International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2025: 7.089

Association of Facet Joint Orientation and Tropism with Lumbar Disc Herniation and Degenerative Spondylolisthesis: A Prospective Study

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Abstract: ***Background**: Facet joint orientation and facet tropism are important anatomical factors influencing lumbar spine biomechanics. Their role in lumbar disc herniation (LDH) and degenerative spondylolisthesis (DS) remains controversial despite several biomechanical and radiological studies. **Objective**: To evaluate the association of facet joint orientation and facet tropism with lumbar disc herniation and degenerative spondylolisthesis and to assess their predictive value for lumbar instability and surgical decision-making. **Methods**: A prospective observational case-control study was conducted involving 50 patients with degenerative lumbar spine pathology and 50 age- and sex-matched controls at a tertiary care center. Facet joint orientation and tropism were measured using axial CT/MRI at L3–L4, L4–L5, and L5–S1 levels. Facet orientation was calculated as the mean of right and left facet angles, while facet tropism was defined as the absolute difference between both sides. Tropism ≥8° was considered significant. Statistical analysis included chi-square test, Fisher's exact test, odds ratio (OR), logistic regression, and ROC curve analysis. Significance was set at $p < 0.05$. **Results**: Sagittal facet orientation was observed in 47 patients (94%) and showed a strong association with degenerative lumbar spine pathology (OR = 15.67, $p < 0.0001$). Facet tropism ≥8° was present in 18 patients (36%) but did not show a statistically significant association with disease (OR = 0.56, $p = 0.19$). ROC analysis demonstrated good predictive ability for facet orientation (AUC ≈ 0.72–0.82), whereas facet tropism showed poor predictive value (AUC ≈ 0.43–0.56). **Conclusion**: Sagittal facet orientation is a significant anatomical predictor of degenerative lumbar spine pathology, particularly degenerative spondylolisthesis, whereas facet tropism alone is not a reliable independent predictor. Assessment of facet morphology may improve preoperative planning and surgical outcomes.*

Keywords: Facet joint orientation, Facet tropism, Lumbar disc herniation, Degenerative spondylolisthesis, Lumbar instability, Spinal biomechanics

1. Introduction

Low back pain is one of the most common musculoskeletal complaints worldwide and is a major cause of disability and socioeconomic burden [11,22]. Lumbar disc herniation (LDH) and degenerative spondylolisthesis (DS) are among the most frequent causes of chronic low back pain and radiculopathy [1,3].

Facet joints, also known as zygapophyseal joints, are paired synovial joints located posteriorly in the vertebral column. They play an essential role in spinal stability by guiding movement, resisting shear forces, and distributing axial loads [13,14]. The orientation of facet joints varies among individuals and lumbar levels, influencing lumbar biomechanics [2,6].

Facet joint orientation refers to the angular relationship of the facet joint relative to the sagittal plane. More sagittally oriented facets reduce resistance to anterior vertebral translation and may predispose to degenerative spondylolisthesis [2,4]. In contrast, coronal orientation provides greater resistance to shear forces and may protect against vertebral slippage.

Facet tropism refers to asymmetry between right and left facet joint angles at the same spinal level. This asymmetry may cause uneven load transmission, altered segmental motion, and accelerated disc degeneration [7,8,12]. Several studies have suggested an association between facet tropism and lumbar disc herniation; however, results remain inconsistent [9,10,18]

Understanding the role of facet orientation and tropism is important in predicting spinal instability and planning surgical treatment. This study aimed to evaluate the association between facet joint orientation, facet tropism, LDH, and DS and to assess their clinical relevance in degenerative lumbar spine pathology.

2. Materials and Methods

Study Design

A prospective observational case-control study was conducted at a tertiary care center involving patients with symptomatic degenerative lumbar spine pathology.

Control Group

A control group consisting of 50 age- and sex-matched individuals without significant degenerative lumbar spine pathology was included for comparative analysis. Controls were selected from patients undergoing MRI evaluation for non-specific low back pain or minor spinal complaints without radiological evidence of lumbar disc herniation, degenerative spondylolisthesis, spinal instability, or major degenerative lumbar disease.

Control subjects underwent the same radiological assessment protocol as study cases. Facet joint orientation and facet tropism were measured at L3–L4, L4–L5, and L5–S1 levels using identical imaging and measurement techniques.

The control group was included to evaluate differences in facet joint morphology between degenerative lumbar spine pathology and non-degenerative lumbar conditions.

