Original Article

A descriptive study on the adjacent segment degeneration related signs following a lumbar fusion procedure

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Background: Adjacent segment degeneration (ASD) is a frequent complication following vertebral fusion procedures and is defined as the condition where patients recover after the initial procedure but develop compatible symptoms with radiological injuries in the segments adjacent to the fused ones at a later stage. The objective of the study was to describe the frequency and analysis of ASD related signs following a lumbar fusion procedure.

Methods: Observational descriptive retrospective study on patients with degenerative or instability conditions, operated on by posterolateral or circumferential lumbar fusion procedure. Pedicle screws, interbody peek cages (polyether-ether-ketone) and autologous bone graft were used. Clinical (pain and disability) and radiological (instability, rotation, disc height loss, radiological degeneration evaluated by X-ray and MR) variables were analysed.

Results: Postoperative disc height loss was observed in 159 free discs among 112 patients (42.6%) (95% CI: 36.4–48.8%). Anterior or posterior slippage (anterolisthesis or retrolisthesis) at the end of the follow-up period was observed in 33 patients (12.5%). Upper segment rotation increased in the postoperative period in 36 patients (13.6%). Radiological disc degeneration was observed in 107 discs among 72 patients, being more frequent in the immediate upper disc with grade 2 and 3 changes at the end of follow-up in 48 discs from 35 patients (13.6%) (95% CI: 13.4–23.1%). Radiological ASD signs were observed in 151 patients (57.4%; 95% CI: 51.2–63.6%) and 53 of them (20.2%; 95% CI: 15.1–25.2%) who also showed clinical ASD symptoms (clinical and radiological ASD). Degeneration changes with degrees IV and V shown by a preoperative and magnetic resonance (MR) study at end of the follow-up period performed in 73 patients (27.7%), were observed in 46 discs among 32 patients (43.8%) (95% CI: 31.8–55.9%).

Conclusions: Radiological ASD signs evaluated in every free disc following a lumbar fusion procedure are observed with a variable frequency. All free discs after fusion were assessed as they could indicate mechanisms of compensation of lordosis loss and should be taken into consideration in a prospective revision surgery.

Keywords: Adjacent segment degeneration (ASD); lumbar fusion; radiological signs

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Introduction

Adjacent segment degeneration (ASD) is a frequent complication following vertebral fusion procedures and is defined as the condition where patients recover after the initial procedure and develop compatible symptoms with radiological injuries in the segments adjacent to the fused ones at a later stage (1).

The reported occurrence of ASD varies mainly based on the different types of study, selection criteria and time of follow-up. There is a wide range of radiological changes (8–100%) related to aging, worsened or not by the procedure. It is less frequently (5.2–18.5%) the reappearance of clinical symptoms that may require a new procedure (2).

The change in appearance of segments adjacent to the one being fused could have a multifactorial origin which could be the consequence of predisposing genetic and anatomic factors, decompression techniques and instrumentation as well as fusion biomechanical consequences (3). Facets and ligaments stabilizing a vertebral segment may be affected during the decompression technique and positioning of pedicular vertebral instrumentation (4). An increase in disc pressure (5), hypermobility (6,7) and facet overloading (8) have been described in the segments adjacent to the ones being fused.

Degeneration-related signs have been described by several authors and may be identified by imaging studies (2,9). Although these signs are more frequent in the upper segment to the fused one and less frequent in the lower one, changes could appear in every non-fused segment which are not commonly analysed in the different studies. We analyse these changes in our study. The objective of the study was to describe the frequency and to assess the radiological and clinical changes of ASD related signs following a lumbar fusion procedure.

We present the following article in accordance with the STROBE reporting checklist (available at https://dx.doi.org/10.21037/jss-21-26).

Methods

Design

A longitudinal retrospective descriptive cohort study of patients operated on by lumbar fusion procedure between January 2006 and December of 2010 with a follow-up period of at least two years.

