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ORIGINAL ARTICLE

Adjacent disc and facet joint degeneration in young adults with low-grade spondylolytic spondylolisthesis: A magnetic resonance imaging study

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young adults

Background/Purpose: Premature adjacent-level degeneration has been attributed to vertebral fusion, but spondylolisthesis has not been reported as a pathological factor responsible for the degeneration of adjacent disc and facet joint. We hypothesized that the degeneration of disc and facet joints in the adjacent levels is correlated with spondylolisthesis.
Methods: Magnetic resonance images of 35 symptomatic young adults (16–29 years old) with low-grade L_5–S_1 spondylolytic spondylolisthesis (Meyerding Grade 1 or 2) and 50 symptomatic young referents (20–29 years old) with L_5–S_1 disc herniation without spondylolisthesis were recruited to compare the differences between disc and facet-joint degenerations at the olisthetic and adjacent levels using the Mantel extension test.
Results: There were statistically significant degenerative changes of the discs and facet joints at the olisthetic and adjacent levels of patients with spondylolytic spondylolisthesis compared with the reference group. There is a trend that the disc and facet joints degenerate the most at the olisthetic level and become less affected at adjacent levels away from the lesion of pars defect.
Conclusion: Low-grade spondylolytic spondylolisthesis was associated with significant degenerations of the disc and facet joints at olisthetic and adjacent levels in young adults.

Conflicts of interest: The authors have no conflicts of interest relevant to this article.

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Introduction

Accelerated adjacent-level degeneration of the spine after segmental vertebral fusion is well known in the literature.[1–4] Premature adjacent disc degeneration can be found without vertebral fusion in young patients with spondylolytic spondylolisthesis,[5,6] however, adjacent degeneration is common on preoperative magnetic resonance images (MRI) of symptomatic spondylolytic spondylolisthesis in children and adolescents.[6] In addition, adjacent degeneration has been observed on axially-loaded MRI in some patients with degenerative spondylolisthesis.[7] We therefore hypothesized that spondylolisthesis is associated with adjacent-level disc and facet-joint degeneration in young patients with spondylolytic spondylolisthesis of L_5—S_1. As patients with spondylolytic spondylolisthesis of L_5—S_1 also had disc bulging or herniation at L_5—S_1,[8,9] we designed an MRI study to compare young adults with low-grade L_5—S_1 spondylolytic spondylolisthesis (Meyerding Grade 1 or 2) with a reference group of symptomatic young adults with L_5—S_1 disc herniation without spondylolisthesis. This study aimed to determine whether the disc and facet-joint degeneration at olisthetic and adjacent levels was significantly different between two groups of young patients with and without spondylolisthesis, to evaluate the effect of spondylolytic spondylolisthesis on the degeneration of the disc and facet joint at olisthetic and adjacent levels, and to eliminate the potential confounding effect of aging.

Table 1 Demographic data and distribution of radiological variables between case group with spondylolytic spondylolisthesis of L_5—S_1 and reference group with disc herniation of L_5—S_1 without spondylolisthesis.

Groups		Cases (n = 35)	Referents (n = 50)
Age	Mean	23.4 y	23.7 years
	Range	16—29 y	20—29 years
Sex		29 males, 6 females	31 males, 19 females
Spondylolisthesis	Meyerding grading	Grade 1 (31 patients) Grade 2 (4 patients)	0
	Mean slippage	15.2%	0
% with sciatica		20/35	36/50
% with back pain		33/35	42/50
Duration from onset of symptoms to magnetic resonance imaging[a]	Days	1	1
	Weeks	0	1
	Months	10	10
	Years (<5 y)	10	22
	≥5 y	6	2
	Missing data	8	14

[a] Mantel extension test for trend, p = 0.175.

