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Journal of Neurosciences in Rural Practice

Original Article

The relationship between bone canal diameter and facet tropism in cases of lumbar spinal stenosis

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ABSTRACT

Objectives: Lumbar spinal stenosis (LSS) is a condition that increases in frequency with the aging of the spine and has adverse effects on the quality of life of individuals. Facet tropism (FT) refers to the difference in the orientation of the facet joints relative to each other in the sagittal plane. This situation may be due to a developmental defect or different stimuli. In many biomechanical studies in the literature, the relationship between FT and lumbar degenerative disorders has been investigated. In this study, we aimed to investigate whether there is a relationship between anteroposterior bone canal diameter and FT in LSS cases

Materials and Methods: We retrospectively evaluated the CT and T2-weighted axial and sagittal magnetic resonance imaging of the lumbar region of 100 LSS patients who were operated on in our clinic between 2015 and 2017. For each patient, the facet joint angles, the degree of FT, and the AP diameter of the spinal canal were determined.

Results: The cases were grouped according to FT types and no correlation was found between midsagittal bone spinal canal measurement and FT types. According to the results, no significant difference was found.

Conclusion: As a result, because of there is no relationship between midsagittal bone canal diameter and FT, we thought that FT may be both a part of the degenerative process and a congenital origin.

Keywords: Lumbar spinal stenosis, Facet tropism, Spinal canal, Diameter

INTRODUCTION

Lumbar spinal stenosis (LSS) is the result of congenital or degenerative narrowing of the neural canal and foramen leading to compression of the lumbosacral nerve root or cauda equina.[1] LSS was etiologically classified by Arnoldi as normal canal, congenital/developmental stenosis, degenerative stenosis, congenital/acquired stenosis with disc herniation, degenerative stenosis with disc herniation, congenital/developmental, and superimposed degenerative stenosis.[1] The symptoms are thought to result from ischemia as a result of compression of the vasa nervorum in the relevant region of the spinal cord and cauda equina nerve fibers.[2-5] It is mainly seen with neurogenic complaints accompanied by degenerative spondylotic changes in individuals in the fourth and fifth decades of life.[2,6] LSS is a well-known and common cause of back pain in addition to radiculopathy and neurogenic claudication.[7-9] Neurogenic claudication may be as bilateral or unilateral hip and lower extremity pain. It is also characterized by heaviness, numbness, tingling or weakness in the feet, and loss of strength is usually not observed. Symptoms are exacerbated by walking and standing and relieved by sitting or leaning forward. Axial loading of the lumbar spine and bending in hyperextension will increase the existing narrowing of the spinal canal, worsening clinical symptoms.[7]

Clinical symptoms and radiological findings provide significant benefits in diagnosis. Magnetic resonance imaging (MRI), computed tomography (CT), and CT myelography may be requested to diagnose patients with suspected LSS. Limit values of generally accepted quantitative parameters in the radiological diagnosis of LSS are 12 mm for the midsagittal diameter of the dural sac, 3 mm for the foramen diameter, and 3 mm for the lateral indentation height.[10-20] However, the limit value of radiological spinal bone canal narrowing, which causes clinically significant stenosis, is not clear.[9] The dural sac cross-sectional area <100 mm 2 in a

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Received: 12 September 2022 **Accepted:** 20 September 2022 **EPub Ahead of Print:** 06 December 2022 **Published:** 16 December 2022 **DOI**: 10.25259/JNRP-2022-7-26

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radiological study of narrow canal cases.[18] In 1950, Verbiest. defined absolute stenosis as an anteroposterior (AP) diameter of <10 mm on CT myelography.[21]

