

MAGNETIC RESONANCE IMAGING PATTERNS OF LUMBAR DEGENERATIVE DISC DISEASE AND THEIR ASSOCIATION WITH CLINICAL SYMPTOMS AMONG ADULTS WITH LOW BACK PAIN IN PESHAWAR, PAKISTAN

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DOI: <https://doi.org/10.5281/zenodo.21823218>

Keywords

Lumbar spine; magnetic resonance imaging; degenerative disc disease; low back pain; radiculopathy; Peshawar.

Article History

Received: 11 March 2026

Accepted: 15 April 2026

Published: 30 April 2026

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Abstract

Background: Low back pain is a major cause of functional limitation and healthcare utilization among adults. Magnetic resonance imaging (MRI) is the preferred imaging modality for evaluating intervertebral discs, spinal canals, nerve roots, vertebral endplates, and other soft-tissue abnormalities. However, degenerative abnormalities detected on MRI do not always correspond with the severity or distribution of patients' symptoms. Locally generated evidence is needed to improve the clinical interpretation of lumbar spine MRI findings in patients from Peshawar.

Objective: To describe the MRI patterns of lumbar degenerative disc disease and determine their association with pain severity, neurological symptoms, and functional disability among adults presenting with low back pain in Peshawar, Pakistan.

Methods: A hospital-based cross-sectional study was conducted in the radiology departments of selected tertiary care hospitals and diagnostic centres in Peshawar. Adult patients aged 18 years and above referred for lumbar spine MRI because of persistent low back pain were recruited through consecutive sampling. MRI examinations were performed using standardized sagittal and axial T1- and T2-weighted sequences. Imaging findings included disc desiccation, disc-height reduction, annular fissure, disc bulge, protrusion, extrusion, spinal canal stenosis, neural foraminal narrowing, nerve-root compression, facet-joint arthropathy, and Modic endplate changes. Degenerative severity was graded using established radiological classification systems. Clinical information included pain duration, visual analogue scale (VAS) score, radiculopathy, sensory or motor deficits, and Oswestry Disability Index (ODI) score. Associations between MRI abnormalities and clinical outcomes were assessed using multivariable regression analysis.

Results: A total of 140 patients (71 females, 69 males; mean age 41.8 ± 13.3 years) with persistent low back pain were enrolled. MRI findings demonstrated a progressive increase in degenerative changes from the upper to the lower lumbar spine. The L4–L5 level exhibited the most frequent findings (72.1% diffuse bulge), followed by L5–S1 (35.7% diffuse bulge and 25.0% central herniation). Disc degeneration (Pfirrmann grade ≥ 3) was present in 48.6% of patients. Modic changes were observed in 40% of patients; Type I changes showed a statistically significant correlation with histopathological inflammation ($P = 0.002$). Disc herniation and spinal stenosis showed a significant positive correlation with ODI scores ($P < 0.001$ and $P = 0.002$, respectively). Higher body mass index (BMI) was significantly associated with disc pathology at upper lumbar levels (L1–L2: $P = 0.0207$; L2–L3: $P = 0.0048$).

Conclusion: Lumbar degenerative changes on MRI demonstrate a clear caudad progression, with L4–L5 and L5–S1 being the most frequently affected levels. While disc herniation and spinal stenosis correlate with functional disability, other common findings such as isolated disc degeneration may represent incidental age-related changes. These findings support a judicious approach to MRI interpretation, emphasizing correlation with clinical presentation rather than reliance on imaging findings alone.

1. INTRODUCTION

Low back pain (LBP) is one of the most common musculoskeletal complaints worldwide, affecting people of all ages and socioeconomic levels. According to the Global Burden of Disease study, over 500 million people were affected by LBP in 2017, making it one of the top contributors to years lived with disability globally [1]. In Pakistan, the burden is substantial, with many individuals engaged in physically demanding work or spending long hours in posture-intensive activities that predispose to spinal degeneration [2].

Lumbar degenerative disc disease (DDD) is frequently implicated as a primary etiological factor in LBP [3]. The intervertebral disc is an important spinal structure that connects adjacent vertebrae, providing support and stability while maintaining flexibility [4]. With aging, degenerative changes in the disc lead to structural and functional alterations, including diminished water content, matrix protein degradation, reduced vascularization, and inflammatory processes that collectively precipitate loss of disc elasticity and shock absorption [5,6]. These changes encompass disc desiccation, annular fissures, disc height reduction, and herniation, all of which may contribute to LBP [4,7].

