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Original Research Article

Frequency of Early Fusion of Bone in the Lumbosacral Spine: Radiographic Evidence of Bridging Bones Following Pedicle Screw Fixation

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Abstract: *Pedicle screw fixation is a widely used surgical procedure for the management of lumbosacral fractures. Despite its frequent application, limited evidence exists regarding its effectiveness in achieving early bone fusion.* ***Objective:*** *To determine the rate of early bone fusion following pedicle screw fixation of lumbosacral fractures and to evaluate the impact of patient factors, including ASA class and smoking status, on fusion outcomes.* ***Methods:*** *A descriptive cross-sectional study was conducted at a tertiary care hospital in Karachi, Pakistan, from January to May 2025 after ethical approval. Patients aged 18–65 years with ASA class <IV who underwent pedicle screw fixation of the lumbosacral spine were included. Participants were followed for three months to assess early bone fusion radiographically. Descriptive statistics were presented as mean (SD) for continuous variables and frequency (%) for categorical variables. Binary logistic regression was performed to adjust for confounders, with adjusted odds ratios (aOR) and 95% confidence intervals (CI) reported.* ***Results:*** *A total of 139 patients were enrolled, with a mean age of 40.70 ± 8.97 years. The cohort comprised 84 females (60.43%) and 55 males (39.57%). Early bone fusion was achieved in 124 patients (89.21%). Smoking status was independently associated with reduced odds of early bone fusion, with lower fusion rates observed among current smokers (aOR: 0.12, 95% CI: 0.03–0.45) and ex-smokers (aOR: 0.14, 95% CI: 0.04–0.51) compared with non-smokers. Similarly, patients with ASA class II (aOR: 0.16, 95% CI: 0.04–0.63) and class III (aOR: 0.04, 95% CI: 0.01–0.32) had significantly lower odds of early fusion compared to ASA class I.* ***Conclusion:*** *Pedicle screw fixation demonstrated a high rate of early bone fusion in lumbosacral fractures. However, smoking and higher ASA class were identified as independent risk factors for reduced fusion, emphasizing the importance of patient optimization and smoking cessation in improving postoperative outcomes.*

Keywords: ASA Physical Status, Bone Fusion, Lumbosacral Vertebrae, Pedicle Screws, Smoking, Spinal Fractures

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Introduction

Pedicle screw fixation is a widely accepted technique for stabilizing the spine and promoting bone fusion in various spinal conditions. The process of early bone fusion, as observed through radiographic imaging, plays a pivotal role in determining the success of these surgical interventions. Pedicle screw fixation provides immediate spinal stability and serves as a framework for bone grafts to facilitate fusion. The use of pedicle screws in lumbar fusion surgeries has been well-documented to improve outcomes in terms of pain relief, spinal alignment, and functional recovery (1,2)

Bone fusion involves complex biological processes, including the proliferation of osteoblasts and the deposition of new bone matrix. Early fusion, indicated by the presence of bridging bone on X-ray, is a critical step towards achieving long-term spinal fusion (3,4). Early fusion is characterized by continuous bony bridging across the disc space, with no gaps or lucencies present (5-7). Early bone fusion is associated with reduced pain, improved functional outcomes, and a decreased likelihood of requiring additional surgeries. Patients who show radiographic evidence of early fusion tend to have a better overall recovery (8,9). The presence of early fusion on X-rays guides post-operative management, including the intensity and timing of rehabilitation exercises. Early detection of fusion helps tailor rehabilitation protocols to enhance recovery while avoiding complications (10,11).

Spinal fusion surgery, particularly involving pedicle screw fixation, is a commonly performed procedure to stabilize the lumbosacral spine and alleviate symptoms associated with degenerative disc disease, trauma, or deformities. One of the critical indicators of surgical success is the early fusion of bones, as evidenced by radiographic bridging of bone between vertebrae. Identifying the early bone fusion and understanding its radiographic manifestations following pedicle screw fixation are essential for improving surgical planning, postoperative management, and patient counseling. To the best of the authors' knowledge, no such previous study has been conducted on this topic in our region. This study aims to address this knowledge gap by evaluating radiographic evidence of bridging bones after pedicle screw fixation in the lumbosacral spine. The findings of our research contribute to the optimization of surgical techniques, selection of graft materials, and postoperative care protocols, ultimately improving patient outcomes and reducing healthcare costs.

