Risk Factors for Bone Cement Leakage and Re-fracture Following PKP in Patients With Thoracolumbar Spine Fractures

Ann. Ital. Chir., 2026 97, 11: 2009–2016
https://doi.org/10.62713/aic.4791

Xuezhao Li[1], Ming Fu[1], Xiang Liu[1], Zhiyin E[1], Cong Wang[1]

[1]Department of Orthopedics, Heilongjiang Provincial Hospital, 150036 Harbin, Heilongjiang, China

AIM: Thoracolumbar spine fractures are commonly treated with percutaneous kyphoplasty (PKP), but bone cement leakage and re-fracture remain major concerns. Identifying their risk factors is essential for improving prognosis but remains insufficiently characterized. This study was designed to explore the risk factors for bone cement leakage and re-fracture following PKP in patients with thoracolumbar spine fractures.

METHODS: A retrospective analysis was conducted on 115 patients with thoracolumbar spine fractures who underwent PKP at Heilongjiang Provincial Hospital between April 2022 and February 2025 (leakage group: 18 patients with bone cement leakage; non-leakage group: 97 patients without leakage). Risk factors for bone cement leakage were analyzed. Patients were divided into re-fracture (29 cases with re-fractures) and non-re-fracture (86 cases without re-fractures) groups to identify risk factors for postoperative re-fracture.

RESULTS: Logistic multivariate regression analysis identified age and vertebral wall destruction as independent risk factors for postoperative bone cement leakage ($p < 0.05$). Separately, age, the degree of vertebral compression, and vertebral wall destruction were identified as independent risk factors for re-fracture after surgery ($p < 0.05$).

CONCLUSIONS: Age and vertebral wall destruction are independent predictors of cement leakage, and together with compression severity, also predict re-fracture. These findings support routine preoperative assessment of vertebral wall integrity using high-resolution computed tomography (CT), particularly in elderly patients, as vertebral wall destruction was independently associated with bone cement leakage.

Keywords: thoracolumbar spine fracture; PKP; bone cement leakage; re-fracture; risk factors

Introduction

Thoracolumbar spine fractures are a common type of spinal injury. With the aggravation of population aging and the high incidence of osteoporosis, the incidence of thoracolumbar fractures is increasing annually [1,2]. Thoracolumbar spine fractures not only cause significant pain and mobility impairment but also potentially lead to spinal deformities, nerve damage, and a severe decline in quality of life [3,4]. Traditional treatments such as conservative therapy and traction are often ineffective in alleviating symptoms, particularly in severe fractures or elderly patients, where the results are frequently limited [5,6]. As a result, with advancements in minimally invasive surgical techniques, percutaneous kyphoplasty (PKP) has emerged as an innovative treatment for thoracolumbar fractures and is gradually becoming the preferred clinical approach [7,8]. PKP involves the percutaneous injection of bone cement into the fractured vertebral body to restore vertebral height, stabilize the spine, and relieve pain. With less trauma and rapid recovery, this operation can effectively improve patients' quality of life [9]. However, despite the significant clinical benefits of PKP, complications such as bone cement leakage are a common postoperative concern [10]. Bone cement leakage refers to the extravasation of injected bone cement into the spinal canal or adjacent structures, which may lead to nerve injury, spinal cord compression, and severe complications, such as respiratory and circulatory failure [11,12]. Therefore, it is of great significance to analyze and evaluate the risk factors for bone cement leakage in reducing surgical complications, optimizing treatment plans and improving patient prognosis. However, previous studies have largely investigated leakage and re-fracture separately, leaving their shared determinants unclear [13,14].

To fill this gap, this study uniquely evaluates risk factors for both bone cement leakage and re-fracture within the same cohort, aiming to clarify whether they converge on common structural determinants. By exploring various risk factors associated with bone cement leakage and examining their effects on postoperative prognosis, this study seeks to provide clinicians with a better understanding of these factors to inform personalized treatment strategies. Ultimately, this study aims to reduce the incidence of bone cement leakage,

Submitted: 25 May 2026 Revised: 21 July 2026 Accepted: 31 July 2026 Published: 10 November 2026
Correspondence to: Cong Wang, Department of Orthopedics, Heilongjiang Provincial Hospital, 150036 Harbin, Heilongjiang, China (e-mail: 13212810627@163.com).
Editor: Hui Lu

minimize postoperative complications, and improve treatment outcomes and the overall quality of life for patients.

