

Investigation of the Effect of Facet Joint Angle Characteristics on the Development of Lumbar Spinal Stenosis in Patients with Lumbar Canal Stenosis

Výzkum vlivu charakteristik úhlu facetového kloubu na rozvoj lumbální spinální stenózy u pacientů se stenózou bederního kanálu

A. EROĞLU, M. ATAR, M. SAPANCI, C. ATABEY

¹ Health Sciences University, Sultan Abdulhamid Han Training and Research Hospital, Neurosurgery Service, Üsküdar- İstanbul, Turkey

ABSTRACT

OBJECTIVES

The aim of our study was to investigate facet tropism and its impact on the development of lumbar spinal canal stenosis (LSCS) in patients with LSCS.

MATERIALS AND METHODS

Bilateral facet joint angles at the L3-4, L4-5, and L5-S1 levels were measured on axial plane in the lumbar magnetic resonance imaging (MRI) scans of 82 patients aged between 32 and 75 with LSCS, and 82 healthy individuals aged between 30 and 66 without LSCS, who were considered as the normal group.

RESULTS

Both groups in our study consisted of both males and females. The mean age was 51.4 for patients with LSCS and 44.7 for the healthy group, with no significant difference ($p>0.05$). A total of 984 facet joint angles were measured, with 164 patients at three intervertebral disc levels each. The presence of facet tropism was found to be a significant risk factor in the LSCS group compared to the healthy group, with an increased risk of 2.125 times at L3-4, 3.389 times at L4-5, and 2.496 times at L5-S1 ($p<0.05$).

CONCLUSIONS

In our study, we determined that facet joint tropism is statistically significant in patients with LSCS compared to the control group ($p<0.05$). We believe that facet tropism plays a predisposing role as a contributing factor in the etiology of LSCS.

Key words: lumbar spinal stenosis, facet tropism, magnetic resonance imaging.

INTRODUCTION

Lumbar spinal canal stenosis (LSCS) is a pathology characterized by the narrowing of the spinal and nerve root canals, resulting in clinical symptoms such as claudication and radiculopathy (2, 13, 21, 25, 30, 31). Enlarged facet joints, thickened ligamentum flavum and accompanying protruded discs contribute to the development of canal stenosis (13, 20, 31). In the lumbar region, the anteroposterior diameter of the spinal canal is typically 15–22 mm (3, 5). On lumbar computed tomography (CT), the spinal canal diameter should be at least 11.5 mm. In 1950, Verbiest defined absolute stenosis on CT myelography as an anteroposterior diameter of <10 mm (31). Canal diameter below this threshold is considered as spinal canal stenosis (5, 16, 20, 31). Research findings show that the incidence of lumbar spinal stenosis is 11% in the general population and ranges from 25% to 39% in those seeking medical care (1, 14). It primarily occurs in individuals in their sixth decades

of life and is often accompanied by degenerative spondylotic changes and neurogenic complaints.

Lumbar facet joints are joint structures located between two adjacent lumbar vertebrae, possessing a complex anatomical structure with versatile biomechanical and functional characteristics. Degeneration of facet joints can be influenced by micro and macro traumas, postural factors involving flexion and rotational movements, as well as structural anomalies such as facet tropism. Due to the frequent association between degenerative changes and the onset of back pain, these structures are postulated to have significant clinical importance (4, 5, 33).

Facet tropism (FT) refers to the difference in orientation of facet joints in the sagittal plane. The facet angle represents the angle between the mid-sagittal line and the vertebral facet. The difference in facet angles between the right and left sides indicates the measurement of FT. Facet tropism leads to an uneven distribution of load in the facet joints. This condition can con-

tribute to the development of degenerative processes, spondylolisthesis, spinal stenosis and discopathy pathologies in the lumbar region (14, 21, 22). In this study, our aim was to investigate the impact of FT on the etiology of LSCS by measuring facet joint angles from lumbar MRIs of our patients.

