

RESEARCH

Open Access



# Comparison of unipedicular and bipedicular kyphoplasty for treating acute osteoporotic vertebral compression fractures in the lower lumbar spine: a retrospective study

Yunfan Qian<sup>1</sup>, Yimin Li<sup>1</sup>, Guangjie Shen<sup>1</sup>, Xiqiang Zhong<sup>1</sup>, Chengxuan Tang<sup>1</sup> and Shaoqi He<sup>1\*</sup>

## Abstract

**Background** Unipedicular and bipedicular approaches for percutaneous kyphoplasty are reportedly both effective in treating osteoporotic vertebral compression fractures (OVCFs). However, most studies have reported thoracolumbar fractures, with few reports describing the treatment of the lower lumbar spine. Here, we compared the clinical and radiological results of unipedicular and bipedicular approaches for percutaneous kyphoplasty for treating osteoporotic vertebral compression fractures.

**Methods** We retrospectively reviewed the records of 160 patients who underwent percutaneous kyphoplasty for lower lumbar (L3–L5) osteoporotic vertebral compression fractures between January 2016 and January 2020. Patient characteristics, surgical outcomes, operation time, blood loss, clinical and radiological features, and complications were compared between two groups. Cement leakage, height restoration, and cement distribution were calculated from the radiographs. Visual pain analog scale (VAS) and Oswestry Disability Index (ODI) were calculated before surgery, immediately post-surgery, and 2 years after surgery.

**Results** The mean age, sex, body mass index, injury time, segmental distribution, and morphological classification of fractures before surgery did not differ significantly between the groups. The results showed significant improvements in the VAS score, ODI score, and vertebral height restoration in each group ( $p < 0.05$ ), with no significant differences between the two groups ( $p > 0.05$ ). The mean operation time and extent of blood loss were lower in the unipedicular group than those in the bipedicular group ( $p < 0.05$ ). Different types of bone cement leakage were observed in both groups. Leakage rate was higher in the bipedicular group than in the unipedicular group. Patients in the bipedicular group showed greater improvement in bone cement distribution than those in the unipedicular group ( $p < 0.05$ ).

**Conclusions** The clinical and radiological results of unipedicular percutaneous kyphoplasty for treating osteoporotic vertebral compression fractures in the lower lumbar region were similar to those of bipedicular percutaneous kyphoplasty. However, the unipedicular approach resulted in shorter surgical time, less blood loss, and less bone cement leakage. Thus, the unipedicular approach may be preferable owing to its several advantages.

**Keywords** Osteoporotic vertebral fracture, Minimally invasive surgery, Osteoporosis, Percutaneous kyphoplasty, Unipedicular, Bipedicular

\*Correspondence:

Shaoqi He

heshaoqi@126.com

Full list of author information is available at the end of the article



© The Author(s) 2023. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>. The Creative Commons Public Domain Dedication waiver (<http://creativecommons.org/publicdomain/zero/1.0/>) applies to the data made available in this article, unless otherwise stated in a credit line to the data.

## Background

Osteoporotic vertebral compression fractures (OVCFs) have become increasingly common in older patients in recent years. Owing to a decrease in bone mass and an increase in bone fragility, even minimal trauma may be sufficient to cause fractures in older patients [1–3]. Various techniques have been developed to treat OVCFs. Among these, percutaneous balloon kyphoplasty (PKP) has been the most effective treatment for OVCFs since it was first described in 1997 [4]. PKP is a minimally invasive spinal surgery technique in which a balloon tamp is inserted into the vertebral body through the pedicle to repair the vertebral height and fix the fracture by injecting polymethyl methacrylate (PMMA) bone cement into the vertebral body [5, 6]. Currently, the standard PKP technique involves a bipedicular approach. In recent years, unipedicular approach has been advocated because of shorter operating and radiation exposure times, which can lower the risk of cement leakage and complications. Most previous studies have shown that the clinical and radiological results of unipedicular percutaneous kyphoplasty for OVCFs are similar to those of bipedicular percutaneous kyphoplasty [7–9]. However, the previous studies have mostly focused on the thoracolumbar spine, and there are few reports on the lower lumbar spine (L3–L5). Owing to the large vertebral bodies, the puncture needle does not easily reach the opposite side in the unilateral approach, and the bone cement filler cannot be evenly distributed throughout the vertebral body; therefore, most surgeons prefer the bipedicular approach. To confirm that both procedures can be successfully used in patients with lower lumbar vertebral compression fractures, we compared the clinical and radiological results of the unipedicular and bipedicular approaches for PKP to treat lower lumbar OVCFs.

