Risk-Factor Analysis of Disc and Facet Joint Degeneration After Inter-Segmental Pedicle Screw Fixation for Lumbar Spondylolysis

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Abstract

Background: To assess the effects of inter-segment pedicle screw fixation for the treatment of lumbar spondylolysis, and evaluate various risk factors potentially predicting the probability of disc and facet joint degeneration after instrumentation.

Methods: The study included 54 male L5 spondylolysis patients who underwent pars repair and inter-segment fixation using pedicle screws. Bony union was evaluated using reconstruction images of computed tomography. Radiographic changes including the disc height, vertebral slip, facet joint and disc degeneration in the grade of adjacent and fixed segments were determined from before to final follow-up. Logistic regression analysis was performed to identify factors associated with the incidence of disc and facet joint degeneration.

Results: Bony union was achieved in all cases. Logistic regression analysis revealed that duration of instrumentation of more than 15.5 months and 21.0 months were significant risk factor of the incidence of L4/5 and L5S1 facet degeneration, respectively.

Conclusions: Inter-segmental pedicle screw fixation provides good surgical outcomes and good isthmic bony union rates in patients with lumbar spondylolysis. The duration of fixation was confirmed as a risk factor of facet joint degeneration. Once bony union is achieved, remove of the instruments should be recommended.

Background

Lumbar spondylolysis refers to a defect of the vertebral pars interarticularis caused by stress fracture and occurs in approximately 6% of the general population, the incidence of symptomatic spondylolysis is reported to be higher in athletes(1). The lesion is mainly located at L5 (71–95%), L4 (5–23%) but can occur at any level(2, 3).

Generally, patients with low back pain because of spondylolysis are often managed conservatively with medication, physical therapy, and injection treatment(4, 5). Surgery is indicated when failure of a comprehensive conservative treatment for more than 6 months, persistent back pain and pars non-union. Increasing pain, worsening of preexisted neurological impairment and progressive olisthesis are also indications for surgical treatment(4, 6, 7).

In this study, we use direct repair plus inter-segment pedicle screw fixation for the treatment of lumbar spondylolysis. Although this method has fixed one active segment and may limit spinal flexibility and causes loads between segments adjacent to the fixed segments, resulting in the problem of adjacent segment degeneration (ASD)(8, 9), pedicle screws can be removed when bony-union was achieved, and whether degeneration in adjacent segments are accelerated is still unclear. To our knowledge, postoperative instability between adjacent segments, facet joint and disc degeneration have not been examined in a single-center study of cases in which lumbar inter-segmental pedicle screw fixation was performed.

The purposes of this study were to reveal the effects of inter-segment pedicle screw fixation for the treatment of lumbar spondylolysis, and evaluate various risk factors potentially predicting the probability of disc and facet joint degeneration.

Materials And Methods

Patients

We retrospectively evaluated consecutive spondylolysis patients who underwent pars repair and segmental fixation using pedicle screws at our institution between January 2016 and January 2018. All 54 patients were male and the lesion is located at L5. Patients with symptomatic spondylolysis were treated with direct iliac bone graft repair combined with inter-segmental pedicle screw fixation. Plain radiographs, computed tomography (CT) and magnetic resonance imaging (MRI) were evaluated at six, twelve, 18 and 24 months postoperatively. Instrumentation was removed after bony union was achieved (illustrative case, Fig. 1).

Spondylolysis of the lumbar spine was diagnosed as follows: all patients with low back pain had taken simple radiographs of the lumbar spine (anteroposterior, lateral, and oblique views), and if needed, CT scan was taken to confirm the presence or absence of spondylolysis. In addition, the patients with definite spondylosis on the lumbar spine radiographs and CT scans underwent MRI of the lumbar spine to detect other spinal problems, such as disc degeneration and herniation. Surgery was indicated when patients with low back pain for a diagnosis of lumbar spondylolysis, did not respond to conservative treatments for at least 6 months, and no disc or slight degeneration at the level of pars defect were found in the MRI scans. Exclusion criteria were radiological signs of spondylolisthesis or instability, previous spinal surgery, significant radicular pain, and who had improved following conservative treatment.