Patients and methods

The study was approved by the Institutional Review Board of the National Cheng Kung University Hospital, Tainan, Taiwan, and was performed in accordance with the Declaration of Helsinki guidelines (ER-99-179). We retrospectively collected the medical records of 35 consecutive young people with low-grade L_5—S_1 spondylolytic spondylolisthesisas for the case group, and 50 consecutive young adults who were suffering from L_5—S_1 disc herniation plus either low back pain or sciatica but without spondylolisthesis as the reference group (summarized in Table 1). From our experience, we have found that conventional spin echo T2-weighted images showed a gray signal instead of a bright signal in the theoretically T2-bright nucleus pulposus of lumbar discs. To increase the detection of marrow lesions and evaluate disc degeneration, we replaced conventional spin echo T2-weighted sagittal imaging with sagittal short tau inversion recovery (STIR) in MRI for the lumbar spine. Although we have no formal validation study to prove the above assertion, we did this to improve the contrast of imaging and possibly improve the accuracy of the final score.

All of the patients underwent an MRI examination of the lumbar spine (Achieva 1.5T; Philips Healthcare, Eindhoven, The Netherlands) between January 2005 and September 2009 at our hospital because of low back pain or sciatica. These examinations included T1-weighted and STIR sequences in the sagittal plane and T1-and T2-weighted sequences in the axial plane.

The data from patients in the case and reference groups were consecutively collected from the work log of Picture Archiving and Communicating System of our hospital. The exclusion criteria of this study included patients with known systemic disease; evidence of benign or malignant vertebral tumor; infective spondylitis; trauma and lumbar vertebral fracture; congenital anomalies such as tethered cord, meningocele, or lipomyelomeningocele; hemivertebra or butterfly vertebra; and patients with scoliosis or kyphosis. The percentage of spondylolisthesis was measured from a sagittal MRI. The grading of disc degeneration was evaluated on sagittal STIR images, and the severity of disc degeneration was determined using disc degenerative grading based on Pfirrmann criteria (Fig. 1),[4,10] which were summarized as follows: Grade I, homogeneous disc structure with a bright hyperintense white signal intensity and a normal disc height; Grade II, inhomogeneous disc structure with a hyperintense white signal; Grade III, inhomogeneous disc structure with an intermediate gray signal intensity; Grade IV, inhomogeneous disc structure with a hypointense dark gray signal intensity, with disc height normal or moderately decreased; and Grade V, inhomogeneous disc structure with a hypointense black signal intensity and collapsed disc space.

The severity of facet joint degeneration was evaluated from axial T2-weighted images based on Grogan's classification[4,11] and included the three grades of facet-joint cartilage, subchondral sclerosis, and osteophyte formation. The cartilage within the facet joint was classified into four grades: Grade 1, characterized by uniformly thick cartilage covering both articular surfaces completely; Grade 2, characterized by cartilage covering the entire surface with eroded or irregular regions; Grade 3, characterized by cartilage incompletely covering the articular surface with the underlying bone exposed to the joint

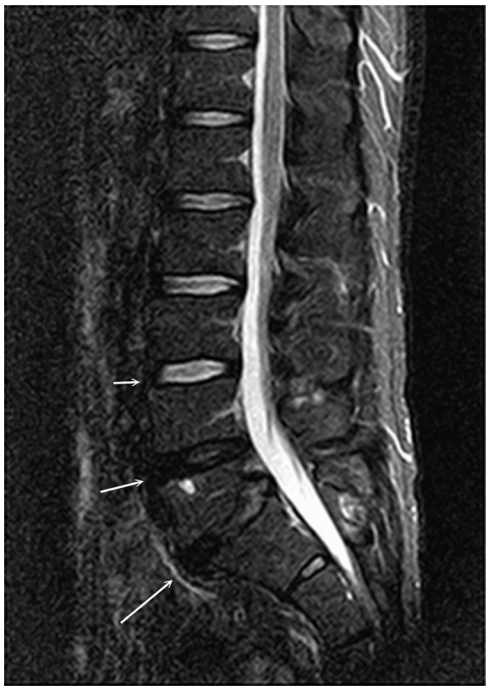

Figure 1 The grading of disc degeneration was evaluated from sagittal T2-weighted image of the lumbar spine according to Pfirrmann criteria. In this image, disc degeneration was graded as Grade 2 for the L_{3-4} disc (shortest arrow), Grade 4 for the L_{4-5} disc (moderate arrow), and Grade 5 for the L_5—S_1 disc (longest arrow).

