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Original Article

PAC System for Radiographic Comparison of Standing and Supine Lateral Views in Patients with Low-Grade Spondylolisthesis

Aatir Javaid[1], Sibtain Raza[1], Usman Amjad[1], Shaharyar Sheikh[2], Izza Nasir[3], Saman Shahid[4]
[1]Department of Orthopedic Surgery, University College of Medicine, University of Lahore,
[2]Department of Neurosurgery, Central Park Medical College, [3]Department of Anesthesia, Mayo Hospital,
[4]Department of Sciences & Humanities, National University of Computer & Emerging Sciences (NUCES), Lahore – Pakistan

ABSTRACT

Objective: Supine views may not adequately depict low-degree spondylolisthesis, thereby confusing surgeons in deciding the best therapy plan. The study aimed to compare the standing vs. supine radiographs for the radiological parameters.

Materials and Methods: A retrospective investigation was conducted on the standing and supine lateral radiographs of 73 patients with graduation I and II spondylolisthesis at the orthopedic Outdoor patient department. The measurements included lumbar lordosis angle, sacral inclination, slip angle, disc slip, and disc height, which were obtained from the PACS. Lumbar lordosis and sacral inclination were calculated as per the guidelines of Wiltse and Winter (1983).

Results: Mean age was 47.28 years with 41% male and 58.9% females. Prevalence showed 46.57% having L4, 5 level involvement and 53.4% having L5, S1 level involvement in spondylolisthesis. The degree of lumbar lordosis turned out to be 41.7 upon standing while it was 34.39 degrees upon supine position. The size of the disc slip was 0.85cm and 0.74 cm in standing and supine positions respectively. Standing sacral inclination was 45.5 degrees and 40.51 degrees in supine. The slip angle was higher in standing (4.5 degrees) versus 3.97 degrees in the supine position. Disc heights were nearly the same in standing or supine (1.2 cm vs. 1.1 cm) positions. There existed a significant difference between standing vs. supine positions for the following: lumbar lordosis, disc slip, sacral inclination, and slip angle.

Conclusion: Supine views may not accurately show important radiological findings, affecting the choice of treatment. Surgeons may use these findings to make informed decisions about the best treatment plan.

Keywords: PACS: picture archiving and communication system, DICOM: digital imaging and communication in medicine, low-grade spondylolisthesis, lumbar lordosis, disc slip, sacral inclination, slip angle, disc height.

Corresponding Author: Aatir Javaid
Department of Orthopedic Surgery
University College of Medicine, University of Lahore, Pakistan
Email: aatir.jav@gmail.com

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INTRODUCTION

Flexion and extension radiographs are the most common method for evaluating spondylolisthesis. However, in patients experiencing symptoms, pain may hinder proper forward bending, leading to a miscalculation of intervertebral motion. Low-grade spondylolisthesis may not be accurately reflected in supine views, potentially misleading surgeons in determining the correct management strategy. Although contemporary comparative research on low-grade spondylolisthesis radiographs is limited, literature on measures acquired manually from analog films, including high-grade spondylolisthesis patients, has been identified. Literature indicates that the degree of the slide differs between standing and supine lateral radiographs. Previous researches indicate that sliding degrees differ for radiographs: sanding vs. supine. Standing radiographs have superior predictive values for percentage slide and slip angles in low-grade spondylolisthesis. Previous researches indicate that sliding degrees differ for radiographs: sanding vs. supine. Standing radiographs have superior predictive values for percentage slide and slip angles in low-grade spondylolisthesis. Computer software is in use for the measurements through DICOM systems.[1-5] We conducted this study as we wanted to affirm the fact that standing radiographs reveal a better predictive value of radiological parameters in low-grade listhesis.[6-7] Lumbar spondylolisthesis is a frequent ailment that requires spinal surgery to correct. It is most commonly caused by congenital dysplasia, trauma, strain, or other anomalies in the bone attachment between neighboring vertebrae, resulting in a partial or full slide of one vertebrae on the surrounding vertebrae. It is worth noting that it seldom results in unilateral pedicle stress fracture. This illness is characterized by neurological deficiencies such as low back discomfort, nerve root irritation, and neural dysfunctions. Isthmic and degenerative spondylolisthesis are the most frequent kinds of this condition. Spondylolisthesis is most frequent in middle-aged women, primarily affecting the L4 – L5 vertebrae.[8-11] Bilateral spondylolisthesis, spondylolysis, and interbody chronic dislocation are all causes of spondylolisthesis. The radiographic examination is a critical component of the diagnosis of lumbar spondylolisthesis to detect its anatomical abnormalities, etiologies, severity, and probable pathogenic pathways to guide therapeutic care and estimate prognosis. Many X-ray, CT, and MRI methods have been used to examine the architecture of vertebrae, lumbar lordosis (LL), and facet joints that are linked with slippage.[12-13]

