ORIGINAL ARTICLE

J Turk Spinal Surg 2026;37(2):71-75

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DOI: 10.4274/jtss.galenos.2026.51523

PREVALENCE OF INTERVERTEBRAL DISC DEGENERATION ON MAGNETIC RESONANCE IMAGING IN LUMBAR SPONDYLOLYSIS AND SPONDYLOLISTHESIS

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ABSTRACT

Objective: To compare the prevalence of cranial lumbar disc degeneration (L1-L4) in patients with spondylolysis (SL) and isthmic spondylolisthesis (IS) with those having L5-S1 lumbar disc herniation (LDH) and asymptomatic individuals with normal lumbar vertebrae (NLV).

Materials and Methods: This retrospective study included 133 individuals aged 25-50 years, divided into four groups: IS (n=28), SL (n=38), LDH (n=34), and NLV (n=33). Lumbar intervertebral discs were evaluated using the Pfirrmann classification on sagittal T2-weighted magnetic resonance imaging. Disc degeneration was defined as Pfirrmann grade ⩾3. Intergroup comparisons of degeneration prevalence were performed using the chi-square test.

Results: Upper lumbar degeneration rates did not differ significantly among the SL, IS, and LDH groups (31.6%, 39.3%, and 29.4%, respectively; p>0.05). However, all three groups demonstrated higher degeneration rates than the NLV group (18.2%; p<0.05). Although the IS group was significantly older than the NLV group (p<0.001), there was no significant correlation between age and degeneration at the upper lumbar levels.

Conclusion: IS and L5-S1 LDH are associated with higher rates of cranial lumbar disc degeneration than in asymptomatic individuals. These findings may suggest that altered biomechanical factors contribute beyond chronological aging; however, causal inference is limited by the retrospective design.

Keywords: Lumbar spine, disc degeneration, MRI, spondylolysis, spondylolisthesis

INTRODUCTION

Lumbar spondylolysis (SL) involves a unilateral or bilateral defect in the pars interarticularis, typically affecting the L5 vertebra. It is a common cause of low back pain in adolescents and young adults, often attributed to repetitive mechanical stress and hyperextension[1-4]. If left untreated or under ongoing mechanical load, this defect can progress to isthmic spondylolisthesis (IS), defined as the anterior slippage of the vertebral body[2,3].

While the relationship between the pars defect and the affected segment is well-documented, the impact of these pathologies on the adjacent and upper lumbar intervertebral discs remains a subject of debate.

Previous literature presents conflicting data regarding disc degeneration in these patients. Some studies suggest that upper adjacent disc degeneration in SL cases is generally no different from that in the normal population[5]. Conversely, other reports indicate an accelerated rate of degeneration at adjacent levels, particularly in young patients with spondylolisthesis[6]. Furthermore, the precise role of disc degeneration in the progression from SL to spondylolisthesis has recently been scrutinized, highlighting a complex interplay between instability and disc integrity[7-9]. Understanding the extent of multilevel disc degeneration is clinically critical, as it influences surgical decision-making-specifically, the choice between direct pars repair and segmental fusion. If the degeneration is confined to the slipping level, motion-preserving techniques or short-segment fusion may be appropriate; however, multilevel degeneration might necessitate a more extensive surgical strategy[10,11].

The aim of this study is to compare the prevalence of cranial lumbar disc degeneration (L1-L4) in patients with SL and IS against those with L5-S1 lumbar disc herniation (LDH) and a strictly selected asymptomatic control group [normal lumbar vertebrae (NLV)]. By doing so, we aim to clarify whether isthmic pathologies are associated with a generalized degenerative pattern in the lumbar spine.

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Received: 19.10.2025 **Accepted:** 02.03.2026 **Epub:** 09.03.2026 **Publication Date:** 18.03.2026

Cite this article as: Karan B, Güdü BO. Prevalence of intervertebral disc degeneration on magnetic resonance imaging in lumbar spondylolysis and spondylolisthesis. J Turk Spinal Surg. 2026;37(2):71-75

MATERIALS AND METHODS

Clinical records and related imaging data of patients visiting the neurosurgery outpatient clinic between February 2017 and July 2024 were retrospectively analyzed.

The study protocol was approved by the İstanbul Medipol University of Non-Interventional Clinical Research Ethics Committee (approval no: E-10840098-202.3.02-6545, date: 05.09.2024). This study was a retrospective study. Patient consent was not required.

This study included four groups of individuals aged 25-50 years. The inclusion criteria were determined for each group. The SL group had bilateral pars interarticularis defects in the L5 vertebra, while the IS group had Meyerding[12] stage 1 or stage 2 mild spondylolisthesis at the L5-S1 level; the normal lumbar spine (NLV) group consisted of asymptomatic individuals aged 25-50 years who underwent lumbar magnetic resonance imaging (MRI) for reasons other than chronic low back pain or radiculopathy, and whose images were assessed as normal (Pfirrmann grade I or II). The exclusion criteria for each group, including the NLV group, were spinal tumors, infection, or previous spinal surgery. In the spondylolisthesis group, patients with non-isthmic disc herniation were excluded from the study. There were 28 patients in the IS group, 38 in the SL group, 34 in the LDH group, and 33 in the NLV group.

