Facet Joint Orientation and Tropism in Lumbar Degenerative Disc Disease and Spondylolisthesis

Witchate Pichaisak MD, FRCOST*,
Chayaporn Chotiyarnwong MD**, Pojchong Chotiyarnwong MD, PhD, FRCOST*

** Department of Orthopaedic Surgery, Siriraj Hospital, Mahidol University, Bangkok, Thailand*
*** Department of Physical Medicine and Rehabilitation, Siriraj Hospital, Mahidol University, Bangkok, Thailand*

Background: *Although degenerative disc disease (DDD) and degenerative spondylolisthesis (DS) are two common causes of back pain in elderly, the association between the lumbar facet joint angle and tropism in these conditions are still unclear.*
Objective: *To evaluate the difference in facet joint angles between normal population and lumbar degenerative disc disease and spondylolisthesis patient.*
Material and Method: *The angle of lumbar facet joints were retrospectively measured with magnetic resonance imaging (MRI) to determine whether there was a difference between degenerative diseases. MRI of patients with DDD, DS, and control group at facet joint between L3-4, L4-5 and L5-S1 level were measured in axial view (60 subjects in each group).*
Results: *There was no difference in facet joint angle in DDD (44.1±11.9) and control (45.6±8.9), but differed in DS (40.1±10.7) and control group (p = 0.010) at L4-5 level. Facet tropism showed difference between degenerative groups and control group at L4-5 level.*
Conclusion: *DS group showed difference in facet joints angle and tropism when compared with control population, while DDD showed difference only in facet tropism. In addition, longitudinal studies are needed to understand the clinical significant between facet joint angle and tropism in spinal degenerative diseases.*

Keywords: *Facet joint orientation, Tropism, Degenerative disc disease (DDD), Degenerative spondylolisthesis (DS)*

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The human spine adaptation to upright position required alteration of articular facet orientation[1]. Facet orientation affects the degree of rotation in various body planes with weight bearing and provides rotational coupling in the lumbar spine[2,3]. This gives the stability and control spinal motion under complex loading in upright position of human. The facet joints (also known as zygapophyseal joint or apophyseal joint), especially at lumbar area, have high level of mobility and supports a large force, so degenerative changes can develop. These cause a potential source of pain and disability[4]. Around 80% of population suffers from back pain once in their lives[5]. The economic burden of health cost, both direct and indirect, estimated to exceed US$ 100 billion[6], calls for an efficient therapy of back pain problem.

Abnormality of facet joint orientation, associated with several spinal disorders causing back pain, such as degenerative disc disease (DDD)[7], facet joint osteoarthritis[4,8], degenerative spondylolisthesis (DS)[9-11], isthmic spondylolisthesis[12], and spondylolysis[12-14] has been reported. However, some literatures show no significance of facet angle and disc degeneration[7,15]. Therefore, the association of facet joint angle and degenerative changes remain unclear. Facet joint angle measurement is one of many methods to study the pathoanatomy of degenerative lumbar spine disorders. Understanding pathoanatomy of spinal degenerative disorder is important for clinical perspective.

The objective of the present study was to evaluate lumbar facet joint angle, orientation, and tropism in degenerative disc disease and spondylolisthesis at lumbar spine level L4-5 in Thai patient using a reproducible measurement technique. This study hypothesized that the more tropism and vertical angle of facet joint would predisposed patients to degenerative changes.

Material and Method

The present study was an observational clinical research in a category of retrospective study. Populations involved in this study were back pain patients, older than 18 years old. Sample size required

Correspondence to:
Chotiyarnwong P, Department of Orthopaedic Surgery, Siriraj Hospital, Mahidol University, 2 Wang Lang Road, Bangkok 10700, Thailand.
Phone: +66-2-4197529, Fax: +66-2-4128172
E-mail: pojchong.cho@mahidol.ac.th

in this study was calculated from previous studies about facet joint orientation in degenerative disc disease, and spondylolisthesis[4,7]. Using computer software “nQuery Advisor®” (Statistical Solutions Ltd.), with alpha level at 0.05 and beta level at 0.2, we calculated that 60 subjects for each should be enough for this study.

