4-6% of the general population. The forward slipping of the upper vertebra typically leads to a decrease in lumbar lordosis, spinal canal stenosis, and foraminal stenosis, which can entrap nerve roots. Clinically, the presentation varies, ranging from mild to severe

symptoms of low back pain, with or without radiculopathy. Most patients with symptomatic spondylolisthesis can initially be managed conservatively with physical therapy, activity modification, and medications. However, when symptoms persist, surgical treatment has been shown to be superior to conservative approaches.

Reduction of spondylolisthesis can be ben-

eficial as it aims to restore the original morphology of the spinal canal, foramina, and alignment. This process can lead to decompression of neural structures and a decrease in shear forces on the spine<sup>1</sup>. However, the extent of reduction in operative management of spondylolisthesis remains controversial. Proponents argue that total reduction can improve spinal biomechanics—such as improve fusion, reducing adjacent segment disease and slowing the degeneration of facet joints and intervertebral discs and pain symptoms. On the other hand, opponents highlight the increased risk of neurological complications due to injury nerve roots during the reduction maneuver. Additionally, reduction may increase operative time, length of hospital stay, infection rates, and the risk of dural tears.

This study aimed to evaluate the correlation between the postoperative slip reduction (Total or partial reduction) in single level low-grade spondylolisthesis and clinical outcomes, radiologic outcomes, and complications.

## **Materials and Methods**

### **Patients**

A retrospective study was conducted on 98 patients who underwent single-level instrumented lumbar interbody fusion (TLIF/PLIF ± PEEK) with intraoperative reduction for low-grade spondylolisthesis, following at least 6 weeks of conservative therapy without improvement in clinical symptoms. The surgeries were performed by multiple surgeons at the Neurological institute of Thailand between 2015 and 2020.

### **Inclusion criteria:**

1. Single-level low grade lumbar spondylolisthesis
2. Treatment with lumbar interbody fusion (TLIF/PLIF) with intraoperative reduction
3. Clinical and radiological follow-up of at least 24 months

### **Exclusion criteria:**

1. Multi-level lumbar spondylolisthesis
2. Previous lumbar spine surgery
3. Local infection or malignancy
4. Motor weakness unrelated to spondylolisthesis

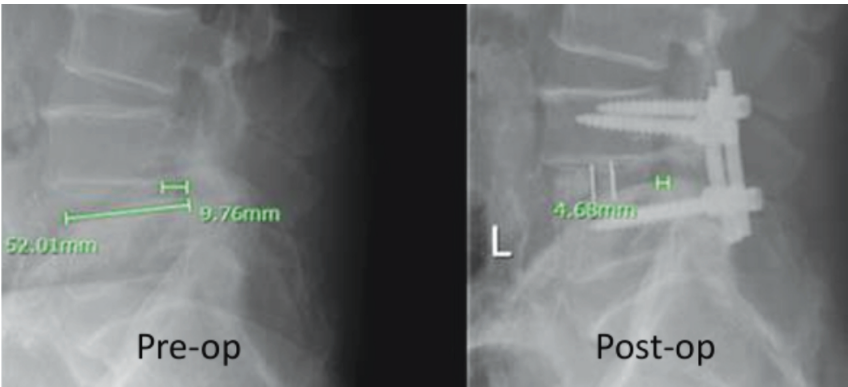
### **Evaluation of clinical, complication and radiological parameters**

Each patient was assigned a serial number according to their consecutive sequence of hospitalization and divided into two groups: the total reduction group, consisting of patients who had no visible spondylolisthesis on postoperative films, and the partial reduction group, consisting of patients who still had visible spondylolisthesis on postoperative films. All patients were followed for more than 24 months.

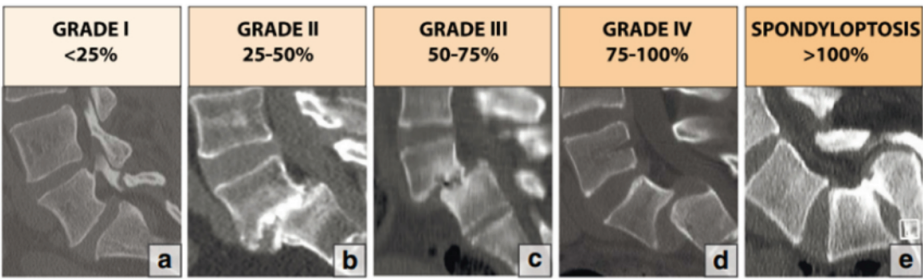
Clinical status was assessed by evaluating the muscle power grading of the spinal nerve root at the level of surgery both preoperatively and immediately postoperatively. Additional metrics included operative time (Minutes), intraoperative blood loss (Milliliters), and length of hospital stay (Day). Pseudarthrosis (symptomatic nonunion) was evaluated 1 year-post-operation with CT scan, while adjacent segment disease was assessed after more than 2 years.