Methodology

A descriptive cross-sectional study was conducted at a tertiary care hospital in Karachi from January to May 2025, following approval from the Ethical Committee of Liaquat National and Medical College, Karachi, Pakistan, via letter no. 1173-2025 LNH-ERC and CPSP/REU/NGS-2023-192-945 dated January 28, 2025. All patients aged between 18 and 65 years with ASA Class <IV and who underwent pedicle screw fixation of the lumbosacral spine were enrolled in the study by using non-probability consecutive sampling. However, patients with osteoporosis, osteopenia, active infection, tumor, and on long-term steroid therapy were excluded. The sample size was calculated using the Open-Epi online sample size calculator, with a 95% confidence level, a 5% desired precision, and a frequency of early bone fusion of 90%. The statistically calculated sample size of our study was 139.

In our study, early bone fusion is defined as fusion of bone within 3 months of surgery. It was evaluated on X-ray, which shows continuous lines or structures of bone tissue connecting the vertebral bodies. Moreover, Patients with HbA1C ≥ 6.5% were labeled as diabetics (12).

Moreover, hypertension was defined as having an SBP greater than 140 mmHg or a DBP greater than 90 mmHg (13).

Data were analyzed using SPSS v.26. The mean (SD) was calculated for quantitative variables, such as age. Normality of data was assessed using the Shapiro-Wilk test. Qualitative variables, such as gender, place of residence, presenting complaints, indication of surgery, comorbidities, smoking status, ASA class, and early bone fusion, were presented as frequencies (%). To control for confounders, binary logistic regression was applied. Initially, univariate analysis was performed; all variables with a p-value <0.25 in the univariate analysis were analyzed in the multivariate model. Both adjusted and unadjusted odds ratios were calculated with a 95% confidence level, taking a p-value ≤ 0.05 as statistically significant.

Results

In this study, we enrolled 139 patients who underwent pedicle screw fixation of the lumbosacral spine. The mean age of patients was 40.70 ± 8.97 years. Among 139 patients, 84 (60.43%) were female, while 55 (39.57%) were male [Figure 1]. Table 1 shows the distribution of place of residence and presenting complaints.

Furthermore, in our study, 19 (13.67%) patients with diabetes and 13 (9.35%) were hypertensive. Additionally, 17 (12.23%) patients were current smokers, and 10 (7.19%) were ex-smokers. The most common indication for surgery was L5-S1 listhesis, at 64 (46.04%), followed by L4-L5 listhesis at 53 (38.13%), and L3 fracture at 8 (5.76%). Details of comorbid, smoking status, ASA class, and indication of surgery are shown in Table 2. Subsequently, early bone fusion after pedicle screw fixation was observed in 124 (89.21%) of patients [Figure 2].

Table 3 presents the association between early bone fusion and baseline characteristics. A significant association was found between smoking status, ASA class, and early bone fusion. Findings of our study show that odds of early bone fusion are lower among current smokers and ex-smokers as compared to non-smokers [aOR 0.12, 95% CI 0.02-0.57, p-value 0.008 and aOR 0.14, 95% CI 0.02-0.94, p-value 0.044, respectively]. Similarly, the odds of early bone fusion among patients belonging to ASA Class II and III are lower as compared to ASA Class I (aOR 0.16, 95% CI 0.03-0.69, p-value 0.015 and aOR 0.04, 95% CI 0.002-0.97, p-value 0.048).

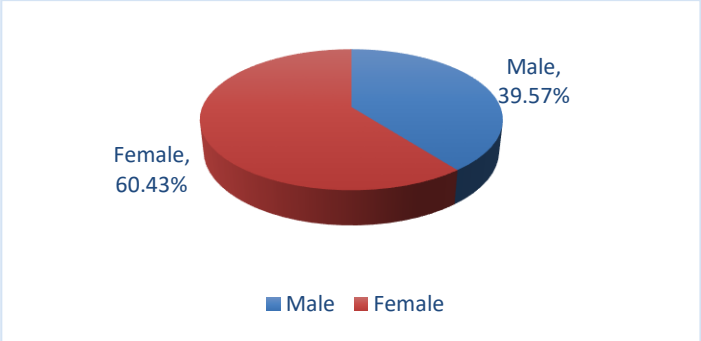

Figure 1: Distribution of gender

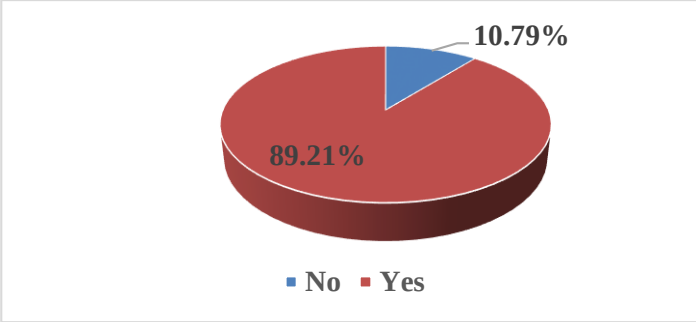

Figure 2: Distribution of early bone fusion after pedicle screw fixation of the lumbosacral spine.

