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Research Article

Percutaneous mesh-container-plasty versus percutaneous kyphoplasty in the treatment of malignant thoracolumbar compression fractures: a retrospective cohort study

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ABSTRACT

Objective: This study aimed to compare the clinical and radiological results of percutaneous mesh-container-plasty versus percutaneous kyphoplasty in the treatment of malignant thoracolumbar compression fractures.

Methods: Patients with malignant thoracolumbar compression fractures treated in a single tertiary care center between January 2011 and December 2020 were retrospectively reviewed and included in the study. Ninety-four patients who were diagnosed by pathological biopsy were divided into 2 groups according to the type of surgical treatment: the percutaneous kyphoplasty group (50 patients: 24 male, 26 female; mean age = 73.02 ± 7.79 years) and the percutaneous mesh-container-plasty group (44 patients: 21 male, 23 female; mean age = 74.68 ± 7.88 years). The epidemiological data, surgical outcomes, and clinical and radiological features were compared between the 2 groups. Cement leakage, height restoration, deformity correction, and cement distribution were calculated from the radiographs. The visual analog scale, Oswestry disability index, Karnofsky performance scale scores, and short-form 36 health survey domains role physical and bodily pain were calculated preoperatively, immediately, and 1 year postoperatively.

Results: The visual analog scale score improved from 5 (range = 4-6) preoperatively to 2 (range = 2-3) immediately postoperatively in the percutaneous kyphoplasty group and from 5 (range = 4-6) preoperatively to 2 (range = 2-2) immediately postoperatively in the percutaneous mesh-container-plasty group; there was a significant difference between the 2 groups ($P = .018$). Although Oswestry disability index, Karnofsky performance scale, short-form 36 health survey domains bodily pain and role physical significantly improved in both groups after surgery compared to the preoperative period, there was no significant difference between the 2 groups ($P > .05$). The mean cost in the percutaneous kyphoplasty group was lower than that in the percutaneous mesh-container-plasty group (5563 ± 439 vs. 6569 ± 344 thousand dollars, $P < .05$). There was no difference between the cement volume in the 2 groups, and cement distribution in the percutaneous mesh-container-plasty group was higher than that in the percutaneous kyphoplasty group (44.30% ± 10.25% vs. 32.54% ± 11.76%, $P < .05$). Cement leakage was found to be lesser in the percutaneous mesh-container-plasty group (7/44) than in the percutaneous kyphoplasty group (18/50, $P < .05$). There were no statistically significant differences in the recovery of vertebral body height and improvement of segmental kyphosis between the 2 groups ($P > .05$).

Conclusion: Percutaneous kyphoplasty and percutaneous mesh-container-plasty both have significant abilities in functional recovery, height restoration, and segment kyphosis improvement in treating malignant thoracolumbar compression fractures. Percutaneous mesh-container-plasty may be better able to relieve pain, inhibit cement leakage, and improve cement distribution than percutaneous kyphoplasty. However, percutaneous mesh-container-plasty requires a relatively longer procedure and is more expensive than percutaneous kyphoplasty.

Level of Evidence: Level III, Therapeutic Study

Introduction

Spinal metastases and the associated fractures are a frequent problem in older adult patients with cancer. Spinal metastases most often affect the thoracic vertebrae, followed by the lumbar and cervical vertebrae.[1,2] Pathological fractures caused by spinal metastases, also called metastatic spinal compression fractures, could affect a patient's quality of life, that includes severe back pain, functional limitations, depression, and disability.[3] Historically, metastatic spinal compression fractures were treated conservatively with chemotherapy, pain medications, physical therapy, and bracing. However, nonoperative treatment could result in continued deformity, progressive functional loss, and constant pain. Barzilai et al[4] proposed that treatment goals for patients with metastatic spinal compression fractures are palliative and include preservation or restoration of neurological function, improved pain control and health-related quality of life, and maintenance of spinal stability.