Population

Patients included in the study were previously diagnosed with a degenerative disease and instability: degenerative disc disease, degenerative spondylolisthesis, canal stenosis, degenerative lumbar scoliosis and isthmic lysis spondylolisthesis. Patients were operated on by posterior approach, performing decompression when required and/or posterolateral (PLF) or circumferential fusion (TLIF/PLIF), using top loading screws (TLS) or side connecting screws (SCS) as well as polyether-ether-ketone interbody (PEEK) cages and surgical field or posterosuperior iliac spine autologous bone. Patients with other diagnosis such as tumours, non-degenerative deformities or revising surgeries were excluded from the study. The sources of information for the study were the patient's clinical history and the radiology image archive of our hospital. Demographic and preoperative clinical data, results of complementary examinations and diagnosis of the lesions were obtained from the clinical history. Surgical protocol sheets were used to collect data on surgical techniques, fusion levels and types of devices used. Patients were contacted by telephone for clinical review and completion of the last radiological study. All interventions were performed by the same two surgeons with the lead surgeon being the first author of this study.

Variables

The following variables were analysed: (I) Demographics: age, gender, diagnosis, type of fusion posterolateral or transforaminal interbody fusion (PLF *vs.* PLIF/TLIF), number of fused levels and type of pedicular instrumentation TLS and SCS. (II) Radiological: lumbar L1–S1 (LL) and lumbosacral (LSL) L4–S1 lordosis measured following Cobb method; anterior, posterior, and middle disc height of every free disc according to Farfan and Miyakhosi methods (10,11); anterior or posterior slippage of the free segments measured in millimetres (mm); rotational deformity in the segment adjacent to the fused one evaluated by Nash-Moe method (12); radiological disc degeneration in every free disc following Weiner scale (13); posterolateral (PLF) and circumferential fusion (PLIF/TLIF) radiological fusion criteria following Lenke (14) and Hackenberg (15) criteria; lumbar (LL) L1–S1 and lumbosacral lordosis (LSL) L4–S1 following Cobb method and disc degeneration evaluated by MR

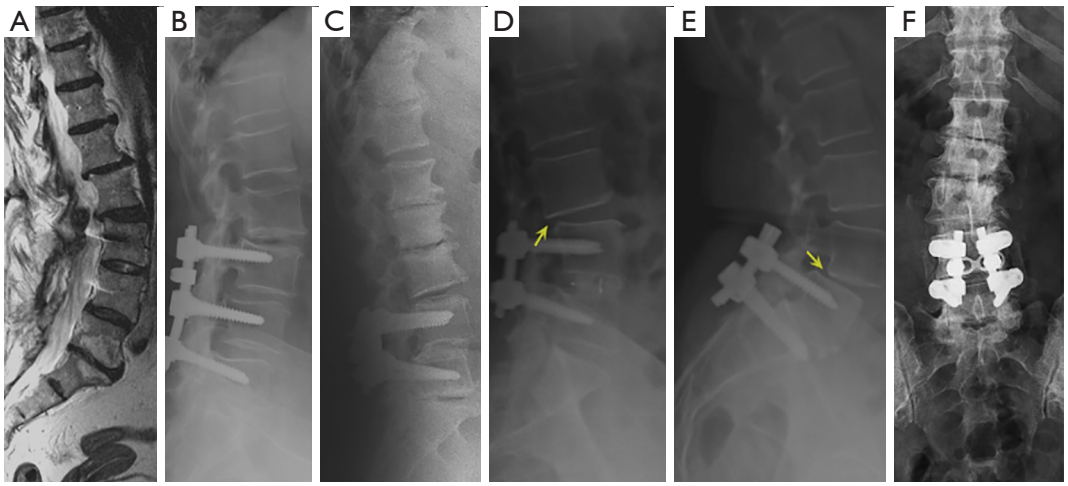


Figure 1 Magnetic resonance and radiological related signs to adjacent segment degeneration. (A) Magnetic resonance showing degenerative disc disease L2–L3 following L3–L5 arthrodesis. (B) Severe disc degeneration L2–L3 following L3–L5 fusion. (C) Loss posterior and increase anterior height L3–L4 and severe degenerative changes L1–L2 and L2–L3 discs. (D,E) Retrolisthesis L3–L4 and anterolisthesis L4–L5 (yellow arrows) following fusion L4–L5 and L5–S1. (F) Asymmetric loss disc height and severe rotation L3–L4 following L4–L5 fusion.