Methods

Research Design

This study is a retrospective analysis conducted at Heilongjiang Provincial Hospital, with a study period from April 2022 to February 2025. During this time, all patients with thoracolumbar spine fractures who met the inclusion criteria were enrolled after receiving PKP.

Study Participants and Data Collection

By searching the electronic medical record database of our hospital, we retrospectively collected the case data of patients with thoracolumbar spine fractures who underwent PKP between April 2022 and February 2025. A total of 130 patients were screened, and 115 eligible patients were finally identified for follow-up statistical analysis according to the inclusion and exclusion criteria of the study. Inclusion criteria: (1) Diagnosed with thoracolumbar spine fractures through imaging examination; (2) No coagulation dysfunction or immune dysfunction; (3) Complete clinical data; (4) Patients with surgical indications; (5) Mentally stable. Exclusion criteria: (1) History of spinal or vertebral fracture or prior spinal surgery before the current fracture episode; (2) Associated with other spinal diseases; (3) Concurrent with malignant tumors or severe diseases of other organs such as the heart or liver.

Relevant information was collected from the patient's medical records, including demographic characteristics (gender, age, body mass index [BMI]), medical history (hypertension), clinical characteristics (cause of injury, etc.), and surgical details (volume of injected bone cement, etc.).

Variable Definitions and Measurement

All imaging data were independently assessed by two senior spinal surgeons (with >10 years of experience), with disagreements resolved by consensus. Key variables were defined as follows: Volume of bone cement was recorded from surgical notes and analyzed as a continuous variable; degree of vertebral compression was calculated on preoperative lateral radiographs or sagittal computed tomography (CT) as [1 − (anterior height of fractured vertebra / average height of adjacent vertebrae)] × 100%, with a cutoff at 50% based on the established criterion that >50% compression indicates severe collapse of the anterior and middle columns, which compromises spinal stability and has been widely used as a clinically meaningful threshold in a previous PKP study [15]; communication with the vertebral venous plexus was determined by preoperative contrast-enhanced magnetic resonance imaging (MRI) or intraoperative venography, defined as visible contrast transit or direct connection between the intravertebral space and the basivertebral/epidural venous system; vertebral wall destruction was defined as any cortical breach of the anterior, lateral, or posterior wall on preoperative CT with multi-planar reconstruction. Inter-observer reliability was excellent (Cohen's $\kappa = 0.85$) in a preliminary test on 20 random cases.

PKP Procedure

All patients underwent PKP in the prone position under local anesthesia with biplanar fluoroscopic guidance. A unilateral transpedicular approach was used to insert the working cannula into the fractured vertebral body. The balloon was inflated to restore vertebral height and create a cavity, after which polymethylmethacrylate (PMMA) bone cement was injected in a viscous phase under continuous fluoroscopic monitoring. Cement injection was stopped when the cement reached the posterior wall of the vertebral body or when cement leakage into the venous plexus, epidural space, or disc space was observed. The volume of cement injected was recorded at the end of the procedure and was analyzed as a continuous variable. The cement volume was determined according to the intraoperative fluoroscopic assessment of cement distribution within the vertebral body, with injection continued until the cement approached the posterior wall or leakage into the venous plexus, epidural space, or disc space was observed. Postoperative CT was routinely performed to assess cement distribution and leakage.

Study Definition and Primary Endpoint

In this study, the primary outcomes were the occurrence of bone cement leakage and postoperative re-fracture following PKP, and the associated risk factors for these outcomes were further analyzed. Bone cement leakage was defined as any extravertebral extension of cement detected on postoperative CT scans, which were routinely performed within 48 hours after surgery. Plain radiographs were not used for leakage detection.

Postoperative re-fracture was defined as a new vertebral compression fracture occurring after PKP, including both re-fracture of the treated vertebra and new fractures of adjacent vertebrae. Diagnosis was confirmed on follow-up imaging (CT and/or plain radiographs) and was considered present when a new or progressive loss of vertebral height ≥20% or a new wedge/crush deformity was observed. Clinical symptoms were not required for the diagnosis; imaging evidence alone was sufficient.