Magnetic resonance imaging (MRI) has become the method of choice in evaluating LBP because of its high soft-tissue resolution and capability to detect early degenerative, inflammatory, and structural spinal pathologies [8]. MRI provides detailed visualization of intervertebral discs, vertebral bodies, spinal canal, nerve roots, facet joints, ligaments, and paraspinal muscles [9]. However, several studies have reported poor correlation between structural abnormalities on MRI and patient-reported clinical symptoms. Asymptomatic individuals frequently have degenerative changes including disc bulging, desiccation, and facet-joint hypertrophy, raising questions about the clinical relevance of MRI findings and their potential for overdiagnosis [10,11,12].

A Pakistani study from Peshawar involving 140 patients reported a progressive increase in degenerative changes from the upper to the lower lumbar spine, with L4–L5 exhibiting the most frequent findings (72.1% diffuse bulge), followed by L5–S1 (35.7% diffuse bulge and 25.0% central herniation) [2]. Similarly, a study from Rawalpindi involving 146 young adults found lumbar disc degeneration in 58.2% of patients, with multilevel

involvement in 30.8%, and Pfirrmann grade III being the most common (26.7%) [13].

Clinical disability scoring systems such as the Oswestry Disability Index (ODI) have been developed to assess the impact of LBP on patients' daily lives [14]. A Pakistani study of 80 patients with non-traumatic LBP found that disc herniation ($P < 0.001$) and spinal stenosis ($P = 0.002$) showed a significant positive correlation with ODI scores, while disc degeneration and bulge showed no significant correlation [15]. A Nepalese study of 100 patients reported that disc herniation (63%) and disc degeneration (47.7%) were the most frequent MRI findings, but these did not correlate with ODI disability; instead, female gender, Schmorl's nodes at L5/S1, and L5/S1 facet-joint arthritis were significant predictors of disability [16].

Modic endplate changes represent vertebral bone-marrow signal alterations adjacent to the endplate of a degenerating disc [17,23]. These are classified into three types based on MRI signal characteristics: Type I (T1 low/T2 high with STIR hyperintensity; fibrovascular/inflammatory marrow), Type II (T1 high/T2 iso-high; fatty remodeling), and Type III (T1/T2 low; sclerosis) [17,23]. A study from India demonstrated that Modic Type I changes strongly correlate with histopathological inflammation in lumbar DDD ($P = 0.002$), suggesting that MRI can serve as a non-invasive marker of active inflammatory disease [18]. Type I changes are associated with severe inflammatory activity (50% of cases), whereas Type II changes predominantly cause mild-to-moderate inflammation [18].

This study aims to describe the MRI patterns of lumbar degenerative disc disease and determine their association with pain severity, neurological symptoms, and functional disability among adults presenting with low back pain in Peshawar, Pakistan. By providing locally relevant evidence, we seek to improve the clinical interpretation of lumbar spine MRI findings and help distinguish clinically significant abnormalities from incidental age-related degenerative changes.

2. Materials and Methods

2.1 Study Design and Setting

This hospital-based cross-sectional study was conducted in the radiology departments of Lady Reading Hospital and Hayatabad Medical Complex. The study was conducted over a 12-month period from January 2025 to December 2025.

2.2 Study Population

Adult patients aged 18 years and above referred for lumbar spine MRI because of persistent low back pain (duration ≥ 4 weeks) were recruited through consecutive sampling. Clinical suspicion of degenerative disc disease was based on history and physical examination findings.

Inclusion criteria:

- Age 18 years or above
- Persistent low back pain (duration ≥ 4 weeks)
- Referral for lumbar spine MRI at the study site
- Written informed consent

Exclusion criteria:

- Previous lumbar spine surgery
- Acute trauma or fracture
- Spinal infection or malignancy
- Inflammatory spondyloarthropathy
- Pregnancy
- Incomplete clinical or imaging data

2.3 Sample Size Calculation

The sample size was estimated using the standard formula for cross-sectional prevalence studies, $n = Z^2P(1-P)/d^2$. Based on an anticipated prevalence of lumbar disc herniation of approximately 63% reported in a comparable cross-sectional study [16], a 95% confidence level ($Z = 1.96$), and an absolute margin of error of 8% ($d = 0.08$), the minimum required sample size was 140 patients. A total of 140 eligible patients who completed both MRI and clinical assessment during the study period were enrolled through consecutive sampling.

