Original Article

Radiological Assessment of Lumbar Spine Degeneration: Correlation with Age and Lumbar Level in Pakistani population

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ABSTRACT

Objective: To evaluate the utility of X-rays in grading lumbar spine degeneration and its correlation with age and lumbar levels in the local Pakistani population to enhance diagnostic accuracy and management of low back pain.

Methodology: This study examined 59 lumbar motion segments (L1-L5) from 13 male human cadavers aged 21-80 years. Ethical approval was obtained, and only segments without deformities, fractures, infections, or metastasis were included. Radiological degeneration scores were assigned based on osteophytes, sclerosis and disc height from X-rays.

Results: Radiological findings showed increased sclerosis and osteophyte formation with advancing age, while Schmorl's nodes were observed in 16% of cases. Mean overall degeneration scores, along with sclerosis and osteophyte scores, correlated positively with both age and spinal level. Mean overall degeneration scores showed significant associations with age ($p<0.001$) and spinal level ($p=0.001$). Spearman's rank correlation revealed significant increases in overall degeneration and osteophyte scores with age ($p<0.001$), whereas sclerosis showed a positive but non-significant association ($\rho=0.7$). A strong positive correlation was also found between spinal level and overall degeneration ($p=0.01$) as well as sclerosis scores ($p=0.04$). Osteophyte scores increased with spinal level ($\rho=0.82$) but without statistical significance ($p=0.089$).

Conclusion: Lumbar spine degeneration increased with age, with L5 most affected, while sclerosis and osteophytes progressed independently. Findings support X-rays as a reliable diagnostic tool, aligning with global studies and highlighting the need for further research on Modic changes and ethnic variations.

KEYWORDS: Intervertebral Disc, Lumbar Vertebrae, Osteophyte, Radiography, Sclerosis, Spine Degeneration.

INTRODUCTION

Lumbar spine degeneration is one of the most prevalent conditions, particularly among the aging population, and is a significant contributor to morbidity worldwide. It encompasses a range of degenerative changes affecting the intervertebral discs, vertebral endplates, vertebral bodies, and facet joints. These changes can lead to clinical manifestations such as low back pain, radiculopathy, and in severe cases, functional impairment. Understanding the correlation between age, specific lumbar levels, and the extent of degeneration is crucial for developing effective diagnostic and therapeutic strategies.

Age is a well-established risk factor for lumbar spine degeneration.[1] Studies have demonstrated a positive correlation between advancing age and the

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prevalence of degenerative changes in the lumbar spine.[2-4] For instance, Mohan et al analyzed 600 lumbar intervertebral discs from 273 cadavers and found that the degree of disc degeneration increased with age, with significant degeneration observed in individuals over 40 years. Similarly, a study reported that the prevalence of lumbar disc degeneration was higher in older adults, with a marked increase in individuals aged 50 and above.[5, 6.]

The anatomical level within the lumbar spine also plays a pivotal role in the pattern of degeneration. Degenerative changes are not uniformly distributed across all lumbar levels.[7]

Hanhivaara observed that the L3-L4 and L4-L5 discs exhibited more pronounced degeneration compared to other lumbar levels.[8] This finding aligns with the biomechanical perspective that these segments bear greater mechanical loads and exhibit higher mobility, predisposing them to accelerated degenerative processes.[9]

While advanced imaging modalities like MRI offer detailed insights into spinal degeneration, their limited availability and higher costs pose challenges, especially in resource-constrained settings.[10,11] Conventional radiography (X-rays) remains a widely accessible and cost-effective diagnostic tool; however, its efficacy in accurately grading spinal degeneration is not fully established.[12] Existing studies on the correlation between radiographic findings and the severity of spinal degeneration are limited and often yield inconsistent results. For example, while X-rays can reveal structural changes such as disc space narrowing and osteophyte formation, they primarily assess bony structures and may not adequately depict soft tissue abnormalities.[12,13] This gap in knowledge underscores the necessity for further research to evaluate the diagnostic accuracy and reliability of X-rays in assessing spinal degeneration. Addressing this gap is essential to enhance diagnostic protocols and optimize patient management, particularly in settings where advanced imaging options are unavailable. Therefore, this study aims to investigate the correlation between radiographic findings of lumbar spine degeneration with age and spinal level. It will provide valuable insights into the utility of X-rays as a diagnostic tool in the absence of advanced imaging modalities.

