Clinical Study

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# Clinical and radiological outcomes of selective fusion for rotatory olisthesis in degenerative lumbar scoliosis: a retrospective cohort study

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**Study Design:** Retrospective cohort study.
**Purpose:** To investigate the long-term clinical and radiological outcomes of selective fusion for rotatory olisthesis (RO) in degenerative lumbar scoliosis (DLS).
**Overview of Literature:** DLS is often associated with RO, and selective fusion of RO is a common surgical treatment option. However, the clinical and radiological outcomes remain controversial.
**Methods:** A cohort of 54 consecutive patients with DLS and RO was included in the study. All the included patients underwent selective RO fusion and at least 2 years of follow-up. They were divided into two groups: group 1 with a curve <30° and group 2 with a curve ≥30°. The clinical outcomes were evaluated by the Oswestry Disability Index (ODI) and Numerical Rating Scale. The radiological assessment included RO location, offset and subluxated-disc orientation, Cobb angle, and coronal as well as sagittal alignments.
**Results:** The offset value was greater in group 2 than in group 1 (13.4±4.7 mm vs. 9.3±3.5 mm, $p<0.001$). The subluxated disc was mainly oriented to the concave side in group 2 (15/21) but to the convex side in group 1 (20/33) ($p=0.022$). Group 2 had a higher rate of postoperative adjacent RO than group 1 (14/21 vs. 1/33, $p<0.001$). The ODI was comparable between both groups preoperatively but higher at the final follow-up in group 2 (34.9±9.5) than in group 1 (24.4±6.2). In the multiple logistic regression analysis, the thoracolumbar/lumbar curve was identified as the risk factor for postoperative adjacent RO (odds ratio, 1.400; $p=0.007$). The receiver operating characteristic analysis verified it with an area under the curve of 0.960 ($p<0.001$).
**Conclusions:** The clinical and radiological outcomes were maintained well in group 1 but not in group 2. Selective RO fusion in DLS with a lumbar curve <30° is a rational option. However, it should be avoided in those with a lumbar curve >30° because of a higher complication rate and a worse clinical outcome at the final follow-up.

**Keywords:** Degenerative lumbar scoliosis; Rotatory olisthesis; Longtime outcome; Postoperative adjacent rotatory olisthesis

## Introduction

Degenerative lumbar scoliosis (DLS) has become a common disease in the older population with an incidence of 64% [1]. It is typically diagnosed in patients aged >40 years with a lumbar curve >10° [2]. The major curve progresses 1°–6° annually [3]. DLS mainly causes two types of problems: mechanical back pain and neurological symptom [4,5]. Mechanical back pain increases linearly with the degree of positive sagittal imbalance [6], and neurological symptoms are mainly caused by spinal stenosis. Schwab et al. [7,8] found that the curve magnitude and number of levels involved in the curve were unrelated to pain; however, pain was related to decreased lumbar lordosis, thoracolumbar kyphosis, and rotatory olisthesis (RO).

In the Schwab classification of adult scoliosis, RO is an important modifier that correlates with the surgery rate [9]. DLS is divided into three groups: 0, no subluxation; +, moderate subluxation 1–6 mm; and ++, marked sublocation >7 mm. The surgery rates were 36% and 52% in group 0 and group ++, respectively ($p$<0.001). Ploumis et al. [10] emphasized RO in their classification of DLS and described it as an important prognostic factor for back pain and curve deterioration. It is generated from asymmetric disc and facet degeneration, vertebral rotation, and rupture of the posterior ligament complex and disc anulus. They divided the RO into three grades: grade 2 (6–10 mm) and grade 3 (>11 mm), which are unstable and require selective fusion.

However, selective short fusion of RO in DLS cases remains controversial [11-13]. We reviewed all DLS cases to determine the long-term clinical and radiological outcomes of selective short fusion of the RO.

## Materials and Methods

In this retrospective cohort study, written informed consent was obtained from all participants, and ethical permission to conduct this retrospective study was obtained from the ethics committee of Shandong Provincial Hospital Affiliated to Shandong First Medical University (NSFC: No. 2022-811). In total, 135 degenerative scoliosis cases were enrolled between September 2009 and December 2020. Of these, 63 patients underwent selective fusion of the RO, and 72 underwent long fusion surgery. Of the 63 patients who underwent selective fusion of the RO, 54 were included in the study, and nine were excluded because of inadequate follow-up period or a history of lumbar spinal surgery. All 54 patients underwent selective segmental fusion of the RO by the same surgeon. The included cases were divided into two groups according to the magnitude of the major thoracolumbar/lumbar (TL/L) curve: group 1 with a TL/L Cobb angle <30° and group 2 with TL/L Cobb angle ≥30°.