Patients were sampled in this study recruited from hospital database. Base on diagnosis in discharge summary, hospital number (HN) of patients who were diagnosed lumbar spinal disorders at L4-5 level (i.e., M511 - Lumbar and other intervertebral disc disorders with radiculopathy, M4316 - Spondylolisthesis lumbar region, M46_6 - Other inflammatory spondylopathies lumbar region, S220 - Fracture of thoracic vertebra, S221 - Multiple fractures of thoracic spine, S320 - Fracture of lumbar vertebra, and C795 - Secondary malignant neoplasm of bone and bone marrow; diagnosis code were shown in ICD-10 system - International Classification of Diseases: WHO), were retrieved from hospital database. Then radiological study was checked with SiPACS® software (Sikraftsolutions Ltd.) whether the patient MRI study was performed in Siriraj Hospital. The diagnosis and level of pathology were confirmed by radiological reports.

Inclusion criteria were firstly, patient had back pain problem treated by spinal operation in Siriraj Hospital. Secondly, patient had MRI performed in Siriraj Hospital. Exclusion criteria were poor quality of MRI imaging or additional pathology apart from degenerative changes reported by a radiologist. Since our study design was retrospective, we did not have lumbar MRI of disease-free subject for control group in our study. Therefore, our control group was defined as a patient who had back pain problem without radiographic pathology of lumbar spine at L3-S1 level from both author reviewed and in radiologist MRI report (except for non-significant degenerative changes that correlate with patient’s age), e.g., fracture or metastatic tumor patients, which pathology was not below the intervertebral disc of L1-L2 level. The studied groups were patient who found degenerative disc and spondylolisthesis at L4-5 level in operative findings.

In term of diagnosis, spondylolisthesis was diagnosed from plain X-ray film in sagittal plane (lateral view) of lumbar spine[16,17] and intra-operatively found a mal-alignment of spinous process or posterior ligamentous complex of lumbar spine. Degenerative disc disease was diagnosed from MRI and the visualization of intervertebral disc bulging in spinal canal intra-operatively[18].

After all data required in the study were complete (patient hospital number, MRI was performed in Siriraj Hospital and diagnosis was confirmed), hospital number were pooled with all other groups to reduce bias by the observer. Parameters were measured from MRI composed of both facet joint angle of L3-4, L4-5, and L5-S1 spine. Each parameter were measured from two observers (Chotiyarnwong P and Chotiyarnwong C), each observer measured twice for each subject in a period of more than one month.

Facet joint angle

Facet joint angle was measured from the angle between mid-sagittal plane and facet joint angle. As shown in Fig. 1, after selection of axial view of MRI that easily sees the facet joint, four lines were drawn. First line was a line that parallels the posterior border of the vertebral body. Second line was a line from tip of spinous process perpendicular to the first line. Third and fourth lines were lines drawn from mid-point of most anterior and posterior facet joint line of right and left facet joint on each level. Angle between the second line and third or fourth line were facet joint angle of right and left side. Facet joint tropism was an absolute number of the difference between right and left facet angle at the same level[4].

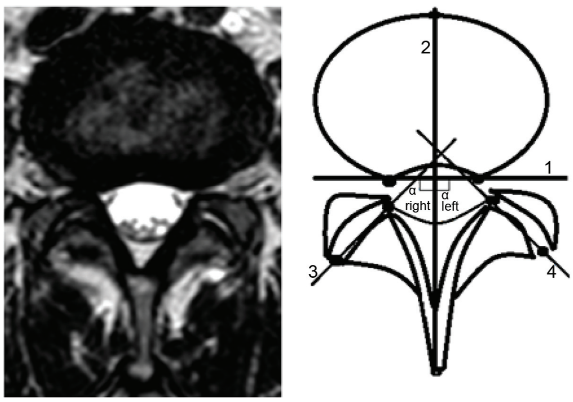

Fig. 1 Facet joint angle measurement: Four lines were drawn in each level of facet joint, first line parallel to posterior aspect of vertebral body, second line perpendicular to first line and pass through tip of spinous process. Third and fourth lines pass through the mid-point of most anterior and posterior facet joint line. Right and left facet joint angles were the angle between second and third or fourth line respectively. Adapt from Kalichman et al[4].