MATERIAL AND METHODS

Patient groups

The study included 82 patients diagnosed with LSCS and 82 individuals considered as a healthy normal group based on their normal lumbar MRI. The mean age of the LSCS group was 54.6 years and 51.3 years in the normal group. Patients with LSCS presented with symptoms such as low back pain, leg pain and neurological claudication. Our normal group consisted of patients who had transient mechanical low back pain and reported that their symptoms resolved within three weeks, with normal findings on the lumbar MRI evaluation. Patients with conditions such as spondylolisthesis, lumbar disc herniation, scoliosis, ankylosing spondylitis and a history of trauma were excluded from the study.

Facet angle measurement method

Facet angle measurements were performed using MRI (Signa Artist 1.5 Tesla, General Electric, USA) in both the LSCS and normal groups. Bilateral L3-4, L4-5, and L5-S1 facet angles were measured. The measure-

ments were taken in 3 mm thick slices in the axial plane. The method described by Kong et al. (19) was used for measurements. A reference plane (RP) was determined by drawing a line perpendicular to the disc and passing through the spinous process. The line drawn between the anteromedial and posteromedial edges of both superior articular facets was defined as the facet line (FL). The angle between the two lines on each side was defined as the facet joint angle (Fig. 1). To determine FT, the mean and standard deviation (SD) values of the tropism angles defined by Noren et al. (26) were calculated. For this study, the mean median value was calculated as 6. FT was defined as a bilateral facet angle difference of more than 6 degrees, which corresponded to 1 SD. The difference between the facet joint angles was classified as follows: no tropism if $<6^\circ$, moderate tropism if between 6° and 12° , severe tropism if $>12^\circ$. In order to get rid of measurement bias, two observers measured the facet angles and they were blinded to each other. Consistency of the values were evaluated by 'The Intra Class Correlation Coefficient' (ICC) test. ICC was calculated as 0.916, that showed high consistency of the obtained two values. Therefore, arithmetic average of the results of the two observers were taken and the angle value was obtained.

Statistical analysis

All analyses were performed using IBM SPSS 21.0 software. A significance level of $p < 0.05$ was considered statistically significant. The normality of continuous variables was assessed using the Kolmogorov-Smirnov test. The Mann-Whitney U test was used to compare two continuous groups and the chi-square test was used to compare two categorical groups (Normal/Tropism; Normal/Grade 1/Grade 2). The association was explored using univariate logistic regression analysis.

RESULTS

Both groups in our study consisted of males and females. The average age was 51.4 for the LSCS group and 44.7 for the normal group, with no significant difference ($p > 0.05$). A total of 984 facet angles were measured in 164 patients, 82 in the LSCS group and 82 in the normal group.

The median angle difference between the right and left sides in the L3-4 level was found to be 3.2 (Interquartile Range-IQR: 2.6) for the normal group, 3.6 (Interquartile Range-IQR: 2.6) for the healthy group, and 3.2 (Interquartile Range-IQR: 2.55) for the LSCS group (Table 1). The difference in angle values between the two groups was not statistically significant ($p = 0.546$).

When all measured angles were considered, the standard value was calculated as 6, where values below 6 were classified as normal and values above 12 were classified as tropism. Tropism between 6 and 12 was classified as grade 1, and tropism above 12 was classified as grade 2. The tropism was normally distributed in 96% ($n = 79$) in the healthy group and 85% ($n = 70$) in the

