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Original Article

Pre- and postoperative radiological changes and their association with pain outcomes in patients with lumbar spondylolisthesis

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Abstract

Aim: In the literature, low-grade isthmic and degenerative lumbar spondylolisthesis (Grade 1-2) types have been evaluated either evaluated in isolation or in combination. Studies investigating the clinical impact of preoperative and postoperative radiological measurements of the lumbar spine and pelvis, including the level of spondylolisthesis, are available. In this study, we investigated whether the degree of radiological correction of slippage was associated with postoperative pain improvement in 110 patients with Grade 1-2 isthmic or degenerative lumbar spondylolisthesis.
Materials and Methods: This retrospective study included a total of 110 patients with lumbar spondylolisthesis who underwent surgery using a standardized technique at a single center between January 2020 and February 2024.
Results: The average age of the 110 patients included in the study was 58.63 ± 9.40 years. When the distrubiton of spondylolisthesis levels were evaluated, 7.3% of patients had spondylolisthesis at the L3–L4 level, 50.9% at the L4–L5 level, and 40.9% at the L5–S1 level. A moderate negative correlation was found between the percentage improvement in postoperative slippage and changes in the patients' VAS scores.
Conclusion: In conclusion, a greater degree of radiological correction was not associated with better short-term pain improvement in patients with low-grade lumbar spondylolisthesis. Our findings suggest that near-complete anatomical restoration of the spine may not provide additional benefit in early clinical outcomes.

Keywords: Spondylolisthesis, visual analog scale, reduction

INTRODUCTION

Spondylolisthesis, a common cause of lower back and leg pain, refers to the anterior displacement of a vertebral body relative to the caudal vertebra (1,2). The most commonly used classification system is the one proposed by Wiltse, which divides spondylolisthesis etiologically into five subtypes: isthmic, degenerative, dysplastic, traumatic, and pathological (3). Another classification, the Meyerding classification, is based on the degree of slippage between two adjacent vertebrae in the lumbar spine: Grade 1 (less than 25%), Grade 2 (25% – 50%), Grade 3 (50% – 75%), Grade 4 (75% – 100%), and Grade 5 (spondyloptosis) > 100% (4).

The most common type of spondylolisthesis is the isthmic type, which involves a unilateral or bilateral pars defect. The most frequent level where the pars defect is observed is at L5-S1. Degenerative spondylolisthesis, an acquired condition, involves ligament thickening, facet joint hypertrophy, and osteophyte formation leading to compression in the neural foramina rather than slippage (5). This is most commonly seen at the L4-5 level and is more prevalent in women over 50 years old (6).

Regardless of the type of spondylolisthesis, the most common symptom is pain. The clinical presentation can vary widely, ranging from simple mechanical back pain to progressive neurological deficits (7). Conservative treatments such as physical therapy, analgesics, and activity modifications are the first line of treatment for spondylolisthesis. However, for patients who do not respond to conservative methods, surgical interventions are applied. Among surgical approaches, posterior techniques are most commonly used (8). Decompressive surgery is widely used for spondylolisthesis. Although posterior instrumentation and interbody fusion are often applied to achieve surgical reduction and reduce the risk of pseudoarthrosis, fusion procedures remain a topic of debate (9,10).

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In the literature, low-grade isthmic and degenerative lumbar spondylolisthesis (Grade 1-2) types have been evaluated either in isolation or in combination, and there are studies investigating the clinical impact of preoperative and postoperative radiological measurements of the lumbar spine and pelvis, including the level of spondylolisthesis. In this study, we aimed to investigate the association between the degree of postoperative slippage correction and pain improvement in 110 patients with Grade 1–2 degenerative or isthmic lumbar spondylolisthesis treated with the same surgical technique.

MATERIALS AND METHODS

Study Design: This research is a retrospective study. A total of 110 patients with lumbar spondylolisthesis who underwent surgery using a standardized technique (posterior decompression, transpedicular screw fixation, and fusion) at a single center between January 2020 and February 2024 were included.

Inclusion criteria were age > 18 years, Grade 1–2 spondylolisthesis according to the Meyerding classification, isthmic or degenerative type according to the Wiltse classification, single-level slippage, no history of spinal surgery, presence of radicular pain or muscle weakness, absence of trauma-related spondylolisthesis, absence of spinal infection or malignant radiological findings, and availability of preoperative dynamic lumbar X-rays, lumbar computed tomography (CT), and lumbar magnetic resonance imaging (MRI).