METHODOLOGY

This cross-sectional analytical study was conducted under the approval of the Ethical Review Committee, University of Health Sciences (UHS), Lahore (Letter #: UHS/REG-21/ERC/6602). Cadavers were obtained from the Anatomy Department, Faisalabad Medical University (FMU), Faisalabad, with permission from relevant authorities. A sample size of 72 vertebral endplates and intervertebral disc junctions was calculated based on an 80% study power and a 5% margin of error (sample size calculator for designing clinical research). Non-probability convenience sampling method was used to obtain samples.

Thirteen lumbar segments were harvested from male cadavers aged 21-80 years and divided into three groups: Group A (21-40 years), Group B (41-60 years), and Group C (61-80 years). A total of 59 motion segments and 118 endplates were analyzed. Lumbar segments without signs of spinal infections, deformities, fractures, or metastases were included.

Soft tissues were removed, and anteroposterior (AP) and lateral radiographs were taken to assess osteophytes, sclerosis, disc height (anterior, middle, and posterior), and vertebral heights. Vertebral body height (VBH) and disc heights were measured using the protocols defined by Zehra et al. (2019). Radiographic scores and grades were assigned following protocol outlined by Zehra et al 2019.[14] Data was entered and analyzed using latest version of Statistical packages for social sciences (SPSS) version 26. Mean ± SD was calculated for quantitative variables and percentages were calculated for qualitative variables. The Spearman correlation test was applied to determine the correlation between radiological degeneration

scores with the age groups and spinal level with a level of significance set at $p < 0.05$.

RESULTS

A total of 13 lumbar segments were harvested from male cadavers aged 21–80 years and divided into three groups: Group A (21–40 years), Group B (41–60 years), and Group C (61–80 years). Overall, 59 motion segments and 118 endplates were analyzed. Radiographically, sclerosis appeared as increased radiodensity (whitish hyperintensity) at the superior and inferior endplates on lateral views, while osteophytes were seen as bony projections arising from vertebral margins on both anteroposterior and lateral radiographs. Young spines showed normal alignment without sclerosis or osteophyte formation, whereas these degenerative changes were prominent in older specimens (Fig. 1). The upper and lower endplates were generally intact, but in 16% of cases, rounded defects consistent with Schmorl's nodes were observed (Fig. 1). Vertebral body height, disc height and disc depth progressively increased from L1-L5 spinal level (Fig. 1). Although these variations were visually more apparent in older individuals, statistical analysis did not demonstrate a significant association with age. The anterior disc height was greater than the central and posterior disc heights in each individual sample. An increased in the disc depth was also observed in lower lumbar segments of the older samples as compared to the young discs. A decreased vertebral height especially at lower lumbar segments was found in few older samples where vertebral bodies were found to be resorbed in the center (Fig.1).

Mean overall radiological degeneration scores and grades based on the combined scores of sclerosis and osteophytes are presented in Table I. Assessment of both superior and inferior endplates (n=118) were averaged to give the degeneration scores of individual motion segments (n=59). The overall radiological degeneration scores ranged between 1-6 corresponding to grades I–III (Fig 2).

Figure I: AP and lateral spine radiographs showing osteophytes, sclerosis, Schmorl's nodes, and intervertebral disc space variations.