The inclusion criteria were as follows [14]: DLS associated with RO, with a major TL/L curve over 10° according to the Cobb method, underwent selective segmental fusion of the RO, and at least 2 years of follow-up. The exclusion criteria were as follows [15]: a history of syndromic scoliosis, idiopathic scoliosis, or neuromuscular scoliosis; a history of prior lumbar spinal surgery; and spinal pathologies such as osteoporosis, vertebral fracture, infection, and tumor.

The standard demographic assessment included age, sex, and comorbidities. The clinical evaluation consisted of surgery information, patient self-assessment measures of health status, and pain assessment using the Oswestry Disability Index (ODI) [16] and Numerical Rating Scale (NRS) [17]. Complications and revision surgery rates were also recorded and reviewed.

Radiological evaluation was performed according to the established positioning protocol for anteroposterior and lateral 36-inch (91.44 cm) standing radiographs [18]. The coronal plane parameters included major and minor curve locations, curve magnitude by the Cobb angle, and coronal vertical axis (CVA). Information on RO included location, subluxated-disc orientation, and magnitude of offset. RO was defined as an intersegmental subluxation at both the frontal and rotational planes. The magnitude offset was measured at the maximum of the subluxation: the distance between a point (corner of the subluxated vertebrae) and the line of the lateral wall of the inferior vertebrae. The subluxated disc orientation was defined as the open side of the subluxated disc (recorded according to the convex or concave side of the main curve) (Fig. 1). The adjacent-segment RO was also measured on postoperative and follow-up anteroposterior and lateral full spine standing X-ray images. Sagittal plane parameters included pelvic incidence, pelvic tilt (PT), sacral slope, lumbar lordosis, thoracolumbar kyphosis, thoracic kyphosis, proximal thoracic kyphosis, cervical lordosis, and sagittal vertical axis (SVA). Lordosis was recorded as negative and kyphosis as positive. Radiological evaluation was performed using Surgimap (Nemaris Inc., New York, NY, USA).

Clinical and radiological evaluations were performed preoperatively, 2 weeks after surgery, and at the final follow-up. Two authors completed the evaluation procedure and statis-

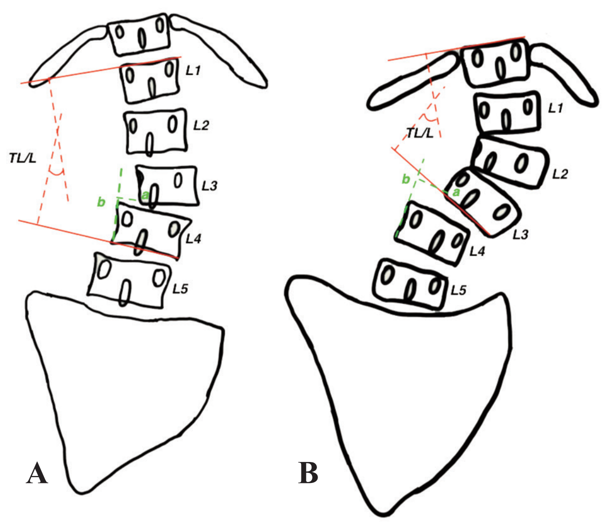


**Fig. 1.** This figure illustrates the measurement information of rotatory olisthesis, the location, subluxated disc orientation and the magnitude of offset. The offset magnitude was the perpendicular distance between the inferior corner of the subluxated vertebra (point a) and the tangential line of the lateral wall of the inferior vertebra. The orientation of the subluxated disc is defined as the open side of the subluxated disc, according to the convex side **(A)** or the concave side **(B)** of the main curve. TL/L, thoracolumbar/lumbar.

tical analysis as independent observers in a blinded manner. Quantitative results were compared between the two groups using an independent *t*-test, and descriptive results were compared using Pearson's chi-square test. Multivariate logistic and receiver operative characteristic (ROC) curve analyses were performed to identify the risk factors for adjacent RO. A *p*-value of <0.05 was considered statistically significant, and two-tailed tests were used in all analyses. The statistical calculations were performed using IBM SPSS Software ver. 29.0 (IBM Corp., Armonk, NY, USA).

**Table 1.** Demographic data and clinical information of the entire cohort

| Characteristic | Preoperative | Final follow-up |
|---|---|---|
| Age (yr) | 59.4±6.6 | - |
| Gender | | - |
| Female | 47 | |
| Male | 7 | |
| Neurological symptom | | |
| None | 12 | |
| TL/L curve concave side | 10 | - |
| TL/L curve convex side | 23 | - |
| Both side | 9 | - |
| Rotatory olisthesis | | |
| Value of offset (mm) | 10.8±4.5 | - |
| Location | | |
| L3/4 | 30 | - |
| L4/5 | 22 | |
| L2/3 | 2 | |
| Subluxated disc orientation | | |
| Concave side | 28 | - |
| Convex side | 26 | |
| Coronal vertical axis (mm) | 26.8±18.7 | 14.1±18.7 |
| Sagittal vertical axis (mm) | 28.0±49.5 | 11.5±36.4 |
| Oswestry Disability Index | 50.9±5.4 | 28.5±9.1 |
| Numerical Rating Scale | 5.6±1.3 | 2.4±1.4 |
| Complications | | |
| Surgical site infection | - | 4 |
| Postoperative adjacent rotatory olisthesis | - | 15 |

Values are presented as mean±standard deviation or number.
TL/L, thoracolumbar/lumbar.