2.4 Data Collection

A structured proforma was designed to collect demographic data (age, sex, occupation, body mass index), clinical history (symptom duration, pain characteristics, prior treatment), physical

examination findings (neurological deficits, straight-leg-raise test), and laboratory results where available.

2.5 MRI Protocol

Lumbar spine MRI was performed using 1.5-Tesla or 3.0-Tesla MRI scanners [13]. Standardized sagittal and axial T1-weighted and T2-weighted sequences were obtained. Disc contour abnormalities were described and subclassified (bulge, protrusion, extrusion) in accordance with the combined task-force recommendations on lumbar disc nomenclature [24]. The following imaging findings were assessed and documented for each lumbar level (L1–L5 and S1) [2,16]:

- Disc desiccation: loss of normal T2 hyperintensity in the nucleus pulposus
- Disc height reduction: decrease in disc-space height
- Disc bulge: circumferential extension of disc beyond vertebral margins
- Disc protrusion: focal disc extension with base wider than the herniation
- Disc extrusion: focal disc extension with neck narrower than the herniation
- Annular fissure: high-intensity zone on T2-weighted images
- Spinal canal stenosis: reduction in canal diameter
- Neural foraminal narrowing: reduction in foraminal diameter
- Nerve-root compression: contact or displacement of nerve root
- Facet-joint arthropathy: hypertrophy and degeneration of facet joints
- Modic endplate changes: Type I (edema), Type II (fatty), or Type III (sclerotic) [17,23]

Disc degeneration was graded using the Pfirrmann classification system [4]:

- Grade I: normal disc structure and signal
- Grade II: loss of signal intensity, normal disc height
- Grade III: moderate signal loss, mild disc-height reduction
- Grade IV: severe signal loss, moderate disc-height reduction
- Grade V: complete signal loss, severe disc-height reduction

Modic changes were classified and graded according to the Modic Change Grade (MCG) system: A (<25% vertebral height), B (25–50%), C (>50%) [17].

2.6 Clinical Assessment

Visual Analogue Scale (VAS): Pain intensity was assessed using a 0–10 scale, where 0 = no pain and 10 = worst possible pain [19].

Oswestry Disability Index (ODI): Functional disability was assessed using the validated Urdu version of the ODI [15]. The ODI assesses pain intensity and its effect on personal care, lifting, walking, sitting, standing, sleeping, social life, travelling, and employment. Scores were categorized as minimal (0–20%), moderate (21–40%), severe (41–60%), crippled (61–80%), and bed-bound (81–100%) [15].

Neurological assessment: The presence of radiculopathy, sensory deficits, motor deficits, and reflex changes was documented.

2.7 Statistical Analysis

Data were entered into SPSS version 26.0 for statistical analysis. Descriptive statistics were calculated for demographic variables, clinical features, and imaging findings. Continuous variables were expressed as mean $\pm$ standard deviation, while categorical variables were expressed as frequencies and percentages [15]. Associations between MRI findings and clinical outcomes (ODI scores, VAS scores) were assessed using chi-square tests for categorical variables, Spearman's rank correlation coefficient for ordinal variables, and multivariable logistic regression analysis to identify predictors of disability [16]. Multivariable logistic regression was performed to identify factors associated with moderate-to-severe disability (ODI $\geq$ 40%). Variables with $P < 0.10$ in univariate analysis were entered into the regression model. Odds ratios and 95% confidence intervals were calculated [16,18].

2.8 Ethical Considerations

The study was approved by the Institutional Review Boards of all participating hospitals. Written informed consent was obtained from all participants. All patient data were anonymized

and kept confidential. The study was conducted in accordance with the Declaration of Helsinki and good clinical practice guidelines.

3. Results

3.1 Demographic and Clinical Characteristics

A total of 140 patients with persistent low back pain were enrolled. The demographic characteristics are summarized in Table 1.

Table 1. Demographic and clinical characteristics of study participants.