Table 1: Distribution of place of residence and presenting a complaint.

Variable	n (%)
Place of Residence	
Urban	32 (23.02)
Rural	107 (76.98)
Presenting Complain	
Claudic	112 (80.58)
LBP	21 (15.11)
Numbness	2 (1.44)
Sciatica	4 (2.88)

Table 1: Distribution of comorbid, smoking status, ASA class, and surgery indication among the study population

Variable	n (%)
Comorbid	
DM	19 (13.67)
HTN	13 (9.35)
Smoking status	
Current smoker	17 (12.23)
Ex-smoker	10 (7.19)
ASA Class	
I	119 (85.61)
II	18 (12.95)
III	2 (1.44)
Indication of surgery	
L2 fracture	5 (3.6)
L3 fracture	8 (5.76)
L3-L4 listhesis	7 (5.04)
L4 fracture	1 (0.72)
L4-L5 listhesis	53 (38.13)
L5-S1 listhesis	64 (46.04)
Other	1 (0.72)

Table 2: Association of baseline characteristics with early bone fusion after pedicle screw fixation of the lumbosacral spine

Variable	Early Bone Fusion		COR (95% CI)	aOR (95% CI)
	No n (%)	Yes n (%)		
Age				
≤ 40 Years	5 (7.46)	62 (92.54)	Ref *	Ref
>40 Years	10 (13.89)	62 (86.11)	0.50 (0.16 - 1.54)	0.81 (0.21 - 3.10)
Gender				
Male	8 (14.55)	47 (85.45)	Ref	Ref
Female	7 (8.33)	77 (91.67)	1.87 (0.63-5.49)	0.70 (0.17 - 2.90)
Residence				
Urban	3 (9.38)	29 (90.63)	Ref	
Rural	12 (11.21)	95 (88.79)	0.81 (0.21-3.10)	
Diabetes				
No	9 (7.5)	111 (92.5)	Ref *	
Yes	6 (31.58)	13 (68.42)	0.17 (0.05-0.57)[£]	
Hypertension				
No	11 (8.73)	115 (91.27)	Ref *	
Yes	4 (30.77)	9 (69.23)	0.21 (0.05-0.81)[£]	
Smoking Status				
Non-smoker	7 (6.25)	105 (93.75)	Ref *	
Current smoker	6 (35.29)	11 (64.71)	0.12 (0.03-0.42)[£]	0.12 (0.02 - 0.57)[£]
Ex-smoker	2 (20)	8 (80)	0.26 (0.04-1.50)	0.14 (0.02 - 0.94)[£]
ASA Class				
I	8 (6.72)	111 (93.28)	Ref *	Ref
II	6 (33.33)	12 (66.67)	0.14 (0.04-0.48) [£]	0.16 (0.03 - 0.69)[£]
III	1 (50)	1 (50)	0.07 (0.004-1.26)	0.04 (0.002 - 0.97)[£]

*COR: Crude Odds Ratio aOR: Adjusted Odds Ratio; * p-value <0.25; [£]p-value <0.05*

Discussion

Pedicle screw fixation is a potential option for patients undergoing lumbar fusion. However, the use of pedicle screws in osteoporotic lumbar spines is supported by limited data. This is the first study to thoroughly evaluate the outcomes of pedicle screw fixation over a prospective follow-up period of 3 months. Our findings demonstrate a high rate of early bone fusion among patients who underwent pedicle screw fixation of the lumbosacral spine. Interestingly, we identified a significant association between smoking status, ASA class, and early bone fusion. Specifically, patients with higher ASA class as well as positive smoking history exhibited significantly lower odds of achieving early bone fusion. In contrast, demographic factors such as age and gender did not show any association with early bone fusion in our study.

