CLINICAL ARTICLE
Korean J Spine 8(3):190-196, 2011

Radiologic Adjacent Segment Degeneration: Two Levels fusion (L3-4-5 and L4-5-S1) Using Percutaneous Pedicle Screw Fixation in Degenerative Lumbar Spinal Disease; A Preliminary Report

Sang-Bae Chae, Sang-Gu Lee, Seong Son, Chan-Woo Park, Woo-Kyung Kim

Department of Neurosurgery, Gachon University, Gil Hospital, Incheon, Korea

Objective: The purpose of this study is to examine radiological adjacent segment degeneration (ASD) and clinical results after two levels percutaneous pedicle screw fixation.
Methods: From 2007 to 2009, 34 patients who underwent percutaneous pedicle screw fixation on L3-4-5 or L4-5-S1 for lumbar degenerative disorders were selected. According to the presence of radiological ASD, ASD group and non-ASD group were compared for clinical results and radiologic results such as total lordotic angle (TLA), segmental lordotic angle (SLA) via lumbar X-rays during follow up periods. Furthermore, we compared pre-operative degree of disc degeneration at adjacent segment between two groups via MRI.
Results: The mean follow-up period and mean age were 27.38±9.45 months and 59.21±12.73 years. ASD group were 7 patients, and non-ASD group were 27 patients. The mean age of the ASD group (67.40±4.81) was significantly older than that of the non-ASD group (57.46±13.18). Pre-operative disc degeneration of cranial adjacent segment in ASD group were 6 patients (25.9%), whereas that in non-ASD group were 4 patients (14.8%), showing that preoperative disc degeneration was significantly more severe in the ASD group.
Conclusion: Percutaneous pedicle screw fixation is favorable technique to prevent ASD for two levels fusion, however, when the patient is old or the preoperative disc degeneration of the adjacent segment is severe, there is the risk of postoperative ASD, and thus special attention should be paid during the follow-up period.

Key Words: Spinal fusion · Intervertebral disc degeneration · Adjacent segment degeneration · Total lordotic angle · Segmental lordotic angle

INTRODUCTION

Since pedicle screw was developed for spinal stability, it has been used as a common operative procedure together with interbody fusion when spinal fusion is required[9,23,25]. Particular for degenerative spinal diseases such as spinal spondylolisthesis and spinal stenosis, pedicle screw fixation has been settled as a general treatment guideline for ensuring stability after nerve decompression. However, conventional posterior pedicle screw fixation causes the weakening of spine supporting structure and resultantly increases load on the adjacent segment[3,7,9]. Moreover, muscle retraction is severe and the duration of surgery is long and, as a result, blood flow to muscle is reduced and this causes necrosis and atrophy and aggravates degenerative changes[20,26].

In order to solve these problems, percutaneous pedicle screw fixation was introduced first in 1977 and this minimized injuries in supporting structures around the spine during pedicle screw fixation, reduced blood loss and infection, and decreased hospital days and medical expenses[9,18,21]. There have been many studies on adjacent segment degeneration (ASD) following percutaneous pedicle screw fixation on the one level, but although the use of multi-segmental percutaneous pedicle screw fixation is increasing recently not many studies have been conducted on ASD resulting from the use of multi-segmental percutaneous screw fixation. This study purposed to examine the incidence and causes of ASD after percutaneous pedicle screw fixation of two levels, L3-4-5 and L4-5-S1.