Operative Procedures

A posterior midline incision was made. After incision of lumbosacral fascia at 2cm paraspinous process, the mutifidus and longissimus muscles were identified and dissected away. The pars defects were exposed, carefully leaving facet joints intact. The lysis was prepared by removing fibrous tissue in and around the gap. The bony elements on both sides of the lysis were decorticated to assure bony healing of the lysis after pars repair. Cancellous bone grafts were taken from the posterior iliac crest and implanted into the pars. Four pedicle screws were implanted to fix the isthmic vertebral and the adjacent distal vertebral. Instrumentation was removed after bony fusion was achieved.

Radiological outcomes

Bony union was evaluated using reconstruction images of CT at each follow-up. Reconstructions were made in both the axial and the sagittal planes, allowing to determine a degree of union.

Radiographic changes including the disc height, vertebral slip, facet joint and disc degeneration in the grade of adjacent and fixed segments were determined from pre-operation to final follow-up. Relationships between CT and MRI findings and the progression of degeneration based on preoperative grade were also evaluated.

Disc height and vertebral slip at the L4/5 and L5/S1 levels were measured on lateral plain radiographs. The disc height was measured by Miyakoshi's procedures(10). On a lateral radiograph, the following points to be marked were identified: the corners of the vertebral bodies, the midpoints of the endplates, and the midpoints of the walls of the vertebral bodies; the points were determined strictly according to the criteria of Quint et al.(11). Using these easily defined points, the height of the L4/5 and L5S1 discs were measured. The disc height (DH) was calculated as the mean of the anterior, middle, and posterior disc heights. The sagittal diameter of the vertebral body from the anterior to posterior margin was measured at the mid-vertebral level, disc height index (DHI) was calculated as disc height/ sagittal diameter of the vertebral body(12).

Disc degeneration of the adjacent and fixed segments were reviewed using MRI during the follow-up. Disc degenerative grading was measured using the Pfirrmann 5-grade classification, which includes grades 1 to 5(13). Facet joint degeneration was measured using the classification for osteoarthritis of the Japanese Orthpaedic Association (JOA), which includes grades 0 to 4. Grade 0 indicates severe degeneration and Grade 4 indicates a normal joint without degeneration(14).

All surgeries were performed using same procedures at our institution, the incidence of complications was compared between the two groups. Potential risk factors of disc and facet joint degeneration, such as age, obesity (Body Mass Index, BMI), duration of the fixation, vertebral slip, and facet joint degeneration before primary surgery, were identified by reviewing medical records. Imaging assessment was assessed by 2 spine surgeons (ZCZ and GMZ)

The Student t test or analysis of variance was used for continuous variables and the Fisher exact test for categorical variables. SPSS software, version 23.0 (SPSS, Chicago, IL, USA) was used for all analyses, and a two-sided p value < 0.05 was considered statistically significant. Logistic regression analysis was performed to identify factors independently associated with the incidence of disc and facet joint degeneration.

Results

At the time of the primary surgery, the mean age was 22.76 years (18 to 34). Mean BMI was 22.81 kg/m^2 (19.23 to 24.77). Bony union was achieved in all cases, as confirmed by CT reconstruction, the mean fixed time was 17.04 months (8 to 39). No complications were observed during the follow-up.

Cases of disc and facet joint degeneration detected on plain radiographs are shown in Table 1. Decreased disc height in the upper adjacent segment L4/5 of ≥ 20% occurred in one patient, whereas decreased disc height in the fixed segment L5/S1 of ≥ 20% was observed in one patient. Decreased disc height in the upper adjacent segment L4/5 between 20% and 10% occurred in 7 patients, whereas in the fixed segment L5/S1 was observed in 8 patients. CT indicated facet joint degeneration at L4/5 and L5/S1 in 7 and 9 patients, respectively. MRI showed disc degeneration at L4/5 and L5/S1 in 5 and 5 patients, respectively.

Table 1
Radiographic disc and facet joint degeneration.

