Article

Clinical Effect of Percutaneous Kyphoplasty and Percutaneous Vertebroplasty in Managing Osteoporotic Vertebral Compression Fractures: A Single-Center Propensity Score-Matched Study

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AIM: This study aims to evaluate the clinical effectiveness of percutaneous vertebroplasty (PVP) and percutaneous kyphoplasty (PKP) in managing osteoporotic vertebral compression fractures (OVCFs).
METHODS: This retrospective study included 268 elderly OVCF individuals, and 144 individuals were selected after propensity score matching. General patient information, perioperative conditions, vertebral height and Cobb angle, lumbar spinal function, degree of pain, incidence of complications, and fracture recurrence rates were compared and analyzed for the patients.
RESULTS: The PKP group exhibited longer surgical duration, greater intraoperative blood loss, and more frequent X-ray fluoroscopy during the perioperative period compared to the PVP group ($p < 0.05$). However, there was no significant difference in the length of hospital stay between the two groups. Furthermore, PKP surgery significantly improved vertebral height, corrected spinal posture, and enhanced lumbar spinal function while mitigating pain levels within the 12-month postoperative period ($p < 0.05$). Additionally, the PKP group showed substantially lower rates of bone cement leakage, nerve injury, and fracture recurrence than the PVP group ($p < 0.05$).
CONCLUSIONS: Compared to PVP, PKP demonstrates better clinical effectiveness with lower incidence of complications in managing OVCF. However, surgical time and intraoperative trauma should be considered.

Keywords: osteoporotic vertebral compression fractures; percutaneous kyphoplasty; percutaneous vertebroplasty; propensity score matching; clinical efficacy

Introduction

Osteoporotic vertebral compression fractures (OVCFs) are a common disease, primarily affecting middle-aged and older individuals. Patients typically experience a decrease in vertebral height, spinal kyphotic deformity, and severe back pain, significantly impacting their quality of life [1, 2, 3]. Presently, percutaneous kyphoplasty (PKP) and percutaneous vertebroplasty (PVP) are widely used interventional methods for managing OVCF [4, 5, 6].
PVP involves directly injecting bone cement or other fillers into the vertebral body to strengthen it, restore vertebral height, and effectively relieve back pain in vertebral compression fracture patients. However, PVP surgery has several limitations [7]. Firstly, there is a high risk of bone cement leakage, especially around the fracture cracks. This leakage may enter the spinal canal and neural foramina, increasing the possibility of nerve injury and other complications. Secondly, PVP is less effective in correcting spinal kyphotic deformities and does not substantially improve spinal stability [8, 9, 10].

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In contrast, PKP surgery offers certain advantages in managing OVCF. This procedure involves restoring vertebral height by inflating a balloon inside the vertebral body, and injecting bone cement under low pressure to stabilize the spine [11, 12]. Compared to PVP surgery, PKP increases spinal stability and minimizes the risk of bone cement leakage, primarily due to a cavity within the affected vertebra, making it a safer option [13, 14].
Considering the distinct characteristics, advantages, and limitations of PKP and PVP in managing OVCF, a comparative analysis of these two procedures is essential. By assessing their efficacy in pain relief, vertebral height restoration, and spinal stability improvement, clinicians can make more accurate treatment decisions to achieve optimal outcomes. Thus, this study aims to compare the efficiency of PKP and PVP in managing OVCF, offering more reliable treatment evidence to guide clinical practice.

Materials and Methods

Patient Information

This retrospective study included 268 elderly individuals who underwent OVCF at our hospital from March 2021 to 2023. Based on the surgical procedures, study participants were categorized into the PVP group (n = 132) and the PKP group (n = 136). This study followed the Declaration of Helsinki guidelines and received ethical approval from the Ethics Committee of Suzhou Hospital of Integrated Traditional Chinese and Western Medicine (grant number: 2024009). Furthermore, all study participants provided informed consent.

Inclusion criteria were set as follows: ① Patients aged ≥60 years; ② Bone mineral density T-score at L1–L4 detected by dual-energy X-ray absorptiometry ≤–2.5; ③ Those with minor trauma history, such as twisting or falling, with localized chest/lumbar back pain within 2 weeks and no neurological symptoms; ④ X-ray, computed tomographic (CT), or magnetic resonance imaging (MRI) revealed a single vertebral compression fracture in the upper third of the thoracolumbar spine (T11–L2) without posterior wall rupture; ⑤ Patients with Osteoporotic Thoracolumbar Injury Classification and Severity Score (OTLICS) ≥4; ⑥ Those who underwent unilateral PVP/PKP surgery under local anesthesia; ⑦ Follow-up period ≥12 months with complete pre- and post-operative imaging data.

The exclusion criteria were as follows: ① Patient with a history of long-term corticosteroid use leading to secondary osteoporosis; ② MRI indicating old vertebral fractures or intravertebral disc changes; ③ Those with vertebral fractures resulting in nerve root and/or spinal cord injury; ④ Non-compliance during the follow-up period or missing data; ⑤ Those with pathological fractures caused by bone tumors or infections.

Surgical Approaches

During PVP, the patient was positioned prone, and preoperative imaging was conducted to identify the fractured vertebra. However, the precise location of the fractured vertebra was confirmed by utilizing a C-arm X-ray for fluoroscopy. The puncture site was marked by locating the skin projection of the spinous process of the fractured vertebra, 1–2 cm laterally. After routine disinfection, a sterile surgical drape was applied. After this, local infiltration anesthesia with 2% lidocaine was administered at the puncture site. Once adequate anesthesia was achieved and the patient's thoracolumbar spine was positioned to increase vertebra repositioning, the puncture needle was advanced to the anterior 2/3 of the fractured vertebra. Bone cement was incrementally injected under fluoroscopic guidance to ensure sufficient fracture expansion and minimize the risk of cement leakage. The injection was immediately stopped upon observing satisfactory cement dispersion or in the event of leakage. After waiting 1–2 minutes, the insertion rod of the delivery cannula was rotated and removed. The gauze was applied to the puncture site to control bleeding, and the area was disinfected and covered with a dressing, completing the procedure.

