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Anatomical Dichotomy in Lumbar Degeneration: The Differing Impacts of Intradiscal and Intrafacet Vacuum Phenomena on Paraspinal Musculature and Facet Geometry

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Abstract

Purpose

To investigate the relationship between intradiscal vacuum phenomenon (IVP) and intrafacet vacuum phenomenon (IfVP) with fatty infiltration in the lumbar paraspinal muscles (multifidus, erector spinae, and psoas), and to evaluate their associations with facet joint orientation (FJO) and facet joint degeneration.

Methods

A primary cohort of 208 patients who underwent surgery for lumbar degenerative disorders between 2013 and 2023 was reviewed retrospectively. Preoperative computed tomography (CT) scans were utilized for assessing the presence of IVP and IfVP from L1–L2 to L5–S1 level. Paraspinal muscle fatty infiltration was evaluated on T2-weighted axial magnetic resonance imaging (MRI) using the Goutallier classification. FJO angles were measured on axial CT. To evaluate the direct association between facet joint degeneration and IfVP, a separate secondary cohort of 139 patients treated between 2016 and 2025 was analyzed.

Results

The presence of IVP at the upper lumbar levels (L1–L2, L2–L3, and L3–L4) was significantly associated with higher total FIS for the multifidus, with L2–L3 IVP serving as a significant independent predictor in regression analysis (OR = 1.163, p = 0.015). On a level-by-level basis, the presence of IVP at L3–L4 was significantly associated with increased psoas FIS at the corresponding level (p = 0.026). Conversely, IfVP predominated in the lower lumbar spine. The presence of IfVP at L4–L5 was predictive for higher total and corresponding segmental FIS for the multifidus (p = 0.001, p = 0.021). The presence IfVP at L3–L4 was predictive for higher total and corresponding segmental FIS for the psoas FIS (p = 0.003). The presence of IVP had no association with global FJO. However, the presence of IfVP at L3–L4 and L4–L5 levels was significantly associated with an increased mean FJO angle throughout the lumbar spine (p = 0.007 and p = 0.017, respectively), indicating a more coronal orientation. In the secondary cohort of 139 participants, the presence of IfVP had was significantly associated with increased facet joint degeneration scores at each lumbar level (L1–L2 to L5–S1, p < 0.001), peaking at the lower levels (L5–S1 OR = 2.429).

Conclusion

This study reveals a distinct topographical division in lumbar spine degeneration patterns. Upper lumbar spine degeneration was characterized by IVP which served as a clinical marker for fatty infiltration in the

multifidus at upper lumbar levels. In contrast, lower lumbar spine degeneration was dominated by IfVP which strongly correlated with fatty infiltration in the segmental paraspinal muscles and advanced facet joint osteoarthritis, and structural remodeling toward a more coronal facet orientation. These findings suggest that IfVP could be a reliable radiographic indicator of mechanical instability in the lower lumbar spine.

1. Introduction

The vacuum phenomenon (VP) refers to the accumulation of gas within a joint and is commonly observed in the intervertebral discs of elderly individuals, with a prevalence of up to 21% (intradiscal VP) [1, 2]. Intradiscal VP is associated with spinal instability, as VP-related changes in disc-endplate pressure can lead to low back pain (LBP) [3]. VP can also occur within the facet joints. However, data on intrafacet VP remain limited. Recent studies suggest that intrafacet VP plays a more significant role in spinal instability than intradiscal VP [4]. Moreover, the disappearance of preexisting intrafacet VP has been linked to spinal instability, albeit to a lesser extent than the onset of new intrafacet VP [5].

Paraspinal muscles play a crucial role in maintaining spinal stability [6]. The multifidus stabilizes spinal segments while the erector spinae extend the spine to maintain an upright posture [7]. The psoas contributes to lumbar extension proximally and hip flexion distally. Several studies have reported associations between reduced muscle strength and endurance, increased fat content, and muscle dysfunction in patients with chronic LBP [8–12]. Fatty infiltration impairs the functional capacity of paraspinal muscles since adipose tissue is non-contractile [13]. The multifidus has been particularly implicated in LBP when atrophied or fat-infiltrated [14]. Increased fatty infiltration in the erector spinae has recently been recognized as a radiological marker of LBP [15, 16]. The psoas, conversely, appears to play a compensatory role, with studies showing a larger cross-sectional area in patients with LBP [17, 18].

A recent study reported the association of intradiscal VP with atrophy of the paraspinal muscles, predominantly the multifidus, in patients who were scheduled for lumbar decompression and fusion [6]. It has been depicted that the multifidus atrophy and more than 40% fatty infiltration in the erector spinae were closely associated with facet joint arthritis [19, 20]. However, the relationship between intrafacet VP and fatty infiltration in the paraspinal muscles has not yet been elucidated.

Given these gaps, the present study aimed to determine whether intradiscal and/or intrafacet VP are associated with fatty infiltration in the paraspinal muscles across the entire lumbar spine. In the second phase of the study, we also evaluated their associations with facet joint orientation (FJO) and facet joint degeneration.

2. Methods

Consecutive patients who underwent surgery for degenerative lumbar spine disorders between 2013 and 2023 at a tertiary spine clinic were included in the present study. The data were drawn from a dataset

established to investigate surgical complications of lumbar decompression and fusion surgery. To evaluate the association between facet joint degeneration and IfVP, a second sample of patients was recruited from the database of another tertiary spine clinic treated for degenerative lumbar spine disorders between 2016 and 2025.

Patients meeting the following criteria were excluded: age < 18 year, history of prior spine surgery, absence of magnetic resonance imaging (MRI), history of trauma, spinal or vertebral tumor, spinal infection, lumbarization or sacralization, high-grade spondylolisthesis (Meyerding grade III or higher), neurological or rheumatic disorders, and pregnancy. The institutional review boards approved the study design and datasets (IRB No. 2024/11/846 and 2025-15/08, respectively). Written informed consent was obtained from all participants, and the study protocol complied with the Declaration of Helsinki and its later amendments.

Routine preoperative lumbar spine MRI and computed tomography (CT) scans were obtained. Intradiscal and intrafacet VP were evaluated on lumbar CT scans from L1–L2 to L5–S1 levels. For ease of statistical analysis, only the presence or absence of intradiscal and intrafacet VP was recorded. To assess global VP presence across the lumbar spine, each level with VP (either intradiscal or intrafacet) was scored as “1” if present and “0” if absent. The total intradiscal VP (IVP) score was calculated as the sum of IVP scores at L1–L2, L2–L3, L3–L4, L4–L5, and L5–S1. Similarly, the total intrafacet VP (IfVP) score was calculated as the sum of IfVP scores across the same levels. Facet joint orientation (FJO) angles were measured at each lumbar level (L1–L2 through L5–S1) by one author using a previously described method [21]. The mean FJO angle for each lumbar level and the overall average across the lumbar spine were calculated.

Fatty infiltration in the paraspinal muscles was assessed on T2-weighted axial MRI scans using the Goutallier classification [22], which categorizes fatty infiltration into five grades: Grade 0, normal muscle; Grade 1, fatty streaks; Grade 2, more muscle than fat; Grade 3, equal amounts of muscle and fat; and Grade 4, more fat than muscle. Each grade was converted into numerical scores to facilitate statistical analysis: Grade 0 = 0 points, Grade 1 = 1 point, Grade 2 = 2 points, Grade 3 = 3 points, and Grade 4 = 4 points. The paraspinal muscles (multifidus, erector spinae, and psoas) were evaluated bilaterally from L1–L2 to L5–S1. The average score for each muscle at each level was obtained by summing the right and left values and dividing by two. Total fatty infiltration scores (FISs) were calculated for each muscle group as follows: FIS (L1–L2) + FIS (L2–L3) + FIS (L3–L4) + FIS (L4–L5) + FIS (L5–S1). Patients with VP (intradiscal or intrafacet) at any lumbar level were compared with those without VP in terms of paraspinal muscle FIS at the corresponding lumbar levels and the total FIS for each muscle group.

