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ORIGINAL ARTICLE

Arthrodesis to L5 versus S1 in long instrumentation and fusion for degenerative lumbar scoliosis

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Abstract There is a debate regarding the distal fusion level for degenerative lumbar scoliosis. Whether a healthy L5-S1 motion segment should be included or not in the fusion remains controversial. The purpose of this study was to determine the optimal indication for the fusion to the sacrum, and to compare the results of distal fusion to L5 versus the sacrum in the long instrumented fusion for degenerative lumbar scoliosis. A total of 45 patients who had undergone long instrumentation and fusion for degenerative lumbar scoliosis were evaluated with a minimum 2 year follow-up. Twenty-four patients (mean age 63.6) underwent fusion to L5 and 21 patients (mean age 65.6) underwent fusion to the sacrum. Supplemental interbody fusion was performed in 12 patients in the L5 group and eleven patients in the sacrum group. The number of levels fused was 6.08 segments (range 4–8) in the L5 group and 6.09 (range 4–9) in the sacrum group. Intraoperative blood loss (2,754 ml versus 2,938 ml) and operative time (220 min versus 229 min) were similar in both groups. The Cobb angle changed from 24.7° before surgery to 6.8° after surgery in the L5 group, and from 22.8° to 7.7° in the sacrum group without statistical difference. Correction of lumbar lordosis was statistically better in the sacrum group ($P = 0.03$). Less correction of lumbar lordosis in the L5 group seemed to be associated with subsequent advanced L5-S1 disc degeneration. The change of coronal and sagittal imbalance was not different in both groups. Subsequent advanced L5-S1 disc degeneration occurred in 58% of the patients in the L5 group. Symptomatic adjacent segment disease at L5-S1 developed in five patients. Interestingly, the development of adjacent segment disease was not related to the preoperative grade of disc degeneration, which proved minimal degeneration in the five patients. In the L5 group, there were nine patients of complications at L5-S1 segment, including adjacent segment disease at L5-S1 and loosening of L5 screws. Seven of the nine patients showed preoperative sagittal imbalance and/or lumbar hypolordosis, which might be risk factors of complications at L5-S1. For the patients with sagittal imbalance and lumbar hypolordosis, L5-S1 should be included in the fusion even if L5-S1 disc was minimal degeneration.

Keywords Adult spinal deformity · Degenerative lumbar scoliosis · Distal fusion level · L5-S1 disc · Disc degeneration

Introduction

Whether a L5-S1 disc in the patients with degenerative lumbar scoliosis may be preserved or included in the fusion remains controversial [2, 7, 11]. Stopping fusion at L5 offers the preservation of the L5-S1 motion segment, and has the advantages of a smaller surgery and a decreased likelihood of pseudarthrosis. The disadvantage of fusion to L5 is subsequent disc degeneration at L5-S1. Subsequent disc degeneration is associated with the loss of sagittal balance and the need for revision surgery. In contrast,

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extension of fusion to the sacrum is more extensive and associated with higher rate of pseudarthrosis at L5-S1.

It is commonly accepted that arthrodesis to the sacrum should be considered positively in patients who have pre-existing pathology at L5-S1 such as marked disc degeneration, spinal stenosis, spondylolisthesis, and lumbosacral obliquity [2, 4]. For patients with a healthy or minimal degenerated disc at L5-S1, saving L5-S1 or fusing to the sacrum has not yet been determined. If the L5-S1 disc is healthy, this segment may not be included in the fusion. However, degeneration can progress even in the healthy L5-S1 disc after long instrumented fusion stopping at L5. Since degenerative lumbar scoliosis usually develops in the elderly population, most patients might have minimal degeneration at the L5-S1 disc. To eliminate the possibility of subsequent advanced disc degeneration, the fusion should be extended to the sacrum initially in all patients.

The purpose of this study was to determine the optimal indication for the fusion to the sacrum, and to compare the results of distal fusion to L5 versus the sacrum in the long instrumentation and fusion for degenerative lumbar scoliosis.

