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Surgical Outcomes and Limitations of Decompression Surgery for Degenerative Spondylolisthesis

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Abstract

Study Design: A retrospective study.

Objectives: To investigate surgical outcomes and limitations of decompression surgery for degenerative spondylolisthesis.

Methods: One hundred patients with degenerative spondylolisthesis who underwent decompression surgery alone were included in this study. The average follow-up period was 3.7 years. Radiography and magnetic resonance imaging were used for radiological assessment. Patients with a recovery rate of >50% throughout the study period were classified as the control group (Group C), while those with a recovery rate of <50% throughout the study period were classified as the poor group (Group P). Patients that had improved symptoms, and yet later showed neurological deterioration due to foraminal stenosis at the same level were classified as the exiting nerve root radiculopathy group (Group E), while those who showed deterioration due to slip progression at the same level were classified as the traversing nerve root radiculopathy group (Group T).

Results: Patient distribution in each group was 73, 12, 7, and 8 in Groups C, P, E, and T, respectively. As for preoperative radiological features, slippage and an upper migrated disc in Group P, disc wedging and an upper migrated disc in Group E, and lamina inclination and posterior opening in Group T were evident. The cutoff value of preoperative slippage with a poor outcome was 13%.

Conclusions: Surgical outcomes of decompression surgery for degenerative spondylolisthesis were successful in 73% cases. Preoperative radiological features for poor outcomes were slippage of more than 13%, an upper migrated disc, disc wedging, and lamina inclination.

Keywords

degenerative spondylolisthesis, decompression surgery, spinal arthrodesis, clinical outcome, radiological feature

Introduction

Surgical management for degenerative spondylolisthesis is still controversial. The majority of researchers have reported that lumbar arthrodesis leads to more satisfactory clinical outcomes for degenerative spondylolisthesis.[1-5] On the other hand, some researchers have reported that surgical outcomes of decompression surgery alone for degenerative spondylolisthesis were practically equivalent to those of lumbar arthrodesis.[6] Furthermore, numerous reports have indicated that the perioperative complication rates were higher in lumbar arthrodesis than those in decompression alone.[7,8] In a previous study that examined surgical complications of posterior lumbar interbody fusion (PLIF), the elucidated union failure and adjacent segment degeneration were revealed to be arthrodesis-specific complications that affect long-term results.[9] Considering the previous

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reports, meticulous management was required for surgical indication/selection for degenerative spondylolisthesis. However, there is no sufficient study that has addressed the limitations of decompression surgery for degenerative spondylolisthesis. The purpose of this study was to investigate (1) surgical outcomes of decompression surgery alone without fusion for degenerative spondylolisthesis, (2) pathogenesis for recurrence of neurological symptoms, and (3) risk factors for the recurrence of neurological symptoms.

Methods

Patients

One hundred consecutive patients (40 men and 60 women) who underwent decompression alone without arthrodesis for degenerative spondylolisthesis between 1997 and 2015 and who were followed-up for more than 1 year were included in this study. All study protocols were approved by the review board of the Osaka Rosai Hospital. The mean percentage of anterior slip was 12.1% (6.5% to 24.6%). The average age at surgery was 70 years (range = 48-88 years), and the mean follow-up period was 3.7 years (range = 1-19 years). Single-segment decompression was performed in 55 patients, 2 segments in 32 patients, and 3 segments in 13 patients. Among patients who underwent multilevel decompression, 11 had spondylolisthesis at 2 levels. No patients had 3-level olisthesis. The level of decompression was L2-3 in 14 patients, L3-4 in 55 patients, L4-5 in 79 patients, L4-S in 1 patient, L5-6 in 2 patients, and L5-S in 7 patients.

Radiological Assessment

Plain radiographs were performed in all patients before surgery and at 1 year postoperatively. Radiological assessment was performed at the highest slip-level in 2 or 3 segments of decompression. Disc wedging was measured by anteroposterior radiographs. In addition, disc height and lamina inclination were measured by neutral lateral radiographs, while the posterior opening of the disc was measured by maximum flexion radiographs. Anterior slip (%slip) was measured by maximum flexion radiographs, and the intervertebral angle was measured by maximum flexion and extension lateral radiographs. Preoperative translation and angulation were evaluated by calculating the difference of anterior slip and intervertebral angle in maximum flexion and extension radiographs. As the index of disc height, the distance between the upper and lower vertebral endplates perpendicularly measured from the point equidistant on the bisector line that connected the middle points of the anterior and posterior disc heights on the neutral lateral radiograph was measured. Lamina inclination angle was defined as the angle formed by a straight line connecting the base of the superior facet with the base of the inferior facet, and a straight line connecting the midpoints of the anterior and posterior vertebral cortices on lateral radiographs was described elsewhere[10] (Figure 1).