Patients excluded from the study were those with multi-level slippage, post-spinal surgery spondylolisthesis, trauma-related spondylolisthesis, spinal infections, spinal tumor radiological findings and those without preoperative dynamic X-ray, lumbar CT, or lumbar MRI evaluations.

Patients' preoperative and postoperative (day 90) Visual Analog Scale (VAS) scores and dynamic X-rays were evaluated based on the recorded discharge summaries and the hospital radiology system. The sample size was calculated using the G*Power software (version 3.1) program with a formula for comparing two dependent arithmetic means with 0.05 alpha error, 80% power, and an effect size of 0.3, yielding a minimum sample size of 90.

Radiological Outcome Measures:

Preoperative and postoperative slippage distance: The distance in millimeters between the posterior edge of the inferior endplate of the cranial vertebra and the posterior edge of the superior endplate of the caudal vertebra.

Percentage of correction (PI): ((preoperative slippage distance - postoperative slippage distance) / preoperative slippage distance) x100.

Patients were grouped based on the percentage of correction:

- **Group A:** 1% – 50% correction
- **Group B:** 51% – 99% correction
- **Group C:** 100% correction

Preoperative and postoperative anterior disc height (ADH): The vertical distance between the anterior portion of the superior endplate of the caudal vertebra and the inferior endplate of the cranial vertebra.

Preoperative and postoperative posterior disc height (PDH): The vertical distance between the posterior portion of the inferior endplate of the cranial vertebra and the superior endplate of the caudal vertebra.

Preoperative and postoperative intervertebral listhetic segmental angle (ILSA): The angle between the inferior endplate of the cranial vertebra and the superior endplate of the caudal vertebra (Figure 1).

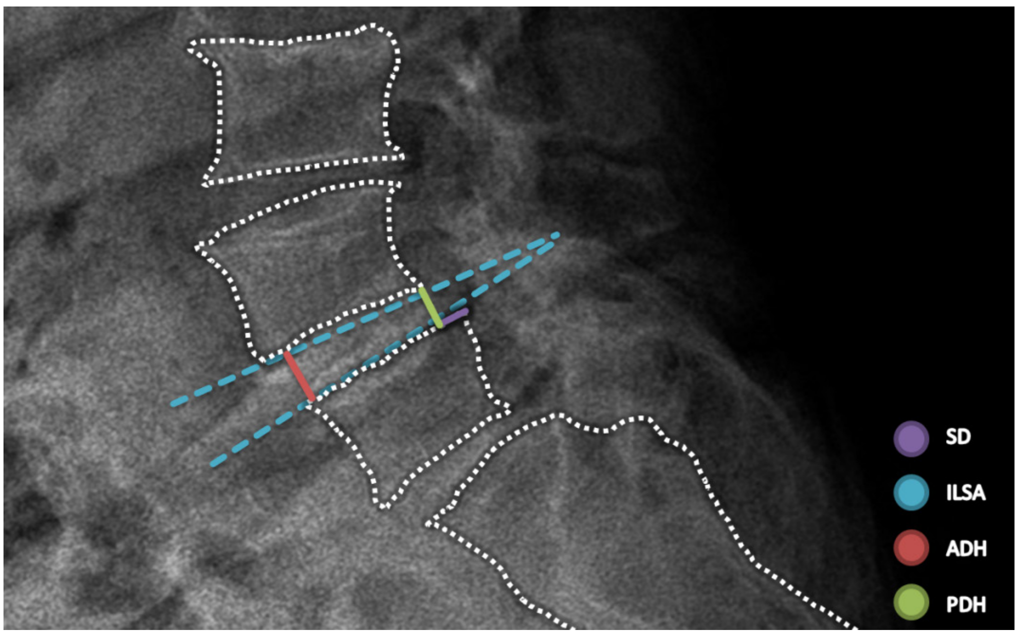

Figure 1. Radiological measures; SD: slippage distance, ILSA: intervertebral listhetic segmental angle, ADH: anterior disc height, PDH: posterior disc height