Study Population
Fifty patients aged between 20 and 70 years with radiologically confirmed LDH or DS were included.

Inclusion Criteria
- Adults aged 20–70 years
- Radiologically confirmed LDH or DS
- Availability of MRI and CT imaging of the lumbar spine

Exclusion Criteria
- Previous lumbar spine surgery
- Congenital spinal deformities
- Traumatic spinal injuries
- Infective spinal pathology
- Neoplastic spinal pathology

Ethical Approval
The study was approved by the Institutional Ethics Committee, and informed consent was obtained from all participants.

Imaging and Measurement
Facet joint angles were measured on axial CT/MRI images using standard radiological methods described in previous studies [7, 29].

The midsagittal line was drawn through the center of the vertebral body and the base of the spinous process. The facet line was drawn between the two peaks of the superior articular facet. The angle between the midsagittal line and facet line was measured separately for both sides.
- Right facet angle = αR
- Left facet angle = αL
- Facet orientation = $(\alpha R + \alpha L)/2$
- Facet tropism = $|\alpha R - \alpha L|$

Facet tropism ≥8° was considered significant. Measurements were performed at L3–L4, L4–L5, and L5–S1 levels.

Statistical Analysis
Comparative analysis between cases and controls was performed to evaluate the association of facet joint morphology with degenerative lumbar spine pathology. Data were analyzed using chi-square test, Fisher's exact test, logistic regression, and odds ratio analysis with significance set at $p < 0.05$. ROC analysis was performed to evaluate the predictive performance of facet orientation and tropism for degenerative lumbar spine pathology.

3. Results

A total of 50 patients with degenerative lumbar spine pathology were included. The mean age was 48.62 ± 9.85 years, with most patients belonging to the 51–60 years age group (36%).

The control group consisted of 50 age- and sex-matched individuals without significant degenerative lumbar spine pathology. Comparative analysis demonstrated a significantly higher prevalence of sagittal facet orientation among cases compared with controls.

Degenerative spondylolisthesis was slightly more common at the L4–L5 level (52%) compared to L5–S1 (48%).

Facet tropism ≥8° was present in 18 patients (36%), while 32 patients (64%) did not show significant asymmetry. At L4–L5, tropism was observed in 34.6% of patients, and at L5–S1 in 37.5%.

Fisher's exact test demonstrated no statistically significant association between facet tropism and degenerative lumbar pathology ($p = 0.19$). The odds ratio was 0.56, suggesting that facet tropism alone was not associated with increased disease risk.

Sagittal facet orientation was observed in 47 patients (94%), whereas only 3 patients (6%) showed non-sagittal orientation. This distribution was highly significant ($p < 0.001$).

Fisher's exact test revealed a highly significant association between sagittal facet orientation and degenerative lumbar pathology ($p < 0.0001$). Patients with sagittally aligned facet joints were approximately 15 times more likely to develop LDH or DS compared with those with non-sagittal orientation (OR = 15.67).

The mean facet orientation angle was 35.4 ± 5.9°, and the mean facet tropism angle was 5.8 ± 3.4°.

ROC analysis for facet tropism demonstrated poor discriminatory ability with an AUC of approximately 0.43–0.56, indicating limited predictive value.

Facet orientation showed better predictive ability with an estimated AUC of 0.72–0.82, indicating moderate to good diagnostic performance for degenerative lumbar pathology.

Tables

Table 1: Demographic Distribution of Patients

Age Group (Years)	Number of Patients	Percentage (%)
31–40	12	24
41–50	15	30
51–60	18	36
61–70	5	10
Total	50	100

Mean age = 48.62 ± 9.85 years

Table 2: Level-wise Distribution of Degenerative Spondylolisthesis

Level	Number of Patients	Percentage (%)
L4–L5	26	52
L5–S1	24	48
Total	50	100

Table 3: Distribution of Facet Tropism

Facet Tropism	Number of Patients	Percentage (%)
Present (≥8°)	18	36
Absent (<8°)	32	64
Total	50	100

Table 4: Distribution of Sagittal Facet Alignment

Facet Orientation	Number of Patients	Percentage (%)
Sagittal Aligned	47	94
Non-Sagittal	3	6
Total	50	100

$p < 0.001$

Table 5: Association Between Facet Orientation and Disease

Facet Orientation	Cases	Controls	Total
Sagittal Aligned	47	25	72
Non-Sagittal	3	25	28
Total	50	50	100

Odds Ratio = 15.67
Values are expressed as number of patients.
OR = odds ratio.