	L4/5 (%)	L5S1 (%)
X-ray		
DH: decrease ≥ 20%	1(2%)	1(2%)
DH: 20% ≥ decrease ≥ 10%	7(13%)	8(15%)
CT		
Facet degeneration + 1 grade	7(13%)	7(13%)
Facet degeneration > 1 grade	0	2(4%)
MRI		
Disc degeneration + 1 grade	5(9%)	5(9%)
Disc degeneration > 1 grade	0	0
DH: disc height.		

The mean disc height in the upper adjacent segment L4/5 was 14.17 ± 1.74 before surgery, and 14.01 ± 2.23 after removal of instruments. The mean DHI in the L4/5 was 0.381 ± 0.03 before surgery, and 0.370 ± 0.04 after removal of instruments. The mean disc height in the fixed segment L5/S1 was 14.13 ± 1.90 before surgery, and 13.82 ± 2.03 after removal of instruments. The mean DHI in the L5S1 was 0.389 ± 0.05 before surgery, and 0.380 ± 0.05 after removal of internal fixation, no significant difference was observed (Table 2). There were 15 patients with DHI decrease ≥ 10%, 39 patients with DHI decrease ≤ 10%. For the L5S1level, the number of patients with pre-operative facet joint degeneration were 9 patients in DHI decrease ≥ 10%, and 34 patients in DHI decrease < 10%. The difference was significant ($p < 0.05$). The number of patients with pre-operative disc degeneration were 12 patients in DHI decrease ≥ 10%, and 29 patients in DHI decrease < 10%, however, the difference was not significant ($p > 0.05$) (Table 3). For the L4/5 level, no significant differences were observed between the DHI changes and pre-operative facet joint and disc degeneration (Table 3).

Table 2
Radiographic changes of disc height on plain radiographs.

	Pre-operation	Post-operation	t value	P value
DH (L4/5)	14.17 ± 1.74	14.01 ± 2.23	0.760	0.451
DHI (L4/5)	0.381 ± 0.03	0.370 ± 0.04	1.993	0.051
DH (L5S1)	14.13 ± 1.90	13.82 ± 2.03	1.712	0.093
DHI (L5S1)	0.389 ± 0.05	0.380 ± 0.05	1.772	0.082
DH: disc height; DHI: disc height index.				

Table 3
Relationship between pre-operative disc and facet joint status and disc degeneration.

	L4/5				L5S1			
	DHI decrease ≥ 10% (n)	DHI decrease < 10% (n)	*F value*	*P value*	DHI decrease ≥ 10% (n)	DHI decrease < 10% (n)	*F value*	*P value*
Facet grade pre-operation			0.000	1.000			4.934	0.026*
Degeneration ≥ 1 grade	8	32			9	34		
No degeneration	3	11			6	5		
Disc grade pre-operation			0.002*	0.964			0.006	0.937
Degeneration ≥ 1 grade	8	34			12	29		
No degeneration	3	9			3	10		
DH: disc height; DHI: disc height index.								
* Test was considered statistically significant at P < 0.05.								

In the analysis of L4/5 and L5S1 disc degeneration, there were no significant differences in demographic data (age, BMI, duration of instrument fixation, vertebral slip, and preoperative facet and disc degeneration change) (Table 4). In the analysis of L4/5 facet degeneration, there were no significant differences in demographic data (BMI, vertebral slip, and preoperative facet and disc degeneration change), however, facet degeneration group showed a significantly older age and longer duration of instrument fixation than no degeneration group (Table 5). In the analysis of L5S1 facet degeneration, there were no significant differences in demographic data (age, vertebral slip, and preoperative facet and disc degeneration change), facet degeneration group showed a significantly higher BMI and longer duration of instrument fixation than no degeneration group (Table 5).

Table 4
The analysis of risk factors for L4/5 and L5S1 discs.