Body anthropometry was assessed using the subcutaneous fat index (SFI), measured as the vertical distance (in mm) between the base of the spinous process and the skin at the L1–L2 level. The threshold for categorizing overweight was set at 8.45 mm for women and 9.4 mm for men [23].

Spinopelvic parameters (lumbar lordosis [LL], pelvic incidence [PI], pelvic tilt [PT], and sacral slope [SS]) were measured by one author on standing lateral lumbar radiographs. LL was defined as the angle

between the upper endplates of L1 and S1, and pelvic parameters were measured according to established methods using Surgimap software (Globus Medical, Massachusetts, USA) [24].

Facet joint degeneration was evaluated on axial CT scans using the Weishaupt method, adapted from Pathria et al.[25]. The classification was defined as: grade 0 for a normal facet joint space (2–4 mm width); grade 1 for joint space narrowing (< 2 mm), small osteophytes, and/or mild hypertrophy of the articular process; grade 2 for joint space narrowing, moderate osteophytes, moderate hypertrophy of the articular process, and/or mild subarticular bone erosions; and grade 3 for joint space narrowing, large osteophytes, severe hypertrophy of the articular process, severe subarticular bone erosions, and/or subchondral cysts [26]. Facet joint degeneration and the presence of IfVP were evaluated separately by one of the authors in a cohort of 139 participants (69.8% women [n = 97], 30.2% men [n = 42]; mean age: 59.43 ± 13.83 year [range: 19–84 yr]) obtained from the second tertiary spine center's database. The presence of IfVP was recorded as binary data (present or absent). In 139 participants, 36.7% (n: 51) had IfVP at any lumbar level. To facilitate statistical analysis, facet joint degeneration grades were converted into numerical scores (i.e., Grade 0 = 0 points, Grade 1 = 1 point, Grade 2 = 2 points, and Grade 3 = 3 points).

Statistical analyses were performed using SPSS version 20.0 (IBM Corp., Armonk, New York). Dichotomous variables were presented as absolute numbers and percentages, while continuous variables were expressed as mean ± standard deviation. Normality of data distribution was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests. As the data were not normally distributed, non-parametric variables were compared using the Mann–Whitney *U* test. Binary logistic regression analysis was conducted to identify independent associated factors of dependent variables, with results presented as odds ratios (ORs) and 95% confidence intervals (95% CIs). Correlation analyses were performed using Spearman’s rank correlation due to the non-normal distribution of the data. Data retrieval and analyses were conducted by authors not involved in the clinical follow-up of participants. Intra-rater and inter-rater reliability were assessed using two-way mixed intraclass correlation coefficients with 95% CIs, graded according to the Landis and Koch criteria [27]. Intra-rater reliability analyses were conducted for ‘FJO angle’ and ‘facet joint degeneration grading’ using data from 20 randomly selected participants, 4 weeks after the initial assessment.

Intra-rater reliability values for the assessment of intradiscal VP, intrafacet VP, fatty infiltration, LL, PI, PT, and SS were moderate to excellent [28, 29]. Intra-rater reliabilities for the assessment of FJO angle and facet joint degeneration were 0.835 ($p < 0.001$) and 0.986 ($p < 0.001$) respectively. Inter-rater reliability values for intradiscal VP, intrafacet VP, and fatty infiltration were moderate to excellent [28, 29]. A p value < 0.05 was considered statistically significant.

3. Results

Demographics

The first study cohort included 208 participants (151 women [72.6%] and 57 men [27.4%]; mean age, 55.02 ± 11.10 year; range, 18–79 year). The mean SFI was 14.92 mm (range, 1.25–43.34 mm), and 150 participants (72.1%) were classified as overweight based on SFI. The mean values for spinopelvic parameters were as follows: lumbar lordosis (LL): 46.81 ± 15.11° (range, 12°–71.4°); pelvic incidence (PI): 55.26 ± 12.35° (range, 16°–84.6°), pelvic tilt (PT): 19.28 ± 10.16° (range, 0.5°–38°), and sacral slope (SS): 35.97 ± 10.19° (range, 6°–56.9°). Intradiscal VP (IVP) was observed in 11.5%, 18.6%, 21.2%, 35.9%, and 37.8% of patients from L1–L2 through L5–S1, respectively (Fig. 1). Intrafacet VP (IfVP) was present in 3.8%, 10.9%, 21.8%, 32.1%, and 21.8% of patients across the same levels (Fig. 2).

Association between Intradiscal Vacuum Phenomenon and Fatty Infiltration in the Paraspinal Muscles

The presence of IVP at the L1-L2, L2-L3, and L3-L4 levels was significantly associated with higher total FIS for the multifidus compared to those without IVP (10.75 ± 2.91 vs. 9.26 ± 3.19, p = 0.030; 10.77 ± 2.74 vs. 9.12 ± 3.21, p = 0.002; 10.26 ± 2.72 vs. 9.20 ± 3.27, p = 0.031). Regression analysis revealed that total multifidus FIS was significantly associated with the presence of IVP at L2-L3 level (OR = 1.163; 95% CI, 1.030–1.312; *p* = 0.015) but not at L1–L2 (OR = 1.141; 95% CI, 0.991–1.313; *p* = 0.067) or L3–L4 (OR = 1.105; 95% CI, 0.985–1.239; *p* = 0.089). Conversely, the presence of IVP at the lower lumbar levels (L4-L5 and L5-S1) did not demonstrate a statistically significant association with total paraspinal FIS (Table 1).

Table 1
Association between intradiscal vacuum phenomenon and total fatty infiltration scores of the paraspinal muscles throughout the lumbar spine

Lumbar level	Presence of IVP	Total FIS of multifidus	P value	Total FIS of Erector Spinae	P value	Total FIS of Psoas	P value
L1-L2	Absent	9.26 ± 3.19	0.030*	8.67 ± 2.95	0.126	3.79 ± 2.18	0.786
	Present	10.75 ± 2.91		9.66 ± 2.98		4.16 ± 3.07	
L2-L3	Absent	9.12 ± 3.21	0.002*	8.64 ± 3.05	0.055	3.74 ± 2.19	0.363
	Present	10.77 ± 2.74		9.41 ± 2.48		4.27 ± 2.69	
L3-L4	Absent	9.20 ± 3.27	0.031*	8.66 ± 3.05	0.216	3.70 ± 2.22	0.183
	Present	10.26 ± 2.72		9.22 ± 2.64		4.33 ± 2.49	
L4-L5	Absent	9.21 ± 2.94	0.504	8.62 ± 2.66	0.533	3.67 ± 2.24	0.187
	Present	9.81 ± 3.58		9.07 ± 3.44		4.12 ± 2.37	
L5-S1	Absent	9.16 ± 3.29	0.073	8.79 ± 3.14	0.634	3.80 ± 2.28	0.708
	Present	9.87 ± 2.98		8.77 ± 2.66		3.89 ± 2.33	

When evaluating the level-by-level direct associations, the local impact of IVP was less pronounced. The presence of IVP at L3-L4 was significantly associated with an increased segmental FIS for the psoas muscle (1.01 ± 0.57 vs. 0.76 ± 0.62, p = 0.026; OR = 1.890; 95% CI, 1.009–3.541; *p* = 0.047). Segmental FIS for the multifidus at L2-L3 level had a borderline significant trend with the presence of IVP (1.71 ± 0.86 vs. 1.40 ± 0.75, p = 0.050) whereas no other level-specific paraspinal changes reached statistical significance (Table 2).

