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Change in Spinopelvic Parameters Before and After Lumbar Disc Herniation Surgery

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Abstract

Background: Sagittal balance depends on the interaction between lumbar alignment and spinopelvic parameters such as lumbar lordosis (LL), pelvic tilt (PT), sacral slope (SS), and pelvic incidence (PI). Although these parameters are well described in deformity surgery, their early and mid-term postoperative behavior in lumbar disc herniation (LDH) is not clearly defined. This study evaluated temporal changes in LL, PT, SS, and PI after single-level microdiscectomy at postoperative day 15 and at 1, 3, and 6 months. Methods: This retrospective study included patients who underwent single-level microdiscectomy (L4-L5 or L5-S1) for radiologically confirmed LDH between 2019 and 2021. Standardized standing lateral radiographs were obtained preoperatively and at each postoperative visit. LL, PT, SS, and PI were independently measured by two radiologists (interobserver reliability ICC > 0.90). Pain severity was assessed using the Visual Analog Scale (VAS). Temporal changes were analyzed using paired comparisons with 95% confidence intervals. Results: PT, PI, and SS demonstrated significant early reductions that continued throughout follow-up ($p < 0.05$). LL increased gradually and reached significance at 6 months ($p < 0.001$). VAS scores decreased markedly at all postoperative time points ($p < 0.001$), indicating substantial and sustained pain improvement. Conclusion: In patients with clinically successful microdiscectomy, PT, SS, and PI showed early postoperative changes consistent with normalization of pain-related posture rather than true structural modification. LL showed a delayed but statistically significant increase by 6 months, which may be related to gradual recovery of muscular and postural function. These findings outline typical radiographic evolution after microdiscectomy and may help clinicians distinguish expected postoperative alignment changes from pathological deviations.

Keywords

Lumbar disc herniation, Spinopelvic parameters, Microdiscectomy

Article History

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1. Introduction

Lumbar disc herniation (LDH) is one of the most frequent causes of low back pain and radiculopathy and may alter the normal biomechanical behavior of the lumbar spine [1,2]. Degenerative changes, including loss of proteoglycans and reduced disc height, can modify segmental motion and contribute to disturbances in sagittal alignment [3-5]. These alterations often trigger compensatory mechanisms involving lumbar lordosis (LL), pelvic tilt (PT), sacral slope (SS), and pelvic incidence (PI), key parameters that together maintain global sagittal balance [6-8].

Recent studies have highlighted the relevance of spinopelvic parameters not only in spinal deformity but also in non-deformity conditions such as LDH. For instance, Pan Y et al. reported that variations in PI-LL mismatch and pelvic morphology were associated with recurrence risk after lumbar disc surgery, emphasizing the biomechanical importance of these angles even in routine degenerative cases. Similarly, Löchel J et al. demonstrated that spinopelvic anatomy, particularly PI and LL, is closely related to the level and morphology of disc herniation, underscoring the anatomical interplay between pelvic alignment and disc pathology [9,10].

Pain-related flexion, antalgic posture, and paraspinal muscle spasm may lead to transient disturbances in sagittal alignment in LDH patients, and these changes are often expected to improve after surgical decompression [11-15]. However, while substantial research has focused on deformity or fusion surgery, data on the early and mid-term postoperative evolution of spinopelvic parameters following microdiscectomy remain limited [16-18].

A clearer understanding of how LL, PT, SS, and PI change after LDH surgery may assist clinicians in interpreting postoperative radiographs and differentiating normal biomechanical recovery from persistent malalignment. Therefore, this study aimed to evaluate temporal changes in spinopelvic parameters from the preoperative period to postoperative day 15, and at 1, 3, and 6 months after successful microdiscectomy.

2. Methods

2.1 Study Design

This retrospective observational study included patients who underwent lumbar microdiscectomy for symptomatic LDH between 2019 and 2021. The study protocol was approved by the institutional ethics committee (Approval No: 2022/191). All procedures were conducted in accordance with the Declaration of Helsinki. Patient identifiers were removed to ensure anonymity in this double-blind review process.

2.2 Participants

Patients were eligible if they had radiologically confirmed LDH with persistent radiculopathy or low back pain unresponsive to medical and physical therapy. Additional inclusion criteria were: preoperative Visual Analog Scale (VAS) score > 7, postoperative VAS ≤ 3 following microdiscectomy (defining successful clinical improvement), and availability of complete radiographic follow-up at the predefined intervals.