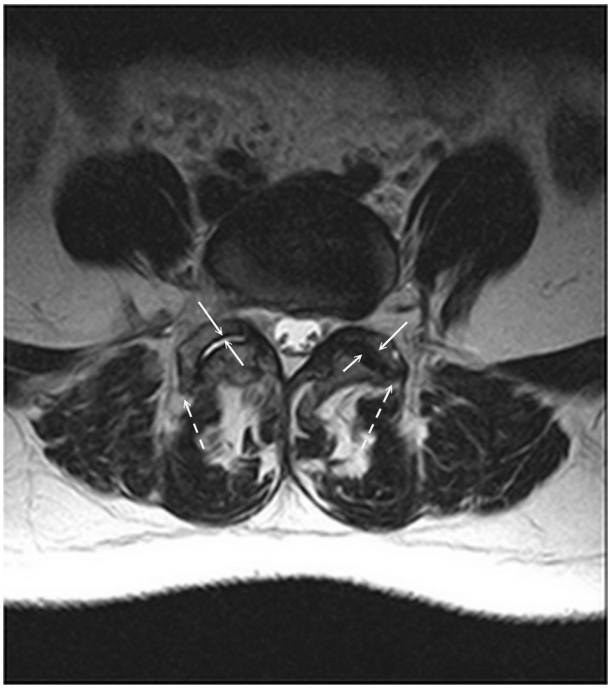

Figure 2 Facet-joint degeneration was graded using axial T2-weighted magnetic resonance images based on Grogan's classification, including grades of cartilage, subchondral sclerosis, and osteophytes. The three grades of Grogan's classification were summed up into a facet degeneration index (FDI). In this image, cartilage degenerations were Grade 2 for the right side and Grade 3 for the left side (short arrows), subchondral scleroses were Grade 2 for the right side and Grade 3 for the left side (long arrows), and osteophytes were Grade 3 for the right side and Grade 3 for the left side (broken arrows). The FDI was 7 for the right facet joint and 9 for the left; thus, the higher FDI value of 9 was recorded for analysis of the facet-joint degeneration of L_{4-5}. FDI, facet degeneration index.

space; and Grade 4, characterized by the complete absence of cartilage. The degree of subchondral sclerosis was classified into four grades: Grade 1 was defined as a uniform thin band of cortical bone; Grade 2 represented a thin band of cortical bone that extended into the space from the articular surface; Grade 3 was defined as dense bone that extended into the joint space but covered less than half the facet; and Grade 4 represented the presence of dense cortical bone that covered greater than half the facet joint. The size of osteophytes at the facet joints also was classified into four grades: Grade 1 indicated no osteophyte; Grade 2 indicated a mild or possible osteophyte; Grade 3 indicated a moderate osteophyte; and Grade 4 indicated a large osteophyte. The three grades of Grogan's classification were summed up into a facet degeneration index (FDI). The side of the more degenerated facet joint with a higher FDI was selected for analysis, and the severity of facet-joint degeneration was given a "facet joint degeneration grading" according to the value of the higher measured FDI (Fig. 2). The differences between disc and facet-joint degenerations at olisthetic and adjacent levels (L_{3-4}, L_{4-5}, and L_5—S_1) were compared using the Mantel extension test.[12]

It was also important to clarify that the difference in adjacent disc degeneration between the case and reference groups was not affected by a time factor. For this reason, we retrospectively investigated the medical record to analyze whether there was low back pain or sciatica in the two groups, and we analyzed the time between the onset of symptoms and the patient undergoing MRI.