Table 2
Association between intradiscal vacuum phenomenon and fatty infiltration scores of the paraspinal muscles, analyzed level by level

Lumbar level	Presence of IVP	FIS of multifidus**	P value	FIS of Erector Spinae**	P value	FIS of Psoas**	P value
L1-L2	Absent	1.29 ± 0.75	0.081	1.28 ± 0.68	0.147	0.48 ± 0.66	0.496
	Present	1.55 ± 0.71		1.52 ± 0.77		0.69 ± 0.87	
L2-L3	Absent	1.40 ± 0.75	0.050	1.31 ± 0.69	0.352	0.56 ± 0.63	0.609
	Present	1.71 ± 0.86		1.39 ± 0.65		0.56 ± 0.87	
L3-L4	Absent	1.72 ± 0.87	0.421	1.50 ± 0.81	0.747	0.76 ± 0.62	0.026*
	Present	1.83 ± 0.80		1.47 ± 0.58		1.01 ± 0.57	
L4-L5	Absent	2.24 ± 0.82	0.557	1.96 ± 0.85	0.851	0.99 ± 0.63	0.932
	Present	2.20 ± 0.90		1.98 ± 0.97		1.01 ± 0.61	
L5-S1	Absent	2.68 ± 0.86	0.643	2.73 ± 0.99	0.328	0.92 ± 0.59	0.573
	Present	2.61 ± 0.82		2.56 ± 0.93		0.96 ± 0.57	

Association between Intrafacet Vacuum Phenomenon and Fatty Infiltration in the Paraspinal Muscles

In contrast to the upper lumbar associations observed with IVP, IfVP demonstrated a strong relationship with fatty infiltration in the paraspinal muscles at the lower lumbar levels. Regarding total muscular burden, the presence of IfVP at the L4-L5 level was highly associated with increased total FIS for the multifidus (10.43 ± 2.71 vs. 8.96 ± 3.29, p = 0.001). Additionally, the presence of IfVP at the L3-L4 level was significantly associated with higher total FIS for the psoas (4.83 ± 2.13 vs. 3.56 ± 2.26, p = 0.003). Regression analysis showed that the total FIS for the multifidus and psoas was significantly associated with the presence of IfVP at L4–L5 (OR = 1.154; 95% CI, 1.036–1.285; *p* = 0.009) and L3–L4 (OR = 1.275; 95% CI, 1.075–1.511; *p* = 0.005), respectively. No other significant associations were observed between IfVP and total muscle FIS at other levels (Table 3).

Table 3
Association between intrafacet vacuum phenomenon and total fatty infiltration scores of the paraspinal muscles throughout the lumbar spine

Lumbar level	Presence of IfVP	Total FIS of multifidus	P value	Total FIS of Erector Spinae	P value	Total FIS of Psoas	P value
L1-L2	Absent	9.39 ± 3.18	0.469	8.75 ± 2.98	0.278	3.81 ± 2.28	0.632
	Present	10.41 ± 3.41		9.75 ± 2.56		4.41 ± 2.80	
L2-L3	Absent	9.33 ± 3.18	0.340	8.76 ± 3.03	0.708	3.82 ± 2.29	0.982
	Present	10.21 ± 3.25		8.94 ± 2.44		3.91 ± 2.37	
L3-L4	Absent	9.31 ± 3.27	0.306	8.65 ± 3.13	0.119	3.56 ± 2.26	0.003*
	Present	9.83 ± 2.87		9.26 ± 2.23		4.83 ± 2.13	
L4-L5	Absent	8.96 ± 3.29	0.001*	8.57 ± 3.13	0.074	3.70 ± 2.26	0.273
	Present	10.43 ± 2.71		9.25 ± 2.53		4.13 ± 2.35	
L5-S1	Absent	9.31 ± 3.30	0.164	8.81 ± 3.10	0.770	3.89 ± 2.32	0.606
	Present	9.83 ± 2.74		8.69 ± 2.45		3.61 ± 2.20	

On level-by-level analysis, the presence of IfVP at L4-L5 level was directly and significantly associated with fatty infiltration in the multifidus at the corresponding level (2.45 ± 0.82 vs. 2.12 ± 0.85, p = 0.021; OR = 1.528; 95% CI, 1.028–2.272; *p* = 0.036). The presence of IfVP at L3-L4 level was significantly associated with increased segmental FIS for the psoas at the corresponding level (1.10 ± 0.54 vs. 0.74 ± 0.62, p = 0.003; OR = 2.596; 95% CI, 1.359–4.961; *p* = 0.004). Level-specific fatty infiltration in the erector spinae muscle was not significantly influenced by the presence of IfVP at any lumbar level (Table 4).

Table 4
Association between intrafacet vacuum phenomenon and fatty infiltration scores of the paraspinal muscles, analyzed level by level

Lumbar level	Presence of IfVP	FIS of multifidus**	P value	FIS of Erector Spinae**	P value	FIS of Psoas**	P value
L1-L2	Absent	1.31 ± 0.73	0.877	1.31 ± 0.70	0.825	0.50 ± 0.65	0.807
	Present	1.50 ± 1.22		1.33 ± 0.51		0.75 ± 1.40	
L2-L3	Absent	1.47 ± 0.78	0.309	1.35 ± 0.71	0.319	0.55 ± 0.66	0.883
	Present	1.35 ± 0.78		1.14 ± 0.38		0.61 ± 0.83	
L3-L4	Absent	1.68 ± 0.83	0.222	1.45 ± 0.76	0.106	0.74 ± 0.62	0.003*
	Present	1.95 ± 0.94		1.66 ± 0.76		1.10 ± 0.54	
L4-L5	Absent	2.12 ± 0.85	0.021*	1.98 ± 0.90	0.961	0.99 ± 0.65	0.735
	Present	2.45 ± 0.82		1.95 ± 0.88		1.02 ± 0.56	
L5-S1	Absent	2.66 ± 0.85	0.880	2.71 ± 1.02	0.203	0.94 ± 0.58	0.727
	Present	2.63 ± 0.80		2.50 ± 0.73		0.94 ± 0.57	

Correlation Analysis of Degenerative Markers and Facet Morphology

Bivariate correlation analysis confirmed a significant interplay between global spine VP and paraspinal muscle quality. Total multifidus FIS demonstrated a significant, positive correlation with both total IVP scores ($r = 0.213$, $p < 0.01$) and total IfVP scores ($r = 0.220$, $p < 0.01$). Additionally, total multifidus FIS was moderately correlated with total erector spinae FIS ($r = 0.528$, $p < 0.01$) and weakly correlated with total psoas FIS ($r = 0.162$, $p < 0.05$). Regarding morphological parameters, the mean FJO angle had no associations with total FIS and total IVP scores. However, the mean FJO angle was positively correlated with the total IfVP score ($r = 0.239$, $p < 0.01$, Table 5).

Table 5
Correlation between vacuum phenomenon, FJO angle and fatty infiltration in the paraspinal muscles

Total multifidus FIS	**Total multifidus FIS**	**Total erector spinae FIS**	**Total psoas FIS**	**Total IVP score**	**Total IfVP score**	**Mean FJO angle**
	N/A	**0.528****	**0.162***	**0.213****	**0.220****	**0.116**
Total erector spinae FIS	0.528**	N/A	0.362**	0.124	0.157	0.099
Total psoas FIS	0.162*	0.362**	N/A	0.120	0.109	0.013
Total IVP score	0.213**	0.124	0.120	N/A	0.188**	-0.099
Total IfVP score	0.220**	0.157	0.109	0.188**	N/A	0.239**
Mean FJO angle	0.116	0.099	0.013	-0.099	0.239**	N/A

Association between Intradiscal Vacuum Phenomenon and Facet Joint Orientation

When analyzing the mean FJO angle throughout the lumbar spine, no statistically significant differences were observed based on the presence or absence of IVP at any specific lumbar level (Table 6). In the segment-by-segment analysis, the presence of IVP demonstrated only isolated segmental associations with FJO angle. Particularly, the presence of IVP at the L3-L4 level was significantly associated with a smaller FJO angle at L2-L3 level (48.27 ± 6.87^{o} vs. 51.26 ± 7.04^{o}, $p = 0.016$). Conversely, the presence of IVP at L5-S1 level was significantly associated with a larger FJO angle at the L3-L4 level (50.22 ± 6.96^{o} vs. 47.74 ± 8.68^{o}, $p = 0.040$). No other individual lumbar level FJO angle configurations reached statistical significance in relation to IVP presence (Table 7).