Exclusion criteria included scoliosis, kyphotic deformity, ankylosing spondylitis, rheumatological disorders, morbid obesity, hip or sacroiliac joint pathology, and prior lumbar surgery.

Baseline demographic and clinical characteristics recorded for each patient included age, sex, body mass index (BMI), smoking status, operated spinal level, side of herniation, type of disc pathology (protrusion, extrusion, sequestration), and symptom duration. Patients who missed any of the scheduled postoperative radiographic assessments (postoperative day 15, and at 1, 3, or 6 months) were excluded from the final analysis. A total of 73 patients met all criteria and completed the full follow-up.

2.3 Surgical Procedure

All operations consisted of standard single-level lumbar microdiscectomy, performed by experienced neurosurgeons. Only patients operated at the L4-L5 or L5-S1 levels were included. No patient underwent multi-level decompression. No instrumentation or fusion procedures were performed in any case. Microsurgical discectomy was carried out under operating microscope magnification, with removal of the herniated fragment and preservation of normal disc tissue whenever possible.

2.4 Radiograph Technique and Standardization

Standardized standing lateral lumbar radiographs were obtained preoperatively and at postoperative day 15, and at 1, 3, and 6 months. Radiographs were acquired using a fixed protocol:

Patients stood upright with hips and knees fully extended.

Feet were positioned shoulder-width apart and aligned symmetrically.

Arms were placed in a relaxed, forward-flexed position to avoid shoulder obstruction.

The X-ray beam was centered at the L3 vertebral body with a 100-120 cm source-to-image distance.

Pelvic rotation was minimized by ensuring equal iliac crest height and symmetric femoral head visualization.

All radiographs were taken by the same radiology technicians familiar with the protocol. Two radiologists independently measured spinopelvic parameters, and interobserver reliability was high (intraclass correlation coefficients, ICC > 0.90).

2.5 Radiographic Measurements

The following sagittal spinopelvic parameters were measured using digital imaging software:

LL: Cobb angle between the superior endplate of L1 and the superior endplate of S1.

PT: Angle between the vertical and the line connecting the sacral midpoint to the femoral head axis.

SS: Angle between the horizontal plane and the sacral endplate.

PI: Angle between the perpendicular to the sacral endplate and the line connecting the sacral midpoint to the femoral head axis.

Each parameter was recorded at all five time points. Measurement discrepancies > 3° between observers were re-evaluated jointly to reach consensus, and the consensus values were used for all statistical analyses. The same consensus procedure was also applied to the repeated measurements in the subsample used for the reliability (Standard Error of Measurement (SEM) and Minimal Detectable Change (MDC)) analysis.

2.6 Clinical Evaluation

Pain severity was assessed using the VAS, a 10-cm horizontal scale where 0 indicates no pain and 10 indicates worst imaginable pain. VAS scores were routinely recorded preoperatively and at each postoperative visit (postoperative day 15, and at 1, 3, and 6 months).

2.7 Statistical Analysis

Statistical analyses were performed using SPSS (version 20.0, IBM Corp., Armonk, NY, USA). The Kolmogorov-Smirnov test was used to assess variable normality. Normally distributed continuous variables were presented as mean ± standard deviation and compared using paired samples t-tests. Non-normally distributed variables were analyzed using Mann-Whitney U or Wilcoxon tests as appropriate. A p-value < 0.05 was considered statistically significant.

Effect sizes (Cohen's d) and 95% confidence intervals were calculated for all preoperative vs. postoperative comparisons to complement p-values. Because repeated measurements were performed across multiple time points, findings were interpreted with caution regarding potential type I error inflation. Post-hoc power calculations were performed for each primary spinopelvic outcome.

3. Results

A total of 73 patients were included in the final analysis, of whom 49 (67.1%) were female and 24 (32.9%) were male. The mean age was 52 ± 11 years in females and 49 ± 16 years in males (p = 0.39). The overall mean BMI was 24.47 ± 2.10 kg/m² (Table 1). Smoking was reported in 31.5% of patients. The operated level was L4-L5 in 58.9% and L5-S1 in 41.1% of cases. Herniation localization was central in 32.9%, right subarticular in 28.8%, left subarticular in 23.3%, right foraminal in 4.1%, and left foraminal in 11.0%. Disc pathology included protrusion (52.1%), extrusion (43.8%), and sequestration in 4.1%. Symptom duration was <3 months in 20.5%, 3-6 months in 53.4%, and >6 months in 26.0% of the cohort. In a subsample of 30 randomly selected patients, intraobserver ICC for spinopelvic measurements ranged from 0.93 to 0.98, indicating high measurement consistency. The corresponding MDC_{95} values were 3.2° for LL, 2.6° for PT, 4.0° for SS, and 3.0° for PI, and these thresholds were used to interpret whether longitudinal angular changes exceeded measurement error.

