Prospective Study

Does the Choice of Operative Side Affect the Clinical Outcome of Unilateral Percutaneous Kyphoplasty for Osteoporotic Vertebral Compression Fracture?

Xin Chai, MD[1], Jiawen Xu, MD[2], Ying Yao, MD[3], Jun-Song Yang, MD[1], Hui Xu, MD[1], Peng Zou, MD[4], Tuan-jiang Liu, MD[1], Lei Chu, MD[5], Ding-Jun Hao, MD[1], and Yuan-Ting Zhao, MD[1]

From: [1]Department of Spine Surgery, Honghui Hospital, Xi'an Jiaotong University Xi'an, Shaanxi, China; [2]Orthopedic Research Institute, Department of Orthopedics, Sichuan University West China Hospital, Chengdu, Sichuan Province, People's Republic of China; [3]Department of blood transfusion, Honghui Hospital, Xi'an Jiaotong University, Xi'an, Shaanxi, China; [4]Department of Orthopedics, Tangdu Hospital, Air Force Medical University, Xi'an, Shaanxi, China, Xi'an; [5]Department of minimally invasive spine surgery, The Second Affiliated Hospital, Chongqing Medical University, Chongqing, China

Address Correspondence:
Ding-Jun Hao, MD
Department of Spine Surgery, Honghui Hospital, Xi'an Jiaotong University Faculty of Medicine, Xi'an, Shaanxi 710054, China
E-mail: dingjun.hao@qq.com

Disclaimer: Xin Chai, Jiawen Xu, Ying Yao, and Jun-Song Yang contributed equally to this study. We thank Shaanxi Provincial Natural Science Basic Research Plan (Project No.2021JM-568), Project of China post-doctoral research fund (project no.: 2016M602943XB), Basic scientific research operating expenses (natural science) scientific research project of the central university (project no.: XZY012019124), Innovation Capability Support Program of Shaanxi (No.2021LCYJ014) and Chongqing Basic research and Foreword Exploration project of Yuzhong District (No.20200108) for providing the grant.

Conflict of interest: Each author certifies that he or she, or a member of his or her immediate family, has no commercial association (i.e., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted manuscript.

Manuscript received: 03-18-2022
Revised manuscript received: 08-24-2022
Accepted for publication: 09-19-2022

Free full manuscript:
www.painphysicianjournal.com

Background: Studies have found that the rate of improvement in pain after percutaneous kyphoplasty (PKP) is 49% to 90%, and there are still some patients who may continue to sustain intractable back pain after surgery.

Objectives: To compare the clinical efficacy and imaging results between unilateral PKP performed from the symptom-dominating side and the non-dominating side in OVCF treatment.

Study Design: Prospective study.

Setting: All data were from Honghui Hospital in Xi'an.

Methods: One hundred forty-two patients of osteoporotic vertebral compression fracture (OVCF) treated with unilateral PKP were eventually recruited and randomly assigned to either the A or B group. Patients in group A received PKP from the symptom-dominating side; patients in group B received PKP from the symptom non-dominating side. The demographic characteristics, related surgical information, and complications observed within both groups were recorded. The clinical outcomes evaluation included the visual analog scale (VAS) score for low back pain and the Oswestry Disability Index (ODI). Evaluation of imaging results included anterior height (AH), kyphosis angulation (KA), and contralateral distribution rate of bone cement.

Results: One hundred eighteen patients (48 men and 70 women; age range: 60-83 years), including 59 patients in the A group and 59 patients in the B group, were available for the complete assessment. There were 5 cases and 7 cases of bone cement leakage in groups A and B, respectively, which were asymptomatic para-vertebral or inter-vertebral leakage without intra-spinal leakage. Compared with the preoperative data, significant improvements in the VAS scores and ODI were observed at each follow-up interval. The VAS score and ODI in the A group were significantly lower than in the B group only within 2 months ($P < 0.05$). Compared with the preoperative data, the AH and KA in the 2 groups were improved ($P < 0.05$). There was no significant difference in AH and KA between the 2 groups at each follow-up interval ($P > 0.05$).

Limitations: A single-center study.

Conclusions: The unilateral PKP performed via the symptom-dominating side can effectively relieve back pain and improve the patient's quality of life at the early stage.

Key words: Kyphoplasty, unilateral approach, postoperative pain, operative side, osteoporotic thoracolumbar fracture

Pain Physician 2023: 26:175-185

Osteoporotic vertebral compression fracture (OVCF) is a brittle fracture characterized by a decrease in the ratio of bone minerals to bone matrix and the degeneration of bone microstructure in the elderly population. The initial clinical manifestations of OVCF are back pain, followed by loss of height, kyphosis deformity, and neurological impairment. Improper choice of treatment can seriously affect the quality of life of patients and even lead to disability and death (1-3). In our previous study, we proposed the assessment system of thoracolumbar osteoporotic fracture (ASTLOF) to evaluate the severity of thoracolumbar osteoporotic fractures and for the quantitative evaluation of surgical indications (4). An ASTLOF score of 5 is the threshold for surgical intervention, and surgical treatment can achieve ideal clinical efficacy (4,5).

Percutaneous kyphoplasty (PKP) was introduced as a minimally invasive surgery for the treatment of acute OVCF to help stabilize the fractured vertebra, control back pain, improve the physical function of individuals, and promote rapid recovery after surgery (6,7). It can effectively improve back pain and achieve sagittal realignment. The process of PKP involves utilizing an inflatable balloon to reduce the collapsed vertebra before the injection of bone cement. This technique has advantages in the form of realigning the spine, decreasing the risk of cement leakage, supporting the height of the fractured vertebrae, correcting kyphosis, and providing back pain relief (6,8). Unilateral PKP places a single expandable balloon in the anterior middle of the injured vertebra, which is located in the center of the fracture. The expanded balloon lifts the endplate as a whole, effectively reducing the injured vertebra and avoiding new fractures during expansion.

