Correlation study between sagittalization of lumbar facet joints and lumbar intervertebral disc degeneration: a retrospective analysis

Leitao Huang
the fourth affiliated hospital of nanjing medical university
Zongpo Shi
the fourth affiliated hospital of nanjing medical university
Kaixiang Yang
Ji Chen
the fourth affiliated hospital of nanjing medical university
Chen Zhang
the fourth affiliated hospital of nanjing medical university
Lei Bi
the fourth affiliated hospital of nanjing medical university
Lei Qi
the fourth affiliated hospital of nanjing medical university
Bin Zhang
the fourth affiliated hospital of nanjing medical university
Boyao Wang (2826664060@qq.com)

Research Article

Keywords: lumbar intervertebral disc, intervertebral disc degeneration, lumbar facet joint angle, facet joint sagittalization

Posted Date: May 24th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1673530/v1

Abstract

Purpose: To investigate the correlation between sagittalization of lumbar facet joints and lumbar intervertebral disc degeneration (IVDD).

Methods: Seventy-five patients with low back pain and forty healthy volunteers (control) underwent standard MRI protocols. The basic information of all patients, including age, gender, body mass index, was collected, and the lumbar facet joint angle (LFJA) was measured on lumbar magnetic resonance imaging (MRI), and the lumbar IVDD was assessed by Pfirrmann grading. All data were analyzed statistically.

Results: Compared with the control group, the LFJA of L3/4, L4/5 and L5/S1 in the patient group were significantly decreased, and there was a statistical difference ($P < 0.05$). The lower the segment, the more significant the sagittalization of the facet joints ($P < 0.05$). In the patient group, there was a statistically significant difference in the LFJA between the Pfirrmann grades of lumbar IVDD, and there was a strong negative correlation ($\rho=-0.736$, $P < 0.05$).

Conclusion: With the increase of the sagittal degree of LFJA, the IVDD also increases significantly, and this relationship has a strong negative correlation. It is indicated that the sagittalization of facet joints can be an important pathological change of lumbar IVDD. The LFJA is a very good predictor for evaluating lumbar IVDD.

1. Introduction

In the population, an estimated 65–80% of individuals will experience low back pain (LBP) in their lifetime [1]. LBP is the most common chronic pain syndrome and the leading cause of limited mobility of the lower back in patients under the age of 45 [2]. The most common cause of LBP is the disease of the lumbar itself, of which degenerative changes of the lumbar are the main factor. Degenerative disease of the lumbar is the same as the progressive aging of human beings, and it is a normal phenomenon of all living things [3]. Many scholars have shown that LBP caused by lumbar intervertebral disc degeneration (IVDD) is related to many factors, including age, weight, occupation, lumbar trauma, and genetic factors and so on [4, 5]. It also mainly includes a series of lumbar spine diseases, including IVD herniation, spinal stenosis and spondylolisthesis [6]. This is also the main direction of most scholars' research now.

However, recent studies have found that lumbar facet joint arthritis accounts for about 30% of the main causes of LBP [7]. And there is a direct relationship between facet joint arthritis and its degeneration. There are also studies reporting that the asymmetry of the lumbar facet joint becomes a good quantitative evaluation index of facet joint degeneration [8, 9]. In recent years, studies have proposed that lumbar facet joint degeneration is also an important factor leading to lumbar IVDD [4, 10]. However, the relationship between sagittalization of the lumbar facet joints and lumbar IVDD is unclear. Therefore, this study will conduct a specific relationship study between the lumbar facet joint angle (LFJA) and the IVDD by employing a case-randomized control experiment.

2. Methods

Study participants

This study was performed after the approval of our Institutional Review Board. All subjects consented to participate in this study.

Inclusion criteria: patients with LBP over 6 months; age over 18 years; body mass index (BMI) 18.5–24.9 kg/m^2; all subjects underwent MRI scans.

Exclusion criteria: lumbar tuberculosis, lumbar intervertebral discitis and lumbar osteomyelitis; severe lumbar congenital dysplasia; spinal tumor, lumbar diffuse metastases; history of lumbar surgery or lumbar fracture trauma; patients with abnormal muscle signal or sacroiliac joint lesions; patients with lumbar disc herniation; patients with IVDD in other spinal segments; patients with mental disorders.

A total of 200 patients with lumbar IVDD from April 2019 to March 2020 in our hospital were collected. According to the inclusion and exclusion criteria, a total of 75 patients were finally selected as the patient group, 40 healthy volunteers served as the control group.

Imaging parameters

Both groups of subjects underwent lumbar spine magnetic resonance imaging (MRI) scans using a MAGNETOM Trio 3.0 T MRI scanner (Tim Trio, Siemens Medical Solutions, Erlangen, Germany). The subjects were in the supine position, and the scanning range was from three IVD segments (L3/L4, L4/5, L5/S1), and a total of 345 IVD were scanned. Scanning conditions: pulse repetition time (TR) 575 ms, echo time (TE) 18.5 ms, field of view (FOV) 160 mm × 160 mm, voxel size 0.4 mm × 0.4 mm × 4.0 mm, slice spacing 0.3 mm. Morphological evaluation of IVD with axial T2-weighted images (T2WI).

Facet joint angle measurement

That is, the lumbar facet joint angle (LFJA) between the line connecting the anterior and posterior end points of the facet joint on this segment and the midsagittal line of the same vertebral body [1] (Fig. 1). Taking 45° as the limit, the angle greater than 45° was regarded as the deviation of the coronal plane, and the angle less than 45° was regarded as the deviation of the sagittal plane, and the LFJA of L3/4, L4/5 and L5/S1 of all subjects were measured.