by Pfirrmann classification (16) (*Figure 1*). (III) Clinical: lumbar and radicular pain, preoperative, postoperative and end of follow up disability degree evaluated by analogic visual analogic scale (VAS) and Oswestry disability index (ODI).

Radiological measurements were performed using the software available in our centre RAIM-PC (Radiological Archive Images Management), with lineal (mm) and angular (degrees) measuring tools in the preoperative and end of follow-up period standing radiological study of the lumbosacral spine.

To perform the reliability test, measurements were repeated by the main researcher and by another independent orthopaedic surgeon in order to establish the intra- and inter-observer agreement using the intraclass correlation coefficient (ICC) and Kappa index for quantitative and qualitative measurements respectively (17).

ASD criteria

The following were considered as radiological degeneration criteria (radiological ASD): (I) anterior, middle and posterior disc height loss ≥1 mm; (II) slippage (anterolisthesis or retrolisthesis ≥3 mm); (III) rotational deformity ≥1 degree in the upper level to the fused one (following Nash-Moe scale); (IV) radiological disc degeneration (Grades 2 and 3 following Weiner scale); (V) severe disc degeneration (Grades 4 and 5 evaluated by RM with Pfirrmann scale) (*Figure 1*). As symptomatic degeneration criteria (clinical ASD), the reappearance of symptoms with VAS ≥3 in lumbar or radicular pain and/or change from moderate to severe disability measured with ODI ≥15. Radiological signs are showed in *Figure 1*.

Statistical analysis

We performed a descriptive analysis of the study patients, including demographic variables, intervention characteristics and radiological measurements expressed in percentage, central tendency and dispersion measurements, depending on the type of variables (95% CI) and comparison of VAS and ODI mean scores by the ANOVA test, checking variable homogeneity and significance degree (P<0.5). The sample size was calculated using the Epidat 3.1 statical program. To perform the reliability test, measurements were repeated by the main researcher and by another independent orthopaedic surgeon in order to establish the intra- and inter-observer agreement using the ICC and Kappa index for quantitative and qualitative measurements respectively.

Ethical statement

This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and approved by the ethical committee of clinical research of our hospital (Acta n° 12/11). Informed consent was obtained from all

Table 1 Demographical data

Demographics variables	N	%
Sex (n=263)		
Male	98	37.3
Female	165	62.7
Diagnosis (n=263)		
Degenerative disc disease	42	15.9
Degenerative spondylolisthesis	52	19.7
Canal lumbar stenosis	85	32.3
Lumbar degenerative scoliosis	11	4.1
Spondylolisthesis lysis isthmic	73	27.7
Fusion type (n=263)		
PL	171	65.8
TLIF	89	34.2
Fused criteria (n=263)		
PL	155	90.7
TLIF	91	98.6
Type pedicle screws (n=263)		
TLS	201	76.5
SCS	62	23.5
Levels of fusion (n=263)		
L4–L5/L5–S1	129	48.7
L4–S1/L3–L5	90	34.2
L2–L5/L3–S1	31	11.7
L2–S1/L1–L5	13	4.9

PL, posterolateral; PLIF/TLIF, posterior/transforaminal lumbar interbody fusion; TLS, top loading screws; SCS, side connecting screws.

patients. The patients consented to have his data published.

Results

Descriptive results

The target population was 293 patients. Thirty patients were excluded (answer rate 89.8%) due to invalid radiological study, unwillingness to participate in the study or death prior to enrolment. A total of 263 patients were included in the study.