The surgical procedure for the PKP group was similar to that of the PVP group, with the only difference being the use of an expandable balloon to restore vertebral height before cement injection. Under the C-arm guidance, the balloon was inflated within the fractured vertebra to facilitate realignment. Once the vertebral height was restored, the balloon was deflated and removed. In the next step, the fractured vertebra underwent incremental injection of bone cement, following the same procedure as in the PVP group. The injection was stopped upon observing satisfactory cement dispersion or in the event of leakage. After waiting for 1–2 minutes, the insertion rod was rotated and removed. The gauze was used at the puncture site to control bleeding, and the area was disinfected and dressed, completing the procedure.

Upon discharge, patients in both groups were advised to wear orthotic devices for one month to prevent falls, continue osteoporosis treatment, and schedule outpatient follow-ups at 1, 3, 6, and 12 months after operation. In this study, continuous treatment of osteoporosis for postoperative patients included drug therapy (such as calcium supplements, vitamin D supplements, bisphosphonates, and calcitonin, with the choice and dosage adjusted to individual conditions and medical advice) and lifestyle intervention. These interventions included increasing physical exercise, such as weight-bearing exercises like walking and jogging to enhance bone strength, improving dietary habits with a focus on calcium-rich foods, vitamin D and protein-rich foods such as dairy, fish, soy products, as well as quitting smoking and limiting alcohol.

Furthermore, to improve postoperative follow-up, refinement of some examinations and indicators was needed. For example, regular bone mineral density tests were conducted to evaluate the efficacy of osteoporosis therapy. Furthermore, imaging examinations such as X-rays, CT, or MRI were performed to monitor vertebral healing, bone cement position, and observe any new fractures. Additionally, lumbar spinal function assessment (such as measurement of lumbar range of motion and muscle strength testing), pain assessment (like inquiries about the specific location, nature, and frequency of pain), and quality of life assessments (using relevant approaches such as the SF-36 questionnaire) were included. Laboratory investigations (such as blood calcium, phosphorus, and alkaline phosphatase levels to examine bone metabolism) and cardiovascular health assessments (such as electrocardiograms and blood pressure tests, considering the association between osteoporosis and cardiovascular diseases) may also be included.

Observational Indexes and Assessment Criteria

(1) We collected general patient data including age, sex, body mass index (BMI), smoking and drinking habits, fracture location, OTLICS score, and the time from injury to surgery.

(2) We compared perioperative conditions between groups, including the duration of the procedure, volume of cement, blood loss, frequency of fluoroscopy, and length of hospital stay.

(3) The vertebral anterior height and Cobb angle before and one day following the operation were compared. Vertebral height was measured using the Distortion-Compensated Roentgen Analysis (DCRA) method, which involves taking measurements from four vertebral morphological reference

