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U. Berlemann
D. J. Jeszenszky
D. W. Bühler
J. Harms

Facet joint remodeling in degenerative spondylolisthesis: an investigation of joint orientation and tropism

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U. Berlemann (✉)
Department of Orthopaedic Surgery,
Inselspital, University of Bern,
Freiburgstrasse,
CH-3010 Bern, Switzerland
Tel.: +41-31-632 2222,
Fax: +41-31-632 3600

D. J. Jeszenszky · J. Harms
Department of Orthopaedic
and Trauma Surgery,
Center for Spinal Surgery,
Karlsbad-Langensteinbach, Germany

D. W. Bühler
M. E. Müller Institute for Biomechanics,
University of Bern, Switzerland

Abstract This study analyzed transverse facet joint angulations at the three lower lumbar levels in 132 patients assigned to one of four groups. Group A comprised 23 patients with degenerative spondylolisthesis (DS) at the level L4-5, group B comprised 40 patients above the age of 50 years, group C comprised 38 patients aged between 35 and 50 years, and group D comprised 31 patients under the age of 35 years. Groups B, C, and D had no evidence of DS. Measurements were taken from hard copies of axial MR or CT images. The transverse plane of facet joints was more sagittally oriented in group A than in any other group. This difference was highly significant at the L4-5 level. The incidence of more sagittally oriented L4-5 facet joints was also significantly higher only in group A. The incidence of facet joint tropism, however, was not different in group A. These results support the view that the pronounced sagittal alignment of facet joints in patients with DS represents a secondary remodeling rather than a pre-existing morphology. Facet joint asymmetry does not seem to play a major role in the development of DS.

Key words Lumbar spine · Facet joint · Remodeling · Degeneration · Ventrolisthesis

Introduction

Several studies have attempted to define etiological factors for the development of degenerative spondylolisthesis (DS), and the orientation of lumbar facet angles relative to the transverse plane has been a major focus of interest. The facet joints play a critical role in maintaining stability of the lumbar spine by sharing load in compression and extension, and protecting the disc from excessive shear and rotational forces [1, 13, 24]. Determined by their spatial orientation, they also guide motion between two adjacent vertebrae. Their oblique orientation in the lumbar spine allows flexion, extension, and lateral bending, but only a small amount of axial rotation [27].

It has been shown that in patients with DS, the facet joints are significantly more sagittally oriented, thus allowing the superior vertebra to glide anteriorly. Individuals with sagittally oriented facet joints have therefore been regarded as candidates for DS [23]. However, it is not clear whether this more pronounced sagittal orientation of the facet joint represents a pre-existing morphology or whether it has to be considered a result of secondary remodeling.

Facet joint asymmetry (tropism) has been claimed to be related to disc herniation and degenerative disc disease due to rotational instability of the spinal segment [6, 8, 20]. Whether facet joint tropism plays a role in the development of DS, however, has not been investigated.

The present study analyzed facet joint orientation in the transverse plane in patients with DS and compared this to patients with no evidence of ventrolisthesis from three different age groups. The working hypothesis was that if the more sagittal orientation in DS was a pre-existing anatomical feature, it then should be possible to identify a younger patient group being "at risk" for the development of DS later in life. The incidence of facet joint tropism in the different groups was also investigated.

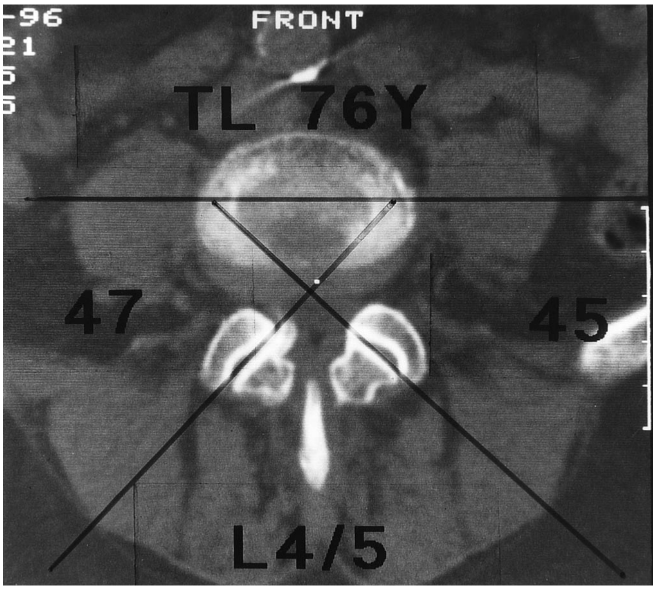

Fig. 1 Measurement of facet joint angulation in the transverse plane (left 47°, right 45°). A line parallel to the coronal posterior vertebral body plane is illustrated as the reference