Facet joints, also known as zygapophyseal joints, are synovial joints between two vertebrae in the posterior column [Figure 1].These joints are the key structure of the posterior column and play an essential role in the stability of the spine. They also play an important role in load sharing and limiting axial rotation.[12,13] Facet tropism (FT) is called as the difference in the orientation of the facet joints relative to each other in the sagittal plane. The facet angle is the angle between the midsagittal line and the vertebral facet. The difference between the facet angle of the two sides gives the FT measurement.[13] In 1967, Farfan and Sullivan found an association between the development of disc herniation as a result of rupture of the posterior annulus and the more coronally facing facet joint.[12] The cutoff value to define FT is not well defined in the literature. Typical cutoff values are considered 10 degrees and below. FT causes unequal loading on the facet joints. This situation leads to an asymmetrical distribution of weight and biomechanical force over the intervertebral disc. It may thus cause a reduction or even flattening of the lumbar lordosis and lead to spondylolisthesis, unilateral foraminal stenosis, and radiculopathy.[16,17] Common symptoms of FT include localized pain and tenderness over the facet joint, low back stiffness, and pain that increases with prolonged standing.[18] Lumbar facet joint asymmetry is a congenital structural finding not related to age or degeneration.[19] In this study; by evaluating whether there is a relationship between the AP bone canal diameter and the degree and type of lumbar FT in our patients with narrow canal operated in our clinic; we aimed to give an idea about the congeniality or acquired of FT.

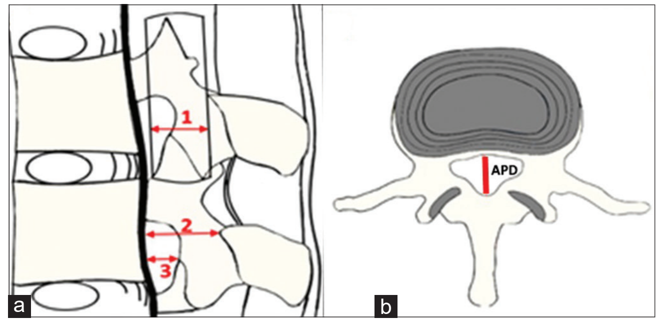

Figure 1: Schematic imagines provide sagittal and axial view of two lumbar vertebrae. (a) First arrow indicates measurement of midsagittal diameter of dural sac, second arrow indicates measurement of anteroposterior diameter of osseous spinal canal, and third arrow indicates measurement of anteroposterior diameter of foramen. (b) APD: Anterior-posterior diameter.

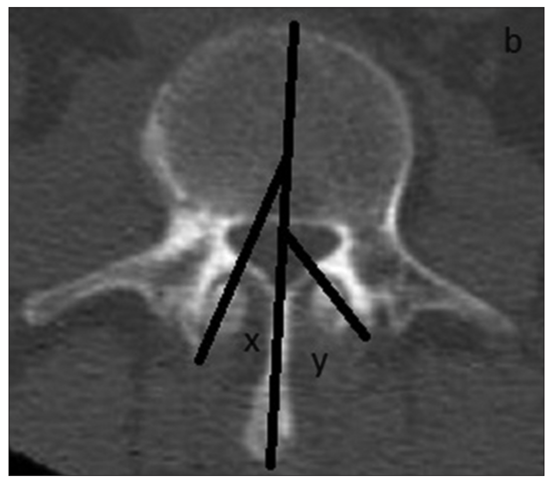

Figure 2: The method of facet angle measurement.

