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ORIGINAL ARTICLE

Clinical efficacy of percutaneous vertebroplasty versus percutaneous kyphoplasty treating osteoporotic vertebral compression fractures with kyphosis

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Abstract

Purpose This study aimed to investigate the clinical efficacy of percutaneous vertebroplasty (PVP) and percutaneous kyphoplasty (PKP) in treating osteoporotic vertebral compression fractures (OVCFs) with kyphosis.

Methods The clinical data included 63 patients in the PVP group and 70 in the PKP group. The study assessed the pain visual analog scale (VAS), Oswestry Disability Index (ODI), wedge angle (WA), local kyphotic angle (LKA), and vertebral height.

Results The operative time was significantly less in the PVP group ($p < 0.05$). Meanwhile, more bone cement was injected into the PKP group ($p < 0.05$), with significantly higher surgical costs ($p > 0.05$). Post-operative VAS, ODI, WA, LKA, and vertebral height were significantly improved in PVP and PKP groups compared with pre-operative measurements ($p < 0.05$). The results revealed insignificant VAS and ODI improvement differences between the two groups at each follow-up time ($p > 0.05$). Vertebral height, WA, and LKA improved more significantly in the PKP group at day 1 and 3 months post-operatively ($p < 0.05$), with insignificant group differences at subsequent time points ($p > 0.05$). The improvements in VAS were unrelated to those in WA, LKA, or vertebral height in either group ($p > 0.05$). The improvement in VAS was unrelated to the amount of bone cement injected ($p > 0.05$); the PKP group demonstrated a lower incidence of cement leakage (12.9%; $p < 0.05$).

Conclusion PVP and PKP can restore partial vertebral height and improve kyphosis with similar clinical outcomes. PVP has a shorter operating time, is more economical, and can represent a therapeutic choice.

Keywords Kyphosis · Vertebroplasty · Kyphoplasty · Osteoporotic · Compression fracture

Introduction

Osteoporotic vertebral compression fractures (OVCFs) are a common complication of osteoporosis, with approximately 1.7 million OVCFs occurring yearly in the USA and Europe [1]. In China, osteoporosis incidence in people over 50 years is approximately 34.65%, and nearly 1/3 leads to fracture [2]. Low back pain is the main symptom of patients with OVCFs. OVCFs cause spinal fracture dislocation, and insufficient vertebral height can lead to kyphosis, decreased cardiopulmonary function, depression, and poorer quality of life, underscoring the importance of surgical intervention [3, 4]. Percutaneous vertebroplasty (PVP), first reported in 1987, is a minimally invasive procedure for managing OVCFs [5], resulting in rapid restoration of vertebral stability, pain relief, and few complications, but controversy remains about its role in correcting kyphosis. Percutaneous kyphoplasty (PKP) was first attempted in the 1990s by Dr. Mark Reiley [6] as another effective minimally invasive procedure; it can also improve back pain and has better results in correcting kyphosis and restoring vertebral height. However, PKP has disadvantages, including unsatisfactory repositioning and height loss after balloon retrieval, especially with severe osteoporosis. Consequently, PVP and PKP have advantages and disadvantages in treating thoracolumbar OVCFs. Previous studies have reported that PKP has a better reduction effect on OVCFs than PVP; however, it is not superior to

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PVP in pain relief. PVP can restore partial vertebral height [7, 8]. However, controversy remains regarding which surgical method has the best clinical outcomes for treating thoracolumbar OVCFs. This study aimed to retrospectively compare the clinical data of patients with thoracolumbar OVCFs with kyphosis treated with PVP and PKP and explore their clinical efficacy and value to determine the ideal therapeutic option.