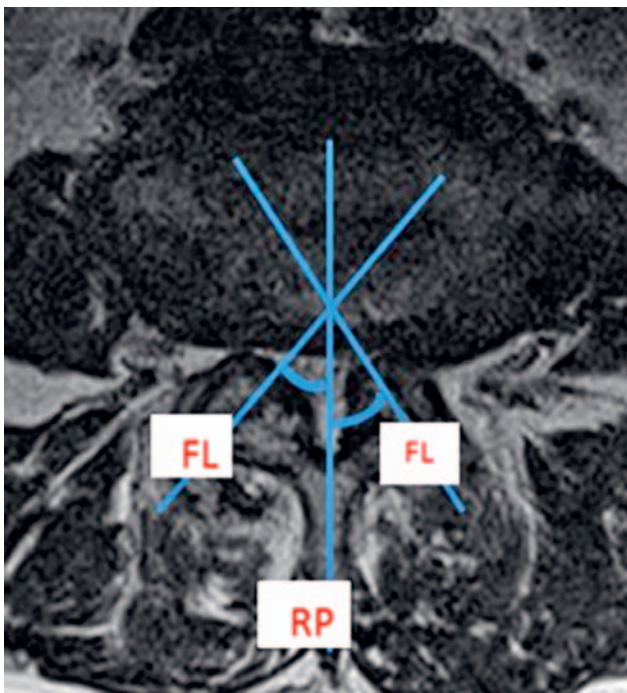


Fig. 1. A vertical line passing through the disc and spinous process was defined as the reference plane (RP). The line drawn between the anteromedial and posteromedial edges of both superior articular facets was defined as the facet line (FL). The angle between the two lines on both sides was defined as the facet joint angle.

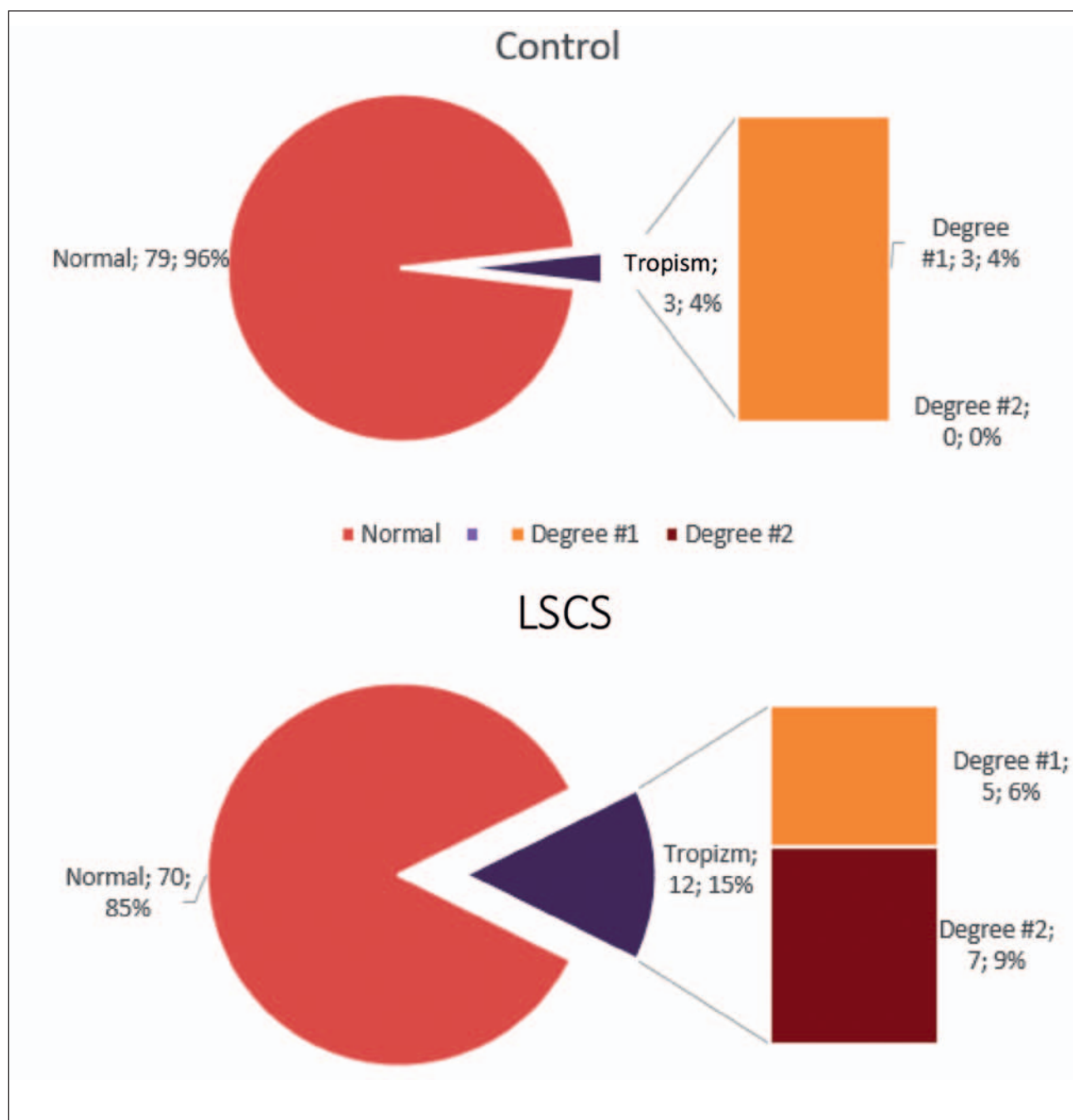


Fig. 2. Distribution of tropism in the healthy and LSCS groups at L3–4.