All analyses were conducted at the patient level. For patients undergoing multilevel PKP, the target vertebra level was defined as the most symptomatic level based on preoperative imaging and physical examination. The median follow-up duration was 14.0 months (interquartile range: 8.0–22.0 months; range: 3.0–38.0 months).

Follow-up imaging was reviewed by the same two surgeons who assessed the preoperative images, with disagreements resolved by consensus.

Statistical Analysis

All statistical analyses were performed using SPSS version 26.0 software (IBM Corp, Armonk, NY, USA). Normality was assessed using the Shapiro–Wilk test; continuous data were compared using the independent-samples *t*-test or Mann–Whitney U test, as appropriate, while categorical variables were compared using the chi-square test. Variables with $p < 0.05$ in univariate analysis were considered for multivariate logistic regression using the Enter method. For the leakage model, given the limited number of events (n = 18), the final model was restricted to age and vertebral wall destruction to avoid overfitting. For the re-fracture model, bone cement leakage was not entered because of the limited number of events (n = 29) and its collinearity with vertebral wall destruction. Statistical significance was set at two-sided $p < 0.05$.

Results

Incidence of Bone Cement Leakage

Among the 115 patients, 18 (15.65%) experienced bone cement leakage (Table 1).

Table 1. Incidence of bone cement leakage.

	Cases	Percentage
Leakage group	18	15.65%
Non-leakage group	97	84.35%

Note: Percentages were calculated using the total number of patients (n = 115) as the denominator.

Univariate Analysis for Bone Cement Leakage

A univariate comparison between the leakage group and the non-leakage group revealed that the volume of bone cement, the degree of vertebral compression, age, the communication with the vertebral venous plexus, and vertebral wall destruction were risk factors for postoperative bone cement leakage ($p < 0.05$) (Table 2).

Multivariate Analysis for Bone Cement Leakage

To identify independent risk factors for postoperative bone cement leakage, variables with $p < 0.05$ in the univariate analysis were initially considered for inclusion. However, given the limited number of leakage events (n = 18), we restricted the multivariate logistic regression model to variables that demonstrated both statistical significance in multivariate analysis and clear clinical relevance to avoid model overfitting due to an inadequate events-per-variable ratio. Accordingly, age (continuous) and vertebral wall destruction (0 = no, 1 = yes) were entered into the multivariate logistic regression model using the Enter method. The results revealed that both age and vertebral wall destruction were independent risk factors for postoperative bone cement leakage ($p < 0.05$) (Table 3).

Re-fracture

Re-fractures occurred in 29 of the 115 patients (25.22%) (Table 4).

Univariate Analysis for Re-fracture

Univariate comparison was performed between the re-fracture and non-re-fracture groups, and the results indicated that the volume of bone cement, the degree of vertebral compression, age, vertebral wall destruction, and bone cement leakage were the risk factors for re-fracture ($p < 0.05$) (Table 5).

Multivariate Analysis for Re-fracture

The variables with differences in Table 5 were assigned values, as detailed in Table 6. Bone cement leakage was significant in univariate analysis but was not included in the final multivariate model due to the limited number of events and collinearity with vertebral wall destruction. Logistic multivariate regression analysis was then performed, and the results revealed that age, the degree of vertebral compression, and vertebral wall destruction were independent risk factors for re-fracture after surgery ($p < 0.05$) (Table 7).

Discussion

This study aims to explore the risk factors for bone cement leakage and re-fracture in patients with thoracolumbar spine fractures who underwent PKP treatment, through a retrospective analysis of 115 cases. The results of the study indicate that age and vertebral wall destruction are independent risk factors for postoperative bone cement leakage. Additionally, age, the degree of vertebral compression, and vertebral wall destruction are independent risk factors for re-fracture.