## Results

Among all the 54 patients enrolled in the study, 47 were female and seven were male, and the mean age was 59±7 years (range, 42–72 years). Moreover, 42 out of 54 cases presented with severe motion- and activity-dependent neurological pain, of which 10 cases were on the concave side, 23 on the convex side, and nine on both sides. In addition, 12 of 54 cases had severe mechanical back pain. Neurological pain presented as radical nerve root pain or neurogenic claudication caused by either foraminal compression or central spinal stenosis. Mechanical back pain presented as lower back pain, often caused by the main curve, RO, muscle fatigue, or degenerated disc. The mean ODI and NRS scores were 50.9±5.4 and 5.6±1.3, respectively. The mean Cobb angle of the major TL/L curve was 28.6°±10.6°. The RO was located at L3/4 (30 out of 54), L4/5 (22 out of 54), and L2/3 only in two cases. The mean offset value was 10.8±4.5 mm. The subluxated disc was oriented to the convex side of the TL/L curve in 26 cases and to the concave side in 28 cases. The mean follow-up time was 4.5 years. Nineteen complications were recorded during follow-up, namely, four cases of surgical site infections and 15 cases of postoperative adjacent lateral olisthesis. No nonunion or pseudoarthrosis was observed in the follow-up (Table 1).

To determine the risk factors for postoperative adjacent RO, both monofactor analysis and multiple logistic regression analysis were performed. Cases with postoperative adjacent RO had a greater TL/L curve (40.7°±8.9°) than cases without adjacent RO (TL/L=23.9°±6.8°) before surgery. Preoperative PT was also different (28.6°±6.5° versus 22.4°±8.5°, *p*=0.024) between patients with and without postoperative adjacent RO (Table 2). In the multiple logistic regression analysis, the major TL/L curve was identified as the risk

**Table 2.** Comparison of radiological parameters between cases with or without postoperative adjacent rotatory olisthesis

| Radiograph parameters | Cases with adjacent rotatory olisthesis | Cases without adjacent rotatory olisthesis | *p*-value |
|---|---|---|---|
| Thoracic curve (°) | 12.4±7.7 | 20.1±10.8 | 0.003** |
| Thoracolumbar/lumbar curve (°) | 24.0±6.8 | 40.7±8.9 | <0.001** |
| Lumbosacral curve (°) | 12.7±8.1 | 19.6±5.7 | 0.004** |
| Rotatory olisthesis | | | |
| Value of offset (mm) | 10.5±4.6 | 11.9±4.2 | 0.313 |
| Location | | | 0.375 |
| L2/3 | 1 | 1 | |
| L3/4 | 20 | 10 | |
| L4/5 | 18 | 4 | |
| Subluxated disc orientation | | | 0.457 |
| Concave | 19 | 9 | |
| Convex | 20 | 6 | |
| Pelvic incidence (°) | 48.2±9.9 | 52.1±9.8 | 0.245 |
| Pelvic tilt (°) | 22.5±8.5 | 28.7±6.5 | 0.024* |
| Sacral slope (°) | 25.8±8.9 | 23.5±8.0 | 0.418 |
| Lumbar lordosis (°) | -31.2±15.3 | -28.5±10.9 | 0.565 |
| Thoracolumbar kyphosis (°) | 2.7±11.2 | 10.8±17.3 | 0.071 |
| Thoracic kyphosis (°) | 20.6±13.0 | 19.5±19.9 | 0.838 |
| Coronal vertical axis (mm) | 26.0±17.9 | 28.1±20.2 | 0.762 |
| Sagittal vertical axis (mm) | 31.7±51.7 | 19.2±44.3 | 0.452 |

Values are presented as mean±standard deviation or number.
*$p$<0.05. **$p$<0.01.

factor for adjacent RO (odds ratio [OR], 1.400; 95% confidence interval [CI], 1.095–1.791; $p$=0.007), as well as preoperative PT (OR, 1.104; 95% CI, 1.008–1.210; $p$=0.034) (Table 3). ROC curve analysis verified a TL/L curve as the risk factor, with an area under the curve (AUC) of 0.960 ($p$<0.001) and the optimal cutoff value of 32.5° yielded a sensitivity at 0.933 and specificity at 0.897 (Fig. 2).