Table 6: Mean Facet Angle Measurements

Parameter	Mean ± SD
Alpha Angle	35.7 ± 7.1°
Beta Angle	35.1 ± 6.8°
Facet Orientation	35.4 ± 5.9°
Facet Tropism	5.8 ± 3.4°

4. Discussion

Facet joint orientation and tropism are important determinants of lumbar spine biomechanics and play a significant role in degenerative lumbar spine pathology. The present study demonstrated a strong association between sagittal facet orientation and degenerative lumbar disorders, particularly degenerative spondylolisthesis, whereas facet tropism did not show a statistically significant independent association.

Sagittal facet orientation reduces resistance to anterior shear forces and facilitates forward vertebral translation, predisposing patients to degenerative spondylolisthesis [2,4,19]. In our study, 94% of patients demonstrated sagittal facet alignment, and the odds ratio of 15.67 indicated that patients with sagittally aligned facets were approximately fifteen times more likely to develop degenerative lumbar pathology. These findings are consistent with studies by Grobler et al. [2], Nagaosa et al. [4], and Berlemann et al. [19], all of whom reported a significant relationship between sagittal facet orientation and vertebral instability.

Conversely, coronal facet orientation provides greater resistance to shear forces and offers relative protection against anterior vertebral slippage. This supports the concept that facet morphology is not merely an anatomical variation but a biomechanical risk factor influencing disease progression.

Facet tropism has been proposed to cause asymmetric loading across lumbar motion segments, leading to accelerated disc degeneration and lumbar disc herniation [7,8,16]. Although facet tropism ≥8° was observed in 36% of our patients, no statistically significant association with degenerative lumbar pathology was identified ($p = 0.19$). Similar findings were reported by Vanharanta et al. [9] and Cassidy et al. [10], who found no consistent relationship between facet asymmetry and disc herniation. However, Ishihara et al. [8] and Karacan et al. [7] reported increased lumbar disc herniation in patients with significant facet tropism. These conflicting findings may be explained by differences in study populations, imaging techniques, measurement criteria, and varying thresholds used to define tropism.

The stabilizing system of the spine described by Panjabi emphasizes the importance of posterior spinal elements, including facet joints, in maintaining spinal stability [14,15]. Alterations in facet orientation can disrupt this balance, resulting in abnormal load transfer, progressive degeneration, and spinal instability.

ROC analysis further supported the clinical value of facet orientation as a predictive factor, with good discriminatory ability (AUC ≈ 0.72–0.82), whereas facet tropism demonstrated poor predictive performance (AUC ≈ 0.43–0.56). This suggests that facet orientation should receive greater emphasis during preoperative radiological evaluation and surgical planning.

Patients with pronounced sagittal orientation may require closer evaluation for instability and may benefit from stabilization procedures, particularly in recurrent disc disease and degenerative spondylolisthesis.

5. Limitations

This study has several limitations. The sample size was relatively small and conducted at a single tertiary care center, which may limit generalizability. Long-term follow-up was not available to assess recurrence and long-term outcomes. Measurement bias may exist despite standardized radiological techniques. Future multicenter studies with larger populations and long-term follow-up are required for stronger validation.

6. Conclusion

Sagittal facet orientation is a significant anatomical and biomechanical predictor of degenerative lumbar spine pathology, particularly degenerative spondylolisthesis. Patients with sagittally aligned facets demonstrate a significantly higher risk of lumbar instability and degenerative disease.

Facet tropism, although present in a subset of patients, does not independently predict disease occurrence in the present study. Routine assessment of facet morphology on preoperative imaging may improve diagnosis, surgical planning, and selection of patients requiring stabilization procedures.

Figures

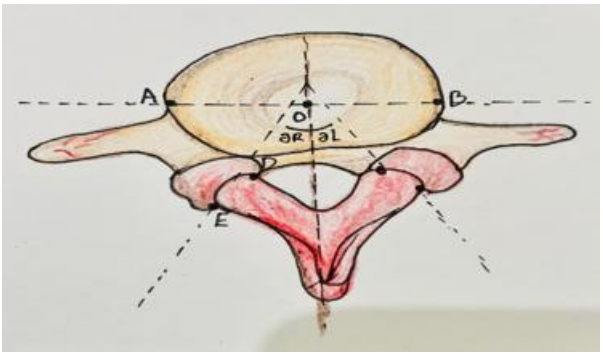

Figure 1: Measurement of Facet Joint Orientation and Facet Tropism

Figure Legend:
Axial imaging demonstrating measurement of facet joint orientation and facet tropism, including midsagittal reference line and bilateral facet angles.