Statistical analysis

Demographic data were analyzed in descriptive statistic. Mean and standard deviation were used in normal distribution variables. For analytical statistic, Chi-square was used for analyzed for sex and type of work parameter. Type of work composed of light work, which include housework, government officer, and monk while heavy work include merchants, agriculturist, and employees. One-way ANOVA were used to compare mean of age, body mass index (BMI = weight in kilogram divided by square of height in meters), and duration of back pain prior to first visit, facet joint angle and orientation in each group. For the difference that were detected between control and experimental groups Dunnett t (2-sided) method were used. Intra- and interobserver reliability were tested by intraclass correlation coefficient (ICC). All statistical analysis was performed using commercially available software (SPSS version 18, SPSS, Inc.).

Results

After data collection was completed, inter- and, intraobserver reliability test were performed. Results showed that high reliability in the present study. Range of ICC for intraobserver in this study was 0.861 to 0.927 and for interobserver was 0.814 to 0.853.

The average age for DDD group was 60.3±10.8, DS group was 63.4±8.3, and control group was 60.9±9.4, which was not statistically different (p = 0.188) (Table 1). BMI in all group found no difference (DDD = 24.38 kg/m^2, DS = 25.57 kg/m^2, and control group = 24.15 kg/m^2, p = 0.194). Type of work of patients in three group also found no difference (Chi^2 p = 0.121). However, back pain duration was found longer in DS group (37.9 months) compared with DDD group (15.7 months) and control group (10.2 months) (p<0.001) (Table 1).

Facet joint angles (Table 2) of control group at L3-L4, L4-L5, and L5-S1 level were 36.58±9.00, 45.57±8.90, and 49.24±8.94, for DDD group were 37.35±10.05, 44.13±11.88, and 47.43±11.81, and for DS group facet angles were 34.33±9.14, 40.17±10.74, and 48.97±11.15 degree, respectively. Interestingly, at facet joint angle level L4-L5, they showed some degrees of difference (p = 0.015). Subgroup analysis was performed.

Table 1. Demographic data of study population

	Degenerative disc disease	Degenerative spondylolisthesis	Control	p-value
Number of patients	60	60	60	
Age (years) (mean ± SD)	60.3±10.8	63.4±8.3	60.9±9.9	0.188
Sex (M/F)	27/33	12/48	26/34	0.006
BMI (kg/m^2) (mean ± SD)	24.38±3.55	25.57±4.49	24.15±4.59	0.194
Duration of back pain (months) (mean ± SD)	15.7±24.9	37.9±45.8	10.2±21.1	<0.001
Type of work (n (%))				0.121
Light work	48 (80)	41 (68.3)	38 (63.3)	
Hard work	12 (20)	19 (31.7)	22 (36.7)	

M/F = male/female; BMI = body mass index

Table 2. Facet joint angle (degree) in each group in each level (mean ± SD)

Level	Side	Degenerative disc disease	Degenerative spondylolisthesis	Control	p-value
L3-L4	Right	34.75±10.31	32.17±9.48	34.38±9.94	0.306
L3-L4	Left	39.95±10.83	36.48±9.89	38.77±9.27	0.159
L3-L4	Both	37.35±10.05	34.33±9.14	36.58±9.00	0.191
L4-L5	Right	42.05±12.14	38.17±11.11	44.48±9.56	0.007
L4-L5	Left	46.22±13.11	42.07±12.00	46.65±9.57	0.060
L4-L5	Both	44.13±11.88	40.17±10.74	45.57±8.90	0.015
L5-S1	Right	46.92±11.70	47.77±10.93	48.93±10.50	0.605
L5-S1	Left	47.95±13.32	50.17±12.42	49.55±9.41	0.572
L5-S1	Both	47.43±11.81	48.97±11.15	49.24±8.94	0.609

From the present study, after multiple comparison study between DDD, DS, and control group at L4-5 level were performed (Table 3), we found significant difference of facet joint angle between control group and DS group (mean difference at -5.14 degree 95% CI -9.76 to -1.14), but no difference between control group and DDD group (p = 0.678).

After facet joint angle study, we analyzed facet joint tropism (Table 4). By the same method of analysis of facet joint angle, we found that at L4-L5 level, facet joint tropism differed between each group (p = 0.010). The average facet joint tropism at L3-L4, L4-L5, and L5-S1 level for control group were 6.85±4.15, 4.93±4.67, and 6.92±5.44, for DDD group were 6.73±4.95, 7.83±5.41, and 6.57±5.28, and for DS group were 6.02±4.89, 7.17±6.02, and 6.03±4.32 degree, respectively.