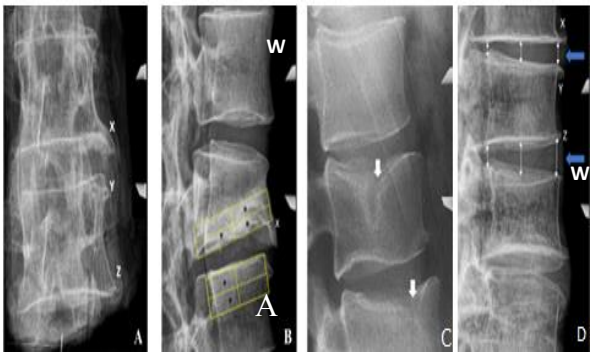

Fig.I: Anteroposterior (A) and lateral (B, C& D) views of radiographs showing different features of radiological degeneration. A: Osteophytes can be seen as small bony projections protruding from the corners of the vertebral bodies at X, Y and Z sites. B: Lateral view showing osteophytes along with sclerosis as black asterisks inside the yellow boxes. C: Schmorl's nodes (white arrows). D: Osteophytes (X, Y and Z) and variations in the disc space between consecutive spinal levels (blue arrows) at anterior, middle and posterior part (white arrows) of the intervertebral space can be seen.

Fig 2: Lateral lumbar radiographs illustrating progressive degeneration from Grade I to III, showing increasing osteophyte formation, endplate sclerosis, and Schmorl's nodes across age groups.

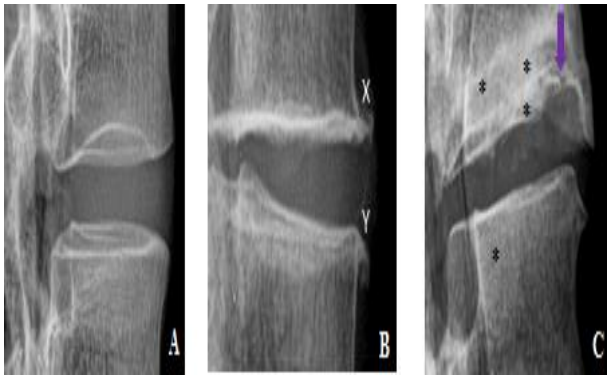

Fig.2: Lateral radiographs of lumbar segments showing radiological features. A: Grade I motion segment without sclerosis and osteophytes at level L2 from age group A. B: Grade II motion segment with mild sclerosis just around the borders of the endplates with osteophytes X and Y at the anterior margins of the superior and inferior vertebrae at L2 from age group B. C: Grade III motion segments with sclerosis (black asterisks), and large osteophyte along the anterior margin of the superior vertebra and Schmorl's node (purple arrow) at L2 from age group C.

The mean overall radiological degeneration scores of all the samples were 4.03 ±1.1. Only 6 % were non-degenerated (grade I), 59% were mildly degenerated (grade II), 35% were moderately degenerated (grade III) and none of the discs exhibited severe degeneration (grade IV).

The sclerosis scores ranged between 1-4 while its mean ± SD was 2.2 ± 0.83. The osteophytes scores ranged between 1-3 while its mean ± SD was 1.8 ± 0.69.

Overall radiological degeneration scores, mean sclerosis scores, and osteophyte scores for the three age groups (group A=21-40 years, group B= 41-60 years and group C= 61-80 years) are shown in Table I and for each spinal level (L1-L5) are shown in Table II.

Table I: Overall Radiological Degeneration Scores, Mean Sclerosis Scores, And Osteophyte Scores and Their Correlations are Shown for the Three Age Groups A, B & C.

Age Groups	Mean overall degeneration scores	Sclerosis scores	Osteophyte scores
	Mean (SD)	Mean (SD)	Mean (SD)
Group A n=20	3.5±1.0	2.04±0.92	1.47±0.5
Group B n=20	3.7±0.8	2.1±0.64	1.5±0.51
Group C n=19	4.7±1.2	2.5± 0.77	2.5±0.51

n= number of samples
Age groups (group A=21-40 years, group B= 41-60 years and group C= 61-80 years).
Values shown are the mean ± SD. SD: standard deviation.
The p-value is calculated using the Spearman Correlation Test.
** indicates correlation is significant at the 0.01 level (2-tailed).

Spearman's rank correlation analysis demonstrated a positive association between age and overall radiological degeneration scores, indicating increased degeneration in older individuals ($\rho = 1.0$, $p < 0.001$). The analysis of individual parameters showed increasing mean sclerosis scores with age ($\rho = 0.7$) though insignificantly ($p=0.642$).

Whereas, mean osteophyte scores increased significantly ($\rho = 1.0$, $p < 0.001$) with the age. These findings indicate that older age groups consistently exhibited higher degeneration, sclerosis, and osteophyte scores.