Radiological parameters were measured by author both pre- and post-operatively. Plain films were used to assess spondylolisthesis and lumbar lordosis. Measurements included the extent of anterior displacement and vertebral body length (Anterior-posterior diameter), as well as the calculation of the percentage of slippage (Figure 1) and Meyerding classification (Figure 2). Segmental

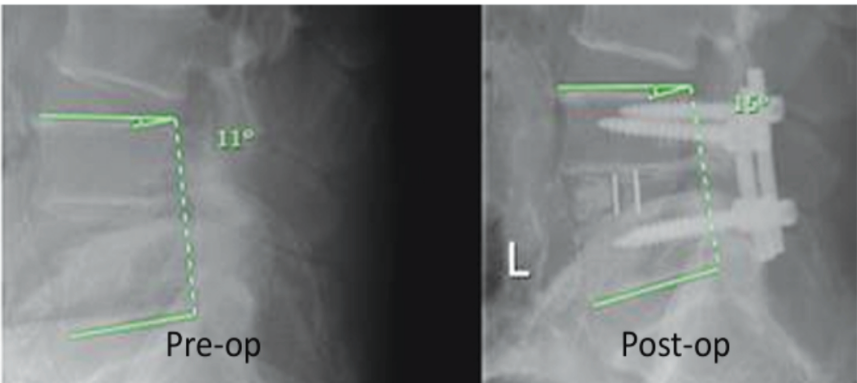
lumbar lordosis (Figure 3) was measured as the angle between the superior endplate of the superior vertebral body and the inferior endplate of the inferior vertebral body. For some patients, pre- and post-operative MRI of the lumbar spine was available to assess disc degeneration (Figure 4) and facet degeneration (Figure 5).



**Figure 1** Extent of anterior displacement 9.76 mm. Vertebral body length 52.01 mm. The pre-operative slip  $9.76/52.01 \times 100 = 18.77\%$ , Meyerding classification grade 1 (Left). The post-operative slip  $4.68/52.01 \times 100 = 9.00\%$  (Right). Percentage of slip reduction  $18.77-9.00 = 9.77\%$



**Figure 2** Meyerding classification2



**Figure 3** The pre-operative segmental lumbar lordosis 11 degree (Left). The post-operative segmental lumbar lordosis 15 degree (Right).






Grade I	Disc has a uniform high signal in the nucleus on T2.	
Grade II	Central horizontal line of low signal intensity.	
Grade III	High intensity in the central part of the nucleus with lower intensity in the peripheral regions of the nucleus.	
Grade IV	Low signal intensity centrally and blurring of the distinction between nucleus and annulus.	
Grade V	Homogeneous low signal with no distinction between nucleus and annulus.	

Figure 4 Grading system of intervertebral disk degeneration<sup>2</sup>

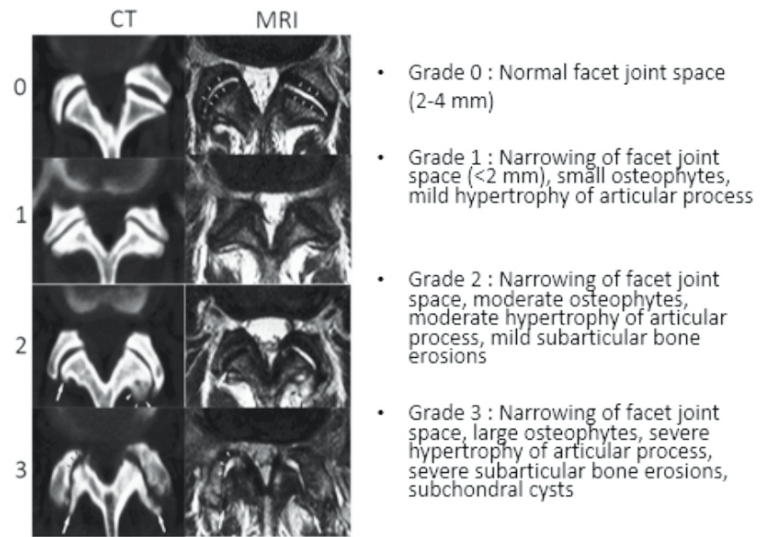


Figure 5 Grading system of facet joint degeneration<sup>3</sup>

Statistical analysis

Statistical calculations were performed using SPSS software (SPSS Inc., Chicago, ILLinois, USA). The correlation between the extent of reduction and operative time, blood loss, and hospital stay was analyzed using the Mann-Whitney U test. The

correlation between the extent of reduction and motor power deficits, adjacent segment degeneration, pseudarthrosis, infection, dural tears, facet joint degeneration, and disc degeneration was assessed using the chi-square test. p-values less than 0.05 were considered statistically significant.