Materials and methods

The study included 132 patients who had undergone MRI or CT scanning of their lumbar spine for various diagnoses, including disc protrusion/prolapse, spinal canal stenosis, and degenerative changes of discs and facet joints. None of the patients had undergone previous surgery to the region of interest. Plain anteroposterior and lateral standing neutral radiographs were used to confirm a five-segmental lumbar spine. Patients with any developmental anomalies, any signs of lytic lesions, or a scoliotic deformity of more than 10° were excluded. The patients were assigned to one of four groups:

Group A: Patients with DS (slip of more than 3 mm) at the level of L4-5. This group included 23 patients (7 male, 16 female) with an average age of 69 years (SD 10.2). The main clinical complaints in this group were neurogenic claudication (30% of patients) and low back pain combined with sciatica (50%).

Group B: Patients above the age of 50 years with no evidence of gliding. This group included 40 patients (9 male, 31 female) with an average age of 63.2 years (SD 8.7). The main clinical complaints were low back pain combined with sciatica (40%), and sciatica only (30%).

Group C: Patients between the age of 35 and 50 years. This group included 38 patients (13 male, 25 female) with an average age of 42.1 years (SD 4.5). The main clinical complaints were low back pain combined with sciatica (40%), and sciatica only (40%).

Group D: Patients under the age of 35 years. This group included 31 patients (14 male, 17 female) with an average age of 28.8 years (SD 4.1). The main clinical complaint was low back pain combined with sciatica (70%).

Measurements were taken from hard copies of axial MR or CT image cuts, which had to be aligned parallel (± 5°) to the endplate at the level of the inferior margin of the intervertebral space. Two points were identified to define the anteromedial and posterolateral margin of each facet. The angles were measured with respect to a coronal reference plane on the posterior wall of the vertebral body (Fig. 1). Values obtained from MR images and CT scans have been shown to be similar [4], and both image modalities were used in this study. All measurements were taken twice by the principal author, and their average was used for further analysis. No attempt was made to assess intra- or interobserver variability, as these have been shown to be insignificant [11].

Data were statistically analyzed using the non-parametric Mann-Whitney U test. The facet joint angulations were also categorized in 20° increments for the sum of both sides, and 5° increments for the difference between left and right. This allowed further analysis of the distribution, using the chi-square test. *P*-values of < 0.05 were accepted as significant, *P*-values of < 0.01 as highly significant.

Results

Using the combined data from all patient groups, the facet joint angulation was not related to the age of the patient. The transverse plane orientation of facet joints was more sagittal in patients with DS than in any other group. This difference was minimal at the L5-S1 level, more obvious at L3-4, and highly significant at L4-5 (Table 1). When female patients are analyzed separately, the significant differences remain, with the exception of the comparison between groups A and D. The mean values are 101.1° (SD 23.8°) for female patients in group A and 87.0° (SD 21.1°) for those in group D. The non-parametric U-test results in a *P*-value of 0.06, probably due to the relatively small number of female patients in group D (n = 17).

The incidence of more sagittally oriented L4-5 facet joints was significantly higher in the group with DS compared to all other groups (Fig. 2B and Table 2). This was also the case when the results for female patients were analyzed separately. Also, a higher incidence of more sagittally oriented joints was found in young patients (group D) compared to elderly patients (group B) for the levels L3-4 and L4-5 (*P*-values < 0.001 and 0.003, respectively, Fig. 2A, B), and compared to patients aged between 35 and 50 years (group C) for the L5-S1 level (*P*-value 0.036, Fig. 2C).

The average facet joint asymmetry at the L3-4 and L4-5 levels was largest in patients with ventrolisthesis (group A), with 5.8° (SD 5.3) and 6.5° (SD 6.3), respectively. Differences with the other groups, however, were small and non-significant. At L5-S1, young patients (group D) had the largest asymmetries, with an average of 8.6° (SD

Table 1 Facet joint angulation in four patient groups: average (SD) of all measurements (sum of angulation of left and right side)

	L3-4	L4-5	L5-S1
Group A	113.8 (16.0)	105.0 (22.6)	79.3 (18.0)
Group B	110.5 (13.2)	89.9 (15.4)**	74.3 (15.1)
Group C	107.5 (14.4)	85.8 (14.8)**	79.0 (15.4)
Group D	106.2 (19.4)	83.8 (19.3)**	76.5 (16.1)