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Statistical Analysis: Statistical analyses were performed using IBM SPSS Statistics for Windows, Version 20.0 (IBM Corp., Armonk, NY, USA). For the presentation of data, mean, standard deviation, median, quartile values, frequencies, and percentages were used. After checking for normal distribution characteristics, the Wilcoxon test was used to compare non-normally distributed dependent groups, and Kruskal-Wallis test was used to compare the means of independent groups. Correlations between measurement data were tested using Spearman correlation analysis. In addition, baseline characteristics across correction groups were further assessed in terms of age, sex, spondylolisthesis type, level, preoperative VAS score, and preoperative slippage severity. Continuous variables were compared among groups using the Kruskal-Wallis test, while categorical variables were analyzed using the chi-square test or Fisher's exact test, as appropriate. When the Kruskal-Wallis test indicated an overall significant difference, pairwise post-hoc comparisons were performed to determine which groups accounted for the difference. Statistical significance was set at $p \leq 0.05$.

Ethics Approval: Ethical approval was received from the Hitit University Ethics Committee in accordance with the Helsinki declaration with the decision number 2024-100 dated 05.04.2024.

RESULTS

The average age of the 110 patients included in the study was 58.63 ± 9.40 years. Of the participants, 80.9% (n = 89) were female. When evaluating the levels of spondylolisthesis in the patients, it was found that 7.3% had spondylolisthesis at the L3-L4 level, 50.9% at the L4-L5 level, and 40.9% at the L5-S1 level. The distribution of some sociodemographic and clinical characteristics of the study group is presented in Table 1 and Table 2.

Table 1. Distribution of some sociodemographic and clinical characteristics of the study group

Variable		Value
Age , median (25th – 75th quartiles)		58 (52.75 – 66.25)
Gender , n (%)	Male	21 (19.1)
	Female	89 (80.9)
Type , n (%)	Degenerative	42 (38.2)
	Isthmic	68 (61.8)
Level, n (%)	L3-L4	9 (8.2)
	L4-L5	56 (50.9)
	L5-S1	45 (40.9)

Table 2. Distribution of patients according to spondylolisthesis type, gender, and level

Patient group	L3-L4	L4-L5	L5-S1	Total
Female, degenerative type	6	31	1	38
Male, degenerative type	0	4	0	4
Female, isthmic type	3	19	29	51
Male, isthmic type	0	2	15	17
Total	9	56	45	110

A moderate negative correlation was found between the percentage of postoperative slippage correction and the change in VAS scores of the patients (r: -0.448; $p < 0.001$). As the percentage of correction increased, the improvement in VAS scores decreased. The correlation between the percentage of slippage correction and improvement in VAS scores is shown in Table 3.

Table 3. Relationship between percentage of slippage correction and VAS score improvements in the study group

Variable	Statistical parameter	Percentage of correction	VAS score changes
Percentage of correction	Correlation coefficient*	1.000	-0.448**
	P value	_	< 0.0001
VAS score changes	Correlation coefficient*	-0.448**	1.000
	P value	.000	_

VAS: visual analog scale; *Spearman correlation analysis was used

In the study group, the average improvement in VAS scores was 8.36 ± 1.37 units in Group A (1% – 50% correction, n = 46), 7.21 ± 1.27 units in Group B (51% – 99% correction, n = 19), and 6.93 ± 1.19 units in Group C (100% correction, n = 45). The group with a correction percentage of 1% – 50% showed greater improvement in VAS scores compared to the other groups ($p < 0.05$). The distribution of VAS score changes in the study group according to the percentage of postoperative slippage correction is shown in Table 4.

Table 4. Distribution of changes in VAS scores in the study group according to the percentage of postoperative slippage correction

Percentage of correction	Median	Minimum	Maximum	Mean	SD	p value*
1% – 50% (Group A)	8.5000	5.00	10.00	8.3696	1.37208	< 0.001
51% – 99% (Group B)	7.0000	5.00	10.00	7.2105	1.27275	
100% (Group C)	7.0000	5.00	9.00	6.9333	1.19469	
Total	7.0000	5.00	10.00	7.5818	1.44236	

SD: standard deviation; *Kruskal – Wallis variance analysis was used

The subgroup analysis revealed that the relationship between slippage correction and VAS score improvement remained consistent across genders. In the male group, those with 1% – 50% correction showed a greater reduction in pain compared to those with 100% correction ($p = 0.022$). Among females, those with 1% – 50% correction had a greater reduction in VAS scores compared to those with 100% and 51% – 99% correction ($p < 0.001$).

