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FACET JOINT MORPHOLOGY IN THE THORACOLUMBAR REGION: AN ANATOMICAL GUIDE FOR UPPER INSTRUMENTED VERTEBRA SELECTION

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ABSTRACT

Objective: This study aimed to systematically evaluate facet joint orientation between T8 and L1 vertebral levels in healthy individuals and to investigate whether these morphological data could guide proximal instrumented level selection in spinal fusion surgery.

Materials and Methods: This retrospective study included 240 healthy individuals who had previously undergone thoracic computed tomography imaging without evidence of spinal pathology. Bilateral facet joint angles were manually measured in the sagittal plane using the picture archiving and communication system system at vertebral levels between T8 and L1. The average of the right and left facet angles was used for each level. Facet tropism was defined as a right-left angle difference of ≥5°.

Results: Significant differences in facet angles were observed across vertebral levels (F=6.20, p<0.001). Facet angles progressively decreased from T8-T9 to T12-L1. Post-hoc analysis revealed a statistically significant difference only between T8-T9 and T10-T11 (p=0.025). Facet tropism was most frequently observed at T10-T11 (21 individuals, 8.8%), with a statistically significant distribution across levels (p=0.023). No significant sex-related differences were found. Measurement reliability was high (intraclass correlation coefficient=0.90).

Conclusion: Significant morphological differences exist in facet joint orientation between T8 and L1 levels. The T8-T9 vertebra, with its more sagittally oriented and symmetrical facet morphology, may represent a biomechanically favorable choice as the upper instrumented vertebra (UIV) in long-segment posterior spinal fusion surgery. The relatively high incidence of tropism at T10-T11 suggests that this level should be carefully considered when selecting the UIV.

Keywords: Facet joint orientation, thoracolumbar junction, facet tropism

INTRODUCTION

Facet joints are fundamental anatomical structures that play a crucial role in spinal load-bearing and contribute to the control of motion in all three planes[1]. Each vertebra forms zygapophyseal joints with the adjacent superior and inferior vertebrae, providing segmental mobility and stability[2]. These joints are particularly important in maintaining biomechanical balance during spinal movements such as rotation, flexion-extension, and lateral bending[3].

Each spinal segment has a unique facet joint orientation, which determines its specific movement characteristics[4]. Variations in facet joint orientation, especially in the thoracolumbar region, are clinically significant as they directly affect intersegmental load distribution and mechanical balance[5].

In long-segment posterior spinal fusion procedures, proper selection of the proximal fusion level is critical to prevent postoperative complications such as proximal junctional kyphosis (PJK), implant loosening, and degeneration of adjacent segments[6-8]. However, there is currently no universally accepted anatomical or biomechanical guideline for determining the optimal level for proximal instrumentation.

To date, no comprehensive study has systematically evaluated facet joint orientation in the thoracolumbar region among healthy individuals in the Turkish population. Moreover, normative data regarding sagittal facet angle values and their variations between the T8 and L1 vertebrae remain limited.

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Therefore, this study aimed to measure sagittal facet joint angles between T9 and L1 vertebrae using computed tomography (CT), and to assess the presence and distribution of facet tropism. The findings are intended to provide anatomical guidance for selecting the optimal proximal fusion level in thoracolumbar junction surgeries.

MATERIALS AND METHODS

This retrospective descriptive study included 240 healthy individuals aged 20 to 40 years who had previously undergone thoracic CT for various indications in the emergency department, with no evidence of spinal pathology. The sample was randomly selected from the hospital's digital archive system. Individuals with musculoskeletal disorders, vertebral fractures, spinal tumors, infections, or a history of spinal surgery were excluded from the study.

Imaging data were obtained from the hospital's picture archiving and communication system. All CT images had a slice thickness of 3 mm and met institutional imaging standards. All measurements were performed in the sagittal plane.