Bone fusion is considered one of the most crucial factors in evaluating the efficacy and safety of pedicle screw fixation in lumbar fusion surgery. The fusion rate at 3 months follow-up was 89.21% after pedicle screw fixation. A recent study conducted in China and Korea reported bone fusion rates of 87.16% and 94.59% at 1 year after pedicle screw fixation, respectively. (14,15). A meta-analysis of 14 studies reported fusion rates of 92.6% between the 12- and 40-month follow-ups. (16The reported fusion rates were slightly higher than those in our current study. Another study from China reported that the bone fusion after pedicle screw fixation at 6 months was 55% (17). The discrepancy in the bone fusion can be attributed to several factors. Firstly, the timing of radiological assessment plays a crucial role; our study evaluates bone fusion at 3 months, whereas most studies reported bone fusion at 6 months or beyond, when fusion is expected to be more consolidated. Secondly, differences in patient characteristics, such as age, bone quality, comorbidities, and lifestyle factors, can influence bone fusion and may account for variability across populations. Additionally, discrepancies in imaging modality and criteria used to define the bone fusion could contribute to reported differences.

Our study findings show that current and ex-smokers had lower odds of early bone fusion as compared to non-smokers. This is consistent with existing literature demonstrating that smoking is a significant risk factor for impaired bone healing and lower bone fusion rates after spinal surgery (3, 18,19). The deleterious effects of smoking are attributed to nicotine-induced vasoconstriction, reduced inflammatory response, and impaired osteoblast function, all of which impair the bone regeneration process3,4. Various clinical studies have shown that smokers experience delayed bone fusion along with an increased risk of another surgery (4,18,19Our findings reinforce the critical importance of pre-operative smoking cessation counselling and targeted interventions to improve surgical outcomes among patients who undergo spinal surgeries.

In this study, we also observed that ASA Class II and III had significantly lower odds of early bone fusion compared to those in ASA Class I. Previous studies have shown that a higher ASA class is associated with perioperative morbidity, mortality, and complications in patients who underwent spinal surgery (20,21). Our results indicate that higher ASA class also negatively impacts the biological success of bone fusion, likely due to impaired wound healing and immune response (21). These findings underscore the need for comprehensive preoperative assessment and optimization of comorbidities to improve post-operative outcomes.

In our study, neither gender nor age was found to be associated with early bone fusion. This finding is consistent with existing literature, which has found that while women may present with worse baseline pain and function, both genders achieve similar bone fusion and clinical improvement after lumbar surgery (22,23). Similarly, although advanced age is associated with a higher complication rate, age alone does not appear to be an independent predictor of bone fusion success when comorbidities are appropriately managed (24,25). In contrast, some of the studies also suggested that female gender and advanced age are associated with a high risk of worse post-operative outcomes (26-28). Our findings suggest that clinical focus should remain on modifiable risk factors such as comorbid management and smoking cessation rather than demographic characteristics.

Early bone fusion stabilizes the spinal construct, allowing for earlier mobilization and rehabilitation, which are critical for regaining independence and reducing the risk of post-operative morbidities such as deep venous thrombosis and muscle deconditioning. Moreover, early bone fusion is associated with improved quality of life, reduced hospital

utilization, and higher patient satisfaction due to fewer complications and re-operations. According to our study findings, preoperative risk assessment should prioritize the identification of modifiable risk factors, such as smoking and comorbidities reflected in a higher ASA class. Smoking cessation counseling and optimization of medical conditions should be integral components of pre-operative planning for patients undergoing lumbosacral pedicle screw fixation. Additionally, our findings support the continued use of pedicle screw fixation as an effective technique for achieving early bone fusion in a diverse population. Future studies should focus on a larger sample size with a multicenter approach and extended follow-up periods to validate our findings and assess long-term outcomes. Evaluation of adjunctive therapies to improve bone healing, particularly in high-risk populations, is also warranted.

Our study enrolled a well-defined cohort with standardized surgical techniques and postoperative protocols to enhance the reliability of the findings. In addition, we collected data on demographic, clinical, and lifestyle factors, allowing the multivariate analysis of predictors of early fusion. Despite these strengths, our study had a few limitations. Firstly, the study was conducted in a single tertiary care hospital, which limits the generalizability of the findings to other settings or populations. Secondly, our analysis focuses on early bone fusion; however, long-term outcomes, such as functional status and complications, were not assessed. As with many surgical studies, there is a possibility of selection bias due to surgeon preference. However, we attempted to mitigate this by using consecutive sampling and clearly reporting baseline characteristics. Lastly, the confirmation of early bone fusion is based on radiological criteria, which may be subject to interobserver variability.