MRI was performed using a 1.5T system (Avanto; Siemens, Erlangen, Germany) with a spine coil. All the patients were examined in the supine position.

On sagittal turbo spin-echo T2-weighted images (TR/TE, 4250/109 msec; FOV, 30; matrix, 384×288; section thickness, 4 mm); L1-2, L2-3, L3-4, L4-5, L5-S1 intervertebral disc spaces were evaluated according to Pfirrmann classification[13]. Grades I and II: the nucleus pulposus may be homogeneous or heterogeneously bright, respectively, whereas in grade II, a thin, black horizontal band may be present. In both grades, the annulus fibrosus borders are distinct, and there is no loss of disc height. Grade III: the nucleus pulposus is heterogeneous with medium signal intensity and is gray in color. The annulus fibrosus borders are indistinct and the disc height is slightly decreased. Grade IV: the nucleus pulposus has a medium-to-low signal intensity and appears dark gray. The annulus fibrosus borders are absent, and the disc height is moderately decreased. Grade V: the nucleus pulposus has a low signal intensity and appears black, the annulus fibrosus borders are absent, and the disc height is significantly decreased. Segments with a grade ⩾3 were considered degenerated (Figure 1).

Statistical Analysis

Statistical analysis was performed using SPSS version 27.0 (IBM Corp., Armonk, NY, USA). Continuous variables were assessed for normality using the Shapiro-Wilk test. Age was normally distributed and is presented as mean ± standard deviation. Disc degeneration was defined as Pfirrmann grade ⩾3. The prevalence of degeneration across groups was compared using the chi-square test. Spearman's rank correlation coefficient was used to assess the relationship between age and disc degeneration. A p-value <0.05 was considered statistically significant.

Radiological Evaluation

"All MRI scans were independently evaluated by two experienced observers (a radiologist and a neurosurgeon) who were blinded to the patients' clinical information and group assignments. Inter-observer reliability was assessed using the Cohen's Kappa coefficient, which demonstrated substantial agreement (Kappa =0.85). In cases of disagreement, a final consensus was reached through joint review. Disc degeneration at each level (L1-S1) was graded according to the Pfirrmann classification system.

RESULTS

The study population consisted of 133 patients, comprising 28 in the IS group, 38 in the SL group, 34 in the L5-S1 LDH group, and 33 in the NLV group. The IS group included 11 men and 17 women aged 25-50 years (mean 42.43±6.03 years); the SL group included 21 men and 17 women (mean 38.03±7.80 years); the L5-S1 LDH group included 20 men and 14 women (mean 36.41±7.17 years); and the NLV group included 9 men and 24 women (mean 35.48±8.82 years). Statistical analysis revealed significant differences among the groups in terms of mean age ($p<0.001$) and gender distribution ($p=0.027$). The IS group had the highest mean age (42.43±6.03 years), while the NLV group was the youngest (35.48±8.82 years). Regarding gender, the NLV group showed a higher female predominance compared to the other groups. Detailed demographic characteristics and statistical comparisons are presented in Table 1.

The proportion of IDD in the upper segments (L1-L4) was 39.3% in the IS group and 31.6% in the SL group, showing no significant difference from the L5-S1 LDH group (29.4%, $p>0.05$). However, all three groups had a higher rate of degeneration compared with the NLV group (18.2%, $p<0.05$) (Figure 2). A significant

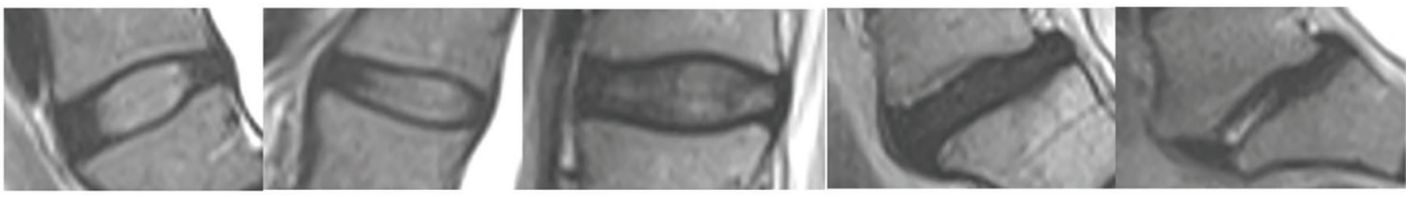

Figure 1. The Pfirrmann grading system for the evaluation of lumbar disc degeneration. The grades range from grade I to grade V, in ascending order

difference among groups was also observed at the L5-S1 level (p<0.001). Age was significantly correlated with degeneration at the L5-S1 level (p=0.015), whereas no significant correlation was found at the upper lumbar levels (p>0.05).