Methods

Forty-five patients who had undergone decompression and fusion with pedicle screw instrumentation for degenerative lumbar scoliosis were evaluated retrospectively with a minimum 2 year follow-up. The average age of the patients was 64.4 years (range 53–75). There were 6 men and 39 women. The average follow-up period was 3.5 ± 1.7 years (range 2–8 years). Twenty-four patients underwent fusion to L5, and 21 patients underwent fusion to the sacrum. Supplemental interbody fusion was performed at L4-5 and L5-S1 in 23 patients, including 12 patients in the L5 group and 11 patients in the S1 group.

This study included the patients with pedicle screw instrumentation from thoracolumbar to the sacrum. Patients who underwent sacro-pelvic fixation with additional iliac screws were excluded from this study. Inclusion criteria were as follows: (1) Cobb angle >10°; (2) Posterior fusions including at least four vertebral segments; (3) No evidence of adolescent idiopathic scoliosis; (4) Age >50 years at the time of surgery.

Hospital records were reviewed for patients' medical co-morbidities, smoking history, estimated intraoperative blood loss, operative time, and any hospital stays. The number of levels fused and the number of levels decompressed were measured.

Long standing anteroposterior and lateral radiographs were reviewed preoperatively, immediate postoperatively, and at the final postoperative follow-up periods. The Cobb angle, lumbar lordosis, coronal and sagittal balance, pelvic incidence, sacral slope, and pelvic tilt were assessed. Lumbar lordosis was measured from the upper endplate of T12 to the endplate of S1. Sagittal balance was measured by the C7 plumb line from the posterosuperior corner of the sacrum. Clinical outcomes were assessed with the Oswestry disability index. We compared the clinical outcomes between the patients with fusion to L5 and those with fusion to the sacrum.

The radiographic grade for the L5-S1 disc was measured in plain radiographs with the modified method by Weiner et al. [12]. The scoring system has four grades. Grade 0 represented no degeneration. Grade 1 was a mild degeneration which was defined by <25% disc space narrowing, small spur formation, minimal eburnation, no listhesis, and no gas. Grade 2 was moderate degeneration, which was defined by 25-75% disc space narrowing, moderate spur formation, moderate eburnation, listhesis >3 mm, and no gas. Grade 3 was advanced degeneration, which was defined by >75% disc space narrowing, large spur formation, marked eburnation, listhesis >5 mm, and the presence of gas.

The loosening of L5 and S1 screws was evaluated meticulously. Implant loosening was defined as change of position and angle of the screws under the following criteria: (1) change of 3 mm or more in the position of the screw tips relative to the endplates of L5 or S1; (2) change of 5° or greater in the angle between the screws and the endplate of L5 or S1.

The statistical analysis was performed using SPSS version 11.5. We used *t*-tests and Pearson chi-square tests. The significance was defined as $P < 0.05$.

Operative procedures

The average number of levels fused was 6.08 segments (range 4–8) in the L5 group and 6.09 (range 4–9) in the sacrum group with no statistical difference. The upper instrumented vertebra (UIV) was T9 in 2 patients, T10 in 11 patients, T11 in 3 patients, T12 in 3 patients, and L1 in 5 patients in the L5 group. In the sacrum group, the UIV was T9 in one patient, T10 in seven patients, T11 in two patients, T12 in one patient, L1 in three patients, and L2 in seven patients.

We usually performed fusion to the sacrum in patients who had severe degenerative change at L5-S1. Regardless of disc degeneration, some patients had definite pathology at L5-S1 including spondylolisthesis and spinal stenosis. Those patients underwent fusion to the sacrum. All patients with grade 3 disc degeneration had fusion to the sacrum. Grade 2 disc degeneration was not an absolute indication for fusion to the sacrum. Eight of 24 patients in the L5

Table 1 Clinical parameters between the L5 and the sacrum group

	L5 group ($n = 24$)	Sacrum group ($n = 21$)	*P*-value
No. of levels fused (n)	6.08 ± 1.3	6.09 ± 1.9	0.98
Age (year)	63.6 ± 6.3	65.6 ± 6.8	0.31
No. of co-morbidities	1.57 ± 0.8	1.73 ± 0.6	0.64
Blood loss (ml)	2,754 ± 1,195	2,938 ± 1,923	0.7
Operative time (min)	220 ± 47	229 ± 65	0.6
No. of decompression	2.0 ± 0.16	2.65 ± 0.22	0.08

group showed grade 2 L5-S1 disc degeneration before surgery. The rest of the patients in the L5 group had a healthy (grade 0 or 1) L5-S1 disc.