MATERIALS AND METHODS

We retrospectively evaluated CT and T2-weighted axial and sagittal magnetic resonance imaging (MRI) images of 100 LSS patients who were operated on in our clinic between 2015 and 2017. Measurements were made by two blinded observers and patients were randomly selected. The AP diameter of the bone spinal canal at the level of the surgically performed lumbar vertebra of each patient was measured using axial CT images. The AP diameter was measured perpendicular to the posterior cortex of the vertebral body with the cranial border of the lamina at the pedicle level.[20] The AP diameter of the bone canal at the level of the lumbar stenosis level of the patients was considered to be <17 mm as congenital LSS. Furthermore, the method described by Noren *et al*. was used to measure the facet joint angle in T2-weighted MRI images of the patients [Figure 2]. For each facet joint surgically treated, a tangential line through the superior articular process was drawn and was intersected with the line passing through the midsagittal plane of the spinal corpus. The angle between the superior articular joint and the central line was measured.[18] The FT degrees of each spine level in the lumbar region were calculated and the mean degree difference of the facet joints at all levels was determined. The angle difference between the right and left facet joints was determined for each level, and the degree of FT was defined according to the types indicated by Boden *et al*. Accordingly, there are four types of FT. (1) There is no facet joint asymmetry in patients whose angle difference between the right and left facet joints is <6 degrees; no FT, (2) there is mild facet joint asymmetry in patients whose angle difference between the right and left facet joints is between 6 and 10 degrees; FT mild, (3) there is moderate facet joint asymmetry in patients whose angle difference between the right and left facet joints is between 11 and 16 degrees; FT moderate, and (4) there is severe facet joint asymmetry in patients whose angle difference between the right and left facet joints is >16 degrees; FT severe. Thus, the degree of FT was classified in this way.[19]

The relationship between FT types and bone canal diameter was evaluated statistically. Patients with a history of the previous spinal surgery, post-traumatic infection, congenital spinal deformities, patients with kyphoscoliosis, and patients with pathologies such as pars defect and a history of tumoral disease were excluded from this study.

Statistical analysis

Since the data obtained from the group consisting of a total of 100 patients did not have a normal (gaussain) distribution, the statistical evaluations between the groups were made using the 2-Sample Kolmogorov–Smirnov (K-S Test) test method. In addition, the Kruskal–Wallis test method, which can make comparisons between multiple groups, was also used. It was evaluated whether the test was statistically significant in the *P* value obtained as a result of the test, and $P < 0.05$ (5%) means a significant difference. All obtained data were stored and analyzed in the MATLAB 2021A Statistics and Machine Learning Toolbox Version 11.2 program. As the descriptive statistical parameters, the mean, standard deviation, and median deviation of the data of the patients in the group were assessed, and 2-sample K-S and Kruskal–Wallis test methods were performed.

RESULTS

In view of the results, 49 (49%) of the cases were in the group without FT and the midsagittal bone canal diameter was 15 mm on average. There was "mild type" FT in 22 (22%) of the cases, and the midsagittal bone canal diameter was 15.9 mm on average. In 15 (15%) of the cases, "middle type" FT was present, and the mean midsagittal bone canal diameter was 16.2 mm. In 14 (14%) of the cases, "severe type" FT was present, and the mean midsagittal bone canal diameter was 15.25 mm [Table 1]. According to our *t*-test results, when the cases were grouped considering FT types, there was no significant relationship between midsagittal bone spinal canal measurement and FT types ($P = 0.4$) [Table 2]. Since the distribution does not show a normal distribution and has an exponential distribution, when the median value is taken into account instead of the statistical sample mean value, it is seen that the dominant region of the FT type belongs to the "no type" class. When the male and female patients were grouped together, the FT scores of both groups were subjected to the 2-sample K-S test with 5% significance, and *P*: 0.9 was obtained, and it was concluded that there was no significant difference between the genders [Table 3]. Fifty-three of our patients were women, 47 were men, and the mean age was 54.7 years. The mean bone spinal diameter was 15.44 mm in women and 15.37 mm in men.

DISCUSSION

Spinal stenosis can be seen at any age, but its frequency increases after the age of 50 and begins to manifest clinically.

Table 1: Distribution of cases according to facet tropism types.

	Mean diameter	STD	Median diameter	Number of patients (%)
None patient group	15.03	2.65	15	49 (49/100)
Mild patient group	15.39	3	15.9	22 (22/100)
Moderate patient group	16.31	2.47	16.2	15 (15/100)
Severe patient group	15.81	3.24	15.25	14 (14/100)

Table 2: Kruskal–Wallis ANOVA table for comparison of AP diameters distribution according to FT types.