Materials and methods

Study population

A retrospective analysis was conducted on 133 patients with thoracolumbar OVCFs accompanied by kyphosis treated with PVP or PKP from January 2018 to January 2020. All patients had osteoporosis and were identified pre-operatively using dual-energy X-ray absorptiometry (DXA) with a bone mineral density T score ≤ –2.0. There was no history of falls or other traumas. All patients had persistent back pain, which was significantly worse with position changes. The patients were diagnosed with fresh OVCF with kyphosis (10° ≤ Cobb angle ≤ 30°) by X-ray, CT, and MRI. The processing segment was located between T10 and L2. Patients were excluded due to the presence of nerve root or spinal cord injury, primary or secondary spinal tumor resulting in fracture, severe scoliosis, neurological disease, or adjacent or distal vertebral fractures after treatment. This study was approved by the Institutional Ethics Committee of our hospital (2023-LW-HG-0004-01). Patients chose PVP or PKP according to their wishes after obtaining detailed information about the surgical procedures, and written informed consent was obtained. All procedures followed the Declaration of Helsinki of the World Medical Association.

Surgical methods

PKP was performed under local anesthesia using G-arm fluoroscopy. Placing the patient in the prone position with a cushion below the sternum and pelvis facilitated abdominal draping with manipulative reduction. A percutaneous pedicle puncture was performed. After reaching the posterior border of the vertebral body, the puncture needle was replaced with a working cannula. The balloon was inserted through the working access to reach the anterior 2/3 of the vertebral body and was slowly expanded to minimize fractures and create a cavity for cement injection. The expansion was stopped when the pressure reached 200 pound-force/square inch (PSI) or the balloon touched the endplate and was removed. Polymethylmethacrylate (PMMA) cement was injected incrementally to fill the cavity when it became doughy. The entire injection process was continuously monitored. The procedure was immediately stopped when high resistance was encountered or when PMMA was near the posterior wall of the vertebral body. The amount of cement used was also measured (Fig. 1).

The PVP procedure was similar to that of PKP, but no balloon was used. Cement filling was performed using G-arm fluoroscopic visualization after replacing the puncture needle with a working cannula (Fig. 2). Six hours after the procedure, the patient was ambulatory with a customized

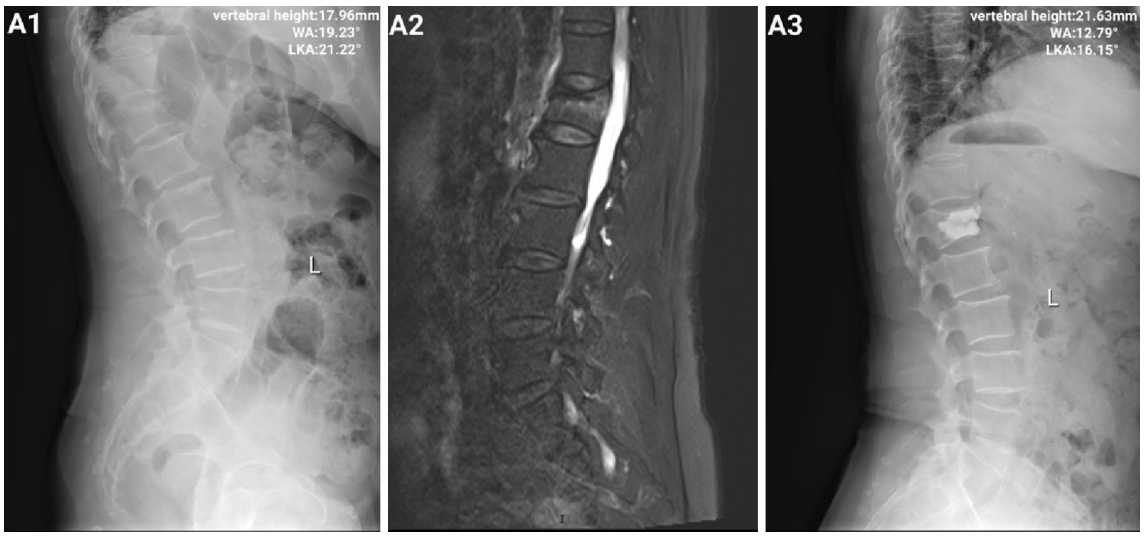

Fig. 1 Pre-operative and post-operative radiographs of a 69-year-old woman with OVCFs of L1 vertebral body treated with PKP. The pre-operative anteroposterior radiograph depicts decreased vertebral height, increased wedge angle, and local kyphotic angle at the L1 level (**A1**). Sagittal MR image displays a fresh vertebral fracture (**A2**). Post-operative lateral radiograph demonstrates recovery of vertebral height with improved wedge angle and local kyphotic angle (**A3**)