Results

Clinical evaluation

The average age was 63.6 (range 53–74) in the L5 group and 65.6 (range 54–74) in the sacrum group with no statistical difference ($P = 0.98$; Table 1). The numbers of medical co-morbidities were similar in both groups. The mean estimated intraoperative blood loss was 2,754 ml in the L5 group and 2,938 ml in the sacrum group ($P = 0.7$). The average operative time was 220 min in the L5 group and 229 min in the sacrum group ($P = 0.6$). It has been recognized in previous reports that extension fusion to the sacrum offered more extensive surgeries with more blood loss and longer operative times. Contrary to these pervious reports, there was no statistical difference of blood loss and operative time between the two groups in this current study. This study included the patients who underwent sacral fixation alone. The patients fused to the pelvis with iliac screws were not included.

Radiological evaluation

Before surgery, the average Cobb angle was 24.7° (range 11–45°) in the L5 group and 22.8° (range 13–42°) in the sacrum group (Table 2). At the last visit, it changed to 6.8° in the L5 group and 7.7° in the sacrum group. The correction of the Cobb angle was similar in both groups ($P = 0.34$).

The restoration of lumbar lordosis was better in the sacrum group ($P = 0.03$). In the L5 group, lumbar lordosis was −26.7° before surgery, −25.8° immediately after surgery, and changed to −20.2° at the last visit. In the sacrum group, it was −24.6° preoperatively, −25° after surgery, and then −25.4° at the last visit. The loss of correction of lumbar lordosis was more in the L5 group

Table 2 Radiological parameters between the L5 and the sacrum group

	L5 group ($n = 24$)	Sacrum group ($n = 21$)	*P*-value
Cobb angle (°)			
Preop	24.7 ± 11.6	22.8 ± 7.5	0.51
Final	6.8 ± 6.5	7.7 ± 5.9	0.63
Change	17.3 ± 10.7	14.7 ± 7.4	0.34
Lumbar lordosis (°)			
Preop	26.7 ± 14.7	24.6 ± 14.3	0.63
Final	20.2 ± 10	25.4 ± 12.6	0.14
Change	−6.6 ± 11.4	0.8 ± 10.5	0.03
Coronal C7 plumb (mm)			
Preop	16.8 ± 11.2	19.1 ± 19.8	0.62
Final	9.7 ± 7.5	10.0 ± 9.2	0.42
Change	7.1 ± 8.0	9.1 ± 7.1	0.42
Sagittal C7 plumb (mm)			
Preop	52.8 ± 36.2	47.0 ± 28.9	0.56
Final	82.8 ± 41.0	75.4 ± 42.5	0.58
Change	−29.9 ± 28.5	−24.7 ± 36.2	0.62

than in the sacrum group, which might be related to the subsequent progression of L5-S1 disc degeneration. The mean segmental lordotic angle at L5-S1 was −7.2° before surgery, and changed to −2.1° at the last visit. The loss of segmental angle at L5-S1 contributed to the loss of overall lumbar lordosis.

The correction of the coronal balance was identical in both groups. The coronal C7 plumb was 16.8 mm preoperatively and 9.7 mm at the last visit in the L5 group. Similarly, it was 19.1 mm before surgery and 10 mm at the last visit in the sacrum group ($P = 0.42$).

The average C7 sagittal plumb was aggravated after pedicle instrumentation alone in both groups. The sagittal C7 plumb changed from 52.8 mm before surgery to 82.8 mm at the last visit in the L5 group. In the sacrum group it changed from 47 to 75.4 mm. There were no differences in the change of sagittal imbalance in both groups ($P = 0.62$). The aggravation of sagittal imbalance was attributed to multiple factors, such as subsequent advanced L5-S1 disc degeneration, instrumentation failure, and pseudarthrosis. Patients with subsequent L5-S1 disc degeneration had a greater forward shift in the sagittal C7 plumb than the patients with no disc degeneration (+90.5 versus +67.5, respectively).