Table 1. Baseline demographic and clinical characteristics

Variable	Female (n = 49)	Male (n = 24)	Total (n = 73)	P-value
Age (years)	52 ± 11	49 ± 16	50.62 ± 12.85	0.39
BMI (kg/m²)	24.69 ± 2.02	24.00 ± 2.23	24.47 ± 2.10	0.28
Gender distribution	67.1%	32.9%	—	—

3.1 Pelvic Tilt

The mean preoperative PT was 19.45 ± 3.37°, decreasing significantly at all postoperative evaluations:

17.85 ± 3.34° at day 15;

17.12 ± 3.40° at 1 month;

16.84 ± 3.29° at 3 months;

16.16 ± 2.88° at 6 months.

All reductions were statistically significant (all $p < 0.001$). The 6-month change demonstrated a large effect size (Cohen's d ≈ 0.96). Sex-based trends were similar, with slightly greater improvement in males.

3.2 Pelvic Incidence

Preoperative PI was 53.59 ± 7.35°. Postoperative values decreased progressively:

50.89 ± 7.09° at day 15;

49.97 ± 6.96° at 1 month;

49.42 ± 6.68° at 3 months;

48.58 ± 6.26° at 6 months.

All values differed significantly from baseline ($p < 0.001$). The 6-month change represented a moderate-large effect (d ≈ 0.74). These variations likely reflect positional rather than anatomical change. Notably, the mean PI reduction of approximately 5° at 6 months exceeded the MDC_{95} of 3.0°, indicating that the observed difference is larger than expected from random measurement error alone; however, given that PI is considered anatomically fixed, this magnitude of change is most plausibly attributable to pelvic rotation and patient positioning during radiography rather than true structural alteration.

3.3 Lumbar Lordosis

LL increased gradually from 47.73 ± 10.82° preoperatively to:

48.51 ± 9.90° at day 15;

48.55 ± 9.63° at 1 month;

48.64 ± 8.82° at 3 months;

50.95 ± 7.86° at 6 months.

A statistically significant increase was observed only at the 6-month evaluation ($p < 0.001$), with a moderate effect size (d ≈ 0.41). Earlier postoperative changes were not significantly different from baseline ($p > 0.05$).

Sex-based exploratory findings: at 6 months, mean LL increased by +2.70° in females and +4.30° in males. These descriptive differences should be interpreted cautiously due to small subgroup sizes and regarded as exploratory rather than confirmatory.

3.4 Sacral Slope

The preoperative SS was 34.12 ± 6.42°, decreasing to:

33.18 ± 6.55° at day 15;

32.88 ± 6.16° at 1 month;

32.74 ± 5.62° at 3 months;

32.41 ± 5.50° at 6 months.

All reductions were significant (all $p < 0.05$). The magnitude of change was greater in males than females, although subgroup analyses remain exploratory.

3.5 Pain Severity (VAS)

Preoperative VAS scores were markedly elevated (>7 by inclusion criteria). Postoperative pain showed a strong and progressive reduction:

Day 15: mean decrease 5.84 ± 0.78, 95% CI 5.65-6.02, $p < 0.001$;

1 month: mean decrease 7.15 ± 0.70, 95% CI 6.99-7.31, $p < 0.001$;

3 months: mean decrease 7.93 ± 0.69, 95% CI 7.77-8.09, $p < 0.001$;

6 months: mean decrease 8.41 ± 0.60, 95% CI 8.27-8.55, $p < 0.001$.

Effect sizes were extremely large (all $d > 2$), confirming robust and sustained symptomatic improvement.