Spearman's rank correlation analysis showed a strong positive correlation between spinal level and mean overall radiological degeneration scores ($\rho = 0.90$, $p = 0.01$), as well as sclerosis scores ($\rho = 0.90$, $p = 0.04$). Osteophyte scores also showed a positive correlation with spinal level ($\rho = 0.82$), although this did not reach statistical significance ($p = 0.089$). These results indicate that degeneration and sclerosis consistently increased toward the lower lumbar levels, with a similar but non-significant trend observed for osteophytes (Table II).

The mean anterior, central, posterior and mean overall disc height in different age groups is shown in Table III whereas at each spinal level from L1 to L5 are shown in Table IV.

Table II: Overall Radiological Degeneration Scores, Mean Sclerosis Scores, and Osteophyte Scores Their Correlations are Shown for Each Spinal Level (L1-L5).

Spinal level	Overall degeneration Scores	Sclerosis scores	Osteophyte scores
	Mean (SD)	Mean (SD)	Mean (SD)
L1 n=13	3.1(0.8)	1.7(0.6)	1.5(0.5)
L2 n=13	3.9(0.9)	2.1(0.9)	1.8(0.6)
L3 n=13	4.5(1.1)	2.5(0.7)	2.0(0.7)
L4 n=10	4.2(1.2)	2.3(0.7)	1.9(0.8)
L5 n=10	4.7(1.4)	2.7(0.8)	2.0(0.8)

n= number of samples
Values are presented as mean (SD), where SD represents the standard deviation.
The p-value is calculated using the Spearman Correlation Test.
** indicates correlation is significant at the 0.01 level (2-tailed).

Radiological assessment showed that sclerotic changes with the expected decline in the height of the segment did not show any correlation with either the overall radiological degeneration scores or osteophytes scores. All the disc heights (anterior, central, posterior, mean overall disc height, mean vertebral height) of each spinal level (L1, L2, L3, L4 and L5) did not show any correlation with age.

Table III: The Mean Anterior, Central, Posterior and Overall Disc Height, are Shown for Three Age Groups

Age groups	Mean anterior disc height	Mean central disc height	Mean posterior disc height	Mean Overall disc height
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Group A n=20	7.2(1.2)	6.9(0.9)	6.4(1.6)	6.9(1.1)
Group B n=20	6.6(1.1)	6.7(0.7)	5.8(1.3)	6.5(0.9)
Group C n=19	7.1(1.5)	6.8(1.3)	5.7(1.4)	6.6(1.3)

n= number of samples
Age groups: (group A=21-40 years, group B= 41-60 years and group C= 61-80 years).
Values shown are the mean ± SD. SD: standard deviation.

Table IV: The Mean Anterior, Central, Posterior and Overall Disc Height, are Shown for Each Spinal Level (L1-L5).

Spinal Level	Mean anterior disc height	Mean central disc height	Mean posterior disc height	Mean Overall disc height
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
L1 n=13	6.2(1.1)	6.0(0.8)	5.1(1.1)	5.9(0.9)
L2 n=13	6.4(0.7)	6.2(0.7)	5.7(0.9)	6.2(0.7)
L3 n=13	7.1(0.8)	7.1(0.9)	6.3(1.1)	6.9(0.9)
L4 n=10	7.6(1.2)	7.4(1.3)	6.4(1.4)	7.3(1.2)
L5 n=10	8.2(1.3)	7.8(1.5)	7.1(1.9)	7.7(1.5)

n= number of samples
Values shown are the mean ± SD. SD: standard deviation.

DISCUSSION

This study evaluated the degenerative changes in human lumbar segment for the first time in Pakistani population. A total of 59 cadaveric specimens from L1-L5, derived from individuals aged 21-80 years, were evaluated at radiological level.