A recent meta-analysis suggested that although both unilateral and bilateral PKP approaches can yield similar satisfactory clinical outcomes, unilateral PKP is recommended given the short surgical time, low bone cement volume, low average radiation dose, low bone cement leakage rate, and low surgery-related costs (9). Furthermore, the unilateral PKP approach was found to even have better effect in pain relief with a lower incidence of clinical complications (10-13). Studies have found that the rate of improvement in pain after PKP is 49% to 90%, and there are still some patients who may continue to sustain intractable back pain after surgery (14,15). Furthermore, previous studies have found that 7.3%-51% of patients with OVCF may have residual low back pain after PKP. Persistent residual back pain after surgery can cause back dysfunction, reduce the patients' surgical satisfaction, and affect the postoperative rehabilitation of patients (16,17).

By clinical observation, we found that the back pain in some patients with OVCF was asymmetrically distributed, often skewed to one side, and more severe. The choice of surgical approach is often random because it is influenced by the surgeon's operating habits or the differences in the position of the fluoroscopy machines in the operating room; moreover, the asymmetry of the symptoms is not considered. Therefore, we believe that the choice of the surgical side may affect the clinical outcome of unilateral PKP for the treatment of OVCF. This study aimed to compare the clinical efficacy and imaging results between unilateral PKP performed from the symptom-dominating side and the non-dominating side in OVCF treatment.

Methods

Study Design

This was a prospective randomized clinical trial (RCT) in patients with OVCF. Patients were randomly assigned to each treatment group at a ratio of 1:1, and the primary outcome was assessed at baseline (preoperation) and 1 day, 1 week, 2, and 12 months after the intervention. The trial flowchart is shown in Fig. 1. The institutional review board of The Honghui Hospital, Affiliated to Xi'an Jiaotong University, approved this study (reference number ChiCTR2200056645), and written informed consent was obtained.

Recruitment

From May 2020 to January 2021, patients attending the outpatient clinics were screened by participating spinal surgeons, whose responsibility was to determine eligible patients for the trial. Surgeons informed eligible patients about the study's significance and provided them with the patient information forms. After informed consent was obtained from the patients, they completed the baseline assessments and were randomly assigned to their treatment allocation.

Selection Criteria

The inclusion criteria were as follows: (1) single symptomatic thoracic or lumbar VCF with a clear back pain skewed to one side; (2) age ≥ 60 years; (3) fracture to hospital interval ≤ 6 weeks and with a definite history of minor trauma; (4) the preoperative magnetic resonance imaging confirmed fresh fracture; (5) no