Grading of intervertebral disc degeneration

The heights of L3/4, L4/5, and L5/S1 IVD were measured on the sagittal plane of MRI. A 25% reduction in the height of the adjacent normal IVD was defined as a low IVD height (Table 1). In order to further exclude subjective factors and better reflect the phenomenon, we redefine the modified Pfirrmann classification according to the signal changes of IVDD and the changes of IVD height (Fig. 2) [11]: divided into 4 grades: grade I, Pfirrmann 1; grade II, Pfifirrmann 2 to 3, based on signal of nucleus pulposus and inner annulus; grade III, Pfifirrmann 4 to 5, based on outer fibers signal of the annulus; grade IV, Pfifirrmann 6 to 8, based on IVD height loss.

Table 1
Modified Pfirrmann classification of LIDD by MRI

Grade	Signal intensity of nucleus pulposus and inner fifibrosus	Difference signal between rear and inner and outer fifibrosus	LIDD height
1	Uniform high signal, and cerebrospinal flfluid signal quite	Obvious	Normal
2	High signal (stronger than sacral fat less than CSF)	Obvious	Normal
3	Or high signal and there are cracks in the nucleus pulposus	Obvious	Normal
4	High signal (less than presacral fat)	Not obvious	Normal
5	Low signal (equal to outer fifibrosus)	Not obvious	Normal
6	Low signal	Not obvious	Reduce < 30%
7	Low signal	Not obvious	Reduce 30%～60%
8	Low signal	Not obvious	Reduce > 60%

Image assessment

All imaging parameters were measured and evaluated by two experienced specialists. The measurement was completed by two members independently, and each each parameter repeat the measurement twice and take the mean value as the LFJA of this patient.

Statistical analysis

All data were statistically analyzed using SPSS version 23.0 (SPSS, IBM, Armonk, NY). Measurement data were expressed as mean ± standard deviation, independent samples *t* test was used for comparison between two groups; one-way ANOVA was used for comparison between multiple groups, and LSD or Tamhane's T2 test was used for pairwise comparison; χ^2 test was used for comparison of enumeration data between groups; The correlation between LFJA and Pfirrmann grade was analyzed by Pearson correlation coefficient. Correlations were considered strong for $\rho > 0.7$, moderate for $0.5 < \rho < 0.7$, and weak for $\rho < 0.5$. The test level was $\alpha = 0.05$, and $P < 0.05$ was considered statistically significant.

3. Results

There were 75 patients in the patient group (42/33 males/females). The mean age was 58.1 ± 12.1 years (range 31–85 years). A total of 40 healthy volunteers were included in the control group (21/19 males/females). The mean age was 55.8 ± 14.4 years (range 29–82 years). There was no significant difference in gender and age between the two groups ($\chi^2 = 0.129$, $P = 0.719$; $t = 0.885$, $P = 0.378$). The mean BMI was 22.16 ± 1.6 kg/m^2 in the patient group (range 18.5–24.5) and 21.6 ± 1.5 kg/m^2 in the control group (range 18.7–24.8), there was no statistical difference between the two groups ($t = 1.878$, $P = 0.063$).

Statistical analysis showed that the LFJA of each segment in the patient group were significantly smaller than those in the control group (Table 2); In the patient group, as the lumbar segment were lower, the LFJA gradually decreased, which was statistically significant ($P < 0.01$), as shown in (Fig. 3).

Table 2
Comparative analysis of lumbar facet joint angle between two groups of patients

Variables	Patient group (n = 75)	Control group(n = 40)	*t* value	*P* value
L3/4 LFJA (°)	42.4 ± 1.9	44.7 ± 1.3	-7.770	0.000***
L4/5 LFJA (°)	36.9 ± 2.2	45.0 ± 1.6	-22.612	0.000***
L5S1 LFJA (°)	30.6 ± 2.1	45.1 ± 1.4	-42.048	0.000***

LFJA lumbar facet joint angle; ***$P < 0.001$.

The homogeneity of variance of the facet joint angles in the patient group was tested by Levene in the analysis of variance. The result showed that the Levene value = 2.19, $P = 0.089 > 0.05$, indicating that the homogeneity of variance. Therefore, the LSD test was used for the pairwise comparative analysis of the LFJA between all levels in the patient group. Among them, there were significant differences in LFJA between grades I vs. III, grades I vs. IV, grades II vs. III, grades II vs. IV, and grades III vs. IV ($P < 0.001$). There was no significant difference in facet joint angle between grade I and grade II ($P > 0.05$), Table 3.

Table 3 Analysis on the difference of facet angle in different grades of lumbar disc degeneration in case group

Grade	N(%)	LFJA (°)	Minimum-Maximum
I	40	41.3±3.1	33.1~45.6
II	71	40.0±4.0	29.7~45.2
III	62	36.1±3.1	28.1~41.4
IV	52	30.9±2.8	27.4~40.2
Patients (A)	Patients (B)	*P* value	95% CI
I	II	0.342	-0.575~3.119
	III	0.000***	3.554~6.944
	IV	0.000***	8.714~12.136
II	III	0.000***	2.341~5.612
	IV	0.000***	7.501~10.806
III	IV	0.000***	3.700~6.653

LFJA lumbar facet joint angle; ***$P < 0.001$.