● Received: August 16, 2011 ● Revised: September 26, 2011
● Accepted: September 26, 2011
Corresponding Author: Sang-Gu Lee, MD
Department of Neurosurgery, Gachon University, Gil Hospital, 1198, Guwol 1-dong, Namdong-gu, Incheon 405-760, Korea
Tel: +82-32-460-3304, FAX: +82-32-460-3899
E-mail: samddal@gilhospital.com

MATERIALS AND METHODS

1. Subjects

The subjects of this study were 34 patients who had received posterior percutaneous pedicle screw fixation of two levels L3-4-5 and L4-5-S1 for degenerative spinal disease during the period from January 2007 to December 2009 sampled based on the retrospective review of lumbar X-ray, patient records, etc. And the 34 patients were divided into two groups based on the presence of radiological ASD (Fig. 1, 2). Indications for the surgery were chronic back pain, degenerative spondylolisthesis or spinal stenosis accompanied by neurologic symptoms not treated by conservative treatment, and segmental lumbar spinal instability. Patients with traumatic lumbar disease, tumor, metabolic bone disease, infection, and re-oper-

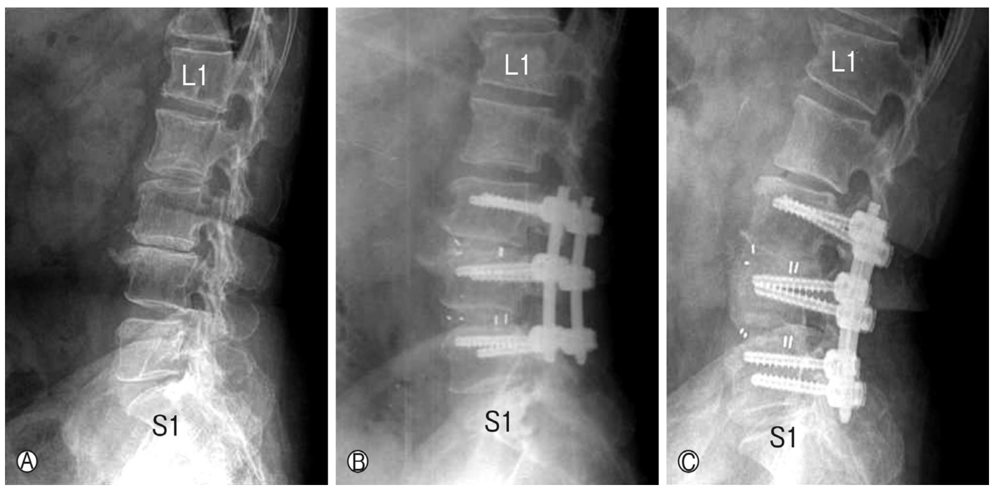

Fig. 1. Series of lumbar spine of patient who showed development of adjacent segmental degeneration (ASD) at the last follow up period. A: Pre-operatrive plain lateral X-ray showed degenerative spondylolisthesis of L3 on L4 and disc space narrowing. B: 3 months after operation (posterior lumbar interbody fusion (PLIF) and posterolateral spinal fusion (PLSF) on L3-4-5 segments). C: At the last follow up period (1 year after operation), adjacent disc space of L2,3 narrowed significantly. And new spondy lolisthesis of L2 on 3 was developed.

