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Analysis of factors influencing ligamentum flavum thickness in lumbar spine - A radiological study of 1070 disc levels in 214 patients

G. Sudhir*, S. Vignesh Jayabalan, Saikrishna Gadde, G. Venkatesh Kumar, K. Karthik Kailash

Spine Surgery Department, Sri Ramachandra Medical University, Chennai, Tamil Nadu, India

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ABSTRACT

Objective: The pathomechanism and factors influencing hypertrophy of the Ligamentum flavum in the lumbar spine still requires a confident specificity. We aimed to analyse the association between various factors and Ligamentum Flavum Thickness (LFT) and also to investigate the major contributor for Ligamentum Flavum Hypertrophy (LFH) at various levels in the lumbar spine.

Patients and methods: The following were evaluated at L1-L2,L2-L3,L3-L4,L4-L5 and L5-S1 levels in MRI of 1070 lumbar disc levels of 214 subjects: Pfirrmann's grade of the disc, anterior and posterior disc height, disc volume, facet tropism and LFT. LFT > 0.4 cm was considered as hypertrophy.Correlation between LFT and other parameters was done and values with $p < 0.05$ was considered statistically significant.

Results: 112 male and 102 female were included. There was an increase in the anterior disc height (0.98 cm to 1.50 cm), posterior disc height (0.84 cm to 0.96 cm), disc volume (7.17cm^3 to 14.6cm^3), facetal angle and LFT on both sides from L1-2 to L5-S1 levels. Highest frequency of LFT was seen at L4-5.Pfirrmann's grade of the disc and anterior disc height had a statistically significant positive correlation with LFT at L1-L2,L2-L3,L3-L4,L4-L5 levels whereas facet tropism was strongly associated with LFT at L5-S1 level.

Conclusion: Higher Pfirrmann's grade and decreased anterior disc height can lead to ligamentum flavum hypertrophy at L1-L2, L2-L3,L3-L4,L4-L5 levels.Whereas at L5-S1 level, it is the presence of facet tropism which can cause LFH. Hence, patients with the presence of above mentioned factors at those respective levels have higher preponderance to develop Lumbar canal stenosis.

1. Introduction

Ligamentum Flavum (LF) also known as the yellow ligament originates from the anterior surface of the lower part of the lamina above and inserts into the posterior surface and superior border of the lamina below [1,2]. It extends from the capsules of facet joint laterally to the point where the laminae fuse to form spinous process medially. With its superficial and deep components it connects the laminae of the adjacent vertebrae in the spinal column thereby preventing separation of the laminae during spinal flexion and also restoring erect posture after flexion. As the age advances, there will be an increase in the collagen fibres and decrease in the elastic fibres reducing the elasticity of the ligament [3,4]. Various studies have shown that LF plays a significant role in degenerative spinal disorders especially spinal canal stenosis in the lumbar region. Thickening or hypertrophy of LF reduces the spinal canal diameter thereby compressing the dura and the nerve roots leading to low back pain, sciatica, neurogenic claudication and neurodeficit [3,10].

Several studies have shown that disc degeneration is the initiator of spinal stenosis. The intervertebral disc has an outer annulus fibrosus and an inner gel like nucleus pulposus. The nucleus pulposus is made up of proteoglycans especially chondroitin sulphate which helps to bind the water molecules together thereby maintain its gel like consistency and keratin sulphate. The amount of chondroitin sulphate is more in children and as age advances, there is a reduction in its quantity resulting in disc degeneration. Kirkaldy Willis et al [8] described three stages in the natural history of disc degeneration. The first stage is characterized by development of radial and circumferential tears in the annulus and synovitis of the facet joints. The second stage is associated with hypermobility and degeneration of the facet joints resulting in capsular laxity and instability. The third stage is characterized by formation of hypertrophic bone around the facet joint and hypertrophy of the LF. Altinkaya et al [13] showed that the LF thickening is due to deformation within the vertebral canal, as a result of disc degeneration, rather than hypertrophy of the LF. The aim of the study is to analyse the factors that influence thickening of the LF at various levels in the

* Corresponding author.
E-mail addresses: sudhir_axon@yahoo.co.in (G. Sudhir), venkatspinedoc@gmail.com (G. Venkatesh Kumar), sudhir_axon@yahoo.co.in (K. Karthik Kailash).