The follow-up period ranged from 24 and 82 months with a mean of 45.9 (SD: 17.8) and a median of 43 months. There were 98 men (37.3%) and 165 women (62.7%) with a mean age of 59.0 years (95% CI: 57.6–60.5). The most frequent diagnoses were lumbar canal stenosis (32.3%), isthmic lysis spondylolisthesis (27.7%) and degenerative spondylolisthesis (19.7%). The PLF technique was used in 65.8% of the cases and TLIF/PLIF fusion technique in 34.2% of the cases. In 201 patients (76.5%) the pedicular instrumentation was TLS and in 62 patients (23.5%) was SCS. One segment fusion (L5-S1 or L4-L5) was performed in 129 patients (48.7%), two segment fusion in 90 patients (34.2%), three segment fusion in 31 patients (11.7%) and four or more segments in 13 patients (4.9%). Following the criteria to evaluate PLF arthrodesis in 171 patients, 93 patients (54.4%) were considered as fused and 62 patients (36,3%) as probably fused. Of those patients with circumferential arthrodesis (PLIF/TLIF), 84 (91.0%) were considered as solid fused and 7 of them (7.6%) as probably fused (*Table 1*). LL L1-S1 decreased in patients with preoperative LL of 51–60°, increased postoperatively in patients with preoperative lordosis of >60° and remained unchanged in patient with preoperative lordosis of 30–50°. LSL L4-S1 decreased in patient with preoperative LSL of 25–40°, increased postoperatively in patients with preoperative LLS of <25°, and remained unchanged postoperatively in patients with preoperative LLS >40°.

ASD criteria

Postoperative disc height loss was observed in 159 free discs among 112 patients (42.6%) (95% CI: 36.4–48.8) (*Table 2*). Anterior or posterior slippage (anterolisthesis or retrolisthesis) ≥3 mm at the end of the follow-up period was observed in 33 patients (12.5%). Retrolisthesis was observed in 28 patients (10.6%): in 20 patients in the first upper disc and in 8 patients in the second and third upper discs to the fused one. Anterolisthesis was observed in 5 patients (1.9%) (*Figure 2*). The rotation in the upper segment to the fused one increased in the postoperative period in 36 patients (13.6%). In 24 patients (9.1%) the upper segment rotation increased by 1 degree, in 11 patients (4.1%) by 2 and in one patient it increased by 3 degrees (*Figure 3*). In 107 discs from 72 patients, a disc degeneration radiological degree was observed. In 48 free discs from 35 patients (13.6%) (95% CI: 13.4–23.1) an increase to Grade 2 and 3 as observed (*Figure 4*). Degenerative changes with degrees IV and V, revealed by preoperative and MR study at the end of the follow up performed in 76 patients (27.7%), were observed

Table 2 Preoperative and end of follow up anterior, posterior and central disc height (mm) difference in every free disc (Methods Farfan and Miyakhosi)

	Difference height (mm) 1st upper disc	Difference height (mm) 2nd upper disc	Difference height (mm) 3rd upper disc	Difference height (mm) 4° upper disc	Difference height (mm) below disc
Anterior height					
Increase	127 (50.2%)	107 (47.6%)	72 (42.9%)	24 (41.4%)	56 (40.1%)
No change	45 (17.8%)	45 (20.0%)	38 (22.6%)	16 (27.6%)	26 (19.0%)
Decrease	21 (32.0%)	73 (22.4%)	58 (34.5%)	18 (31.0%)	55 (40.1%)
Posterior height					
Increase	57 (26.1%)	59 (26.7%)	46 (27.1%)	14 (23.7%)	39 (28.5%)
No change	65 (24.7%)	78 (35.3%)	56 (32.9%)	30 (50.8%)	44 (32.1%)
Decrease	127 (51%)	84 (38%)	68 (40%)	15 (25.4%)	54 (39.4%)
Central height					
Increase	26 (21.3%)	35 (13.3%)	32 (12.2%)	13 (22.4%)	32 (23.4%)
No change	54 (10.3)	55 (29.9%)	46 (17.5%)	21 (36.2%)	41 (29.9%)
Decrease	173 (68.4%)	135 (51.3%)	90 (34.2%)	24 (41.4%)	64 (46.7%)