According to the magnitude of the TL/L curve, groups 1 and 2 included 33 and 21 cases, respectively. Significant differences in age, sex, preoperative ODI, and NRS were observed between the two groups. The location of the RO was similar between the two groups ($p$=0.130). However, the subluxated-disc orientation was different between the two groups ($p$=0.022) and the offset value (9.26±3.48 mm in group 1 versus 13.40±4.71 mm in group 2, $p$=0.001). In group 1, 13 cases with the subluxated disc were oriented to the concave side of the TL/L curve and 20 cases to the convex side. In group 2, 15 cases were oriented to the concave

**Table 3.** Multiple various logistic regression analysis of risk factors for postoperative adjacent rotatory olisthesis

| Variable | OR (95% CI) | *p*-value |
|---|---|---|
| Thoracic curve | 1.101 (1.025–1.183) | 0.008** |
| Thoracolumbar/lumbar curve | 1.411 (1.154–1.725) | 0.001** |
| Lumbosacral curve | 1.123 (1.030–1.223) | 0.008** |
| Rotatory olisthesis | | |
| Value of offset | 1.071 (0.938–1.223) | 0.309 |
| Location | 2.250 (0.599–8.447) | 0.230 |
| Subluxated disc orientation | 1.579 (0.471–5.289) | 0.459 |
| Pelvic incidence | 1.041 (0.973–1.113) | 0.241 |
| Pelvic tilt | 1.104 (1.008–1.210) | 0.034* |
| Sacral slope | 0.969 (0.898–1.045) | 0.410 |
| Lumbar lordosis | 1.014 (0.968–1.062) | 0.557 |
| Thoracolumbar kyphosis | 1.052 (0.994–1.113) | 0.078 |
| Thoracic kyphosis | 0.995 (0.954–1.039) | 0.833 |
| Coronal vertical axis | 1.006 (0.969–1.044) | 0.754 |
| Sagittal vertical axis | 0.995 (0.981–1.009) | 0.444 |

OR, odds ratio; CI, confidence interval.
*$p$<0.05. **$p$<0.01.

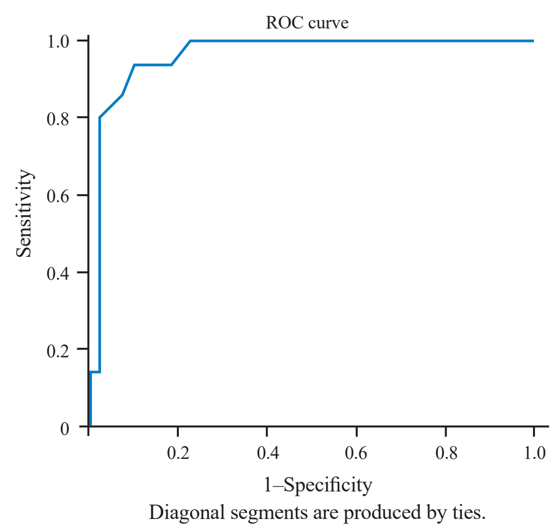


**Fig. 2.** The Receiver operating characteristics (ROC) curve analysis of risk factors of adjacent rotatory olisthesis. Area under ROC curve is 0.960 for thoracolumbar/lumbar (TL/L) curve ($p$=0.001).

side and six cases to the convex side ($p$=0.022) (Table 4). Postoperative adjacent RO occurred in one out of 33 cases in group 1 at the final follow-up but in 14 out of 21 cases in group 2 ($p$=0.000). CVA was similar between both groups (25.6±20.2 mm versus 27.7±17.6 mm, $p$=0.752) before surgery, but significantly different at the final follow-up (6.3±3.3 mm versus 19.2±22.7 mm, $p$=0.033). The ODI and NRS scores at the final follow-up were 24.4±6.16 and 1.87±1.02 in group 1 and 34.9±9.47 and 3.28±1.38 in group 2 ($p$<0.001).