Source	SS	Df	MS	Chi-square	Prob >Chi-square
Groups	2435.4	3	811.79	2.89	0.4082
Error	80858.6	96	842.277		
Total	83294	99			

AP: Anteroposterior

LSS progresses due to degenerative processes and stenosis of the spinal canal increases. It also causes an increase in vascular compression of neural structures. As a result, patients' pain does not respond to almost any conservative treatment. Therefore, surgery is recommended for patients and LSS is the most common indication for spinal surgery in patients over 65 years of age. The spinal cord and neural elements show less individual variation than the bone spinal canal. In elderly patients, lumbar canal narrowing can often be detected radiologically. However, this degree of narrowing may not be proportional to the severity of symptoms. In fact, most patients are asymptomatic. For this reason, making the correct diagnosis remains a challenge for both clinicians and radiologists. The normal sagittal diameter of the bone spinal canal in the lumbar region is between 15 and 25 mm.[1,3,4,8,22,23] It was first systematically described by Verbiest, both anatomically and clinically. If the AP diameter of the spinal canal in the lumbar region is <10 mm, it is called absolute stenosis, and if it is between 10 and 13 mm, it is called relative stenosis.[21] However, the degree of narrowing of the neural canal causing clinically symptomatic stenosis is not clear radiologically and individual differences are common. For this reason, radiological findings alone are not sufficient to determine clinical severity and treatment plan.[8] There is focal, segmental, or diffuse narrowing in the LSS that compresses the spinal cord and/or the lumbosacral nerve roots.[24] The most common cause of LSS is various degenerative changes that occur in the discs, facet joints, or vertebral bodies.[1] In acquired LSS (ALSS), osteophyte formation in the facet joints, thickening of the ligamentum flavum, and swelling of the intervertebral disc are remarkable. This situation compresses the lateral areas of the spinal cord and/or nerve roots, and patients develop symptoms. CLSS

Table 3: Two sample Kolmogorov–Smirnov test results.

	AP diameter of spinal canal for male patient group				AP diameter of spinal canal for female patient group				K-S Test Result (*P*-value)
	Number of Patients	Mean	STD	Median	Number of Patients	Mean	STD	Median	
Diameter (mm)	47 (47%)	15.37	2.95	15.6	53 (53%)	15.44	2.67	15.2	0.9

AP: Anteroposterior

has a shorter pedicle length and smaller cross-sectional spinal cord area due to dysplasia of the bone structure. CLSS is likely to result from abnormal fetal and postnatal development of the lumbar spine, and symptoms appear earlier, usually in the 4th–5th decades of life. In CLSS, there is stenosis at the level of at least three vertebrae in the sagittal diameter of the spinal canal. Normal values for spinal canal diameter in the lumbar region are as below <19 mm for L1 level, <19 mm for L2 level, <18 mm for L3 level, <18 mm for L4 level, <18 mm for L5 level, and <16mm for S1 level.[2,25-27]