Table 6
Distribution of mean facet joint orientation angle thorough the whole lumbar spine among the participants according to presence/absence of intradiscal vacuum phenomenon

IVP evaluation level	Presence of IVP	Mean FJO angle (º)	P value
L1-L2	Absent	48.41 ± 5.21	0.323
	Present	47.16 ± 5.58	
L2-L3	Absent	48.35 ± 5.11	0.761
	Present	48.04 ± 6.04	
L3-L4	Absent	48.53 ± 5.27	0.198
	Present	47.34 ± 5.07	
L4-L5	Absent	48.75 ± 5.27	0.091
	Present	47.45 ± 5.12	
L5-S1	Absent	47.97 ± 5.52	0.198
	Present	48.97 ± 4.61	

Table 7
Distribution of facet joint orientation angle at each lumbar level among the participants according to presence/absence of intradiscal vacuum phenomenon

IVP evaluation level	Lumbar level of FJO angle	Presence of IVP	FJO angle (º)	P value
L1-L2	L1-L2	Absent	51.06 ± 6.87	0.998
		Present	50.65 ± 6.28	
	L2-L3	Absent	50.89 ± 7.11	0.243
		Present	48.62 ± 6.66	
	L3-L4	Absent	48.81 ± 8.36	0.097
		Present	46.14 ± 6.33	
	L4-L5	Absent	45.10 ± 8.76	0.815
		Present	45.00 ± 10.34	
	L5-S1	Absent	46.22 ± 8.68	0.602
		Present	45.41 ± 9.24	
L2-L3	L1-L2	Absent	51.29 ± 6.58	0.180
		Present	49.54 ± 7.92	
	L2-L3	Absent	51.01 ± 6.92	0.125
		Present	48.91 ± 7.82	
	L3-L4	Absent	48.51 ± 8.18	0.833
		Present	48.85 ± 8.56	
	L4-L5	Absent	45.08 ± 8.72	0.980
		Present	45.13 ± 9.93	
	L5-S1	Absent	45.85 ± 8.94	0.250
		Present	47.78 ± 7.30	
L3-L4	L1-L2	Absent	51.33 ± 6.79	0.178
		Present	49.72 ± 6.84	
	L2-L3	Absent	51.26 ± 7.04	0.016*
		Present	48.27 ± 6.87	
	L3-L4	Absent	48.83 ± 8.14	0.343
		Present	47.45 ± 8.55	

IVP evaluation level	Lumbar level of FJO angle	Presence of IVP	FJO angle (º)	P value
	L4-L5	Absent	45.01 ± 9.06	0.786
		Present	45.44 ± 8.21	
	L5-S1	Absent	46.22 ± 8.94	0.792
		Present	45.82 ± 7.82	
L4-L5	L1-L2	Absent	51.61 ± 7.02	0.087
		Present	49.91 ± 6.30	
	L2-L3	Absent	51.19 ± 7.17	0.154
		Present	49.72 ± 6.89	
	L3-L4	Absent	48.84 ± 8.52	0.507
		Present	48.04 ± 7.64	
	L4-L5	Absent	45.40 ± 8.81	0.487
		Present	44.50 ± 9.07	
	L5-S1	Absent	46.69 ± 8.74	0.212
		Present	45.10 ± 8.64	
L5-S1	L1-L2	Absent	50.42 ± 7.19	0.071
		Present	52.23 ± 5.83	
	L2-L3	Absent	50.45 ± 7.30	0.497
		Present	51.16 ± 6.66	
	L3-L4	Absent	47.74 ± 8.68	0.040*
		Present	50.22 ± 6.96	
	L4-L5	Absent	44.58 ± 9.03	0.240
		Present	46.12 ± 8.57	
	L5-S1	Absent	46.66 ± 9.29	0.190
		Present	45.10 ± 7.37	

Association between Intrafacet Vacuum Phenomenon and Facet Joint Orientation

The presence of an IfVP demonstrated a more widespread and statistically significant relationship with FJO angle. On a global level, the presence of IfVP at L3-L4 and L4-L5 levels was significantly associated with an increased mean FJO angle throughout the lumbar spine (50.12 ± 4.63^{o} vs. 47.77 ± 5.31^{o}, p =

0.007; 49.61 ± 5.62^{o} vs. 47.73 ± 4.99^{o}, p = 0.017; respectively, Table 8). Level-specific analyses revealed that IfVP was consistently linked to significantly larger (more coronal) FJO angles at adjacent or lower lumbar segments: The presence of IfVP at L1-L2 level was associated with a significantly larger FJO angle at L4-L5 (54.75 ± 8.93^{o} vs. 44.75 ± 8.72^{o}, p = 0.009) and L5-S1 (53.11 ± 5.09^{o} vs. 45.90 ± 8.72^{o}, p = 0.018). The presence of IfVP at L3-L4 level was associated with larger FJO angles at L3-L4 (50.79 ± 8.35^{o} vs. 47.91 ± 8.09^{o}, p = 0.034), L4-L5 (47.65 ± 8.45^{o} vs. 44.34 ± 8.90^{o}, p = 0.025), and L5-S1 levels (49.01 ± 8.06^{o} vs. 45.31 ± 8.74^{o}, p = 0.010). The presence of IfVP at L4-L5 level was associated with significantly larger FJO angles at L3-L4 (50.96 ± 9.21^{o} vs. 47.52 ± 7.55^{o}, p = 0.005), and L4-L5 levels (47.61 ± 9.12^{o} vs. 44.00 ± 8.59^{o}, p = 0.007). No significant structural differences in FJO angle were noted in relation with the presence of IfVP at L2-L3 or L5-S1 levels (Table 9).

Table 8
Distribution of mean facet joint orientation angle thorough the whole lumbar spine among the participants according to presence/absence of intrafacet vacuum phenomenon

IfVP evaluation level	Presence of IfVP	Mean FJO angle (^{o})	P value
L1-L2	Absent	48.18 ± 5.26	0.077
	Present	51.74 ± 3.77	
L2-L3	Absent	48.17 ± 5.17	0.280
	Present	49.48 ± 5.88	
L3-L4	Absent	47.77 ± 5.31	0.007*
	Present	50.12 ± 4.63	
L4-L5	Absent	47.73 ± 4.99	0.017*
	Present	49.61 ± 5.62	
L5-S1	Absent	48.08 ± 5.33	0.193
	Present	49.30 ± 4.80	

Table 9
Distribution of facet joint orientation angle at each lumbar level among the participants according to presence/absence of intrafacet vacuum phenomenon

IfVP evaluation level	Lumbar level of FJO angle	Presence of IfVP	FJO angle (º)	P value
L1-L2	L1-L2	Absent	51.03 ± 6.81	0.964
		Present	50.78 ± 7.37	
	L2-L3	Absent	50.72 ± 7.11	0.752
		Present	49.45 ± 6.75	
	L3-L4	Absent	48.49 ± 8.33	0.322
		Present	50.62 ± 3.37	
	L4-L5	Absent	44.75 ± 8.72	0.009*
		Present	54.75 ± 8.93	
	L5-S1	Absent	45.90 ± 8.72	0.018*
		Present	53.11 ± 5.09	
L2-L3	L1-L2	Absent	51.05 ± 6.64	0.934
		Present	50.79 ± 8.37	
	L2-L3	Absent	50.65 ± 6.65	0.936
		Present	50.97 ± 10.44	
	L3-L4	Absent	48.36 ± 8.30	0.186
		Present	50.33 ± 7.35	
	L4-L5	Absent	44.94 ± 9.01	0.587
		Present	46.42 ± 7.87	
	L5-S1	Absent	45.84 ± 8.84	0.097
		Present	48.88 ± 7.19	
L3-L4	L1-L2	Absent	51.01 ± 6.88	0.974
		Present	51.05 ± 6.65	
	L2-L3	Absent	50.27 ± 6.73	0.166
		Present	52.09 ± 8.13	
	L3-L4	Absent	47.91 ± 8.09	0.034*
		Present	50.79 ± 8.35	