The pelvic parameters were not different between the two groups. The mean pelvic incidence was similar in both groups, 57.6° in L5 group and 58.3° in sacrum group ($P = 0.827$). Sacral slope and pelvic tilt were also similar before and after surgery between the two groups (Table 3).

Table 3 Pelvic parameters between the L5 and the sacrum group

	L5 group ($n = 24$)	Sacrum group ($n = 21$)	*P*-value
Pelvic incidence (°)	57.6 ± 9.4	58.3 ± 10.2	0.827
Sacral slope (°)			
Preop	25.3 ± 5.7	21.1 ± 6.2	0.97
Final	20.7 ± 4.9	22.5 ± 6.2	0.27
Pelvic tilt (°)			
Preop	31.9 ± 12.4	36.3 ± 8.8	0.20
Final	37.4 ± 8.1	36.6 ± 8.8	0.62

Subsequent progression of L5-S1 disc degeneration

The L5-S1 disc degeneration was assessed by the Weiner method [12]. Grade 0 or 1 disc degeneration was considered healthy, whereas grade 2 or 3 was considered as advanced degeneration. Of 24 patients in the L5 group, 3 patients had grade 0 disc degeneration, 13 patients had grade 1, and 8 patients had grade 2 at L5-S1 before surgery. The average grade of L5-S1 disc degeneration was 1.1 before surgery and progressed to 2.3 at the last follow-up in the L5 group. In the sacrum group, the preoperative L5-S1 disc degeneration grade was 1.82 (Fig. 1).

Subsequent advanced disc degeneration was defined as change from a healthy disc (grade 0, 1) before surgery to an advanced disc (grade 2, 3) at the last visit. Subsequent