In the absence of pars interarticular defect, spondylolisthesis is the anterior translation of the superior vertebral body over the inferior vertebral body. The disorder might be acquired or idiopathic. It can be isthmic, degenerative, dysplastic, or traumatic in etiology, with the severity determined by the degree of spinal slippage. Patients may be asymptomatic or have intermittent or chronic low back pain, radicular symptoms, with or without neurologic impairment, and intermittent neurogenic claudication.[14-18] It has been found that 10% of women and 5% of men have lumbar spondylolisthesis without a pars deformity. Spondylolisthesis at L4 and L5 are often asymptomatic. 6 The prevalence of degenerative Spondylolisthesis rises with age. Spondylolisthesis of high grade is occasionally degenerative. Because of the chronic nature of the illness, clinical symptoms may resolve spontaneously as a result of concurrent stabilization. The measurement of instability in degenerative lumbar Spondylolisthesis is critical to therapy.[19-21] Standing digital radiographs, on the other hand, offer a higher predictive value for measuring many parameters in degenerative Spondylolisthesis, such as lumbar lordosis, percentage of slip, disc height, sacrum inclination, and slip angle. An MRI and CT scan in the supine position revealed that the anterolisthed section

had shrunk. 8, 9 But, they are expensive, and the risks of radiation must be overlooked.[14]

MATERIALS AND METHODS

Study Setting & Design

We performed a retrospective investigation on the standing and supine lateral radiographs of 73 patients with symptomatic grade I and II spondylolisthesis at the orthopedic Outdoor patient department of the University of Lahore teaching hospital and the Social Security Teaching Hospital Lahore (an associate hospital of the University College of Medicine, University of Lahore). The study was conducted for 6 months from 20th September 2022 till 20th March 2023.

Radiological Data

The radiographs were obtained at the same distance and using the same methodology. Our measures comprised the lumbar lordosis angle, sacral inclination, slip angle, disc slip, and disc height, which were received from the PACS and DICOM and entered into a Microsoft Excel file.

Calculations of the Radiological Parameters

The lumbar lordosis angle was measured as an angle between the upper planes of the lumbar vertebrae L1 and the sacral vertebrae S1. [1] Sacral inclination is measured as an angle between the posterior surface of the first sacral vertebra and a vertical line. The slip angle was measured as an angle between the inferior end plate of the slipped vertebra and the upper-end plate of the lower vertebra. Disc slip is measured from posterosuperior end of the lower vertebra to the posteroinferior end of the slipped upper vertebra. Disc height was measured from the posterior inferior end of the upper vertebra to the posterior superior end of the lower vertebra. The same doctor had taken all the measurements.

Data Analysis

The data were analyzed through SPSS 26. Statistical analysis was performed using the student t-test to analyze the significant/ insignificant difference between 'standing' and 'supine' positions in the following parameters: lumbar lordosis (degrees), disc slip (cm), sacral inclination (degrees), slip angle (degrees), and disc height (cm). The chi-square test was applied to see the significant/insignificant difference between listhesis levels and gender under cross-tabulation.

RESULTS

Age & Gender Distributions

The mean age was 47.28 years with (30) 41% male and (43) 58.9% females. See Table 1 for the background and clinical information on patients with low-grade spondylolisthesis.