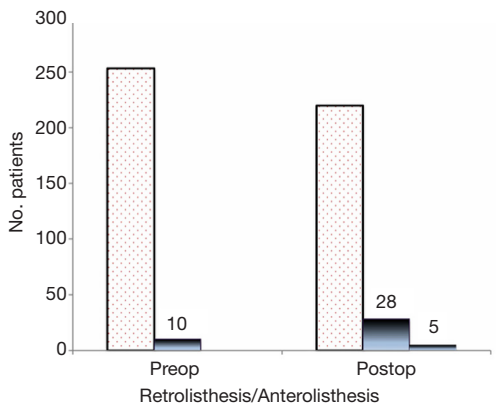


Figure 2 Preoperative and end of follow up upper and lower free segments anterolisthesis/retrolisthesis patient distribution.

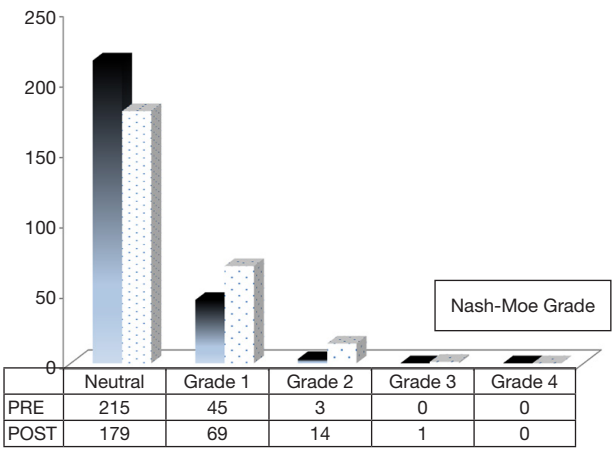


Figure 3 Preoperative and end of follow up vertebral rotation degree of the free segments' patient distribution.

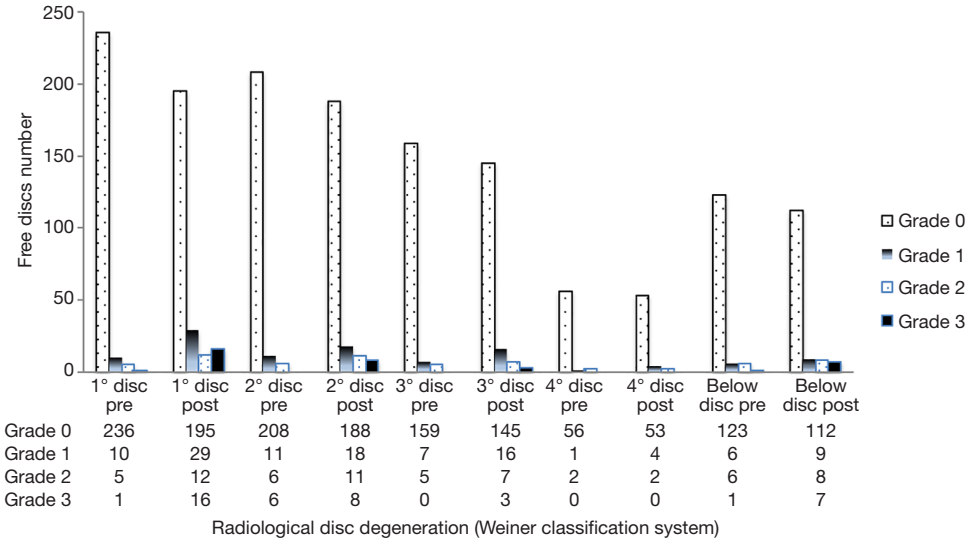
in 46 discs from 32 patients (43.8%) (95% CI: 31.8–55.9) (*Figure 5*).