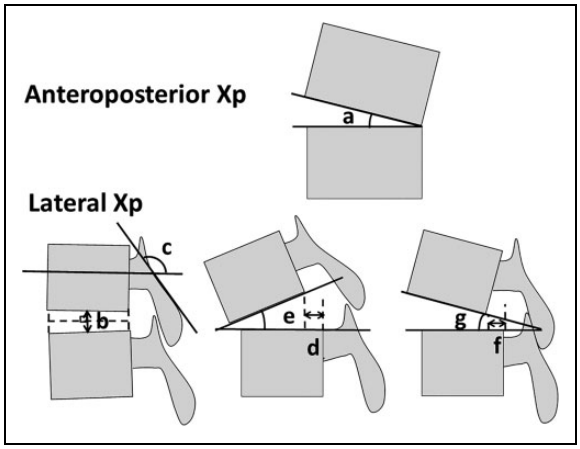

Figure 1. The scheme of parameters in radiographs. (a) Disc wedging was measured by anteroposterior radiographs. (b, c) Disk height and lamina inclination were measured by neutral lateral radiographs. (d, e) Anterior slip (%slip) and posterior opening of the disc were measured by maximum flexion radiographs (e, g) and intervertebral angle was measured by maximum flexion and extension lateral radiographs. Preoperative translation (difference between d and f) and angulation (difference between e and g) were evaluated by calculating the difference of anterior slip and intervertebral angle in maximum flexion and extension radiographs. Lordosis was calculated as positive value, and kyphosis was calculated as negative value.

Magnetic resonance imaging (MRI) of the lumbar spine was also performed in all patients preoperatively. The upper migrated disk at the level of degenerative spondylolisthesis was speculated to be a risk factor of postoperative foraminal stenosis. As patients with an upper migrated disc underwent posterior decompression, the dynamic factor, such as progression of a decreasing disc height, when accelerated, caused exiting nerve root radiculopathy at the foramen, especially in patients with disc wedging. Therefore, preoperatively, an upper migrated disc was measured on MRI sagittal images and was defined as the rate (%) of upper bulging disc to posterior vertebral wall height (Figure 2).

Surgical Indication and Procedure

All patients considered for surgery had severe, disabling leg pain with or without low back pain and gait disturbance, and were unresponsive to conservative treatment, such as medication, physical therapy, and root and/or epidural block. Patients agreed to the informed consent for the risks and benefits of both PLIF and decompression alone prior to surgery. Although PLIF was selected for degenerative spondylolisthesis, more than 10% slippage needed to be found preoperatively, with a posterior opening of the disc measuring more than 5°, this surgery was not recommended to elderly patients over 70 years old before 2005 in this institution. Furthermore, decompression was selected as the primary operation in patients with severe comorbidities or for those who rejected the implant surgery.

Surgical procedures consisted of complete decompression of the neural elements in the stenotic levels. All decompression procedures were performed using the same technique.

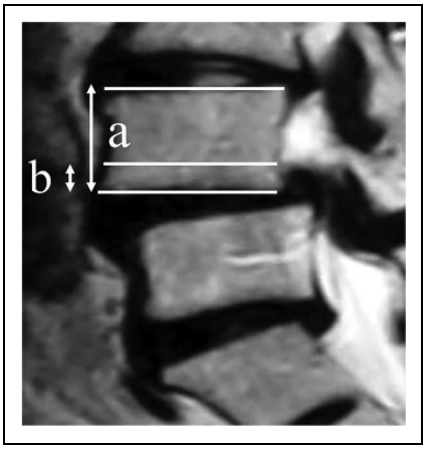

Figure 2. Measurement method for preoperative upper migrated discs. The percentage of upper bulging disk for the vertebral height (b/a × 100) is measured.