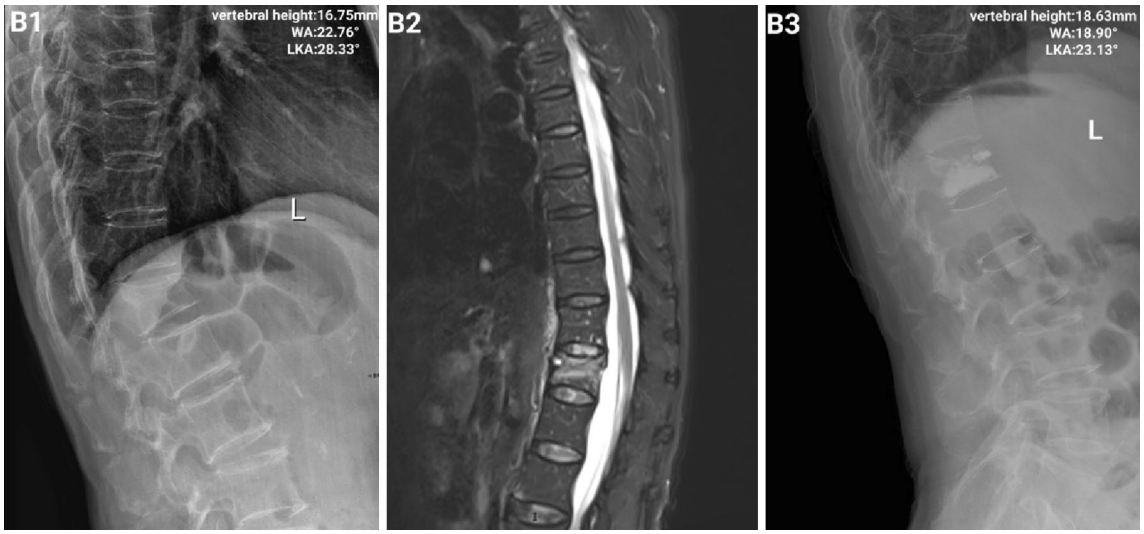

Fig. 2 Pre-operative and post-operative radiographs of a 65-year-old woman with OVCFs of L1 vertebral body treated with PVP. The pre-operative anteroposterior radiograph presents decreased vertebral height, increased wedge angle, and local kyphotic angle at the L1 level (**B1**). Sagittal MR image displays a fresh vertebral fracture (**B2**). The post-operative lateral radiograph manifests recovery of vertebral height with improved wedge angle and local kyphotic angle (**B3**)

brace and discharged on day 3. Osteoporosis treatment was conducted in the outpatient department.

Data collection and outcome assessment

The results of clinical and radiographic evaluations pre-operatively were recorded at day 1, 3 months, as well as 1 and 2 years post-operatively. The visual analog scale (VAS) [9] was used to assess changes in back pain severity. The Oswestry Disability Index (ODI) [10] was employed to estimate the outcome of patient function. Considering the lifestyle and age of the patients, the ODI items about sexual activity were eliminated, which brought the number of scoring items to 9, with 45 points in total. The parameters used to evaluate the procedure outcomes included the vertebral height, wedge angle (WA), and local kyphotic angle (LKA). The vertebral height was measured as the anterior vertebral height [11]. The WA was equal to the angle between the upper and lower endplates of the vertebral body before and after the operation [12]. The LKA was calculated from the segmental Cobb angle, formed by the superior endplate of the upper vertebra and the inferior endplate of the vertebra on lateral plain radiographs [13]. All imaging measurements were performed in a double-blinded fashion by two physicians.