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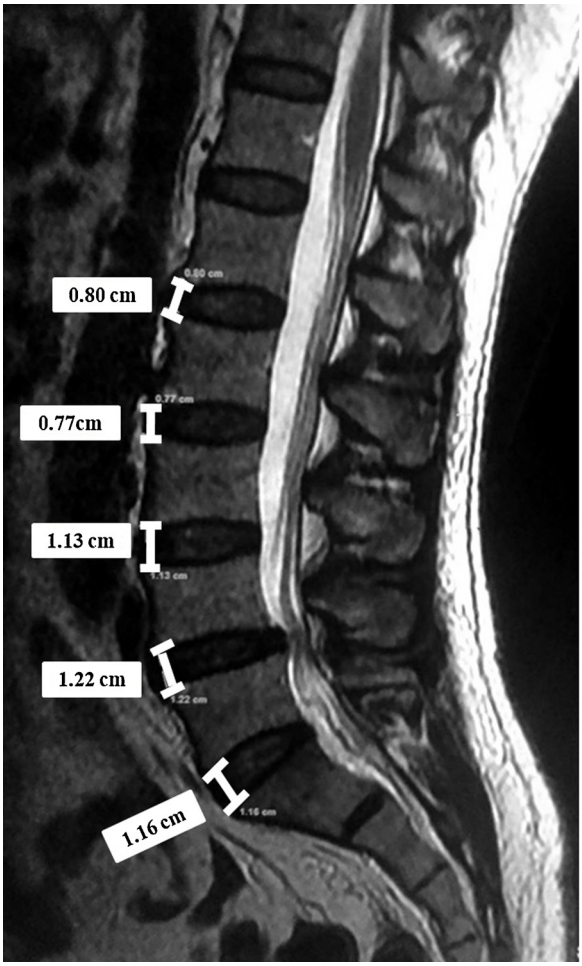

Fig. 1. Anterior disc height.

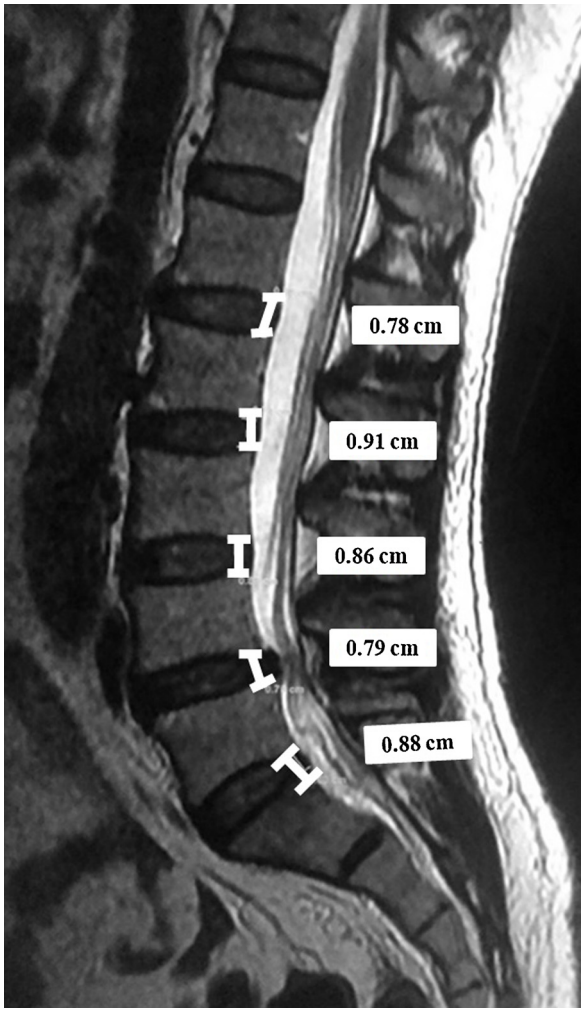

Fig. 2. Posterior disc height.

lumbar spine.