**Table 4.** Comparison of clinical and radiological parameters between group 1 and 2

| Variable | Group 1 | Group 2 | *p*-value |
|---|---|---|---|
| Thoracic curve (°) | | | |
| Preoperative | 12.7±7.9 | 17.8±10.8 | 0.050* |
| Final follow-up | 10.7±9.9 | 21.5±11.0 | 0.017* |
| Thoracolumbar/lumbar curve (°) | | | |
| Preoperative | 21.9±4.6 | 39.2±8.2 | <0.001** |
| Final follow-up | 16.7±5.0 | 38.9±11.5 | <0.001** |
| Lumbosacral curve (°) | | | |
| Preoperative | 10.5±6.5 | 21.2±5.6 | <0.001** |
| Final follow-up | 6.2±5.1 | 18.3±6.5 | <0.001** |
| Rotatory olisthesis | | | |
| Value of offset (mm) | 9.3±3.5 | 13.4±4.7 | 0.001** |
| Location | | | 0.130 |
| L3/4 | 15 | 15 | |
| L4/5 | 17 | 5 | |
| L2/3 | 1 | 1 | |
| Subluxated disc orientation | | | 0.022* |
| Concave | 13 | 15 | |
| Convex | 20 | 6 | |
| Coronal vertical axis (mm) | | | |
| Preoperative | 25.6±20.2 | 27.7±17.6 | 0.752 |
| Final follow-up | 6.3±3.3 | 19.2±22.7 | 0.033* |
| Sagittal vertical axis (mm) | | | |
| Preoperative | 27.3±56.7 | 28.9±43.8 | 0.916 |
| Final follow-up | -5.8±36.8 | 24.4±31.3 | 0.027* |
| Pelvic incidence (°) | 47.4±10.5 | 51.2±8.9 | 0.152 |
| Pelvic tilt (°) | | | |
| Preoperative | 20.0±7.4 | 29.4±6.7 | 0.001** |
| Final follow-up | 17.5±6.7 | 24.8±6.9 | 0.015* |
| Sacral slope (°) | | | |
| Preoperative | 27.3±7.1 | 22.4±9.7 | 0.064 |
| Final follow-up | 29.3±5.9 | 26.4±11.1 | 0.374 |
| Lumbar lordosis (°) | | | |
| Preoperative | -34.9±11.4 | -24.9±15.3 | 0.021* |
| Final follow-up | -44.7±5.3 | -32.6±13.5 | 0.007* |
| Thoracic kyphosis (°) | | | |
| Preoperative | 22.8±12.0 | 17.3±18.1 | 0.231 |
| Final follow-up | 29.7±6.1 | 24.0±9.4 | 0.080 |
| Oswestry Disability Index | | | |
| Preoperative | 49.7±3.8 | 52.9±6.9 | 0.058 |
| Final follow-up | 24.4±6.2 | 34.9±9.5 | <0.001** |
| Numerical Rating Scale | | | |
| Preoperative | 5.4±1.1 | 6.0±1.5 | 0.090 |
| Final follow-up | 1.9±1.0 | 3.2±1.4 | 0.001** |
| Postoperative adjacent rotatory olisthesis | 1/32 | 14/21 | <0.001** |

Values are presented as mean±standard deviation or number.
*$p$<0.05. **$p$<0.01.

## Discussion

In DLS, RO is commonly located at the junctional region between the TL/L and lumbosacral curves, mainly at L3/4 and L4/5, with the subluxated disc oriented to the convex or concave side of the TL/L curve. It correlated with the magnitude of the TL/L curve with the subluxated disc oriented more often to the concave side in group 2 (15/21) and to the convex side in group 1 (20/33). RO caused spinal instability and stenosis, generating moderate to severe mechanical back pain, as well as motion- and activity-dependent neurological pain. Neurological pain might occur on either side or both sides.

RO also causes both coronal and sagittal imbalance [19], which is often shown by deranged CVA and SVA on standing full spine radiographs [20]. Typical imbalance symptoms include back pain, difficulty with ambulation, and inability to maintain a forward gaze when upright. Bridwell et al. [19] divided sagittal imbalance into two types according to etiology: segmental and global. The global etiology refers to global spinal malalignment. RO is considered a segmental etiology. A selective short fusion of RO has a good chance of relieving the imbalance and is maintained well at follow-up in group 1.

However, the clinical and radiological outcomes were not maintained well in group 2; the CVA, SVA, ODI, and NRS increased at the final follow-up. The large curve of DLS cases in group 2 led to moderate to severe global imbalance with large CVA and SVA. The severe global imbalance cannot be improved by stabilizing a local segment of the RO. Along with DLS progression, the CVA and SVA increased in the subsequent follow-up. The progressed DLS also caused moderate back pain, mechanical complications, and deteriorated clinical outcomes.

The complication of postoperative adjacent RO was another problem in group 2, with a high rate (14 out of 21 cases in group 2) (Fig. 3). It is much higher than that in group 1 (Fig. 4). It is one of the causes of postoperative moderate back pain and probably a cause of the aggravation of clinical outcome at follow-up. Despite the increased ODI and NRS, none of the 15 patients with postoperative adjacent RO required revision surgery. Nearly all postoperative adjacent RO occurred proximal to the fusion segment, which indicated stress concentration at the junctional region beneath the apical segment (Fig. 5).