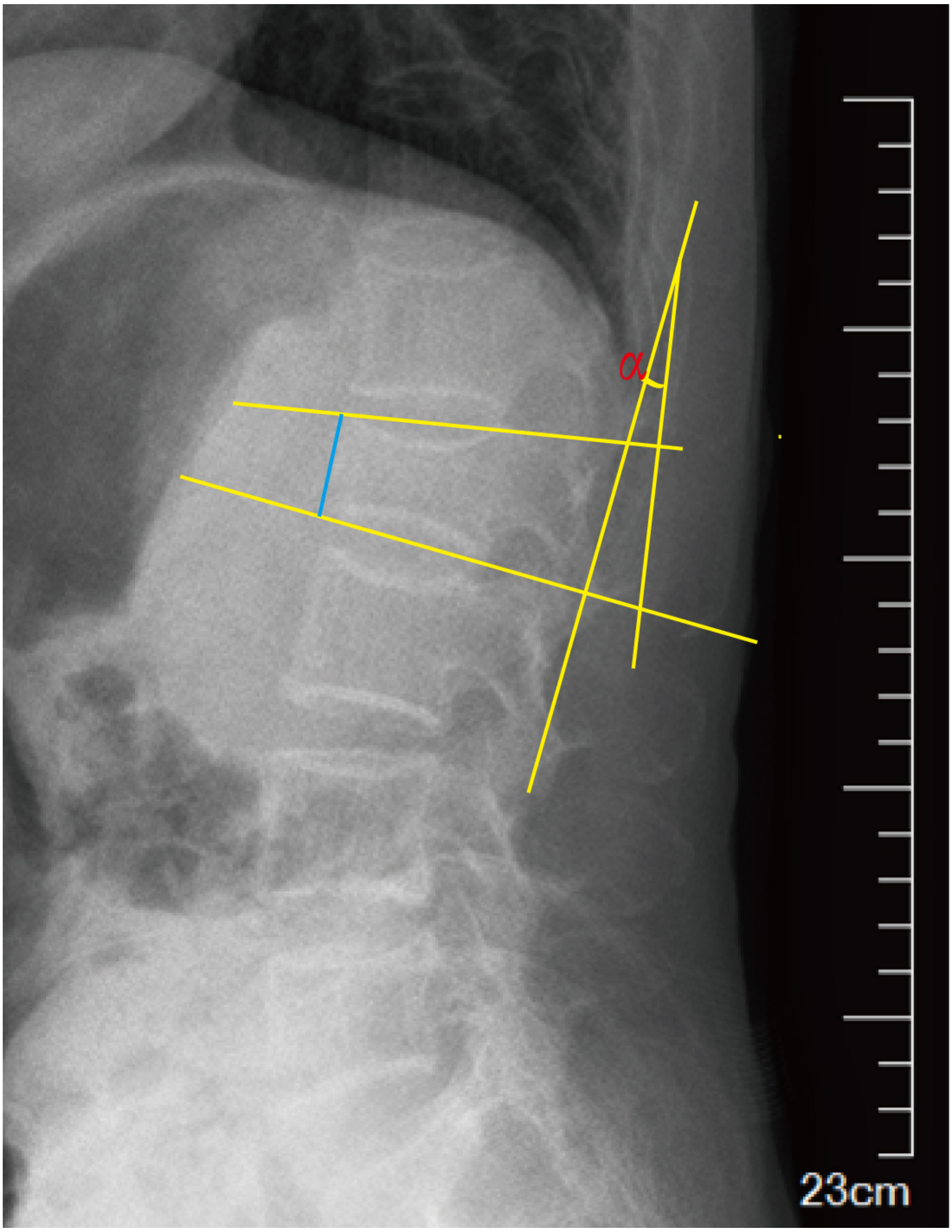

Fig. 1. Schematic diagram measuring the anterior edge height and Cobb angle of the vertebral body. The blue line represents the anterior edge height of the vertebral body, and the α angle is the Cobb angle. The blue line represents the anterior edge height of the vertebral body. The α angle is the Cobb anglewhich is formed by the lines (yellow lines) extending from the upper and lower edges of the vertebral body.

points of the adjacent intervertebral disc to determine vertebral body height. The anterior height represents the vertical distance from the mid-sagittal plane of the vertebral body [15]. The Cobb angle is calculated from lateral X-ray images by measuring the angle formed by lines extending from the upper and lower vertebral edges of the vertebrae at the location of the kyphotic deformity (The specific measurement method is shown in Fig. 1) [16].

(4) Lumbar spinal function in both groups before surgery and at the 12-month post-operative mark was assessed for comparison. Spinal function recovery was determined using the Japanese Orthopaedic Association (JOA) score, which measures subjective symptoms, clinical signs, limitation in daily activities, and bladder function [17]. The first 3 categories were scored between 9 and 14, with higher scores indicating better recovery. The bladder function was scored from –6 to 0, reflecting the level of functional recovery.

(5) Pain levels of the individuals were compared before surgery, as well as 1 day and 12 months after the operation.