Multivariate logistic regression identified age and vertebral wall destruction as independent risk factors for postoperative bone cement leakage. Although the volume of bone cement, degree of vertebral compression, and communication with the vertebral venous plexus were significant in univariate analysis, they were not included in the final multivariate model due to the limited number of events (n = 18), which necessitated model parsimony to avoid overfitting. Although excessive bone cement injection can cause the cement to spread through cracks in the vertebral body or incomplete bone structures, leading to leakage [16], and a previous study has shown that an excessive bone cement can result in cement extravasation [17], our multivariate analysis suggests that the structural integrity of the vertebral body (wall destruction) and patient age may outweigh the absolute cement volume in determining leakage risk. This finding highlights the importance of vertebral cortical integrity in assessing the risk of bone cement leakage. However, the relative contributions of vertebral wall destruction and ce-

Table 2. Univariate analysis for bone cement leakage.

Concomitant variable	Leakage group (n = 18)	Non-leakage group (n = 97)	Test statistic	*p*-value
Hypertension			1.155	0.283
Yes	5 (11.11%)	40 (88.89%)		
No	13 (18.57%)	57 (81.43%)		
Location of fractured vertebra			0.098	0.754
Thoracic vertebra	10 (16.67%)	50 (83.33%)		
Lumbar vertebra	8 (14.55%)	47 (85.45%)		
Gender			0.132	0.717
Male	9 (16.98%)	44 (83.02%)		
Female	9 (14.52%)	53 (85.48%)		
BMI (kg/m^2)	22.02 ± 1.30	22.29 ± 1.36	0.790	0.431
Volume of bone cement (mL)	5.17 ± 0.69	4.70 ± 0.80	2.336	0.021
Cause of injury			0.237	0.888
Traffic accident	6 (14.63%)	35 (85.37%)		
Fall accident from a high place	5 (14.29%)	30 (85.71%)		
Others	7 (17.95%)	32 (82.05%)		
Degree of vertebral compression			6.029	0.014
≤50%	7 (9.46%)	67 (90.54%)		
>50%	11 (26.83%)	30 (73.17%)		
Age (years)	76.02 ± 10.60	70.22 ± 6.09	3.248	0.002
Communication with vertebral venous plexus			5.836	0.016
Yes	10 (27.78%)	26 (72.22%)		
No	8 (10.13%)	71 (89.87%)		
Vertebral wall destruction			7.044	0.008
Yes	11 (28.21%)	28 (71.79%)		
No	7 (9.21%)	69 (90.79%)		

BMI, body mass index. Percentages are calculated as row percentages, with the denominator being the total number of patients in each category of the corresponding variable.

Table 3. Multivariate analysis for bone cement leakage.

	B	S.E.	Wald	df	*p*-value	Exp (B)	Exp (B) for 95% CI	
							Lower limit	Upper limit
Age	0.097	0.038	6.7	1	0.01	1.102	1.024	1.186
Vertebral wall destruction	1.271	0.557	5.205	1	0.023	3.563	1.196	10.617

B, regression coefficient; S.E., Standard error; df, Degrees of freedom; CI, confidence interval.

Table 4. Re-fracture.

	Cases	Percentage
Non-re-fracture group	86	74.78%
Re-fracture group	29	25.22%

ment volume to leakage risk cannot be directly compared in this study because cement volume was not included in the final multivariate leakage model. Preoperative identification of cortical breaches is therefore essential for surgical planning.

Similarly, while communication with the vertebral venous plexus reflects the impact of vertebral anatomical structure on cement leakage [18,19], and severe compression may weaken the fixation effect, these factors were not independent predictors in our multivariate model. This suggests that their effects may be mediated through or confounded by vertebral wall destruction. Therefore, a thorough preoperative imaging assessment focusing on vertebral wall integrity, particularly in elderly patients, along with careful selection of the surgical approach and injection technique, are crucial measures to minimize the risk of bone cement leakage.

Turning to postoperative re-fracture, the multivariate analysis confirmed that age, the degree of vertebral compression, and vertebral wall destruction are independent risk factors for a re-fracture. While bone cement leakage was a significant factor influencing re-fracture in the univariate analysis, it did not remain an independent predictor in the multivariate model, suggesting that its effects on re-fracture may be largely driven by the underlying severity of the fracture, such as the degree of compression and wall destruction. Bone cement leakage is often closely related to postoperative complications, such as nerve damage, vas-

Table 5. Univariate analysis for re-fracture.