## Methods

### Patients

We retrospectively analyzed patients with OVCFs of the lower lumbar spine (L3–L5) who underwent PKP between January 2016 and January 2020. The inclusion criteria were (1) age > 50 years, (2) single-level OVCFs, and (3) preoperative magnetic resonance imaging (MRI) performed to assess acute fractures, in which T2-weighted short tau inversion recovery sequence (STIR) showed obvious bone edema in the fractured vertebral body, and (4) PKP performed within 4 weeks of OVCFs occurrence, and (5) the patients received anti-osteoporosis therapy (calcium supplementation and vitamin D) and rehabilitation training postoperatively. The exclusion criteria were (1) OVCFs treated with percutaneous mesh container-plasty, (2) multiple lesions or previous compression fractures, (3) symptoms

of neurological deficits, (4) severe spinal deformities or severe comorbidities (ankylosing spondylitis, multiple myeloma, tumor, thyroid or parathyroid disease, hepatic disease, and kidney disease), and (5) vertebral compression fracture due to causes other than osteoporosis. In total, 160 patients were enrolled in this study. The patients were divided into two groups according to the PKP approach: the unipedicular group ( $n=82$ ) and the bipedicular group ( $n=78$ ). The following data were collected for demographic analysis: age, sex, body mass index (BMI), injury time, segmental distribution, and morphological classification of the fractures. The fractures were classified as A (wedging), B (biconcavity), and C (crush) based on morphology, according to the EVOSG classification published in 1999 [10].

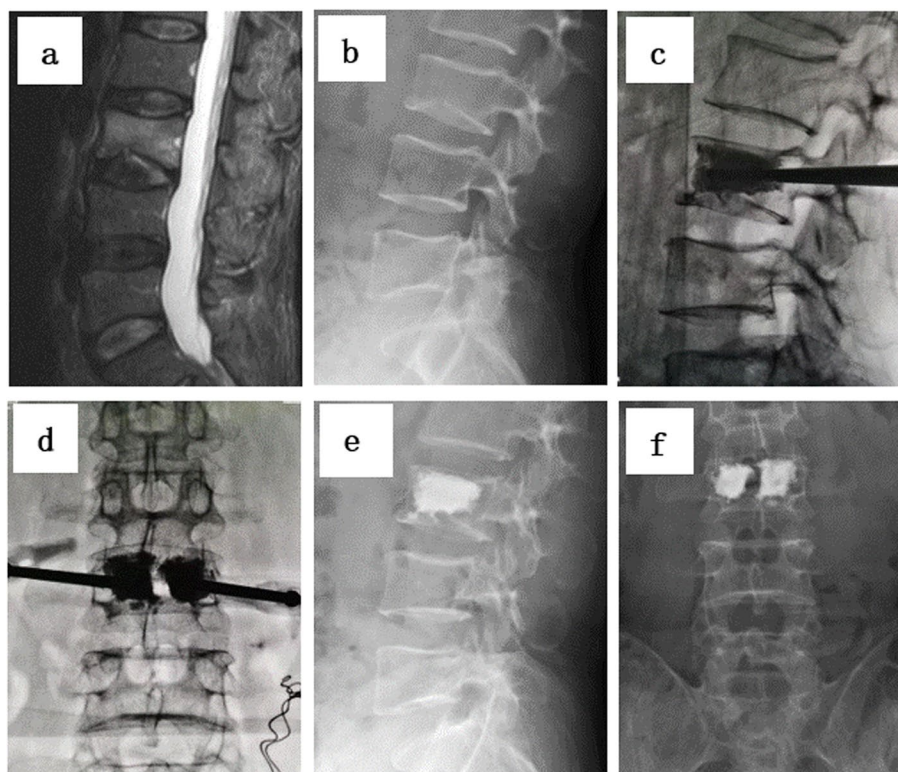
### Surgical techniques

The PKP was performed by a single surgeon. All procedures were performed under local anesthesia. The patients were placed in the prone position on four bolsters on a radiolucent operating table with the abdomen freely suspended.

A 1-cm skin incision was made percutaneously lateral to the desired entry point of the pedicle. A trocar (Shandong Guanlong Medical Utensils Co., Ltd., Jinan City, Shandong Province, China) in a cannula was inserted into the pedicle at the fractured vertebra using a pedicular approach as the working channel. After the trocar was removed, a balloon was placed in the working channel and slowly inflated to create a low-pressure cavity for cement injection. Inflation continued until the balloon pressure reached 300 psi. The balloon was then deflated and removed. Next, the PMMA cement was injected into the defect of the fractured body through the cannula under continuous fluoroscopic monitoring. The PMMA insertion was considered complete when it reached the posterior third of the vertebral body or had a tendency toward cortical, epidural, or anterior venous cement leakage. In the bipedicular approach, the same surgical steps are performed for both pedicles. In the unipedicular approach, the puncture angle was increased, with the end of the cannula placed as close to the midline as possible so that the inflated balloon could exceed the midline of the vertebra on the anteroposterior view to allow the PMMA to spread as much as possible throughout the vertebral body (Figs. 1 and 2).