Clinical Information

Prevalence showed 46.57% having L4, 5 level involvement and 53.4% having L5, S1 level involvement in spondylolisthesis. The degree of lumbar lordosis turned out to be 41.7 upon standing while it was 34.39 degrees upon supine position, (p-value: 0.0001). The size of the disc slip was 0.85 cm and 0.74 cm in standing and supine positions respectively (p-value of 0.0076). Standing sacral inclination was 45.5 degrees and 40.51 degrees in supine (P-value 0.0001). The slip angle was higher in standing (4.5 degrees) versus 3.97 degrees in the supine position (p-value 0.0023). Disc heights were nearly the same in standing or supine (1.2 cm vs. 1.1 cm) positions.

Gender-wise Distribution of Listhesis Levels

Out of 30 males, 17 patients had L5S1 while 13 patients had L4, 5 involvements. Out of 43 females, 22 had L5S1 and 21 had L4, 5 levels involved. See Table 2.

Table 1: Background and Clinical Information of Patients with Low-Grade Spondylolisthesis (n = 73).

Variables	**Mean ± SD**
Age (years)	47.283 ± 13.39
Gender	**Prevalence n (%)**
Male	30 (41.09%)
Female	43 (58.90%)
Level	**Prevalence n (%)**
L4L5	34 (46.57%)
L5S1	39 (53.42%)
Lumbar Lordosis (degrees)	**Mean ± SD**
Standing	41.71±8.39
Supine	34.39 ± 7.99
t-test evaluation: standing vs. supine for lumbar lordosis	p-value< 0.0001* t = 5.4350; df = 146
Disc Slip (cm)	**Mean ± SD**
Standing	0.85 ± 0.244
Supine	0.74 ± 0.250
t-test evaluation: standing vs. supine for disc slip	p-value = 0.0076* t = 2.70; df = 146
Sacral Inclination (degrees)	**Mean ± SD**
Standing	45.48 ± 6.23
Supine	40.51 ± 6.74
t-test evaluation: standing vs. supine for sacral inclination	p-value < 0.0001* t = 4.65; df = 146
Slip Angle(degrees)	**Mean ± SD**
Standing	4.5 ± 1.47
Supine	3.97 ± 1.34
t-test evaluation: standing vs. supine for slip angle	p-value = 0.0023* t = 2.29; df = 146
Disc Height (cm)	**Mean ± SD**
Standing	1.2 ± 0.11
Supine	1.1 ± 0.03
t-test evaluation: standing vs. supine for disc height	p-value = 0.4518 t = 0.75; df = 146

*Significant result

Table 2: Gender-wise Distribution of Listhesis Levels

Listhesis Levels	**L4L5**	**L5S1**	**Chi-Square**
Male (n = 30)	13	17	χ = 0.215
Female (n = 43)	21	22	p-value=0.642

Gender-wise Distribution of Radiological Variables

Lumbar lordosis in 30 males was 44 degrees in standing and 36.5 in the supine position, whereas in females (43), it was 40 degrees in standing and 33 degrees in the supine position.

Disc slip was 0.8 and 0.7 cm in standing and supine position respectively in males. And it was 0.89 cm and 0.78 in females in standing and supine positions respectively.

Sacral inclination was 40 degrees in either position in males, but it was 45.8 degrees in standing females as compared to 40 degrees in the supine position.

Slip angle in standing males was 4.5 and 3.8 in supine, while it was 4.5 and 4.1 degrees in females in standing and supine positions. Disc height remained the same averaging 1.1cm. See Table 3.

Table 3: Gender-wise Distribution of Radiological Parameters.

Lumbar Lordosis (Degrees)		**Standing (Average)**	**Supine (Average)**
Male	(n = 30)	44.36	36.5
Female	(n = 43)	39.83	33
Disc Slip (cm)		**Standing (Average)**	**Supine (Average)**
Male	(n = 30)	0.813	0.703
Female	n = 43)	0.8958	0.781
Sacral Inclination (Degrees)		**Standing (Average)**	**Supine (Average)**
Male	(n = 30)	40.06	40.76
Female	(n = 43)	45.76	40.53
Slip Angle (Degrees)		**Standing (Average)**	**Supine (Average)**
Male	(n = 30)	4.5	3.8
Female	(n = 43)	4.5	4.1
Disc Height (cm)		**Standing (Average)**	**Supine (Average)**
Male	(n = 30)	1.42	1.14
Female	n = 43)	1.15	1.13

Listhesis Level Wise Distribution of Radiological Variables

L4, 5 level, standing position listhesis was 41.9 degrees and 34.6 degrees in the supine position. L5, S1 level standing position listhesis was 41.5 degrees and 34.3 degrees in supine.