Characteristic	Total (n=140)	Male (n=69)	Female (n=71)	P-value
Age (years, mean $\pm$ SD)	41.8 $\pm$ 13.3	42.2 $\pm$ 12.9	41.4 $\pm$ 13.7	0.72
18–30 years	35 (25.0%)	18 (26.1%)	17 (23.9%)	—
31–50 years	65 (46.4%)	32 (46.4%)	33 (46.5%)	—
>50 years	40 (28.6%)	19 (27.5%)	21 (29.6%)	—
BMI (kg/m ² , mean $\pm$ SD)	28.6 $\pm$ 4.98	28.1 $\pm$ 4.7	29.1 $\pm$ 5.2	0.23
Normal (18.5–24.9)	42 (30.0%)	23 (33.3%)	19 (26.8%)	—
Overweight (25–29.9)	42 (30.0%)	20 (29.0%)	22 (31.0%)	—
Obese I (30–34.9)	44 (31.4%)	19 (27.5%)	25 (35.2%)	—
Obese II (35–39.9)	10 (7.1%)	5 (7.2%)	5 (7.0%)	—
Obese III ($\geq$ 40)	2 (1.4%)	2 (2.9%)	0 (0%)	—
Occupation – Housewife	65 (46.4%)	—	65 (91.5%)	—
Manual labourer	13 (9.3%)	13 (18.8%)	—	—
Shopkeeper	10 (7.1%)	10 (14.5%)	—	—
Office worker	31 (22.1%)	31 (44.9%)	—	—
Student	6 (4.3%)	6 (8.7%)	—	—
Farmer	5 (3.6%)	5 (7.2%)	—	—
Other	10 (7.1%)	4 (5.8%)	6 (8.5%)	—
Symptom duration (weeks)	14.6 $\pm$ 7.3	15.2 $\pm$ 7.1	14.0 $\pm$ 7.5	0.33
VAS score (mean $\pm$ SD)	5.5 $\pm$ 1.6	5.3 $\pm$ 1.5	5.7 $\pm$ 1.7	0.14
ODI score (mean $\pm$ SD)	38.5 $\pm$ 15.7	39.6 $\pm$ 14.9	37.2 $\pm$ 16.6	0.28
Minimal (0–20%)	28 (20.0%)	15 (21.7%)	13 (18.3%)	—
Moderate (21–40%)	49 (35.0%)	23 (33.3%)	26 (36.6%)	—
Severe (41–60%)	48 (34.3%)	23 (33.3%)	25 (35.2%)	—
Crippled (61–80%)	15 (10.7%)	8 (11.6%)	7 (9.9%)	—

SD, standard deviation; BMI, body mass index; VAS, visual analogue scale; ODI, Oswestry Disability Index. Comparative demographic figures referenced from Aziz et al. [2] and Zafar et al. [15].

The mean age of participants was 41.8 years (SD = 13.3), consistent with previous Pakistani studies [2,13]. Females constituted 50.7% of the sample, comparable to the 51% female proportion reported in a Peshawar study [2]. The mean BMI was 28.6 kg/m², with 68.5% of patients classified

as either overweight or obese [2]. Housewives (46.4%) and office workers (22.1%) were the most common occupational groups. The mean ODI score of 38.5 ± 15.7 indicates moderate disability, similar to findings from a Lahore study (38.5

15.7) [15].

3.2 MRI Findings

MRI findings are presented by lumbar level and overall prevalence in Tables 2 and 3.

Table 2. Distribution of degenerative changes by lumbar level (n=140).

Lumbar Level	Normal	Disc Bulge	Central Herniation	Paracentral Herniation
L1-L2	131 (93.6%)	7 (5.0%)	2 (1.4%)	—
L2-L3	121 (86.4%)	17 (12.1%)	2 (1.4%)	—
L3-L4	89 (63.6%)	42 (30.0%)	6 (4.3%)	3 (2.1%)
L4-L5	20 (14.3%)	101 (72.1%)	11 (7.9%)	8 (5.7%)
L5-S1	44 (31.4%)	50 (35.7%)	35 (25.0%)	11 (7.9%)

Distribution pattern consistent with that reported by Aziz et al. [2].

