Radiographic Predisposing Factors for Degenerative Spondylolisthesis

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This study was a retrospective radiographic study involving analysis of computed tomography scans obtained for patients with degenerative spondylolisthesis of the L4-L5 segment and a control group. The purpose of the study was to identify radiological predisposing factors for degenerative spondylolisthesis of the L4-L5 segment. The authors reviewed all computed tomography scans (N=3370) performed at their institution between January 2005 and December 2008. Eighty-four patients with degenerative spondylolisthesis were identified and compared with a control group regarding facet joint orientation, the presence of sacralization of the L5 vertebra, the presence of major degenerative changes in the L5-S1 disk space, and the location of the intercrestal line. There was a statistically significant difference between the 2 groups regarding facet joint orientation, with more sagittal facet joints in the degenerative spondylolisthesis group (56° and 54° in the right and left facets, respectively, in the study group, and 46° and 42° in the right and left facets, respectively, in the control group) (P<.001). There was no statistically significant difference between the 2 groups regarding the presence of sacralization of the L5 vertebra, the presence of major degenerative changes in the L5-S1 disk space, and the location of the intercrestal line relative to the lumbar spine. There is an association between sagittal orientation of the facet joints at the L4-L5 segment and degenerative spondylolisthesis at the same level.

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Although slipping of the fourth lumbar vertebra with an intact neural arch was described at the beginning of the 20th century, controversy continues regarding the etiology and pathomechanism of the vertebral slippage process. It is thought that the mechanical stress on the L4-L5 segment causes degenerative changes at the L4-L5 disk and facet joint, which leads to segmental instability at this level. These changes in the L4-L5 facet joint cause a deformity at the facet joints, with the more sagittal-oriented facets allowing anterior slippage of the L4 vertebra.

This theory has some disadvantages. It does not explain the slippage of the L4 vertebra in cases where the facets are oriented in the coronal plane. Perhaps more importantly, the degenerative changes in the disk and facet joints are part of the aging process, so one must investigate other factors that may influence the creation of instability and spondylolisthesis.

Several studies have described different causes for degenerative spondylolisthesis, including a stiff L5-S1 segment (sacralization of the L5 vertebra), sagittal orientation of the facet joints, high position of the L4-L5 disk in relation to the intercrestal line, loss of soft tissue resistance, and decreased anterior disk height. Some of these studies were based on radiographs rather than on computed tomography (CT). Other studies evaluated a relatively small number of patients and some had contradictory conclusions.

The authors of the current study compared several radiographic characteristics between a group of degenerative spondylolisthesis patients and a control group to evaluate whether these factors may predispose a patient to degenerative spondylolisthesis at the L4-L5 segment.

**Materials and Methods**

The authors reviewed all CT scans performed between January 2005 and December 2008 at their institution. Of the 3370 CT scans reviewed, 91 (2.7%) patients were diagnosed with degenerative spondylolisthesis at the L4-L5 segment. These 91 CT scans were retrospectively reviewed. In 3 cases there was a misdiagnosis, and these patients did not have L4-L5 degenerative spondylolisthesis. In 4 other cases, the quality of the CT scan was not good enough to produce meaningful data. After accounting for these 7 cases, the final study group included 84 patients with degenerative spondylolisthesis. From the 3279 CT scans that were not included in the study group (no degenerative spondylolisthesis), a list was created of patients age- and sex-matched to the degenerative spondylolisthesis group. From this list, 84 patients were randomly selected to serve as the control group (Figure 1).

The radiographic characteristics that were examined included facet orientation angle, the existence of sacralization (complete or partial) of the L5 vertebra, advanced degeneration of the L5-S1 disk space, and the location of the intercrestal line (Tuffier’s line) in relation to the other vertebra.

The facet orientation angle was measured on an axial view at the level of the superior endplate of L5, as described by Grobler et al. The facet orientation angle was measured between 2 lines. The first line was drawn tangential to the posterior vertebral body. The second line connected 2 points at the facet joint: one at the anteromedial part of the facet and the second at the posterolateral part of the facet. The facet orientation angle was measured at the junction of these 2 lines (Figure 2).

The existence of sacralization (complete or partial) of the L5 vertebra was recorded. Sacralization is defined as an enlargement of the transverse process of L5, which creates a connection to the sacrum or the ileum.
The intercrestal line connects 2 points, each on the highest part of the iliac crest from the right and left. The height of the intercrestal line is determined by the structure it crosses in the lumbar spine: L3-L4 disk space, superior endplate of L4, vertebral body of L4, inferior endplate of L4, L4-L5 disk space, superior endplate of L5, vertebral body of L5, or inferior endplate of L5.

The authors documented any degenerative changes at the L5-S1 disk space. Changes included loss of height, sclerosis, and the presence of osteophytes.