LSCS group, the difference was statistically significant ($p=0.027$). All 6 cases in the control group were classified as grade 1 tropism, while 5 of 12 tropism cases in the LSCS group were classified as grade 1 and 7 cases as grade 2 ($p=0.018$) (Fig. 2).

The median angle difference between the right and left sides at the L4–5 level was found to be 4.00 (Interquartile Range-IQR: 4.775) 3.7 (Interquartile Range-IQR: 1.95) for the healthy group and 5.5 (Interquartile Range-IQR: 9.23) for the LSCS group. The difference in angle values between the two groups is statistically significant ($p<0.0001$).

In the healthy group, 93% ($n=76$) and in the LSCS group, 52% ($n=43$) exhibit normal tropism and the difference is statistically significant ($p=0.0001$). All 6 measurements in the healthy group were classified as grade 1 tropism, while 17 of 39 measurements in the LSCS group were classified as grade 1 and 22 as grade 2 ($p=0.0001$) (Fig. 3).

The median angle difference between the right and left sides at the L5–S1 level was found to be 3.25 (Interquartile Range-IQR: 4.15), 2.60 (Interquartile Range-IQR: 2.73) for the healthy group and 4.10 (Interquartile Range-IQR: 9.40) for the LSCS group (Table 1). The

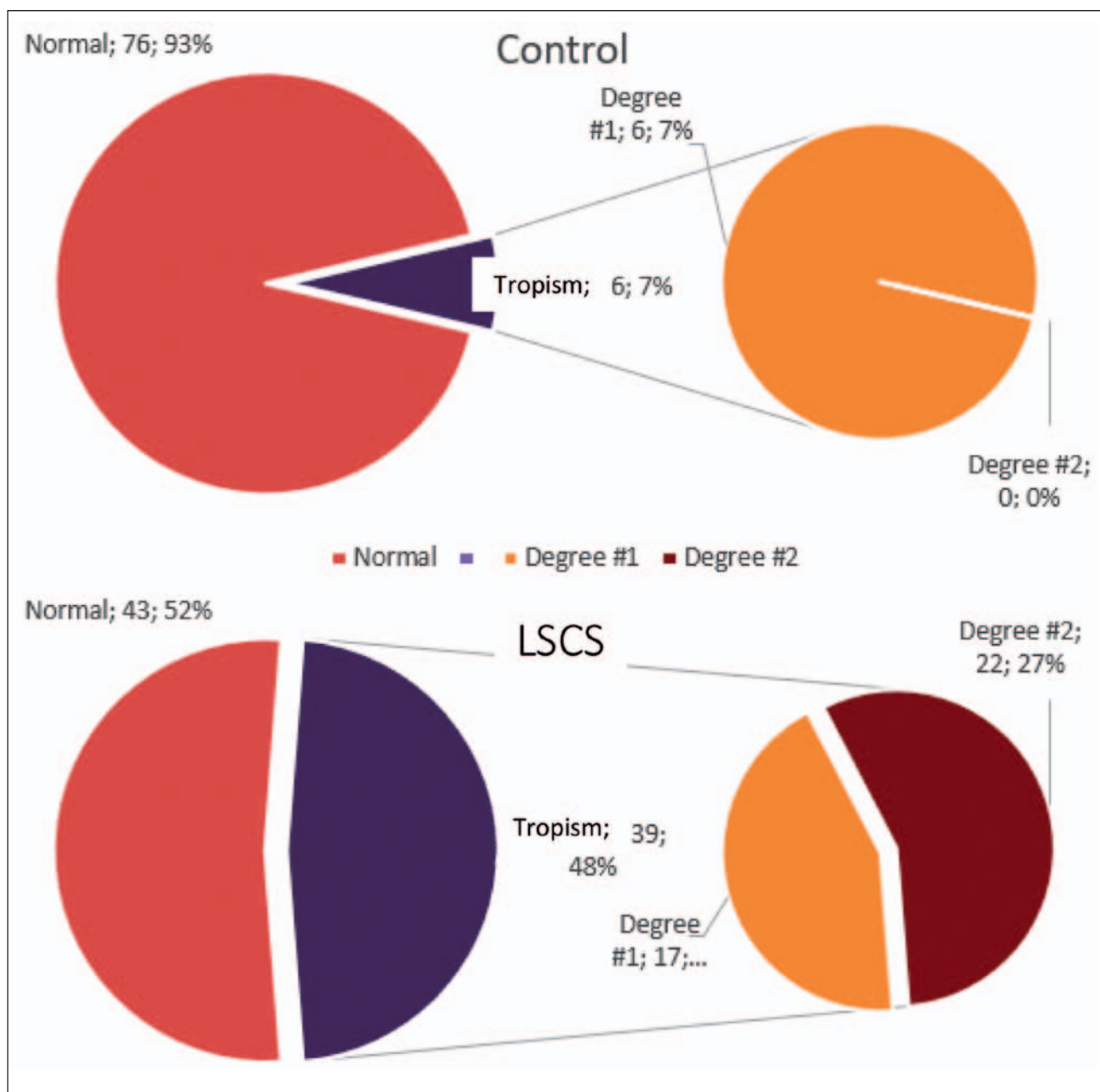


Fig. 3. Distribution of tropism in the healthy and LSCS groups at L4-5.

difference in angle values between the two groups is statistically significant ($p < 0.0001$).

The tropism was normally distributed in 90% ($n=74$) in the healthy group and 60% ($n=49$) in the LSCS group, the difference being statistically significant. All 8 cases in the normalcontrol group were classified as grade 1 tropism, whereas 13 tropism cases in the LSCS group were classified as grade 1 and 20 cases as grade 2 ($p=0.0001$) (Fig. 4).

The presence of tropism was found to be a statistically significant risk factor 2.125 times for L3-4, 3.389 times for L4-5 and 2.496 times for L5-S1 in the LSCS group compared to the healthy group ($p < 0.05$) (Table 2).

DISCUSSION

LSCS is a common degenerative condition that primarily affects individuals over the age of 65, leading to pain in the lower back and legs, as well as difficulty walking. These pathologies significantly impact the quality of life and impose substantial costs on national economies (18, 14, 29). Thickening of ligaments, facet hypertrophy, thickening of the lamina, and disc protrusion are factors that contribute to the narrowing of the spinal canal. In LSCS, compression on vascular structures that supply neural tissues leads to impaired circulation and gives rise to symptoms of neurogenic claudication (13, 14, 16, 18, 25).