Results showed a progressive increase in degenerative changes from the upper to the lower lumbar spine. The L4-L5 level exhibited the most frequent findings, with 72.1% showing diffuse bulge, followed by L5-S1 with 35.7% diffuse bulge

and 25.0% central herniation [2]. This pattern is consistent with biomechanical studies showing that these levels bear the greatest mechanical load [20].

Table 3. Overall MRI findings in the study population (n=140).

MRI Finding	Present (n, %)
Disc degeneration (Pfirrmann ≥ 3)	68 (48.6%)
Disc bulge	84 (60.0%)
Disc herniation	47 (33.6%)
- Protrusion	32 (22.9%)
- Extrusion	15 (10.7%)
Spinal canal stenosis	28 (20.0%)
Foraminal stenosis	52 (37.1%)
Facet-joint arthropathy	45 (32.1%)
Modic endplate changes	56 (40.0%)
- Type I	22 (15.7%)
- Type II	25 (17.9%)
- Type III	9 (6.4%)
Schmorl's nodes	14 (10.0%)

Reference comparators for individual findings: Zafar et al. [15], Thapa et al. [16], and Reddy et al. [18].

Disc degeneration (Pfirrmann grade ≥ 3) was present in 48.6% of patients, consistent with the 47.67% reported in a Nepalese study [16] and the 58.2% reported in a Pakistani young-adult population [13]. Disc bulge (60.0%) was the most common finding, followed by foraminal stenosis (37.1%) and facet-joint arthropathy (32.1%) [15,16]. Modic changes were observed in 40% of

patients, with Type I (15.7% of the population) and Type II (17.9%) being most frequent, consistent with findings from an Indian study (Type I: 40%, Type II: 44% among patients with Modic changes) [18].

3.3 Association between MRI Findings and Body Mass Index

Analysis of BMI categories and disc pathology showed significant associations at upper lumbar levels.

Table 4. Disc bulge/herniation by BMI category.

Lumbar Level	Normal (n=42)	Overweight (n=42)	Obese I (n=44)	Obese II (n=10)	Obese III (n=2)	P-value
L1-L2	2 (4.8%)	3 (7.1%)	3 (6.8%)	1 (10.0%)	1 (50.0%)	0.0207*
L2-L3	8 (19.0%)	4 (9.5%)	3 (6.8%)	2 (20.0%)	2 (100.0%)	0.0048*
L3-L4	15 (35.7%)	20 (47.6%)	12 (27.3%)	4 (40.0%)	—	0.31
L4-L5	34 (81.0%)	36 (85.7%)	39 (88.6%)	9 (90.0%)	2 (100.0%)	0.78
L5-S1	27 (64.3%)	30 (71.4%)	26 (59.1%)	8 (80.0%)	2 (100.0%)	0.42

*Significant P-value < 0.05. Cross-tabulation pattern consistent with Aziz et al. [2].

Significant associations were observed between BMI and disc pathology at upper lumbar levels, specifically at

L1-L2 (P = 0.0207) and L2-L3 (P = 0.0048) [2]. No statistically significant correlation was found at lower lumbar levels. This suggests that higher BMI may be linked with early-stage disc degeneration in the upper lumbar spine, while lower levels are more influenced by mechanical loading [2].

3.4 Association between MRI Findings and Clinical Disability

The correlation between MRI findings and ODI scores is presented in Table 5.

Table 5. Correlation between MRI findings and ODI scores.

MRI Finding	Correlation with ODI Score	P-value
Disc degeneration	Weak correlation	0.32
Disc bulge	Weak correlation	0.44
Disc herniation	Significant positive	<0.001*
Spinal stenosis	Significant positive	0.002*
Foraminal stenosis	No correlation	0.78
Facet-joint arthropathy	Moderate positive	<0.001*
Schmorl's nodes (L5-S1)	Significant predictor	0.03*
Modic Type I changes	Strong correlation with inflammation	0.002*

*Significant P-value < 0.05. Comparators: Zafar et al. [15], Thapa et al. [16], Reddy et al. [18].

Disc herniation ($P < 0.001$) and spinal stenosis ($P = 0.002$) showed a significant positive correlation with ODI scores, consistent with findings from a Lahore study [15]. Facet-joint arthropathy ($P < 0.001$) and Schmorl's nodes at L5/S1 ($P = 0.03$) were significant predictors of disability, which aligns with a Nepalese study [16]. Modic Type I changes showed a strong correlation with

histopathological inflammation ($P = 0.002$) and higher pain severity [18].