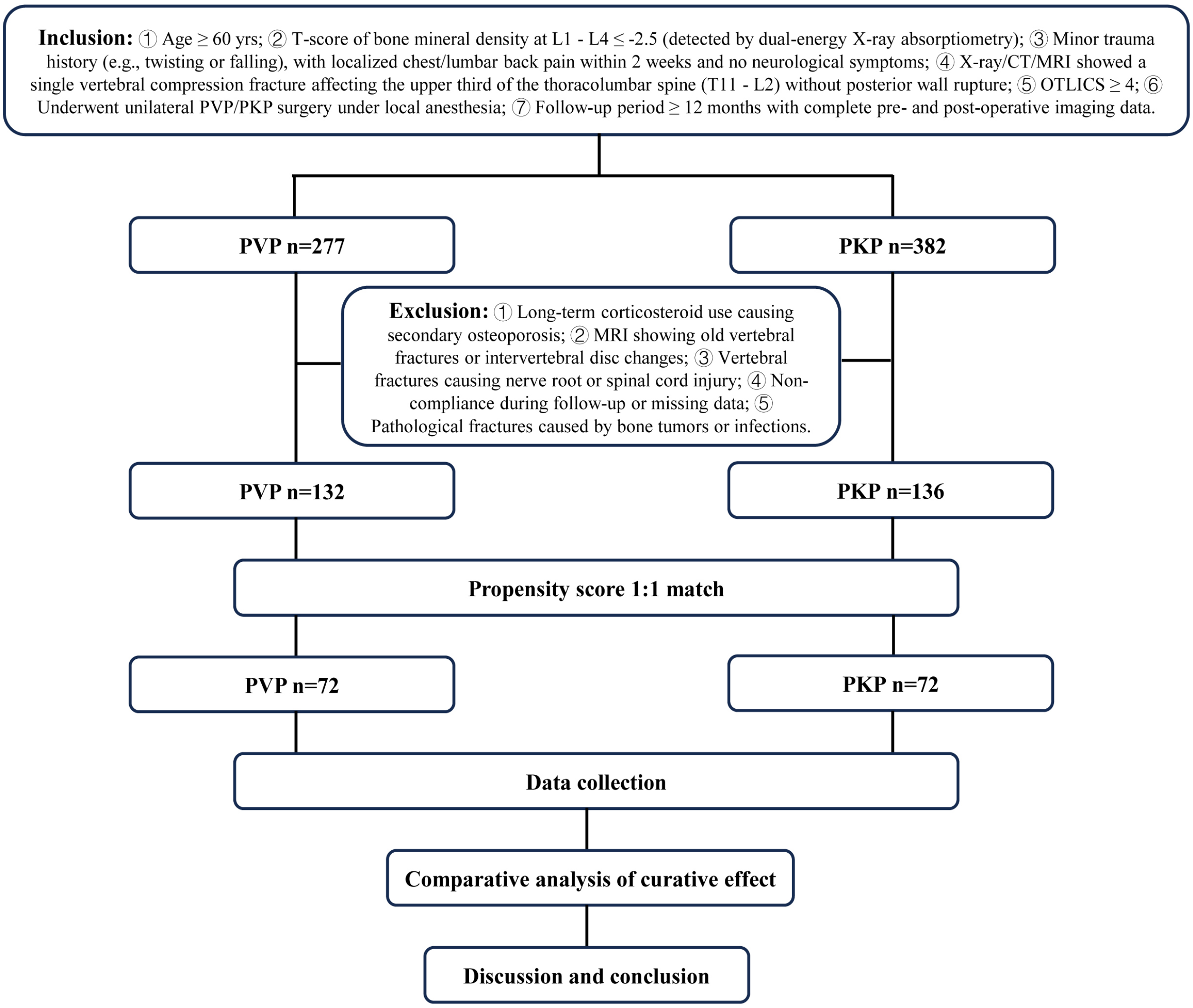

Fig. 2. A flow chart of the study design. CT, computed tomographic; MRI, magnetic resonance imaging; OTLICS, Osteoporotic Thoracolumbar Injury Classification and Severity Score; PVP, percutaneous vertebroplasty; PKP, percutaneous kyphoplasty.

Pain severity during rest and activity was examined using the Visual Analogue Scale (VAS) [18], which ranges from 0 to 10, with higher scores indicating greater subjective pain levels.

(6) Surgical complications, such as cement leakage, nerve injury, and pulmonary embolism, were recorded and compared between the two groups at 12 months of follow-up.

(7) The rate of recurrent fractures (refracture at the surgical site) within 12 months post-surgery was compared between the two groups.

(8) Imaging from typical cases was assessed before and after PVP and PKP surgeries.

Statistical Analysis

Statistical analysis was performed using the SPSS 25.0 (IBM Corp., Armonk, NY, USA). Continuous data were presented as mean ± standard deviation ($\bar{x} \pm$ s) and checked for normal distribution. For normally distributed continuous data between groups, a comparison was done utilizing the independent samples *t*-test. Repeated measures analysis of variance was employed to compare normally distributed data collected at various time points within groups, followed by post-hoc Least Significant Difference-t (LSD-t) test. Categorical data (n, %) were compared using the chi-squared test. Statistical significance was achieved at $p < 0.05$.

To reduce selection bias between the two groups, propensity score matching (PSM) [19] was employed. Covariates such as age, gender, BMI, smoking history, drinking history, fracture site, OTLICS, and time from injury to surgery were used for 1:1 matching, with a caliper value set at 0.1. Statistical significance was considered at a *p*-value less than 0.05. The flowchart of this study is depicted in Fig. 2.

Results

General Data before and after Matching

The baseline characteristics of the patients pre- and post-PSM are shown in Table 1. Before PSM, there were significant differences in age, BMI, and time from injury to

Table 1. Comparison of baseline characteristics pre- and post-PSM between groups.

Characters	Before PSM		t/χ^2	p	After PSM		t/χ^2	p
	PVP (132)	PKP (136)			PVP (72)	PKP (72)		
Age (years)	71.28 ± 7.53	69.49 ± 8.42	–3.371	0.023	70.24 ± 7.81	70.44 ± 8.54	–0.153	0.879
Sex (n, %)			0.248	0.618			0.041	0.839
Male	24 (18.18)	28 (20.59)			15 (20.83)	16 (22.22)		
Female	108 (81.82)	108 (79.41)			57 (79.17)	56 (77.78)		
BMI (kg/m^2)	21.74 ± 2.60	22.56 ± 2.79	–2.569	0.045	21.72 ± 2.59	22.07 ± 2.59	–0.804	0.423
Smoking (n, %)			0.496	0.481			0.036	0.849
yes	36 (27.27)	32 (23.53)			19 (26.39)	18 (25.00)		
no	96 (72.73)	104 (76.47)			53 (73.61)	54 (75.00)		
Drinking (n, %)			0.084	0.772			0.039	0.843
yes	31 (23.48)	34 (25.00)			16 (22.22)	17 (23.61)		
no	101 (76.52)	102 (75.00)			56 (77.78)	55 (76.39)		
Fracture site (n, %)			0.504	0.918			0.280	0.964
T11	13 (9.85)	12 (8.82)			5 (6.94)	6 (8.33)		
T12	44 (33.33)	49 (36.03)			25 (34.72)	27 (37.50)		
L1	48 (36.36)	45 (33.09)			26 (36.11)	24 (33.33)		
L2	27 (20.45)	30 (22.06)			16 (22.22)	15 (20.83)		
OTLICS (points)	4.67 ± 0.47	4.74 ± 0.43	0.822	0.584	4.69 ± 0.60	4.63 ± 0.52	0.747	0.456
Interval between injury and surgery (days)	3.61 ± 1.44	3.03 ± 1.72	2.528	0.046	3.54 ± 1.78	3.10 ± 1.59	1.577	0.117

PSM, propensity score matching; BMI, body mass index; OTLICS, Osteoporotic Thoracolumbar Injury Classification and Severity Score; PVP, percutaneous vertebroplasty; PKP, percutaneous kyphoplasty.