Axial vertebral diagram demonstrating midsagittal reference line, right facet angle (αR), left facet angle (αL), and facet joint line used for measurement of facet orientation and facet tropism.

Formula used:
Facet Orientation = (αR + αL)/2
Facet Tropism = |αR − αL|

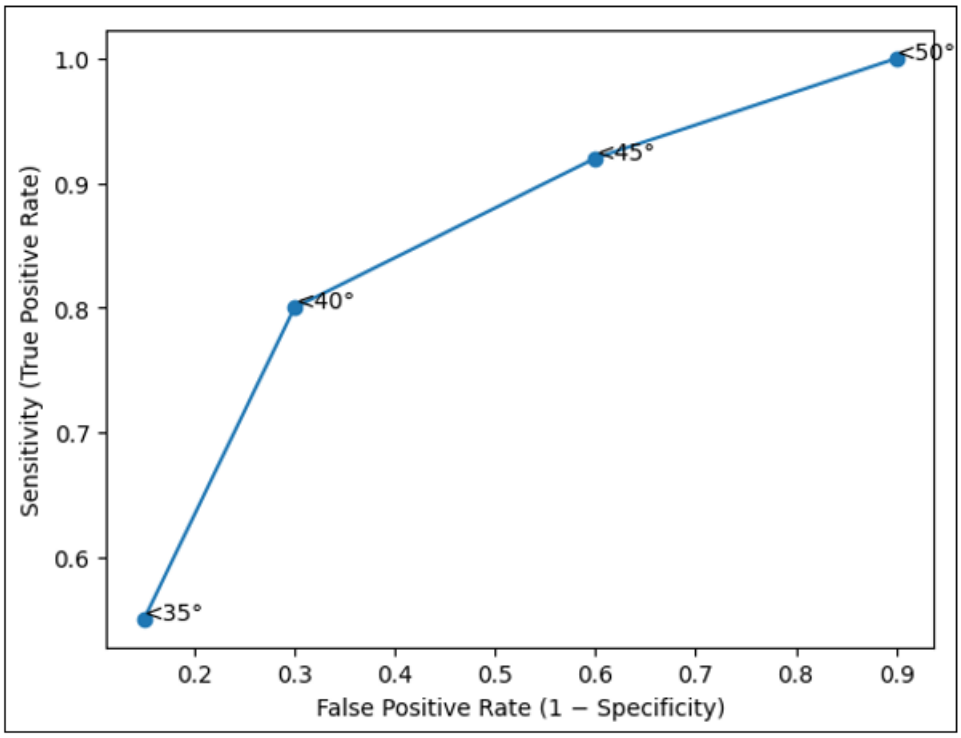

Figure 2: ROC Curve for Facet Orientation

Figure Legend:
Receiver operating characteristic (ROC) curve demonstrating predictive ability of facet orientation for degenerative lumbar pathology (AUC 0.72–0.82).

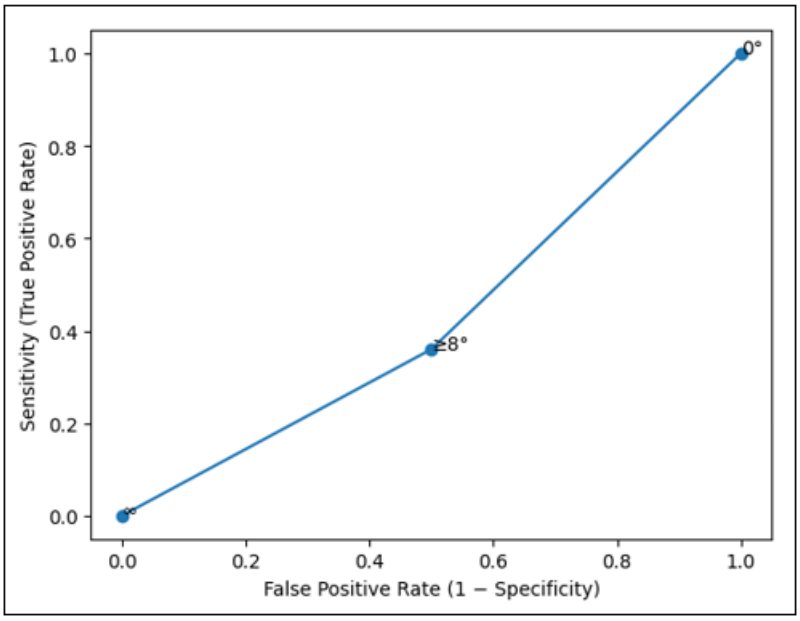

Figure 3: ROC Curve for Facet Tropism

Figure Legend:
ROC curve demonstrating poor predictive performance of facet tropism (AUC 0.43–0.56).