Both monofactor analysis and multiple logistic regression analysis indicated the major TL/L curve

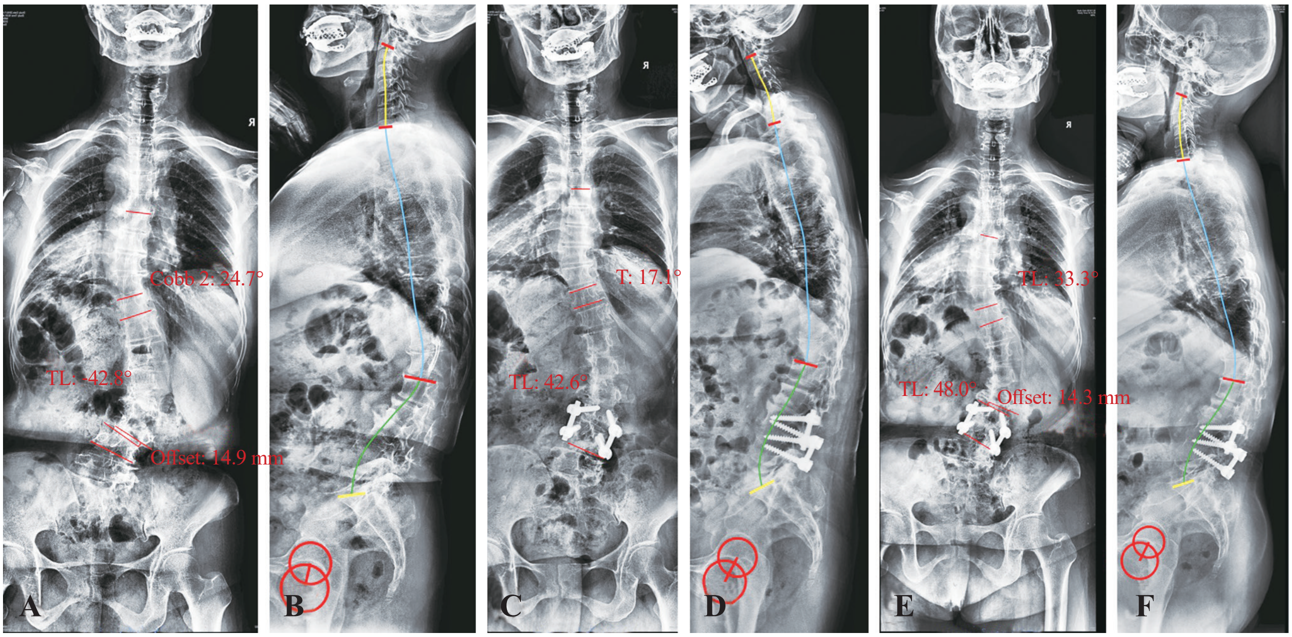


**Fig. 3.** This figure shows a 61-year-old female patient with a 43° major thoracolumbar (TL) curve and a 14.9 mm rotatory olisthesis at L3/4 **(A)**. Imbalance was illustrated by a 31° pelvic tilt and increased PI–LL mismatch (18°) **(B)**. The selective short fusion does not change the lumbar curve **(C)** but improve the sagittal spinal balance **(D)**. Adjacent rotatory olisthesis occurs at the proximal segment at the 1-year follow-up **(E)**. The TL curve deteriorates, as well as the sagittal spinal balance **(F)**.