The change in VAS scores according to the percentage of slippage correction also varied between the degenerative and isthmic groups ($p < 0.05$). In both subgroups, individuals with 1% – 50% correction had greater changes in VAS scores compared to those with 100% correction ($p = 0.009$, $p < 0.001$).

When analyzed by level, no significant difference was observed in VAS score changes at the L3-L4 level according to the percentage of slippage correction ($p = 0.083$). However, at the L4-L5 level, the group with 1% – 50% slippage correction showed greater changes in VAS scores compared to the group with 100% correction ($p = 0.047$). At the L5-S1 level, VAS score changes were greater in the group with 1% – 50% correction compared to those with 100% and 51% – 99% correction ($p = 0.001$). The distribution of VAS score changes according to the percentage of slippage correction, gender, spondylolisthesis type, and level is presented in Table 5.

Table 5. Distribution of changes in VAS scores according to the percentage of slippage correction, gender, type, and level of spondylolisthesis

Variable	Subgroup	Percentage of correction	VAS score changes (SD)	p value**
Gender	**Male**	**1% – 50% (Group A)**	8.70 (1.49)*	**0.022**
		51% – 99% (Group B)	7.00 (0)	
		100% (Group C)	6.70 (1.25)	
	Female	**1% – 50% (Group A)**	8.28 (1.34)*	**< 0.001**
		51%–99% (Group B)	7.22 (1.31)	
		100% (Group C)	7.00 (1.19)	
Type	**Degenerative**	**1% – 50% (Group A)**	8.8 (1.40)*	**0.009**
		51% – 99% (Group B)	7.44 (0.88)	
		100% (Group C)	7.17 (1.11)	
	Isthmic	**1% – 50% (Group A)**	8.25 (1.36)*	**< 0.001**
		51% – 99% (Group B)	7.00 (1.56)	
		100% (Group C)	6.68 (1.25)	
Level	**L3-L4**	**1% – 50% (Group A)**	8.50 (1.29)*	0.083
		51% – 99% (Group B)	7.50 (0.70)	
		100% (Group C)	6.33 (0.57)	
	L4-L5	**1% – 50% (Group A)**	8.17 (1.26)*	**0.047**
		51% – 99% (Group B)	7.54 (1.43)	
		100% (Group C)	7.18 (1.18)	
	L5-S1	**1% – 50% (Group A)**	8.57 (1.53)*	**0.001**
		51% – 99% (Group B)	6.50 (0.83)	
		100% (Group C)	6.75 (1.25)	

VAS: visual analog scale, SD: standard deviation; *Kruskal-Wallis variance analysis was used to identify the differing group

In the study group, preoperative and postoperative anatomical measurement values were evaluated based on the level of spondylolisthesis. Postoperatively, PDH measurements decreased, while ADH and ILSA increased ($p < 0.05$ for each). When evaluated according to the type and level of spondylolisthesis, similar changes were observed in ADH, PDH, and ILSA ($p < 0.05$ for each). The preoperative and postoperative changes in anatomical measurement values in the study group are presented in Table 6.

Table 6. Preoperative and postoperative changes in anatomical measurement values in the study group

Variable	Subgroup	Preop ADH (SD)	Postop ADH (SD)	p value*
Type	**Degenerative**	9.11 (2.59)	10.96 (2.28)	**< 0.001**
	Isthmic	8.26 (3.20)	9.62 (3.52)	**< 0.001**
Level	**L3-L4**	7.23 (2.39)	9.00 (1.78)	**0.021**
	L4-L5	8.76 (2.95)	10.21 (3.06)	**< 0.001**
	L5-S1	8.64 (3.15)	10.26 (3.50)	**< 0.001**
		Preop PDH (SD)	**Postop PDH (SD)**	
Type	**Degenerative**	6.21 (1.91)	5.36 (1.89)	**0.001**
	Isthmic	4.72 (1.60)	3.97 (1.49)	**< 0.001**
Level	**L3-L4**	4.63 (1.71)	4.54 (1.32)	0.515
	L4-L5	5.88 (1.96)	5.00 (1.95)	**< 0.001**
	L5-S1	4.68 (1.52)	3.86 (1.43)	**< 0.001**
		Preop ILSA (SD)	**Postop ILSA (SD)**	
Type	**Degenerative**	11.34 (3.32)	12.65 (3.13)	**0.003**
	Isthmic	10.00 (3.53)	11.14 (3.11)	**< 0.001**
Level	**L3-L4**	10.33 (1.91)	12.47 (1.84)	**0.008**
	L4-L5	10.60 (3.56)	12.01 (3.46)	**< 0.001**
	L5-S1	10.42 (3.72)	11.20 (3.01)	**0.010**