	L4/5				**L5S1**			
	Degeneration	No change		*P value*	Degeneration	No change		*P value*
Age (y)	25.60 ± 5.46	22.47 ± 4.42	1.479	0.145	23.00 ± 5.15	22.73 ± 4.55	0.123	0.903
BMI	22.34 ± 1.97	22.86 ± 0.91	-1.070	0.290	22.69 ± 0.51	22.82 ± 1.08	-0.257	0.799
Fixed time (m)	17.60 ± 1.97	16.98 ± 6.51	0.202	0.841	15.20 ± 4.97	17.29 ± 6.61	-0.684	0.497
Vertebral slip (n)	5	49	0.117	0.732	5	49	0.000*	1.000
yes	1	19			2	18		
no	4	30			3	31		
Facet grade pre-operation	5	49	2.305	0.310			1.870	0.641
Grade 4	0	13			4	7		
Grade 3	5	28			7	14		
Grade 2	0	8			4	9		
Grade 1	0	0			1	8		
Grade 0	0	0			0	0		
Disc grade pre-operation	5	49	3.094	0.347	5	49	6.854	0.113
Grade 1	2	9			3	10		
Grade 2	2	26			0	22		
Grade 3	0	10			2	10		
Grade 4	1	4			0	6		
Grade 5	0	0			0	1		

BMI: Body Mass Index.

* Test was considered statistically significant at $P < 0.05$.

Table 5
The analysis of risk factors for L4/5 and L5S1 facet joints.

	L4/5				**L5S1**			
	Degeneration	No change		P value	Degeneration	No change		P value
Age (y)	26.29 ± 5.38	22.23 ± 4.24	2.278	0.027*	23.22 ± 4.82	22.67 ± 4.56	0.331	0.742
BMI	23.37 ± 0.59	22.72 ± 1.06	1.572	0.122	23.49 ± 0.81	22.67 ± 1.03	2.225	0.030*
Fixed time (m)	25.86 ± 8.86	15.72 ± 4.98	4.495	0.000*	25.56 ± 4.67	15.33 ± 5.39	5.297	0.000*
Vertebral slip (no.)			0.000	1.000			1.922	0.166
yes	3	17			1	19		
no	4	30			8	26		
Facet grade pre-operation			0.614	0.852			3.569	0.389
Grade 4	1	13			1	10		
Grade 3	5	27			4	17		
Grade 2	1	7			3	10		
Grade 1	0	0			1	8		
Grade 0	0	0			0	0		
Disc grade pre-operation			2.934	0.317			6.404	0.145
Grade 1	1	11			1	12		
Grade 2	2	26			6	16		
Grade 3	2	7			0	12		
Grade 4	2	7			2	4		
Grade 5	0	0			0	1		

BMI: Body Mass Index.

* Test was considered statistically significant at $P < 0.05$.

Logistic Regression Analysis

To reveal the relative impact of variables on the facet and disc degeneration, logistic regression analysis was performed. The variables from the univariate analysis which were associated with the incidence of ASD were age, BMI, duration of instrument fixation, vertebral slip, and preoperative facet and disc degeneration change. Logistic regression analysis revealed that duration of instrument fixation of more than 15.5 months was a significant risk factor of the incidence of L4/5 facet degeneration (P = 0.006; odds ratio: 1.337, 95% CI: 1.108–1.615). For the duration of fixation, a cut-off value of 15.5 months was determined to discriminate with the highest sensitivity a receiver operating characteristic curve (ROC)d specificity by receiver operating characteristic curve (ROC) analysis. The area under the curve (AUC) is 0.86 (95% confidence interval 0.74–0.99). Duration of fixation more than 21.0 months was a significant risk factor of the incidence of L5S1 facet degeneration (P = 0.001; odds ratio: 1.379, 95% CI: 1.133–1.679). The AUC is 0.95 (95% confidence interval 0.88–1.00) (Table 6 and Fig. 2).

Table 6
Mutivariate Logistic Regression for facet joint degeneration.

Level	Risk Factor	P value	OR(95%CI)
L4/5	Fixed time	0.006	1.270(1.072–1.503)
L5S1	Fixed time	0.001	1.379(1.133–1.679)

Evaluation of aggravation based on pre-operative grade suggested that patients with facet joint degeneration at L4/5 pre-operation had no significant difference for greater progression of degeneration compared to patients without preoperative facet joint degeneration. A similar relationship with pre-operative grade was not found at L5/S1. The pre-operative grade of facet degeneration was not associated with post-operative progression of disc degeneration, and pre-operative disc degeneration had no relationship with post-operative progression of facet degeneration.