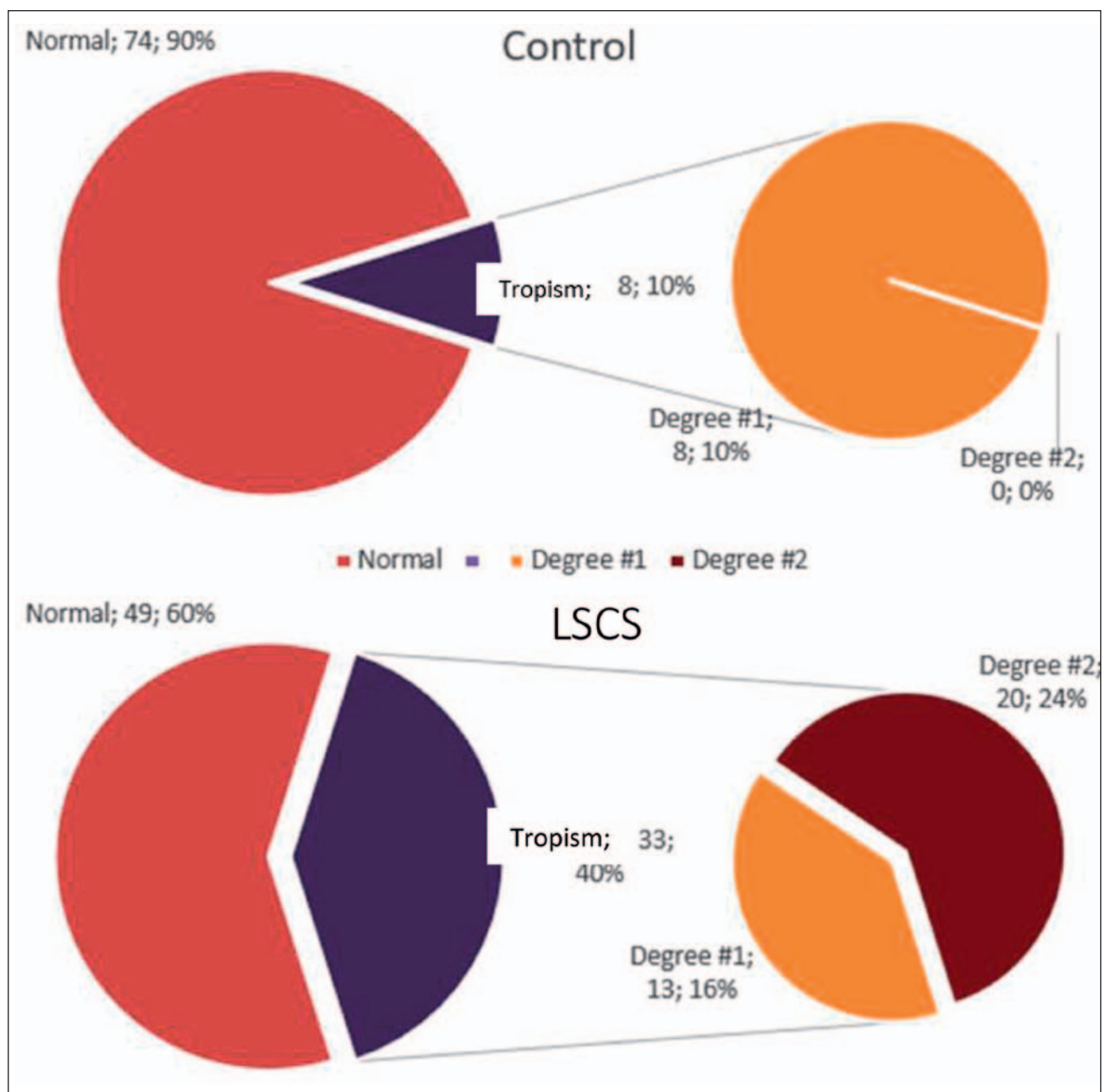


Fig. 4. Distribution of tropism in the healthy and LSCS groups at L5–S1.

The diameter of the spinal canal in the lumbar region typically ranges from 15 to 25 mm. LSCS was first described by Verbiest (24). A definitive diagnosis of stenosis is made when the anteroposterior diameter of the lumbar canal is below 10 mm (4, 20, 31). Although radiological findings are helpful in the diagnosis, the clinical presentation can vary among individuals. We may encounter patients with a reduced anteroposterior diameter of the lumbar canal, as low as 7 mm, who do not exhibit any symptoms. Therefore, the decision for surgical intervention should be based on a combination of radiological and clinical examination. In progressive cases where conservative treatment fails to yield satisfactory results, surgical

intervention becomes inevitable (4, 13, 14, 18, 20, 25).

Facet joints in the spine are structures that allow for the physiological range of motion of the vertebrae. In the lumbar region, the function of movement relies on the coordinated interaction between the intervertebral disc in the front and the two facet joints at the back. The facet joint plays a significant role in controlling backward movement of the spine. Additionally, it carries approximately 16% of the load in the lumbar spine (6, 7, 11, 21, 22, 27, 32).