Statistical analysis

Statistical analyses were performed using SPSS version 19.0 statistical software (IBM SPSS, Chicago, Illinois, USA). All data are expressed as the mean ± SD. Independent sample t tests were used to analyze intergroup differences. Pre- and post-operative values between different subgroups were compared using a paired *t* test. Numerical data were compared using the χ^2 test. Pearson's correlation coefficients were calculated to assess the relationship between decreased values of VAS and improved vertebral height, WA, and LKA. $p < 0.05$ indicated statistical significance.

Results

Patient characteristics

A total of 14 men and 49 women with an average age of 74.4 years (60–90 years) underwent PVP, and 12 men and 58 women with an average age of 75.3 years (60–90 years) underwent PKP. The vertebral fracture locations included T10 ($n = 23$), T11 ($n = 20$), T12 ($n = 32$), L1 ($n = 29$), and L2 ($n = 29$). The PVP and PKP groups showed insignificant differences regarding gender, age, bone mineral density (BMD), body mass index (BMI), and vertebral fracture location ($p > 0.05$). The operative time of the PKP group (50.29 ± 6.4 min) was significantly longer than that of the PVP group (24.56 ± 2.8 min). The average cement

Table 1 Patient characteristics and intra-operative conditions

Characteristics	PVP ($N=63$)	PKP ($N=70$)	t/χ^2 value	p value
Age (years)	74.48 ± 10.08	75.36 ± 8.76	− 0.535	0.593
Sex				
Male	14	12	0.544	0.515
Female	49	58		
Location				
Thoracic vertebrae	18	14	1.333	0.311
Lumbar vertebrae	45	56		
BMI (kg/m^2)	23.0 ± 2.5	23.1 ± 2.4	− 0.266	0.791
BMD (T score)	3.2 ± 0.49	3.2 ± 0.46	0.117	0.907
Operative time (min)	24.56 ± 2.8	50.29 ± 6.4	− 30.446	< 0.01
Blood loss (mL)	9.97 ± 3.24	10.17 ± 3.24	− 0.361	0.719
Volume of bone cement (mL)	3.0 ± 0.65	5.0 ± 0.64	− 18.214	< 0.01
Operation cost (CNY/W)	2.5 ± 3.2	3.5 ± 2.8	− 19.6	< 0.01
Cement leakage				
Yes	18	9	5.061	0.031
No	45	61		

Values are mean ± SD, number of participants, or as otherwise indicated

PKP percutaneous kyphoplasty, *PVP* percutaneous vertebroplasty, *BMD* bone mineral density, *BMI* body mass index

volume was 5.0 ± 0.64 mL in PKP, more than in PVP (3.0 ± 0.65 mL). The PKP group had significantly higher surgical costs than the PVP group ($p < 0.01$) (Table 1).

Clinical and radiological outcomes

The VAS scores decreased significantly from a pre-operative value of PVP: 7.9 ± 0.7 and PKP: 8.1 ± 0.8 to a post-operative value of PVP: 3.0 ± 0.1 and PKP: 3.0 ± 0.2 and were maintained at PVP: 1.1 ± 0.2 and PKP: 1.1 ± 0.3 at the final follow-up. The ODI scores decreased significantly from a pre-operative value of PVP: 74.18 ± 9.92 and PKP: 71.32 ± 7.31 to a post-operative value of PVP: 32.75 ± 6.77 and PKP: 31.19 ± 5.22 and were PVP: 31.94 ± 3.61 and PKP: 31.78 ± 4.83 at the final follow-up. Therefore, both groups elicited significant VAS and ODI improvement after the operation. However, the degree of improvement achieved had insignificant intergroup differences ($p > 0.05$). Post-operatively, increased vertebral height and decreased WA and LKA were observed in PVP and PKP. The changes in vertebral height, WA, and LKA at day 1 and 3 months post-operatively were significantly different between the two groups ($p < 0.05$). However, VH, WA, and LKA improvement differences between PVP and PKP were insignificant at 1 and 2 years after operation ($p > 0.05$) (Table 2).