### Measurements

Imaging findings and clinical outcomes were analyzed before and after surgery. Anterior, middle, and posterior vertebral body height ratios (AVBHR, MVBHR, and PVBHR, respectively) were measured using lateral radiographs, as described previously [11]. The methods used



**Fig. 1** a-f Percutaneous kyphoplasty for the treatment of a L3 vertebral compression fracture in bipedicular approach. a-b Preoperative lateral radiograph and MRI showing a L3 vertebral compression fracture. c-d Intraoperative view (e-f) Postoperative lateral radiograph showing cement distribution after undergoing PKP surgery of L3 vertebral compression fracture

to measure the vertebral body height ratios are shown in Fig. 3. Vertebral height was defined as the endplate-to-endplate distance measured from the anterior aspect of the vertebral body on the lateral radiographs. Operation time, estimated blood loss, length of hospital stay, and complications were recorded. The visual analog scale (VAS) was used to evaluate analgesic efficacy (on a scale of 0–10), while the Oswestry Low Back Pain Disability Index (ODI) was used for functional assessment. Cement distribution was calculated using anteroposterior and lateral radiographs. Cement leakage was determined using X-ray films. The immediate and 2-year postoperative follow-up findings of all patients were recorded. Incidence of cement leakage from the vertebral body on postoperative radiographs and type of bone cement leakage were also recorded.

Furthermore, two independent spine surgeons performed the clinical evaluation of the patients. Additionally, three other spine surgeons assessed the radiographs.

#### Statistical analysis

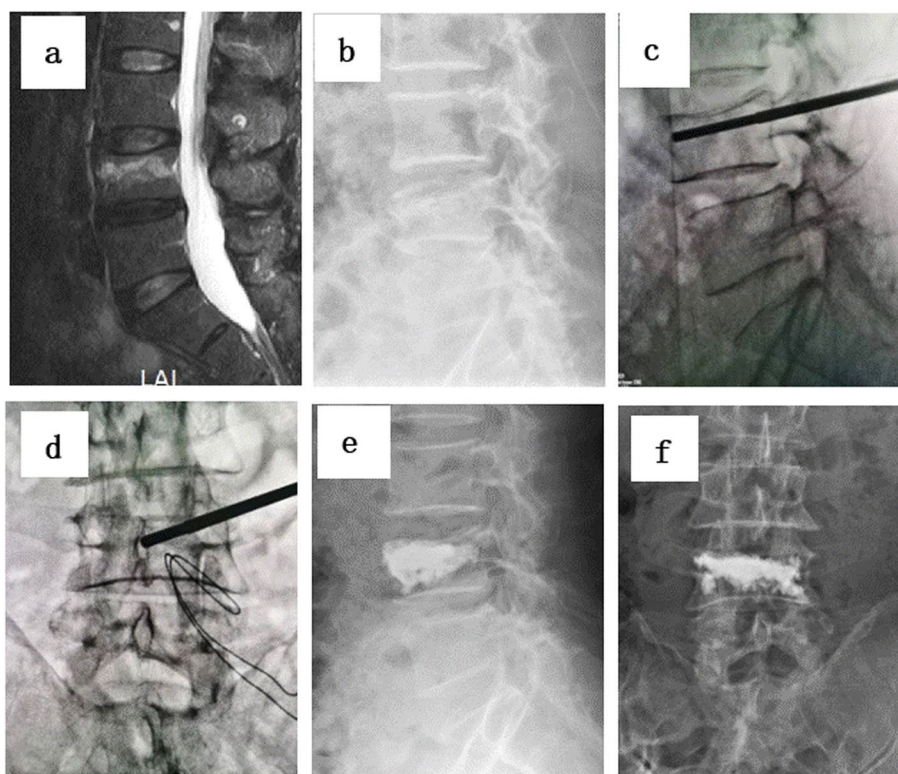
Statistical analyses were performed using the PASW Statistics for Windows (version 18.0; SPSS Inc., Chicago, IL,

USA). Numeric variables are presented as means  $\pm$  standard deviation. Repeated-measures analysis of variance (ANOVA) was used to analyze the differences between preoperative and postoperative VAS scores, ODI scores, and vertebral height restoration. Student's t-test was used to compare measurements between the two groups. Nominal variables (sex, distribution of the fractured vertebra, and cement leakage) were presented as numbers (percentages) and compared using chi-square tests. *P* values  $< 0.05$  were considered to indicate statistically significant differences.