Recently, percutaneous kyphoplasty (PKP) has emerged as a minimally invasive surgical treatment option for these patients. Patients with metastatic spinal compression fractures without neurologic deficits who underwent PKP demonstrated good clinical and radiological results. However, studies have shown some complications of PKP, including cement leakage, loss of the restored height, and kyphotic alignment after balloon deflation before cement injection.[5-7] A mesh container was developed with the cement leakage prevention, height restoration, and kyphotic angle reduction[8] to avoid these complications. Nowadays,

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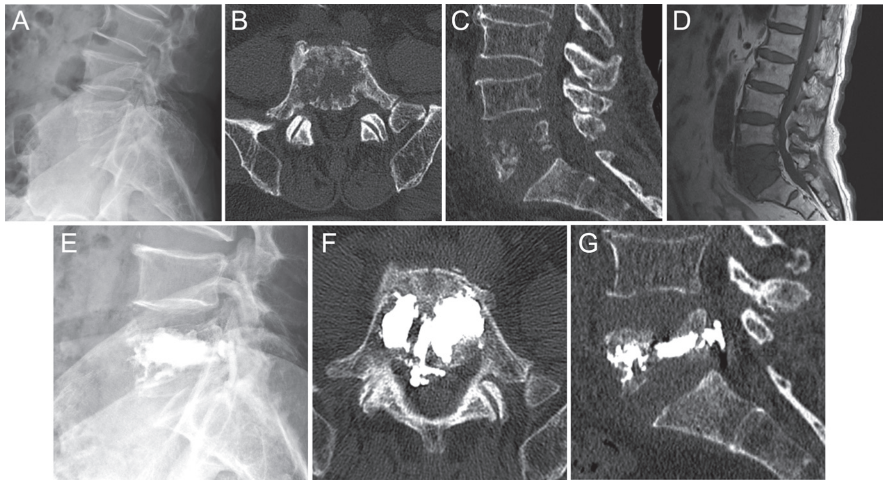

Figure 1. A-G. (A) Preoperative lateral radiograph showing a metastatic spinal compression fractures of L5. (B-C) Preoperative axial and sagittal CT scan showing a bone destruction in the L5 vertebral body. (D) Preoperative lateral MRI showing a metastatic spinal compression fractures of L5. (E) Postoperative lateral radiograph showing cement leakage after undergoing PKP surgery of L5 metastatic spinal compression fractures. (F-G) Postoperative axial and sagittal CT scan showing cement leakage after undergoing PKP surgery of L5 metastatic spinal compression fractures. CT, computed tomography; MRI, magnetic resonance imaging; PKP, percutaneous kyphoplasty.

both PKP and percutaneous mesh-container-plasty (PMCP) are important tools in the treatment of metastatic spinal compression fractures.

Few reports have compared the effect of PKP and PMCP in the treatment of metastatic spinal compression fractures.[9] The purpose of this study was to compare the efficacy and safety of PKP and PMCP in the treatment of 94 patients with metastatic spinal compression fractures admitted to the Third affiliated Hospital of Wenzhou Medical University between January 2011 and December 2020.

Materials and Methods

Study design

The study was approved by the ethics committee of our institution (YJ2020006). Written informed consent was obtained from patients who participated in this study. The inclusion criteria were as follows: (1) age ≥55 years, (2) diagnosis of malignant thoracolumbar compression fracture confirmed by pathological biopsy, (3) involvement of a single segment fracture, (4) ineffective conservative treatment, and (5) PKP or PMCP surgery and followed up to 1 year postoperatively. The exclusion criteria were: (1) age <55 years, (2) inability to tolerate surgery, (3) involvement of multiple segments, and (4) less than 1 year of follow-up.

From January 2011 to December 2020, 94 patients who sustained metastatic spinal compression fractures without neurologic deficits were included in this study according to the inclusion and exclusion criteria. Vertebral biopsies were obtained during vertebroplasty for histological examination of each patient. Fifty patients underwent PKP, and 44 patients underwent PMCP. The differences between PKP and PMCP were explained to all patients preoperatively, including the cost of the procedure, potential complications, and surgical time, and the surgical methods were selected according to patient preference.

Preoperatively, patients underwent 3-dimensional (3D) vertebral reconstruction scanned with computed tomography (CT), x-rays of the relevant spinal region in 2 planes, and magnetic resonance imaging (MRI). Standard clinical examination and evaluation, including medical history, physical examination of percussion pain, assessment of pain intensity [visual analog scale (VAS)], activity level [Oswestry disability index (ODI)], Karnofsky performance scale (KPS),[10] and short-form 36 health survey domains role physical (SF-36 rp) and bodily pain (SF-36 bp) were evaluated.

Surgical technique

All operations were performed by the same senior chief physician under local anesthesia.