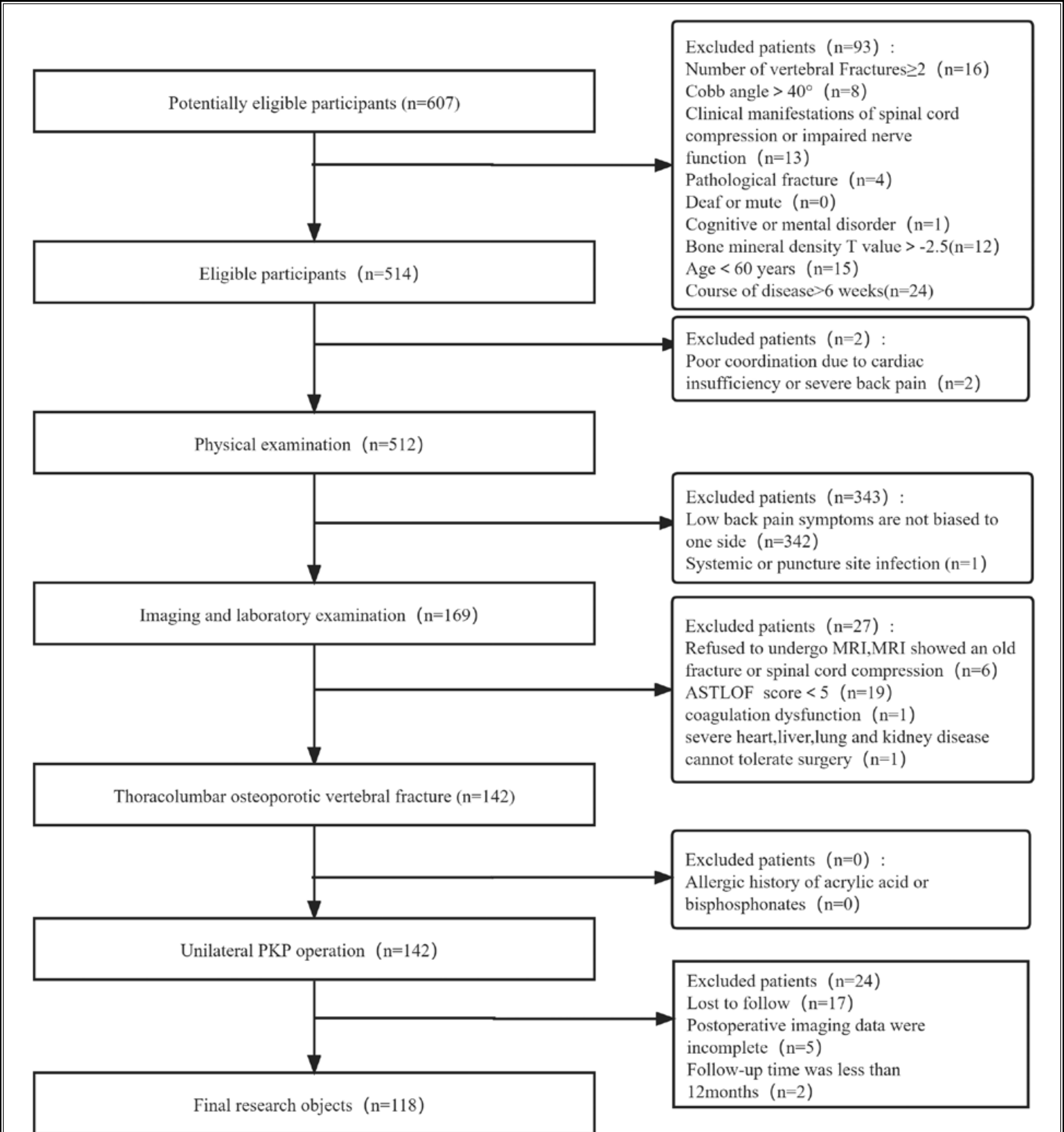

Fig. 1. *Flow diagram of patient recruitment and study procedures.*

symptoms of nerve root and/or spinal cord compression; (6) bone mineral density (BMD), T score ≤ -2.5; (7) total score of ASTLOF ≥ 5; (8) those regularly treated with an anti-osteoporotic during the follow-up period after PKP; and (9) regular pre- and postoperative radiologic follow-up for more than one year.

The exclusion criteria were as follows: (1) multiple-level OVCF; (2) severe compression fractures with Cobb angle > 40°; (3) patients with breaks in the posterior vertebral body wall were excluded since a broken posterior wall is associated with a higher rate of cement leakage; (4) with symptoms of nerve root and/or spinal cord compression; (5) old fracture or pathological fractures, such as hemangioma, multiple myeloma, and bone tuberculosis; (6) patients with severe cardiopulmonary dysfunction, liver failure, or renal dysfunction who could not tolerate surgery; (7) uncorrectable bleeding disorders; (8) systemic or local spine infections; and (9) patients lost to follow-up or incomplete clinical data.

Randomization and Blinding

Eligible patients who consented to participate in this study were randomized to the A and B groups at a ratio of 1:1 using an online computer-based randomization service. Patients in group A received unilateral PKP performed from the symptom-dominating side. Patients in group B received unilateral PKP performed from the symptom non-dominating side. To ensure that the patients and study team were masked to the treatment assignments and data collection, an unmasked third party, including 5 spinal surgeons, was involved. The investigator provided the unmasked surgeons with the necessary information to support treatment assignment and data collection.

Unilateral PKP Surgical Procedure

After local anesthesia, the patient was placed in the prone position. The pedicle of the vertebral arch was punctured unilaterally. Then the guide needle, dilated cannula, and working cannula were inserted to establish the working passage. Lateral fluoroscopy showed that the tip of the puncture needle was located at the junction of the pedicle and vertebral body. This ensured that the puncture needle passed through the pedicle and reached the first third of the vertebral body. After removing the puncture needle, bone cement was injected into the injured vertebral body at the later stage of wire drawing. After the hardening of the cement, we removed the needle and disinfected the wound, and dressed it with a sterile dressing. Intravenous antibiotics were routinely used for 2 to 3 days after the operation.

Follow-up Pain Assessment

The visual analog scale (VAS) score (in the range of 0 to 10) was used to evaluate the severity of pain, and the Oswestry Disability Index (ODI) was used for functional assessment. The measures were recorded preoperatively, 1 day, 1 week, and 2 months after surgery, and at the last follow-up. Plain radiographs were taken preoperatively, 1 day, and 2 months after surgery, and at the last follow-up. X-ray was used to record the anterior height (AH) and kyphosis angulation (KA) of the vertebrae on the lateral radiographs at the corresponding time points. We used the contralateral distribution rate of bone cement shown in Fig. 2 to evaluate the uniformity of bone cement distribution. Formula: distance from the furthest point of bone cement on the contralateral side to the orthostatic midline of the vertebral body/distance from the middle of the outer edge of the contralateral side to the orthostatic midline of the vertebral body × 100%.

Statistical Analysis

All data were analyzed by SPSS version 23.0 (IBM Corporation, Armonk, NY). The VAS scores are expressed as mean ± standard deviation ($\bar{x} \pm s$). For continuous variables, comparisons between the 2 groups were analyzed with Student's t-test or paired t-test as appropriate. For categorical data, a chi-square test was used for comparison between the 2 groups. Repeated ANOVA was used to compare the differences between the 2 groups. $P < 0.05$ was considered statistically significant.

Results

The trial flowchart is presented in Fig. 1. Successful surgical treatment was achieved in both groups, and no patient required conversion to an open procedure. A total of 607 patients with OVCF were recruited, and 142 patients met the inclusion criteria and were randomly assigned to the A and B groups. During the 12-month follow-up, 7 patients in the A group and 10 patients in the B group were lost to follow-up. Finally, a total of 118 patients (48 men and 70 women; age range: 60-83 years), including 59 patients in the A group and 59 patients in the B group, were available for the complete assessment. The demographic characteristics are summarized in Table 1. All demographic variables were identified to have no significant differences between the 2 treatment groups ($P > 0.05$). There were no bone cement adverse reactions, cardiac and cerebrovascular adverse events, and no complications such as accidental puncture needle into the spinal canal and nerve injury in both groups during and after the operation. There were 5 cases and 7 cases of bone cement leakage in groups A and B, respectively, which were asymptomatic para-vertebral or inter-vertebral leakage without intraspinal leakage. Infection and new compression fractures were not reported in any of the patients within the 12-month follow-up.

Fig. 2. ***The calculation diagram of the contralateral distribution rate of bone cement.***
Line a is the outer edge of the contralateral side of the vertebral body. Line b is the orthostatic midline of the vertebral body. Point A is the middle point of the outer edge of the contralateral side of the vertebral body. Point B is the intersection of Point A perpendicular to Line b. Point C is the furthest point of bone cement on the contralateral side. Point D is the intersection of Point C perpendicular to Line b. The formula: distance from the furthest point of bone cement on the contralateral side to the orthostatic midline of the vertebral body/distance from the middle of the outer edge of the contralateral side to the orthostatic midline of the vertebral body × 100%, which equals to the distance of CD/the distance of AB.