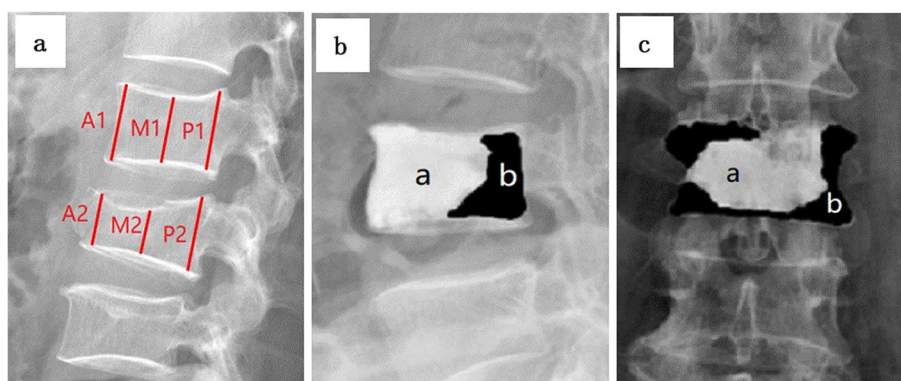
#### Results

The clinical characteristics of the 160 patients are summarized in Table 1. The mean ages of the patients in the unipedicular and bipedicular groups were  $75.86 \pm 7.74$  years and  $74.23 \pm 8.17$  years, respectively. Age, sex, injury time, BMI, segmental distribution, and morphological classification of fractures before surgery did not differ significantly between the groups. Operation time and blood loss were significantly reduced in the unipedicular group compared to the bipedicular group





**Fig. 2** a-f Percutaneous kyphoplasty for the treatment of a L4 vertebral compression fracture in unipedicular approach. a-b Preoperative lateral radiograph and MRI showing a L4 vertebral compression fracture. c-d intraoperative view (e-f) Postoperative lateral radiograph showing cement distribution after undergoing PKP surgery of L4 vertebral compression fracture



**Fig. 3** a-c Methods of measurements on images. a Lateral radiograph showing evaluation of the anterior vertebral body height ratio (AVBHR), middle vertebral body height ratio (MVBHR), and posterior vertebral body height ratio (PVBHR). AVBHR=A2/A1, MVBHR=M2/M1, and PVBHR=P2/P1. b-c Lateral and Frontal radiograph showing the evaluation of cement distribution. Cement distribution =a/(a+b)

( $32.01 \pm 4.48$  vs.  $42.42 \pm 6.01$ ,  $5.46 \pm 1.22$  vs.  $8.73 \pm 1.20$ ;  $p < 0.05$ ). There were no significant differences in the lengths of hospital stay between the two groups. Details are presented in Table 2.

**Clinical outcomes**

Most patients in both groups experienced excellent pain relief and improved physical abilities. The VAS

scores decreased from  $7.30 \pm 1.01$  preoperatively to  $2.39 \pm 0.76$  postoperatively in the unipedicular group ( $p < 0.05$ ) and from  $7.23 \pm 0.88$  preoperatively to  $2.38 \pm 0.72$  postoperatively in the bipedicular group ( $p < 0.05$ ). The ODI scores decreased from  $70.59 \pm 4.22$  preoperatively to  $26.74 \pm 2.50$  postoperatively in the unipedicular group ( $p < 0.05$ ) and from  $70.88 \pm 3.66$  preoperatively to  $26.58 \pm 2.46$  postoperatively in the

**Table 1** Baseline patient characteristics

	Unipedicular group	Bipedicular group	t( $\chi^2$ )	P
NO of cases	82	78		-
Age	75.86 ± 7.74	74.23 ± 8.17	t = 1.300	0.196
Male/Female	9/73	15/63	$\chi^2 = 2.137$	0.185
BMI	23.77 ± 3.78	23.49 ± 3.57	t = 0.488	0.312
Distribution			$\chi^2 = 0.267$	0.875
L3	34	32		-
L4	31	32		-
L5	17	14		-
Vertebral morphometry			$\chi^2 = 0.188$	0.888
A (wedging)	25	26		
B (biconcavity)	47	44		
C (crush)	10	8		
Injure time(day)	4.53 + 3.52	4.20 + 3.89	t = 0.565	0.573