2. Materials and methods

After obtaining Institutional ethics committee and review board approval, retrospective examination of MRI of 1070 lumbar disc levels was done in 214 patients with chronic low back ache i.e., patients suffering from low back pain for a period of more than 12 weeks. Mean age was 52.57 years. Age < 25 years. subjects with vertebral fractures, tumors, infections, kyphotic or scoliotic deformities, congenital malformations were excluded from the study. Pfirrmann's grade of disc degeneration [14], anterior disc height, posterior disc height, disc volume, facet tropism and Ligamentum Flavum Thickness were evaluated at L1-L2, L2-L3, L3-L4, L4-L5 and L5-S1 levels.

Anterior disc height was measured by drawing a longitudinal line between the end plates of adjacent vertebrae in the anterior column in T2 midsagittal images (Fig. 1) and posterior disc height was measured by drawing a longitudinal line between the end plates of adjacent vertebrae in the posterior column in T2 midsagittal images (Fig. 2). The disc was considered as a cuboid and the traditional formula for the calculation of volume of a cuboid was applied by measuring length, width and height in mid coronal and mid sagittal planes (Fig. 3). Facetal angle was measured using Noren's method. Two lines were drawn in axial T2 weighted image at the half of the corresponding disc level. First line was drawn in the midsagittal axis of the vertebra and the second was line drawn parallel to the facet joint. The angle between these two lines was measured as the facetal angle (Fig. 4). Facet tropism was calculated as the difference between facetal angle on both sides. It was considered as normal tropism if the angle was < 7 °, moderate if it was between 7–15 degrees and > 15 ° was considered severe (Fig. 5). Ligamentum Flavum Thickness (LFT) was measured at the thickest part of the ligamentum flavum in mid axial T2 images (Fig. 6). LFT more than 0.4 cm was considered as hypertrophy.

The data was subjected to statistical analysis with IBM-SPSS statistics software 23.0 version. To describe about the data, descriptive statistics, frequency & percentage analysis were used for categorical variables. Mean and Standard deviation were used for continous variables. To fit the model, binary logistic regression with backward stepwise (ward) method was used. Correlation between LFT and the rest of the parameters was done. Values with $p < 0.05$ was considered statistically significant

3. Results

112 were male and 102 were female of the total 214 patients with a mean age of 52.57 yrs (Table 1). There was an increase in the anterior disc height (0.98 cm to 1.50 cm) (Table 2), posterior disc height (0.84 cm to 0.86 cm) (Table 3), disc volume (7.17cm^3 to 14.5cm^3) (Table 4) from L1-2 to L5-S1 levels. Anterior disc height, posterior disc height and disc volume was maximum at the L5-S1 level.

Tables 5 and 6 suggests that facet angle increases caudally (42.6° to 58.8° on right side, 45.6° to 56.4° on left side) and confirms the change in the orientation of the facet joints from sagittal plane towards the coronal plane caudally. It also revealed that maximum variation of the facet angle is present at L3-L4 level proved by its widest range among