Tables 2 and 3 show the VAS and ODI scores of the 2 groups at 5 time points, and the influences of treatment methods and time points on the VAS and ODI scores of patients were investigated. Firstly, there was no significant difference in the preoperative VAS scores and ODI between the 2 groups ($P > 0.05$). Compared with the preoperative data, significant improvements in the VAS scores of back pains and ODI were observed at each follow-up interval ($P < 0.05$). The time point effect can significantly affect the change of VAS score, F (4,113) = 7 10.328, $P = 0.001 < 0.05$, which means that the VAS score of patients will change significantly with time points. Secondly, treatment significantly affected the VAS score, F (1,116) = 9 4.426, $P = 0.001 < 0.05$. It should be noted that there was a significant interaction effect between the time point and the treatment method, F (4,113) = 12.264, $P = 0.001 < 0.05$, indicating that the variation trend of VAS scores at different time points would be different due to different treatment methods (Table 2; Fig. 3). Meanwhile, the time point effect can significantly affect the change of ODI score,

Table 1. *General data of patients between the 2 groups.*

Group	n	Gender		Age (years)	Body mass index (kg/cm²)	T value of bone mineral density (SD)	Injury cause		Time from injury to operation (days)	Injured level						
		Male	Female				Tumble	Wrenched		T10	T11	T12	L1	L2	L3	L4
A	59	23	36	70.78 ± 6.36	21.11 ± 1.58	−2.84 ± 0.33	27	32	3.58 ± 1.32	8	7	11	13	10	8	2
B	59	25	34	72.03 ± 5.71	20.81 ± 1.63	−2.93 ± 0.37	33	26	3.78 ± 1.18	7	9	13	14	11	5	0
Statistic		$\chi^2 = 0.140$ $P = 0.708$		t = -1.127 $P = 0.262$	t = 0.991 $P = 0.324$	t = 1.322 $P = 0.189$	$\chi^2 = 1.221$ $P = 0.269$		t = -0.885 $P = 0.378$	$\chi^2 = 3.260$ $P = 0.776$						

Table 2. *VAS score between the 2 groups before and after operation. (Mean ± SD)*

Group	n	VAS score					
		Preoperative	Postoperative at 1 day	Postoperative at 1 week	Postoperative at 2 months	Postoperative at 1 year	Statistic
A	59	6.95 ± 1.15	2.54 ± 0.68*	2.12 ± 0.56*	1.49 ± 0.57*	1.20 ± 0.58*	time effect F = 710.328, $P = 0.001$ interaction effect F = 12.264, $P = 0.001$
B	59	7.17 ± 1.00	3.81 ± 0.84*	3.05 ± 0.54*	2.27 ± 0.52*	1.34 ± 0.61*	group effect F = 94.426, $P = 0.001$

Notes: *Compared with preoperative value, $P < 0.05$; Data are presented as number or Mean ± SD.
Abbreviations: VAS, visual analog scale; ODI, Oswestry Disability Index.

Table 3. *ODI between the 2 groups before and after operation. (Mean ± SD)*

Group	n	ODI(%) Preoperative	Postoperative at 1 day	Postoperative at 1 week	Postoperative at 2 months	Postoperative at 1 year	Statistic
A	59	78.31 ± 1.99	25.49 ± 2.26*	23.05 ± 2.56*	18.05 ± 2.26*	14.49 ± 2.37*	time effect F=15648.053, P = 0.001
							interaction effect F=113.913, P = 0.001
B	59	77.63 ± 2.24	35.92 ± 2.75*	32.34 ± 2.70*	23.37 ± 2.09*	14.90 ± 1.89*	group effect F=489.391, P = 0.001

Notes: *Compared with preoperative value, P < 0.05; Data are presented as number or Mean ± SD.
Abbreviations: ODI, Oswestry Disability Index; SD, standard deviation.

F (4,113) = 15648.053, P = 0.001 < 0.05, which means that ODI score of patients will change significantly with time points. Treatment significantly affected the ODI score, F (1,116) = 489.391, P = 0.001 < 0.05. And there was a significant interaction effect between the time point and the treatment method, F (4,113) = 113.913, P = 0.001 < 0.05, indicating that the variation trend of ODI score at different time points would be different due to different treatment methods (Table 3; Fig. 4). As can be clearly seen from Table 4, the VAS and ODI scores of group A and Group B showed no significant difference before surgery (P_{VAS} = 0.270 > 0.05, P_{ODI} = 0.085 > 0.05) and 1 year after surgery (P_{VAS} = 0.085 > 0.05, P_{ODI} = 0.304 > 0.05), but there were significant differences between the 2 groups at 1 day, 1 week, and 2 months after surgery (P = 0.001 < 0.05, respectively). The VAS and ODI scores in the A group were significantly lower than those in the B group at the 1-day, 1-week, and 2-month follow-up (Tables 2-4; Figs. 3,4).

There was no significant difference in the operation time, amount of bone cement injection, the incidence of bone cement leakage, and the contralateral distribution ratio of bone cement between the 2 groups (P > 0.05; Table 5). No significant difference in AH and KA was found between the 2 groups preoperatively (P > 0.05). The postoperative AH was slightly higher than the preoperative AH in both groups, and the postoperative KA was slightly lower than the preoperative KA in both groups. There was no significant difference in AH and KA between the 2 groups at the 1-day, 2-month, and 1-year follow-ups (P > 0.05; Tables 6,7).