Preop ADH: Preoperative anterior disc height, Postop ADH: Postoperative anterior disc height, Preop PDH: Preoperative posterior disc height, Postop PDH: Postoperative posterior disc height, Preop ILSA: Preoperative intervertebral listhetic segmental angle, Postop ILSA: Postoperative intervertebral listhetic segmental angle, SD: Standard deviation; *Wilcoxon test was used

DISCUSSION

The prevalence of spondylolisthesis is based on symptomatic cases or those shown radiologically as a result of lysis. The exact prevalence is difficult to determine as many spondylolisthesis patients are asymptomatic (11). In studies evaluating the subtypes and epidemiology of spondylolisthesis, Hagenmaier et al. reported 72 patients with isthmic type (51% of cases) and degenerative type (29%), with 30 cases at L4-5 and 35 cases at L5-S1. Hongvei et al., in a study of 125 patients, found isthmic type in 59 (42%) and degenerative type in 66 (52%) patients, with 89 at L4-5 and 36 at L5-S1 (12,13). Our study aligns with the literature, with 61.8% of cases being isthmic, 83.3% of degenerative cases occurring at L4-5, and a higher prevalence of isthmic type in women (75%).

In the literature, studies have primarily focused on reduction, with the aim of correcting the ICslippage distances and found no relationship between correcting the slipped segment and clinical outcomes in low-grade degenerative and isthmic spondylolisthesis after one year (12). Oikonomidis et al. measured preoperative and postoperative anterior slippage distances and pelvic parameters in degenerative type patients and found no significant clinical difference with reduction, except for a significant difference in the EQ-5D quality of life scale after one year, which disappeared after two years (14). Lian et al. observed no significant difference between the reduction in slippage percentage and clinical outcomes in degenerative spondylolisthesis patients (15). Tay KS et al. found that correcting slippage percentage had no significant clinical effect over five years in low-grade spondylolisthesis, and they emphasized that decompression with fusion was the most beneficial technique (16). In patients with low-grade spondylolisthesis, numerous studies have reported that complete or near-complete anatomical reduction of the slipped segment during surgery does not provide a significant advantage in terms of clinical outcomes. The literature emphasizes that the degree of radiological correction does not always directly translate into patient-centered outcomes such as pain relief and clinical improvement (17-20).

In our study, postoperative slippage distance and VAS scores decreased in all patients. The reduction in VAS scores demonstrated that spondylolisthesis surgery helped alleviate pain. The average improvement in VAS scores in Group A (1% – 50% slippage correction) was 8.36 ± 1.37 units ($p < 0.001$), while in Groups B and C, it was 7.21 ± 1.27 ($p < 0.001$) and 6.93 ± 1.19 ($p < 0.001$), respectively. Even when the slippage was fully or nearly corrected in Group C, Group A showed more significant improvements in VAS scores.

When comparing anatomical measurements preoperatively and postoperatively, ADH, PDH, and ILSA were assessed, with significant increases in ADH and ILSA and a decrease in PDH ($p < 0.05$). Some studies including interbody fusion have reported increases in both ADH and PDH (12,13,21). In our study, however, despite the absence of an increase in PDH, the significant improvement in VAS scores without additional radicular complaints suggests that decompression may have contributed more to early symptom relief than anatomical correction alone. The concomitant increase in ADH and ILSA with a decrease in PDH may reflect segmental realignment rather than uniform restoration of disc height across the entire intervertebral space. In patients treated with posterolateral fusion alone, this radiological pattern may indicate limited restoration of the posterior disc space despite improvement in anterior disc height and segmental alignment. Previous comparative studies have similarly shown that although interbody techniques may provide greater radiological correction than PLF, this does not necessarily translate into superior short-term clinical outcomes (20,22,23). In summary, numerous studies in the literature have shown that, in the surgical treatment of low-grade lumbar spondylolisthesis, radiological improvement in disc height, lumbar lordosis, segmental angle, and pelvic parameters, as well as restoration of near-normal spinal alignment, does not support a clinically meaningful superiority of one surgical technique over another (18,20,22).