Conclusion

Our study demonstrates the high rate of early bone fusion among patients who underwent pedicle screw fixation of the lumbosacral spine, with higher ASA class and smoking status identified as independent risk factors for reduced bone fusion. These findings underscore the importance of comprehensive preoperative assessment and targeted interventions to enhance surgical outcomes. Our findings contribute to the growing body of evidence supporting the effectiveness of pedicle screw fixation and underscore the need for ongoing efforts to address the modifiable risk factors in spinal fusion surgery.

Declarations

Data Availability statement
All data generated or analysed during the study are included in the manuscript.

Ethics approval and consent to participate
Approved by the department concerned. (1173-2025 LNH-ERC)

Consent for publication
Approved

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Conflict of interest

The authors declared the absence of a conflict of interest.

Author Contribution

HKA
Manuscript drafting, Study Design,
AS
Review of Literature, Data entry, Data analysis, and drafting an article. Conception of Study, Development of Research Methodology Design,
AG
Study Design, manuscript review, and critical input.

All authors reviewed the results and approved the final version of the manuscript. They are also accountable for the integrity of the study.

References

1. Yang S, Xia H, Cong M, Guo A, Ma K, Song M. Unilateral pedicle screw fixation of lumbar spine: A safe internal fixation method. Heliyon. 2022;8(11):e11621. https://doi.org/10.1016/j.heliyon.2022.e11621
2. Matsukawa K, Yato Y. Lumbar pedicle screw fixation with cortical bone trajectory: A review from anatomical and biomechanical standpoints. Spine Surg Relat Res. 2017;1(4):164-73. https://doi.org/10.22603/ssrr.1.2017-0006
3. Berman D, Oren JH, Bendo J, Spivak J. The effect of smoking on spinal fusion. Int J Spine Surg. 2017;11(4):29. https://doi.org/10.14444/4029
4. Lau D, Chou D, Ziewacz JE, Mummaneni PV. The effects of smoking on perioperative outcomes and pseudarthrosis following anterior cervical corpectomy: Clinical article. J Neurosurg Spine. 2014;21(4):547-58. https://doi.org/10.3171/2014.6.SPINE13762
5. Zhang H, Dial B, Brown C. Early fusion rates after direct lateral lumbar interbody fusion with bone-morphogenetic protein. Int J Spine Surg. 2021;15(3):423-8. https://doi.org/10.14444/8063
6. Goel A. Is evidence of bone "formation" and "fusion" in the spinal segment evidence of segmental spinal instability? J Craniovertebral Junction Spine. 2022;13(4):365-7. https://doi.org/10.4103/jcvjs.jcvjs_139_22
7. Scott-Young M, Nielsen D, Rathbone E, Riar S, Gantt M. Efficacy of stand-alone anterior lumbar interbody fusion with PEEK cages, BMP-2, and allografts for treating discogenic low back pain: Assessing clinical and radiographic outcomes. Int J Spine Surg. 2024;18(5):502-13. https://doi.org/10.14444/8679
8. Koenders N, Rushton A, Verra ML, Willems PC, Hoogeboom TJ, Staal JB. Pain and disability after first-time spinal fusion for lumbar degenerative disorders: A systematic review and meta-analysis. Eur Spine J. 2019;28(4):696-9. https://doi.org/10.1007/s00586-018-5680-3
9. Wu J, Li J, Zhang H, Wu L, Shen X, Lv W. Predicting functional outcome after open lumbar fusion surgery: A retrospective multicenter cohort study. Eur J Radiol. 2025;182:111836. https://doi.org/10.1016/j.ejrad.2024.111836
10. Kernc D, Strojnik V, Vengust R. Early initiation of a strength training-based rehabilitation after lumbar spine fusion improves core muscle strength: A randomized controlled trial. J Orthop Surg Res. 2018;13(1):151. https://doi.org/10.1186/s13018-018-0853-7
11. Yang S, Yi YG, Kim Y, Jang DS, Chang MC. Postoperative rehabilitation for pain and functional recovery following anterior cervical discectomy and fusion: A narrative review. J Pain Res. 2025;18:4173-83. https://doi.org/10.2147/JPR.S533252
12. American Diabetes Association. Understanding A1C Diagnosis. 2023 [cited 2025 Sep 11]. Available from: https://diabetes.org/diabetes/a1c/diagnosis
13. American Family Physician. JNC 8 guidelines for the management of hypertension in adults. 2014 [cited 2025 Sep 11]. Available from: https://www.aafp.org/pubs/afp/issues/2014/1001/p503.html
14. Wu C, Hu X, Liu R, Xu C, Jiang Y, Ge Z, et al. Comparison of the clinical and radiographic outcomes of cortical bone trajectory and traditional trajectory pedicle screw fixation in transforaminal lumbar interbody fusion: A randomized controlled trial. Eur Spine J. 2024;33(3):1069-80. https://doi.org/10.1007/s00586-023-08086-5
15. Lee GW, Ahn M-W. Comparative study of cortical bone trajectory-pedicle screw (cortical screw) versus conventional pedicle screw in single-level posterior lumbar interbody fusion: A 2-year post hoc analysis