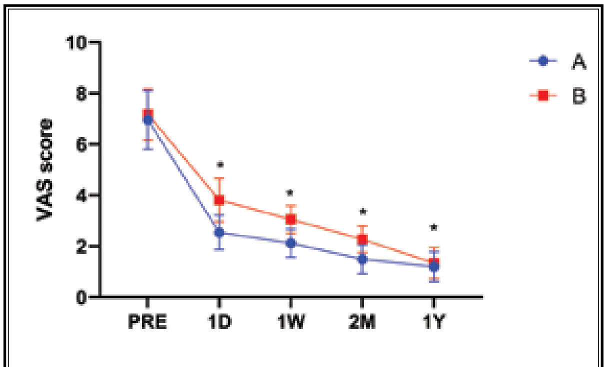

Fig. 3. *Changes of pre- and post-operative VAS scores of back pain. A: unilateral PKP performed from the symptom-dominating side; B: unilateral PKP performed from the symptom non-dominating side. * P ≤ 0.05*

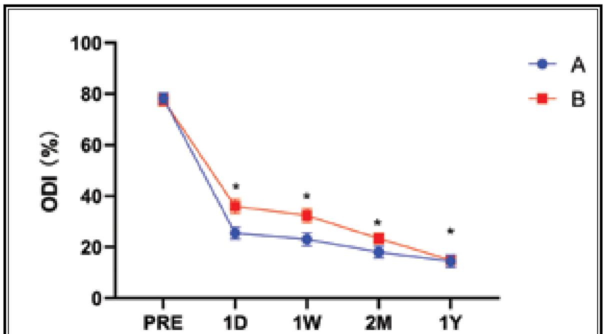

Fig. 4. *Changes of pre- and post-operative ODI scores of back pain. A: unilateral PKP performed from the symptom-dominating side; B: unilateral PKP performed from the symptom non-dominating side .* P ≤ 0.05*

Discussion

This study indicates that the VAS score and ODI in the A group were significantly lower than that in the B group at the 1-day, 1-week, and 2-month follow-ups. The results showed that unilateral PKP from the symptom-dominating side was more beneficial for improving short-term pain and spinal function than unilateral PKP from the symptom non-dominating side. There were no significant differences in VAS and ODI scores between the 2 groups 1 year after surgery, indicating that the long-term efficacy of PKP from the symptom-dominating side versus the symptom non-dominating side was the

Table 4. *Simple effect analysis of treatment modalities.*

	Time	(I) Group	(J) Group	Mean difference (I-J)	Standard error	Sig. b	95% Confidence Interval for the Difference b	
							Lower	Upper
VAS	Pre	A	B	-.220	.199	.270	-.614	.173
	1D	A	B	-1.271*	.141	.000	-1.550	-.993
	1W	A	B	-.932*	.101	.000	-1.133	-.732
	2M	A	B	-.780*	.100	.000	-.978	-.581
	1Y	A	B	-.136	.109	.217	-.352	.081
ODI	Pre	A	B	.678	.391	.085	-.096	1.452
	1D	A	B	-10.424*	.464	.000	-11.342	-9.506
	1W	A	B	-9.288*	.484	.000	-10.247	-8.329
	2M	A	B	-5.322*	.401	.000	-6.117	-4.528
	1Y	A	B	-.407	.394	.304	-1.188	.374

Notes: * $P < 0.05$, The choice of treatment methods has different effects on patients.

Table 5. *Indexes about surgery between the 2 groups of patients. (Mean ± SD)*

Group	n	Operation time (minutes)	Bone cement injection amount (mL)	Incidence of bone cement leakage (%)	The contralateral distribution ratio of bone cement (%)
A	59	28.90 ± 2.43	5.96 ± 0.61	8.47	25.43 ± 5.22
B	59	29.42 ± 2.97	5.75 ± 0.67	11.86	24.38 ± 4.74
Statistic		t = -1.052 $P = 0.295$	t = 1.815 $P = 0.072$	$\chi^2 = 0.371$ $P = 0.542$	t = 1.137 $P = 0.258$

Table 6. *Comparison of AH between the 2 groups before and after operation. (Mean ± SD)*

Group	n	AH(mm)				
		Preoperative	Postoperative at 1 day	Postoperative at 2 months	Postoperative at 1 year	Statistic
A	59	18.99 ± 0.88	21.74 ± 0.78*	21.06 ± 0.85*	20.28 ± 0.79*	time effect F = 526.133, $P = 0.001$ interaction effect F = 1.573, $P = 0.186$ group effect F = 0.204, $P = 0.652$
B	59	19.03 ± 0.55	21.73 ± 0.64*	21.15 ± 0.61*	20.37 ± 0.59*	

Notes: *Compared with preoperative value, $P < 0.05$; Data are presented as number or Mean ± SD.
Abbreviations: AH, anterior height; SD, standard deviation.

Table 7. *Comparison of KA between the 2 groups before and after operation. (Mean±SD)*

Group	n	KA(°)				
		Preoperative	Postoperative at 1 day	Postoperative at 2 months	Postoperative at 1 year	Statistic
A	59	17.64 ± 0.87	14.20 ± 0.50*	14.30 ± 0.46*	15.74 ± 0.46*	time effect F = 526.133, $P = 0.001$ interaction effect F = 1.573, $P = 0.186$ group effect F = 0.204, $P = 0.652$
B	59	17.86 ± 0.79	14.28 ± 0.47*	14.37 ± 0.48*	15.78 ± 0.52*	

Notes: *Compared with preoperative value, $P < 0.05$; Data are presented as number or Mean ± SD.
Abbreviations: KA, kyphosis angulation; SD, standard deviation

same. Both groups achieved a good postoperative reduction in the number of injured vertebrae. X-ray and computed tomography reexamination showed that bone cement was distributed in the anterior and central fracture area of the vertebral body, concentrated in the space formed by the balloon expansion, and fully dispersed along the fracture fissure without leakage in the spinal canal.