The correlation between LFJA and Pfirrmann grade was analyzed by Pearson correlation coefficient. After statistical analysis, it was found that with the increase of the Pfirrmann grade of the IVD, the degree of sagittalization of the LFJA became more significant, and there was a strong negative correlation between them ($\rho = -0.736$, $P < 0.01$) Fig. 4.

Consistency comparison of IVDD grade and LFJA between groups. The inter-group agreement between Pfirrmann grades of lumbar discs was good (Cranbach's α = -0.799), especially for grade I (Cronbach's α = -0.858). The inter-group consistency of LFJA was good (Cranbach's α = -0.752).

4. Discussion

Lumbar intervertebral disc degeneration (IVDD) is a complex process involving many factors. At present, the mechanism of lumbar IVDD is still not fully understood [10]. Youn et al. [12] found that factors such as biomechanics, nutritional status, apoptosis, cytokines and degrading enzymes have a great influence on IVDD. The latest research reports: In the population coding, a certain genetic mutation of aggrecan was found, and the aggrecan can shorten the length of the proteoglycan core protein chain [13]. Interestingly, through further investigation, it was found that these certain populations are more prone to multi-segment degenerative disc changes clinically, which may indicate that the IVDD is related to human genetic factors [14]. In addition, according to related studies, the combined use of in vitro insulin-like growth factor and platelet-derived growth factor can delay the rate of apoptosis in IVDD [15]. The main biomechanical feature of the IVD is to maintain the height of the intervertebral space, resist the compressive force from the longitudinal direction and limit the relative motion of the two adjacent vertebral bodies to a small painless range [16]. Therefore, abnormal or uncoordinated mechanical loading can lead to the formation of intervertebral disc degeneration. In particular, axial-related force factors and trauma (mechanical violence) have been regarded as the main pathogenic factors of intervertebral disc degeneration [17]. Some studies have found that the sagittal changes of facet joints are related to the IVDD [5, 18].

According to previous studies, the changes in the shape and position of the facet joints of the lumbar spine are caused by many factors, such as facet joint osteoarthritis, IVDD and other factors [19]. The exact cause of the shift has not yet formed a unified view in the academic world. Some people think that it is caused by acquired facet joint remodeling, while some scholars believe that it is caused by congenital [10, 20]. There are many studies on the relationship between the lumbar facet joints and the IVDD, but the relationship between the sagittalization of the lumbar facet joints and the degree of IVDD has always been controversial [21, 22]. Therefore, this study takes the LFJA as the starting point, and focuses on the relationship between LFJA and IVDD.

In terms of biomechanics and anatomy, the IVD and the facet joint behind it together form a "three-joint complex", which is the functional unit of the spinal movement system [23]. The IVD has the functions of buffering pressure, bearing load, and maintaining the stability of the spine. When the mechanical balance is destroyed, the stability and motor function of the spine will inevitably be affected [24]. It may affect the adjacent functional units of the spine and even affect the overall stability and motor function of the spine. Previous studies have established that facet sagittalization is associated with vertebral advancement in degenerative lumbar spine, and that increasing the location and direction of vertebral advancement greatly increases the risk of facet instability [25, 26]. Regarding the relationship between lumbar IVD and facet joints, Huang et al. [27] believed that lumbar facet joints and IVDD are interrelated and causal in the whole process of lumbar degeneration. The main causes of lumbar IVDD and facet joint degeneration are natural aging and abnormal stress. Wang et al. [28] believed that lumbar vertebral degeneration begins with facet joint degeneration, and lumbar IVDD and facet joint degeneration affect each other. With the increase of age, lumbar IVDD accelerates and gradually surpasses the speed of lumbar facet joint degeneration. Some foreign scholars believe that lumbar spine degeneration begins with IVDD [25, 29, 30]. Due to the dehydration of the IVD and the loss of the height of the intervertebral space, the stress of the facet joints changes, which in turn leads to degeneration of the facet joints.

In 2001, Pfirrmann et al. [31] proposed their own grading method for IVDD based on the signal intensity of the IVD on MRI, the structure of the IVD, the demarcation between the nucleus pulposus and the annulus fibrosus, and the height of the IVD, and confirmed that it has high reliability. (kappa = 0.69–0.90). This study reclassified IVDD according to the modified Pfifirrmann score [31]: grade I, Pfifirrmann 1; grade II, Pfifirrmann 2, 3, based on signal from nucleus pulposus and inner annulus; grade III, Pfifirrmann 4, 5, based on external Signal of annulus fibrosus; grade IV, Pfifirrmann 6–8, based on loss of disc height. This is mainly to reduce subjective evaluation errors, but also to highlight differences in classification.

The results of this study showed that the LFJA of each segment in the patient group were significantly smaller than those in the control group ($P < 0.01$). In the patient group, as the lumbar vertebral segment were lower, the LFJA gradually decreased, which was statistically significant ($P < 0.01$). In addition, according to the Pfifirrmann classification, it was showed that there was no significant difference in the LFJA between grades I and II ($P > 0.05$). Further, we analyzed the relationship between the LFJA and the Pfirrmann score by using Pearson correlation. It was found that with the increase of the Pfirrmann grade of the IVD, the LFJA gradually decreased, and the degree of sagittalization of the facet joint became more significant. There was a strong negative correlation ($\rho = -0.736$, $P < 0.001$). These results fully indicate that there is a close relationship between the sagittalization of the facet joints and the degree of IVDD, and the sagittalization of the facet joints is likely to be the main pathogenic factor of IVDD.