Patients were placed in the prone position with the abdomen suspended. A 1-cm skin incision was made lateral to the desired entry point of the pedicle percutaneously. A trocar (Shandong Guanlong Medical Utensils Co., Ltd., Jinan City, Shandong Province, China) in a cannula was inserted into the pedicle as a working channel. After removing the trocar, a balloon was placed into the working channel and slowly inflated to create a low-pressure cavity for cement injection.

In the PKP group, poly-(methyl methacrylate) (PMMA) cement (Heraeus Medical, Wehrheim, Germany) was injected into the treated vertebra through the cannula under continuous fluoroscopic monitoring. Poly-methyl methacrylate insertion was considered complete when it reached the posterior third of the vertebral body or until the point at which cortical, epidural, and anterior venous cement leakage were considered possible (Figure 1).

In the PMCP group, a mesh container (Shandong Guanlong Medical Utensils Co., Ltd.; Figure 2) was advanced into the cavity. The material of the mesh container is 75D/36F high-strength wire comprising

HIGHLIGHTS

- Percutaneous kyphoplasty (PKP) has emerged as a minimally invasive surgical treatment option for patients with metastatic spinal compression fractures. A mesh container was developed to avoid the potential complications of PKP. This study aimed to compare the efficacy and safety of PKP and percutaneous mesh-container-plasty (PMCP) in treatment of metastatic spinal compression fractures.
- The results showed that both PKP and PMCP have significant abilities in functional recovery, height restoration, and segment kyphosis improvement. Additionally PMCP was associated with better pain relief, can also inhibit cement leakage and improve cement distribution compared to PKP however, it has a higher cost.
- The results from this study indicate that PMCP can be considered as an alternative to PKP when treating patients with metastatic spinal compression fractures. Despite being safer, the higher cost is a point to keep in mind.

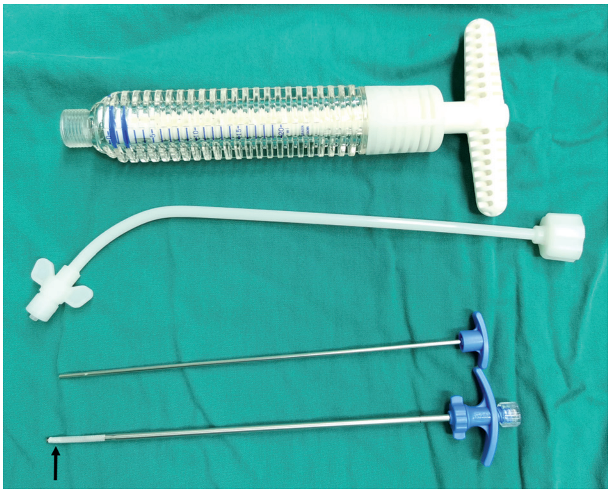

Figure 2. The black arrow indicates the mesh container of Shandong Guanlong Medical Utensils Co., Ltd.

100% polyethylene terephthalate with a fineness of 166.5 dtex and a strength of 6.75 cN/dtex. The mesh container is made of a relatively thick high-strength wire that exhibits good biocompatibility. Thereafter, the PMMA cement (Heraeus Medical) was manually injected into the mesh container within the treated vertebra by applying a cement perfusion apparatus under fluoroscopic guidance. The PMMA cement leaked outside of the mesh container from the meshes and entered the bone trabeculae at a certain injection amount (Figure 3, and Supplementary Figure 1–7).

A neurological examination was performed immediately after the operation. The patients were encouraged to walk while wearing a 3-point fixation brace after surgery. Radiographs and CT images were obtained to evaluate the reduction of the vertebra, improvement in segmental kyphosis, and distribution of the cement. Operation time, cost, hospital stay, cement volume, and complications (cement leakage, cerebrospinal fluid leakage, and infection) were also noted. Back pain intensity was recorded using the VAS; functional outcome was evaluated using ODI, SF-36 rp, and SF-36 bp; and long-term quality of life was assessed by KPS. All patients were postoperatively followed up clinically and radiologically immediately and at 1, 3, and 6 months and 1 year postoperatively.

The Cobb angle and anterior, middle, and posterior vertebral body height ratios (AVBHr, MVBHr, and PVBHr, respectively) were measured using lateral radiographs, as described in a previous study.[11,12] The cement distribution was calculated using CT images, and cement leakage was determined using x-ray CT images of the vertebra (Figure 4).