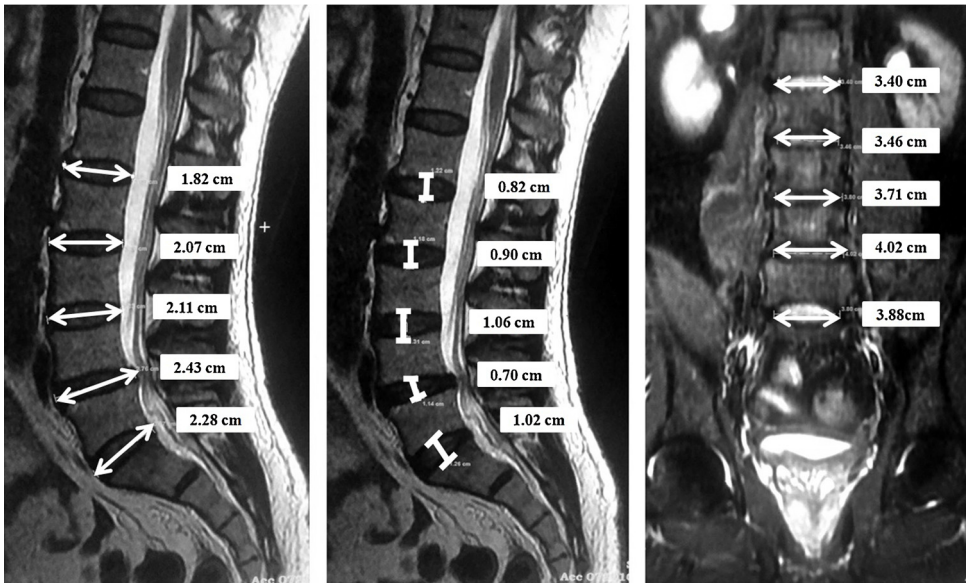

Fig. 3. Disc volume.

all the levels.

LFT increases caudally (0.32 cm to 0.48 cm on right side, 0.31 cm to 0.44 cm on left side) (Tables 7 and 8) and the highest frequency of hypertrophy is present at L4-L5 (64.4% of patients) and L5-S1 (54.4% of patients). The right sided LFT was more than the left side and the highest frequency of LF hypertrophy was at L4-5 level. highest frequency of facet tropism was noted at L4-5 level (22.8% moderate tropism and 5.9% severe tropism) (Table 9).

Of the various factors analysed, we found Pfirrmann's grade of disc degeneration and anterior disc height had a statistically significant positive correlation with LFT at L1-L2, L2-L3, L3-L4 and L4-L5. However at L5-S1, a statistically significant positive correlation was found between facet tropism and LFT (Table 10).

4. Discussion

The Ligamentum flavum is an yellow elastic ligament that extends from the second cervical to first sacral vertebra and an important contributor for spinal canal stenosis especially in the lumbar spine [1,2]. Though the exact function of ligamentum flavum is not clearly understood, it plays a vital role in spinal stability by controlling the movement of spine. Various studies have shown that the ligamentum flavum loses its elasticity as the age advances though the exact mechanism of which remains unclear. Few authors suggest that aging increases fibrosis of the ligament along with increase in collagen to elastin ratio thereby decreasing its elasticity while others have postulated that it is merely buckling of the ligament due to disc degeneration thereby reducing the disc height ultimately reducing the canal diameter leading to spinal canal stenosis [3–7]. Kirkaldy Willis et al. [8] in their description of natural history of disc degeneration have stated that loss of disc height due to disc degeneration leads to a sequence of events which ultimately results in hypertrophy of the ligmentum flavum and the facet joints. Based on this theory, we conducted this study to analyse the LFT, the correlation between various parameters and LFT and the significant factors leading to LFT at various levels in the lumbar spine.