According to the results obtained in this study, we analyzed its main mechanism in two points: First, the "three-joint complex" formed by the IVD and the facet joints on both sides—This special structure plays a very important role in maintaining and stabilizing the balance and coordination of lumbar spine activities [23, 26]. Abnormalities in any one part will affect the other two parts and thus the whole. The lumbar IVD of the patients in this study group all have different degrees of degeneration. The earliest due to the IVDD changes, the intervertebral space is narrowed, the height of the IVD is lost, and the lumbar vertebral is unstable, which further causes local load bearing on the facet joints [32]. As a result, the stress-increasing site are more prone to bone hyperplasia, and the stress-reduced site is more prone to osteoporosis, accompanied by the existence of corresponding soft tissue repair and reconstruction, and finally the sagittal change of the facet joints. Second, there are different biomechanical factors in L4/5 and L5/S1 IVDD. The degeneration of the L4/5 IVD is mainly related to the way of rotational movement, and the morphological basis of the L4/5 facet joint is the curved articular surface [32] The degeneration of the L5/S1 IVD is mainly related to the stability of the spine and the gravitational load. The morphological basis of the L5/S1 facet joint is a straight articular surface [25, 26]. This causes the lower the lumbar vertebrae segment, the more sagittal the LFJA. This change in the LFJA causes stress concentration in the force transmitted from top to bottom, so the gravitational load on the L5/S1 facet joint will increase, which will seriously affect the function of this joint, further causing instability of the spine and in turn promoting the IVDD [33] .

This study has certain limitations: First, this is a retrospective study; Second, factors such as occupation, smoking, age, and body mass index were not included in the analysis of the relationship between the LFJA and IVDD, which may lead to differences in the observed IVDD and LFJA [28–31]; Finally, this study provides only key insights into the association of facet joint parameters with L3/4, L4/5, and L5/S1 IVDD. The more vertebral segments and influencing factors need to be included for in-depth research.

5. Conclusion

In this study, we analyzed the Pfifirrmann degeneration grades of three IVD L3/4, L4/5, and L5/S1 on MRI, and measured the LFJA of the corresponding vertebral segments. It has been confirmed that the LFJA and the IVDD are closely connection.

This study was concluded that there is a strong negative correlation between IVDD and LFJA. This relationship was more pronounced in the lower lumbar vertebrae. It is indicated that the sagittalization of facet joints can be an important pathological change of lumbar IVDD. And the LFJA is a very good predictor for evaluating IVDD.

Abbreviations

BMI: Body mass index; LBP: Low back pain; LFJA: Lumbar facet joint angle; IVD: Intervertebral disc; IVDD: Intervertebral disc degeneration; MRI: Magnetic resonance imaging; FOV: Field of view; T2Wis: T2-weighted images; TE: Echo time; TR: Repetition time.

Declarations

Acknowledgments

None.

Funding

This study was supported by the Science and Technology Development Fund of Nanjing Medical University (No. NMUB20210044).

Availability of data and materials

The data supporting our findings can be found in the article.

Authors’ contributions

HLT designed and performed the study, and wrote and edited the manuscript. SZP and YKX revised the manuscript, conceived and designed the study. CJ analyzed and interpreted the data. ZC revised the manuscript. BL and QL assisted with data presentation and drafting of the manuscript. ZB and WBY conceived and designed the study, and assisted with the research, drafting, and revision of the manuscript. All authors read and approved the final manuscript.

Competing interests

No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

References

1. Chepurin D, Chamoli U, Sheldrick K, et al. Bony stress in the lumbar spine is associated with intervertebral disc degeneration and low back pain: a retrospective case-control MRI study of patients under 25 years of age. Eur Spine J. 2019. 28(11): 2470–2477.
2. Farmer C, O'Connor DA, Lee H, et al. Consumer understanding of terms used in imaging reports requested for low back pain: a cross-sectional survey. BMJ Open. 2021. 11(9): e049938.
3. Lv B, Yuan J, Ding H, et al. Relationship between Endplate Defects, Modic Change, Disc Degeneration, and Facet Joint Degeneration in Patients with Low Back Pain. Biomed Res Int. 2019. 2019: 9369853.
4. MKL L, PWH C, AUID- Oho, et al. The profile of the spinal column in subjects with lumbar developmental spinal stenosis. Bone Joint J. 2021. 103-B(4): 725–733.
5. Garcia-Ramos CL, Valenzuela-Gonzalez J, Baeza-Alvarez VB, Rosales-Olivarez LM, Alpizar-Aguirre A, Reyes-Sanchez A. Degenerative spondylolisthesis I: general principles. Acta Ortop Mex. 2020. 34(5): 324–328.
6. Cornaz F, Widmer J, Farshad-Amacker NA, Spirig JM, Snedeker JG, Farshad M. Intervertebral disc degeneration relates to biomechanical changes of spinal ligaments. Spine J. 2021. 21(8): 1399–1407.
7. Minetama M, Kawakami M, Teraguchi M, et al. Endplate defects, not the severity of spinal stenosis, contribute to low back pain in patients with lumbar spinal stenosis. Spine J. 2022. 22(3): 370–378.
8. Jiang X, Chen D, Li Z, Lou Y. Correlation between Lumbar Spine Facet Joint Orientation and Intervertebral Disk Degeneration: A Positional MRI Analysis. J Neurol Surg A Cent Eur Neurosurg. 2019. 80(4): 255–261.
9. Celenlioglu AE, Sencan S, Gunduz OH. Does facet tropism negatively affect the response to transforaminal epidural steroid injections? A prospective clinical study. Skeletal Radiol. 2019. 48(7): 1051–1058.
10. Mesregah MK, Lee H, Roberts S, et al. Evaluation of facet joints and segmental motion in patients with different grades of L5/S1 intervertebral disc degeneration: a kinematic MRI study. Eur Spine J. 2020. 29(10): 2609–2618.
11. Griffith JF, Wang YX, Antonio GE, et al. Modified Pfirrmann grading system for lumbar intervertebral disc degeneration. Spine (Phila Pa 1976). 2007. 32(24): E708-12.
12. Youn MS, Shin JK, Goh TS, Lee JS. Predictors of Clinical Outcome After Endoscopic Partial Facetectomy for Degenerative Lumbar Foraminal Stenosis. World Neurosurg. 2019. 126: e1482-e1488.
13. AYL W, 0000-0002-5911-5756 AO, Parent EC, et al. Differential patient responses to spinal manipulative therapy and their relation to spinal degeneration and post-treatment changes in disc diffusion. Eur Spine J. 2019. 28(2): 259–269.
14. Zehra U, JPY C, 0000-0002-7052-0875 AO, et al. Multidimensional vertebral endplate defects are associated with disc degeneration, modic changes, facet joint abnormalities, and pain. J Orthop Res. 2019. 37(5): 1080–1089.