The mean of the lumbar pain scores were the following: 8.36 at preoperative, 3.83 at postoperative and 3.73 at end of follow-up periods, with a statistical significance difference (P<0.001). The mean radicular pain values/scores were the following: 7.83 at preoperative, 3.10 at postoperative and 3.14 at the end of follow-up (P<0.001). Preoperative disability degree was 51.57, postoperative was 24.88 and at the end of the follow-up was 25.02 (<0.01).

The signs considered as criteria for ASD are shown in *Table 3*.

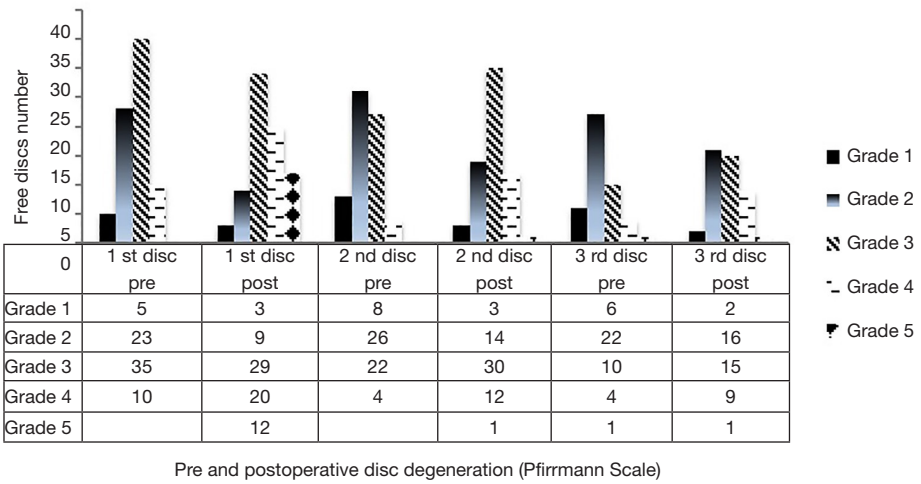
Radiological and clinical degeneration incidence

Radiological changes (radiological ASD) considered as degeneration criteria were observed in 151 patients (57.4%) (95% CI: 51.2–63.6) and 53 (20.2%) (95% CI: 15.1–25.2)



	1° disc pre	1° disc post	2° disc pre	2° disc post	3° disc pre	3° disc post	4° disc pre	4° disc post	Below disc pre	Below disc post
Grade 0	236	195	208	188	159	145	56	53	123	112
Grade 1	10	29	11	18	7	16	1	4	6	9
Grade 2	5	12	6	11	5	7	2	2	6	8
Grade 3	1	16	6	8	0	3	0	0	1	7

Figure 4 Preoperative and end of follow up radiological degeneration following Weiner scale.



0	1 st disc pre	1 st disc post	2 nd disc pre	2 nd disc post	3 rd disc pre	3 rd disc post
Grade 1	5	3	8	3	6	2
Grade 2	23	9	26	14	22	16
Grade 3	35	29	22	30	10	15
Grade 4	10	20	4	12	4	9
Grade 5		12		1	1	1

Figure 5 Preoperative and end of follow up free disc degeneration degree evaluated by MR study following Pfirrmann scale graphical representation.

Table 3 Radiological ASD related variables frequency and radiological (RASD) and clinical (CASD) degeneration patient distribution

Radiological changes in all adjacent free segments	N (%)	95% CI
Retrolisthesis/anterolisthesis free segments ≥3 mm (n=263)	33 (12.5)	8.4–16.7
Loss of global height disc ≥1 mm (n=263)	112 (42.6)	3.4–48.8
Moderate or severe radiological degeneration discs (n=263)	35 (13.3)	9.0–17.6
Rotation of free segments (n=263)	40 (15.2)	10.7–19.7
Moderate or severe disc degeneration (RM) (n=76)	45 (59.2)	47.5–70.9

ASD, adjacent segment degeneration; CASD, clinical adjacent segment degeneration; RASD, radiological adjacent segment degeneration.