IfVP evaluation level	Lumbar level of FJO angle	Presence of IfVP	FJO angle (º)	P value
	L4-L5	Absent	44.34 ± 8.90	0.025*
		Present	47.65 ± 8.45	
	L5-S1	Absent	45.31 ± 8.74	0.010*
		Present	49.01 ± 8.06	
L4-L5	L1-L2	Absent	51.05 ± 6.88	0.937
		Present	50.96 ± 6.71	
	L2-L3	Absent	50.41 ± 6.97	0.395
		Present	51.32 ± 7.37	
	L3-L4	Absent	47.52 ± 7.55	0.005*
		Present	50.96 ± 9.21	
	L4-L5	Absent	44.00 ± 8.59	0.007*
		Present	47.61 ± 9.12	
	L5-S1	Absent	45.68 ± 8.72	0.243
		Present	47.22 ± 8.67	
L5-S1	L1-L2	Absent	50.98 ± 6.88	0.867
		Present	51.19 ± 6.59	
	L2-L3	Absent	50.59 ± 7.23	0.679
		Present	51.11 ± 6.50	
	L3-L4	Absent	48.22 ± 8.32	0.206
		Present	50.09 ± 7.67	
	L4-L5	Absent	44.86 ± 8.94	0.425
		Present	46.13 ± 8.67	
	L5-S1	Absent	45.73 ± 8.91	0.150
		Present	47.99 ± 7.62	

Correlation between Fatty Infiltration in the Paraspinal Muscles and Facet Joint Orientation

To determine if overall muscular degradation correlated directly with bony facet architecture, a bivariate correlation analysis was executed between total paraspinal muscle FIS and individual segmental FJO angles. The analysis demonstrated no statistically significant correlation across any of the evaluated

lumbar levels. Total FIS for the multifidus, erector spinae, and psoas muscles varied independently of the facet joint angles throughout whole lumbar spine showing that overall muscular fat volume was not directly correlated to static segmental facet orientation (Table 10).

Table 10
Correlation between fatty infiltration in the paraspinal muscles and facet joint orientation angle at each lumbar level

Lumbar level	Paraspinal muscle*	Correlation	P value
L1-L2	Multifidus	-0.018	0.826
	Erector spinae	-0.122	0.127
	Psoas	-0.045	0.573
L2-L3	Multifidus	0.077	0.338
	Erector spinae	0.020	0.801
	Psoas	-0.081	0.312
L3-L4	Multifidus	0.087	0.277
	Erector spinae	0.111	0.165
	Psoas	-0.013	0.872
L4-L5	Multifidus	0.084	0.293
	Erector spinae	0.114	0.155
	Psoas	0.076	0.345
L5-S1	Multifidus	0.126	0.115
	Erector spinae	0.111	0.167
	Psoas	0.075	0.349

Association between Facet Joint Degeneration and Intrafacet Vacuum Phenomenon

Across every single lumbar level (from L1-L2 down to L5-S1) and in the cumulative total, there was a highly statistically significant association between the presence of IfVP and higher facet joint degeneration scores. For both groups (those with and without IfVP), the average degeneration scores generally increased down the lumbar spine, peaking at L4-L5 and L5-S1. The presence of IfVP at the L5-S1 level carried the highest odds ratio (OR = 2.429, Table 11).

Table 11
Association between facet joint degeneration and intrafacet vacuum phenomenon

Lumbar level	Status of IfVP	Facet joint degeneration score*	P value	OR (95% CI)	P value
L1-L2	Absent	1.05 ± 0.91	0.013**	1.614 (1.110–2.346)	0.012**
	Present	1.48 ± 0.98			
L2-L3	Absent	0.89 ± 0.86	< 0.001**	2.096 (1.424–3.084)	< 0.001**
	Present	1.56 ± 1.04			
L3-L4	Absent	1.00 ± 0.98	< 0.001**	2.227 (1.538–3.226)	< 0.001**
	Present	1.83 ± 0.99			
L4-L5	Absent	1.18 ± 1.08	< 0.001**	2.119 (1.489–3.016)	< 0.001**
	Present	2.06 ± 1.05			
L5-S1	Absent	1.28 ± 1.04	< 0.001**	2.429 (1.650–3.576)	< 0.001**
	Present	2.21 ± 0.91			
Total	Absent	5.41 ± 4.10	< 0.001**	1.236 (1.126–1.358)	< 0.001**
	Present	9.15 ± 4.19			

4. Discussion

The intervertebral discs, facet joints, and paraspinal muscles synergistically maintain spinal stability. The presence of VP within the intervertebral discs and facet joints, as well as fatty infiltration or atrophy of the paraspinal muscles, can impair spinal stability and contribute to low back pain (LBP) [3, 4, 30]. Growing evidence underscores the association between intradiscal VP (IVP) and fatty infiltration or degeneration of the paraspinal muscles [6, 20]. Even though intrafacet VP has gained attention in recent years, its role in spinal stability and its association with paraspinal muscle fatty infiltration remain less understood compared to IVP [31].

Main Findings & Anatomical Dichotomy

The present study revealed a distinct anatomical division in the pattern of lumbar spine degeneration regarding fatty infiltration in the paraspinal musculature and the onset of vacuum phenomena. The upper lumbar spine was primarily vulnerable to IVP, which was heavily linked to upper lumbar multifidus fatty infiltration. Conversely, the lower lumbar segments were predominantly characterized by IfVP, which demonstrated a strong association with local paraspinal muscle fatty infiltration and structural remodeling of the facet joints (i.e., becoming more coronally oriented). The presence of IVP in the upper lumbar intervertebral discs (L1–L2 to L3–L4) demonstrated a significant correlation with total multifidus fatty infiltration, with the L2–L3 level emerging as the most robust statistical predictor. On a strict level-

by-level basis, the presence of IVP at L3–L4 level was uniquely associated with severe segmental fatty infiltration in the psoas rather than the multifidus. Concurrently, the presence of IfVP in the mid-to-lower lumbar segments (L3–L4 and L4–L5) was predictive of increased cumulative fatty infiltration in both the multifidus and psoas musculature. Locally, an IfVP at L4–L5 was associated with severe fatty infiltration of the multifidus at that exact level, whereas an IfVP at L3–L4 correlated with severe fatty infiltration of the local psoas.

The relationship between IVP and paraspinal muscular degeneration remains less thoroughly characterized than its associations with structural osteodegenerative changes. The number of studies addressing this issue is limited, and their evaluations of the paraspinal muscles have focused only on specific lumbar levels, most notably L4–L5 [6, 20]. Camino-Willhuber et al. [6] found that IVP severity score, measured as the total score of the entire lumbar spine, positively correlated with fatty infiltration in the paraspinal muscles. This correlation was stronger for the multifidus than the erector spinae, whereas no correlation was observed with fatty infiltration in the psoas muscle. Similarly, Hambrecht et al. [20] demonstrated that a fatty infiltration rate greater than 40% in the erector spinae was highly correlated with a higher combined vacuum severity score. In contrast to a continuous score assessment, the simple presence or absence of IVP in the upper intervertebral discs was strongly associated with a higher total multifidus fatty infiltration score (FIS), with L2–L3 serving as the strongest predictor. While prior studies focused strictly on cumulative scores at isolated levels [6, 20], our level-by-level approach revealed that an IVP at L3–L4 uniquely predicted severe localized fatty infiltration in the psoas rather than the multifidus.