Facet joint angles were measured using a method similar to that described by Masharawi et al.[9] For each vertebra, the midline of the vertebral body was identified on a standardized sagittal slice. A reference line was drawn along the posterior surface of the vertebral body, extending from the superior endplate to the inferior endplate. This line represented the sagittal inclination of the vertebral body. Subsequently, the angle between this reference line and the plane of each facet joint (right and left) was measured. The mean of the right and left facet angles was used for analysis at each vertebral segment. Measurements were repeated for each level between T8-T9 and T12-L1. These measurements were performed on standardized sagittal CT slices (Figure 1). All measurements were performed independently and at different times by two experienced spine surgeons. Intraobserver and interobserver reliability were assessed using the intraclass correlation coefficient (ICC).

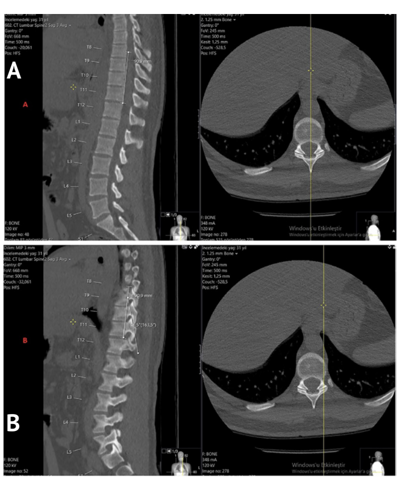

Figure 1. (A) On the sagittal slice of the T11 vertebra, a reference line was drawn from the posterior cortex. This line was fixed by the system and remained constant across all images. (B) The measurement of the facet angle was performed at the facet joint level relative to this fixed reference line

For each vertebral segment, right and left facet joint angles were measured separately, and the mean angle was used for analysis. The presence of facet tropism was also evaluated based on the absolute difference between right and left facet angles. Tropism was defined as a difference of ≥5° between the two sides[10]. This study was approved by the Scientific Research Ethics Committee of Health Sciences University, Erzurum Faculty of Medicine (decision number: 2025/02-28, date: 12.02.2025).

Statistical Analysis

All statistical analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). The normality of data distribution was assessed using the Shapiro-Wilk test. Normally distributed variables were presented as mean ± standard deviation, while non-normally distributed data were reported as median (minimum-maximum).

Comparisons of facet joint angles across vertebral levels were performed using repeated measures analysis of variance, followed by Tukey post-hoc test when significant differences were detected. For non-normally distributed data, the Friedman test was used. Sex-based differences were assessed using the independent samples t-test or Mann-Whitney U test, as appropriate. A p-value <0.05 was considered statistically significant in all analyses.

RESULTS

This study included a total of 240 healthy individuals aged between 20 and 40 years. The mean age of participants was 33.2±2.6 years, with 137 males (57.1%) and 103 females (42.9%).

Facet Joint Orientation

For each participant, right and left facet joint angles were measured separately at the vertebral levels between T8 and L1. The average of the right and left measurements was used for each segment in the final analysis. The measurement results are summarized below in Table 1. A statistically significant difference was found between vertebral levels (F=6.20, p<0.001) (Figure 2 and Table 2). In the post-hoc analysis, a statistically significant difference was observed only between the T8-T9 and T10-T11 levels (p=0.025). No significant differences were

Table 1. Facet joint angles measured at each vertebral level from T8 to L1

Vertebral level	Mean angle (°)	Standard deviation (°)
T8-T9	165.32	6.71
T9-T10	164.14	5.83
T10-T11	163.79	8.60
T11-T12	162.91	8.10
T12-L1	161.18	8.70

found between the other vertebral level pairs (p>0.05). The angular trend is illustrated in the figure below and detailed in Table 3.

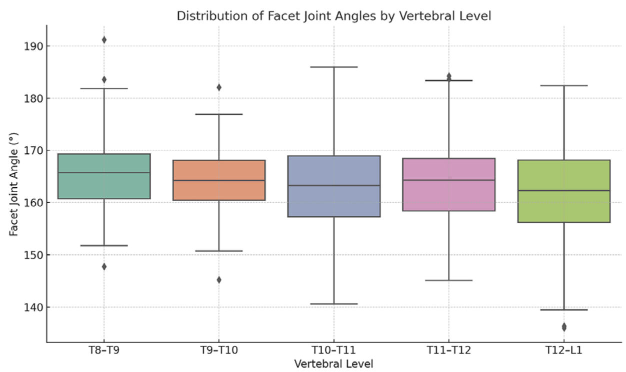

Figure 2. Distribution of sagittal facet joint angles across vertebral levels from T8-T9 to T12-L1