Two independent blinded spine surgeons performed clinical evaluation of the patients. Two senior spine surgeons (work experience of over 10 years) read the x-ray and CT before and after the operation independently to measure radiological data, and they had to reach a consensus. If a consensus could not be reached, the opinion of a third senior spine surgeons with more experience (over 20 years) was asked.

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences version 19.0 software (IBM SPSS Corp., Armonk, NY, USA). The numerical variables are presented as the mean ± SD or median (interquartile range). Student's *t*-test or Wilcoxon signed-rank test was used to compare the measurements between the 2 groups. Repeated measures analysis of variance was used to compare the measurements of VAS, ODI, KPS, SF-36, AVBHr, MVBHr, PVBHr, and Cobb angle preoperatively, postoperatively, and 1 year postoperatively. The nominal variables (sex and cement leakage) are presented as numbers (percentages) and compared using the chi-square test. Statistical significance was set at a 2-sided *P*-value of <.05.

Results

Ninety-four patients were divided into the PKP group (50—24 men and 26 women) and PMCP group (44—21 men, 23 women) according

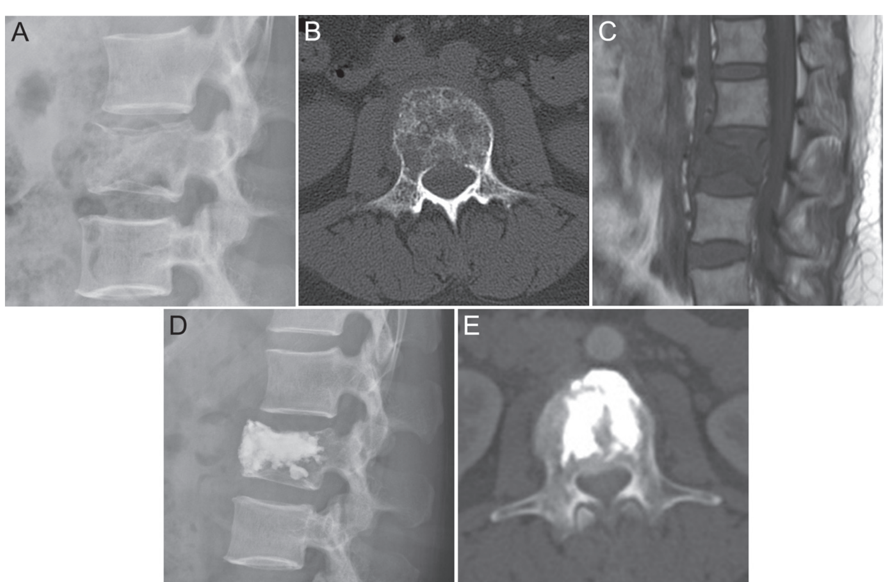

Figure 3. A-E. (A) Preoperative lateral radiograph showing a metastatic spinal compression fractures of L3. (B) Preoperative CT images showing bone destruction in the L3 vertebral body. (C) Preoperative magnetic resonance image (T1-weighted sequences) showing bone destruction in the L3 vertebral body. (D) Postoperative lateral radiograph after PMCP surgery. (E) Postoperative CT images showing good distribution of cement in the L3 vertebral body without leakage. CT, computed tomography; PMCP, percutaneous mesh-container-plasty.