The mean restoration of vertebral height was 2.83 mm in the PVP and 4.25 mm in PKP. The mean improvements in WA and LKA were 4.50° and 3.26° in PVP and 7.86° and 7.7° in PKP. The improvement in the VAS score had an insignificant correlation with the improvement in vertebral height, WA, or LKA, as well as cement volume (Table 3).

None of the patients had spinal cord injuries, pulmonary embolisms, infections, or other fatal complications. In the PKP group, asymptomatic cement leakage occurred in nine cases (12.9%), with four into the intervertebral space, three lateral to the vertebral body, one into the spinal canal, and one into the paravertebral vein. In the PVP group, asymptomatic cement leakage occurred in 18 cases (28.6%), with six into the intervertebral space, nine lateral to the vertebral body, one into the spinal canal, and two into the paravertebral vein. The number of cement leakage cases differed significantly between the two groups ($p < 0.05$) (Table 1).

Discussion

The OVCFs incidence increases with the advent of the aging society worldwide. OVCFs in the thoracolumbar segment tend to cause kyphotic deformities, decreasing quality of life and increasing patient mortality. With the recognition of osteoporotic fractures and findings based on retrospective studies with large sample sizes, more patients are willing to accept PVP or PKP, which has proven safe and effective in treating OVCFs, to quickly regain independent living ability and improve their quality of life [14, 15].

Pain and function are essential clinical indicators that emphasize the effectiveness of the procedure and serve as surrogate markers of the quality of life. Zhang et al. [8, 16] reported pain relief and functional improvement after PVP

Table 2 Comparison of VAS, ODI, vertebral height, WA, and LKA

Variable	Pre-operative		Post-operative 1 day		Post-operative 3 months		Post-operative 1 year		Post-operative 2 years	
	PVP	PKP	PVP	PKP	PVP	PKP	PVP	PKP	PVP	PKP
VAS score	7.9 ± 0.7	8.1 ± 0.8	$3.0 \pm 0.1^{\Delta}$	$3.0 \pm 0.2^{\Delta}$	$1.9 \pm 0.4^{\Delta}$	$2.0 \pm 0.2^{\Delta}$	$1.4 \pm 0.5^{\Delta}$	$1.5 \pm 0.5^{\Delta}$	$1.1 \pm 0.2^{\Delta}$	$1.1 \pm 0.3^{\Delta}$
ODI (%)	74.18 ± 9.92	71.32 ± 7.31	$32.75 \pm 6.77^{\Delta}$	$31.19 \pm 5.22^{\Delta}$	$31.19 \pm 6.85^{\Delta}$	$33.12 \pm 6.21^{\Delta}$	$33.53 \pm 5.16^{\Delta}$	$32.00 \pm 4.98^{\Delta}$	$31.94 \pm 3.61^{\Delta}$	$31.78 \pm 4.83^{\Delta}$
Vertebral height (mm)	15.97 ± 1.60	15.47 ± 1.48	$18.81 \pm 1.75^{\blacktriangle\Delta}$	$19.73 \pm 1.45^{\Delta}$	$18.67 \pm 1.76^{\blacktriangle\Delta}$	$19.44 \pm 1.46^{\Delta}$	$17.53 \pm 1.77^{\Delta}$	$18.03 \pm 1.48^{\Delta}$	$17.44 \pm 1.77^{\Delta}$	$17.92 \pm 1.47^{\Delta}$
WA (°)	19.94 ± 3.21	20.12 ± 3.18	$15.44 \pm 3.22^{\blacktriangle\Delta}$	$12.26 \pm 3.50^{\Delta}$	$15.61 \pm 3.23^{\blacktriangle\Delta}$	$12.72 \pm 3.48^{\Delta}$	$16.50 \pm 3.24^{\Delta}$	$15.42 \pm 3.54^{\Delta}$	$16.70 \pm 3.25^{\Delta}$	$15.76 \pm 3.55^{\Delta}$
LKA (°)	22.02 ± 3.81	23.12 ± 3.18	$18.76 \pm 3.80^{\blacktriangle\Delta}$	$15.40 \pm 3.30^{\Delta}$	$19.01 \pm 3.79^{\blacktriangle\Delta}$	$15.86 \pm 3.29^{\Delta}$	$20.26 \pm 3.78^{\Delta}$	$19.30 \pm 3.31^{\Delta}$	$20.37 \pm 3.77^{\Delta}$	$19.44 \pm 3.32^{\Delta}$