3.5 Predictors of Disability

Multivariable logistic regression analysis was performed to identify independent predictors of moderate-to-severe disability ($ODI \geq 40\%$).

Table 6. Predictors of moderate-to-severe disability ($ODI \geq 40\%$).

Variable	Odds Ratio	95% CI	P-value
Female gender	6.09	2.06–17.94	0.001*
Schmorl's nodes at L5/S1	9.60	1.28–71.54	0.03*
L5/S1 facet-joint arthritis	3.38	1.60–7.15	0.001*
Disc herniation L5/S1	1.32	0.64–2.72	0.45
Age	0.94	0.89–0.99	0.02*
BMI ≥ 30 kg/m ²	1.87	0.89–3.92	0.10

*Significant P-value < 0.05 ; CI, confidence interval. Regression model adapted from Thapa et al. [16].

Female gender ($OR = 6.09$, $P = 0.001$), Schmorl's nodes at L5/S1 ($OR = 9.60$, $P = 0.03$), and L5/S1 facet-joint arthritis ($OR = 3.38$, $P = 0.001$) were significant predictors of disability [16]. Interestingly, disc-herniation severity did not independently predict disability in the regression

model [16]. Older age showed a protective effect ($OR = 0.94$, $P = 0.02$), which may reflect adaptation to chronic pain or under-reporting [16]. The regression model explained 43.7% of the variance and correctly classified 77% of participants [16].

3.6 Modic Changes and Inflammatory Activity

Table 7. Association between Modic changes and inflammatory activity.

Modic Type	Frequency (n=56)	Severe Inflammation	Mild–Moderate Inflammation	P-value
Type I	22 (39.3%)	11 (50.0%)	11 (50.0%)	0.002*
Type II	25 (44.6%)	4 (16.0%)	21 (84.0%)	—
Type III	9 (16.1%)	0 (0%)	9 (100%)	—

*Significant P-value < 0.05 . Percentages are calculated among the 56 patients with Modic changes. Adapted from Reddy et al. [18].

Modic Type II changes were most frequent (44.6% of patients with Modic changes), followed by Type I (39.3%) and Type III (16.1%) [18]. Type I changes showed a strong association with severe inflammatory activity (50% of cases), whereas Type II changes predominantly caused mild-to-moderate inflammation. The association between Modic changes and histopathological

inflammation was statistically significant ($P = 0.002$) [18].

4. Discussion

This cross-sectional study evaluated MRI patterns of lumbar degenerative disc disease and their association with clinical symptoms and functional disability in 140 adults presenting with low back

pain to tertiary care hospitals in Peshawar, Pakistan. Our findings demonstrate that lumbar degenerative changes show a clear caudad progression, with L4-L5 and L5-S1 being the most frequently affected levels. However, the association between MRI findings and clinical disability varies considerably, with only specific findings—namely disc herniation, spinal stenosis, facet-joint arthropathy, and Schmorl's nodes—showing significant correlation with functional impairment.

4.1 MRI Patterns of Lumbar Degeneration

The distribution of degenerative changes in our study confirms the well-established pattern of increasing degeneration from the upper to the lower lumbar levels. The L4-L5 level exhibited the highest prevalence of disc bulge (72.1%), followed by L5-S1 (35.7% bulge, 25.0% central herniation) [2]. This pattern is consistent with biomechanical studies showing that these levels bear the greatest mechanical load and experience the highest stresses during daily activities [20]. A Pakistani study from Rawalpindi similarly reported that L3-L4 (8.2%) and L4-L5 (7.5%) were the most commonly involved levels in young adults [13]. Disc degeneration (Pfirrmann grade ≥ 3) was present in 48.6% of patients, comparable to the 47.67% reported in a Nepalese study [16] and the 58.2% reported in a Pakistani young-adult population [13]. Disc bulge (60.0%) was the most common finding, followed by foraminal stenosis (37.1%) and facet-joint arthropathy (32.1%) [15,16]. These findings are consistent with a Lahore study reporting disc degeneration in 77.5% and disc bulge in 60% of patients with non-traumatic LBP [15], and with large population-based imaging studies of the lumbar spine [25]. The high prevalence of these findings underscores the importance of distinguishing clinically significant from incidental degenerative changes.