Data are presented as mean ± standard deviation

**Table 2** Patient's perioperative parameters comparison between unipedicular group and bipedicular group in this study

	Unipedicular group	Bipedicular group	t( $\chi^2$ )	P
Operation time (min)	32.01 ± 4.48	42.42 ± 6.01	t = -12.465	< 0.001
Blood lose (mL)	5.46 ± 1.22	8.73 ± 1.20	t = -17.058	< 0.001
Hospital stay (days)	4.90 ± 1.46	4.79 ± 1.35	t = 0.482	0.630
Bone cement leakage	19(23.1%)	20(25.6%)	$\chi^2 = 0.132$	0.716
vein leakage	6	5	$\chi^2 = 0.208$	0.648
Intervertebral leakage	5	4	$\chi^2 = 0.219$	0.640
Paravertebral leakage	8	10	$\chi^2 = 0.244$	0.621

Data are presented as mean ± standard deviation

**Table 3** Clinical comparisons unipedicular group and bipedicular group in this study

	Unipedicular group	Bipedicular group	t	P
VAS				
Preoperative	7.30 ± 1.01	7.23 ± 0.88	0.492	0.623
Postoperative	2.39 ± 0.76*	2.38 ± 0.72*	0.048	0.962
2 years Postoperative	1.75 ± 0.62*	1.68 ± 0.63*	0.773	0.441
ODI				
Preoperative	70.59 ± 4.22	70.88 ± 3.66	-0.458	0.647
Postoperative	26.74 ± 2.50*	26.58 ± 2.46*	0.424	0.672
2 years Postoperative	16.77 ± 1.71*	16.72 ± 1.70*	0.190	0.850

Data are presented as the mean ± standard deviation. ODI: Oswestry disability index; VAS: visual analogue scale. \* Repeated-measures analysis of variance was used for statistical analysis. There were significant differences ( $p < 0.05$ ) between the postoperative or final 2 years postoperative and preoperative values in these two groups

bipedicular group ( $p < 0.05$ ). The VAS and ODI scores did not differ significantly between the two groups either postoperatively or 2 years postoperatively. The operation time and blood loss in the unipedicular group were less than those in the bipedicular group (32.01 ± 4.48 vs. 42.42 ± 6.01, 5.46 ± 1.22 vs. 8.73 ± 1.20;  $p < 0.05$ ). The details are presented in Tables 2 and 3.

### Radiographic evaluation

The anterior, middle, and posterior vertebral height ratios improved from (85.46% ± 10.26%, 80.32% ± 13.81%, and 90.87% ± 8.91%, respectively) preoperatively to (92.34% ± 9.42%, 86.58% ± 14.22%, and 92.50% ± 8.86%, respectively) postoperatively in the unipedicular group and from (85.69% ± 11.22%, 77.26% ± 12.81%,

and  $88.81\% \pm 9.96\%$ , respectively) preoperatively to ( $90.86\% \pm 8.98\%$ ,  $85.26\% \pm 11.84\%$ , and  $90.03\% \pm 8.39\%$ , respectively) postoperatively in the bipedicular group. The cement distribution on the lateral radiographs did not differ significantly between the two groups ( $62.17\% \pm 11.40\%$  vs.  $62.05\% \pm 10.26\%$ ;  $p > 0.05$ ). However, the anteroposterior radiographs showed a higher cement distribution in the bipedicular group compared to that in the unipedicular group ( $57.78\% \pm 11.36\%$  vs.  $52.13\% \pm 10.39\%$ ;  $p < 0.05$ ). Bone cement exceeded the midline of the vertebral body in all patients. The radiographic results are presented in Table 4.

### Complications

Leakage of bone cement outside the vertebral body was observed in both groups on the postoperative anteroposterior and lateral radiographs. The bone cement leakage rates were 23.1% (19 of 82) in the unipedicular group (six in the disc, five in the vertebral vein, and eight in the paravertebral vein) and 25.6% (20 of 78) in the bipedicular group (five in the disc, four in the vertebral vein, and 10 in the paravertebral vein) and did not differ significantly between the two groups ( $p = 0.716$ ) (Table 2). None of the bone cement leakages required special treatment and no clinical symptoms were attributed to cement leakage. No other major postoperative complications, such as neurological damage, hemorrhage, infection, or pulmonary embolism, were observed.

### Discussion

Both unilateral and bilateral PKP have proven effective in the treatment of OVCFs. Previous studies have shown that both the unipedicular and bipedicular approaches can achieve considerable improvements in vertebral height restoration and pain relief. However, few studies have been conducted on the lower lumbar spine. While Rebolledo et al. [12] compared unilateral and bilateral PKP in the lower lumbar vertebrae, they included only seven patients. Chen et al. [13] reported four cases of L3 and L4 in 2010. The present study included 66 cases of L3, 63 cases of L4, and 31 cases of L5 OVCFs, respectively, which have not been previously reported.