Pathophysiology of Intradiscal Vacuum Phenomenon

The intervertebral disc, together with the bilateral facet joints, forms a three-joint complex responsible for both load-bearing support and segmental spinal flexibility [32]. The intervertebral disc consists of the outer annulus fibrosus and the inner nucleus pulposus, both enclosed by a cartilage endplate [33]. The annulus fibrosus is a dense, fibrotic outer ring composed of 50–70% collagen, 20% proteoglycans, and 2% elastin. In contrast, the central nucleus pulposus is a fluid-rich core primarily containing water, 35–65% proteoglycans, 5–20% type II collagen, elastin, and non-collagenous proteins. Capping these structures is the cartilage endplate, a 0.6-mm-thick layer of hyaline cartilage. This endplate serves as a mechanical barrier separating the nucleus pulposus from the adjacent vertebrae, while its capillary network facilitates nutrient delivery and waste removal for the former [34–36]. Intervertebral disc degeneration (IVDD) is driven by an interplay of aging, genetics, lifestyle factors, and mechanical stress, which collectively disrupt the disc's biomechanical homeostasis and impair resident cell function. Consequent extracellular matrix degradation leads to a loss of proteoglycans and a phenotypic shift from type II to type I collagen within the nucleus pulposus, thereby diminishing its swelling capacity and structural resilience. This cellular stress cascade activates inflammatory and catabolic signaling pathways, causing reactive oxygen species (ROS) to accumulate and accelerate tissue breakdown. Given that the disc features minimal vascularity and a limited progenitor cell pool, its capacity for self-repair is severely restricted; this drives progressive annulus fibrosus and cartilaginous endplate damage that

eventually exposes the nucleus pulposus to the systemic environment. This exposure incites an autoimmune reaction, neural ingrowth, and aberrant vascularization, ultimately culminating in discogenic low back pain (LBP)—the leading cause of disability worldwide [37–44]. As this microstructural matrix collapse progresses, it physically manifests as the macro-level cracks and compressible clefts that characterize the vacuum phenomenon. As these spaces expand under spinal motion, they activate the physical mechanisms governed by Henry's and Boyle's laws [45]. When an enclosed tissue space expands in response to an external impact, the volume increases, and pressure decreases (Boyle's Law). Reduced pressure decreases gas solubility (Henry's Law), resulting in gas accumulation—mainly nitrogen—within the space [46–48]. Individuals with LBP exhibit greater shear, compressive, and torsional forces at the lower lumbar levels (L3–S1) compared to healthy individuals [49]. The L4 and L5 vertebrae are most frequently affected by lumbar instability [50, 51], and intradiscal VP is commonly observed at these lower levels [1]. We found that IVP was most frequent at L4-L5 and L5-S1 levels (35.9%, and 37.8%, respectively).

Intrafacet Vacuum Phenomenon and Segmental Instability

The lumbar facet joints are paired zygapophyseal joints—the only synovial joints of the spine—articulating between adjacent vertebral levels [52–54]. These joints facilitate flexion, extension, and rotation movements of the lumbar spine [52, 55, 56]. Facet joint degeneration increases with age, reaching a prevalence of 89.2% among individuals aged 60–69 year [57]. Facet joint-related LBP accounts for 7.7%–75% of cases and represents the second most common cause treated by interventional pain management [58, 59]. The facet joints play a central role within the mobile segment of the spine [19]. The intervertebral disc, facet joints, and paraspinal muscles function in a coordinated manner to ensure stability. While the disc resists compression, it is less equipped to counteract axial rotation. Therefore, the vertebral bodies and intervertebral discs depend on the posterior elements—including the facet joints, ligaments, and posterior paraspinal muscles (multifidus and erector spinae)—for stability during axial rotation [60]. During flexion, the inferior articular processes glide over the superior articular processes until tension in the joint capsule limits further motion [60, 61]. The axis of this motion lies within the disc below the moving vertebra [62].

Several studies have discussed the relationship between facet joint arthritis and paraspinal muscle fatty infiltration or atrophy [19, 20, 63–65]. Understanding this relationship requires knowledge of the innervation patterns of these structures. The dorsal rami of the lumbar spinal nerves divide into medial, intermediate, and lateral branches. The medial branch innervates both the facet joints and the multifidus, while the intermediate and lateral branches supply the erector spinae [60, 66]. The psoas muscle, innervated by the ventral rami of L1–L4, exhibits a segmental structure similar to the posterior paraspinal muscles [67]. Yu et al. [65] proposed two mechanisms through which facet joint arthritis may affect the multifidus: (1) impairment of the shared innervation via the medial branch of the dorsal ramus and (2) secretion of proinflammatory cytokines leading to muscle atrophy. However, the latter theory has been disputed [19]. Although IfVP has been presumed to accompany facet osteoarthritis, direct evidence remains limited [68]. In the present study, using a distinct cohort of patients with chronic LBP, we

demonstrated a strong, significant association between facet joint arthropathy and the presence of IfVP, which was most pronounced at the L5-S1 level. Specifically, IfVP occurred most frequently at the L4-L5 level (32.1%) in the main cohort. Given that degenerative spondylolisthesis, for which facet degeneration is considered a key factor, most commonly occurs at L4–L5 [69], our findings of a higher prevalence of IfVP at this level may indicate a potential association with degenerative spondylolisthesis. Our data strongly suggest that IfVP could serve as a reliable radiographic marker for severe facet joint degeneration. Because the odds ratios and mean scores were particularly high in the lower lumbar spine (L3 to S1 levels), clinical focus and therapeutic interventions regarding IfVP-related degeneration were most critical at these lower, heavy weight-bearing levels. We also identified a correlation between the FIS of the multifidus and VP severity. The multifidus accounts for over two-thirds of lumbar spine stiffness in the neutral zone [70]. It is a short, thick muscle with deep fibers spanning two vertebral levels and superficial fibers spanning three to five [71, 72]. The deep fibers primarily maintain segmental stability [73]. Fatty infiltration in the multifidus was positively correlated with the severity of both IVP and IfVP, underscoring how muscular degeneration compromises its critical stabilizing role.

Biomechanical Implications on Paraspinal Musculature

As noted above, local muscle degeneration at L3–L4 and L4–L5 is heavily driven by regional biomechanics. Given that the L3–L4 intervertebral disc forms the apex of lumbar lordosis, it bears unique axial loads that demand substantial systemic and muscular resilience; thus, a systemic depletion in muscle reserve/bone density likely manifests early as localized psoas degeneration at this highly stressed biomechanical pivot [74–76]. Mechanically, the psoas muscle exerts a dual effect, driving hip flexion caudally and lumbar extension cranially; additionally, it serves as a reliable clinical proxy for whole-body muscle reserve, with established links to osteoporosis [77, 78]. This regional biomechanical profile is supported by historical data from Bogduk et al., who demonstrated that posterior paraspinal muscles exert their maximum posterior shear force at the L3–L4 level. Interestingly, this dynamic reverses into an anterior shear force at the L5–S1 level, thereby imposing substantial mechanical demands on the lumbosacral junction, the L4–L5 disc, and the adjacent facet joints. Similar to L3–L4, the L4–L5 segment aligns closely with the body's center of gravity and is pivotal for daily functional kinetics. The center of rotation for the L4–L5 segment shifts from 75% posterior to the anterior disc border during flexion to 92% during extension. Consequently, functional failure of the multifidus, a premier segmental stabilizer, parallels the mechanical failure patterns observed in facet joint at L4–L5, suggesting these degenerative changes may work synergistically to exacerbate low back complaints. A reciprocal, compensatory relationship between the multifidus and psoas muscles at the L4–L5 level to neutralize early degenerative changes has been proposed formerly [18]. Ultimately, this intricate structural interplay between the multifidus, psoas, and facet joints warrants validation through future biomechanical and finite element analyses (Fig. 3).

Facet Joint Geometry and Orientation

On a global scale, IVP exhibited no substantial correlation with the FJO angle, demonstrating only sparse, inconsistent adjacent-level alterations. Conversely, a widespread and highly significant association was observed between IfVP and the FJO angle; the presence of an IfVP at either L3–L4 or L4–L5 was linked to a significantly increased FJO angle throughout the entire lumbar spine, indicating a more coronal orientation.

Prior literature regarding facet orientation remains highly inconsistent, with historical data linking both sagittal and coronal alignments to facet osteoarthritis [79–81]. While several studies suggest that facet arthropathy and paraspinal muscle infiltration are predominantly tied to sagittally oriented joints [81, 82], our data revealed the opposite pattern. In the present study, IfVP occurred significantly more frequently in participants with coronally aligned joints, whereas IVP favored a sagittal configuration. Interestingly, we observed no significant association between facet joint orientation and paraspinal muscle fatty infiltration, a discrepancy that likely reflects distinct cohort characteristics and disease stages. Nonetheless, to the best of our knowledge, this remains the first study to report a direct, positive correlation between the mean FJO angle and IfVP severity.