Our study showed no gender difference in the LFT and the other parameters which is similar to other studies [8,9]. There is a paucity of literature regarding the LFT between both sides. We found that the LFT was more on the right side compared to the left side which was similar to the findings by Abbas et al. [9] who noted that ligamentum flavum was thicker on the right side compared to left at L3–L4 and L5–S1 levels which could be due to the inbuilt right sided rotation of the middle and lower thoracic spine resulting in left sided rotation of the lumbar spine as a compensatory mechanism ultimately increasing the tensile forces on the right sided structures including the facet joints and the

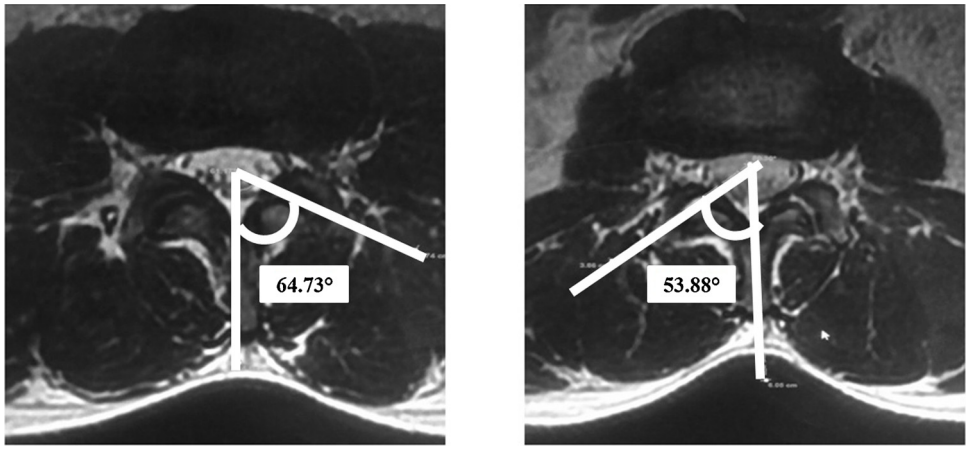

Fig. 4. Facetal angle.

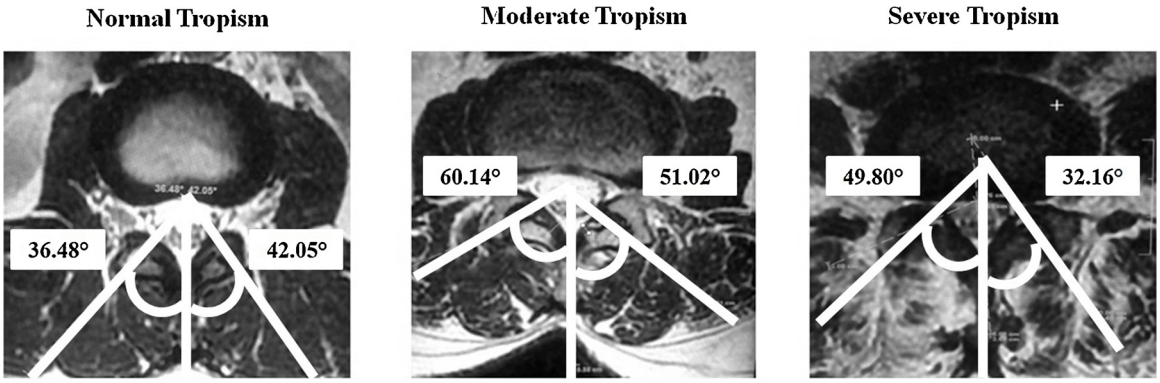

Fig. 5. Facet tropism.