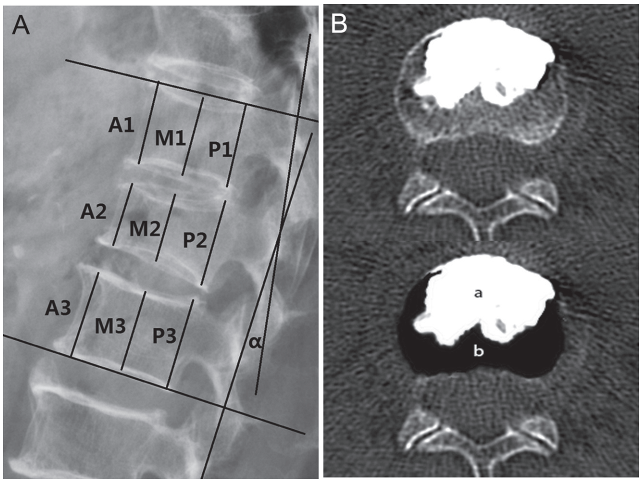

Figure 4. A-B. Methods of measurements on images. (A) Lateral radiograph showing evaluation of the Cobb angle, AVBHr, MVBHr, and PVBHr. The Cobb angle = α, AVBHr = $2 \times A2 / (A1 + A3)$, MVBHr = $2 \times M2/(M1+M3)$, and PVBHr = $2 \times P2/(P1+P3)$. (B) CT plain image showing the evaluation of cement distribution. Cement distribution of a single CT section = $a/(a+b)$. Cement distribution was calculated as the mean of all CT sections of the treated vertebra. AVBHr, anterior vertebral body height ratio; CT, computed tomography; MVBHr, middle vertebral body height ratio; PCBHr, posterior vertebral body height ratio.

to the surgical treatment they received. In the PKP group, 14 cases originated from the respiratory system, 18 from the digestive system, 12 from the urinary/reproductive system, and 6 from other systems. In the PMCP group, 15, 10, 14, and 5 cases were from each of these systems, respectively. All patients had no internal organ metastasis and were followed up for at least 1 year. The clinical characteristics of the patients are summarized in Table 1. No statistical differences were noted in the demographic data, including age, sex, segmental distribution, fracture type, survival time, Charlson comorbidity index, and primary lesion of the involved vertebrae between the 2 groups. The mean cost in the PKP group was lower than that in the PMCP group (5563 ± 439 vs. 6569 ± 344 dollars, $P < .05$), while the operation time of PMCP was longer than PKP. There were no significant differences in cement volume and hospital stay between the 2 groups. The details are presented in Table 2.

Clinical evaluation

The VAS scores and ODI values were significantly lower in both groups ($P < .05$), while KPS, SF-36 rp, and SF-36 bp scores were significantly improved in both groups ($P < .05$) compared with the values before surgery. The follow-up results showed no significant changes in the VAS, ODI, KPS, and SF-36 scores 1 year after surgery. The differences in ODI, KPS, and SF-36 scores between the 2 groups were not statistically significant at postoperative and 1 year postoperatively, while the PMCP group showed a statistically significant advantage over the PKP group in terms of postoperative pain relief ($P < .05$). The details are presented in Table 3.

Therefore, both PKP and PMCP showed significant functional recovery in the treatment of metastatic spinal compression fractures at postoperative and 1 year postoperatively, and no difference was noted between the 2 groups. Percutaneous mesh-container-plasty is advantageous over PKP in the ability to relieve pain.

Radiologic evaluation

Anterior vertebral body height ratio, MVBHr, PVBHr, and Cobb angle scores improved from 77.00% ± 10.51%, 75.91% ± 10.26%, 87.27% ± 6.44%, and 10.22° ± 2.83°, respectively, preoperatively to 81.48% ± 9.50%, 81.59% ± 9.20%, 89.04% ± 5.79%, and 7.14° ± 2.20°, respectively, postoperatively in the PKP group and from 76.16% ± 11.34%, 73.49% ± 11.57%, 86.92% ± 7.06%, and 10.20° ± 2.21°, respectively, preoperatively to 83.56% ± 8.93%, 82.18% ± 8.37%, 89.20% ± 5.96%, and 6.43° ± 1.52°, respectively, postoperatively in the PMCP group

Table 1. Basic characteristics and comparative analysis between PKP and PMCP for the treatment of the 94 patients with metastatic spinal compression fractures in this study ($x \pm s$)

	PKP (n = 50)	PMCP (n = 44)	$t(\chi^2)$	P
Age (years)	73.02 ± 7.79	74.68 ± 7.88	$t = -1.026$	.307
Sex				
Male/female	24/26	21/23	$\chi^2 = 0.001$	.979
Segments				
T5-T9	10	7	$\chi^2 = 0.348$	.840
T10-L2	28	27		
L3-L5	12	10		
Primary lesion				
Respiratory system	14	15	$\chi^2 = 2.191$	.534
Digestive system	18	10		
Urinary/reproductive system	12	14		
Other sources	6	5		
Survival time (months)	17.08 ± 3.38	16.11 ± 2.66	$t = 1.525$	.131
Charlson comorbidity index	12.46 ± 1.63	12.18 ± 1.57	$t = -0.835$	.406

PKP, percutaneous kyphoplasty; PMCP, percutaneous mesh-container-plasty.