A midline incision centered over the relevant interspace was planned. Bilateral paraspinal muscles were elevated off the interspinous and interlaminar intervals in the subperiosteal plane. The interspinous-suprasupinous ligaments and the lower half of the cephalad spinous process were removed. The lower half of the cephalad lamina up to the origin of the ligament flavum was excised, and subsequently, the thickened ligament flavum was removed to provide central decompression. Medial facetectomies were performed in a trumpet manner to accomplish subarticular decompression of nerve roots. On the basis of decompression, the medial edge of the superior facet was excised to the medial edge of pedicle.No patients underwent foraminotomy in addition to decompression surgery at levels of spondylolisthesis, as it was determined that the exiting nerve root was not the responsible lesion, based on preoperative physical examination and radiological assessment. In addition, no patient underwent discectomy as traversing nerve root decompression was confirmed or sequestrated disc herniation was not observed during the operation. Walking was permitted on the second postoperative day, and a brace was utilized until 2 months after surgery.

Clinical Assessment

Clinical outcomes were assessed using the scoring system proposed by the Japanese Orthopaedic Association (JOA score). This scoring system consists of subjective symptoms (low back pain, 3 points; leg pain, 3 points; gait, 3 points), clinical symptoms (straight leg raising test, 2 points; sensory abnormality, 2 points; motor disturbance, 2 points), restriction of activities of daily living (14 points), and urinary bladder function (−6 points). A normal JOA score is 29 points. The recovery rate was then evaluated using the JOA score by Hirabayashi's method as follows:

$$\begin{aligned}\text{Recovery rate } (\%) = (&\text{ Postoperative score}\\ &- \text{ Preoperative score})\\ &\times 100/(\text{ Full score} - \text{ Preoperative score})\end{aligned}$$

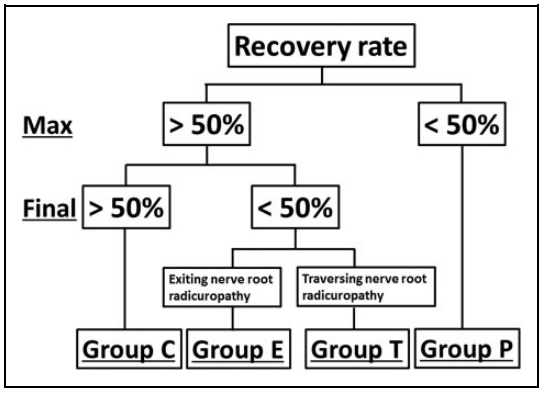

Figure 3. Flowchart dividing the patients into each group. The patients who had a recovery rate of more than 50% throughout the study period were classified in Group C. Those whose recovery rate decreased to less than 50% at final follow-up were classified in either Group E or Group T. After operation, exiting nerve root radiculopathy was observed in patients in Group E and traversing nerve root radiculopathy was observed in patients in Group T. The patients with a recovery rate of less than 50% throughout the study period were classified in Group P. Groups C, E, T, and P indicate the control group, exiting nerve root radiculopathy group, traversing nerve root radiculopathy group, and poor group, respectively.

Clinical assessments were performed for all patients before surgery, at 6 and 12 months after surgery, and then annually.

The patients were divided into 4 groups. Patients with a recovery rate of more than 50% throughout the study period were classified as the control group (Group C), while those with a recovery rate less than 50% throughout the study period were classified as the poor group (Group P). Patients who showed neurological deterioration due to intra-/extraforaminal stenosis at the same level were placed into the exiting nerve root radiculopathy group (Group E). Patients who showed neurological deterioration due to slip progression at the same level were classified as the traversing nerve root radiculopathy group (Group T). Although patients in Group E and Group T once had improved recovery rates of more than 50%, the rates gradually deteriorated to less than 50% (Figure 3). There was no patient who showed recurrence for cauda equina syndrome.

Statistical Analysis

Statistical analyses were performed using SPSS for Windows (version 21.0, IBM). The data was analyzed using the Student *t* test and χ^2 test. A P value <.05 indicated statistical significance in this study. A receiver-operating characteristic (ROC) curve from the value of %slip in Group C and Group P was constructed to assess the limitation of decompression surgery alone according to the degree of slippage. The cutoff values were calculated as the best values that differentiated the clinical outcomes. Sensitivity and specificity were plotted. The optimal cutoff values of the ROC curve were chosen as the points on the ROC curve closest to the left corner. The area under the ROC curve (AUC) was a quantitative method used to measure the accuracy of a test and compared the diagnostic test with a

Table 1. Summary of Clinical Results.