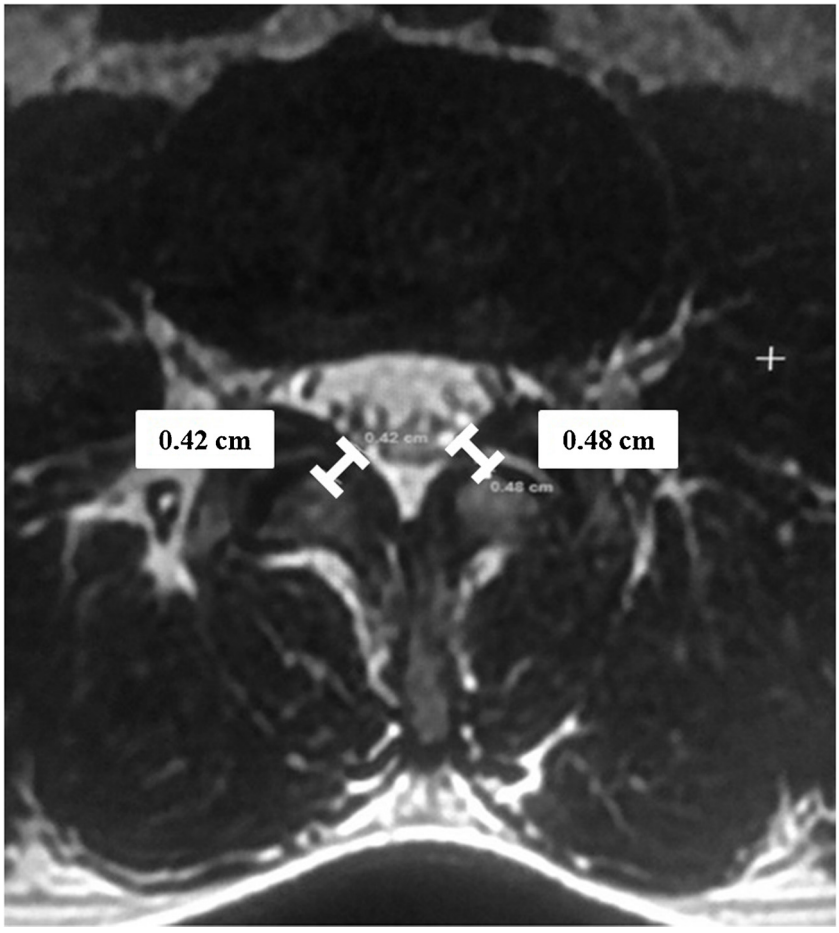

Fig. 6. Ligamentum flavum thickness.

Table 1
AGE DISTRIBUTION OF THE PATIENTS.

AGE	IN YEARS
Range	26-86
Mean age	52.57
Standard deviation	13.75

(n = 166 ; male – 85 ; female- 81).

Table 2
MEAN VALUES OF ANTERIOR DISC HEIGHT AT DIFFERENT LEVELS.

DISC LEVEL	MEAN VALUE (in cm)	STANDARD ERROR	MINIMUM (in cm)	MAXIMUM (in cm)
L1-L2	0.9805	0.27283	0.50	1.64
L2-L3	1.1166	0.25081	0.60	1.86
L3-L4	1.3156	0.27449	0.64	1.91
L4-L5	1.4201	0.32337	0.63	1.97
L5-S1	1.5016	0.37530	0.22	2.15

ligamentum flavum. On the contrary, Safak et al showed that LFT was more on the left side and they postulated that it could be due to developmental instability or asymmetrical mechanical stresses based on the side preference of the individual [10]. However, Subhash Kolte et al. [11] could not find any difference between both the sides.

We found that anterior disc height, posterior disc height, disc volume, facet tropism and LFT increased from L1-2 to L5-S1 levels. The

Table 3
MEAN VALUES OF POSTERIOR DISC HEIGHT AT DIFFERENT LEVELS.

DISC LEVEL	MEAN VALUE (in cm)	STANDARD ERROR	MINIMUM (in cm)	MAXIMUM (in cm)
L1-L2	0.8427	0.20087	0.52	1.40
L2-L3	0.8339	0.20924	0.41	1.24
L3-L4	0.8497	0.24175	0.30	1.43
L4-L5	0.8598	0.25615	0.36	1.44
L5-S1	0.8615	0.28686	0.16	1.62

Table 4
MEAN VALUES OF DISC VOLUME AT DIFFERENT LEVELS.