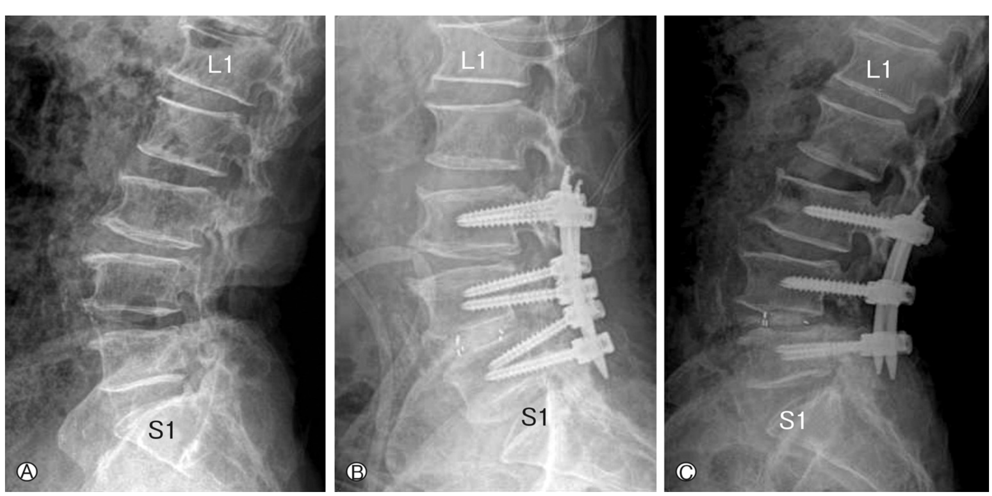

Fig. 2. Series of lumbar spine of patient who showed no development of adjacent segmental degeneration (ASD) at the last follow up period. A: Pre-operatrive plain lateral X-ray showed degenerative retrolisthesis of L3 on L4. B: 3 months after operation (posterior lumbar interbody fusion (PLIF) on L4, 5 and posterolateral spinal fusion (PLSF) on L3-4-5 segments). C: At the last follow up period (1 year after operation), there was no change at adjacent disc space of L2, 3.

ation, severe spinal spondylolisthesis of Grade III or higher, severe osteoporosis, and those with very severe degenerative scoliosis were also excluded.

2. Operative procedure

For all the cases, the patient was laid in the supine position under general anesthesia, and lumbar vertebrae 3-4-5 and lumbar vertebrae 4-5-sacral vertebra 1 were approached from posterior, and depending on the degree of stenosis, partial laminectomy and nerve decompression, and medial partial facetectomy were done before percutaneous screw fixation was performed. Then, Posterolateral interbody fusion (PLIF) of transforaminal interbody fusion (TLIF) was performed unilaterally or bilaterally using a cage fixed with allograft bone chip and bone marrow.

First of all, the vertebral body at the site where the screw was to be inserted was checked through the AP view under C-arm-type X-ray fluoroscopy. In order to the vertebral body to be placed exactly in the middle, the pedicles in both sides should appear uniformly, and the accurate AP view was obtained by making the interface of the superior vertebral body at the pedicle site appear to be a single straight line rather than two lines. Under C-arm-type X-ray fluoroscopy, the upper and lower parts of the pedicle were marked using a marking pen, and then a small incision was made on the skin around 4-5 cm from the middle so that a 22-gauge spinal needle (e.g. Jamshidi needle) could reach the superior lateral border of the pedicle under C-arm-type X-ray fluoroscopy. Then, the Jamshidi needle was positioned in 2 or 10 o'clock direction or almost horizontally (3 or 9 o'clock), and the precise starting entry point was set through the AP view and the lateral view. Which is the most important performance percutaneous screw fixation is setting the starting entry point. If the direction or the position is set erroneously at the beginning, it is hardly correctable, and if it is corrected repeatedly the fixation strength of the screw may go down and the screw may pull out. Therefore, it is important to set the starting entry point correctly at the beginning. Percutaneous screw fixation was performed at the cranial and caudal parts first and then at the middle part last in order to maintain alignment. After the starting entry point was set, the spinal needle was inserted gradually under C-arm-type X-ray fluoroscopy until it reached around 1/3 of the vertebral body. If the spinal needle reached the exact position, the guide wire was inserted carefully through the spinal needle so that it did not pass through the front of the vertebral body. Then its position was confirmed and fixed so that the guide wire did not move, and then the spinal needle was removed. In addition, dilators were inserted one by one to make a space for inserting a screw, and only the last dilator was left and tapping was done using a tapper. Then, with the guide wire maintained as it was, the tapper and the last dilator were removed, and an adequate screw prepared in advance was inserted through the guide wire. Then the rod was inserted according to the method of each surgical appliance, and our hospital used SEXTANT® System (Medtronic Sofamor Danek, Memphis, TN, U.S.A), 4CIS® Apollon System (Solco Biomedical Co., Gyeonggi, Korea), VIPER® (DePuy Spine Inc., Raynham, MA, U.S.A), and AnyPlus®MIS system (GS Medical Co., Seoul, Korea). After the rod was inserted, it was compressed using a compressor from outside the skin so that it was fixed firmly, and then structures supporting the screw were removed.