15. Kundakci YE, Unver DN, Guler I, Uysal II, Fazliogullari Z, Karabulut AK. Evaluation of the facet joints with magnetic resonance images in the patients with disc degeneration and spondylolisthesis. Surg Radiol Anat. 2018. 40(9): 1063–1075.
16. RJS S, Khan A, Hutchinson C. An Objective Assessment of Lumbar Spine Degeneration/Ageing Seen on MRI Using An Ensemble Method-A Novel Approach to Lumbar MRI Reporting. Spine (Phila Pa 1976). 2022. 47(5): E187-E195.
17. Yu X, Zhao J, Feng F, et al. Inclination of the small laminar slope angle leads to lumbar spinal stenosis due to hypertrophy of the ligamentum flavum. J Orthop Surg (Hong Kong). 2021. 29(2): 23094990211012846.
18. Zheng K, Wen Z, Li D, 0000-0002-6292-2727 AO. The Clinical Diagnostic Value of Lumbar Intervertebral Disc Herniation Based on MRI Images. J Healthc Eng. 2021. 2021: 5594920.
19. Naeem K, Nathani KR, Barakzai MD, et al. Modifications in lumbar facet joint are associated with spondylolisthesis in the degenerative spine diseases: a comparative analysis. Acta Neurochir (Wien). 2021. 163(3): 863–871.
20. Furunes H, Berg L, Espeland A, et al. Facet Arthropathy Following Disc Replacement Versus Rehabilitation: A Prospective Study With 8-Year Follow-Up. Spine (Phila Pa 1976). 2020. 45(21): 1467–1475.
21. Shi S, Zhou Z, Liao JJ, et al. The impact and distinction of 'lipid healthy but obese' and 'lipid abnormal but not obese' phenotypes on lumbar disc degeneration in Chinese. J Transl Med. 2020. 18(1): 211.
22. Chen X, Tamai K, Yang JJ, et al. Impact of High-intensity Zones on Their Corresponding Lumbar Spine Segments: A Propensity Score-matched Analysis. Clin Spine Surg. 2021. 34(1): 32–38.
23. Song Q, Liu X, Chen DJ, et al. Evaluation of MRI and CT parameters to analyze the correlation between disc and facet joint degeneration in the lumbar three-joint complex. Medicine (Baltimore). 2019. 98(40): e17336.
24. Schwarz-Nemec U, Friedrich KM, Arnoldner MA, et al. When an incidental MRI finding becomes a clinical issue: Posterior lumbar subcutaneous edema in degenerative, inflammatory, and infectious conditions of the lumbar spine. Wien Klin Wochenschr. 2020. 132(1–2): 27–34.
25. Cooley JR, AUID- Oho, Walker BF, et al. Relationships between paraspinal muscle morphology and neurocompressive conditions of the lumbar spine: a systematic review with meta-analysis. BMC Musculoskelet Disord. 2018. 19(1): 351.
26. Guo R, Yang X, Zhong Y, et al. Correlations between Modic change and degeneration in 3-joint complex of the lower lumbar spine: A retrospective study. Medicine (Baltimore). 2018. 97(38): e12496.
27. Huang X, Zhu B, Liu X. Quantitative 3D Trajectory Measurement for Percutaneous Endoscopic Lumbar Discectomy. Pain Physician. 2018. 21(4): E355-E365.
28. Wang T, Pelletier MH, Christou C, Oliver R, Mobbs RJ, Walsh WR. A novel in vivo large animal model of lumbar spinal joint degeneration. Spine J. 2018. 18(10): 1896–1909.