Results

As summarized in Table 1, there were 33 patients with low back pain and 20 patients with sciatica (1 with bilateral sciatica and 19 with unilateral sciatica) in the case group; the times between the onset of clinical symptoms and MRI ranged from 3 days to 9 years, and the average was about 5 months. In the reference group, there were 42 patients with low back pain and 36 patients with sciatica (7 with bilateral sciatica and 29 with unilateral sciatica); the MRI to symptoms ranged from 1 day to 2 years. The average was also about 5 months. The times between the onset of clinical symptoms and patients receiving MRI in both groups are summarized in Table 1, which indicates no statistically significant difference (Mantel extension test for trend, $p = 0.175$).

There were significant degenerative changes of the discs and facet joints at the olisthetic and adjacent levels in the case group compared with the reference group (all $p < 0.001$; Tables 2 and 3). The severity of disc degeneration was the highest for L_5—S_1 followed by L_{4-5}, while that of L_{3-4} seemed the mildest; however, the severity of facet joint degeneration was higher at the L_5—S_1 and L_{4-5} levels

Table 2 Differences in disc degeneration scores at the olisthetic and adjacent levels in the case group with spondylolytic spondylolisthesis of L_5—S_1 and the reference group with disc herniation of L_5—S_1 without spondylolisthesis.

Disc levels	Groups	Grade I	Grade II	Grade III	Grade IV	Grade V	p^a
L_{3-4}	Cases ($n = 35$)	0	30	4	1	0	<0.001
	Referents ($n = 50$)	9	38	3	0	0	
L_{4-5}	Cases ($n = 35$)	0	5	25	5	0	<0.001
	Referents ($n = 50$)	3	38	8	1	0	
L_5—S_1	Cases ($n = 35$)	0	0	10	12	13	<0.001
	Referents ($n = 50$)	1	21	24	4	0	

[a] Mantel extension test to determine trend.

than that in L_{3-4}. Namely, there is a trend that the disc and facet joints degenerate the most at the olisthetic level and become less affected at adjacent levels away from the lesion of pars defect in the case group with spondylolytic spondylolisthesis.

Discussion

There are several reports[5,6] on the premature adjacent-level degeneration of the L_{4-5} disc that occurs in young adults with L_5—S_1 spondylolytic spondylolisthesis, but few focus on changes to the L_{3-4} disc and the trends relating to the severity of degeneration of the disc and facet joints at adjacent levels in patients with such a pathology. In this study, we have demonstrated that there were significant ($p < 0.001$) degenerative changes of the disc and facet joints at the adjacent (L_{3-4}, L_{4-5}) and olisthetic levels (L_5—S_1) in the case group compared with the reference group. This supports our hypothesis about premature degeneration of the discs and facet joints on adjacent levels in young adults with low-grade spondylolytic spondylolisthesis of L_5—S_1. The region of pars interarticularis of L_5 is connected with the L_{4-5} and L_5—S_1 facet joints, and is much closer to the L_{4-5} facet joint than the L_5—S_1 facet joint in the anatomical position. The L_{4-5} facet joint is therefore also liable to degeneration along with the degeneration of L_5—S_1 facet joint in young adults with low grade spondylolytic spondylolisthesis. As summarized in Tables 2 and 3, only five out of 35 Grade 4—5 disc degeneration cases are noted at L_{4-5}, whereas this increases to 25 out of 35 cases at L_5—S_1. All cases had facet joint degeneration with higher facet degeneration scores (7—12) at L_{4-5} and 34 out of 35 cases had higher scores at L_5—S_1. Thus, although the influence of adjacent degeneration becomes less with increasing distance from the lesion, facet joint degeneration seems more severe at both the L_{4-5} and L_5—S_1 levels because of their proximity to the degeneration, followed by L_{3-4}. The stability and function of the L_5—S_1 disc determine whether or not spondylolisthesis of L_5—S_1 will occur after spondylolysis of L_5. Slippages between L_5—S_1will occur if the degeneration of the disc and facet joint at the olisthetic (L_5—S_1) and adjacent levels (L_{4-5} and some L_{3-4}) is severe enough that the disc and facet joint stabilizers cannot resist the shearing force at L_5—S_1. Thus, we hypothesize that spondylolisthesis may be a complication resulting from a combination of the degeneration of disc and facet joints at the olisthetic and adjacent levels, associated with a pars defect or fracture in patients with spondylolytic spondylolisthesis. In addition, disc bulging or herniation of L_5—S_1 at the olisthetic level might be induced and concomitantly occur with spondylolytic spondylolisthesis of L_5—S_1[8,9] due to the total instability. This resulted in the adjacent degeneration of the disc and facet joints in the case group with spondylolytic spondylolisthesis at L_5—S_1. As the major pathology difference between the two groups was spondylolytic spondylolisthesis at L_5—S_1, we tentatively conclude that the above factor is associated with adjacent L_{4-5} and possibly L_{3-4} degenerations. Additional studies are needed to corroborate our findings.