3.6 Overall Summary

PT, PI, and SS exhibited significant and immediate postoperative improvement, with progressive normalization through 6 months. LL showed a delayed but significant increase only at the 6-month evaluation, likely reflecting recovery of paraspinal muscle function and normalization of posture. Radiographic improvements were accompanied by substantial and consistent reduction in pain severity. When interpreted in light of the MDC_{95} values, the 6-month reductions in PT and the increase in LL slightly exceeded their respective thresholds (2.6° and 3.2°), suggesting that at least part of these changes may represent true biomechanical normalization. In contrast, the modest decrease in SS remained below its MDC_{95} (4.0°) and should therefore be interpreted with caution. Measurement techniques are shown in Figure 1, while temporal changes in spinopelvic parameters are presented in Tables 2-4. Postoperative trends for LL, PT, and SS are illustrated in Figure 2A-C, demonstrating the progressive changes at postoperative day 15 and at 1, 3, and 6 months (x-axis: time points; y-axis: angular measurements).

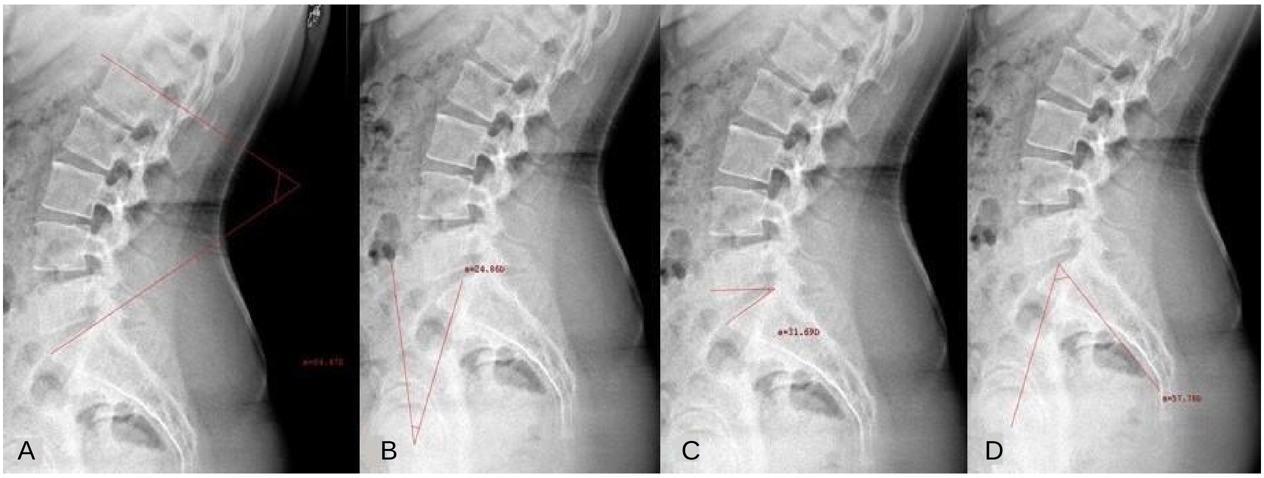

Figure 1. Lateral lumbosacral radiographic measurements illustrating: (A) lumbar lordosis (L1-S1 Cobb angle), (B) pelvic tilt, (C) sacral slope, and (D) pelvic incidence.