Some studies have found that poor diffusion of bone cement in the fracture line can affect the short-term outcome of vertebroplasty and increase the probability of kyphosis after kyphoplasty (18-21). The biomechanical balance effect of the unipedicular approach in kyphoplasty depends on the distribution of bone cement. The stiffness on both sides of the vertebral body was consistent when the bone cement reinforcement exceeded the midline. Thus, the biomechanical equilibrium can be achieved (22-24). The stiffness of both vertebral bodies is enhanced in a balanced way, reducing the risk of postoperative vertebral physical deflection and the recurrence of wedge fracture on the non-punctured side (22). The contralateral distribution rate of bone cement was similar between the A and B groups (25.43 ± 5.22% vs 24.38 ± 4.74%, respectively; $P > 0.05$), indicating that bone cement was distributed across the midline to the contralateral vertebra in both groups. The contralateral distribution rate of bone cement in both groups was less than 50%, indicating that its distribution was more inclined to the punctured side. Therefore, to ensure the distribution of bone cement to the contralateral vertebrae, it is necessary to standardize the surgical procedure and improve the pedicle puncture technique and bone cement injection technique. No further collapse of the injured vertebra was found at the 2-months and 1-year follow-ups after surgery, indicating that unilateral bone cement perfusion could maintain the height of the injured vertebra.

PKP from the symptom-dominating side and non-dominating side were performed on the same horizontal segment of vertebral fractures. Patients in the symptom-dominating side operation group had improved short-term clinical outcomes for the following reasons: Due to the different mechanisms of violent injury, the injured side of acute osteoporotic thoracolumbar fracture is directly affected by violence, and the condition of injury is more severe; meanwhile, the injury of distal fracture is less due to indirect conduction. Based on the bone structure asymmetry (Figs. 5,6), when the symptoms of back pain are prominent, the muscles of the lower back often contract and spasm in order to form a more stable structure to reduce the stimulation of the nerve and blood vessels of the broken end. In order to compensate for the pain, the patient's body is bent to one side. Through using a balloon to inject bone cement, the symptom-dominating side operation ensures the uniform distribution of bone cement in the curved side, thus promoting the effective recovery of vertebral structure and function and effectively relieving muscle spasms in the curved side. In contrast, due to the limited puncture distance and relatively small distribution of bone cement in the contralateral vertebral body, pain-induced compensatory lateral curvature was not significantly improved. Meanwhile, local anesthetic lidocaine hydrochloride can temporarily block pain in the dorsal medial branch of the spinal nerve and improve blood circulation around the dorsal branch of the spinal nerve by blocking the sympathetic nerve. Because the symptom-dominating side operation has the effect of "facet joint block," the improvement in the effects of relieving muscle spasms and pain in the curved side is relatively significant.

Due to the different degrees of vertebral compres-

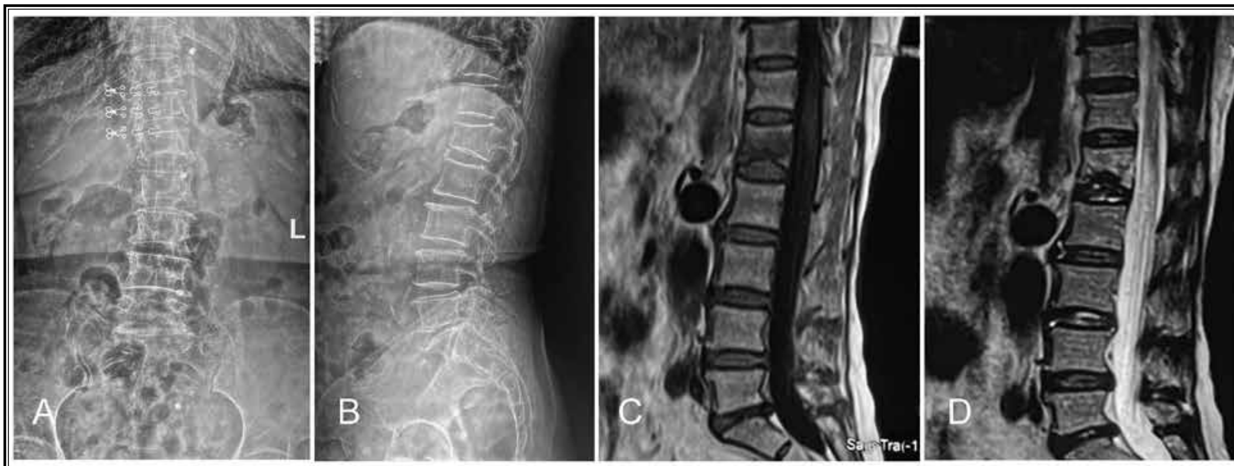

Fig. 5. *Preoperative imaging images of a 72-year-old woman with an OVCF at L1. She complained of lower back pain skewed to one side, with a VAS score of 7. Preoperative (A) anteroposterior and (B) lateral radiographs of the lumbar spine showed that OVCF involvement in L1 was mainly caused by the collapse of the right upper endplate. Preoperative sagittal (C) T1- and (D) T2-weighted magnetic resonance images showing the OVCF at L1.*