Table 3 Differences in facet degeneration scores at the olisthetic and adjacent levels in the case group with spondylolytic spondylolisthesis of L_5—S_1 and reference group with disc herniation of L_5—S_1 without spondylolisthesis.

Levels	Groups	Facet degeneration scores				p^a
		≤3	4—6	7—9	10—12	
L_{3-4}	Cases ($n = 35$)	0	21	13	1	<0.001
	Referents ($n = 50$)	11	39	0	0	
L_{4-5}	Cases ($n = 35$)	0	0	25	10	<0.001
	Referents ($n = 50$)	1	48	1	0	
L_5—S_1	Cases ($n = 35$)	0	1	22	12	<0.001
	Referents ($n = 50$)	0	44	6	0	

[a] Mantel extension test to determine trend.

The pars interarticularis defect occurs mostly at L_5 in spondylolysis and spondylolytic spondylolisthesis of L_5—S_1, and it is the most common cause of low back pain in children and adolescents.[13] The etiology of spondylolytic spondylolisthesis is attributed to genetic, mechanical, hormonal, and other factors[14—16]; however, repeated trauma and stress accumulation are important for further progression of the slippage.[17] The pars interarticularis defect is a pseudarthorosis, composed of noninnervated ligament-like tissue with an enthesis structure.[18] A pars defect or fracture of L_5 may therefore alter the biomechanics of the spine, especially at the L_{4-5} and L_5—S_1 segments, and may raise the level of stress and strain energy on the discs and facet joints of L_{4-5} and L_5—S_1 under axial loading or the motion of our body. In fact, the stability of L_{3-4} is also affected to some extent, as shown by the degeneration of discs and facet joints (Tables 2 and 3).

Spondylolysis develops early in childhood, but most young adults with L_5—S_1 spondylolytic spondylolisthesis are asymptomatic.[19,20] Current consensus seems to recommend early conservative treatment, such as rest, bracing, and physical rehabilitation.[17,19—21] Surgical intervention usually is usually for symptomatic patients resistant to nonoperative treatment, or those with mechanical back pain, radicular signs, or at risk of further progression of the slip.[19,22] Our findings of concomitant degeneration of the adjacent disc and facet joints among these patients imply that all treatments should include a proactive strategy for the prevention of aggravation of degenerative changes and/or instability of adjacent disc and facet joints. For example, the severity of preexisting adjacent-level degeneration of the disc and facet joints must be carefully evaluated and considered to prevent possible junctional problems before an operation is performed in patients with spondylolytic spondylolisthesis or degenerative spondylolisthesis.[7] Early repair of defects in the pars interarticularis may be considered for symptomatic young patients with spondylolysis or low-grade spondylolytic spondylolisthesis who have failed conservative treatment to help prevent further slippage of vertebrae and the progression of premature degenerative change in the disc and facet joints.

In conclusion, the adjacent-level degeneration of the disc and facet joints (L_{4-5} and possibly L_{3-4}) occurred in low-grade spondylolytic spondylolisthesis (L_5—S_1) of symptomatic young adults; the closer to the primary affected site, the more severe the degeneration of these joints.

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