Limitations & Strengths

The present study has several limitations. As this was a cross-sectional analysis of retrospective databases, a cause-and-effect relationship cannot be established. Future biomechanical studies are necessary to validate our hypotheses regarding the interactions between VP and fatty infiltration in the paraspinal muscles. Many patients had incomplete data regarding bone mineral density and lifestyle factors; therefore, potential associations between these variables, VP, and paraspinal muscle degeneration could not be determined.

Ethnic variation may influence fatty infiltration patterns in the paraspinal muscles. For example, Korean, Hungarian, and Finnish populations exhibit higher fatty infiltration rates in the erector spinae, whereas the Swiss population demonstrates greater fatty infiltration in the multifidus [83–86]. In the present study, all participants were from a single geographic region with relatively homogeneous ethnicity. Consequently, the findings may not be generalizable to populations with different ethnic backgrounds.

Additionally, the absence of long-cassette plain radiographs prevented us from assessing potential associations between sagittal or coronal alignment and VP or paraspinal muscle characteristics.

We evaluated the associations of VP with paraspinal muscle fatty infiltration in one cohort, and facet joint degeneration with IfVP in a separate cohort. While comparing different cohorts could be seen as a bias, the distinct objectives of each analysis ensured that the integrity of the overall findings was not compromised. A major strength of this study is that it is the first to evaluate both intradiscal and intrafacet VP in relation to fatty infiltration of the paraspinal muscles across all lumbar levels, both globally and on a level-by-level basis. We also clearly demonstrated an association between facet joint degeneration and IfVP.

5. Conclusion

This study demonstrates a distinct anatomical compartmentalization in lumbar spine degeneration patterns relative to VP and paraspinal muscle degeneration. While the upper lumbar segments were primarily vulnerable to IVP, serving as a key surrogate for upper lumbar multifidus fatty infiltration, the lower lumbar spine was predominantly characterized by IfVP. The presence of IfVP was strongly associated with lower lumbar paraspinal muscle fatty infiltration and a structural shift of the facet joints toward a more coronal orientation. Furthermore, a highly significant correlation existed between IfVP and advanced facet joint arthropathy, particularly at the caudal, heavy weight-bearing levels (L3–L4 to L5–S1). These insights underscored that IfVP constitutes a reliable radiographic indicator of mechanical instability and localized structural failure, emphasizing the need for a comprehensive evaluation of the spinal multi-joint complex—discs, facet joints, and paraspinal musculature—in the management of degenerative lumbar disorders.

Declarations

Competing Interests

Authors declare that they have no conflict of interest related to the current study content. Murat Şakir EKŞİ, M.D. receives honorarium from Elsevier.

Author Contribution

EEÖE, MŞE, MK, RR, EZ, AB, ÖE, YAG, MAR, and AA retrieved the data; EEÖE and MŞE wrote the manuscript; AEA, DK, and TK prepared the figures and the tables; MŞE made the statistical analyses, EEÖE and MŞE supervised the study, all authors reviewed and approved the final version of the manuscript. The study has been completed under the auspices of the Istanbul Spine Study Group.

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Figures

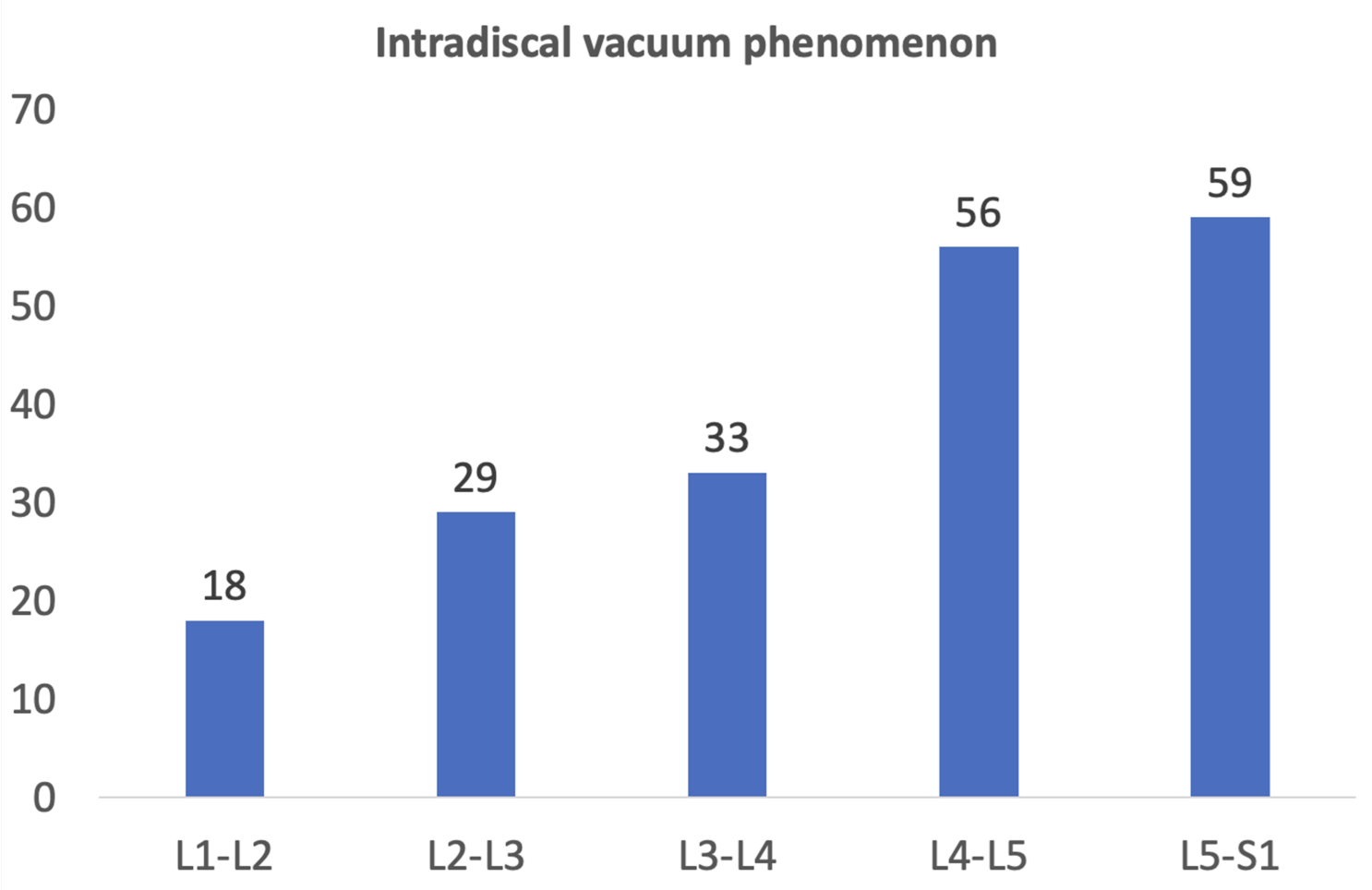


Figure 1

Frequency of intradiscal vacuum phenomenon (IVP) at each lumbar level.