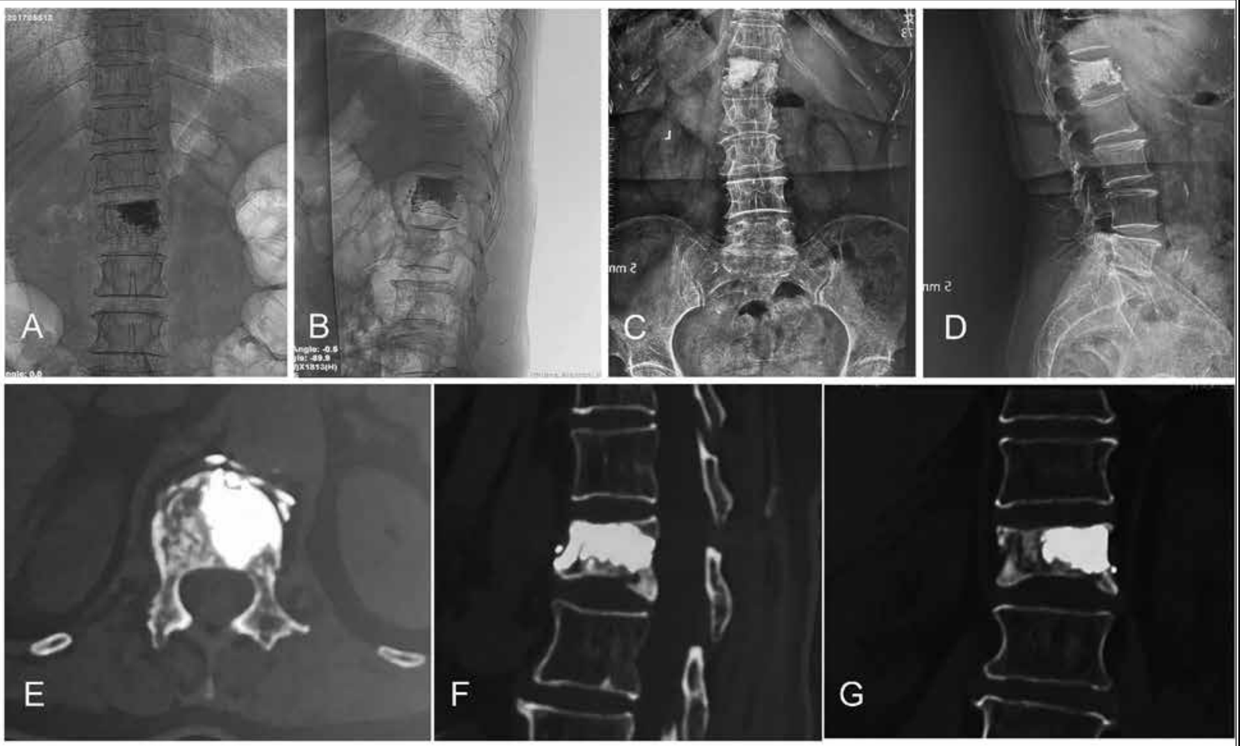

Fig. 6. *The 72-year-old female patient obtained PKP from the left side (symptom non-dominating side). One week after surgery, the patient still had obvious pain symptoms, and the VAS score was 4. The pain was relieved 2 months after surgery, and the VAS score was 2, which decreased to 1 at 12 months. Anteroposterior (A) and lateral (B) radiographs of the lumbar spine 1 day postoperatively showed that although bone cement crossed the midline, it tended to be distributed on the left side. Anteroposterior (C) and lateral (D) radiographs of the lumbar spine at 2-month follow-up showed collapse of the right upper endplate of the L1 and curvature of the spine to the right. At 12 months of follow-up, lumbar CT showed that the distribution of bone cement in L1 was biased to the left, the L1 vertebral body was partially hardened, and the right upper endplate did not collapse further.*

sion of the fracture line on both sides, the microfracture stability of the side with heavier compression is poor, and the pain symptoms are more obvious. Therefore, some patients have the same clinical symptoms of bilateral pain, while some patients' symptoms are skewed to one side. Injecting bone cement into the damaged vertebra effectively restored the strength, stiffness, and height of the injured vertebra. Bone cement can stabilize the vertebral micromovements, fill the gap between microfractures, and reduce the stimulation of vertebral nerves caused by vertebral trabecular bone micro-fractures. With the enhancement of the stability of the spine and the decrease in the stress of the injured vertebra, the abnormal stress and abnormal activity of the injured vertebra were decreased. The stimulation of the periosteum and nociceptors around the injured vertebra was weakened, and so the pain was relieved. Both the toxicity of bone cement monomer resulting in decreased sensitivity of the nerve endings, and the destruction of sensory nerve endings in the surrounding tissue during the polymeric exothermic process can also play a role in the analgesic effects. For patients with upper- or lower-end plate collapse fracture, due to end-plate collapse, the compressed bone trabecular can form a dense hardening zone, which increases the viscosity resistance between the bone trabecular and the pushing pressure of bone cement, affecting the diffusion of bone cement in PKP. Compared with the non-dominating side unilateral PKP puncture, if the bone cement is evenly dispersed and crosses the midline of the vertebral body, more cement will be injected on the symptom-dominating side, and the stability of the bone structure will be better recovered. If unilateral PKP is performed on the non-dominant side, the distribution of bone cement tends to be on the puncture side, and the distribution on the contralateral side is relatively insufficient; thus, the microfracture on the dominant side is still serious and unstable. Therefore, the early short-term efficacy in group B was not as significant as that in group A. With fracture healing, the fracture stability gradually improved, so there was no significant difference in the long-term outcomes.

Limitations

First, this study was a single-center study and may be prone to selection bias due to the small sample size. Second, because the morphological classification of osteoporotic vertebral compression fracture is not clear enough, different fracture patterns need to be further analyzed. Third, the contralateral distribution rate of bone cement was not used to accurately reflect the bone cement distribution patterns in the 3-dimensional structure layer. Therefore, in this study, the indicator for assessing bone cement distribution needs to be improved.

Conclusions

Unilateral PKP performed via the symptom-dominating side can effectively relieve back pain and improve the patient's quality of life at the early stage. Therefore, careful preoperative physical examination should be performed when unilateral PKP is selected for OVCF treatment. Overall, operating from the side with severe symptoms can optimize short-term efficacy and improve patient satisfaction.

Acknowledgments

The authors thank all the local investigators of the participating hospital.

Ethics Approval and Informed Consent

The institutional review board of The Honghui Hospital, Affiliated to Xi'an Jiaotong University, approved this study (reference number 202111008), and written informed consent was received.

Data Availability

The datasets generated during the current study are public at the email doczhaoyuanting@163.com.