PKP percutaneous kyphoplasty, *PVP* percutaneous vertebroplasty, *VAS* visual analog scale, *ODI* Oswestry Disability Index, *WA* wedge angle, *LKA* local kyphotic angle

$^{\blacktriangle}p < 0.05$ compared with the PKP group; $^{\Delta}p < 0.05$ compared with pre-operation

Table 3 Correlation coefficient (r) between the decreased values of VAS and improvement of vertebral height, WA, LKA, and cement volume

	PVP ($N = 63$)		PKP ($N = 70$)	
	r	p	r	p
ΔVertebral height	− 0.072	0.573	0.138	0.253
ΔWA	− 0.172	0.177	0.048	0.691
ΔLKA	0.007	0.956	− 0.122	0.315
Cement volume	− 0.008	0.948	0.173	0.152

PKP percutaneous kyphoplasty, *PVP* percutaneous vertebroplasty, *WA* wedge angle, *LKA* local kyphotic angle

treatment. Chen et al. [17] reported a sustained decrease in VAS scores, and the ODI scores improved significantly at 24 months after PKP. Herein, all patients had better VAS scores and ODI at the post-operative follow-up time than the pre-operative one, with insignificant differences between the two groups. PVP and PKP could relieve pain and recover functionality after treatment; however, PKP was not more advantageous than PVP. The reduced VAS score was not significantly associated with improved vertebral height, WA or LKA, or cement volume. These findings suggest that pain may be unrelated to kyphosis severity or decreased vertebral height. The leading cause of pain in OVCFs may be due to micro-movements of vertebral fractures [18]. Effective pain relief and satisfactory clinical outcomes can be achieved with vertebral stabilization. Liu et al. [19] and Wang et al. [20] reported that it is impossible to determine which surgical approach was more beneficial for pain relief and functional recovery.

Retaining vertebral height is a valuable quantitative indicator of the efficacy of vertebroplasty and kyphoplasty. Reducing LKA and WA can be used to measure the effectiveness of vertebroplasty and kyphoplasty in improving kyphosis. PVP had a limited effect on vertebral height recovery and an insignificant effect on kyphosis correction. Firanescu et al. [21] reported a progressive decrease in height of 0–3 mm in 118 PVP patients without a detailed report on the recovery of vertebral height. Blasco et al. [22] reported insignificant vertebral height recovery in PVP at 12 months. However, PVP has some orthopedic effects; Farrohki et al. [3] reported 8 mm of restored vertebral height and 8° of corrected deformity after PVP. Dublin et al. [23] also indicated 47.6% restoration of vertebral height, 6.0° improvement in kyphosis, and 3.5° reduction in wedge angle after PVP of 40 vertebrae. This study found that the average recovery of vertebral height was 2.83 mm, and the mean improvement in WA and LKA was 4.50° and 3.26°, respectively, after PVP. Vertebral height recovery improvement in WA and LKA groups was more advantageous in the PKP group at day 1 and 3 months post-operatively. However, the clinical efficacy

contrasts between the two groups were insignificantly different. Patients were asked to wear a customized brace for daily activities within 3 months; then, the brace could be removed. During follow-up, vertebral height, WA, and LKA stabilization were largely maintained in both groups within 3 months post-operatively. The recovery of vertebral height and reduction in WA and LKA at each subsequent time point were partially lost. However, there were no clinical differences in pain relief and functional recovery compared with the previous period. Consequently, vertebral height loss and the increase in WA and LKA did not affect the clinical efficacy of OVCFs after PVP or PKP. The prone surgical position and manipulative reduction allow for partial or complete repositioning of the injured vertebral body, and cement allows for fixation and maintenance of the vertebral height. Consequently, PVP can restore vertebral height and reduce WA and LKA to a certain extent.