Discussion

A considerable number of patients, especially young patients, complain of lumbar pain or have bilateral lumbar spondylolysis during physical examination, without or only mild lumbar spondylolisthesis, and usually have no neurological problems in imaging, symptoms, and signs(15). However, there is no consensus or guideline for the treatment of this part of patients. The treatment of simple bilateral lumbar spondylolysis can be divided into conservative treatment and surgical treatment(16). The current clinically accepted view is that active surgical treatment should be adopted for patients who are ineffective in conservative treatment for 6 months and are in the terminal stage of isthmic fissure on imaging(4, 17).

Previous studies have revealed a great number and variety of surgical techniques for the spondylolysis repair, demonstrating the lack of consensus on a satisfactory procedure. It mainly includes inter-segmental fusion and intra-segmental isthmus repair(18). For patients with simple lumbar spondylolysis, fusion has a definite effect on the fixation of the vertebral body, effectively preventing the diseased vertebrae from further spondylolisthesis, however, it will sacrifice the mobility of the fused segment, and may accelerate the degeneration of the adjacent segments of the vertebral body and intervertebral disc; while the intra-segment repair is considered to preserve the anatomical structure(19). With the improvement of surgical technique and material development. The method of fixing the diseased segment by direct repair surgery gradually develops from the early isthmic lag screw(20), transverse process-spinous process wire(21), screw-hook construct(22) to the shaped rod and combination techniques. However, each of these approaches has its drawbacks. The isthmus is too small to choose a suitable lag screw, and the lack of bone grafting in the isthmus leads to difficulties in bone healing. The wiring technique requires greater surgical exposure, with extensive stripping of the muscle in order to expose the transverse process completely. The uneven force on the bilateral transverse processes can lead to complications such as transverse process fractures and wire loosening, which may lead to nonunion of the pars defect. Gillet et al. (23) firstly use "V" rods to connect bilateral pedicle screws instead of laminar hook fixation. Ulibarri et al. (24) used this improved method to implant bilateral pedicle universal screws to connect the bent "U"-shaped titanium rod have achieved a satisfactory fusion rate(25). Although the hook-screw and shaped rod methods have achieved satisfactory results, a considerable number of spondylolysis patients are associated with laminosis or dysplasia of spinous processes, which may affect fixation strength.

In this study, the pars defect repair we propose using inter-segmental pedicle screws seems to be a technically simple and safe procedure that presents the advantage of placing the spondylolysis under strong compression to help ensure fusion. Unlike other techniques, which demands extensive muscle stripping, exposing the transverse process, injury of the interspinous ligament during the procedure. Easy surgical access through the Wiltse approach allows minimal soft tissue dissection and reduced blood loss. Since hyperextension and rotation are the main stresses in the fatigue fracture of the isthmus, these above-mentioned various methods of inter-segment fixation have a weaker ability to resist rotation and extension, and the inter-segment fixation provides stronger stability. In addition, the connecting of two screws allows for progressive compression across the isthmus, which increase the degree of bony contact to promote higher fusion rate. Otherwise, for cases with spondylolisthesis within grade 1 and mild disc degeneration, motion segment fixation can correct and stabilize the spondylolisthesis. Compared with the method of inter-segment fixation, its disadvantage is that the original motion segment is fixed. Therefore, in order to restore the motion of this segment, the patients in our study have been removed the internal fixation after CT confirmed that the pars have completely union.