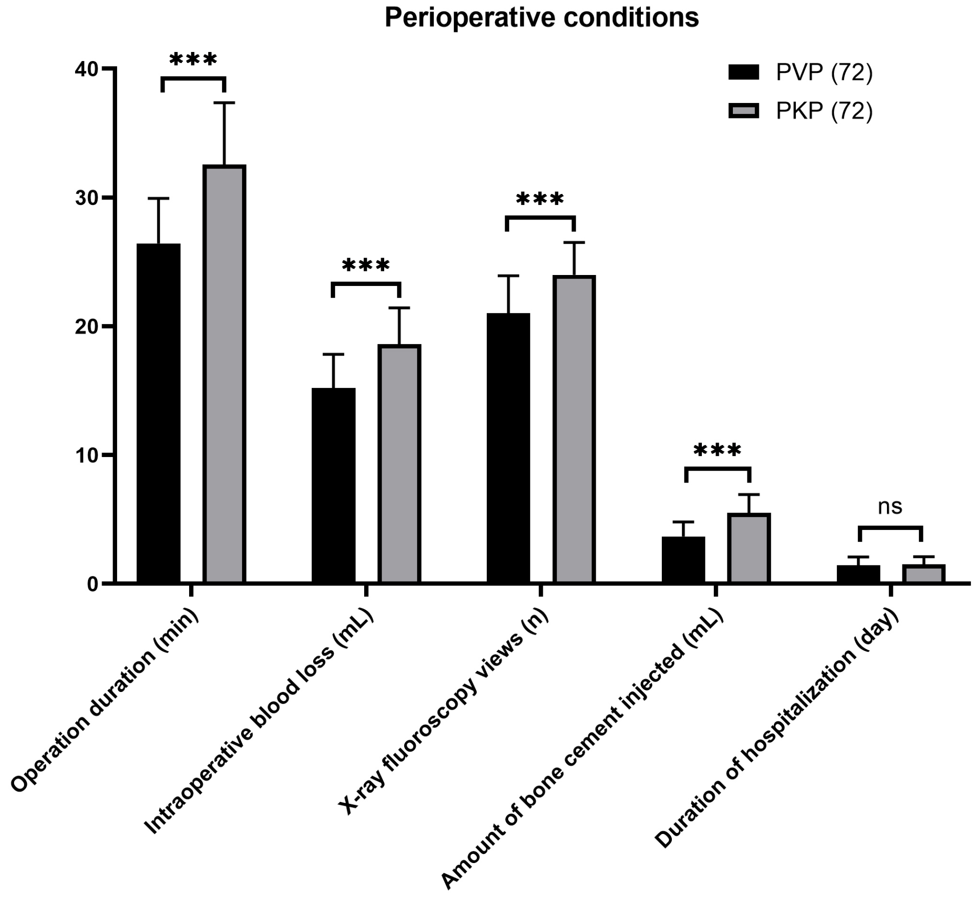

Fig. 3. Comparison of the perioperative conditions between the two groups. *** $p < 0.001$; ns, the difference was not significant; PVP, percutaneous vertebroplasty; PKP, percutaneous kyphoplasty.

Table 2. Comparison of vertebral body anterior-edge height and the Cobb angle ($\bar{x} \pm$ s).

Experimental Group (n)	Height of the anterior edge (mm)		Cobb angle (°)	
	Before	After	Before	After
PVP (72)	11.67 ± 1.64	17.63 ± 2.16*	14.56 ± 4.03	9.82 ± 2.64*
PKP (72)	11.60 ± 1.48	21.49 ± 2.20*	15.39 ± 3.81	7.79 ± 2.39*
t	0.266	–10.627	–1.274	4.826
p	0.790	<0.001	0.205	<0.001

* Signifies remarkable change following treatment in contrast to before the treatment. PVP, percutaneous vertebroplasty; PKP, percutaneous kyphoplasty.

Table 3. Comparison of lumbar spine mobility between the two groups ($\bar{x} \pm$ s).

Experimental Group (n)	Subjective symptoms		Clinical signs	
	Before	After	Before	After
PVP (72)	4.46 ± 1.51	5.92 ± 1.52*	2.86 ± 0.74	3.47 ± 0.96*
PKP (72)	4.32 ± 1.48	7.01 ± 1.38*	2.74 ± 0.73	4.01 ± 0.93*
t	0.557	–4.541	1.021	–3.438
p	0.578	<0.001	0.309	0.001
Experimental Group (n)	Extent of restricted mobility		Bladder function	
	Before	After	Before	After
PVP (72)	9.06 ± 1.24	10.25 ± 1.33*	–2.61 ± 0.86	–2.07 ± 0.66*
PKP (72)	8.99 ± 1.25	11.42 ± 1.23*	–2.76 ± 1.00	–1.71 ± 0.59*
t	0.334	–5.465	0.981	–3.465
p	0.739	<0.001	0.328	0.001

* Signifies remarkable change following treatment in contrast to before the treatment. PVP, percutaneous vertebroplasty; PKP, percutaneous kyphoplasty.

surgery ($p < 0.05$). However, after PSM, 72 pairs were successfully matched, and no substantial differences were found in the general data between groups ($p > 0.05$).

Perioperative Comparisons

Fig. 3 shows the results of surgical duration, intraoperative blood loss, X-ray fluoroscopy frequency, amount of bone cement, and length of hospital stay for both patient groups. The duration of surgery (32.56 ± 4.81 *vs.* 26.44 ± 3.49), intraoperative blood loss (18.63 ± 2.80 *vs.* 15.21 ± 2.62), X-ray fluoroscopy frequency (24.01 ± 2.50 *vs.* 21.00 ± 2.92), and amount of cement (5.51 ± 1.44 *vs.* 3.68 ± 1.14) were substantially higher in the PKP group than in the PVP group ($p < 0.05$). However, there was no considerable difference in the length of hospital stay between groups (1.53 ± 0.58 *vs.* 1.46 ± 0.63, $p > 0.05$).

Comparison of Vertebral Height and Cobb Angle

Before surgery, there were no significant variations between groups regarding the vertebral anterior height and Cobb angle of the injured vertebrae. Conversely, a substantial decrease in Cobb angle and a significant increase in vertebral anterior height were observed in both groups one-day post-surgery mark, with the PKP group indicating a substantially greater improvement than the PVP group ($p < 0.05$, Table 2).