Results

Demographics

The study population consisted of 98 patients, 34 patients in the partial reduction group and 64 patients in the total reduction group, mean follow up time 59.70 month. The mean age of 57.59 years at

the time of surgery. The most commonly affected spondylolisthesis segment was L4-L5 (84.7%), followed by L5-S1 (13.3%). The most common grade of spondylolisthesis was grade I (66.3%), followed by grade II (33.7%) (Table 1).

The mean percentage of slip reduction was

Table 1 Demographic data

Demographics	Percentage of slip reduction	
	Partial reduction	Total reduction
Total patient (%)	34 (34.7)	64 (65.3)
Male	9 (26.5)	24 (37.5)
Female	25 (73.5)	40 (62.5)
Mean age (Years)	59.41	56.63
BMI (Kg/M <sup>2</sup> )	26.70	26.20
Spondylolisthesis level (%)		
L2-3	1(2.9)	0
L3-4	0	1 (1.6)
L4-5	29 (85.3)	54 (84.4)
L5-S1	4 (11.8)	9 (14.1)
Grade of spondylolisthesis (%)		
Grade I	16 (47.1.8)	49 (76.6)
Grade II	18 (52.9)	15 (23.4)
Operative time (Minutes)	245.21	201.70
Blood loss (Milliliters)	427.65	414.22
Length of hospital stay (Day)	7.12	6.45
Radiological parameters		
Pre-operative slip %	23.88	18.50
Post-operative slip %	10.30	0
Slip reduction %	13.58	18.50
Length of reduction (Millimeters)	5.74	7.75
Pre-op lordosis (Degree)	1.32	4.94
Post-op lordosis (Degree)	5.41	12.11
Increase lumbar lordosis (Degree)	4.09	7.17



16.80%, with preoperative measurements at 20.37% significantly reduced to 3.57% after surgery. The mean length of reduction was 7.05 millimeters, with preoperative measurements at 8.56 millimeters significantly reduced to 1.52 millimeters postoperatively. The mean increase in lumbar lordosis was 6.10 degrees, with preoperative measurements at 3.68 degrees significantly increasing to 9.78 degrees after surgery.

The average operative time was 216.80 minutes, with 245.21 minutes in the partial reduction group and 201.70 minutes in the total reduction

group, showing a statistically significant difference between the two groups ( $p = 0.001$ ). The average blood loss during surgery was 418.88 milliliters, with 427.65 milliliters in the partial reduction group and 414.22 milliliters in the total reduction group, with no statistically significant difference between the two groups ( $p = 0.238$ ). The average length of hospital stay was 6.68 days, with 7.12 days in the partial reduction group and 6.45 days in the total reduction group, showing no statistically significant difference between the two groups ( $p = 0.349$ ). (Table 2)

Table 2 Clinical outcome and complication

Clinical outcome	Percentage of slip reduction		
	Partial reduction (%)	Total reduction (%)	p-value
Motor power deficit	3 (8.8)	5 (7.8)	0.290
Infection	1 (2.9)	1 (1.6)	0.458
Dural tear	1 (2.9)	1 (1.6)	0.458

Motor power deficits were observed in 3 patients in the partial reduction group and 5 patients in the total reduction group, with no statistically significant difference between the two groups ( $p$

$= 0.290$ ). All patients who experienced motor deficits regained normal motor power within 1 month postoperatively, with half of them recovering within the first week after surgery. (Table 3)

Table 3 Motor outcome and slip reduction

Motor power	Motor power deficit (N = 8)	Motor power intact (N =90)
Pre-operative slip %	21.87	20.23
Post-operative slip %	5.04	3.44
Slip reduction %	16.82	16.79
Length of Reduction (Millimeters)	6.91	7.06

Among the patients, 8 (8.16%) experienced motor power deficits. The average percentage of slip reduction was 16.82% in the motor power

deficit group and 16.79% in the no motor power deficit group, with no statistically significant difference between the two groups ( $p = 0.716$ ). The

average reduction in length was 6.91 mm in the motor power deficit group and 7.06 mm in the no motor power deficit group, also showing no statis-

tically significant difference between the groups ( $p= 0.938$ ). (Table 4)