Facet joints and discs are both involved in stability of the lumbar spine construct(26, 27) and considered the relationships among facet joints and discs in adjacent segment degeneration(28, 29). To our knowledge, the incidence and risk factors of fixed and adjacent segment degeneration after inter-segment pedicle screw fixation for lumbar spondylolysis, have not been previously investigated. In this study, we identify the risk factors for facet joint and disc degeneration in order to predict and prevent this condition. After the follow-up on 54 patients, 100% bone healing were achieved. Only one patient had a reduction in disc height of ≥ 20% in the upper and fixed segments, respectively. When the internal fixation is removed,we found a 9% incidence of disc degeneration for 1 grade at the L4/5 and L5S1 levels, respectively (based on the Pfirrmann 5-grade classification system). However, no previous studies compare the development of adjacent and fixed disc degeneration in the patients treated with inter-segment pedicle screw fixation. Previous studies reported adjacent biomechanical alterations after lumbar fusion. Umehara et al.(30) reported that the load burden and weight shearing of the posterior column increased significantly at the adjacent segments. Weinhoffer et al.(31) also reported a significant increase in the disc pressure in the levels above the fused segments. In a systematic review, Harrop et al.(32) reported a 9% incidence of ASD after total disc replacement and a 34% incidence after fusion. We also found a 15% incidence of disc height decrease more than 10% at the L4/5 level and 17% incidence at the L5S1 level, however, the differences were not significant between pre- and post-surgery. The incidence of facet joint degeneration was 13% at the L4/5 level and 17% at the L5S1level, respectively. Facet joint degeneration may arise from different mechanisms. Firstly, surgical factors such as damage to the articular process during screw placement may lead to an increased risk of facet joint degeneration. Increased loading of the adjacent level after fixation also increases the load on the surrounding facet joints(33, 34). Biomechanical studies have shown that the facet load can increase at the level of surgery after intervertebral fusion. Although there is no intervertebral fusion in this study, inter-segmental fixation may also increase the load on the facet joint.

This result of present study suggests that the duration of fixation as a risk factor associated with the occurrence of facet joint degeneration. In these patients, fixed time is considered as a significant factor for facet degeneration. The non-degeneration cut-off value of fixed time has been speculated to be within 15.5 months. As a matter of fact, patients in this series with successful pars union presented a mean value of fixed time of 17.04 months. Therefore, regular postoperative follow-up is required to determine the bony union of the pars defect. Once bony union is achieved, remove of the internal fixation should be recommended. In addition, bone morphogenetic protein-2 (BMP-2) can be used to achieve earlier and enhance fusion. The earlier the bony union occurs, the lower the incidence of facet joint degeneration. Secondary, our results have shown that older age and higher BMI are associated with the occurrence of facet joint degeneration at the L4/5 and L5S1 levels, respectively. In addition, Sagittal balance and spino-pelvic parameters also probably influence facet joint degeneration development. Further study is needed to analyze spinopelvic parameters.

This study has some limitations. First, it was a retrospective study and was not performed as a comparative study. Second, the sample size in the present study was limited. It may increase the chances of making a type II error. Third, radiologic evaluations, including sagittal alignment assessment, were not performed.

Conclusions

In this study, inter-segmental pedicle screw fixation provides good surgical outcomes and good isthmic bony union rates in patients with lumbar spondylolysis. The duration of fixation was confirmed as a risk factor of facet joint degeneration. Once bony union is achieved, remove of the instruments should be recommended.

Abbreviations

ASD adjacent segment degeneration; CT:computed tomography; MRI:magnetic resonance imaging; DH:disc height; DHI:disc height index; JOA:Japanese Orthpaedic Association; BMI:Body Mass Index; AUC:area under the curve; ROC:receiver operating characteristic curve; BMP-2:bone morphogenetic protein-2.

Declarations

Ethics approval and consent to participate

The clinical retrospective study protocol was established, according to the ethical guidelines of the Helsinki Declaration and was approved by the Human Ethics Committee of the Seventh Medical Center of PLA General Hospital. Written informed consent was obtained from individual or guardian participants.

Consent for publication

The patients consented to the publication of their pictures as well as their anonymous and clustered data.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

HM was involved in conception and design, drafting the article, analysis and interpretation of data. YG was responsible for analysis and interpretation of data. PL was involved in study data collection and preliminary data analysis. GMZ, ZCZ, and TSS was involved in study conception, surgery, and patient's management. FL was involved in study conception, supervision, and administrative support. The authors read and approved the final manuscript.