The authors did not quantify loss of disk height and length of slip because they believe that these factors do not predispose to spondylolisthesis because they are in fact caused by spondylolisthesis.

Statistical analyses were performed with SigmaPlot software (Systat Inc, San Jose, California). Pearson product moment tests were implemented to examine the correlation between radiographic predisposing factors and patient demographics. Chi-squared tests were used to investigate the relationship between sacralization and the existence of degenerative spondylolisthesis. Paired t tests were used to compare the facet angles and the height of the intercrestal line between control patients and degenerative spondylolisthesis patients. P values less than .05 were accepted as statistically significant, and correlation coefficients greater than 0 were indicative of positive relationships within the data set.

RESULTS

From 3370 CT scans, the authors found 88 (2.6%) patients with degenerative spondylolisthesis of L4-L5. Four CT scans were of poor quality and were not included in the study. The study population included 168 patients, with 84 patients in the study group (diagnosed degenerative spondylolisthesis) and 84 patients in the control group (no degenerative spondylolisthesis).

Average patient age of the final study group was 69 years (range, 52-84 years). There were 57 women and 27 men in each group.

Average right and left facet joint angles in patients with degenerative spondylolisthesis were 56° (range, 34°-82°) and 54° (range, 32°-80°), respectively. Average right and left facet joint angles in patients in the control group were 46° (range, 17°-77°) and 42° (range, 14°-73°), respectively. There was a statistically significant difference between the study and control groups (P<.001) (Table).

The difference between the study and control groups regarding orientation of the facet was significant in all age groups, and there was no correlation between age and facet joint orientation (Pearson’s correlation test).

In the degenerative spondylolisthesis group, 30 (36%) of the 84 patients had some kind of connection (sacralization) between the L5 transverse process and the S1 vertebra. Of these 30 patients, 18 had bilateral sacralization and 12 had unilateral sacralization. In the control group, 25 (30%) patients had a connection between the L5 transverse process and the S1 vertebra. In 13 patients the connection between the L5 transverse process was bilateral, and in 12 patients the connection was unilateral. There was no statistically significant difference between the control and study groups regarding the existence of a connection between the L5 transverse processes and the S1 vertebra (P=.405).

In the degenerative spondylolisthesis group, 30 (36%) patients had degenerative changes at the L5-S1 disk space, whereas in the control group, 35 (41.6%) patients had these changes. There was no statis-
Another study claimed that that malorientation of the facet joints is merely the result of degenerative remodeling, not the cause of it. In this study, a group of 23 patients with degenerative spondylolisthesis was compared with 3 other control groups of patients of different age groups. The L4-L5 facet joints were oriented more in the sagittal plane in patients with degenerative spondylolisthesis than in control group patients. The investigators could not detect a group of younger patients with sagittal alignment of their facet joints (ie, patients with a predisposition for degenerative spondylolisthesis later in life) and concluded that the difference in facet joint orientation is due to a secondary remodeling of the joint orientation rather than a preexisting morphological feature. However, considering the overall low prevalence of degenerative spondylolisthesis in the population, it is more likely that a random sample of young patients will not reflect the risk for degenerative spondylolisthesis.

The current study included 84 patients in the degenerative spondylolisthesis group and 84 patients in the control group. Mean patient age and male/female distribution were identical in both groups. This was true for young patients and older patients with degenerative spondylolisthesis of the L4-L5. There was also no correlation between age and facet joint orientation, indicating that facet joint orientation plays a role at the pathogenetic core of the slipping process. In the past few years, some studies have demonstrated that a greater pelvic incidence may lead to the development and progression of vertebral slip. It is claimed that the relatively vertical inclination of the S1 endplate is predisposing for an anterior translation of L4 on L5 and that the sagittally oriented facet joints are not capable of retaining this anterior vertebral displacement. Studies have demonstrated a correlation between partial or complete sacralization of the L5 vertebra and the presence of degenerative spondylolisthesis of the L4-L5 segment. Other studies have demonstrated a relationship between the height of the intercrestal line and the presence of degenerative spondylolisthesis of the L4-L5 segment and degenerative changes at the L5-S1 disk space.

The current study has several limitations, including the methodology of a retrospective CT-based study. Another limitation is that all CT scans were performed supine, and it is possible for supine images to miss degenerative spondylolisthesis. Also, because the authors manually reviewed more than 3370 CT scans, the potential exists for diagnoses to be missed.

**Conclusion**

This study demonstrates an association between the sagittal orientation of the facet joints at the L4-L5 segment and degenerative spondylolisthesis at the same level.

**References**

1. Junghanns H. Spondylolisthesen ohne Spalttim Zwischergelenkstulcz (Pseudospondylis-

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<td><strong>L4-L5 Facet Angles</strong></td>
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**Abbreviation:** deg, degrees.