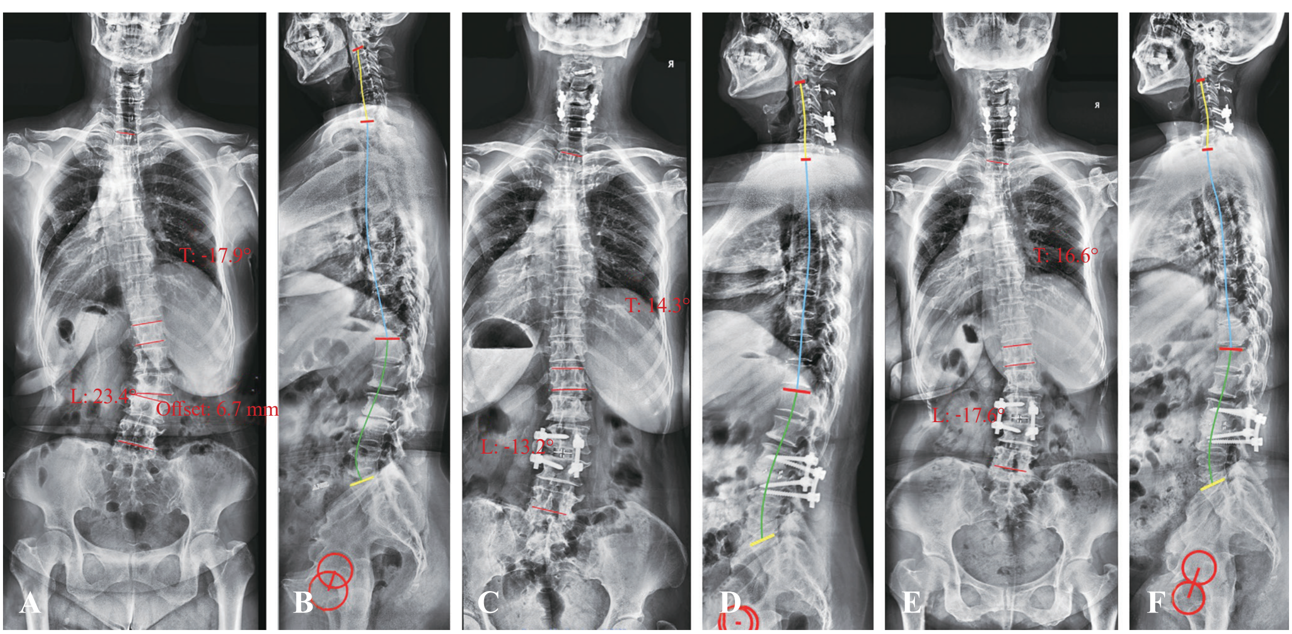


**Fig. 4.** This figure shows a 53-year-old female patient with a L3/4 rotatory olisthesis **(A)** and a 13º thoracolumbar kyphosis **(B)**. She underwent selective short fusion with well reduction of L3/4 rotatory olisthesis **(C)** with sagittal alignment improvement **(D)**. The lumbar curve progressed slightly **(E)** and the global spinopelvic alignment remained well **(F)** at the final follow-up after 3 years.

magnitude as the greatest risk factor with an OR of 1.400 (95% CI, 1.095–1.791; $p$=0.007). The T and lumbosacral curves are risk factors as well because they are the compensatory curves of the major TL/L curve. PT, which is a parameter of pelvic position, was also identified as a risk factor. A high PT represents a retroverted pelvis as a pelvic compensation response to spinal sagittal imbalance. In this study, PT correlated with the rate of postoperative adjacent RO and the magnitude of the TL/L curve. This indicates that the coronal and sagittal planes are coupled.

The ROC curve analysis verifies the major TL/L curve as a risk factor for postoperative adjacent RO with an AUC of 0.960 ($p$<0.001). The optimal cutoff

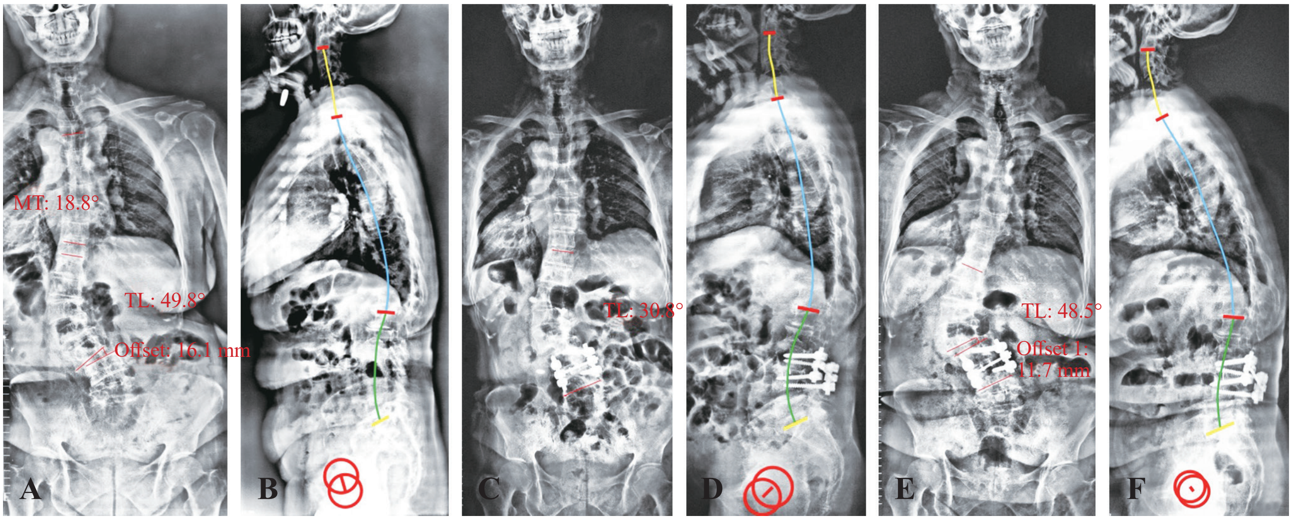


**Fig. 5.** This figure shows a 72-year-old female patient with a 49.8° major thoracolumbar (TL) curve and a 16.1 mm rotatory olisthesis at L3/4 **(A)**. Sagittal imbalance is also presented with a 70 mm sagittal vertical axis (SVA) **(B)**. Selective fusion of rotatory olisthesis is performed, both coronal and sagittal balance are improved after the surgery **(C, D)**. However, adjacent rotatory olisthesis occurs at the proximal segment to the fusion level at a 2-year follow-up **(E)**, sagittal imbalance also deteriorates much with a 93.3 mm SVA **(F)**. MT, main thoracic.

with the highest sensitivity and specificity is 32.5°. This suggests that for main curves of >32° selective short fusion of only the RO should be avoided. It concurs with finding by Pritchett and Bortel [3] that adult degenerative scoliosis cases with a curve magnitude >30°, apical rotation of grade >II, lateral olisthesis >6 mm, and intercrest line through L5 have a higher degree of progression.