DISC LEVEL	MEAN VALUE (in cm^3)	STANDARD ERROR	MINIMUM (in cm^3)	MAXIMUM (in cm^3)
L1-L2	7.1716	1.70299	3.90	12.40
L2-L3	8.4525	1.96757	5.40	14.30
L3-L4	8.4786	2.11857	2.54	16.30
L4-L5	8.4441	2.20165	2.86	18.39
L5-S1	14.5973	5.7266	2.54	22.01

Table 5
MEAN VALUE OF RIGHT FACET ANGLE AT DIFFERENT LEVELS.

LEVEL	RIGHT FACET ANGLE	STANDARD DEVIATION	MINIMUM ANGLE	MAXIMUM ANGLE
L1-L2	45.5747	6.23137	33.40	65.50
L2-L3	44.7767	5.77422	33.85	67.53
L3-L4	49.1657	8.11638	35.66	75.23
L4-L5	55.2096	6.74669	40.97	73.64
L5-S1	58.7930	6.50521	44.36	78.38

Table 6
MEAN VALUE OF LEFT FACET ANGLE AT DIFFERENT LEVELS.

LEVEL	LEFT FACET ANGLE	STANDARD DEVIATION	MINIMUM ANGLE	MAXIMUM ANGLE
L1-L2	41.6708	6.62839	31.18	60.13
L2-L3	43.1270	5.19022	34.74	58.90
L3-L4	47.2590	7.05254	25.47	71.73
L4-L5	51.4503	7.35314	35.88	77.04
L5-S1	56.4056	7.87712	43.30	74.57

Table 7
MEAN VALUES OF LFT ON THE RIGHT SIDE AT DIFFERENT LEVELS.

DISC LEVEL	LFT ON THE RIGHT SIDE (in cm)	STANDARD DEVIATION	MINIMUM (in cm)	MAXIMUM (in cm)
L1-L2	0.3259	0.11372	0.10	0.60
L2-L3	0.3333	0.11137	0.12	0.63
L3-L4	0.3759	0.11809	0.10	0.61
L4-L5	0.4549	0.13600	0.15	0.69
L5-S1	0.4807	0.13093	0.15	0.74

LFT was greatest at L5-S1 which is in contrast to that reported in other studies [11–13]. The mean LFT at L4-5 was 4.5 mm on right side and 4.2 cm on left side whereas at L5-S1 it was 4.8 mm on right side and 4.4 mm on left side. According to the study by Horwitz et al. [12] the LF thickness at L4–L5 was 3.8 mm and 3.6 mm at L5–S1. Subhash Kolte et al. [11] also had similar results (L4-5: left-3.84 mm, right-3.70 mm; L5–S1: left-3.78 mm, right-3.65 mm). However, Ramani et al. [15] showed high values upto 6.13 mm as also Spurling et al. [16]. Subhash Kolte et al. [11] stated that the reason for higher values in other studies could be because of the fact that it was conducted in elderly patients.

Table 8
MEAN VALUE OF LFT ON THE LEFT SIDE AT DIFFERENT LEVELS.

DISC LEVEL	LFT ON THE LEFT SIDE (in cm)	STANDARD DEVIATION	MINIMUM (in cm)	MAXIMUM (in cm)
L1-L2	0.3061	0.11296	0.09	0.61
L2-L3	0.3329	0.10567	0.08	0.61
L3-L4	0.3584	0.11857	0.09	0.69
L4-L5	0.4171	0.14729	0.09	0.80
L5-S1	0.4428	0.14617	0.13	0.73

Table 9
FREQUENCY OF FACET TROPISM AT DIFFERENT LEVELS.

DISC LEVEL	MODERATE TROPISM	SEVERE TROPISM
L1-L2	2%	0%
L2-L3	12.9%	0%
L3-L4	9.9%	4%
L4-L5	22.8%	5.9%
L5-S1	17.8%	4.1%

But our series included subjects of all age groups and there was no predominance of a particular age group. Though the average LF thickness was more at L5-S1 than L4-5, the highest frequency of LF hypertrophy (> 4 mm) was seen at L4-5. This could be attributed by the fact that L4-5 segment is hypermobile compared to relatively less mobile L5-S1 due to large transverse process of L5 and the attached iliolumbar ligament [13].