3. Radiological analysis and clinical evaluation

For all the patients, the total lordotic angle was measured in simple lateral X-ray in order to evaluate the stability of spinal segments, and changes in the cranial and caudal segmental lordotic angle of the adjacent segment were measured using flexion and extension photographs before the operation, after the operation in 3 and 6 months from the operation, and at the last follow-up in order to check the instability of the adjacent segment that might happen after the fixation. The total lordotic angle was measured by Cobbs' method with the angle formed by the line parallel with the upper part of the 1st lumbar body and the line parallel with the upper part of the 1st 1sacral vertebra. The segmental angle was measured with the angle formed by the line parallel with the lower part of the upper lumbar body of the adjacent segment and the line parallel with the upper part of the lower lumbar body using simple lateral X-ray and flexion and extension photographs, and difference between the angle on extension and that on flexion was obtained (Fig. 3). In addition, according to White & Panjabi's lumbar instability standard, we defined a case to have potential instability if the change in the segmental angle between lumbar vertebra 2 and 3 exceeds 15° and the change in the angle between lumbar vertebra 4 and 5 exceeds 20° and the change in the angle between lumbar vertebra 5 and sacral vertebra 1 exceeds 25°. ASD was confirmed through simple X-ray without aggravation of postoperative symptoms. ASD was defined as a case having significantly decreased disc height of irrelevant adjacent segments, spondylolisthesis or retrolisthesis, and obvious inter-segmental instability.

In preoperative lumbar MRI of cranial adjacent segments, disc degeneration was evaluated using Eyre's classification of disc degeneration (Table 1), and cases of Grade IV or lower were defined to have preoperative disc degeneration. The degree of bone fusion rate after percutaneous pedicle screw fixation was evaluated using Brantigan & Steffee's fusion classification through simple lumbar spine X-ray at the last follow-up, and screw loosening was determined by checking the presence of halo effect around the screw.

For the clinical evaluation of patients after percutaneous screw fixation, Odom's criteria, reoperation and complications were investigated.

4. Statistic analysis

Collected data were processed using SPSS/WIN Ver. 12.0, and analyzed through frequency analysis, tests, and repeated measurement ANOVA. Statistical significance was accepted if $p<0.05$.

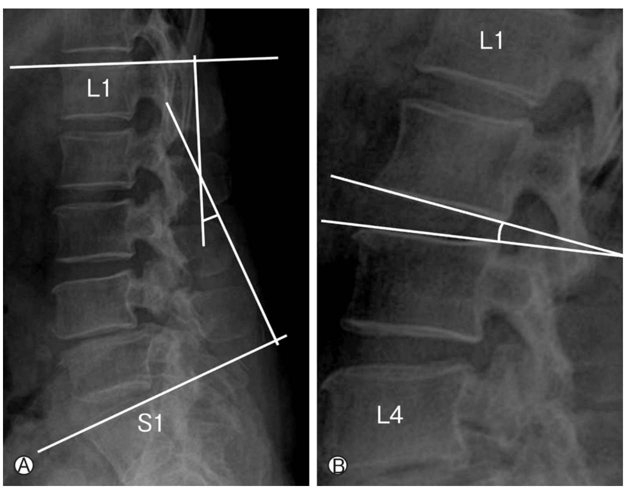

Fig. 3. Sagittal angle measurement by Cobb's angle method on plain X-ray. A: To measure the lordotic angle, line along the superior end plate of the L1 body and line along the superior end plate of the S1 body were drawn. Then, lines perpendicular to each line are drawn. The angle between two perpendicular lines was a lumbar lordotic angle. B: Segmental angle accounted for flexion-extension angle between fused segment and cranial or caudal adjacent segment. To measure it, line along the end plate of adjacent vertebra body and line along the end plate of the most superior or inferior fused vertebra body were drawn. The angle between two lines was an adjacent segmental angle.