Comparison of Lumbar Spinal Function

The JOA scores for the two groups were found to be similar before surgery. However, at the 12-month follow-up post-surgery, both groups showed a substantial increase in JOA scores, with the PKP group demonstrating significantly higher scores ($p < 0.05$) compared to the PVP group (Table 3).

Comparison of Pain Levels

Both groups exhibited substantially reduced VAS scores at 1 day and 12 months post-operation compared to pre-surgery. There were no significant differences in VAS scores between groups 1 day after operation. However, at 12 months post-operation, the VAS score for the PKP group was considerably lower than that of the PVP group ($p < 0.05$, Fig. 4).

Comparison of Complication Rates

The PVP group had 9 cases of cement leakage, 2 cases of pulmonary embolism, and 3 cases of nerve injury, resulting in a complication rate of 19.44%. Conversely, the PKP group had 2 cases of cement leakage and 2 cases of nerve injury, leading to a substantially lower complication rate of 5.56% compared to the PVP group ($p < 0.05$, Table 4).

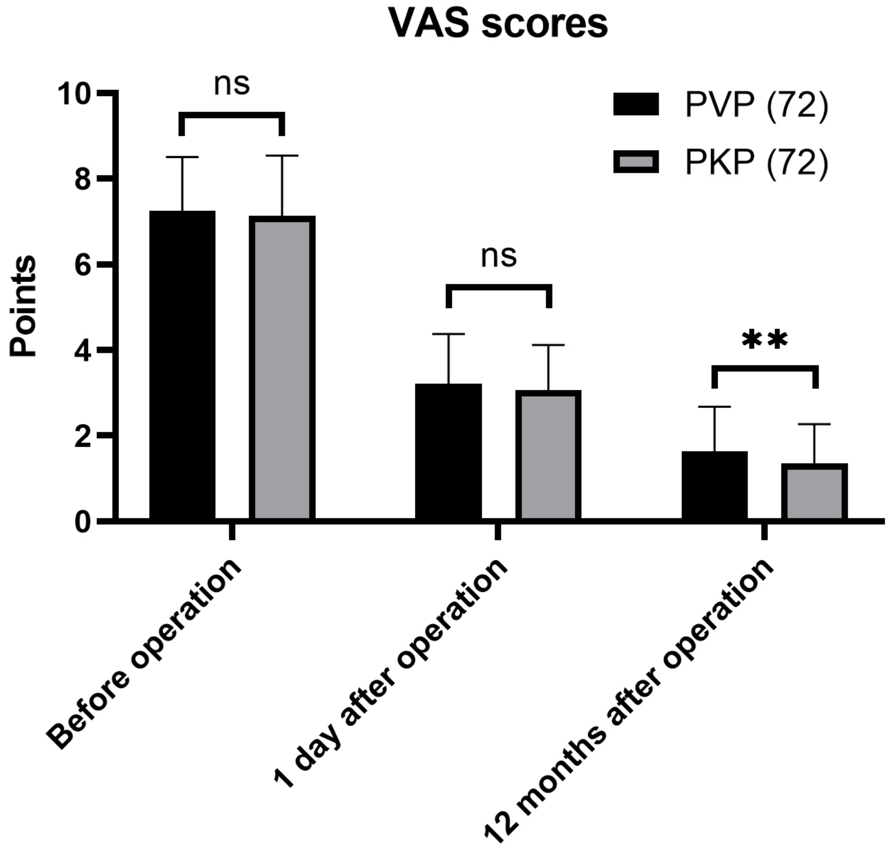

Fig. 4. Comparison of VAS scores between the two groups. ** $p < 0.01$; ns, no significance; PVP, percutaneous vertebroplasty; PKP, percutaneous kyphoplasty; VAS, Visual Analogue Scale.

Table 4. Incidence of adverse reactions [n (%)].

Experimental Group (n)	Cement extravasation	Nerve injury	Pulmonary embolism	Overall incidence
PVP (72)	9 (12.50)	3 (4.17)	2 (2.78)	14 (19.44)
PKP (72)	2 (2.78)	2 (2.78)	0 (0.00)	4 (5.56)
χ^2				6.349
p				0.012

Table 5. Comparison of fracture recurrence rate between the two groups.

Experimental Group (n)	Recurrence rate (%)
PVP (72)	12 (16.67)
PKP (72)	4 (5.56)
χ^2	4.500
p	0.034

Comparison of Fracture Recurrence Rates

The fracture recurrence rate at 1 year after operation was 16.67% for the PVP group and 5.56% for the PKP group, indicating a significant variation between groups ($p < 0.05$, Table 5).

Image Features Analysis before and after Surgery

Patient A, a 68-year-old female who underwent PVP, suffered from lumbar back pain and limited mobility for 2 days due to accidental fall. Patient B, a 74-year-old female who underwent PKP, experienced chest and back pain with restricted mobility for 3 days due to accidental twisting. The X-ray examination results of the two patients before surgery, 1 day after operation, and 12 months after operation are shown in Fig. 5.

Discussion

OVCF can adversely impact the stability and biomechanical strength of the spinal vertebral bodies. OVCF patients often experience increased stress on the anterior edge of the vertebral body, leading to spinal curvature, vertebral deformity, and intense pain, which can significantly affect their daily lives [20, 21]. Older individuals are more vulnerable to OVCF, and with the accelerating aging process in our country, the incidence of this condition is rising [22]. Traditional conservative treatments for OVCF often involve prolonged bed rest and carry a high risk of disease recurrence, failing to meet practical clinical needs.