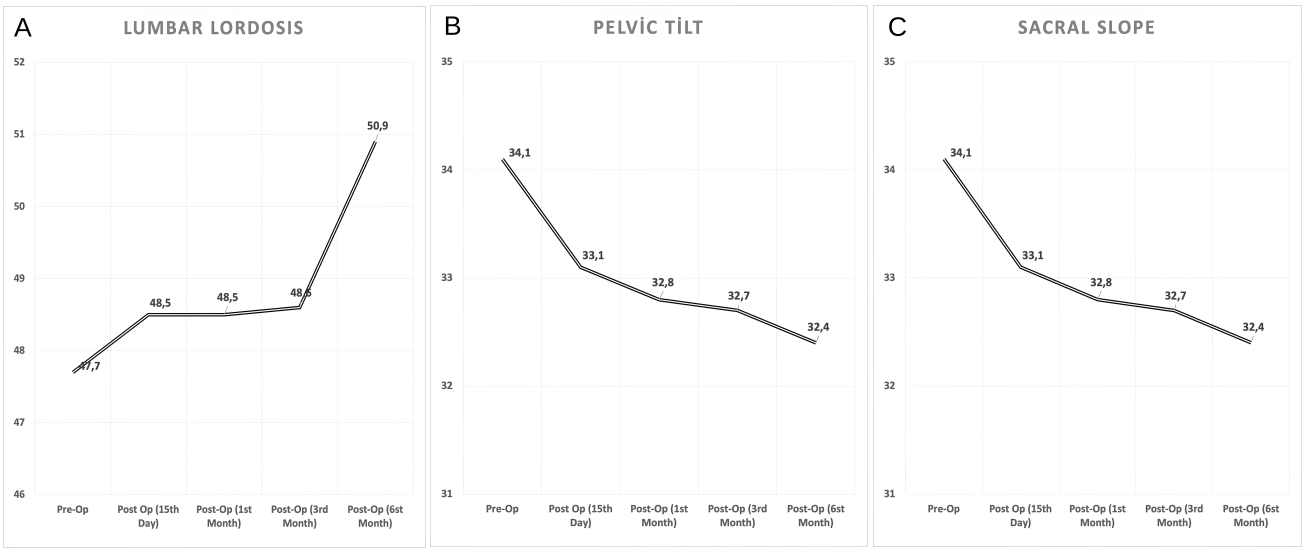

Figure 2. (A) Postoperative changes in lumbar lordosis at day 15, and at 1, 3, and 6 months. (B) Postoperative changes in pelvic tilt at day 15, and at 1, 3, and 6 months. (C) Postoperative changes in sacral slope at day 15, and at 1, 3, and 6 months.

Table 2. Spinopelvic parameters before and after microdiscectomy (all patients).

Measurement	Pre-op Mean ± SD	Post-op Imaging Day	Mean ± SD	95% CI (Lower-Upper)	p-value
Lumbar Lordosis (°)	47.73 ± 10.82	15th day	48.51 ± 9.90	-2.397 - 0.835	0.339
		1st month	48.55 ± 9.63	-2.593 - 0.949	0.358
		3rd month	48.64 ± 8.82	-2.879 - 1.043	0.354
		6th month	50.95 ± 7.86	-5.047 - -1.392	<0.001
Pelvic Tilt (°)	19.45 ± 3.37	15th day	17.85 ± 3.34	1.168 - 2.037	<0.001
		1st month	17.12 ± 3.40	1.788 - 2.869	<0.001
		3rd month	16.84 ± 3.29	1.997 - 3.236	<0.001
		6th month	16.16 ± 2.88	2.678 - 3.897	<0.001
Sacral Slope (°)	34.12 ± 6.42	15th day	33.18 ± 6.55	0.011 - 1.879	0.047
		1st month	32.88 ± 6.16	0.205 - 2.288	0.020
		3rd month	32.74 ± 5.62	0.236 - 2.532	0.019
		6th month	32.41 ± 5.50	0.394 - 3.031	0.012
Pelvic Incidence (°)	53.59 ± 7.35	15th day	50.89 ± 7.09	1.649 - 3.748	<0.001
		1st month	49.97 ± 6.96	2.484 - 4.749	<0.001
		3rd month	49.42 ± 6.68	2.766 - 5.563	<0.001
		6th month	48.58 ± 6.26	3.489 - 6.538	<0.001

Table 3. Spinopelvic parameters before and after microdiscectomy (female patients).

Measurement	Pre-op Mean ± SD	Post-op Imaging Day	Mean ± SD	95% CI (Lower-Upper)
Lumbar Lordosis (°)	47.67 ± 11.45	15th day	48.31 ± 10.51	-2.681 - 1.416
		1st month	48.43 ± 10.08	-3.017 - 1.507
		3rd month	48.10 ± 9.29	-2.917 - 2.060
		6th month	50.37 ± 8.18	-5.094 - -0.294
Pelvic Tilt (°)	19.33 ± 3.47	15th day	17.76 ± 3.39	0.988 - 2.155
		1st month	17.02 ± 3.77	1.559 - 3.053
		3rd month	16.96 ± 3.64	1.564 - 3.171
		6th month	16.18 ± 3.12	2.430 - 3.856
Sacral Slope (°)	33.98 ± 6.92	15th day	33.43 ± 7.25	-0.638 - 1.740
		1st month	33.20 ± 6.99	-0.573 - 2.124
		3rd month	33.20 ± 6.32	-0.725 - 2.276
		6th month	32.96 ± 6.20	-0.602 - 2.643
Pelvic Incidence (°)	53.33 ± 8.00	15th day	50.98 ± 8.08	0.974 - 3.720
		1st month	50.18 ± 7.87	1.632 - 4.654
		3rd month	50.16 ± 7.42	1.377 - 4.950
		6th month	49.14 ± 6.99	2.211 - 6.156

Note: Exploratory descriptive subgroup data; no p-values reported due to limited sample size.