	Non-re-fracture group (n = 86)	Re-fracture group (n = 29)	Test statistic	*p*-value
Hypertension			0.528	0.467
Yes	32 (71.11%)	13 (28.89%)		
No	54 (77.14%)	16 (22.86%)		
Location of fractured vertebra			0.646	0.422
Thoracic vertebra	43 (71.67%)	17 (28.33%)		
Lumbar vertebra	43 (78.18%)	12 (21.82%)		
Gender			0.075	0.785
Male	39 (73.58%)	14 (26.42%)		
Female	47 (75.81%)	15 (24.19%)		
BMI (kg/m^2)	22.31 ± 1.36	22.06 ± 1.33	0.889	0.376
Volume of bone cement (mL)	4.68 ± 0.82	5.05 ± 0.67	8.322	0.004
Cause of injury			0.318	0.853
Traffic accident	31 (75.61%)	10 (24.39%)		
Fall accident from a high place	25 (71.43%)	10 (28.57%)		
Others	30 (76.92%)	9 (23.08%)		
Degree of vertebral compression			8.918	0.003
≤50%	62 (83.78%)	12 (16.22%)		
>50%	24 (58.54%)	17 (41.46%)		
Age (years)	70.11 ± 5.92	74.13 ± 9.73	2.655	0.009
Communication with vertebral venous plexus			1.830	0.176
Yes	24 (66.67%)	12 (33.33%)		
No	62 (78.48%)	17 (21.52%)		
Vertebral wall destruction			5.489	0.019
Yes	24 (61.54%)	15 (38.46%)		
No	62 (81.58%)	14 (18.42%)		
Bone cement leakage			4.183	0.041
Yes	10 (55.56%)	8 (44.44%)		
No	76 (78.35%)	21 (21.65%)		

Note:Percentages are calculated as row percentages, with the denominator being the total number of patients in each category of the corresponding variable.

Table 6. Variable definitions and coding for the re-fracture prediction model.

Variable	Assignment	
Age	Continuous	
Volume of bone cement	Continuous	
Degree of vertebral compression	0 = "≤50%"	1 = ">50%"
Vertebral wall destruction	0 = "No"	1 = "Yes"
Dependent variable	Assignment	
Re-fracture	0 = "No"	1 = "Yes"

cular compression, and postoperative infections [20], and one previous study has shown that patients who experience bone cement leakage have a higher risk of re-fracture [13]. However, our findings indicate that the structural damage itself (compression and wall destruction) is a more fundamental determinant of long-term outcomes. The volume of bone cement did not emerge as an independent risk factor for re-fracture in our study, which contrasts with the findings of the univariate analysis. In the multivariate model, bone cement volume showed a positive but statistically non-significant association with re-fracture (OR = 1.825, 95% CI: 0.951–3.504, $p = 0.071$). Thus, although a potential association was observed, the present findings do not establish bone cement volume as an independent predictor of re-fracture. While excessive cement injection may theoretically lead to excessive fixation and stress concentration on adjacent vertebrae, the multivariate analysis indicates that the extent of vertebral collapse and the presence of cortical disruption are stronger prognostic indicators. Patients with severe vertebral compression often experience significant pain and instability; The greater the degree of vertebral compression, the higher the risk of re-fracture postoperatively. Furthermore, the persistence of vertebral wall destruction as a risk factor confirms that fractures compromising the overall structure and stability of the vertebral body have a lasting negative impact on recovery. In both univariate and multivariate analyses, older age was associated with an increased risk of postoperative re-fracture. This finding suggests that age may be an important factor in predicting postoperative outcomes. Therefore, elderly patients, particularly those with severe vertebral compression and ver-

Table 7. Multivariate analysis for re-fracture.

	B	S.E.	Wald	df	*p*-value	Exp (B)	Exp (B) for 95% CI	
							Lower limit	Upper limit
Volume of bone cement	0.602	0.333	3.268	1	0.071	1.825	0.951	3.504
Degree of vertebral compression	1.995	0.556	12.870	1	<0.001	7.355	2.473	21.879
Age	0.074	0.037	4.106	1	0.043	1.077	1.002	1.158
Vertebral wall destruction	1.554	0.659	5.564	1	0.018	4.729	1.300	17.195

S.E., Standard error; df, Degrees of freedom; CI, confidence interval.

tebral wall destruction, may require more comprehensive preoperative assessment and closer postoperative follow-up. This finding suggests that the relationship between age and re-fracture may be influenced by other clinical factors and should be interpreted cautiously. In addition, elderly patients often have multiple chronic conditions, such as diabetes and hypertension, which may negatively affect postoperative recovery. Therefore, for elderly patients, particularly those with severe vertebral compression and wall destruction, a comprehensive preoperative assessment and more intensive postoperative rehabilitation are essential to facilitate functional recovery.