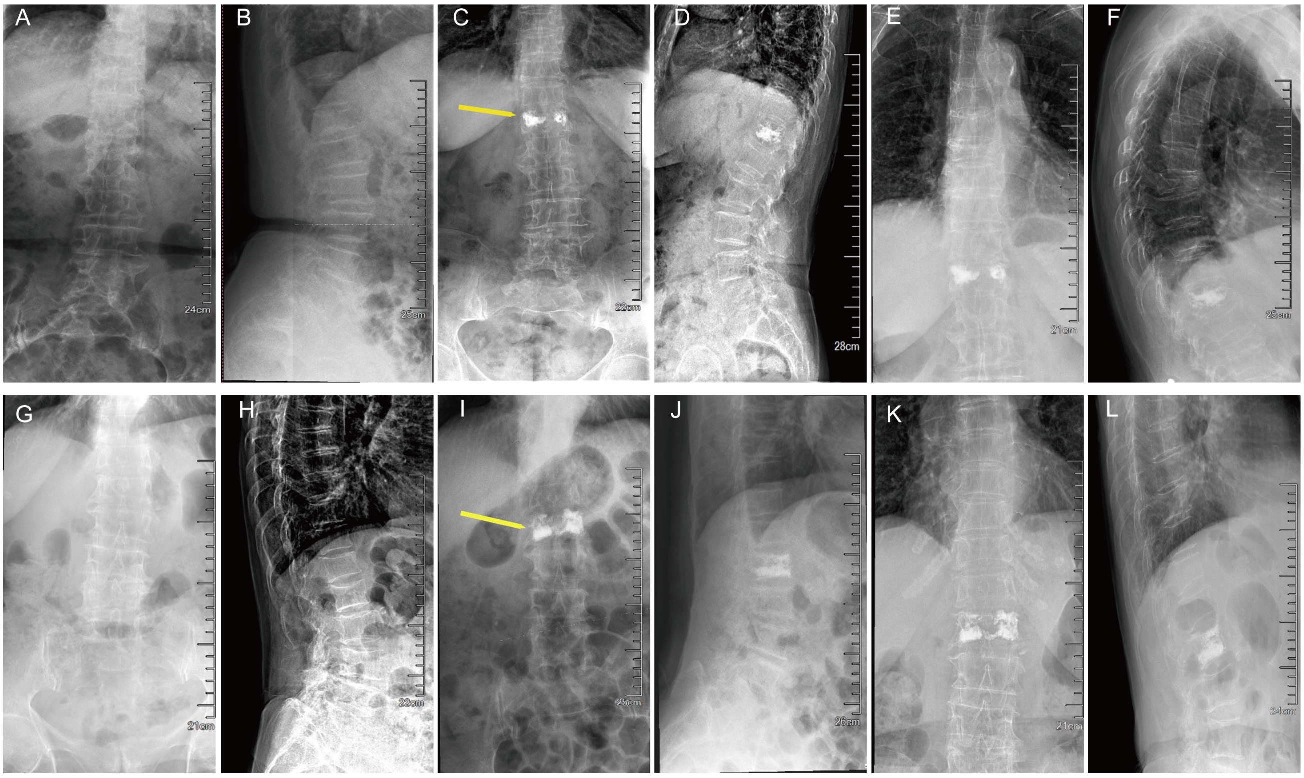

Fig. 5. The preoperative, 1-day postoperative, and 1-year postoperative statuses of representative cases who underwent PVP and PKP treatments (patient A: (A–F); patient B: (G–L)). (A,B) Preoperative anteroposterior and lateral X-rays show the presence of a T12 vertebral compression fracture. (C,D) X-rays obtained 1 day after surgery demonstrate well-healed fracture, satisfactory position of bone cement, absence of loosening or displacement, and no evidence of minor cement leakage. (E,F) CT images at 12 months post-surgery illustrate well-healed fracture, satisfactory position of bone cement, absence of loosening or displacement, and no evidence of minor cement leakage. (G,H) Preoperative X-rays show the presence of an L1 vertebral compression fracture. (I,J) X-rays obtained 1 day after surgery reveal well-healed fracture, satisfactory position of bone cement, absence of loosening or displacement, and no evidence of cement leakage. (K,L) X-rays at 12 months post-surgery depict well-healed fracture, satisfactory position of bone cement, absence of loosening or displacement, no evidence of cement leakage, and minimal change in the vertebral body as opposed to the 1-day postoperative images. The vertebral body indicated by the yellow arrow is the vertebral body of fracture and bone cement injection.

Minimally invasive spine surgery has advanced rapidly, leading to the widespread adoption of techniques like PKP and PVP for treating OVCF. PKP and PVP surgeries are known for their minimal trauma, reduced intraoperative blood loss, and aim to enhance joint strength through bone cement injection, which can improve joint function [23, 24]. In this retrospective study, we observed significant differences in patient characteristics, such as age, BMI, and time from injury to surgery, before using PSM. PSM was utilized to minimize bias associated with patient characteristic, successfully matching 72 pairs of patients and resulting in no substantial differences in baseline characteristics between groups.

Furthermore, perioperative outcomes revealed that the PKP group had substantially longer surgical durations, elevated intraoperative blood loss, and more frequent X-ray fluoroscopy compared to the PVP group. These results indicate that the PKP procedure involves a higher level of radiation exposure and requires a longer period in the prone surgical position, which potentially increases the perioperative risk for patients. However, it could enhance the overall surgical outcome [25]. The higher risk in the PKP group may be attributed to the additional balloon expansion step, which requires repeated X-ray confirmation and poses a potential risk of vascular and tissue injuries due to balloon inflation.