Multiple comparison study between DDD, DS, and control group in facet joint tropism at L4-5 level were performed (Table 5). We found statistical significant difference of facet joint tropism between control group and DDD group (p = 0.007) with mean difference of 2.90 degree (95% CI 0.7 to 5.1). Control group and spondylolisthesis group were also statistically significant different (p = 0.046) (mean difference at 2.33 degree 95% CI 0.4-4.3).

Discussion

In the present study, we could not detect a difference in age, BMI, and type of work in all group. However, for sex distribution, a significant difference between spondylolisthesis was found. This is similar to the literature. In degenerative lumbar spondylolisthesis, Jacobson et al epidemiological survey 4,151 participants of the Copenhagen Osteoarthritis Study, and found it more common in female[19]. For duration of pain, a statistically significant difference was also observed in DS group, comparing DDD (p = 0.005) and control (p<0.001) groups. Radcliff et al reported that a retrospective subgroup analysis in 2011 showed that there was no difference in the outcome of patients with DS according to symptom duration less or more than 12 months[20]. This probably was the reason why spondylolisthesis patients received conservative treatment for longer time than others condition of back pain.

During the measurement of facet joint angle, some patient had a difficulty in the judgment of reference point for the measurement such as in patient

Table 3. Subgroup analysis of L4-L5 level facet joint angle comparing between control, degenerative disc disease (DDD) and degenerative spondylolisthesis (DS) groups

L4-L5 level	Mean difference	Standard error	p-value	95% CI
Right side				
Degenerative disc disease	-2.43	2.00	0.373	-6.91 to 2.04
Degenerative spondylolisthesis	-6.32	2.00	0.004	-10.79 to -1.84
Left side				
Degenerative disc disease	-0.43	2.12	0.970	-5.16 to 4.29
Degenerative spondylolisthesis	-4.58	2.12	0.059	-9.31 to 0.14
Both side				
Degenerative disc disease	-1.43	1.93	0.678	-5.74 to 2.87
Degenerative spondylolisthesis	-5.14	1.93	0.010	-9.76 to -1.14

Table 4. Facet joint tropism in each group in each level (mean ± SD)

Level	Degenerative disc disease	Degenarative spondylolisthesis	Control	p-value
L3-L4	6.73±4.95	6.02±4.89	6.85±4.15	0.573
L4-L5	7.83±5.41	7.17±6.02	4.93±4.67	0.010
L5-S1	6.57±5.28	6.03±4.32	6.92±5.44	0.627

Table 5. Subgroup analysis of L4-L5 level facet joint tropism comparing between control, DDD and DS groups

L4-L5 level	Mean difference	Standard error	p-value	95% CI
Degenerative disc disease	2.90	0.99	0.007	0.7 to 5.1
Degenerative spondylolisthesis	2.33	0.99	0.046	0.4 to 4.3

with facet joint that had large osteophyte or widening of facet joint space. However, our method for facet joint angle measurement was not so difficult. As we could easily see the facet joint in the MRI, marking of the point to draw a line for facet joint angle as described in material and method part from same or different observer could reproduce the result of measurement. The reliability test range was more than 0.8 in all measurement of intra- and interobserver reliability test. This is comparing to Kalichman et al where intraobserver reliability varied between 0.64 and 1.00 and interobserver reliability ranged from 0.59 to 0.98[4].

Like the previous study[1,4,9,13,21], facet joint angle in the present study increased caudally. Oblique orientation of lumbar facet joints function in stabilized the motion in flexion and extension position of lumbar spine[1]. For these reasons, patient with spondylolisthesis who has less facet joint angle at the affected level have less resistance to force that pass through facet joint than the control group. This leads the ligament function on the affected level to increase. When degeneration process continues, ligament elasticity decreases, then anterior slipping of vertebra occurs. The statistical significant difference between control group and DS group was also observed in the present study, similar to the previous study[4,9-11,22]. However, for the DDD group, no significant difference between facet joint angle comparing to control group, which differed from Boden et al[7] and Noren et al[15] studies.

The present study demonstrated that facet joint tropism at L4-L5 level of DDD and DS was statistically different compared with control group. Previous study has reported lumbar facet asymmetry in lumbar intervertebral disc herniation[23,24] and spondylolisthesis[10], except the study from Kalichman et al that found no statistically significant[4].