Table 4. Spinopelvic parameters before and after microdiscectomy (male patients).

Measurement	Pre-op Mean ± SD	Post-op Imaging Day	Mean ± SD	95% CI (Lower-Upper)
Lumbar Lordosis (°)	47.83 ± 9.64	15th day	48.51 ± 9.90	-2.397 - 0.835
		1st month	48.55 ± 9.63	-2.593 - 0.949
		3rd month	48.64 ± 8.82	-2.879 - 1.043
		6th month	50.95 ± 7.86	-5.047 - -1.392
Pelvic Tilt (°)	19.71 ± 3.21	15th day	18.04 ± 3.32	1.036 - 2.298
		1st month	17.33 ± 2.55	1.684 - 3.066
		3rd month	16.58 ± 2.48	2.150 - 4.100
		6th month	16.13 ± 2.38	2.364 - 4.803
Sacral Slope (°)	34.42 ± 5.37	15th day	32.67 ± 4.93	0.204 - 3.296
		1st month	32.21 ± 4.02	0.575 - 3.841
		3rd month	31.79 ± 3.72	0.914 - 4.336
		6th month	31.29 ± 3.53	0.801 - 5.449
Pelvic Incidence (°)	54.13 ± 5.93	15th day	50.71 ± 4.56	1.789 - 5.045
		1st month	49.54 ± 4.67	2.970 - 6.197
		3rd month	47.92 ± 4.61	4.084 - 8.332
		6th month	47.42 ± 4.31	4.364 - 9.053

Note: Exploratory descriptive subgroup data; no p-values reported due to limited sample size.

4. Discussion

The present study demonstrates that, in patients with clinically successful microdiscectomy for LDH, most spinopelvic parameters showed significant early and mid-term postoperative changes. PT, SL, and PI showed immediate postoperative changes, whereas LL exhibited a delayed improvement, reaching statistical significance only at the 6-month follow-up.

These temporal patterns suggest that early postoperative alignment reflects positional normalization after pain relief and resolution of antalgic posture, while later changes, particularly in LL, may be related to gradual restoration of paraspinal muscle function. Given the retrospective design, these findings should be interpreted as associations rather than evidence of direct causation.

Spinopelvic alignment is strongly influenced by degenerative changes of the intervertebral disc, which can disrupt normal sagittal mechanics and increase compensatory pelvic motion [1-5].

The association between pelvic morphology, PI-LL mismatch, and disc herniation has been emphasized in recent literature, highlighting the relevance of sagittal balance even in non-deformity spine conditions. Pan et al. reported that variations in pelvic parameters may predispose to recurrence after disc surgery, underlining the biomechanical interplay between pelvic morphology and postoperative outcomes. Löchel et al. similarly found strong associations between spinopelvic anatomy and the level of disc herniation, reinforcing the importance of pelvic parameters in degenerative lumbar pathology. In our study, PT decreased significantly as early as postoperative day 15, with progressive improvement through 6 months. This rapid normalization is consistent with prior evidence suggesting that PT reflects a compensatory mechanism during painful flexed postures and improves promptly once radicular pain is relieved [13-15]. When interpreted in light of the MDC_{95} value for PT (2.6°), the 6-month reduction exceeds the expected measurement error and therefore likely represents a true change in pelvic orientation rather than mere noise.

SS also showed significant early reductions. Because SS and PT are positional parameters, these immediate changes likely represent the transition from an antalgic posture to a more upright sagittal alignment after pain resolution. The progressive improvement over time may also relate to enhanced standing tolerance, improved hip extension, and reduced guarding. However, the absolute change in SS over 6 months remained below its MDC_{95} (4.0°), suggesting that at least part of the observed reduction may still lie within the range of measurement and positional variability and should therefore be interpreted with caution.

PI, a structural parameter, is traditionally considered constant in adults. Although our findings showed statistically significant decreases in PI at all postoperative time points, these changes are most plausibly attributed to positional or measurement-related variation rather than true anatomical modification. Small variations in pelvic rotation, standing posture, or radiographic positioning can lead to measurable PI fluctuations, especially in patients with painful preoperative postures. Similar observations have been reported in prior studies examining postoperative and position-dependent PI changes [19,20]. In our cohort, the mean PI reduction of approximately 5° at 6 months exceeded the MDC_{95} of 3.0°, indicating that the difference is larger than random measurement error alone; nevertheless, considering that PI is anatomically fixed, this magnitude of change remains most consistent with pelvic rotation and posture-related factors rather than structural alteration. Taken together, the reliability analysis and MDC thresholds support a primarily functional/postural rather than structural interpretation of PI variability in this setting.