Table 2. Comparison of perioperative parameters between the PKP and PMCP groups for the treatment of the 94 patients with metastatic spinal compression fractures in this study ($x \pm s$)

	PKP (n = 50)	PMCP (n = 44)	$t(\chi^2)$	P
Operation time (minutes)	31.00 ± 4.40	35.23 ± 5.17	$t = -4.283$	<.001
Hospital stay (days)	11.46 ± 9.52	10.75 ± 7.01	$t = 0.407$	.685
Cost (dollar)	5563 ± 439	6569 ± 344	$t = -12.293$	<.001
Cement leakage	18/50	7/44	$\chi^2 = 4.839$	.028
Cement volume (mL)	6.43 ± 1.27	6.80 ± 1.34	$t = -1.359$	.177

PKP, percutaneous kyphoplasty; PMCP, percutaneous mesh-container-plasty.

Table 3. Clinical comparisons between the PKP and PMCP groups for the treatment of the 94 patients with metastatic spinal compression fractures in this study [$x \pm s$ or median (interquartile range)]

	PKP (n = 50)	PMCP (n = 44)	$t(Z)$	P
VAS				
Preoperative	5 (4-6)	5 (4-6)	$Z = -0.768$	.442
Postoperative	2 (2-3)*	2 (2-2)*	$Z = -2.358$	.018
1 year postoperative	2 (2-2)*	2 (1-2)*	$Z = -3.164$	.002
ODI				
Preoperative	65.24 ± 6.59	66.45 ± 6.04	$t = -0.927$	.356
Postoperative	23.00 ± 3.29*	21.86 ± 3.99*	$t = -1.514$	.133
1 year postoperative	19.68 ± 3.93*	18.14 ± 3.64*	$t = 1.967$	.052
KPS				
Preoperative	40 (40-50)	40 (40-50)	$Z = -0.648$	.517
Postoperative	70 (70-80)*	70 (70-80)*	$Z = -0.643$	.526
1 year postoperative	75 (70-80)*	80 (70-80)*	$Z = -1.030$	.303
SF-36 bp				
Preoperative	22 (12-28.38)	22 (21-28.75)	$Z = -0.298$	.766
Postoperative	84 (84-84) *	84 (84-84) *	$Z = -0.702$	.483
1 year postoperative	84 (84-84) *	84 (84-84) *	$Z = -0.536$	.592
SF-36 rp				
Preoperative	25 (25-25)	25 (25-25)	$Z = -0.267$	.789
Postoperative	75 (75-75)*	75 (75-75)*	$Z = -0.154$	.877
1 year postoperative	75(75-100)*	75 (75-93.75)*	$Z = -0.499$	.618

*Repeated measures variance analysis was used for the statistical analysis. There were significant differences ($P < .05$) between the postoperative or 1 year postoperative and preoperative values of these 2 groups.
KPS, Karnofsky performance scale; ODI, Oswestry disability index; PKP, percutaneous kyphoplasty; PMCP, percutaneous mesh-container-plasty; SF-36 bp, short-form 36 health survey domain bodily pain; SF-36 rp, short-form 36 health survey domain role physical; VAS, visual pain analog scale.