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Figures

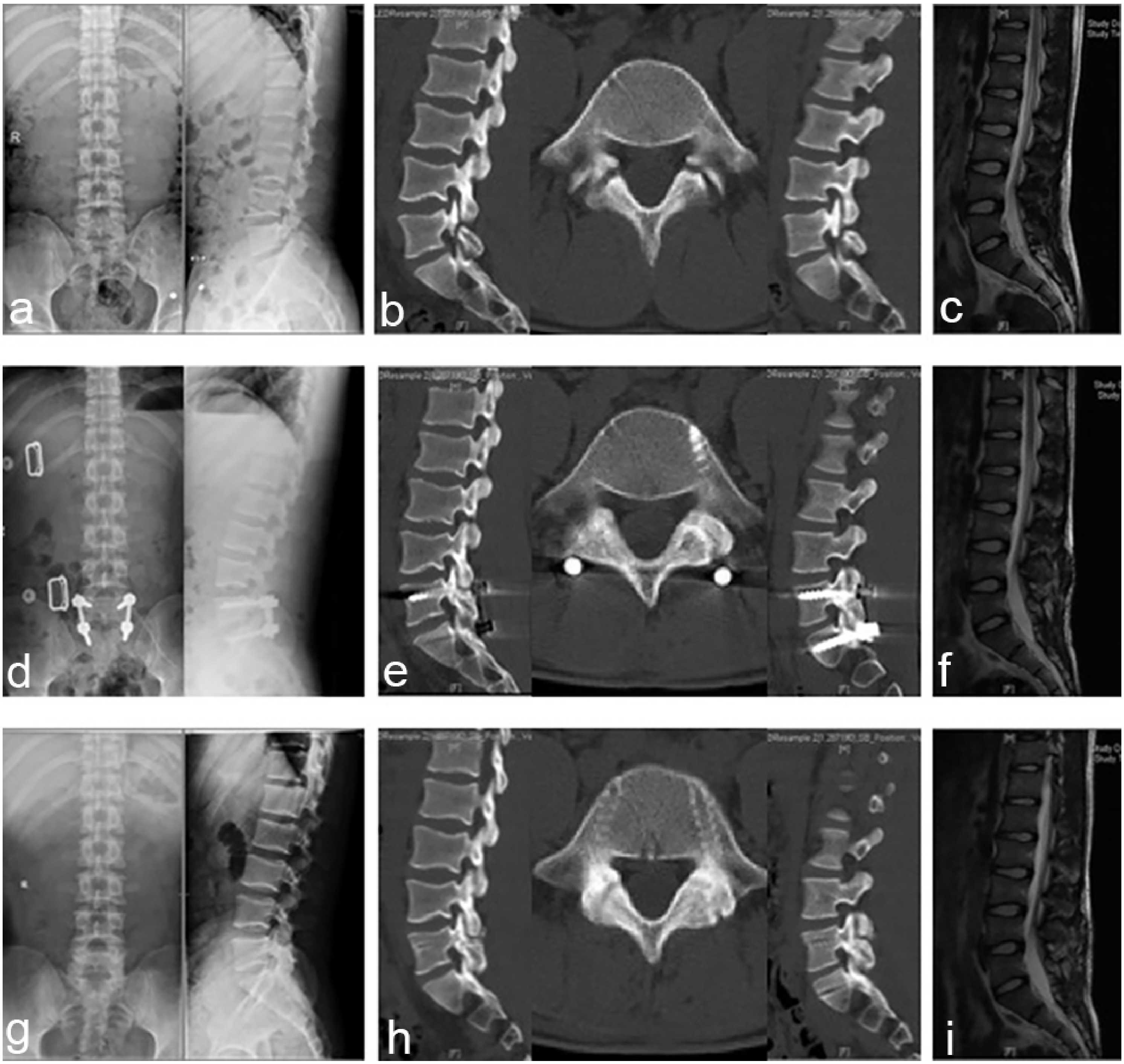

Figure 1

Preoperative and postoperative images obtained in a 21-year-old man with L5 spondylolysis. a-c: Pre-operative radiographs, CT scan and MRI. d: One-week post-operative radiographs. e: 12-months follow-up CT scan showed bilateral bony union of the pars defect. f: 15-months post-operative MRI. g: 15-months post-operative radiographs showed the lumbar instrumentations had been removed. h-i. 15-months post-operative CT scan and MRI.