For single-segment fresh OVCFs, injuries typically affect the anterior part of the vertebral body. Loss of vertebral height can lead to kyphotic deformity of the spine [26]. Additionally, increased Cobb angle and changes in spinal biomechanics can change the force distribution on the injured vertebra, resulting in decreased force on the posterior column structure and exacerbating the biomechanical load on the anterior part. This worsening condition may increase the risk of kyphotic deformity, additional fractures in the injured vertebra, and compression fractures in adjacent segments [27].

In our study, both surgical methods substantially improved vertebral anterior height and Cobb angle, with the PKP group demonstrating superior results compared to the PVP group. These observations indicate that PKP surgery is more effective in restoring vertebral height and improving spinal posture. PVP enhances stability by injecting bone cement into the affected vertebra, which integrates closely with surrounding bone tissue and aligns with the normal bone trabecular elastic model. However, injecting bone cement during PVP may cause vertebral volume compression, resulting in elevated intra-vertebral pressure and a higher risk of bone cement leakage, which can lead to abnormal biomechanical changes in the lumbar spine and disrupt stress balance among various segments after surgery [28], potentially exacerbating pain in the injured vertebra. PKP, an advanced form of PVP, retains simplicity and low invasiveness while further compressing the cancellous bone around the cavity to form a natural barrier against cement leakage. This mechanism makes PKP more effective in promoting vertebral height recovery and enhancing vertebral stability [29].

Our study indicated that both surgical techniques substantially improved JOA scores and VAS at 1 day and 12 months after surgery, suggesting that both procedures effectively stabilized vertebrae through bone cement injection, increasing vertebral strength, and rapidly alleviating lumbar back pain, consistent with previous research [30]. Nevertheless, compared to the PVP group, the PKP group had a significantly higher JOA score at the 12-month follow-up, indicating PKP's ability in vertebral stability and functional recovery.

Furthermore, both groups showed substantial improvement in pain levels after surgery. Nonetheless, the PKP group exhibited lower VAS scores at 12 months post-operation, demonstrating better pain relief. Complications were an important concern in our findings [31]. We observed a significant decrease in cement leakage and nerve injury in the PKP group compared to the PVP group. This reduction could be attributed to the greater precision in cement injection during PKP surgery, where balloon expansion forms a more controlled vertebral cavity, reducing the risk of leakage [32]. In PKP surgery, a cavity is formed by inserting and inflating a balloon before cement injection. This helps better control cement distribution, reducing the risk of leakage as the doctor can inject it more precisely into the predetermined area. In contrast, PVP surgery involves direct cement injection, making its distribution difficult to control due to the internal structure and pressure of the vertebral body, which increases the possibility of leakage. Additionally, balloon expansion in PKP surgery can partially restore vertebral body height, providing a better space and pressure environment for bone cement injection. This process allows for more even distribution of the cement and improves injection precision. However, the occurrence of complications rates in both groups still needs to be carefully monitored and managed in clinical practice. Furthermore, the PKP group exhibited a markedly lower rate of fracture recurrence than the PVP group, suggesting that PKP surgery provides better stability and durability in preventing recurrent fractures.

Previous studies have compared the clinical efficacy of PKP and PVP. For example, Wang *et al*. [33] found that PKP surgery is more effective in treating OVCF patients, reducing the incidence of pain and adverse reactions while promoting the recovery of kyphosis Cobb angle, which aligns with the results of this study. Additionally, the study by Li *et al*. [34] showed a lower incidence of bone cement leakage in PKP surgery, which is consistent with our findings.

However, there are some similarities and differences between our study and previous research. Compared to Zhang *et al*. [35], our study further confirmed that PKP improved lumbar spine function at 12 months postoperatively, which may be related to the stricter inclusion criteria and more accurate measurement methods used in this study. Furthermore, we found that the PKP group had better pain relief at 12 months postoperatively, which differed from Zhang *et al*.'s findings [35]. This variation could be due to differences in the timing and methods used for pain assessment.

The strength of this study is the use of the propensity score matching (PSM) method, which effectively reduces patient characteristics bias, making the two groups more comparable. Furthermore, we conducted a detailed analysis of multiple observational indicators, including surgery-related indicators, vertebral height and Cobb angle, lumbar spine function, pain level, complication rate, and fracture recurrence rate, to provide more comprehensive information for clinical decision-making.

This study has some limitations which must be acknowledged. The potential for biases related to information and recall is introduced by the retrospective design, which is the primary issue. Furthermore, as a single-center study, the results may be influenced by local differences and individual variations. To enhance future studies, we recommend conducting multicenter, prospective, randomized controlled trials to validate our results and delve deeper into related clinical indicators and underlying mechanisms. Long-term follow-up studies would be helpful to evaluate the lasting effects of the conditions.

Conclusions

Overall, based on our research findings, PKP surgery demonstrates better effectiveness than PVP surgery in restoring vertebral height, improving spinal posture, alleviating pain, and lowering the rates of complications and fracture recurrence. However, it is essential to recognize that PKP surgery involves longer surgical time and imposes greater intraoperative trauma. Therefore, clinicians should carefully assess these factors and make decisions based on individual patient situations.

Availability of Data and Materials

All experimental data included in this study can be obtained by contacting the first author if needed.

Author Contributions

DYC designed and performed the research and wrote the paper; XT designed the research and supervised the report; BZ designed the research and contributed to the analysis; JL provided clinical advice and interpreted data for the study; PW analyzed the data and supervised the report. All authors contributed to important editorial changes in the manuscript. 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 followed the Declaration of Helsinki guidelines and received ethical approval from the Ethics Committee of Suzhou Hospital of Integrated Traditional Chinese and Western Medicine (grant number: 2024009). Furthermore, all study participants provided informed consent.

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Conflict of Interest

The authors declare no conflict of interest.

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