29. Im IK, Son ES, Kim DH. Lumbar Epidural Varix Causing Radicular Pain: A Case Report and Differential Diagnosis of Lumbar Cystic Lesions. PM R. 2018. 10(11): 1283–1287.
30. Sabnis AB, Chamoli U, Diwan AD. Is L5-S1 motion segment different from the rest? A radiographic kinematic assessment of 72 patients with chronic low back pain. Eur Spine J. 2018. 27(5): 1127–1135.
31. Pfirrmann CW, Metzdorf A, Zanetti M, Hodler J, Boos N. Magnetic resonance classification of lumbar intervertebral disc degeneration. Spine (Phila Pa 1976). 2001. 26(17): 1873–8.
32. Li GQ, Tong T, Wang LF. Comparative analysis of the effects of OLIF and TLIF on adjacent segments after treatment of L4 degenerative lumbar spondylolisthesis. J Orthop Surg Res. 2022. 17(1): 203.
33. Ouchida J, Nakashima H, AUID- Oho, et al. Adjacent Segment Degeneration after Short-Segment Lateral Lumbar Interbody Fusion (LLIF). Biomed Res Int. 2022. 2022: 5161503.

Figures

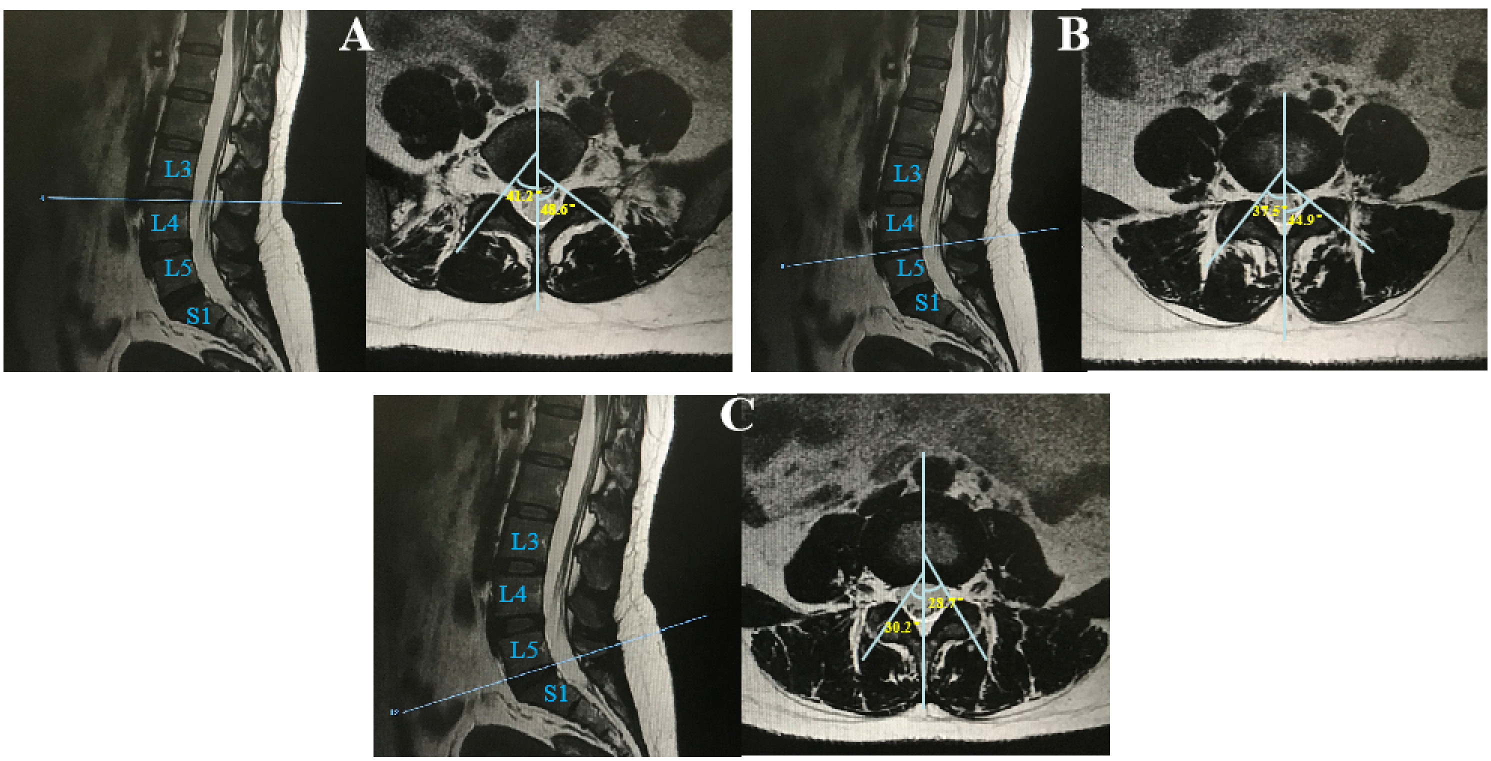

Figure 1

Examples of facet joint angles measured on sagittal and corresponding cross-sectional images of T2W axial lumbar MRI are shown. (A)-(C) Illustration of facet joint measurements for L3/4, L4/5, and L5S1, respectively.