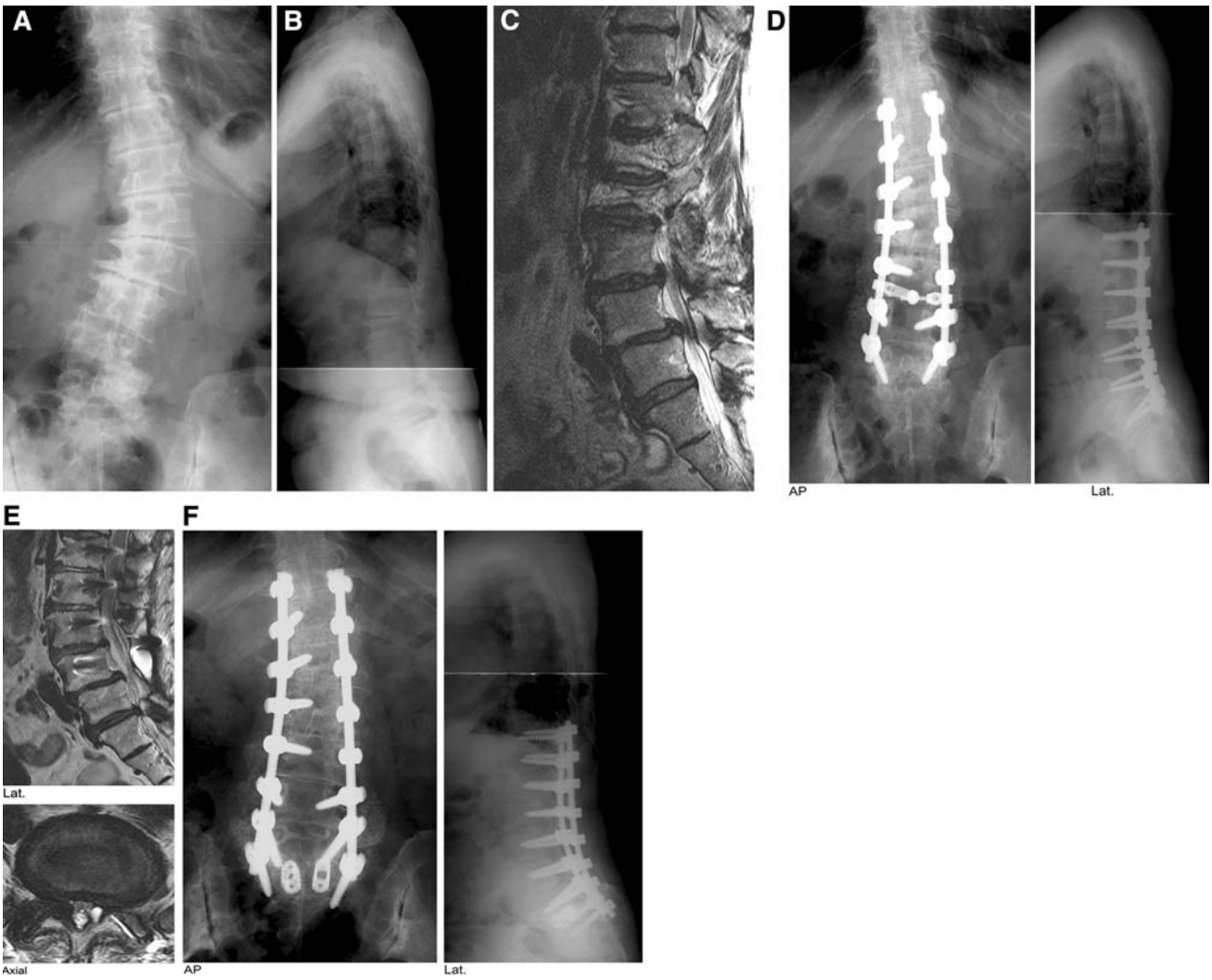

Fig. 1 **a** This 72-year-old lady had degenerative lumbar scoliosis. **b** Standing preoperative sagittal radiograph showed C7 plumb shifted to anterior about 10 cm and showed a healthy L5-S1 disc. (Grade 1 disc degeneration by modified Weiner method). **c** Preoperative MRI also showed a minimal degenerated L5-S1 disc. **d** As the L5-S1 disc was healthy, we performed spinal instrumented fusion to L5. **e** After 1 year after surgery, spinal stenosis developed at L5-S1. **f** The patient underwent extension of fusion to the sacrum with decompression surgery for the spinal stenosis at the L5-S1

advanced disc degeneration also included the patients with symptomatic adjacent segment disease at L5-S1 during the follow-up period. Subsequent advanced disc degeneration may not cause pain, whereas adjacent segment disease such as herniated disc or spinal stenosis can cause clinical symptoms.

With this definition, subsequent advanced L5-S1 disc degeneration occurred in 14 (58%) of 24 patients (Table 4). The risk factors for subsequent advanced disc degeneration were evaluated. The preoperative status of disc degeneration was not found as a risk factor for subsequent advanced degeneration. Of 16 patients with healthy disc, 12 (75%) patients showed progression of disc degeneration at the most recent follow-up. Preoperative sagittal imbalance was also not a risk factor for the subsequent L5-S1 disc degeneration. For patients with preoperative balanced sagittal alignment (C7 plumb <50 mm), subsequent disc degeneration developed in 8 (62%) of 13 patients. In the sagittal imbalance with preoperative C7 plumb >50 mm, subsequent degeneration developed in 8 (73%) of 11 patients.

Symptomatic adjacent segment disease at L5-S1 occurred in five patients in the L5 group, including spinal stenosis ($n = 2$), junctional kyphosis ($n = 2$), and a herniated lumbar disc ($n = 1$). For these five patients, the L5-S1 disc was healthy (grade 1) before surgery. This finding demonstrated that the preoperative disc degeneration was not associated with the development of adjacent segment disease. On the other hand, the patients who had preoperative sagittal imbalance and lumbar hypolordosis were more likely to develop adjacent segment disease at L5-S1. Of five patients with adjacent segment disease, four patients showed preoperative sagittal imbalance (sagittal C7 plumb >5 cm), and lumbar hypolordosis (<30°). It also appeared that preoperative sagittal imbalance and lumbar hypolordosis were closely related to the development of loosening of L5 screws. Three of four patients with loosening of L5 screws had sagittal imbalance and lumbar hypolordosis before surgery.

Table 4 Subsequent progression of L5-S1 disc degeneration in the L5 group

Grade of disc degeneration		No. of patients
Preop	Final	
0	1	2
	2	1
1	1	2
	2	4
	3	4
	Operated	3
2	3	6
	Operated	2

Surgical correction of sagittal imbalance did not prevent the development of adjacent segment disease. Adjacent segment disease occurred in three of five patients in whom preoperative sagittal imbalance was restored immediately after surgery. This result revealed that adjacent segment disease might develop regardless of surgical correction of sagittal imbalance.