### Clinical outcomes

The primary purpose of kyphoplasty is to relieve pain and improve patient function, thereby improving quality of life. In the present study, the VAS and ODI scores significantly improved in both groups postoperatively ( $p < 0.05$ ), with no statistically significant difference between the unilateral and bilateral groups, a finding consistent with previous reports. Wang et al. [7] reported better VAS and ODI scores in the bipedicular group than in the unipedicular group postoperatively; however, the difference was not statistically significant. Zhang et al. [14] reported superior 3-month follow-up outcomes of the bipedicular approach for PKP compared to the unipedicular approach. Some articles reported contradictory findings; Song et al. [8] reported greater improvement in VAS scores in the unipedicular group than in the bipedicular

**Table 4** Radiological comparisons unipedicular group and bipedicular group in this study

	Unipedicular group	Bipedicular group	t	P
AVBHR(%)				
Preoperative	$85.46 \pm 10.26$	$85.69 \pm 11.22$	-0.137	0.892
Postoperative	$92.34 \pm 9.42^*$	$90.86 \pm 8.98^*$	1.018	0.310
2 years Postoperative	$88.63 \pm 10.08^*$	$86.35 \pm 8.78^*$	1.531	0.128
MVBHR(%)				
Preoperative	$80.32 \pm 13.81$	$77.26 \pm 12.81$	1.448	0.150
Postoperative	$86.58 \pm 14.22^*$	$85.26 \pm 11.84^*$	0.636	0.526
2 years Postoperative	$84.59 \pm 14.34^*$	$82.55 \pm 11.27^*$	0.996	0.321
PVBHR(%)				
Preoperative	$90.87 \pm 8.91$	$88.81 \pm 9.96$	1.628	0.105
Postoperative	$92.50 \pm 8.86^*$	$90.03 \pm 8.39^*$	1.814	0.072
2 years Postoperative	$90.27 \pm 9.47^*$	$88.55 \pm 8.81^*$	1.184	0.238
Cement distribution(%)				
Anteroposterior radiographs	$52.13 \pm 10.39$	$57.78 \pm 11.36$	-3.283	< 0.001
lateral radiographs	$62.17 \pm 11.40$	$62.05 \pm 10.26$	0.070	0.944

Data are presented as the mean  $\pm$  standard deviation. AVBHR: anterior vertebral body height ratio; MVBHR: middle vertebral body height ratio; PVBHR: posterior vertebral body height ratio

\* Repeated-measures analysis of variance was used for statistical analysis. There were significant differences ( $p < 0.05$ ) between the postoperative or the 2 years postoperative and preoperative values in these two groups

group. However, most previous studies focused on the thoracolumbar spine, with few reports on the lower lumbar spine; thus, additional studies are required.

### Radiographic evaluation

Both techniques can effectively restore vertebral body height. In 2010, Chen et al. [15] reported that bipedicular PKP was more effective than unipedicular PKP in improving the vertebral height. More recently, in their 2020 study, Lee et al. [9] reported no differences in height restoration between the two techniques. We also concluded that both techniques provided similar restoration of vertebral height, with no differences in the anterior or middle vertebral heights post-operatively. However, the imaging findings in the present study showed an unremarkable degree of vertebral compression of the fractured segment in the lower lumbar region; therefore, the recovery of vertebral height postoperatively was limited in both groups.

Bone cement distribution is important for postoperative functional improvement and stabilization of the vertebral body, and likely plays a major role in pain relief [16–21]. Tan et al. [22] reported that a fully distributed bone cement can better restore the strength and maintain the height of the vertebral body. In the present study, the distribution of cement on the lateral radiographs did not differ between the two groups; however, the anteroposterior radiographs showed a wider distribution for the bipedicular approach than for the unipedicular approach. Owing to the large puncture angle, the end of the cannula should reach the midline as far as possible. Therefore, the cement exceeded the midline of the vertebral body in the anteroposterior radiographs of the selected cases in the unipedicular approach group. Chen et al. [17] showed that cement augmentation crossing the midline resulted in increased stiffness on both sides, with strong potential for achieving biomechanical balance. The present study showed similar radiographic and clinical outcomes between the unilateral and bilateral groups. Thus, unilateral kyphoplasty can provide stability for lower lumbar compression fractures when the cement exceeds the midline of the vertebral body.