Despite the statistically significant difference observed in the present study, degree of difference is probably not clinically significant as suggested from previous study[24]. However, this probably increased the risk of symptomatic spinal pathology in both disc degeneration and spondylolisthesis. These might help predict further progression of severity if facet angle is much less than normal population. Several studies[11,25] suggest that facet joint angle in spondylolisthesis represents a secondary remodeling rather than a pre-existing morphology.

The strengths of our study included the use of a large control samples. Our measurement technique had two independent measurements of each facet angle, which shown highly reproducible. The measurement values were consistent with values available from several previous studies[4,7,13]. Our study also provided normative data for additional study of the orientation of the lumbar facet joint and facet tropism.

The limitation of our study was that it was a retrospective study. The control group was not subjects who have no pathology. We used control group from patients with some spinal pathology but no obvious pathology shown in MRI at measured level (L3-S1), except for reasonable degenerative changes. Second, the clinical data such as pain characteristic, pain severity, and duration could not be completely collected since the medical records were incomplete. Therefore, a clinical significance could not be evaluated in this study.

In conclusion, the present study confirmed that facet joint angle in our study was increased caudally with significant association between sagittal orientation of the lumbar facet joints and spondylolisthesis. Facet tropism was not associated with the occurrence of DDD or DS. The results suggested that morphological abnormality of the lumbar facet joint was a predisposing factor in the development of DS. Additional, studies are needed to understand the causal relationship between facet joint morphology and spondylolisthesis.

What is already known on this topic?

The more sagittal orientation of facet joint angle could be associated with DS but not associated with DDD. The facet joint angle is increase caudally.

What this study adds?

The technique for facet joint angle measurement is not difficult and is reproducible.

The normal values of facet joint angle and tropism at L3-S1 level in Thai adult population, from the average of 60 subjects.

The more difference of facet joint angle (tropism) could lead to the pathology of spine from degenerative change either DDD or DS.

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Potential of conflicts of interest

None.

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การศึกษาความสัมพันธ์ของมุมและการเบนของข้อฟาเซ็ตที่กระดูกสันหลังระดับเอวในโรคหมอนรองกระดูกเสื่อมกดทับเส้นประสาทและโรคกระดูกสันหลังเสื่อมเคลื่อนทับเส้นประสาท

วิทเชษฐ พิชัยศักดิ์, ชยาภรณ์ โชติญาณวงษ์, โพชฌงค์ โชติญาณวงษ์

ภูมิหลัง: *สาเหตุสองประการของอาการปวดหลังที่พบได้บ่อยคือ โรคหมอนรองกระดูกเสื่อมกดทับเส้นประสาท (degenerative disc disease, DDD) และโรคกระดูกสันหลังเสื่อมเคลื่อนทับเส้นประสาท (degenerative spondylolisthesis , DS) แต่ความสัมพันธ์ระหว่างมุมและการเบนของข้อฟาเซ็ตที่กระดูกสันหลังกับอาการปวดหลังจากโรคดังกล่าวยังไม่แน่ชัด*

วัตถุประสงค์: *เพื่อทราบถึงความสัมพันธ์ระหว่างมุมและการเบนของข้อฟาเซ็ตที่กระดูกสันหลังระดับเอวกับความผิดปกติของกระดูกสันหลังบริเวณเอว*

วัสดุและวิธีการ: *ทำการวัดมุม (angle) และการเบน (tropism) ของข้อฟาเซ็ตของกระดูกสันหลังโดยวัดจากภาพเอ็มอาร์ไอในผู้ป่วย DDD, DS, และกลุ่มควบคุมที่กระดูกสันหลังระดับ L3 ถึง S1 (60 ราย ต่อกลุ่ม)*

ผลการศึกษา: *ที่ระดับ L4-5 มุมข้อฟาเซ็ตมีความแตกต่างในโรคกระดูกสันหลังเสื่อมเคลื่อนทับเส้นประสาทกับกลุ่มควบคุม ($p = 0.010$) สำหรับการเบนพบว่าทั้งสองกลุ่มมีความแตกต่างกับกลุ่มควบคุม ($p = 0.007$ ใน DDD และ $p = 0.046$ ใน DS)*

สรุป: *การศึกษานี้ได้แสดงความแตกต่างอย่างมีนัยสำคัญทางสถิติระหว่างมุมข้อฟาเซ็ตและการเบนที่ระดับ L4—L5 ใน DDD และ DS กับประชากรปกติ*