DISCUSSION

The principal finding of this study is that patients with IS and L5-S1 disc herniation (LDH) exhibit significantly higher rates of intervertebral disc degeneration (IDD) in the upper lumbar segments (L1-L4) compared to healthy controls. Interestingly, while the SL group did not demonstrate a statistically significant increase in degeneration compared to the normal population at the L4-5 level, the transition to spondylolisthesis appears to be associated with more widespread degenerative changes.

Our findings regarding the SL group are generally consistent with previous literature suggesting that isolated pars defects do not necessarily accelerate degeneration at adjacent levels[5]. Although the difference between the SL and NLV groups at the L4-5 level approached statistical significance (p=0.052), this finding did not reach formal significance and should therefore be interpreted cautiously. While this borderline result may suggest a possible degenerative tendency, it cannot be used to support mechanistic conclusions. Larger prospective studies are required to determine whether a true association exists. These findings may reflect the relatively stable biological behavior of isolated SL compared with the more extensive degenerative patterns observed in IS.

In contrast, the IS group demonstrated significantly higher rates of disc degeneration at cranial levels compared to healthy controls. This pattern suggests a broader degenerative involvement beyond the index level. While some earlier studies have suggested that unaffected segments in IS patients may resemble physiological aging, our findings indicate that degeneration in these patients cannot be fully explained by chronological age alone. Intervertebral discs typically begin to degenerate after the third decade of life, influenced by poor posture, abnormal loading, environmental factors, and genetics; however, the exact underlying mechanism remains unclear[14-16]. While Dai[5] reported a strong link between patient age and the

Table 1. Demographic characteristics of the study groups

Parameter	IS (n=28)	SL (n=38)	L5-S1 LDH (n=34)	NLV (n=33)	p-value
Age (mean ± SD)	42.43±6.03	38.03±7.80	36.41±7.17	35.48±8.82	<0.001*
Gender (male/female)	11/17	21/17	20/14	9/24	0.027*

*: Significant differences (p<0.05) are indicated with an asterisk, IS: Isthmic spondylolisthesis, SL: Spondylolysis, LDH: Lumbar disc herniation, NLV: Normal lumbar vertebrae, SD: Standard deviation