Table 4 Radiological and clinical adjacent segment degeneration incidence

Adjacent segment degeneration (ASD)	Radiological adjacent segment degeneration (RASD)		
	Yes (%)	No (%)	All (%)
Clinical adjacent segment degeneration (CASD)			
Yes	53 (20.2)	19 (7.2)	72 (27.4)
No	98 (37.3)	93 (35.4)	191 (72.6)
Total	151 (57.4)	112 (42.6)	263 (100.0)

patients were considered as symptomatic (clinical ASD), following lumbar pain, radicular pain or claudication reappearance clinical criteria. A total of 98 patients (37.4%) with radiological changes did not present symptoms. Lumbar or radicular pain only persisted in 19 patients (7.2%), not show radiological changes. 93 patients (35.4%) presented no clinical or radiological changes (*Table 4*). Survival analysis was performed by the author and risk of a second surgical procedure due to clinical changes is 3-fold higher in patients with three or more levels of fusion, and 2.5-fold higher in patients intervened with top-loading pedicle screws (18).

Discussion

The radiological changes that characterise ASD have been widely described and could explain the great variability of its occurrence depending on the selection criteria (2,9). The true incidence is difficult to establish, since most studies are retrospective, with variable follow-up periods and dependent on the definition applied.

Standing spinal X-ray allows us to identify upright related changes not visible in supine position. Vertebral rotation, anterior or posterior slippage of the upper vertebra, disc height loss and instability, as well as LL and sagittal and coronal balance after fusion procedure-related changes are radiological findings which may go unnoticed in supine position. Furthermore, although most authors describe the incidence based in image studies at the upper segment, which is generally responsible for the symptoms, changes in other free upper or lower discs to the fused ones are not infrequent. All the degeneration-related signs have been analysed in this study.

Loss of LL after fusion of mobile segments with possible sagittal deformity sets in motion the compensation mechanisms, which starts in the lumbar spine (19). Lordosis loss after one or more mobile segments fusion, generally of the lower segments (L4-S1) where lordosis represents the 60% of the total LL, determines compensating mechanisms in the proximal segments (20). This mechanism increases the stress on posterior structures, only limited by the facet anatomy, more coronal in lowers segments and sagittal toward upper segments (21). Upper segment instability, generally retrolisthesis, represents the final phase of the lordosis loss compensating mechanism after the fusion procedure, expressing the maximum compensating hyperextension of the unfused upper segments. In 33 study patients (12.5%), slippage was observed: a posterior slippage in 28 patients (10.6%) opposite to an anterior slippage (anterolisthesis) in just 5 patients (1.9%). It was generally located in upper segments (we only observed one patient with L5-S1 listhesis who had previously been treated for arthrodesis).

Lumbar segment instability may be defined by clinical and radiological criteria. Although there is not a precise definition for instability, the one proposed by Panjabi defined as "spinal condition which generates abnormal movements leading to physiological vertebral movement restriction to compensate the pain" is generally accepted (22). Radiological instability is defined in dynamic flexion-extension X-rays (23), with variable translational criteria measured in millimeters (24) or disc opening measured in degrees (25). In our study, the absence of dynamic X-rays has conditioned the instability evaluation as a degenerative radiological sign. However, we have measured the changes in disc opening degrees in lateral standing X-rays following the lower fused segment. The immediate upper disc to the fused one shows more changes with an increase in the disc anterior opening in 66% of the patients, followed by the second upper disc in 61% of the patients. Changes are less common in the lower disc (45.6%), due to the lower opening degree of the disc. Although the lower disc morphology, generally in L5–S1 (26), highly contributes to LL, the upper segments' compensatory responding ability after fusion is restricted

by the coronal orientation of the facets (facet tropism) associated the presence of ilio-lumbar ligaments.