Restoring the listhetic vertebra to its anatomical position (through reduction or interbody fusion) has been associated with complications such as root injury, dura tears, prolonged surgery time, and increased blood loss, as noted in the literature (24,25). Farokhi et al., in a series of 80 cases of isthmic spondylolisthesis, compared PLIF (Posterior Lumbar Interbody Fusion) and PLF (Posterolateral Fusion) and reported that while PLIF had better fusion rates, PLF resulted in significantly better improvement in low back pain (26). Pooswamy et al. found an insignificant increase in leg pain in the TLIF (Transforaminal Lumbar Interbody Fusion) group compared to the preoperative period, while Hoy et al. reported significantly more blood loss and longer surgery times with TLIF. Pooswamy et al. also noted that TLIF surgeries took an average of 50 minutes longer. Aimar et al. reported that the use of cages in PLIF was associated with higher complication rates compared with PLF; moreover, it prolonged operative time and length of hospital stay, while also increasing the rates of blood transfusion requirement, dural tears, and radicular deficits (17). These findings highlighted that PLF and decompression are simpler and safer procedures for treating low-grade spondylolisthesis (27,28).

Fusion rates have been reported to be higher in patients undergoing PLIF than in those treated with posterolateral fusion (19,29). However, despite this radiological advantage, no significant difference has been found in clinical outcomes between patients treated with PLIF and those undergoing posterolateral fusion (18-20). Reduction maneuvers can increase stress on vertebrae and posterior instrumentation, increasing the risk of screw loosening or pull-out (30). In our study, we applied a reduction-free PLF and decompression (total laminectomy + medial facetectomy) approach. No root injuries were observed in any patient during the perioperative period. Five patients had durotomies, but appropriate dura repairs were made, and no postoperative wound problems were observed. Nine patients required perioperative red blood cell suspensions, but no patient needed more than one unit of blood. Postoperatively, no additional neurological deficits or wound infections were observed in any patient. None of the patients showed screw loosening or pull-out during their 3-month follow-up.

In contrast to the literature, our study grouped patients according to slippage correction percentage, gender, level (L4-5, L5-S1), and type (isthmic or degenerative) for evaluation. A striking finding was that VAS improvement was significantly greater in Group A, where anatomical correction was less, compared to other groups. This suggests that decompression and fusion play a more critical role in improving symptoms, regardless of gender, level, or spondylolisthesis type.

Limitations

the follow-up period was limited to 3 months, and longerterm follow-up would help to better assess the durability of surgical outcomes. The single-center design may limit the generalizability of the results. A further limitation of this study is that clinical outcomes were assessed only by VAS scores. The absence of functional outcome measures, such as disability indices or quality-of-life scales, limits the broader interpretation of clinical benefit. Because no multivariable regression analysis was performed, the observed association between correction degree and pain improvement may have been influenced by baseline differences between patients.

CONCLUSION

In conclusion, a greater degree of radiological correction was not associated with better short-term pain improvement in patients with low-grade lumbar spondylolisthesis. Our findings suggest that near-complete anatomical restoration of the spine may not provide additional benefit in early clinical outcomes. Nevertheless, prospective controlled studies are needed to compare the clinical efficacy and safety of different surgical techniques.

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Conflict of Interests
The authors declare that there is no conflict of interest in the study.

Financial Disclosure
The authors declare that there is no financial support.

Ethical Approval
Ethical approval was received from the Hitit University Ethics Committee in accordance with the Helsinki declaration with the decision number 2024-100 dated 05.04.2024.

Informed Consent
Because this retrospective study involved only the review of anonymized clinical and radiological records, individual informed consent was not required.

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