Table 2. Repeated measures results for facet joint angles across vertebral levels

Source of variation	SS	df	MS	F	p-value
Between levels	482.1	4	120.5	6.20	<0.001
Within subjects (error)	9237.6	476	19.4		
Total	9719.7	599			

SS: Sum of squares, df: Degrees of freedom, MS: Mean square

Facet Tropism

Facet tropism was defined as a side-to-side difference of ≥5° between the right and left facet joint angles at the same vertebral level. Tropism frequency differed significantly across vertebral levels (chi-square test, p=0.023), with the highest incidence observed at the T10-T11 level. The distribution of tropism is shown below in Table 4.

Although the tropism rate at the T10-T11 level was statistically significant, the absolute difference was relatively small and should be interpreted with caution in terms of clinical effect size.

Sex-Based Comparison and Measurement Reliability

No statistically significant differences were observed between males and females in facet joint angle measurements across all vertebral levels (p>0.05).

All measurements were independently performed by two experienced spine surgeons. Measurement reliability was assessed using the ICC:

• Intraobserver agreement: ICC=0.90
• Interobserver agreement: ICC=0.90

These values indicate a high level of measurement reliability.

DISCUSSION

The present study highlights the distinct anatomical characteristics of the thoracolumbar facet joints, revealing that the T8-T9 level possesses a more sagittally oriented and symmetrical facet morphology compared to lower levels. This finding suggests that T8-T9 may offer biomechanical advantages as a transition point during long-segment posterior spinal fusion. The presence of sagittal and symmetrical facets at this level may facilitate more stable load distribution and smoother transition between fused and mobile segments of the spine. These features are clinically relevant when determining the optimal level for the upper instrumented vertebra (UIV), as they may contribute to reducing the mechanical stress that can lead to junctional failure, such as PJK. Thus, understanding facet joint orientation patterns could inform more anatomically sound surgical strategies in spinal deformity correction.

The aim of this study was to provide anatomical reference data to guide the selection of the proximal instrumentation level in long-segment posterior spinal fusion. Incorrect selection of the UIV has been associated with a higher risk of PJK. Although sagittal alignment, pelvic parameters, and local kyphosis angles are commonly used in decision-making, the role of facet joint orientation has not been adequately studied[6,7,11]. Facet joints are key anatomical structures in load-bearing and motion control, and their orientation in the sagittal plane may directly affect segmental stability and load transfer[10,12].

Facet tropism, defined as a side-to-side asymmetry in facet joint orientation exceeding 5°, has been associated with altered load distribution and increased shear forces at the affected segment. Although the 5° threshold is widely accepted in the literature[10], its biomechanical relevance lies in its potential to disrupt symmetrical motion patterns and predispose to adjacent segment degeneration or postoperative complications such as PJK[13,14]. In our study, the highest incidence of tropism was observed at the T10-T11 level, which may reflect a transitional zone prone to biomechanical stress. From a surgical perspective, selecting a UIV level with pronounced facet asymmetry could potentially compromise construct stability or accelerate adjacent segment deterioration. Therefore, the presence of facet tropism should be considered during preoperative planning, particularly in long-segment fusions where junctional integrity is critical.

Although prior cadaveric studies by Masharawi et al.[9] and Boden et al.[12] demonstrated variation in facet orientation across vertebral levels[9,12], these investigations were limited by small sample sizes and lacked systematic sagittal plane evaluations in large populations. Our findings confirm the progressive transition from sagittal to more coronally oriented facets toward the lower thoracic spine, consistent with these earlier studies. Additionally, the high incidence of facet tropism at the T10-T11 level may indicate a region of biomechanical vulnerability due to asymmetric load transfer. Importantly, this study provides normative reference data specific to the Turkish population and offers directly applicable anatomical insights for spinal surgical planning.