PKP improves vertebral height recovery, WA, and LKA better than PVP. However, Zhang et al. [24] suggested that PVP and PKP could increase vertebral height, correct kyphosis, and maintain the clinical effects. Yu et al. [25] reported an insignificant difference in vertebral height recovery and kyphotic correction 3 days after PVP and PKP. Our study found that the vertebral height recovered in the PKP group and the improvement in WA and LKA was better than that in the PVP group at day 1 and 3 months after surgery, with insignificant differences between the two groups at 1 and 2 years post-operatively. Moreover, no correlation existed between changes in imaging and clinical outcomes. Accordingly, both surgical approaches are effective for height restoration, WA, and LKA improvement, and PKP has an insignificant advantage over PVP. The vertebral collapse after PKP might be because the adjacent upper and lower vertebral and surrounding muscle soft tissues would squeeze the suspended vertebral again after balloon extraction, resulting in an unmaintained distraction height and partial loss of reduction. Balloon expansion further crushes the loose trabecular bone, reducing the contact area of the cement with the bone tissue interface within the vertebra. Consequently, the kyphotic deformity of the spine is partially corrected, further reducing the vertebral height in the distant post-operative period.

Cement leakage is a common intra-operative complication of vertebroplasty and kyphoplasty, including paraspinal soft tissue or intervertebral space leakage, often without obvious clinical symptoms. Leakage into the spinal canal or intervertebral foramen may cause damage to the spinal cord or nerve root, and paravertebral vein leakage may cause venous embolism [26]. In a meta-analysis by Patel et al. [7], the cement leakage rate in vertebroplasty ranged from 1.21 to 91.3% and in kyphoplasty from 0 to 45.1%. Herein, the leakage incidence was 12.9% for PKP and 28.6% for PVP. The cement leakage rate of kyphoplasty is lower than that of vertebroplasty. This may have created a cemented injection cavity due to balloon expansion, allowing more cement volume at a lower injection pressure. Generally, patients receiving PKP or PVP treatment have complicated circumstances and multiple comorbid medical diseases, and the choice of local anesthesia can reduce the length of stay. Here, the average hospitalization expenses of PKP were higher than those of PVP.

This preliminary study revealed an insignificant difference in the clinical efficacy between PKP and PVP. Accordingly, whether patients have health insurance coverage, they must consider the pressure of the financial costs. The limitations of our study were its single-center retrospective design, small number of patients, and lack of a case–control study of multisegmental thoracolumbar vertebral fractures with kyphosis. Further prospective, multicenter, and controlled studies involving more cases and longer follow-up periods are warranted.

Conclusion

Our clinical and radiographic evaluations demonstrated that PVP and PKP can regain vertebral height and improve the wedge and local kyphotic angles. Both surgical approaches have shown benefits in terms of pain reduction and improved patient function. PKP has not exhibit better results than PVP. PKP has a low incidence of cement leakage; however, PVP has a shorter operative time, is more economical, and can be used as the preferred method for minimally invasive surgery for thoracolumbar OVCFs with kyphosis.

Authors contributions DL contributed significantly to the analysis and wrote the manuscript; JP and RP performed the data analyses; XZ and XZ helped perform the analysis with constructive discussions. All authors read and approved the final manuscript.

Availability of data and materials The datasets used or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest No conflict of interest exits in the submission of this manuscript.

Ethical approval This study was approved by the medical Ethics Committee of the Luoyang Orthopedic-Traumatological Hospital Of Henan Province (Henan Provincial Orthopedic Hospital) institution.

Consent to publish Manuscript is approved by all authors for publication.

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