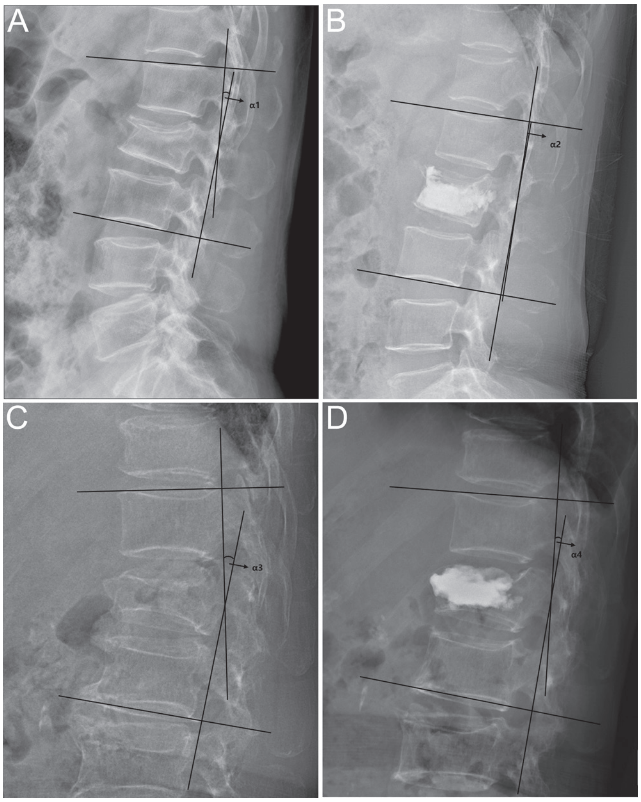

Figure 5. A-D. (A) Preoperative lateral radiograph showing the Cobb angle ($\alpha 1$) of the patient in the PMCP group is 7°. (B) Postoperative lateral radiograph showing the Cobb angle ($\alpha 2$) of the patient in the PMCP group is 2°. (C) Preoperative lateral radiograph showing the Cobb angle ($\alpha 3$) of the patient in the PKP group is 13°. (D) Postoperative lateral radiograph showing the Cobb angle ($\alpha 4$) of the patient in the PKP group is 6°. PKP, percutaneous kyphoplasty; PMCP, percutaneous mesh-container-plasty.

($P < .05$). Moreover, the long-term follow-up results showed that the AVBHr, MVBHr, PVBHr, and Cobb angle in the PKP and PMCP groups did not change significantly at 1 year postoperatively. No statistically significant difference was noted in the improvement of AVBHr, MVBHr, PVBHr and correction of the Cobb angle (Figure 5) between the PMCP and PKP groups. The cement distribution in the PMCP group was significantly higher than that in the PKP group (44.30% ± 10.25% vs. 32.54% ± 11.76%, $P < .05$). All radiographic results are presented in Table 4. No significant difference was noted in the restoration of vertebral body height and improvement in segmental kyphosis between PKP and PMCP in the treatment of metastatic spinal compression fractures. The PMCP group had a significant advantage over the PKP group in terms of cement distribution.

Surgical complications

A CT scan was performed immediately to assess cement leakage after surgery. Cement leakage was observed in 36% (18/50) of patients in the PKP group (4 anterior to the vertebral body, 4 lateral to the vertebral, 9 into the disk, and 1 into the canal without sequelae) and in 16% (7/44) of patients in the PMCP group (2 anterior to the vertebral body, 2 lateral to the vertebral, and 3 into the disk without sequelae) ($P < .05$) (Table 2). The patient with intracanalicular cement leakage in the PKP group (Figure 1) presented with transient lower extremity radiating pain, numbness, and decreased muscle strength postoperatively. Fortunately, the patient's symptoms gradually resolved without surgical intervention after we provided appropriate treatment to reduce nerve root edema and nerve nutrition. Postoperative

Table 4. Radiologic comparisons between the PKP and PMCP groups for treatment of the 94 patients with metastatic spinal compression fractures in this study ($x \pm s$)

	PKP (n=50)	PMCP (n=44)	*t*	*P*
AVBHr (%)				
Preoperative	77.00 ± 10.51	76.16 ± 11.34	0.373	.710
Postoperative	81.48 ± 9.50*	83.56 ± 8.93*	−1.091	.278
1 year postoperative	79.69 ± 9.39*	82.49 ± 9.03*	−1.465	.146
MVBHr (%)				
Preoperative	75.91 ± 10.26	73.49 ± 11.57	1.071	.287
Postoperative	81.59 ± 9.20*	82.18 ± 8.37*	−0.327	.745
1 year postoperative	79.91 ± 9.62*	80.98 ± 8.65*	−0.560	.577
PVBHr (%)				
Preoperative	87.27 ± 6.44	86.92 ± 7.06	0.250	.803
Postoperative	89.04 ± 5.79*	89.20 ± 5.96*	−0.133	.894
1 year postoperative	88.12 ± 5.75*	88.56 ± 6.01*	−0.363	.717
The Cobb angle (°)				
Preoperative	10.22 ± 2.83	10.20 ± 2.21	0.029	.977
Postoperative	7.14 ± 2.20*	6.43 ± 1.52*	1.791	.077
1 year postoperative	7.88 ± 2.45*	7.25 ± 1.81*	1.404	.164
Cement distribution (%)	32.54 ± 11.76	44.30 ± 10.25	−5.136	<.001

*Repeated measures variance analysis was used for the statistical analysis. There were significant differences ($P < .05$) between postoperative or 1 year postoperative and preoperative values of these 2 groups.
AVBHr, anterior vertebral body height ratio; MVBHr, middle vertebral body height ratio; PKP, percutaneous kyphoplasty; PMCP, percutaneous mesh-container-plasty; PVBHr, posterior vertebral body height ratio.

complications, such as neurological functional aggravation, hemorrhage, wound healing abnormalities, infection, and pulmonary embolism, were not observed during the 1-year follow-up period. These data suggest that PMCP is safer than PKP in controlling cement leakage in metastatic spinal compression fractures.