Table 4 Adjacent segment disease and slip reduction

Adjacent segment disease	Adjacent (N = 14)	No Adjacent (N = 84)
Pre-operative slip %	16.15	21.07
Post-operative slip %	2.89	3.68
Slip reduction %	13.25	17.38
Length of Reduction (Millimeters)	5.57	7.29

In the study, 14 patients (14.28%) had adjacent segment degeneration, with no statistically significant difference between the groups ( $p = 0.136$ ). The average time to onset of adjacent segment degeneration was 43.93 months. Most cases, 9 patients (64%), involved the upper adjacent segment, and 1 patient in the partial reduction group required additional surgery. The average percentage of slip reduction was 13.25 in adjacent degeneration group and 17.38 in no adjacent degeneration group. Statistically was not significant difference between the two groups ( $p = 0.174$ ). The average reduction length was 5.57 mm. in adjacent degeneration group and 7.29 mm. in no adjacent degeneration group. Statistically was not significant difference between the two groups ( $p = 0.148$ ).

Although there was no statistical significance, it was observed that patients who did not experience

adjacent degeneration had a greater reduction in the percentage of slip and reduction length compared to those who developed adjacent degeneration.

Pseudarthrosis occurred in 2 patients in the partial reduction group and 1 patient in the total reduction group, with no statistically significant difference between the two groups ( $p = 0.236$ ). The patient was pseudarthrosis 3 (3.06%) patients in the study. The average percentage of slip reduction was 15.06 in pseudarthrosis group and 17.38 in fusion group. Statistically was not significant difference between the two groups ( $p = 0.829$ ). The average reduction length was 7.28 mm. in pseudarthrosis group and 7.05 mm. in fusion group. Statistically was not significant difference between the two groups ( $p = 0.749$ ). (Table 5)

Although there was no statistical significance,

Table 5 Pseudarthrosis and slip reduction

Fusion	Pseudarthrosis (N = 3)	Fusion (N = 95)
Pre-operative slip %	30.52	20.05
Post-operative slip %	15.46	3.68
Slip reduction %	15.06	16.85
Length of Reduction (Millimeters)	7.28	7.05



it was observed that patients who fusion had a lower post-operative percentage of slip compared to those who developed pseudarthrosis ( $p = 0.072$ ).

A total of 21 patients underwent spinal MRI due to new-onset back pain, and 7 of them were diagnosed with adjacent segment disease. All patients had L4-5 spondylolisthesis. The average time from post-operation to MRI was 57 months. The

study found no statistically significant difference in disc degeneration and facet degeneration between the two groups. However, disc degeneration and facet degeneration tended to be more prevalent in the partial reduction group compared to the total reduction group, although this difference was not statistically significant. (Table 6)

Table 6 MRI radiographic outcomes

Radiologic outcome	Percentage of slip reduction		p-value
	Partial reduction (N = 34)	Total reduction (N = 64)	
MRI patient	10	11	
Disc degeneration above (%)	4 (40)	1 (9.09)	0.149
Disc degeneration below (%)	5 (50)	4 (36.36)	0.670
Facet degeneration above (%)	4 (40)	3 (27.27)	0.361
Facet degeneration below (%)	5 (50)	3 (27.27)	0.670

Discussion

Lumbar spondylolisthesis is a common spinal condition, degenerative spondylolisthesis is especially common in individuals over 50 years of age, impacting about 4-6% of the general population. It is an acquired condition, meaning it develops over time, largely due to age-related degeneration of the spine. The Copenhagen Osteoarthritis Study found an incidence of 2.7% in males and 8.4% in females<sup>4</sup>. Clinically, the presentation varies, ranging from mild to severe symptoms of low back pain, with or without radiculopathy. Most patients with symptomatic spondylolisthesis can initially be managed conservatively with physical therapy, activity modification, and medications. However, when symptoms persist, surgical treatment has been shown to be superior to conservative ap-

proaches.<sup>4</sup> The Spine Patient Outcomes Research Trial (SPORT) 4 prospectively followed patients with degenerative spondylolisthesis for 2 and 4 years. Final as-treated analysis showed that patients who underwent surgery appeared to have statistically significantly better outcomes. Both pain and function were analyzed. The results were significant at both 2- and 4-year follow-up periods.