At the L4, 5 levels, the disc slip was 0.85 cm in

standing and 0.74 cm in the supine position. At level, L5 S1, disc slip was 0.88cm in the standing position and 0.76cm in the supine position.

Sacral inclination at L4, 5 was 46 degrees in standing and 42 degrees in the supine position. Sacral inclination at L5, S1 was 44.7 degrees and 40 degrees in the supine position.

The slip angle at L4, 5 levels were 4.5 degrees while standing and it was 4 degrees upon supine position. Slip angle at L5, S1 level was 4.7 degrees and 4.2 degrees in standing and supine positions respectively. Disc heights remained nearly the same at around 1.1cm. See Table 4.

Table 4: Listhesis Level Wise Distribution of Radiological Parameters.

Lumbar Lordosis (Degrees)		**Standing (Average)**	**Supine (Average)**
L4 – L5	(n = 34)	41.91	34.58
L5 – S1	(n = 39)	41.51	34.30
Disc Slip (cm)		**Standing (Average)**	**Supine (Average)**
L4 – L5	(n = 34)	0.846	0.741
L5 – S1	(n = 39)	0.875	0.756
Sacral Inclination (Degrees)		**Standing (Average)**	**Supine (Average)**
L4 – L5	(n = 34)	46.35	41.58
L5 – S1	(n = 39)	44.71	39.79
Slip Angle (Degrees)		**Standing (Average)**	**Supine (Average)**
L4 – L5	(n = 34)	4.5	3.98
L5 – S1	(n = 39)	4.7	4.2
Disc Height (cm)		**Standing (Average)**	**Supine (Average)**
L4 – L5	(n = 34)	1.47	1.17
L5 – S1	(n = 39)	1.08	1.11

DISCUSSION

Standing radiographs, which show an increase in slip % due to spinal stress, can be utilized to efficiently evaluate spondylolisthesis. This worsens the deformity, suggesting instability and impacting treatment plans, especially in individuals with symptomatic low-grade

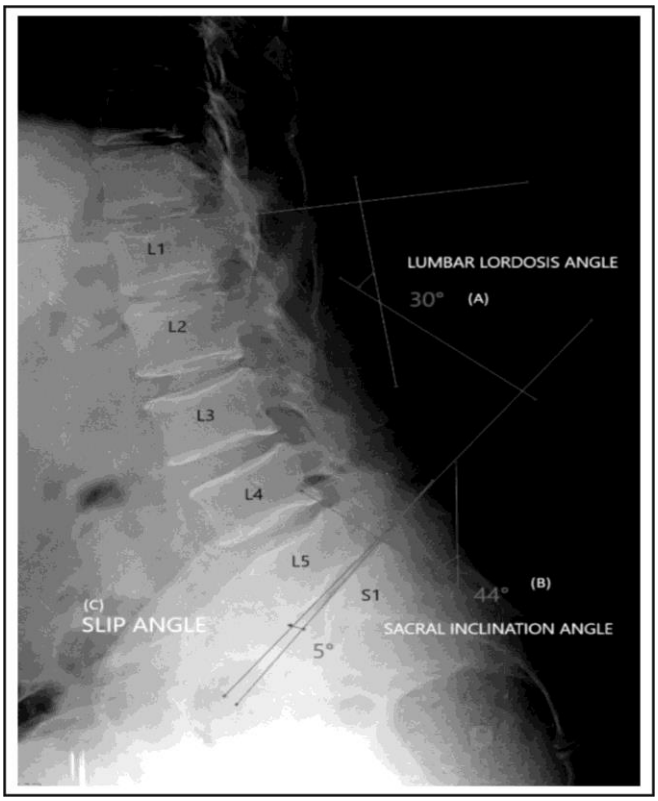

Figure 1: Indication of A) Lumbar Lordosis Angle, B) Sacral Inclination Angle, and C) Slip Angle.