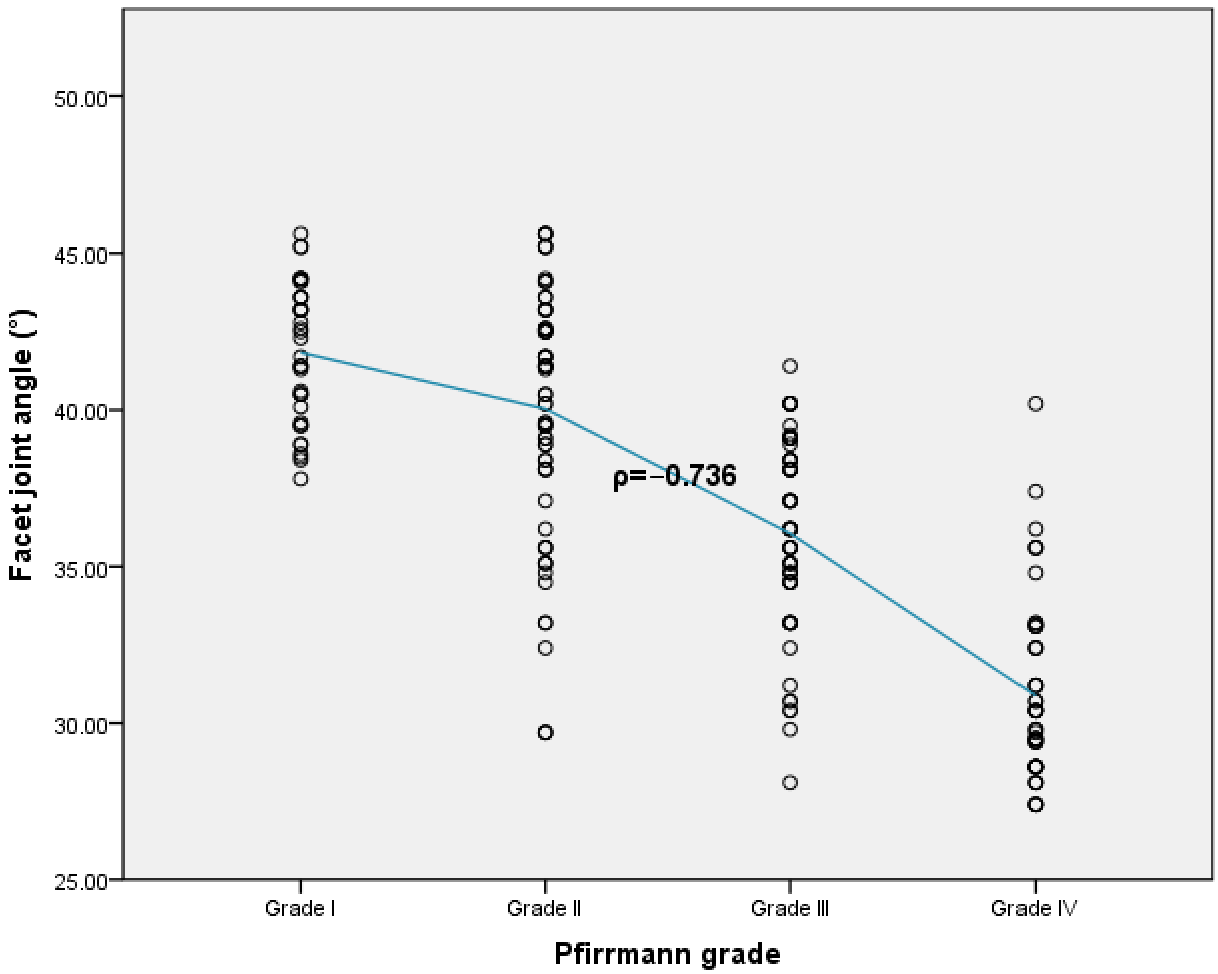

Figure 2

Illustration of Pfifirrmann grading on MRI of different lumbar IVDD.