FT refers to the asymmetry between the angles of the right and left facet joints in the spine. First described by Farfan and Sullivan in 1967, FT defines the presence

Table 1. Effect of tropism in the LSCS group compared to the healthy group – univariate analysis

	Healthy	LSCS	Total	p
L3-4 Difference (Median IQR)	3.6 (2.6)	3.2 (2.55)	3.2 (2.6)	0.5461
L3-4 Facet Angle Degree (number)				0.0182*
Normal	79 (%96.34)	70 (%85.37)	149 (%181.71)	
1. Degree	3 (%3.66)	5 (%6.1)	8 (%9.76)	
2. Degree	0 (%0)	7 (%8.54)	7 (%8.54)	
L4-5 Difference (Median IQR)	3.7 (1.95)	5.5 (9.225)	4 (4.775)	0.00011*
L4-5 Facet Angle Degree (number)				0.00012*
Normal	76 (%92.68)	43 (%52.44)	119 (%145.12)	
1. Degree	6 (%7.32)	17 (%20.73)	23 (%28.05)	
2. Degree	0 (%0)	22 (%26.83)	22 (%26.83)	
L5-S1 Difference (Median IQR)	2.6 (2.725)	4.1 (9.4)	3.25 (4.15)	0.00011*
L5-S1 Facet Angle Degree (number)				0.00012*
Normal	74 (%90.24)	49 (%59.76)	123 (%150)	
1. Degree	8 (%9.76)	13 (%15.85)	21 (%25.61)	
2. Degree	0 (%0)	20 (%24.39)	20 (%24.39)	

1 – Mann-Whitney U test, 2 – Chi-square test, * – statistically significant

Table 2. Effect of tropism in the LSCS group compared to the healthy group – univariate analysis

	B	p	Exp(B)	95% C.I. for EXP(B)	
				Lower	Upper
L3-4 (Ref : Normal)	0.754	0.024	2.125	1.106	4.081
L4-5 (Ref : Normal)	1.221	0.0001	3.389	2.121	5.416
L5-S1 (Ref : Normal)	0.915	0.0001	2.496	1.630	3.823

of asymmetry between the angles of the right and left facet joints in a vertebra (7, 8, 9, 12). Facet joint tropism is characterized by a significant angle difference above a certain SD between the corresponding right and left facet joints. In the literature, the average difference in facet joint angles has been calculated as the SD, and angle differences above the SD have been referred to as FT (19, 26).

This angle difference is generally considered normal up to an average of 7 degrees, and publications have suggested that angle differences greater than 7 degrees can be considered as FT (5, 19, 27). Ishihara et al. (15) defined FT as an angle difference between facet joint angles greater than 1–10 degrees or exceeding 1 SD. Grogan et al. (12) classified facet joint tropism into three categories. They found the SD to be 7 and classified angle differences between corresponding facet joints as follows: no tropism if the difference was less than 7 degrees (1 SD), moderate tropism for differences between 7–15 degrees, and severe tropism for differences exceeding 15 degrees (2 SD). Noren et al. (26) considered a facet tropism when the difference between bilateral facet angles was greater than 5 degrees. In our study, we calculated 1 SD as 6 degrees and defined no FT for differences below 6 degrees, moderate FT for

differences between 6–12 degrees, and severe FT for angle differences greater than 12 degrees.

The diagnosis of FT is typically made through radiological imaging examinations used to evaluate pathologies associated with lower back pain (10, 17). Magnetic resonance imaging (MRI) is a non-invasive imaging method that does not involve ionizing radiation. It has high sensitivity in diagnosing LSCS and provides excellent visualization of soft tissues. It effectively shows abnormalities in the spinal cord, nerve roots and bone marrow, making it the preferred imaging modality for diagnosing FT (1). However, the degree of narrowing observed radiologically may not always correlate with symptoms, as the clinical presentation can vary among individuals. Therefore, it is not appropriate to determine the severity of the condition and plan treatment solely based on radiological findings (4).