The radiological assessment conducted in this study offered insightful observations into the distinct patterns of degeneration present within the lumbar spine. Radiological assessment revealed sclerosis and osteophyte formation and their scores were combined to obtain the overall radiological degeneration score. The results highlighted that sclerosis and osteophytes were more common in the older samples. Additionally, bony endplates (BEP) defects, characterized as Schmorl's nodes, were present in only 16% of the samples. In spite of the fact that overall radiological degeneration scores were derived from the cumulative scores of sclerosis and osteophytes, there was no significant correlation found between sclerosis and osteophyte scores, implying that these two factors may be developing independently. The majority of samples showed mild to moderate degeneration (94%), with no cases of severe degeneration, possibly because the samples were taken from cadavers representing cohort from the normal local population.

A significant increase in overall radiological degeneration scores with age was seen, which has also been reported by many earlier studies done on different population cohorts.[14, 15]

Similarly, the increase in osteophyte score with advancing age, as observed in this study, also aligns well with earlier studies which have reported increase in osteophyte scores and degeneration in thoracolumbar spines with aging.[16,17,18] The possible explanation is the altered mechanics and increased pressure at the lower spinal level causing these features.[17] The insignificant correlation between sclerosis and aging, as observed in this study also aligns well with earlier studies done on different populations implying that the radiographic density of vertebral end plates is not altered with aging. There might be other factors involved like Modic changes which reflect a regenerative process in the marrow with new bone formation.[19,20,21]

While analyzing the impact of spinal level on radiological degeneration scores, a consistent and

statistically significant increase in overall degeneration scores was observed moving down from higher to lower lumbar levels. The L5 exhibited the highest degeneration scores across all age groups. Despite being the plain radiograph-based study done for the first time ever on cadavers from a Pakistani population, its outcomes closely correspond with earlier investigations where Roberts and Suthar have reported L4/5 as the most commonly degenerated segment, while Cheung identified L5/S1 as the most affected level.[20,21]

Similarly, Zehra et al 2019 also reported pronounced increase in sclerosis scores in lumbar vertebra as compared to the thoracic ones suggesting an increased occurrence of sclerosis as we move from higher towards lower spinal levels.[14] The hyperintensity around the lower lumbar endplates could be due to the degeneration-driven bone formation interpreted as sclerosis in more degenerated lower spinal levels.[19]

However, in contrast to earlier studies, our study did not find a significant relation between number of osteophytes and increasing spinal level.[22] A possible explanation to this could be due to different ethnicity.

Furthermore, the assessment of IVD height in our study shed light on the dynamic nature of degeneration across different spinal levels. IVD heights (anterior, middle, posterior and average) increased from L1 to L5 indicating a bigger disc size at lower level. Radiological assessment revealed greater anterior disc height compared to the middle and posterior regions across lumbar levels in the same sample, reflecting the unique anatomy that compensates for the increased mechanical demands. However, all of these disc height measurements (anterior, middle, posterior, and standardized), at each lumbar level (L1-L5), neither correlated significantly with the age nor with the radiological degeneration grades, including sclerosis and osteophyte grades.

Our findings of the stable disc heights at each spinal level from L1 to L5 with increasing age is in line with the common belief that either the disc height remains stable or increases linearly with age. It could be due to the changes in concavity of the vertebral body which would affect the disc height.[23] In contrast, some studies have reported a thinning of discs as a normal part of the aging process.[24, 25]

These observations signify the crucial role of radiological images in clinical settings when diagnosing spinal diseases, as they provide a comparable level of detail to MRI scans, which may not always offer both macroscopic and microscopic insights. In settings where MRI is unavailable, standard radiographs (X-rays) serve as a valuable tool for assessing spinal degeneration. X-rays can effectively reveal structural changes such as disc space narrowing, osteophyte formation, and vertebral endplate sclerosis, which are indicative of degenerative processes. Utilizing established grading systems, clinicians can rely on high-quality radiographic images to accurately evaluate the severity of spinal degeneration and guide appropriate management strategies.

CONCLUSION

This study provides the first radiographic evaluation of lumbar spine degeneration in the Pakistani population. Degeneration increased with age, with L5 showing the highest scores, but sclerosis and osteophytes progressed independently. No significant correlation was found between osteophytes and spinal level or between disc height and age. The findings align with global studies, reinforcing conventional radiography as a reliable diagnostic tool. Future research should explore additional factors like Modic changes and ethnic variations.

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