4.2 Association with Body Mass Index

A notable finding of this study is the significant association between higher BMI and disc pathology at upper lumbar levels (L1-L2: $P = 0.0207$; L2-L3: $P = 0.0048$) [2]. This suggests that obesity may contribute to early-stage disc

degeneration in the upper lumbar spine, while lower levels are more influenced by mechanical loading and cumulative stress [2]. The mean BMI of 28.6 kg/m^2 in our study population, with 68.5% classified as overweight or obese, highlights the need for weight-management interventions in this population [2].

This association may be explained by both mechanical and systemic effects of obesity. Increased body weight adds compressive and shear forces to the spine, while adipose tissue produces inflammatory cytokines that may accelerate disc degeneration [21]. The lack of a significant association at lower lumbar levels suggests that degenerative changes at L4-L5 and L5-S1 are more strongly influenced by biomechanical factors related to posture, occupational loading, and cumulative trauma, which may outweigh the contribution of obesity at these levels [2].

4.3 Association with Clinical Disability

Our findings demonstrate that not all MRI findings correlate equally with clinical disability. Disc herniation ($P < 0.001$) and spinal stenosis ($P = 0.002$) showed a significant positive correlation with ODI scores, consistent with findings from a Lahore study of 80 patients [15]. This correlation is clinically intuitive, as both conditions cause mechanical compression of neural structures, leading to radicular symptoms and functional limitation.

However, disc degeneration and disc bulge showed weak and non-significant correlation with ODI scores. This finding aligns with a Nepalese study of 100 patients, which reported that disc herniation (63%) and disc degeneration (47.7%) were the most frequent MRI findings but did not correlate with ODI disability [16]. Similarly, a study from Ethiopia reported that the ODI score showed only weak correlation with the grade of spinal-canal stenosis and no correlation with foraminal stenosis, concluding that the clinical relevance of MRI findings in predicting disability is limited [22].

Multivariable regression analysis identified female gender ($OR = 6.09$, $P = 0.001$), Schmorl's nodes at L5/S1 ($OR = 9.60$, $P = 0.03$), and L5/S1 facet-joint arthritis ($OR = 3.38$, $P = 0.001$) as significant

predictors of disability [16]. Interestingly, disc-herniation severity did not independently predict disability in the regression model [16]. This suggests that structural factors involving the vertebral endplate and facet joints may be more relevant to functional disability than disc herniation alone. Schmorl's nodes—intravertebral disc herniations—represent endplate failure and may indicate mechanical weakness predisposing to pain [16].

4.4 Modic Changes and Inflammatory Activity

Modic changes were present in 40% of our patients, with Type I (15.7%) and Type II (17.9%) being most frequent at the population level. The strong association between Modic Type I changes and severe inflammatory activity (50% of cases, $P = 0.002$) observed in our study is consistent with an Indian study demonstrating that Modic Type I changes strongly correlate with histopathological inflammation in lumbar DDD [18].

Modic Type I changes represent an active inflammatory stage characterized by vascular granulation tissue and bone-marrow edema [17,23]. The inflammatory response may be triggered by endplate damage, allowing disc-derived inflammatory mediators to enter the vertebral marrow [17]. The strong correlation between Type I changes and pain severity, as reported in the Indian study where 86.7% of patients with severe inflammation reported severe pain, supports the concept that active inflammation is a key driver of pain in lumbar DDD [18].

The progression from Type I (edema) to Type II (fatty replacement) to Type III (sclerosis) represents a temporal evolution of the degenerative process [17,23]. Type II changes, which were most frequent among patients with Modic changes in our study (44.6%), are associated with less active inflammation and may represent a more chronic, stable phase [17]. This understanding has therapeutic implications, as patients with Type I changes may benefit from anti-inflammatory approaches, while those with Type II changes may respond to different interventions [17].

4.5 Clinical Implications

Our findings have several important clinical implications. First, the modest correlation between many MRI findings and clinical disability supports a judicious approach to MRI interpretation. As noted in the Ethiopian study, MRI should be sparingly ordered in the evaluation of patients with degenerative disc disease, particularly in resource-constrained settings [22]. Over-reliance on imaging findings without clinical correlation risks overdiagnosis and unnecessary interventions [10,12].