### Complications

Kyphoplasty carries the risk of complications, including pulmonary embolism, cement leakage, neurological deficits, and even paraplegia [23, 24]. The most common complication of percutaneous vertebroplasty is cement leakage, particularly cortical and venous leakages. Bone cement can enter the pulmonary artery through the paravertebral vein and cause a pulmonary embolism, which can lead to death. Risk factors for postoperative cement leakage include cortical disruption, higher cement

volume, intravertebral cleft, and solid cement distribution [25, 26]. Previous studies have demonstrated that the unipedicular approach results in fewer cement leaks. Zhang et al. [14] reported bone cement leakage rates of 20.8% (five of 24) in the unipedicular group and 34.6% (nine in 26) in the bipedicular group, which did not differ significantly between groups. Lee et al. [9] reported no significant differences in the leakage rates of cement into the intradiscal space (14% in the unipedicular group and 18% in the bipedicular group). A 2019 meta-analysis by Chen et al. concluded that the unilateral approach decreased the incidence of cement leakage in PKP [27]. Similar to previous reports, the cement leakage rate in the bipedicular group (25.6%) in the present study was higher than that in the unipedicular group (21.3%). However, there were no significant differences between the two groups.

### Limitations

The present study had some limitations. First, it was a retrospective analysis with incomplete data for some cases and inadequate follow-up time. Additionally, postoperative CT images were lacking, which may have more accurately reflected the distribution of bone cement postoperatively. Further prospective studies with longer or more frequent follow-ups are required to confirm our findings.

### Conclusions

The results of our study demonstrated that both unipedicular and bipedicular PKP techniques were effective for treating OVCFs in the lower lumbar region. However, the bipedicular approach provided better cement distribution than the unipedicular approach. We observed no statistically significant differences in pain relief, functional recovery, or vertebral height restoration between the two groups. However, the unipedicular approach has the advantages of short operation time, less blood loss, and less radiation exposure. In conclusion, the unipedicular approach may be clinically preferred because of its advantages.

### Abbreviations

ANOVA	Analysis of variance
BMI	Body mass index
MRI	Magnetic resonance imaging
ODI	Oswestry Low Back Pain Disability Index
OVCFs	Osteoporotic vertebral compression fractures
PKP	Percutaneous balloon kyphoplasty
PMMA	Polymethyl methacrylate
STIR	Short tau inversion recovery
VAS	Visual analog scale

### Acknowledgements

Not applicable.

**Authors' contributions**

Concept: YQ and SH; Design: YQ and YL; Supervision: CT; Materials: GS and XZ; Data Collection and/or Processing: YL and GS; Analysis and/or Interpretation: YQ and YL; Literature Review: GS and CT; Writing: YQ; Critical Review: YQ and SH. All authors read and approved the final manuscript.

**Funding**

The authors declare that this study has received no financial support.

**Availability of data and materials**

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

**Declarations****Ethics approval and consent to participate**

This study was approved by the Ethics Committee of the Third Affiliated Hospital of Wenzhou Medical University. The Committee waived the requirement for informed consent. All procedures were carried out in accordance with the relevant guidelines and regulations.

**Consent for publication**

Not applicable.

**Competing interests**

The authors declare that they have no competing interests.

**Author details**

<sup>1</sup>Department of Orthopaedic Surgery, Third Affiliated Hospital of Wenzhou Medical University, 108 WanSong Road, Ruian, Wenzhou, Zhejiang, China.