	Group C	Group P	Group E	Group T	Total
Number	73	12	7	8	100
Average age	68	75*	73	71	70
Male/female	31/42	5/7	2/5	2/6	40/60
Clinical outcomes					
Preoperative JOA scores	12	10	10	14	12
Postoperative max JOA scores	26	16**	25	25	25
Final JOA scores	25	15**	16**	14**	22
Recovery rate, max (%)	80	32**	79	76	74
Recovery rate, final (%)	75	27**	28**	−3**	60

Abbreviation: JOA, Japanese Orthopaedic Association.
*$P < .05$ versus Group C. **$P < .01$ versus Group C.

perfect test. A 100% sensitivity and specificity equals an AUC of 1.0.

Results

Clinical Outcomes

Clinical results are shown in Table 1. The distribution of each group was as follows: 73 in Group C, 12 in Group P, 7 in Group E (4 with single-level decompression and 3 with multilevel decompression), and 8 in Group T (6 with single-level decompression and 2 with multilevel decompression). There was no significant difference in frequency of neurological deterioration after surgery between single and multilevel decompression ($P = .33$). The mean age at the time of the primary surgery was significantly higher in Group P than in Group C. Overall, the mean JOA score of patients preoperatively, postoperative maximum, and at final follow-up were 12 (range, −2 to 21), 25 (range, 8 to 29), and 22 (range, 4 to 29) points, respectively. Overall, the mean recovery rate of patients at the postoperative maximum and at final follow-up were 74% (range, 25% to 100%) and 60% (range, −56% to 100%), respectively. The average JOA score of each group preoperatively, postoperative maximum, and at final follow-up were 12 (range, −2 to 21), 26 (range, 17 to 29), and 25 (range, 17to29) points in Group C; 10 (range, 1 to 16), 16 (range, 8 to 22), and 15 (range, 5 to 22) in Group P; 10 (range, 2 to 17), 25 (range, 21 to 28), and 16 (range, 6 to 20) points in Group E; and 14 (range, 7 to 18), 25 (range, 22 to 28), and 14 (range, 4 to 21) in Group T, respectively (Figure 4). The mean recovery rate of each group at the postoperative maximum and final follow-up were 80% (range, 50% to 100%) and 75% (range, 50% to 100%) in Group C, 32% (range, 7% to 46%) and 27% (range, 4% to 46%) in Group P, 79% (range, 52% to 93%) and 28% (range, −15% to55%) in Group E, and 76% (range, 64% to 91%) and −3% (range, −56% to 43%) in Group T, respectively. All patients in Group E and Group T experienced some improvement in their symptoms after the primary surgery, but then gradually deteriorated. The average time period until neurological deterioration occurred was 9.0 months (range, 1 to 36 months) in Group E and 21.6 months (range, 6 to 28.8 months) in Group T.

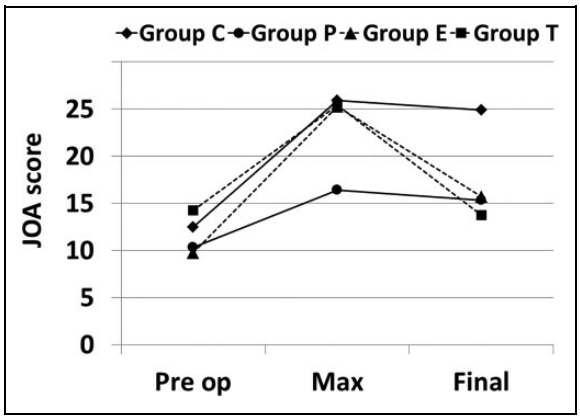

Figure 4. Change of the JOA score in each group. JOA score of Group P was low throughout the study period. On the other hand, that of Group E and Group T were once above the postoperative maximum, but then decreased again at final follow-up. Pre-op indicates preoperative. Max indicates postoperative maximum. Final indicates final follow-up. Groups C, P, E, and T indicate the control group, poor group, exiting nerve root radiculopathy group, and traversing nerve root radiculopathy group, respectively.

Table 2. Summary of Radiologic Measurements.