Authors' Contributions

Ding-Jun Hao and Yuan-Ting Zhao conceived the study design. Hui Xu, Jiawen Xu, Ying Yao, Peng Zou, Tuan-Jiang Liu, and Lei Chu supervised the data collection and literature review. Xin Chai and Jun-Song Yang drafted the manuscript. Ding-Jun Hao and Yuan-Ting Zhao are responsible for this article.

References

1. Zhang J, He X, Fan Y, Du J, Hao D. Risk factors for conservative treatment failure in acute osteoporotic vertebral compression fractures (OVCFs). *Arch Osteoporos* 2019; 14:24.
2. Lamanna A, Maingard J, Kok HK, et al. Vertebroplasty for acute painful osteoporotic vertebral compression fractures: An update. *J Med Imaging Radiat Oncol* 2019; 63:779-785.
3. McCarthy J, Davis A. Diagnosis and management of vertebral compression fractures. *Am Fam Physician* 2016; 94:44-50.
4. Xu Z, Hao D, He L, et al. An assessment system for evaluating the severity of thoracolumbar osteoporotic fracture and its clinical application: A retrospective study of 381 cases. *Clin Neurol Neurosurg* 2015; 139:70-75.
5. Rajasekaran S, Kanna RM, Schnake KJ, et al. Osteoporotic thoracolumbar fractures-how are they different?-Classification and treatment algorithm. *J Orthop Trauma* 2017; 31:S49-S56.
6. Coumans JV, Reinhardt MK, Lieberman IH. Kyphoplasty for vertebral compression fractures: 1-year clinical outcomes from a prospective study. *J Neurosurg* 2003; 99:44-50.
7. Chandra RV, Maingard J, Asadi H, et al. Vertebroplasty and kyphoplasty for osteoporotic vertebral fractures: What are the latest data? *AJNR Am J Neuroradiol* 2018; 39:798-806.
8. Gill JB, Kuper M, Chin PC, Zhang Y, Schutt R, Jr. Comparing pain reduction following kyphoplasty and vertebroplasty for osteoporotic vertebral compression fractures. *Pain Physician* 2007; 10:583-590.
9. Yin P, Ji Q, Wang Y, et al. Percutaneous kyphoplasty for osteoporotic vertebral compression fractures via unilateral versus bilateral approach: A meta-analysis. *J Clin Neurosci* 2019; 59: 146-154.
10. Song BK, Eun JP, Oh YM. Clinical and radiological comparison of unipedicular versus bipedicular balloon kyphoplasty for the treatment of vertebral compression fractures. *Osteoporos Int* 2009; 20:1717-1723.
11. Feng H, Huang P, Zhang X, Zheng G, Wang Y. Unilateral versus bilateral percutaneous kyphoplasty for osteoporotic vertebral compression fractures: A systematic review and meta-analysis of RCTs. *J Orthop Res* 2015; 33:1713-1723.
12. Chen H, Tang P, Zhao Y, Gao Y, Wang Y. Unilateral versus bilateral balloon kyphoplasty in the treatment of osteoporotic vertebral compression fractures. *Orthopedics* 2014; 37:e828-e835.
13. Li LH, Sun TS, Liu Z, et al. Comparison of unipedicular and bipedicular percutaneous kyphoplasty for treating osteoporotic vertebral compression fractures: A meta-analysis. *Chin Med J (Engl)* 2013; 126:3956-3961.
14. Georgy BA. Interventional techniques in managing persistent pain after vertebral augmentation procedures: A retrospective evaluation. *Pain Physician* 2007; 10:673-676.

15. Li Y, Yue J, Huang M, et al. Risk factors for postoperative residual back pain after percutaneous kyphoplasty for osteoporotic vertebral compression fractures. *Eur Spine J* 2020; 29:2568-2575.
16. Taylor RS, Taylor RJ, Fritzell P. Balloon kyphoplasty and vertebroplasty for vertebral compression fractures: A comparative systematic review of efficacy and safety. *Spine (Phila Pa 1976)* 2006; 31:2747-2755.
17. Dohm M, Black CM, Dacre A, Tillman JB, Fueredi G; KAVIAR investigators. A randomized trial comparing balloon kyphoplasty and vertebroplasty for vertebral compression fractures due to osteoporosis. *AJNR Am J Neuroradiol* 2014; 35:2227-2236.
18. Belkoff SM, Mathis JM, Jasper LE, Deramond H. The biomechanics of vertebroplasty. The effect of cement volume on mechanical behavior. *Spine (Phila Pa 1976)* 2001; 26:1537-1541.
19. Tanigawa N, Komemushi A, Kariya S, et al. Relationship between cement distribution pattern and new compression fracture after percutaneous vertebroplasty. *AJR Am J Roentgenol* 2007; 189:W348-W352.
20. Chevalier Y, Pahr D, Charlebois M, Heini P, Schneider E, Zysset P. Cement distribution, volume, and compliance in vertebroplasty: Some answers from an anatomy-based nonlinear finite element study. *Spine (Phila Pa 1976)* 2008; 33:1722-1730.
21. Higgins KB, Harten RD, Langrana NA, Reiter MF. Biomechanical effects of unipedicular vertebroplasty on intact vertebrae. *Spine (Phila Pa 1976)* 2003; 28:1540-1548.
22. Sun G, Jin P, Li FD, et al. Preliminary study on a single balloon cross-midline expansion via unipedicular approach in kyphoplasty. *Chin Med J (Engl)* 2008; 121:1811-1814.
23. Molloy S, Riley LH 3rd, Belkoff SM. Effect of cement volume and placement on mechanical-property restoration resulting from vertebroplasty. *AJNR Am J Neuroradiol* 2005; 26:401-404.
24. He S, Zhang Y, Lv N, Wang S, Wang Y, Wu S, et al. The effect of bone cement distribution on clinical efficacy after percutaneous kyphoplasty for osteoporotic vertebral compression fractures. *Medicine (Baltimore)* 2019; 98:e18217.