The term LF thickening often refers to buckling of LF due to disc degeneration and subsequent loss of disc height. Both these terms are used interchangeably in literature. Studies [2,13,17] have been conducted to analyse whether LF hypertrophy is a mere increased thickness of LF or is it due to decreased disc height resulting in buckling of LF into the spinal canal. Altinkaya et al. [13] found that the LF thickness was more in patients with higher grades of disc degeneration and concluded that LF thickening seen in MRI is due to buckling of the same. Contrast to this study by Sakamaki et al. [2] showed that LF thickening can occur in the absence of disc degeneration and it is mainly associated with degeneration of the facet joints. They also postulated that LF thickness was more on the side with severe facet joint changes. Studies [2,6] also favor scarring due to inflammation as a potential cause for LF thickening. Our study showed a statistically significant positive correlation of anterior disc height and Pfirrman's grading with LF thickness. Though disc height is a part of Pfirrman's grading system, it is not specific whether it is anterior or posterior disc height as the disc height is not uniform anteroposteriorly. Hence, we analysed each variable separately including disc volume and found that it is the anterior disc height which had a significant correlation with LF thickness.

Studies have shown correlation between facet tropism and disc degeneration, disc prolapse and osteoarthritis of the facet joints which eventually leads to Ligamentum flavum hypertrophy [18,19]. But none of them analysed the relationship between LFT and facet tropism. Our study showed a statistically significant positive correlation between facet tropism and LFT at L5-S1 level and not at other levels though the highest frequency of facet tropism was seen at L4-5.

As per the natural history of disc disease as explained by Kirkaldy Willis et al. [8], reduced disc height because of disc dehydration is the first indication that the degenerative cascade has commenced which can progress to the later stages of instability and facetal and ligamentum flavum hypertrophy ultimately leading to lumbar canal stenosis. This in turn results in neurogenic claudication and neurological deficit. Hence, if the patients are intervened at the stage of reduced anterior disc height or with higher Pfirrman's grade, the progression of disc degeneration can be prevented.

The following are the limitations of this study. The observational

Table 10
DESCRIPTION OF SIGNIFICANT VARIABLES INFLUENCING THE LIGAMENTUM FLAVUM THICKENING.

DISC LEVEL	VARIABLE	STANDARD ERROR	p VALUE	CI (LOWER)	CI (UPPER)
L1-L2	Pfirmanns Grade	0.614	0.003	1.985	21.011
	Anterior Disc Height	1.125	0.003	3.029	248.925
L2-L3	Pfirmanns Grade	0.439	0.002	1.806	13.658
	Anterior Disc Height	1.046	0.001	14.831	163.97
L3-L4	Pfirmanns Grade	0.316	0.002	1.426	4.916
L4-L5	Pfirmanns Grade	0.95	0.001	1.254	5.604
	Anterrior Disc Height	0.902	0.000	4.809	165.253
L5-S1	Presence Of Facet Tropism	0.602	0.0085	0.866	9.171

Significant p value: < 0.05 ; CI : confidence index.

nature of the study conducted at a single point of time prevented us from following up the subjects. Though we demonstrated a statistically significant correlation between anterior disc height and Pfirrmann's grade with Ligamentum flavum hypertrophy, the clinical progression of the degeneration cascade could not be monitored.

5. Conclusion

In conclusion, higher Pfirrmann's grade and decreased anterior disc height may lead to thickening of LF due to buckling at L1-L2, L2-L3, L3-L4, L4-L5 levels. Whereas at L5-S1 level, it is the presence of facet tropism which may cause LFH. Hence, patients with the presence of above mentioned factors at those respective levels have higher preponderance to develop Lumbar canal stenosis due to LF buckling or thickening which can be identified at an early stage to prevent the progression of the same.

Conflict of interest

Nil

Funding received

Nil

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