	Group C	Group P	Group E	Group T
Preoperative %slip (%)	11.5	15.4*	12.7	12.7
Postoperative %slip (%)	12.9	16.7*	13.5	22.0*
Disk height (mm)	8.5	8.7	7.2	8.4
Lamina inclination (°)	123.8	124.5	124.7	127.9*
Posterior opening (°)	−0.1	1.1	0	2.4*
Disc wedging (°)	1.6	1.8	3.7*	2.8
Preoperative translation (mm)	1.7	2.3	2.6	1.2
Preoperative angulation (°)	6.6	5.5	6.7	6.3
Upper migrated disc (%)	12.5	18.3**	21.7**	15.3

*$P < .05$ versus Group C. **$P < .01$ versus Group C.

Radiological Outcomes

Radiological outcomes are shown in Table 2. Regarding preoperative radiological features in Group P compared to Group C, there were significant differences in %slip (Group P, 15.4%; Group C, 11.5%) and an upper migrated disc (Group P, 18.3%; Group C, 12.5%). In terms of preoperative radiological features in Group E compared to Group C, significant differences were found in disc wedging (Group E, 3.7°; Group C, 1.6°) and an upper migrated disc (Group E, 21.7%; Group C, 12.5%). In contrast, for those in Group T, lamina inclination (Group T, 127.9°; Group C, 123.8°) and posterior opening (Group T, 2.4°; Group C, −0.1°) were significantly larger than Group C. Furthermore, postoperative %slip was significantly larger in Group T than in Group C (Group T, 22.0%; Group C, 12.9%).

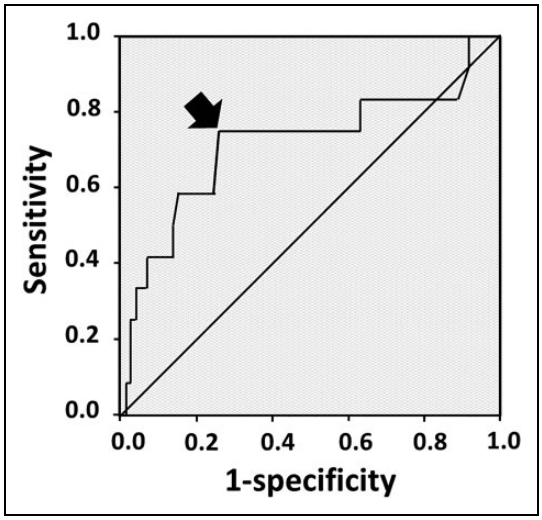

Figure 5. ROC curve that differentiated Group C to Group P. The cutoff value of the preoperative slippage on the ROC curve was 13% (sensitivity 75%, specificity 74%) and the area under the curve (AUC) was 0.72. Black arrow indicates cut off value.

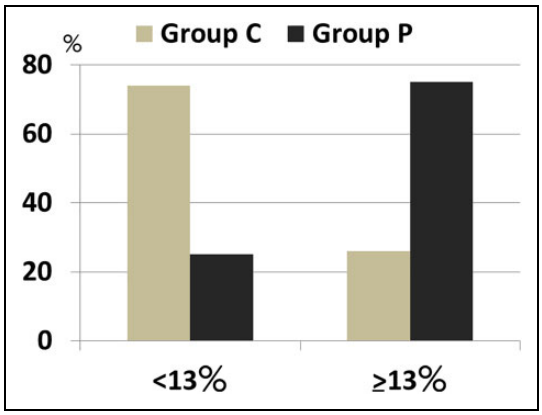

Figure 6. The patients with a cutoff value of %slip in Group P and C are separated. The ratio of Group P was significantly higher in patients with %slip of more than 13% (Group C, 26%; Group P, 75%), which was significantly lower in %slip of less than 13% (Group C, 74%; Group P, 25%) evaluated by the χ^2 test ($P = .001$). Groups C and P indicate the control group and poor group, respectively.

Cutoff Value of %slip

The cutoff value of the preoperative slippage on the ROC curve that differentiated Group C from Group P was 13% (sensitivity 75%, specificity 74%; Figure 5). The AUC was 0.72. Separating the patients with this cutoff value, the ratio of Group P was significantly higher in patients with preoperative slippage of more than 13% (Group C, 26%; Group P, 75%), which was significantly lower in preoperative slippage of less than 13% (Group C, 74%; Group P, 25%; Figure 6).