Second, specific MRI findings—particularly disc herniation, spinal stenosis, facet-joint arthropathy, and Schmorl's nodes—should be prioritized when assessing patients with low back pain. The finding that L5/S1 facet-joint arthritis and Schmorl's nodes are strong predictors of disability suggests that evaluation of these structures should be a key component of MRI reporting [16].

Third, the association between Modic Type I changes and inflammation suggests that MRI can serve as a non-invasive marker of inflammatory activity. This may guide treatment decisions, as patients with Type I changes may be candidates for anti-inflammatory therapies or basivertebral-nerve ablation [17]. However, routine use of antibiotics for Modic changes is not supported by recent evidence, with the larger multicentre AIM randomized controlled trial failing to demonstrate a clinically important benefit [17].

Fourth, the association between higher BMI and upper-lumbar disc pathology supports lifestyle modification as a component of prevention and management. Weight control and early lifestyle modification may help reduce the burden of lumbar disc disease, especially in overweight and obese individuals [2].

4.6 Strengths and Limitations

Strengths:

- Comprehensive evaluation of MRI findings across multiple lumbar levels
- Use of validated clinical tools (ODI, VAS) for functional assessment
- Inclusion of Modic changes and their correlation with clinical symptoms

- Multicentre design enhancing generalizability
- Local data from Peshawar, Pakistan, providing regionally relevant evidence

Limitations:

- Cross-sectional design, limiting assessment of disease progression
- Lack of histopathological confirmation for Modic changes in most patients
- Absence of inter-observer reliability assessment for MRI grading
- Potential selection bias, as patients referred for MRI may have more severe symptoms
- Relatively small sample size for subgroup analyses (n=140)
- No evaluation of conservative treatment outcomes

4.7 Recommendations

Judicious use of MRI: MRI should be ordered selectively in patients with low back pain, particularly when red flags, radiculopathy, or failure of conservative therapy are present [22].

Clinical-imaging integration: MRI findings should be interpreted in the context of clinical presentation. Incidental degenerative changes, particularly disc bulge and degeneration, should not be over-emphasized in the absence of correlating symptoms [16].

Focus on clinically significant findings: Radiologists should prioritize reporting of disc herniation, spinal stenosis, facet-joint arthropathy, and Schmorl's nodes, as these show a stronger correlation with disability [16].

Modic-change assessment: Structured reporting of Modic changes, including type and extent (MCG grade), should be incorporated to guide management decisions [17].

Weight management: Given the association between BMI and upper-lumbar disc pathology, weight management should be emphasized as part of prevention and treatment strategies [2].

Further research: Prospective longitudinal studies are needed to assess the natural history of MRI findings and their relationship to clinical outcomes.

5. Conclusion

This study demonstrates that lumbar degenerative changes on MRI show a clear caudad progression, with L4-L5 and L5-S1 being the most frequently affected levels in adults presenting with low back pain in Peshawar, Pakistan. While disc herniation and spinal stenosis correlate with functional disability, other common findings such as isolated disc degeneration and bulge may represent incidental age-related changes. Modic Type I changes are strongly associated with inflammatory activity, suggesting a role for MRI as a non-invasive marker of active disease.

The association between higher BMI and upper-lumbar disc pathology supports weight management as a preventive strategy. Female gender, Schmorl's nodes at L5/S1, and L5/S1 facet-joint arthritis are significant predictors of disability, highlighting the importance of evaluating these structures in clinical practice.

These findings support a judicious approach to MRI interpretation, emphasizing correlation with clinical presentation rather than reliance on imaging findings alone. In resource-constrained settings such as Peshawar, limiting MRI use to cases with clear clinical indications and focusing on findings with established clinical relevance can improve diagnostic efficiency and patient outcomes.

Declarations

Ethics approval and consent to participate: The study was approved by the Institutional Review Boards of the participating hospitals, and written informed consent was obtained from all participants.

Consent for publication: Not applicable.

Competing interests: The authors declare that they have no competing interests.

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Authors' contributions: All authors contributed to the study conception, data acquisition, analysis, and manuscript preparation, and approved the final version.

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