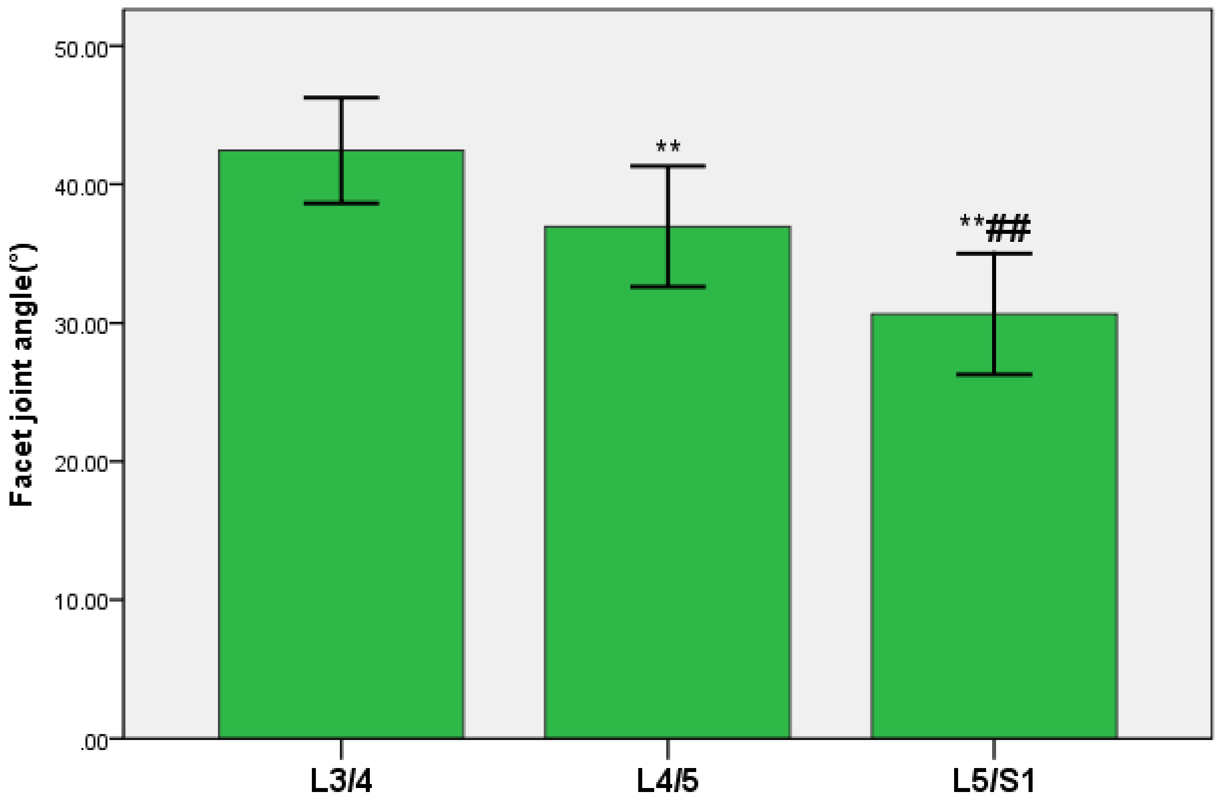

Figure 3

Comparison of LFJA of lumbar different segments in patients. The LFJA of L3/4 were significantly different from those of L4/5 and L5/S1, respectively (L3/4 vs. L4/5: 42.4 ± 1.9° vs. 36.9 ± 2.2°; L3/4 vs. L5/S1: 42.4 ± 1.9° vs. 30.6±2.1°) (**, *P* < 0.01); The LFJA of L5/S1 was significantly lower than that of L4/5, and the difference was statistically significant (30.6±2.1° vs. 36.9 ± 2.2°, ##, *P* < 0.01).

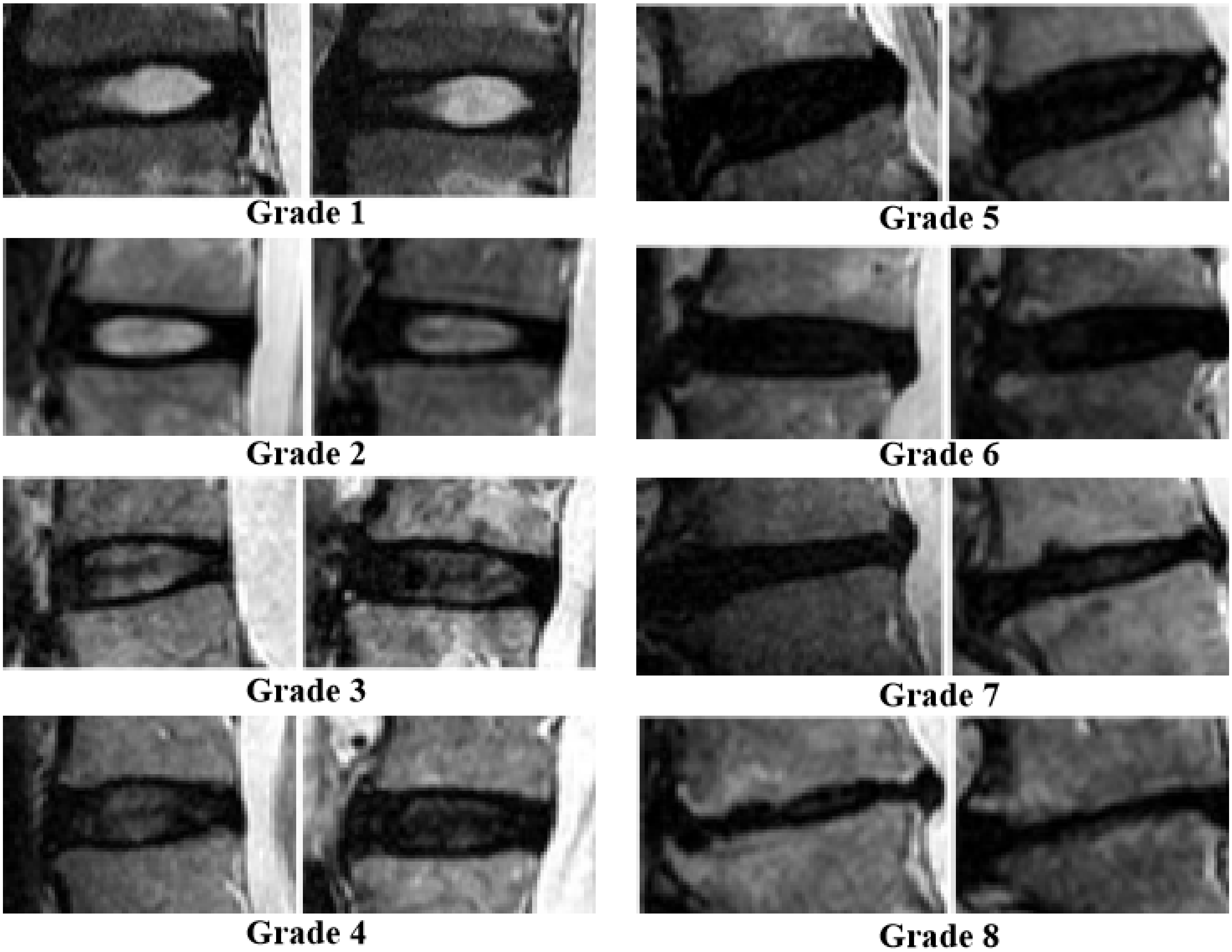

Figure 4

Scatter plots and linear regression lines indicating correlations between a LFJA value (°) and Pfirrmann grade:the LFJA value and grade I-IV ($\rho = -0.736$, $P = 0.000$).