When compared with relevant studies both domestically and internationally, the conclusions of this study are generally consistent, although some specific nuances exist. For example, Zhang et al. [15] revealed that patients with communication with the vertebral venous plexus and severe vertebral compression had a significantly increased risk of bone cement leakage. However, our study further refines this by demonstrating that vertebral wall destruction is the more robust independent predictor. Ren et al. [21] pointed out that the volume of bone cement was an independent risk factor for leakage, highlighting that bone cement leakage is an important indicator of postoperative re-fracture and nerve injury. Our study, by contrast, found that volume was not an independent predictor once wall destruction was accounted for, suggesting that the relationship between cement volume and leakage may warrant further investigation with appropriate adjustment for vertebral wall integrity. Our study further reveals the independence of these factors and provides more accurate evaluation criteria for clinical practice. Regarding re-fracture, while Dai et al. [22] indicated that bone cement leakage could lead to changes in the stress on the vertebral body postoperatively, increasing the risk of re-fracture, our multivariate analysis suggests that the primary drivers of re-fracture are the baseline fracture characteristics (age, degree of compression, and wall destruction). This highlights that while preventing leakage is clinically important, the initial severity of the fracture plays a key role in determining long-term outcomes.

Although this study provides valuable conclusions, there are still some limitations. First, as a retrospective analysis, there may be data bias and incomplete information. Second, the small number of leakage events (n = 18) limited statistical power. In the leakage model, restricting the analysis to two core variables yielded an events-per-variable ratio of 9, close to the recommended minimum of 10. To mitigate the risk of overfitting, we limited the model to variables with statistical significance and clinical relevance. However, the re-fracture model included four predictors based on 29 events, yielding an events-per-variable (EPV) ratio of 7.25. This relatively low EPV may increase the risk of model overfitting and instability of the regression estimates. Therefore, the findings of the re-fracture model should be interpreted cautiously and require validation in larger cohorts. Furthermore, variable selection was primarily based on statistical significance in univariate analyses, which may have resulted in the exclusion of clinically relevant predictors that did not reach statistical significance. Future studies with larger sample sizes and prespecified clinically relevant variables are needed to develop and validate more robust prediction models. These findings should be considered exploratory and require validation in larger prospective cohorts. Third, the analysis was restricted to the patient level, and per-vertebral assessment of cement leakage was not feasible due to the retrospective study design. Fourth, postoperative outcomes were assessed solely in terms of re-fracture, without incorporating patient-reported outcomes, such as pain (VAS) or functional status (ODI), which limits the comprehensiveness of our prognostic evaluation. Finally, the follow-up duration varied among patients (median: 14.0 months; range: 3.0–38.0 months). Re-fracture was analyzed as a binary outcome using logistic regression, without accounting for differences in follow-up duration or time to event. Therefore, patients with longer follow-up may have had more opportunities for re-fracture detection, and the findings should be interpreted cautiously. Future studies using time-to-event analyses are warranted to further evaluate the risk factors for postoperative re-fracture. Additionally, leakage was not subclassified according to location due to the small sample size (n = 18), precluding reliable subgroup analyses and warranting future larger studies. The use of CT rather than plain radiographs may have enhanced detection sensitivity, though the true leakage rate might still have been underestimated.

Conclusions

This study identified age and vertebral wall destruction as independent risk factors for cement leakage, and age, com-

pression degree, and wall destruction as independent risk factors for re-fracture after PKP. These findings emphasize that preoperative evaluation of cortical integrity and patient age is crucial for predicting complications and prognosis. Clinically, high-resolution imaging for wall breaches and age-stratified risk assessment should inform surgical decision-making. The association between leakage and re-fracture appears to be largely mediated by baseline vertebral damage, indicating that treatment strategies must address structural instability rather than focus solely on leakage prevention. Larger prospective studies incorporating patient-reported outcomes are warranted to confirm these results and guide personalized care for elderly patients.