This study has several limitations. First, it is a single-center study, only including a small number of patients. Second, there is some bias caused by the retrospective nature of the study. Finally, clinical data regarding bone mineral density and disc degeneration (Pfirmann grade).were limited.

## Conclusions

The clinical and radiological outcomes of selective RO fusion are well maintained in degenerative scoliosis with a lumbar curve <30° but not as well in degenerative scoliosis with a lumbar curve of >30°. Selective RO fusion is a rational option in DLS with a lumbar curve within 30°. It should be avoided in those with a lumbar curve >30° because of a higher complication rate of postoperative adjacent RO and a worse clinical outcome at the final follow-up.

## Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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## Author Contributions

YL and JS did the data collection and analysis. GW and CZ finished the measurement. KL did the critical revision. GW designed the study and wrote the article. All authors read and approved the final manuscript.

## References

1. Diebo BG, Shah NV, Boachie-Adjei O, et al. Adult spinal

deformity. Lancet 2019;394:160-72.
2. Robin GC, Span Y, Steinberg R, Makin M, Menczel J. Scoliosis in the elderly: a follow-up study. Spine (Phila Pa 1976) 1982;7:355-9.
3. Pritchett JW, Bortel DT. Degenerative symptomatic lumbar scoliosis. Spine (Phila Pa 1976) 1993;18:700-3.
4. Wang G, Cui X, Jiang Z, Li T, Liu X, Sun J. Evaluation and surgical management of adult degenerative scoliosis associated with lumbar stenosis. Medicine (Baltimore) 2016;95:e3394.
5. Zeng Y, White AP, Albert TJ, Chen Z. Surgical strategy in adult lumbar scoliosis: the utility of categorization into 2 groups based on primary symptom, each with 2-year minimum follow-up. Spine (Phila Pa 1976) 2012;37:E556-61.
6. Glassman SD, Bridwell K, Dimar JR, Horton W, Berven S, Schwab F. The impact of positive sagittal balance in adult spinal deformity. Spine (Phila Pa 1976) 2005;30:2024-9.
7. Schwab F, Ungar B, Blondel B, et al. Scoliosis Research Society-Schwab adult spinal deformity classification: a validation study. Spine (Phila Pa 1976) 2012;37:1077-82.
8. Schwab FJ, Smith VA, Biserni M, Gamez L, Farcy JP, Pagala M. Adult scoliosis: a quantitative radiographic and clinical analysis. Spine (Phila Pa 1976) 2002;27:387-92.
9. Schwab F, Farcy JP, Bridwell K, et al. A clinical impact classification of scoliosis in the adult. Spine (Phila Pa 1976) 2006;31:2109-14.
10. Ploumis A, Transfledt EE, Denis F. Degenerative lumbar scoliosis associated with spinal stenosis. Spine J 2007;7:428-36.
11. Aebi M. The adult scoliosis. Eur Spine J 2005;14:925-48.
12. Silva FE, Lenke LG. Adult degenerative scoliosis: evaluation and management. Neurosurg Focus 2010;28:E1.
13. Pellise F, Vila-Casademunt A, Nunez-Pereira S, et al. The Adult Deformity Surgery Complexity Index (ADSCI): a valid tool to quantify the complexity of posterior adult spinal deformity surgery and predict postoperative complications. Spine J 2018;18:216-25.
14. Simmons ED. Surgical treatment of patients with lumbar spinal stenosis with associated scoliosis. Clin Orthop Relat Res 2001;(384):45-53.
15. Terran J, Schwab F, Shaffrey CI, et al. The SRS-Schwab adult spinal deformity classification: assessment and clinical correlations based on a prospective operative and nonoperative cohort. Neurosurgery 2013;73:559-68.
16. Fairbank JC, Pynsent PB. The Oswestry Disability Index. Spine (Phila Pa 1976) 2000;25:2940-52.
17. Hjermstad MJ, Fayers PM, Haugen DF, et al. Studies comparing Numerical Rating Scales, Verbal Rating Scales, and Visual Analogue Scales for assessment of pain intensity in adults: a systematic literature review. J Pain Symptom Manage 2011;41:1073-93.
18. Horton W. Is there an optimal patient stance for obtaining a lateral 36” X-ray?: a critical comparison of three techniques. In: Proceedings of the 38th Annual Meeting of the Scoliosis Research Society; 2003 Sep 10-13; Quebec, Canada. Milwaukee (WI): Scoliosis Research Society; 2003.
19. Bridwell KH, Lenke LG, Lewis SJ. Treatment of spinal stenosis and fixed sagittal imbalance. Clin Orthop Relat Res 2001;(384):35-44.
20. Booth KC, Bridwell KH, Lenke LG, Baldus CR, Blanke KM. Complications and predictive factors for the successful treatment of flatback deformity (fixed sagittal imbalance). Spine (Phila Pa 1976) 1999;24:1712-20.