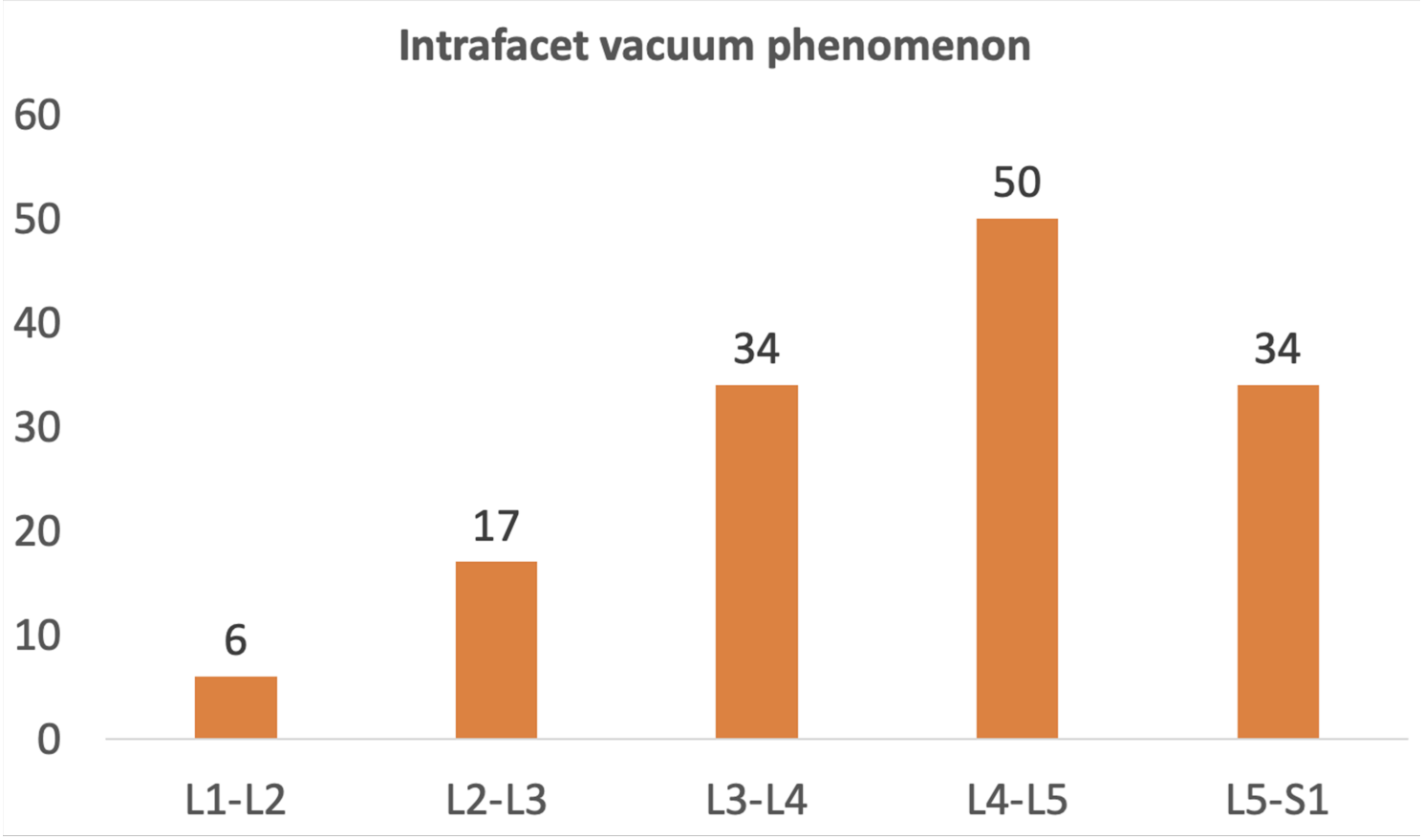


Figure 2

Frequency of intrafacet vacuum phenomenon (IfVP) at each lumbar level.

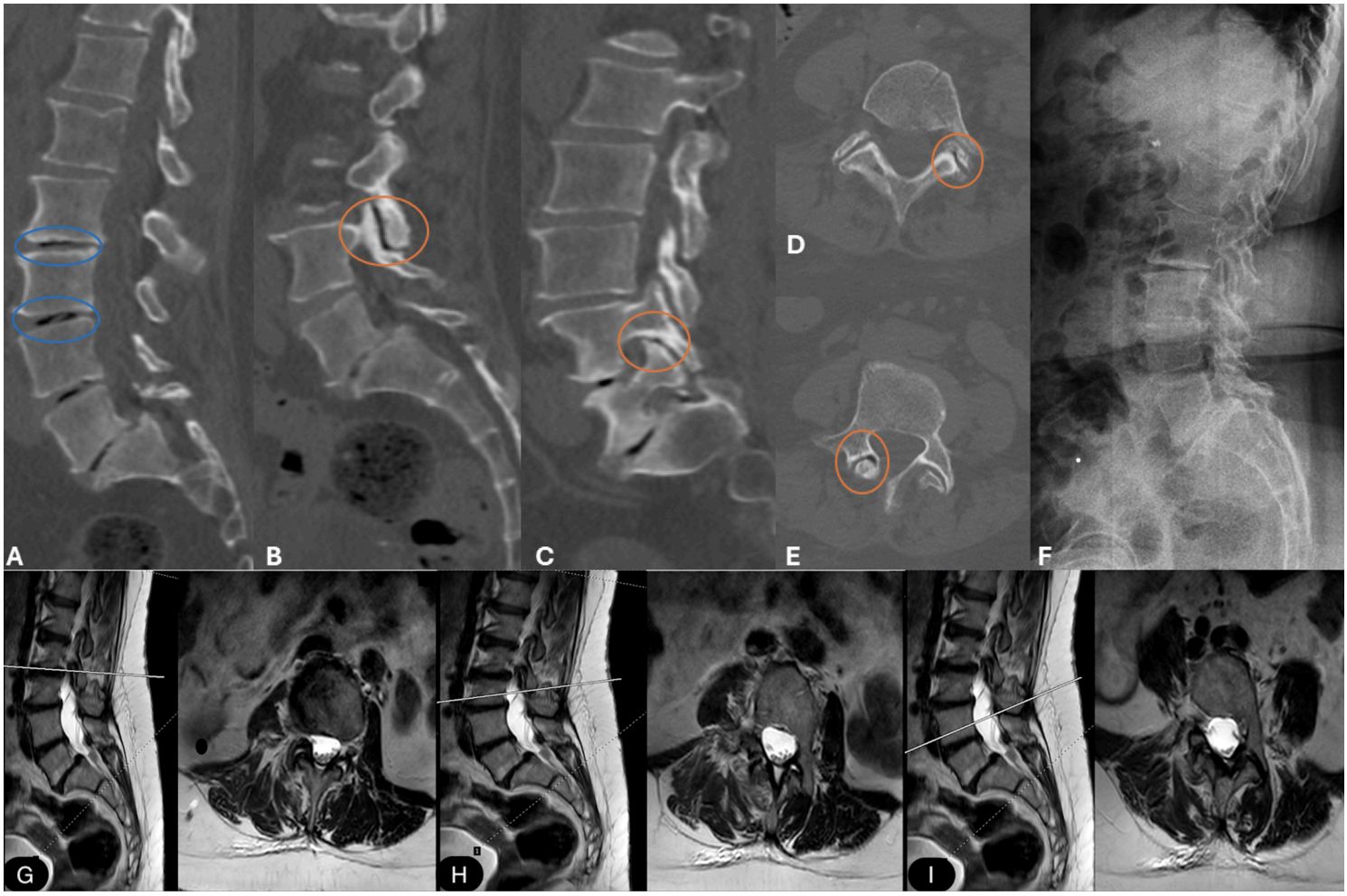


Figure 3

A 58-year-old female patient was admitted with low back pain and right leg pain. CT revealed intradiscal vacuum phenomena at L2–3, L3–4, L4-L5 and L5-S1 levels (A). There were intrafacet vacuum phenomena at L3–4 (B), L4–5 and L5-S1 levels (C). Intrafacet vacuum phenomenon was detected at left-sided facet joint at L3–4 (D) and right-sided facet joint at L4–5 (E) level. Lumbar lordosis (LL: 64.1°), pelvic incidence (PI: 83.7°), pelvic tilt (PT: 36.7°), and sacral slope (SS: 47.0°) were measured on lumbar standing plain radiograph (F). Sagittal and axial T2-weighted MR images at L2–3, L3–4, and L4–5 (G–I) levels are shown. Paraspinal muscles had asymmetric fatty infiltration. Goutallier scores for the fatty infiltration in the right-sided and left-sided paraspinal muscles (psoas, erector spinae, and multifidus) were 2 and 1, respectively (G). Goutallier scores were 3 for the right-sided multifidus and psoas muscles, 2 for the right-sided erector spinae, and 1 on the left-sided paraspinal muscles (H). Goutallier scores were 1 for the right-sided psoas, 2 for the right-sided erector spinae and multifidus, and 2 for the left-sided paraspinal muscles (I).