According to a study, FT was defined as the difference in symmetry resulting from unequal rotation of the right and left facet joints relative to each other in the axial plane of a vertebral level.[28] This situation may be caused by a developmental defect or different stimuli. Studies in the literature have shown that the incidence of FT and related syndromes in the lumbar region varies between 40% and 70%, and the most frequently affected level is the L4-L5 level.[14,29] In addition to this, Karacan *et al*. found the rate of FT in the lumbar region to be 14–28%.[27] FT is more than just a radiological finding, as it has been implicated in the etiopathogenesis of facet joint degeneration, disc herniation, and degenerative spondylolisthesis. However, the diagnosis of FT is usually made using radiological imaging examinations taken to evaluate pathologies associated with low back pain. Xu *et al*. found that CT and MRI studies were reliable in assessing the severity of FT.[28] However, facet joint blockade can be performed for both diagnostic and therapeutic purposes in low back pain secondary to FT. FT can also cause a reduction or even flattening of the lumbar lordosis, while causing a slight scoliosis or change in position in the sagittal plane of the spine. During the flexion-extension movement in a normal healthy spine, the zygapophyseal joint in each facet moves with sliding movement over each other in the sagittal plane. Consequently, these joints play an important role in restricting axial rotation. However, the fact that one of the facet joints is closer to the coronal region limits flexion and extension movements. This causes the spine to rotate toward the facet joint, which is closer to the sagittal axis. As a result of FT, torsional stress is higher in the annulus fibrosus due to unrestricted rotation on the side with the larger facet angle. This results in unequal biomechanical forces on the facet joint and intervertebral disc during rotational movements. It has been suggested that this condition predisposes individuals to degenerative diseases and is a potential risk factor for low back pain in individuals. However, disc degeneration begins in the second decade of life in individuals. This process becomes evident in the presence of FT.[14,16,29,30-33] In 1967, Farfan and Sullivan studied the relationship between facet joint asymmetry and tear patterns of the posterior annulus. As a result, they found a high correlation between the herniated side of the disc and the more coronal facet joint.[12] There are various studies investigating whether there is a relationship between FT and the development of facet joint degeneration. Giles *et al.* observed greater loss of hyaline cartilage in the more sagittalized facet of the patient with FT.[31] Boden *et al*. divided FT into four groups as no tropism, light, moderate, and heavy tropism.[19] Akar *et al*. compared the morphological features of congenital and acquired LSS in their study. According to this study, facet joint angle and type of tropism are not distinguishing factors in the etiology of congenital and acquired LSS.[32] Linov *et al*. examined the association between facet orientation, tropism, and facet joint osteoarthritis and found no association between FT and the development of facet joint osteoarthritis.[33] Zhu *et al*. investigated the association between lumbar disc herniation and facet joint osteoarthritis and found no association between FT and facet joint osteoarthritis.[34] Cassidy *et al*. reported that the relationship of facet asymmetry with the disc herniation side is controversial.[35] In their study on 21 cadavers, Grogan *et al*. suggested that facet joint tropism in the lumbar region is ineffective in accelerating facet joint degeneration.[36] Fujiwara *et al*. reported that more sagittal facet joint orientation occurs secondary to osteoarthritis remodeling.[37] In addition, we grouped the cases according to FT types and found that there was no relationship between midsagittal bone spinal canal measurement and FT types. According to our findings, "none type" FT was present in most of our cases. Accordingly, we could not find a relationship between LSS and FT. In addition, when we compared bone canal measurement and FT types, there was no relationship between canal diameter and FT. Correspondingly, there was no correlation between decreased bone canal diameter or congenital spinal stenosis and FT. Masharawi *et al*. stated that asymmetry in facet orientation is usually a normal feature in the thoracic spine, but it may be associated with pathological conditions in the lumbar spine.[38] Mohanty *et al*. determined the prevalence of FT in L1-L2, L2-L3, L3-L4, L4-L5, and L5-S1 as 22.42%, 25%, 27.19%, 47.82%, and 38.5%, respectively.

The higher prevalence of FT in L4-L5 and L5-S1 seen in this study may explain the higher incidence of disc herniation and other degenerative disorders at these levels.[39] Degulmadi *et al*. aimed to elucidate the relationship of FT with lumbar degenerative listesis and disc herniation. Kong *et al*. studied the effect of lumbar FT on intervertebral disc degeneration, facet joint degeneration, and segmental translational motion. This study showed that FT was significantly associated with the presence of high-grade facet joint degeneration at L4-L5. This suggests that FT may predispose to facet joint degeneration in active regions of segmental motion.[40] In our study, it was determined that there was no relationship between midsagittal bone spinal canal measurement and FT types when grouped according to FT types.

CONCLUSION

Based on the results of our study, as there was no association between less midsagittal bone canal diameter and FT, we concluded that FT may be part of the degenerative process, but we cannot exclude a congenital origin.

Declaration of patient consent

Patient's consent not required as there are no patients in this study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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How to cite this article: Akar E, Toprak F, Öğrenci A. The relationship between bone canal diameter and facet tropism in cases of lumbar spinal stenosis. J Neurosci Rural Pract 2022;13:641-6.