Received: 12 January 2023 Accepted: 18 May 2023

Published online: 23 May 2023

**References**

- Papapoulos SE. Anabolic bone therapies in 2014: New bone-forming treatments for osteoporosis. *Nat Rev Endocrinol*. 2015;11:69–70.
- Litwic A, Cooper C, Dennison E. Osteoporosis therapies in 2014. *Panminerva Med*. 2014;56:273–83.
- Kim KW, Cho KJ, Kim SW, et al. A nation-wide, outpatient-based survey on the pain, disability, and satisfaction of patients with osteoporotic vertebral compression fractures. *Asian spine journal*. 2013;7:301–7.
- Galibert P, Deramond H, Rosat P, et al. Preliminary note on the treatment of vertebral angioma by percutaneous acrylic vertebroplasty. *Neurochirurgie*. 1987;33:166–8.
- Liu J, Li X, Tang D, et al. Comparing pain reduction following vertebroplasty and conservative treatment for osteoporotic vertebral compression fractures: a meta-analysis of randomized controlled trials. *Pain Physician*. 2013;16:455–64.
- Theodorou DJ, Theodorou SJ, Duncan TD, et al. Percutaneous balloon kyphoplasty for the correction of spinal deformity in painful vertebral body compression fractures. *Clin Imaging*. 2002;26:1–5.
- Wang W, Duan K, Ma M, et al. Can an unipedicular approach replace bipedicular percutaneous vertebroplasty for osteoporotic vertebral compression fracture? *J Back Musculoskelet Rehabil*. 2019;32:261–7.
- Song BK, Eun JP, Oh YM. Clinical and radiological comparison of unipedicular versus bipedicular balloon kyphoplasty for the treatment of vertebral compression fractures. *Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA*. 2009;20:1717–23.
- Lee CH, Kim HJ, Lee MK, et al. Comparison of efficacies of unipedicular kyphoplasty and bipedicular kyphoplasty for treatment of single-level osteoporotic vertebral compression fractures: A STROBE-compliant retrospective study. *Medicine*. 2020;99:e22046.
- Ismail A, Cooper C, Felsenberg D, et al. Number and type of vertebral deformities: epidemiological characteristics and relation to back pain and height loss. *European Vertebral Osteoporosis Study Group. Osteoporosis int*. 1999;9:206–13.
- Thaler M, Lechner R, Nogler M, et al. Surgical procedure and initial radiographic results of a new augmentation technique for vertebral compression fractures. *Eur spine j*. 2013;22:1608–16.
- Rebolledo BJ, Gladnick BP, Unnanuntana A, et al. Comparison of unipedicular and bipedicular balloon kyphoplasty for the treatment of osteoporotic vertebral compression fractures: a prospective randomised study. *Bone joint j*. 2013;95-B:401–6.
- Chen L, Yang H, Tang T. Unilateral versus bilateral balloon kyphoplasty for multilevel osteoporotic vertebral compression fractures: a prospective study. *Spine*. 2011;36:534–40.
- Zhang L, Liu Z, Wang J, et al. Unipedicular versus bipedicular percutaneous vertebroplasty for osteoporotic vertebral compression fractures: a prospective randomized study. *BMC Musculoskelet Disord*. 2015;16:145.
- Chen C, Chen L, Gu Y, et al. Kyphoplasty for chronic painful osteoporotic vertebral compression fractures via unipedicular versus bipedicular approach: a comparative study in early stage. *Injury*. 2010;41:356–9.
- Evans AJ, Jensen ME, Kip KE, et al. Vertebral compression fractures: pain reduction and improvement in functional mobility after percutaneous polymethylmethacrylate vertebroplasty retrospective report of 245 cases. *Radiology*. 2003;226:366–72.
- Chen B, Li Y, Xie D, et al. Comparison of unipedicular and bipedicular kyphoplasty on the stiffness and biomechanical balance of compression fractured vertebrae. *Eur spine j*. 2011;20:1272–80.
- Liang D, Ye LQ, Jiang XB, et al. Biomechanical effects of cement distribution in the fractured area on osteoporotic vertebral compression fractures: a three-dimensional finite element analysis. *J Surg Res*. 2015;195:246–56.
- He X, Li H, Meng Y, et al. Percutaneous Kyphoplasty Evaluated by Cement Volume and Distribution: An Analysis of Clinical Data. *Pain Physician*. 2016;19:495–506.
- Li Q, Long X, Wang Y, et al. Clinical observation of two bone cement distribution modes after percutaneous vertebroplasty for osteoporotic vertebral compression fractures. *BMC Musculoskelet Disord*. 2021;22:577.
- Mo L, Wu Z, Liang, et al. Influence of bone cement distribution on outcomes following percutaneous vertebroplasty: a retrospective matched-cohort study. *J Int Med Res*. 2021;49:3000605211022287.
- Tan L, Wen B, Guo Z, et al. The effect of bone cement distribution on the outcome of percutaneous Vertebroplasty: a case cohort study. *BMC Musculoskelet Disord*. 2020;21:541.
- Nieuwenhuijse MJ, Van Erkel AR, Dijkstra PD. Cement leakage in percutaneous vertebroplasty for osteoporotic vertebral compression fractures: identification of risk factors. *The spine j*. 2011;11:839–48.
- Kim YJ, Lee JW, Park KW, et al. Pulmonary cement embolism after percutaneous vertebroplasty in osteoporotic vertebral compression fractures: incidence, characteristics, and risk factors. *Radiology*. 2009;251:250–9.
- Tang B, Cui L, Chen X, et al. Risk Factors for Cement Leakage in Percutaneous Vertebroplasty for Osteoporotic Vertebral Compression Fractures: An Analysis of 1456 Vertebrae Augmented by Low-Viscosity Bone Cement. *Spine*. 2021;46:216–22.
- Hong SJ, Lee S, Yoon JS, et al. Analysis of intradiscal cement leakage during percutaneous vertebroplasty: multivariate study of risk factors emphasizing preoperative MR findings. *J Neuroradio*. 2014;41:195–201.
- Chen W, Xie W, Xiao Z, et al. Incidence of Cement Leakage Between Unilateral and Bilateral Percutaneous Vertebral Augmentation for Osteoporotic Vertebral Compression Fractures: A Meta-Analysis of Randomized Controlled Trials. *World neurosurgery*. 2019;122:342–8.

**Publisher's Note**

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.