RESULTS

Among the 34 patients, 7 patients (20.6%) were found to have ASD through simple X-ray and 27 (79.4%) patients were not during the period of follow-up, which was 27 months on the average. The mean age was 67.40±4.81 in the ASD group and 57.46±13.18 in the non-ASD group, and the difference was significant. However, the follow-up period and the male-female ratio were not statistically significantly different between the two groups (Table 2).

When the preoperative disc degeneration of the cranial adjacent segment was examined by Eyre's disc degeneration classification through MRI, 6 out of the 7 patients in the ASD group were Grade IV or higher before the operation while only 4 out of 27 in the non-ASD group were, and the difference was statistically significant.

The total lordotic angle was measured before the operation, in 3 and 6 month after the operation, and at the last follow-up, and it was significantly different between the ASD group and the non-ASD group before the operation and at the last follow-up. In the ASD group, the total lordotic angle decreased from 38.35±10.56° to 36.08±11.02°, but in the non-ASD group it increased from 36.06±12.06° to 39.03±10.71°. The change in the cranial segmental angle of the adjacent segment was also significantly different between the two groups. While the cranial segmental angle of the adjacent segment increased from 11.49±7.79° to 16.99±3.49° in the ASD group, it changed little from 12.06±6.19° to 12.94±6.39° in the non-ASD group. However, the change in the caudal segmental angle was not significantly different between the two groups (Table 3).

In order to compare postoperative satisfaction between the ASD group and the non-ASD group, we checked Odom's criteria. Among the 7 patients in the ASD group, 0 was Excellent, 3 (42.9%) Good, 3 (42.9%) Fair, and 1 (14.2%) Poor, and among the 27 patients in the non-ASD group, 8 (29.7%) were Excel-

Table 1. Classification of disc degeneration [Modified from Pearce (cited by Eyre et al)])

Grade	Structure	DNA	Signal Intensity	HID
I	Homogeneous, bright white	Clear	Hyperintense, isointense	Normal
II	Inhomogeneous with or without horizontal bands	Clear	Hyperintense, isointense	Normal
III	Inhomogeneous, gray	Unclear	Intermediate	Normal*
IV	Inhomogeneous, gray to black	Lost	Intermediate to hypointense	Normal†
V	Inhomogeneous, black	Lost	Hypointense	Collapsed

DNA: distinction of nucleus and annulus, HID: height of intervertebral disc. *nomal to slightly decreased
†normal to moderated decreased

Table 2. Summary of pre-operative data comparison in ASD group and non ASD group

	Patients with ASD	Patients without ASD	p-value
Number of Patients	7	27	
Age (years)	67.4±4.8	57.5±13.2	p<0.05
Follow-up period (months)	28.4±8.8	26.8±12.9	p>0.05
Female sex ratio (%)	60.0%	54.2%	p>0.05
DDU*	6	4	p<0.05

ASD: Adjacent Segment Degeneration
*Disc degeneration of upper adjacent segment (Lower than grade III)

Table 3. Summary of sagittal angle in ASD group and non ASD group

	Patients with ASD				Patients without ASD			
	Pre OP	Post OP 3 months	Post OP 6 months	Last Follow up	Pre OP	Post OP 3 months	Post OP 6 months	Last Follow up
MLA	38.4±10.6	38.9±9.9	37.6±10.7	36.1±11.0*	36.1±12.1	38.5±8.9	38.9±9.6	39.0±10.7
Cranial†	11.5±7.8	13.5±5.6	15.2±6.3	17.0±13.5*	12.1±6.2	11.9±5.7	12.2±5.8	12.9±6.4
Caudal‡	19.6±10.4	19.6±10.9	19.9±10.4	20.0±11.1	19.5±8.1	19.8±9.4	20.5±9.0	21.8±9.2