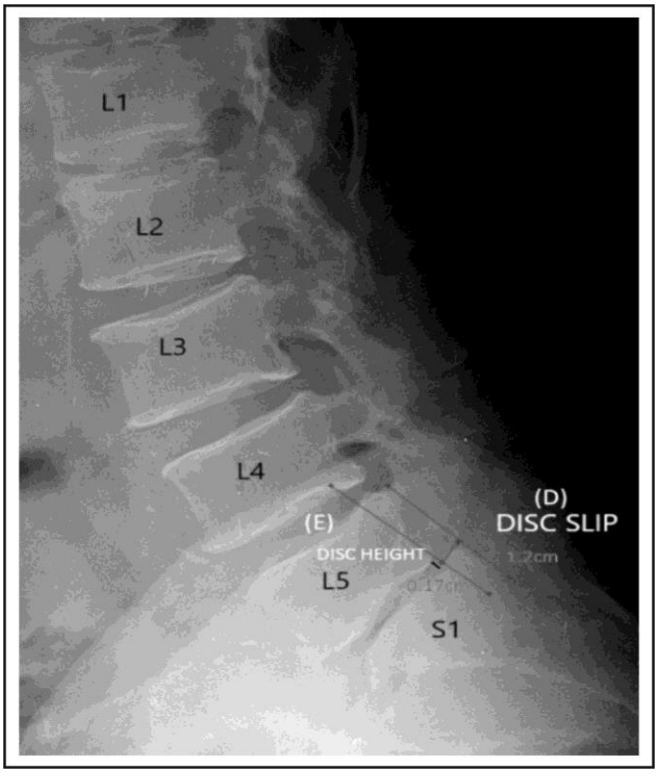

Figure 2: Indication of D) Disc Slip and E) Disc Height.

spondylolisthesis. Furthermore, it aids in the diagnosis of symptomatic instability in patients who are unable to have flexion/extension radiographs taken. Radiograph digitization and software measurements minimize the requirement for manual retrieval and computations. Radiographs of standing postures in spondylolisthesis indicate the increased slip %. The incremental value indicates the spine stress which exacerbates the deformity and can develop instability. Further, it can lead to an impact on the slip grading and this can alter the treatment. The digitization of radiographs and software measures eliminates the need for manual retrieval and computations. Supine views may not accurately portray low-degree spondylolisthesis, causing surgeons to become confused while deciding on the appropriate therapeutic approach. The research intended to examine standing vs. supine radiographs for the following characteristics in individuals with low-degree spondylolisthesis: lumbar lordosis, disc slide, disc height, sacral inclination, and slip angle. The average age was 47.28 years, with 41% men and 58.9% women. The prevalence of spondylolisthesis was 46.57% at the L4, 5 levels and 53.4% at the L5, S1 levels. The degree of lumbar lordosis was 41.7 degrees when standing and 34.39 degrees when lying down. In the standing and supine postures, the disc slip measured 0.85 cm and 0.74 cm, respectively. Standing sacrum inclination was 45.5 degrees, while supine sacral inclination was 40.51 degrees. The slip angle was greater in the standing position (4.5 degrees) than in the supine position (3.97 degrees). Standing and supine disc heights were approximately identical (1.2 cm vs. 1.1 cm). There was a substantial difference in disc slide, and slip angle between standing and supine postures.

In our investigation of 73 patients with grade I and II spondylolisthesis, standing radiographs showed a significantly higher level of translational instability compared to supine radiographs. This result is consistent with earlier research, which showed that supine postures had fewer slides than upright positions. Dhakal et al,[1] finding a state that standing radiographs were an effective way to show an increase in slip%. This may significantly modify slip grading, which may change the treatment strategy. In addition, raising the slip values on standing X-rays introduces an instability parameter that the management plan may need to bead dressed. It was suggested that patients with spondylolisthesis undergo radiographs while standing. It becomes more relevant in low-degree spondylolisthesis since it may spontaneously diminish in the recumbent posture.[5] The proportion of individuals with lumbar spondylolisthesis found to have dynamic instability based on flexion and extension standing radiographs against neutral standing radiographs and supine MRI was studied by Chan et al,[23] L4 – 5 and L5 – S1 were the most typically afflicted levels. The average difference between a neutral standing radiograph and a supine MRI was 3.77 mm, with 60.7% of patients having dynamic instability. Using neutral standing radiographs and supine MRI, they discovered that more patients had dynamic instability. Conventional supine magnetic resonance imaging is frequently used to detect lumbar degenerative spondylolisthesis (LDS) (MRI). Many investigations have demonstrated, however, that when the patient is supine, the degree of spondylolisthesis can be decreased or eliminated when compared to standing lateral and flexion extension (SLFE) radiographs. In patients with L4 – L5 LDS, Kuhns et al,[24] compared the sensitivity of supine MRI with SLFE radiography. 98% of lateral films and 78% of MRIs revealed lumbar degenerative spondylolisthesis. The average slide on lateral standing radiographs was 10.0 mm and 6.6 mm on MRI. Using mobile LDS, 48% of patients were detected. Facet joint effusion's positive predictive value for mobile LDS rose from 52% for effusions bigger than 1 mm to 100% for effusions higher than 3.5 mm. According to their findings, MRI has