from prospectively randomized data. World Neurosurg. 2018;109:e194-2. https://doi.org/10.1016/j.wneu.2017.09.137
16. Wang J, He X, Sun T. Comparative clinical efficacy and safety of cortical bone trajectory screw fixation and traditional pedicle screw fixation in posterior lumbar fusion: A systematic review and meta-analysis. Eur Spine J. 2019;28(7):1678-89. https://doi.org/10.1007/s00586-019-05999-y
17. Ding H, Hai Y, Liu Y, Guan L, Pan A, Zhang X, et al. Cortical trajectory fixation versus traditional pedicle-screw fixation in the treatment of lumbar degenerative patients with osteoporosis: A prospective randomized controlled trial. Clin Interv Aging. 2022;17:175-84. https://doi.org/10.2147/CIA.S349533
18. Zheng L-m, Zhang Z-w, Wang W, Li Y, Wen F. Relationship between smoking and postoperative complications of cervical spine surgery: A systematic review and meta-analysis. Sci Rep. 2022;12(1):9172. https://doi.org/10.1038/s41598-022-13198-x
19. Li Y, Zheng LM, Zhang ZW, He CJ. The effect of smoking on the fusion rate of spinal fusion surgery: A systematic review and meta-analysis. World Neurosurg. 2021;154:e222-35. https://doi.org/10.1016/j.wneu.2021.07.011
20. Somani S, Capua JD, Kim JS, Phan K, Lee NJ, Kothari P, et al. ASA classification as a risk stratification tool in adult spinal deformity surgery: A study of 5805 patients. Global Spine J. 2017;7(8):719-26. https://doi.org/10.1177/2192568217700106
21. Lynch CP, Cha EDK, Geoghegan CE, Jadczak CN, Mohan S, Singh K. Higher American Society of Anesthesiologists classification does not limit safety or improvement following minimally invasive transforaminal lumbar interbody fusion. Neurospine. 2022;19(3):533-43. https://doi.org/10.14245/ns.2142088.044
22. Hartman TJ, Nie JW, MacGregor KR, Oyetayo OO, Zheng E, Singh K. Impact of gender on outcomes following single-level anterior lumbar interbody fusion. J Clin Orthop Trauma. 2022;34:102019. https://doi.org/10.1016/j.jcot.2022.102019
23. Ciobanu-Caraus O, Grob A, Rohr J, Stumpo V, Ricciardi L, Maldaner N, et al. Sex differences in patient-rated outcomes after lumbar spinal fusion for degenerative disease: A multicenter cohort study. Spine. 2025;50(13):924-31. https://doi.org/10.1097/BRS.0000000000005183
24. Ibrahim JM, Singh P, Beckerman D, Hu SS, Tay B, Deviren V, et al. Outcomes and Quality of Life Improvement After Multilevel Spinal Fusion in Elderly Patients. Global Spine J. 2020;10(2):153-9. https://doi.org/10.1177/2192568219849393
25. Reis RC, de Oliveira MF, Rotta JM, Botelho RV. Risk of complications in spine surgery: A prospective study. Open Orthop J. 2015;9:20-5. https://doi.org/10.2174/1874325001509010020
26. Hartman TJ, Nie JW, MacGregor KR, Oyetayo OO, Zheng E, Singh K. Impact of gender on outcomes following single-level anterior lumbar interbody fusion. J Clin Orthop Trauma. 2022;34:102019. https://doi.org/10.1016/j.jcot.2022.102019
27. Salamanna F, Contartese D, Tschon M, Borsari V, Griffoni C, Gasbarrini A, et al. Sex and gender determinants following spinal fusion surgery: A systematic review of clinical data. Front Surg. 2022;9:983931. https://doi.org/10.3389/fsurg.2022.983931
28. Liu C, Guo C, Meng F, Zhu Z, Xia W, Liu H. Perioperative risk factors related to complications of lumbar spine fusion surgery in elderly patients. BMC Musculoskelet Disord. 2023;24(1):573. https://doi.org/10.1186/s12891-023-06689-z