Table 3. Tukey post-hoc analysis of pairwise comparisons between vertebral levels

Comparison	Mean difference (°)	p-value	95% CI	Statistical significance
T10-T11 vs. T8-T9	+2.06	0.025	(0.17, 3.96)	Significant
T10-T11 vs. T9-T10	+1.10	0.503	(-0.79, 3.00)	Not significant
T10-T11 vs. T11-T12	+0.66	0.875	(-1.23, 2.56)	Not significant
T10-T11 vs. T12-L1	-1.20	0.416	(-3.09, 0.70)	Not significant
T11-T12 vs. T12-L1	-1.86	0.057	(-3.76, 0.03)	Trend toward significance (optional)

CI: Confidence interval

Table 4. Tropism frequency by vertebral level (T8-T9 to T12-L1)

Vertebral level	Tropism present (n)	Tropism frequency (%)	Chi-square (χ^2)	p-value
T8-T9	6	2.5%		
T9-T10	9	3.8%		
T10-T11	21	8.8%		
T11-T12	14	5.8%		
T12-L1	11	4.6%		
Total	-	-	11.31	0.023

Although small angular differences may not appear statistically significant, they can have clinically meaningful consequences, especially in spinal surgical planning. Even deviations of 3-5 degrees in facet joint orientation may lead to asymmetrical load transmission and affect segmental mobility, potentially influencing the mechanical stress at adjacent levels and the risk of junctional pathology[15]. This is particularly relevant when selecting the UIV, as inappropriate alignment can predispose patients to PJK or adjacent segment disease. Masharawi et al.[9] demonstrated that even subtle morphological asymmetries in the thoracic spine can contribute to mechanical imbalances. Therefore, these minor angular differences should not be overlooked and must be integrated into the surgical decision-making process. Our findings highlight the importance of considering such parameters in preoperative planning.

Although this study provides valuable normative data on thoracolumbar facet morphology in healthy adults aged 20-40 years, it does not fully represent the typical surgical population. Long-segment posterior spinal instrumentation is most frequently performed in older adults with degenerative spinal pathologies, whose facet joint anatomy may differ significantly due to age-related structural changes. Therefore, caution is warranted when generalizing these results to elderly surgical cohorts. Nevertheless, posterior instrumentation is also commonly applied in younger patients, particularly in cases of adolescent idiopathic scoliosis. In this context, our findings may still offer partial guidance for selecting upper instrumentation levels in adolescent deformity surgery. Future studies incorporating a broader age range and pathological cases would enhance the generalizability and clinical relevance of these anatomical observations.

The study has several limitations. Measurements were performed manually using retrospective CT images. However, the high ICC value supports the reliability of the findings. Additionally, the analysis was limited to the sagittal plane; this unidimensional approach may overlook complex 3D joint morphology, such as axial rotation or coronal tilt. Future studies incorporating three-dimensional imaging modalities (e.g., 3D CT or magnetic resonance imaging) may yield more comprehensive and clinically applicable anatomical insights.

CONCLUSION

This study systematically evaluated facet joint orientation between T8 and L1 in healthy adults aged 20-40 years. Significant anatomical differences in facet angle were observed across vertebral levels, with angles becoming progressively more horizontal in caudal levels. Facet tropism was significantly more frequent at the T10-T11 level compared to other levels.
These findings suggest that T11 should be carefully evaluated before being selected as the UIV. Furthermore, the study highlights that facet joint morphology, in addition to sagittal alignment and pelvic parameters, may be an important factor when determining the proximal fusion level.
The results offer anatomical and biomechanical guidance for surgical planning in posterior spinal instrumentation. Further studies in diverse populations and clinical cohorts are needed to validate these findings and enhance their generalizability.

Ethics

Ethics Committee Approval: This study was approved by the Scientific Research Ethics Committee of Health Sciences University, Erzurum Faculty of Medicine (decision number: 2025/02-28, date: 12.02.2025).
Informed Consent: Retrospective study.

Footnotes

Authorship Contributions

Surgical and Medical Practices: B.P., M.D., Concept: B.P., Design: B.P., Data Collection or Processing: M.D., Analysis or Interpretation: M.D., Literature Search: B.P., M.D., Writing: B.P.
Conflict of Interest: No conflict of interest was declared by the authors.
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