ASD: adjacent segment degeneration, MLA: mean lordotic angle, OP: operation
*Significant intergroup differences (p<0.05) in angular changes from preperative angle in each group
†Cranial segmental lordotic angle change.
‡Caudal segmental lordotic angle change

Table 4. Summary of clinical outcome and reoperation in ASD group and non ASD group

Odom's criteia	Patients with ASD (n=7)	Patients without ASD (n=27)	p-value
Excellent	0(0/0%)	8 (29.7%)	p>0.05
Good	3(42.9%)	11 (40.6%)	p>0.05
Fair	3(42.9%)	8 (29.7%)	p>0.05
Poor	1(14.2%)	0 (0.0%)	p>0.05

ASD: adjacent segment degeneration

lent, 11 (40.6%) Good, 8 (29.7%) Fair and 0 Poor. The difference between the two groups was not statistically significant (Table 4) and thus the presence of ASD did not necessarily mean poor prognosis. Among the 7 patients having a degenerative change in the adjacent segment during the follow-up, only 1 was required to have secondary surgical treatment.

Lastly, in order to examine the presence of postoperative bone fusion rate, we used Brantigan & Steffee's classification. When Grade 4 and 5 were regarded as bone fusion, all of the 34 patients were classified as Grade 4 or higher, so were considered to have bone fusion, but it is necessary to confirm bone fusion through further follow-up and CT scan. In addition, a halo effect around the screw or screw pullout was observed in none of the patients, so screw failure did not happen among the patients. Furthermore, screw mal-position was not observed, and surgical complications such as deep infection and nerve root injury did not occur in any of the patients.

DISCUSSION

Since pedicle screw was developed in order to ensure spinal stability, pedicle screw fixation has been used as a common operative procedure along with spinal fusion in case spinal fusion is required. Particularly for degenerative spinal diseases such as spinal stenosis and spondylolisthesis, it was settled as a general treatment guideline for attaining nerve decompression and stability[15]. Since then, pedicle screw fixation has been used in many cases of degenerative lumbar disease, but degenerative change occurring in the adjacent segment after fixation has been raised as a problem.

In 2004, Hilibrand and Robbins explained that ASD is a radiological change occurring in the adjacent segment after spinal fixation regardless of the patient's symptoms[11]. Moreover, it has been reported that ASD occurs in various degrees of around 8-100% after spinal fixation[19], and with regard to the causes of ASD many studies have reported differences in joint hypermobility, age, sex, the number of fixed spinal segments, operative procedure, etc[7,22].

Lee et al.[17] confirmed that, after spinal fusion, the postoperative sagittal rotation angle of the cranial adjacent segment increased by 37% compared to the preoperative one, and Kumar et al.[16] reported that if the postoperative total lordotic angle decreases more it increases the joint hypermobility of the adjacent segment and this, in turn, results in the joint degeneration of the adjacent segment. In our study as well, the total lordotic angle decreased significantly from 38.35±10.56° to 36.08±11.02° after the operation in the ASD group, but increased from 36.06±12.06° to 39.03±10.71° in 3 months from the operation in the non-ASD group. In addition, the cranial segmental angle of the adjacent segment increased from 11.49±7.79° to 16.99±3.49° in the ASD group, but changed little from 12.06±6.19° to 12.94±6.39° in the non-ASD group.

On the contrary, Axelsson et al.[2] and Hoogendoorn et al.[12] argued that joint hypermobility did not occur in the adjacent segment and, as meant literally by degenerative change, degeneration occurred over time and not because of the hypermobility of the facet joint caused by spinal fusion.

Ahn et al.[7] reported that ASD showed poorer prognosis in old patients, saying that the incidence of ASD is higher in old patients because an old age makes it difficult to adapt to biomechanical changes and degeneration is already in progress due to factors such as the negative effect of osteoporosis. Aota et al.[3] also suggested that an age of 55 or older is one of major risk factors of ASD after spinal fusion. In our study as well, the mean age of the ASD group was 67.40±4.81, significantly order than 57.46±13.18 the mean age of the non-ASD group.