LL did not show significant early postoperative change but improved significantly at six months. Liang et al. reported that sagittal imbalance in LDH patients may result from pain-induced muscle inhibition and reduced paraspinal activity [17], supporting our finding that the delayed improvement in LL likely reflects gradual recovery of paraspinal muscle strength rather than an immediate postoperative effect. Increased physical activity after the early postoperative period may further contribute to the restoration of lordosis [21]. Notably, the 6-month increase in LL slightly exceeded its MDC_{95} (3.2°), suggesting that at least part of this change represents a true biomechanical adaptation accompanying clinical recovery rather than measurement variability alone.

Sex-based differences were exploratory findings in our study. While males demonstrated more pronounced changes in LL and SS, these results should be interpreted cautiously due to limited subgroup sizes. Previous anatomical studies have reported sex-related differences in pelvic morphology and muscle mass, which may contribute to variation in realignment patterns [19,22,23]. However, the current sample does not permit strong conclusions. Accordingly, the sex-based analyses should be regarded as exploratory and hypothesis-generating rather than confirmatory. Consistent with the radiographic improvements, pain severity showed a marked and sustained reduction at all follow-up points. Large effect sizes were observed for pain improvement; however, the clinical relevance of the observed angular changes remains more uncertain and should be interpreted in the context of measurement variability (as quantified by MDC_{95}) and the absence of functional outcome measures.

The large effect sizes support the clinical relevance of the findings and suggest that radiographic normalization parallels symptomatic improvement. Because functional outcome tools (e.g., ODI, SF-36) were not included, the relationship between radiographic improvement and functional recovery remains unclear, highlighting a key limitation and a need for future prospective research.

This study has several limitations. Its retrospective design may introduce selection bias, although the use of strict inclusion criteria and complete radiographic follow-up reduces this concern to some extent. In addition, despite standardized radiographic protocols, PI measurements can still be influenced by subtle variations in patient posture, which may contribute to the observed fluctuations. The male-female subgroup comparisons were based on relatively small samples, making these findings exploratory rather than definitive. Moreover, the absence of patient-reported outcome measures limits the ability to relate radiographic improvements to functional recovery, which should be addressed in future research. Our follow-up was limited to six months, and longer-term studies are needed to determine whether the observed spinopelvic changes remain stable, continue to progress, or influence the risk of recurrent symptoms and degenerative changes over time.

Despite these limitations, this study provides detailed early and mid-term radiographic data after microdiscectomy and demonstrates significant postoperative normalization in PT, SS, and PI, with later improvement in LL. These findings contribute to the understanding of sagittal parameter evolution after decompression surgery and may help clinicians differentiate expected postoperative alignment changes from pathological findings. By incorporating measurement error through SEM and MDC_{95}, our results also offer a more nuanced framework for distinguishing true biomechanical adaptations from variations that may be attributable to positioning or measurement variability, which may be useful when interpreting follow-up radiographs in clinical practice.

5. Conclusion

This study shows that, in patients with clinically successful lumbar microdiscectomy, sagittal spinopelvic parameters display characteristic early and mid-term postoperative changes. PT, SS, and PI improved early, most likely reflecting normalization of pain-related posture rather than true structural modification, while LL showed a delayed increase at 6 months that may be related to gradual recovery of muscle function. Considering measurement variability, changes in PT and LL appear more likely to represent true biomechanical adaptation, whereas other angular variations may remain within the range of positional or measurement-related differences. Sex-based findings were exploratory due to limited subgroup size. Overall, these results help characterize typical radiographic evolution after microdiscectomy and may assist clinicians in distinguishing expected postoperative alignment changes from pathological deviations. Further prospective studies with functional outcome measures and longer follow-up are needed to clarify the clinical impact and long-term implications of these alignment patterns.

Ethics Statement

This work approved by Abant Izzet Baysal University Ethics Committee (Approval No: 2022/191).

Informed Consent

Informed consent was obtained from all participants.

Conflict of Interest

The authors declare that no conflict of interest.

Generative AI Statement

The authors declare that no Gen AI was used in the creation of this manuscript.

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