Recent advances in surgical techniques, Instrumented fusion many techniques have been developed to achieve stability and restore spinal alignment in degenerative spondylolisthesis by utilizing implanted instrumentation to promote bony fusion across previously mobile spinal elements. However, a major component of the pathology to be addressed involves collapse and slippage of ventral components of the spinal column, an

area that takes on about 80% of weight bearing but is unaddressed by posterolateral fusion alone. Therefore many strategies for restoring disk height and alignment by interbody fusion. This allows the surgeon to attain “360-degree fusion”, thus optimizing stability across a mobile segment of the spinal column<sup>7</sup>. Reduction of spondylolisthesis in patients with degenerative spondylolisthesis is more often grade I or II have suggested that restoration of lumbosacral alignment may result in better outcomes in degenerative spondylolisthesis. The optimal of slip reduction (Total or partial reduction) for managing low-grade spondylolisthesis is controversial. Total reduction has been linked to higher rates of postoperative neurological deficits, blood loss, operative time, hospital stay and other surgical complications compared to partial reduction. However, total reduction offers the advantage of correcting sagittal alignment at the lumbosacral junction, potentially enhancing fusion rates and reducing adjacent segment disease, as well as facet and disk degeneration, by minimizing shear forces. The authors conducted a retrospective study to investigate the clinical outcomes of patients who underwent interbody fusion with reduction for degenerative lumbar spondylolisthesis. They collected data on motor function, adjacent segment disease, blood loss, hospital stay, operative time, surgical complications, and radiologic outcomes. Patients were divided into two subgroups: total reduction and partial reduction groups, according to the restoration of anterior slippage on postoperative images. The strengths of the present study include a large sample size (N = 98) and a follow-up period of over 24 months (mean 59.70 months). The study focused solely on patients with low-

grade spondylolisthesis, all of whom underwent lumbar interbody fusion with reduction surgery. However, several limitations must be noted. First, the study involved multiple surgeons and interbody fusion techniques, as well as different types of spondylolisthesis, including both isthmic and degenerative origins. Additionally, all radiographic parameters were measured using plain lateral radiographs of the lumbar spine taken by the authors. Our analysis of pooled data indicated that total reduction did not lead to an increase in surgical complications, including motor deficits, operative time, hospital stay duration, infection rates, or the risk of dural tears when compared to partial reduction. Moreover, there was a trend toward reduced pseudarthrosis, adjacent segment disease, and slower degeneration of facet joints and discs, particularly in patients who achieved normal reduction, although these findings were not statistically significant. The only significant difference observed was in operative time, because in the group where total reduction was achieved, the surgery was performed by a senior surgeon.

Longo et al.<sup>8</sup> (2014) conducted a systematic review of eight studies comparing arthrodesis in situ and arthrodesis after reduction techniques in terms of clinical and radiographic outcomes and safety. Pseudarthrosis was observed in nine (5.5%) of the 165 patients in the reduction group compared to eighteen (17.8%) of the 101 patients in the arthrodesis in situ group ( $p = 0.004$ ). Other variables, such as neurologic deficits (7.9%), instrumentation failure (4.8%), deep wound infection (3.0%), and dural tears (0.6%), showed no statistically significant differences compared to arthrodesis in situ.

Zhan et al. (2021)<sup>9</sup> conducted a systematic

review and meta-analysis that included six cohort studies, all with Newcastle-Ottawa quality assessment scale (NOS) scores of 6 or higher. The study examined whether reduction or in-situ arthrodesis is the optimal choice for adolescent spondylolisthesis. No significant differences were found in operative time, blood loss, neurological complications, or total complications between the two approaches. However, patients undergoing reduction achieved better radiographic results: fusion rate ( $p = 0.02$ ), postoperative pseudarthrosis ( $p = 0.01$ ), percentage of slippage ( $p < 0.00001$ ), and slipping angle ( $p < 0.0001$ ).

In the present study of 98 patients, pseudarthrosis occurred in 3 cases (3.06%), a lower incidence compared to the findings of Longo et al. (2014). Other outcomes were similar, including neurologic deficits (8.16%)—which were temporary and resolved within four weeks—deep wound infections (2.04%), and dural tears (2.04%). According to the above research, the percentage of slip reduction, whether total, partial, or in-situ fusion, did not affect the complication rate. However, a key

advantage of reduction is its potential to decrease postoperative pseudarthrosis. It is believed that reduction of spondylolisthesis can be beneficial as it aims to restore the original sagittal alignment and morphology of the spinal canal, foramina, and alignment<sup>1</sup>. This process can lead to decompression of neural structures and a decrease in shear forces on the spine, potentially enhancing fusion rates and reducing adjacent segment disease, as well as facet and disk degeneration.

## Conclusion

In the treatment of symptomatic lumbar spondylolisthesis, we found total reduction does not lead to better outcomes than partial reduction, although this difference was not statistically significant. However, it also does not increase the rate of complications. Total reduction of spondylolisthesis potentially improves fusion rates, reduces adjacent segment disease, slows facet and disc degeneration by correcting local deformities by reducing vertebral slippage, which in turn decreases shear forces.

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