In addition, sex is still controversial as a cause of ASD, but the incidence of ASD is believed to be higher in women because degenerative diseases such as spinal stenosis and degenerative spondylolisthesis are more common in female patients. However, Harrop et al.[13] reported that the number of patients re-operated for ASD after spinal fusion was larger among male patients, and Ahn et al.[7] also reported that the ASD survival rate after spinal fusion was higher in women than in men and the incidence of ASD was higher among patients doing hard labor. In our study, the male-female ratio was not significantly different between the ASD group and the non-ASD group.

In spinal fusion, the number of fixed spinal segments is one of important issues related to the incidence of ASD. Some authors say that the number of fixed segments is nothing to do with the degeneration of the adjacent segment[4,10], but some others insist that a larger number of fixed segments increase the risk of degenerative change[5,8,23,27]. Considering this, the number of segments in the first spinal fusion may affect the later incidence of ASD and thus it is considered an import matter to decide segments to be operated in the first surgery.

Recently, the use of percutaneous pedicle screw fixation is increasing in substitute for conventional pedicle screw fixation[9,18,21]. In conventional pedicle screw fixation, the superior facet joint needs to be resected for making a starting entry point to insert the screw and this causes instability to the facet joint of the adjacent segment[1,7,14,28]. Wiltse et al.[24] reported that conventional pedicle screw fixation gave an injury to the superior facet joint of the adjacent segment in around 24-32%, and Chen et al.[6] reported that conventional pedicle screw fixation gave an injury to the superior facet joint of the adjacent segment in around 25-100%. In addition, Son et al.[25] reported that in conventional pedicle screw fixation for two levels lumbar segments, ASD occurred in 24 (48%) out of 50 patients and 7 (14%) of them had reoperation. According to the report of Knox et al.[14], however, percutaneous pedicle screw fixation gave an injury to the superior facet joint only in 11.48%, suggesting that percutaneous pedicle screw fixation may reduce facet joint injury and, consequently, the risk of ASD.

It has been reported, moreover, that percutaneous pedicle screw fixation damages muscle and soft tissue less than conventional pedicle screw fixation. In conventional pedicle screw fixation, muscle pull is severe and the duration of surgery is long, and these factors reduce blood flow to muscle and cause necrosis and atrophy. It is reported that, as a result, muscle strength decreases after the operation, and therefore higher pressure is delivered to the disc and the flexion and extension of muscle is reduced, and this decreases the total lordotic angle and causes hypermobility in the adjacent segment, aggravating degenerative change[20,26]. Therefore, percutaneous pedicle screw fixation is believed to lower the risk of ASD by reducing the injury of surrounding tissue.

In our study, ASD occurred in 7 patients (20.6%) among 34 patients who had percutaneous pedicle screw fixation and 1 (2.9%) of them had reoperation, showing relatively low incidence of ASD and reoperation. The reoperation patient had spinal fusion of lumbar vertebra 3-4-5 in the first surgery, and the preoperative disc degeneration of upper lumbar 2 and 3 was already severe as Grade IV, but spinal stenosis was not severe and instability was not observed. Thus, in case disc degeneration is severe in the first operation, we may need to consider extending fusion to the upper lumbar.

This study has a number of limitations. One is that, as a retrospective study, it could not exclude or control all the factors that might affect the results. In addition, because the incidence of ASD was investigated during a relatively short period of follow-up, 27 months on the average, ASD was likely to happen after the period. Thus, a longer follow-up may be necessary in future research. Lastly, direct comparison with conventional two levels pedicle screw fixation is necessary.

CONCLUSION

Percutaneous pedicle screw fixation can be a substitutional technique to prevent ASD for two levels fusion. However, it also has some risk of postoperative ASD when the patient is relatively old or the pre-operative severe disc degeneration of the adjacent segment, thus, special attention should be paid during follow-up periods.

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