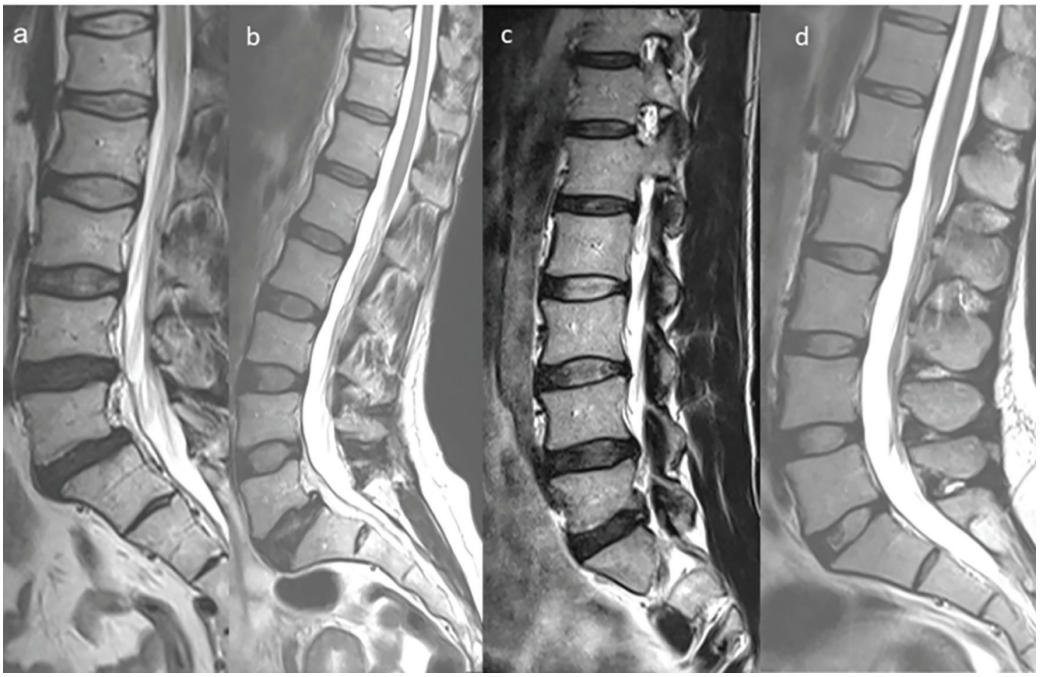

Figure 2. Comparison of lumbar intervertebral disc degeneration in patient groups with isthmic spondylolisthesis and spondylolysis and lumbar disc herniation and normal lumbar vertebrae. T2 sagital weighted MRI show lumbar intervertebral spaces. **a)** Forty-three-year-old man patient with isthmic spondylolisthesis. The patient has Pfirrmann grade 4 degeneration at levels L5-S1 and L4-5, grade 3 at levels L3-4 and L1-2 and grade 2 at level L2-3. **b)** Thirty-nine-year-old female patient with spondylolysis. The patient has Pfirrmann grade 4 degeneration at level L5-S1 and grade 3 at level L1-2, grade 2 at levels L2-3, L3-4 and L4-5. **c)** Forty-four-year old man patient with lumbar disc herniation. The patient has Pfirrmann grade 4 degeneration at levels L5-S1, L4-5 and L1-2, grade 3 at level L3-4 and grade 2 L2-3. **d)** Thirty-five-year-old female with normal lumbar vertebrae. The patient has Pfirrmann grade 2 degeneration at all levels. MRI: Magnetic resonance imaging

severity of disc degeneration above a spondylolytic defect, our findings offer a different perspective.

Although the IS group in our study was significantly older than the NLV group ($p<0.001$), age showed no significant correlation with degeneration at the upper lumbar levels (L1-L4) A significant correlation was observed only at the L5-S1 level ($p=0.015$). These results suggest that additional biomechanical factors may contribute to multilevel degeneration in IS, although the retrospective design limits definitive causal interpretation. This distinction between SL and IS may suggest that segmental instability, rather than the pars defect itself, contributes to multilevel degeneration.

The discrepancy between our findings and earlier reports may be explained by altered spinal biomechanics. Spondylolisthesis results in sagittal imbalance and increased shear forces[6,11]. To maintain an upright posture, patients often exhibit compensatory mechanisms, such as increased lumbar lordosis or pelvic tilt changes[9,11]. We hypothesize that this compensatory hyperextension places excessive stress on the posterior column and annulus fibrosus of the cranial adjacent segments, accelerating degeneration as observed in our IS and LDH groups. This supports the view that adjacent level degeneration is more prevalent in spondylolisthesis, particularly in younger cohorts[6].

Consequently, this has significant implications for clinical practice. During surgical planning, the condition of the intervertebral discs is crucial for deciding between direct repair and segmental fusion[5,10,17]. Preoperative MRI is essential for assessing disc abnormalities at both the affected and adjacent segments[18,19]. As stated by Dai[5] the feasibility of direct repair is not necessarily limited by the patient's age, provided that the adjacent intervertebral disc remains healthy. Our study reinforces this view by showing that disc health is more a factor of mechanical environment than chronological age, thus informing the selection of the most appropriate surgical intervention."

Study Limitations

This study has several limitations that should be acknowledged. First, the retrospective design and relatively small sample size may limit the generalizability of our findings and the statistical power to detect subtle differences. Second, objective spinopelvic radiographic parameters such as pelvic incidence, sacral slope, and lumbar lordosis were not evaluated. Since our interpretation includes a biomechanical hypothesis, the absence of these parameters limits direct validation of sagittal balance-related mechanisms.

Additionally, our assessment was based solely on morphological changes on MRI, and clinical outcome measures (e.g., visual analog scale or Oswestry disability index scores) were not included.

Finally, although the control group consisted of asymptomatic individuals with normal MRIs, complete matching for environmental and lifestyle factors is inherently limited in retrospective analyses.

CONCLUSION

Our study demonstrates that IS and L5-S1 disc herniation are associated with higher rates of IDD in the upper lumbar segments compared to healthy individuals. Although no significant correlation was found between age and degeneration at the upper levels, these findings may suggest a contribution of altered biomechanical factors beyond chronological aging. However, given the retrospective design and absence of objective spinopelvic parameters, definitive causal inferences cannot be established. These results highlight the importance of comprehensive preoperative MRI evaluation of the entire lumbar spine when planning surgical interventions such as pars repair or fusion.

Ethics

Ethics Committee Approval: The study protocol was approved by the İstanbul Medipol University of Non-Interventional Clinical Research Ethics Committee (approval no: E-10840098-202.3.02-6545, date: 05.09.2024).

Informed Consent: This study was a retrospective study. Patient consent was not required.

Footnotes

Authorship Contributions

Surgical and Medical Practices: B.K., B.O.G., Concept: B.K., B.O.G., Design: B.K., B.O.G., Data Collection or Processing: B.K., B.O.G., Analysis or Interpretation: B.K., B.O.G., Literature Search: B.K., B.O.G., Writing: B.K., B.O.G.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: This work was supported by the 2025 İstanbul Medipol University research fund.

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