** *P* < 0.01 (highly significant, with respect to group A)

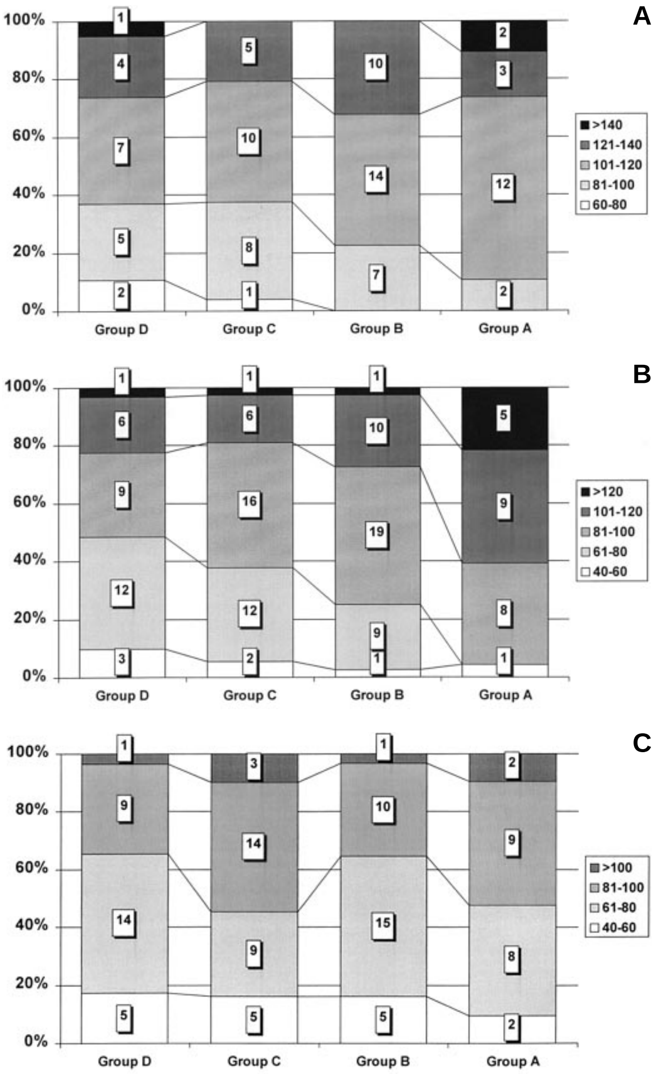

Fig. 2 A–C Distribution of facet joint angulations (sum of both sides), categorized in 20° increments for the three lower lumbar levels: **A** L3-4, **B** L4-5, and **C** L5-S1

Table 2 *P*-values of chi-square test for categorized facet joint angulations, L4-5

	Group B	Group C	Group D
Group A	< 0.001	< 0.001	< 0.001
Group B	–	0.345	0.003
Group C	–	–	0.216

8.0), which was also not significantly different to the other groups.

The proportion of patients with a facet joint asymmetry of more than 10° was variable from level to level. At L3-4 21.1% of patients with ventrolisthesis and 0% of young patients fell into this category. At L4-5 the proportion was similar in all groups, whereas at L5-S1 37.9% of young patients showed a facet joint asymmetry of more than 10° (Table 3). At this level there was a clear trend towards increased joint tropism in the young age group. *P*-values of the chi-square test were 0.084 (comparison to group A), 0.033 (comparison to group B), and 0.088 (comparison to group C).

Table 3 Percentage of patients with facet joint tropism of more than 10° and 20°, all levels

		> 10° to 20°	> 20°
L3-4	Group A	21.1	0
	Group B	9.7	0
	Group C	12.5	0
	Group D	0	0
L4-5	Group A	13.0	4.3
	Group B	17.5	2.5
	Group C	18.9	2.7
	Group D	16.1	3.2
L5-S1	Group A	19.0	0
	Group B	16.1	0
	Group C	19.4	0
	Group D	24.1	13.8

Fig. 3 Remodeling of facet joint due to osteophytic degeneration in a male patient with degenerative spondylolisthesis at the level L4-5. It appears that the joint line changed orientation from *a* to *b*