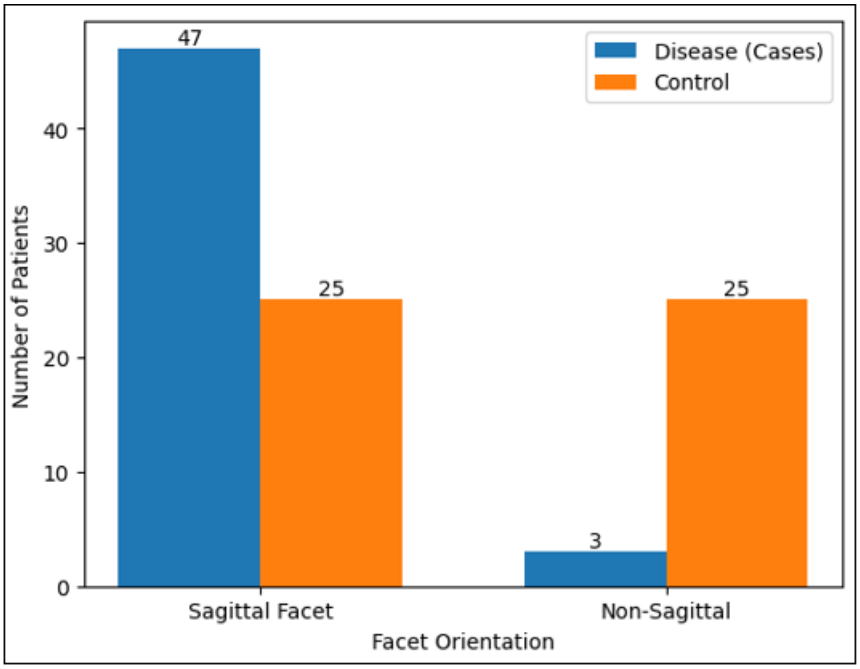

Figure 4: Comparison of Facet Orientation Between Cases and Controls

Figure Legend:
Comparison of sagittal and non-sagittal facet orientation between cases and controls, showing higher prevalence of sagittal alignment among cases.

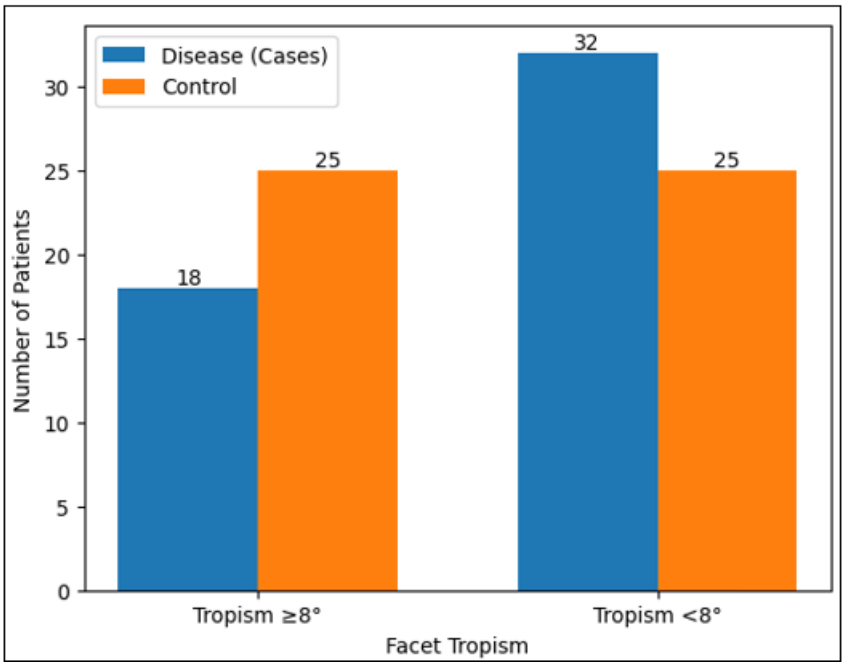

Figure 5: Comparison of Facet Tropism Between Cases and Controls

Figure Legend:
Comparison of presence and absence of facet tropism between cases and controls.

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