Discussion

In general, spondylolisthesis has been treated with lumbar arthrodesis. Ghogawara et al have reported that surgical outcomes of lumbar arthrodesis for spondylolisthesis were more effective than those with decompression alone.[5] Although satisfactory clinical outcomes of lumbar arthrodesis for spondylolisthesis have often been reported,[1-5] higher complication rates of lumbar arthrodesis has also been reported, especially in elderly patients.[7,8] On the other hand, several researchers have reported favorable outcomes of decompression for spondylolisthesis.[11,12] Forsth et al conducted a randomized controlled trial and reported that surgical outcomes of decompression alone for degenerative spondylolisthesis were comparable to those of decompression with fusion.[6] However, there was no report regarding surgical limitations of decompression alone for spondylolisthesis.

The current study revealed surgical outcomes and limitations of decompression alone for degenerative lumbar spondylolisthesis. Overall, the average recovery rate was 60%, and 73% of patients showed a recovery rate of more than 50% throughout the study period. However, 12 patients (Group P) showed a recovery rate of less than 50% throughout the study period. With respect to preoperative radiological features in Group P compared with Group C, significant differences were detected in preoperative slippage and an upper migrated disc. The cutoff value of the preoperative slippage was 13%. Patients with preoperative slippage of more than 13% were classified into Group P with a 75% probability. These results suggested that preoperative slippage of more than 13% was a major limitation factor of decompression alone for spondylolisthesis.

All patients with recurrent neurological symptoms once had an improvement in their symptoms after the primary operation; however, symptoms gradually worsened within the 2-year follow-up period. There were 2 different pathogeneses for neurological deteriorations. The pathogenesis of Group E was based on foraminal stenosis. Many reports have described the pathogenesis for foraminal stenosis, such as an upper migrated disc herniation, spondylolisthesis, scoliosis, and rotational instability. In the present study, preoperative radiological features of Group E were disc wedging and an upper migrated disc. As the patients with disc wedging and an upper migrated disc underwent posterior decompression, the dynamic factor, such as the progression of disc wedging or the decrease in disc height, might be accelerated due to resection of the posterior elements and may have caused superior nerve root radiculopathy at the foramen of the concave side. In contrast to Group E, the pathogenesis of Group T was based on lateral recess stenosis. Preoperative radiological features of Group T were lamina inclination and posterior opening of the disc. Lamina inclination has been considered to be related to the etiology of degenerative spondylolisthesis as a crucial factor in sagittal instability.[10] Furthermore, posterior opening of the disc has indicated segmental instability, including intervertebral discs or facet joints. Coexistence of these factors might lead to progression of the slippage after resection of posterior elements, and would morph into the same condition of Group P as a result.

Previous biomechanical studies reported that the supra- and interspinous ligaments resist 19% of flexion forces and the

facet capsular ligaments resist up to 39%.[13,14] Therefore, resection of the midline supraspinous/interspinous ligament complex could accelerate flexion instability. Recently, satisfactory outcomes of less-invasive decompression surgeries for spondylolisthesis have been well reported.[15-17] Microscopic bilateral decompression via a unilateral approach or microendoscopic decompression enabled a complete successful decompression, preserving the posterior components. These less-invasive decompression surgeries that preserve the posterior components might prevent the neurological deterioration observed in Group E and Group T. However, 73% of the patients with spondylolisthesis did show a recovery rate of more than 50% throughout the study period using conventional decompression surgery. Decompression surgery appeared to be one of the more useful procedures for spondylolisthesis, especially in elderly patients.

There were some limitations in this study, however. First, this was a retrospective study with a wide-ranging follow-up period, and assessment was not performed at fixed time points. Second, the selection of study participants was somewhat biased because a majority of the current participants were elderly who did not select lumbar arthrodesis by the intention of the surgeon or the patients' own desire, and the number of patients who showed neurological deterioration was very low. Therefore, it is possible that the surgical outcome of decompression surgery in degenerative spondylolisthesis is better in a larger number of patients without such bias. Further studies with a larger number of participants will be necessary to clarify whether the present theories adapt to global populations with degenerative spondylolisthesis. Despite the limitations listed in this study, no previous studies have reported any specific limitations of decompression surgery on patients with degenerative spondylolisthesis. Thus, this study could determine the applications of decompression surgery, which can be considered as making progress to enhance its understanding.

Conclusion

The surgical outcome of decompression surgery in patients with degenerative spondylolisthesis was relatively successful in the mean follow-up period of 3.7 years. Slippage of more than 13%, an upper migrated disc, disc wedging, and lamina inclination in preoperative imaging were risk factors of poor outcomes.

Declaration of Conflicting Interests

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