Structural anomalies such as FT play a significant role in the development of microtraumas in the lumbar region (7, 10, 17, 20). In the presence of FT, equal distribution of load during axial rotation and load-bearing is compromised, leading to accelerated degeneration of the discs and facet joints. The asymmetry resulting from FT particularly disrupts the homogeneous load distribution and balance during repetitive movements

of the lumbar region, increasing mechanical stress. This, in turn, results in the deterioration of the disc and facet structures, leading to accelerated lumbar degeneration (20, 24, 28). In a normal and healthy spine, the zygapophyseal joints in each facet move with sliding motion upon each other in the sagittal plane during flexion and extension movements. Consequently, these joints play a crucial role in limiting axial rotation. However, when one facet joint is closer to the coronal plane, it restricts flexion and extension movements, causing the spine to rotate towards the facet joint closer to the sagittal plane. The side with a larger facet angle allows unrestricted rotation, leading to higher torsional stress on the annulus fibrosus. This results in uneven biomechanical forces on the facet joints and intervertebral discs during rotational movements. It has been suggested that this condition predisposes individuals to degenerative diseases and serves as a potential risk factor for lower back pain (3, 4, 9).

The higher FT rate observed at the L4-L5 and L5-S1 levels explains the higher incidence of disc degeneration, spinal canal stenosis and other degenerative disc herniation at these levels. Degulmadi et al. reported a 40% correlation between FT and lumbar region pathology, with the most commonly affected level being L4-5 at a rate of 70% (6). Karacan et al. reported that subjects with disc herniation exhibited asymmetry and sagittalization in the facet joints (17). Park et al. suggested that the degree of FT may influence the type of disc herniation (e.g., far lateral or posterolateral) (28). Liu et al., in their study investigating the relationship between lumbar disc degeneration and FT, found a significant increase in the rate of FT from L2-3 to L5-S1 in patients with spinal canal stenosis compared to the control group, indicating a significantly higher incidence of FT in spinal canal stenosis patients (21). Mohanty et al. reported the incidence of FT in the lumbar region as follows: L1-L2: 22.42%, L2-L3: 25%, L3-L4: 27.19%, L4-L5: 47.82%, and L5-S1: 38.5% (24).

Miyazaki et al. examined the relationship between FT and changes in the spinal cord kinematics and lumbar spinal canal diameter. They noted that patients with sagittal facets had narrow bony canals, whereas those with coronal facets had wider bony canals. They reported that facet tropism is a contributing factor in the etiology of LSCS (23). Miyazaki et al. performed this study with dynamic MR. we did it with MR in neutral position and reached the same result. A meta-analysis study emphasized the high rates of FT at the L4-5 level in patients with lumbar spondylosis (14, 23). Grobler et al. reported a higher incidence of FT at the L4-5 level in patients with LSCS compared to the normal population (11). Abbas et al., in their study investigating the impact of FT in patients with LSCS, reported that FT is a predisposing factor in the development of LSCS and In their study, they reported that facet tropism in the distance from L3-4 to L5-S1 increased the risk of developing LSCS by 2.4 to 3.4 times (3). In our study, we found that the presence of facet tropism increased the risk of

developing LSCS by 2.12 times for the L3-4 distance, 3.38 times for the L4-5 distance, and 2.49 times for the L5-S1 distance. Akar et al. conducted a study on FT in 100 patients with LSCS and reported no significant relationship between FT and LSCS (4). We found that in our cases with LSCS, the facet tropism rate was predominantly high in the L4-5 and L5-S1 distances, 36% had mild type (1st degree), 39% had moderate type (2nd degree), and 12% had severe type (more than 2nd degree) facet tropism and we found that there is a statistically significant relationship in LSCS formation. Kong et al. examined the effect of lumbar FT on intervertebral disc degeneration and facet joint degeneration. Their study specifically reported high-grade facet joint degeneration, particularly at the L4-5 level (19). In our study, we also found that facet joint tropism plays a role in the development of LSCS. We observed particularly high rates of FT at the L4-5 level, which explains the frequent occurrence of LSCS at this level.

CONCLUSIONS

In conclusion, asymmetry resulting from FT, especially during repetitive movements of the lumbar region, leads to non-uniform distribution of load and impaired balance. This, combined with increased mechanical stress, contributes to the disruption of the disc and facet structures, accelerating lumbar degeneration and the development of LSCS. Our statistical findings suggest that facet joint tropism is involved in the development of LSCS.

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Corresponding author:

Ass. Prof. Ahmet Eroğlu
Health Sciences University
Sultan Abdulhamid Han Training and Research Hospital,
Neurosurgery Service
Üsküdar – İstanbul, Turkey
E-mail: drahmeteroglu@gmail.com