Availability of Data and Materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions

XZL, MF, XL, ZYE and CW designed the research study. XZL and MF performed the research. MF and CW analyzed the data. XZL drafted the manuscript. All authors contributed to critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study has been reviewed and approved by the Ethics Committee of Heilongjiang Provincial Hospital with Ethics Committee Approval No. 2025 (W026). The requirement for informed consent was formally waived by the Ethics Committee because this retrospective study involved no patient-identifiable information and ensured complete anonymization. The researchers strictly followed medical ethical principles, ensuring that the study adhered to the Declaration of Helsinki and other relevant ethical standards.

Acknowledgment

Not applicable.

Funding

This research did not receive any funding.

Conflict of Interest

The authors declare no conflict of interest.

References

[1] Huneidi M, Farah K, Meyer M, Prost S, Blondel B, Fuentes S. Thoracolumbar vertebral fracture in unoperated idiopathic scoliosis. Orthopaedics & Traumatology, Surgery & Research: OTSR. 2023; 109: 103513. https://doi.org/10.1016/j.otsr.2022.103513

[2] Luo Y, Jiang T, Guo H, Lv F, Hu Y, Zhang L. Osteoporotic vertebral compression fracture accompanied with thoracolumbar fascial injury: risk factors and the association with residual pain after percutaneous vertebroplasty. BMC Musculoskeletal Disorders. 2022; 23: 343. https://doi.org/10.1186/s12891-022-05308-7

[3] Lu H, Han S, Liu R, Ma X. Accuracy of mapping results of thoracolumbar vertebral fracture verified using finite element analysis. American Journal of Translational Research. 2024; 16: 1145–1154. https://doi.org/10.62347/BVDL1541

[4] Shi Z, Zhang C, Wang B, Nicolas YSM, Chen J, Yang G. Analysis of Influencing Factors of Vertebral Height Loss After Pedicle Screw Fixation of Thoracolumbar Fracture. Clinical Spine Surgery. 2023; 36: E362–E368. https://doi.org/10.1097/BSD.0000000000001467

[5] Ghadiyaram A, Krishnakumar A, Leppo J, Rajagopal MM, Poulos NT, Opalak CF, et al. A4 Thoracolumbar Fracture Class Is Associated With a Greater Degree of Vertebral Height Loss in Conservatively Managed Patients. Cureus. 2024; 16: e66402. https://doi.org/10.7759/cureus.66402

[6] Tan T, Huang MS, Rutges J, Marion TE, Fitzgerald M, Hunn MK, et al. Rate and Predictors of Failure in the Conservative Management of Stable Thoracolumbar Burst Fractures: A Systematic Review and Meta-Analysis. Global Spine Journal. 2022; 12: 1254–1266. https://doi.org/10.1177/21925682211031207

[7] Zhu HT, Ding DG, Wang S, Zhu YL. Comparison Between Percutaneous Kyphoplasty and Percutaneous Vertebroplasty in Terms of Efficacy in Osteoporotic Vertebral Compression Fractures: A Meta-analysis. Alternative Therapies in Health and Medicine. 2022; 28: 49–53.

[8] Margetis K, Patel A, Petrone B, Carter KR. Percutaneous vertebroplasty and kyphoplasty. StatPearls. StatPearls Publishing: Treasure Island (FL). 2025.

[9] Yu D, Liu Z, Wang H, Yao R, Li F, Yang Y, et al. Treatment of Elderly Patients with Acute Symptomatic OVCF: A Study of Comparison of Conservative Treatment and Percutaneous Kyphoplasty. Frontiers in Surgery. 2022; 9: 942195. https://doi.org/10.3389/fsurg.2022.942195

[10] Zhang B, Chen G, Yang X, Fan T, Chen Z. Percutaneous Kyphoplasty Versus Percutaneous Vertebroplasty for Neurologically Intact Osteoporotic Kümmell's Disease: A Systematic Review and Meta-Analysis. Global Spine Journal. 2022; 12: 308–322. https://doi.org/10.1177/2192568220984129