a 78% sensitivity for diagnosing L4 – L5 LDS compared to 98% for lateral standing films. Facet effusion size was also established as a predictor of mobile LDS. Our findings imply that, especially in the case of facet effusions, the comprehensive workup of patients with LDS should include standing radiography.[24]

In individuals with degenerative lumbar spondylolisthesis, segmental instability is a justification for surgical intervention. Lumbar standing flexion-extension radiographs are the most often used tool for assessing segmental mobility. However, various simple radiographs have been reported to indicate segmental instability, such as a standing upright radiograph, a supine sagittal magnetic resonance imaging (MRI), or supine lateral radiograph, or a slump or natural sitting lateral radiograph. Nevertheless, in one group of patients, such prevalent position radiographs were not clearly described. Zhao et al,[25] conducted retrospective research on 62 individuals with symptomatic degenerative lumbar spondylolisthesis at L4 who wanted to have surgery. Their findings show that a sitting radiograph shows a high slip percentage and that a supine sagittal MRI shows a decrease in anterolisthesis. A seated radiograph indicates a large slip percentage, but a supine sagittal MRI demonstrates a reduction in anterolisthesis. Kabir et al,[14] examined the percentage of slip difference in symptomatic degenerative lumbar Spondylolisthesis utilizing standing and supine lateral radiographs. All patients had standing and supine lateral radiographs taken. 57% of patients had L4 – L5 spondylolisthesis, whereas 43.33% had L5 – S1 spondylolisthesis. The mean slip percentage on standing radiographs was 34.60 20.03 and 11.978.65 on supine radiographs, indicating a considerable slip reduction on supine radiographs. Supine lateral radiographs revealed a considerable decrease in the slide in degenerative Spondylolisthesis. Nonetheless, they advocated for the frequent use of supine lateral radiographs in the diagnosis of degenerative Spondylolisthesis.[14]

CONCLUSION

In conclusion, the study highlights the importance of considering both standing and supine radiographs while evaluating low-grade spondylolisthesis. The results demonstrate that supine views may not provide an accurate depiction of certain parameters, such as lumbar lordosis, disc slip, sacral inclination, and slip angle, which are crucial in deciding the best therapy plan. The findings of this study may guide surgeons to make informed decisions and choose the most appropriate treatment strategy for patients with low-grade spondylolisthesis. Further research in this area can provide more insights and improve the diagnosis and management of this condition.

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Additional Information

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Ethical Review Board Approval: The study was retrospective.
Human Subjects: Consent was obtained by all patients/participants in this study.
Conflicts of Interest:
In compliance with the ICMJE uniform disclosure form, all authors declare the following:
Financial Relationships: All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work.
Other Relationships: All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

AUTHORS CONTRIBUTIONS

Sr.#	Author's Full Name	Intellectual Contribution to Paper in Terms of:
1.	Aatir Javaid& Sibtain Raza	1. Study design and methodology.
2.	Saman Shahid	2. Paper writing, literature review and data analysis.
3.	Sibtain Raza & Aatir Javaid	3. Data collection.
4.	Usman Amjad	4. Literature review and referencing.
5.	Shaharyar Sheikh	5. Literature review and Interpretation of results.
6.	Izza Nasir	6. Literature review and referencing.