Complications

Loosening of implant fixation occurred in four patients in the L5 group. Of the patients, two underwent posterior instrumentation alone and two underwent combined posterior instrumentation and interbody fusion at L4-5. In spite of concomitant interbody fusion, loosening of L5 screws developed in two patients. In the sacrum group, loosening of fixation occurred at the sacral screws in five patients. This study did not include the patients with sacro-pelvic fixation. For that reason, there seemed to be relatively high incidence of loosening of fixation.

Pseudarthrosis was identified at L5-S1 in one patient. Pseudarthrosis was closely related to the loosening of fixation. The patients with loosening of fixation were likely to have pseudarthrosis simultaneously. But they were counted as loosening of fixation, not counted twice in the category of pseudarthrosis (Table 5).

There were no differences in the incidences of perioperative medical complications between the two groups. There were seven cases of perioperative complications in the L5 group, and eight cases in the sacrum group. The most common perioperative complications were respiratory complications, involving two patients in the L5 group and three patients in the sacrum group.

Revision surgeries were performed in nine patients, five patients in the L5 group, and four patients in the sacrum group. In the L5 group, extension of fusion to the sacrum

Table 5 Late complications

	L5 group ($n = 24$)	Sacrum group ($n = 21$)
Failure of instrumentation at L5, S1	4	5
Pseudarthrosis L5-S1	–	1
Distal adjacent segment disease at L5-S1		
Spinal stenosis	2	–
Herniated lumbar disc	1	–
Junctional kyphosis	2	–
Proximal adjacent segment disease		
Junctional kyphosis	2	1
Compression fracture	2	2
Disc collapse	1	2
Total	14	11

was performed in three patients for adjacent segment disease at L5-S1 and a patient for loosening of L5 screws. A compression fracture at T12 was required extension of fusion to T10. In the sacrum group, one patient with junctional kyphosis at L1-L2 was revised. One case of pseudarthrosis with segmental kyphosis at the L5-S1 underwent extension of fusion to the pelvis with reinforcing iliac screws. Two patients with loosening of S1 screws were revised to bicortical sacral screw fixation and supplemental interbody fusion.

Clinical outcomes

The improvement of the Oswestry score was similar in both groups ($P = 0.83$). The mean Oswestry disability index improved from 38.5 preoperatively to 26.9 at the last visit in the L5 group, and in the sacral group from 45.7 preoperatively to 32.6 at the last visit.

Discussion

Most patients in the elderly population with degenerative lumbar scoliosis have degenerative changes at L5-S1, minimal or advanced. Determination of distal fusion level, whether to fuse L5-S1 or not, is still controversial especially in the patients with minimal L5-S1 disc degeneration [1, 4, 7].

The indications for arthrodesis to the sacrum have been reported as follows [2, 4, 11]: (1) spinal deformity involving the lumbosacral junction, (2) advanced degeneration of the L5-S1 motion segment, (3) lumbosacral instability due to spondylolysis or a prior decompression. In addition to these recognized indications, the aim of this study was to determine the optimal indications to fuse to the sacrum in the patients with a minimal L5-S1 disc degeneration.

Long fusions to the sacrum lead to several problems [2, 5]. First, exposing the sacrum requires longer operation times and more blood loss. Second, the pseudarthrosis rate is substantially higher, especially when posterior fusion alone is performed. Third, fusion to the sacrum removes the motion at the lumbosacral motion segment, resulting in altering the mechanics of gait. Finally, some may have concerns regarding the subsequent degeneration of the sacroiliac joints.

Edwards II et al. [5] found that major complications occurred more frequently in the sacrum cohort than in the L5 cohort. Contrary to the previous study, the current study showed that fusions to the sacrum were found to have a similar operative time and estimated blood loss in both groups. There seemed to be two reasons for these different findings. First, the average number of levels fused was similar between the L5 group and the sacrum group. The number of patients receiving interbody fusion was also similar in both groups. Second, the previous other studies commonly used iliac screws in addition to the sacral screws for sacro-pelvic fixation. This study excluded the patients using iliac screw fixation. In the revision procedures for the patients with instrumentation failure at S1 screws, the sacral screws were reinforced with iliac screw fixation.