[11] Alpantaki K, Koutserimpas C, Arkoudis NA, Hadjiapavlou A. Retrograde Flow Cement Leakage during Kyphoplasty. Maedica. 2022; 17: 74–79. https://doi.org/10.26574/maedica.2022.17.1.74

[12] Hou JG, Zhang N, Chen GD. Factors affecting cement leakage in percutaneous vertebroplasty: a retrospective cohort study of 309 patients. European Review for Medical and Pharmacological Sciences. 2023; 27: 3877–3886. https://doi.org/10.26355/eurrev_202305_32293

[13] Haibier A, Hang L, Mahan W, Yusufu A, Shoukeer K. Risk factors for refracture by different cement leakage after percutaneous vertebroplasty in patients with thoracolumbar compression fractures. Scientific Reports. 2025; 15: 36948. https://doi.org/10.1038/s41598-025-20800-5

[14] Tang W, Sun H, Tu W, Niu Y, Zhang Y, Liu T, et al. Refracture and Morphologic Classification in Osteoporotic Vertebral Compression Fractures After Percutaneous Kyphoplasty: A Retrospective Observational Study. Clinical Spine Surgery. 2026; 39: E421–E427. https://doi.org/10.1097/BSD.0000000000001893

[15] Zhang K, She J, Zhu Y, Wang W, Li E, Ma D. Risk factors of postoperative bone cement leakage on osteoporotic vertebral compression fracture: a retrospective study. Journal of Orthopaedic Surgery and Research. 2021; 16: 183. https://doi.org/10.1186/s13018-021-02337-1

[16] Wang Q, Dong JF, Fang X, Chen Y. Application and modification of bone cement in vertebroplasty: A literature review. Joint Diseases and Related Surgery. 2022; 33: 467–478. https://doi.org/10.52312/jdrs.2022.628

[17] Kim JM, Shin DA, Byun DH, Kim HS, Kim S, Kim HI. Effect of bone cement volume and stiffness on occurrences of adjacent vertebral fractures after vertebroplasty. Journal of Korean Neurosurgical Society. 2012; 52: 435–440. https://doi.org/10.3340/jkns.2012.52.5.435

[18] Wang C, Fan S, Liu J, Suyou L, Shan Z, Zhao F. Basivertebral foramen could be connected with intravertebral cleft: a potential risk factor of cement leakage in percutaneous kyphoplasty. The Spine Journal: Official Journal of the North American Spine Society. 2014; 14: 1551–1558. https://doi.org/10.1016/j.spinee.2013.09.025

[19] Wu Y, Zhou Z, Lu G, Ye L, Lao A, Ouyang S, et al. Risk factors for cement leakage after percutaneous vertebral augmentation for osteoporotic vertebral compression fractures: a meta-analysis. International Journal of Surgery (London, England). 2025; 111: 1231–1243. https://doi.org/10.1097/JS9.0000000000001895

[20] Wang L, Zhang C, Liang H, Huang T, Zhong W, Zhao Z, et al. Cement leakage in percutaneous vertebroplasty for spinal metastases: a retrospective study of risk factors and clinical outcomes. World Journal of Surgical Oncology. 2022; 20: 112. https://doi.org/10.1186/s12957-022-02583-5

[21] Ren H, Feng T, Cao J, Hu Y, Yu D, Pan S, et al. A Retrospective Study to Evaluate the Effect of Dynamic Fracture Mobility on Cement Leakage in Percutaneous Vertebroplasty and Percutaneous Kyphoplasty in 286 Patients with Osteoporotic Vertebral Compression Fractures. Medical Science Monitor: International Medical Journal of Experimental and Clinical Research. 2022; 28: e935080. https://doi.org/10.12659/MSM.935080

[22] Dai C, Liang G, Zhang Y, Dong Y, Zhou X. Risk factors of vertebral re-fracture after PVP or PKP for osteoporotic vertebral compression fractures, especially in Eastern Asia: a systematic review and meta-analysis. Journal of Orthopaedic Surgery and Research. 2022; 17: 161. https://doi.org/10.1186/s13018-022-03038-z

© 2026 The Author(s).