Discussion

Degenerative lumbar spondylolisthesis (DS) is a common and important condition of the aging spine, which frequently presents with symptoms of spinal canal stenosis [14]. It occurs most often at the L4-5 level and predominantly in women. The sex ratio of 1 : 2.2 found in this study is slightly lower than that reported by others [21, 23]. Several hormonal and mechanical factors have been reported to contribute to the development of DS [3, 9, 21, 22]. Facet joints and particularly their spatial orientation, however, seem to represent a significant factor. Biomechanically, the facet joints share load mainly in compression and extension of the lumbar spine [1]. They furthermore protect the disc from excessive rotational strain and anterior shear forces [2, 15]. It therefore has been argued that more sagittal alignment of the joint leads to anterior gliding due to a reduced resistance to anterior shear forces [10, 24]. These forces are particularly large in the lower two segments of the lumbar spine, as lordosis and horizontal vertebral tilt increase. This is reflected by the generally more coronal orientation of the L5-S1 facet joint compared to L3-4 and L4-5 [9], which was also shown by the data of this study. Others have reported an increased incidence of L5 sacralization in patients with DS [21]. The additional stress on the first free segment, L4-5, may also contribute to the development of an olisthesis. Our data do not allow a comment on this, as in this study all patients with sacralization were excluded due to uniform criteria in all groups.

Several radiological studies have indicated a correlation between DS and an increased sagittal orientation of the L4-5 facet joints [4, 9, 18. 23]. Our data confirmed this with a high statistical significance. The angulations measured in this study were similar to the angulations reported by others (Table 1) [17, 23, 25]. The question, however, remains whether this pronounced sagittal facet joint orientation at L4-5 should be considered a cause or an effect of DS. Some authors have stated that this facet joint orientation is developmental or pre-existing and thereby a causative factor in the etiology of DS [17, 23]. Boden et al. [4] found a more sagittal orientation of the facet joints also at adjacent levels to the slip without signs of DS. In their view, this strongly suggested a predisposing morphological joint configuration, seen at multiple levels in certain patients. In the present study we confirmed a more sagittal alignment of facet joints at the uninvolved L3-4 level in patients with DS at the L4-5 level. However, differences with the comparison groups were not significant. Furthermore, the incidence of cases with sagittally oriented L4-5 facet joints was increased only in patients with DS. No significant differences were detected between any of the other groups (Fig. 2 B and Table 2). It was therefore not possible to detect a younger patient group predisposed to DS later in life by “congenital” sagittal alignment of their facet joints. These findings rather support the view that a remodeling of the joint orientation may occur as an expression of hypertrophic degeneration. Osteoarthritic changes of facet joints are a common finding in patients with DS. In contrast to other synovial joints pronounced osteophytes and subchondral sclerosis are frequently found even when the articular cartilage is still retained [26]. This may result in a secondary reorientation of the joint. Figure 3 illustrates such a case, where the facet joint volume also is enlarged due to osteophytic remodeling. The consequence is a narrowing of the paramedial zone [18], mainly by the superior facet of the caudal vertebra, which could only be addressed by bony decompression rather than a reduction of the olisthesis. However, only longitudinal imaging studies could finally resolve this remodeling issue. At the present time this does not seem practical, and the approach used in this study, comparing different age groups, seemed the best possible compromise.

Studies relating facet joint tropism and the development of disc herniation have yielded conflicting results. Farfan et al. [8] stated that facet joint asymmetry caused additional torsional stress on the anulus, which eventually could lead to a herniation of disc. Several studies have supported this hypothesis [6, 19], others have denied it [5, 12]. A similar controversy exists concerning the correlation of facet joint tropism and degenerative disc disease. Dai and Jia [7] found a significant influence of facet joint asymmetry on the development of lumbar disorders, but Boden et al. [4] and Murtagh et al. [19] could not find an association between tropism and disc degeneration. According to our data there seems no relationship between facet joint tropism and the development of DS. There were no significant differences in tropism between the patients with ventrolisthesis (group A) and the other groups. At level L4-5 about 20% of patients showed an asymmetry of more than 10° in all groups (Table 3). However, there was a clear trend of more pronounced asymmetry at the L5-S1 level in young patients (group D). This supports the results of a recently published study of disc herniations in children and adolescents, which found the frequency of facet joint asymmetry in the juvenile group to be five times higher than that in the adult group [16].

Conclusion

Facet joint orientation in patients with DS at the level L4-5 was found to be significantly more sagittal compared to patients with no evidence of DS. This difference is more likely due to a secondary remodeling of the joint orientation rather than a pre-existing morphological feature. There is no evidence that facet joint tropism plays a major role in the development of DS.

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