Changes in every rotational degree in free segments after lumbar fusion during the postoperative period have been considered as ASD signs. Previous animal and human cadaver studies show variable degrees in upper segments rotational changes when they are put under flexion, extension and lateral charges/loads, especially in the first segment (4). The rotation in the proximal segment to the fused one, particularly the first upper disc, has been related to asymmetric disc degeneration and facet tropism changes (27,28). In our study, the rotational degree has been evaluated by the Nash and Moe scale, observing rotational changes in the proximal segments in 36 patients (13.6%), 24 of them (9.1%) with grade 1 rotation and 11 of them (4.1%) with grade 2 rotation.

Disc height loss has been considered as an ASD sign. Multiple measuring systems have been proposed to evaluate disc height. Ekman *et al.* provide a highly reliable description of anterior and posterior disc height by digital measuring (29) and Frobin *et al.* describe the compensated distortion measuring method to evaluate disc height precisely (30). In our study, the measurement of disc height was performed similar to Ekman's measurement system, with substantial reliability in the measurements. This finding was observed on 159 discs in 112 (42.6%) patients.

Disc degenerative changes represent the final compensating mechanism and may be related either to an increase of the previous degeneration or be of new appearance, determined by the fusion biomechanical consequences as hypermobility (6,7), variable rigidity of the inferior fused segment and disc pressure increase (5,31). Changes evaluated by the Weiner scale (13) were observed in our study in every non-fused disc in 48 discs from 35 patients (13.5%). Although these changes are accentuated in the first free superior disc to the fused one, both quantitatively and qualitatively, they may appear in every free segment as an expression of previous degeneration progression and/or individual response of every free disc to fusion.

Changes in free segments adjacent to the fused one evaluated by MR have also been described as ASD signs. The MR study allows us to identify disc and facet changes, as well as its consequences on radicular or spinal cord compromise. Disc changes have been described as disc hydration loss, "bulging" and disc herniation, with variable clinical consequences as radicular or axial pain (13). Facet changes include variable degeneration and facet hypertrophy degrees which may produce central or foraminal stenosis. However, based on the aim of our study, MR could only be performed in 73 patients (27.7%). The appearance of changes at the end of the follow-up period with moderate or severe degeneration in patients with mild or moderate degeneration in the preoperative study has been considered as degeneration signs. This was observed in 45 patients (43.8%) with MR in the preoperative period and at the end of follow-up period.

Finally, Park *et al.* also describe scoliosis as a degeneration sign, coronal, sagittal or both (2). In our opinion, the imbalance deformities should be considered as secondary to a fusion procedure and as it was seen in our study, in long fusions where L1 was the upper level. In three (23%) of the 13 patients with L1 and L2 upper fusion levels, we observed coronal and/or sagittal deformity. In these cases, a preoperative planning and an adequate upper fusion level selection should be taken into account. The presence of previous posttraumatic or degenerative thoracolumbar kyphosis is considered as upper degeneration risk factor (32-34). The upper fusion level selection in lower thoracic spine T9-T11 and more recently the neutral vertebra, are related to a lower upper degeneration incidence (35).

As a limitation in our study, the lack of a full standing radiographic spine study in all patients ruled out pre- and post- operative evaluation of the sagittal axis, as a possible determining factor of the appearance of changes linked to the repositioning of spinal and pelvic parameters.

Conclusions

The radiological signs characterising ASD have been described by several authors, mostly at the upper segment, and have been identified as responsible for the new clinical symptoms with a variable incidence. In our study, all free discs after fusion were assessed as they could indicate mechanisms of compensation of lordosis loss and should be taken into consideration in a prospective revision surgery.

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Footnote

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://dx.doi.org/10.21037/jss-21-26). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and approved by the ethical committee of clinical research of our hospital (Acta n° 12/11). Informed consent was obtained from all patients. The patients consented to have his data published.

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