It has generally been accepted that the pseudarthrosis rate is higher when the fusion is extended to the sacrum than stopping fusion at L5 [8, 9]. Higher rates of pseudarthrosis may be associated with a less rigid fixation method. Emami et al. [6] found a significant pseudarthrosis rate in 36% of patients with the Luque Galveston technique and 14% of patients with the sacral and iliac screws. Bridwell et al. [2] noted that they did not have a failure of the sacral screws by combination with anterior structural support and iliac screw fixation. However, even with this approach they encountered pseudarthrosis at L5-S1.

Long fusion constructs are often associated with instrumentation failure [6, 10]. Instrumentation failures result from inadequate fixation, poor bone quality, and multiple levels requiring arthrodesis. In the sacrum group, there were five patients with loosening of screws and one pseudarthrosis. These high rates (25%) of instrumentation failure suggest that sacral fixation alone might be insufficient for long segment fixation to the sacrum. In reference to biomechanical studies, two important principles are well known to reduce the incidence of instrumentation failure. Supplemental interbody fusion at the lumbosacral junction is usually recommended to enhance the fusion and to reduce the stress at sacral fixation points. In addition to S1 screws, sacro-pelvic fixation or additional sacral screws would be considered to reinforce S1 screws. As well as sacral screws, instrumentation failure of the L5 screws in long fusion was also common. The L5 pedicles are shorter and more cancellous than those used in the upper lumbar spine. The fixation with two pedicle screws for short and cancellous L5 pedicles may be inadequate for long fusion [2, 10].

Emami et al. [6] investigated 54 patients who underwent long fusion to the sacrum for adult spinal deformity. They favored bicortical sacral screws with structural anterior column support at the lumbosacral junction in patients with good bone stock, and when the coronal and sagittal balance is achievable. In circumstances where coronal and sagittal balance cannot be achieved, or in cases with significant pelvic obliquity, a combined fixation with iliac screws should be used in addition to the sacral screws.

The most common complication with stopping fusion at L5 seems to be the subsequent progression of L5-S1 disc degeneration. It has been reported that subsequent advanced L5-S1 disc degeneration developed in 38–61% of

patients in the literature [2–4, 7]. Our result showed similar rate (58%) of subsequent advanced disc degeneration to other studies. Although subsequent advanced disc degeneration was associated with loss of lumbar lordosis or positive sagittal imbalance, it was less likely to cause symptoms. On the other hand, adjacent segment disease could adversely affect clinical outcomes and necessitate further surgical intervention.

Symptomatic adjacent segment disease at L5-S1 developed in 5 (21%) patients in the L5 group. Three (60%) of five patients with adjacent segment disease underwent revision surgery. It is essential to reduce the incidence of adjacent segment disease to improve the clinical outcome. This current study demonstrated that preoperative sagittal imbalance and poor lumbar lordosis were associated with the development of adjacent segment disease at L5-S1.

Conclusions

Fusion to the sacrum demonstrated better correction of lumbar lordosis than fusion stopping at L5. Less correction of lumbar lordosis in the L5 group seemed to be related to subsequent advanced L5-S1 disc degeneration. Correction of sagittal imbalance was not acceptable with only posterior instrumentation. Poor correction of sagittal imbalance was associated with multiple factors, including advanced disc degeneration, instrumentation failure and pseudarthrosis. Those complications occurred considerably in both groups.

Subsequent advanced L5-S1 disc degeneration developed in 14 (58%) of the 24 patients in the L5 group. Symptomatic adjacent segment disease at L5-S1 developed in 5 (21%) patients in the L5 group. For these five patients, the L5-S1 disc was minimal degeneration (grade 1) before surgery. According to the current findings, the risk factors of adjacent segment disease at L5-S1 were preoperative sagittal imbalance and lumbar hypolordosis. It has been accepted that fusion to the sacrum can be performed for advanced L5-S1 disc degeneration. For minimal L5-S1 disc degeneration, fusion to the sacrum is recommended in the patients with sagittal imbalance and lumbar hypolordosis before surgery.

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