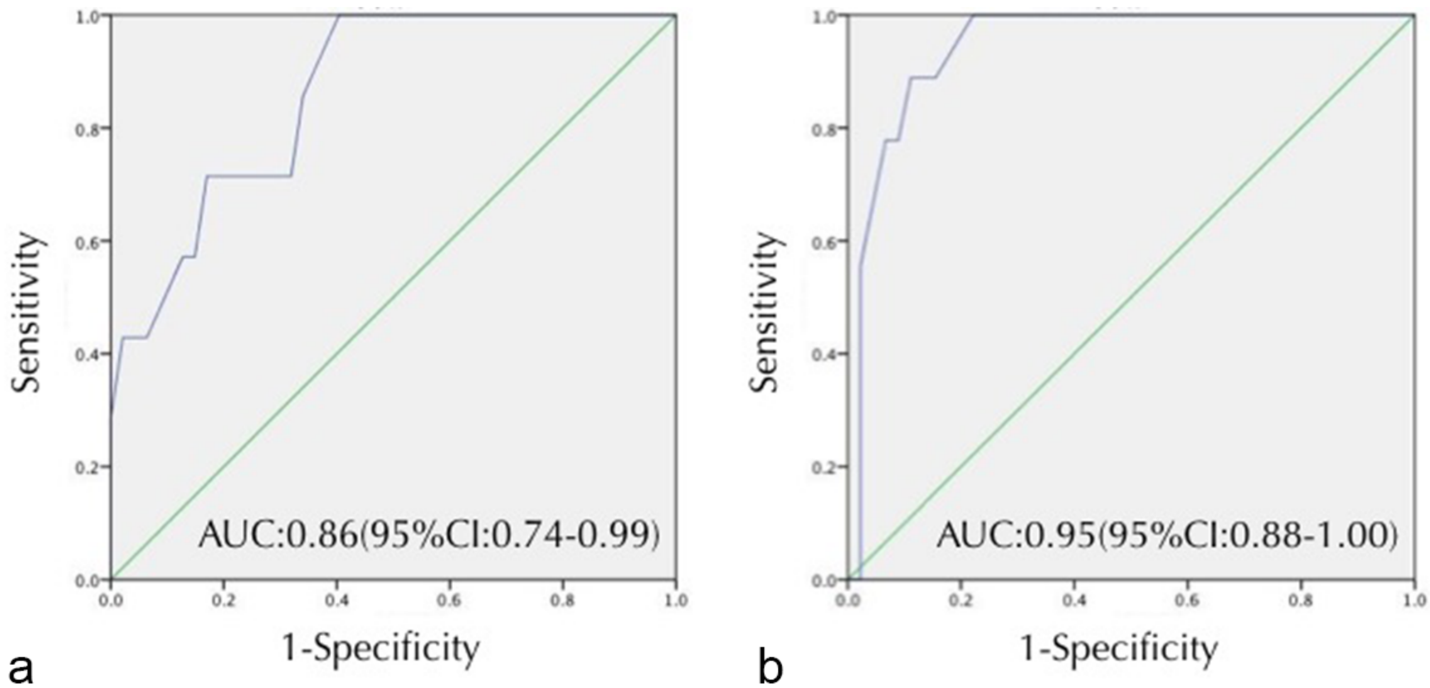

Figure 2

Logistic regression and ROC analysis. A: L4/5: a cut-off value of 15.5 months at which classification according to fixed time yields a sensitivity of 100% and specificity of 60%. The area under the curve AUC is 0.80. B: L5S1: a cut-off value of 21.0 months at which classification according to fixed time yields a sensitivity of 89% and specificity of 89%. The area under the curve AUC is 0.80.