Discussion

Patients with spinal metastases are mostly in advanced stages of cancer and often present with complications, such as pathological fractures of the vertebral body, spinal instability, spinal cord, and nerve root compression, which mainly present clinically as persistent and intractable pain and a gradual decrease in the quality of life. Vertebroplasty was introduced by Galibert and Deramend in 1984 in France for treating hemangiomas at the C2 vertebra.[13] Percutaneous kyphoplasty, first performed in 1998, is a minimally invasive surgical technique that corrects kyphosis secondary to collapsed vertebral bodies using a balloon (an inflation bone tamp).[14] PVP and PKP have been demonstrated to produce good results when treating pain in patients with vertebral collapse secondary to metastatic disease.[15,16] However, PVP and PKP often have serious complications, of which cement leakage is the most common with incidence rates of 22%-82%.[17] To reduce the occurrence of cement leakage, mesh container has been used in vertebroplasty.[18] Nowadays, both PKP and PMCP are now important tools in the treatment of metastatic spinal compression fractures to relieve pain due to pathological fractures and metastatic tumor destruction of the vertebral body, as well as to prevent further tumor destruction of the diseased vertebral body, leading to continued collapse and loss of vertebral body height. Studies have shown that patients experienced significant pain relief of 80%-98% within 48 hours of PKP, and its efficacy was evaluated mainly in terms of the degree of postoperative pain relief, maintenance of spinal stability, and improvement in the quality of life.[19,20] However, few reports have compared the curative effect of PKP and PMCP in the treatment of metastatic spinal compression fractures. Therefore, this study aimed to compare the clinical efficacy and safety of PKP and PMCP for the treatment of metastatic spinal compression fractures.

In this study, 94 patients with metastatic spinal compression fractures (50 in the PKP group and 44 in the PMCP group) were included, and all the surgeries were successfully performed. The scores of VAS, ODI, KPS, SF-36 bp, and SF-36rp at different time points after surgery of 2 groups were significantly improved, and the degree of pain and dysfunction were significantly relieved compared with those on the day before surgery. The results suggest that both PKP and PMCP techniques showed significant improvements in pain relief and quality of life in the treatment of metastatic spinal compression fractures. Moreover, PMCP had an advantage over PKP in terms of postoperative pain relief, and a statistically significant difference was observed between the 2 groups.

Furthermore, PMCP had better safety than PKP in terms of cement leakage and cement distribution ability. Cement leakage is one of the most common complications of PKP, especially spinal cord and nerve root compression due to intravertebral cement leakage and lethal pulmonary embolism due to paravertebral vascular leakage. The leakage rate of metastatic spinal compression fractures tends to be higher than that of osteoporotic vertebral fractures alone, which may stem from tumor-induced destruction of the bone cortex of the vertebral body or tumor-rich vascularity and blood flow.[21] Sun et al[22] found that in the treatment of metastases, the leakage rate was 2.5% when the posterior wall of the vertebral body was intact, 5.1% when the non-posterior wall was defective, 7.7% when the posterior wall of the vertebral body was locally fragmented and defective, and 13.3% in the posterior wall with severe defects. Mesh containers were developed to reduce the risk of cement leakage. Bone-filling mesh containers are dense mesh structures made of polyethylene terephthalate fibers with a tiny mesh. A cavity is formed in the treated vertebral body by applying a bone expansion brace to cut the bone tissues in the PMCP technique. The mesh container is advanced into the cavity after withdrawal of the bone expansion brace, and PMMA cement is injected into the mesh container. The mesh container expands and reaches the edge of the cavity during the cement injection process. Continuous cement injection causes the mesh container to impart pressure on the surrounding bone tissues, and the height of the vertebral body is gradually restored. Bone cement leaks outside of the mesh container from the meshes when the perfusion pressure reaches a certain degree and enters the bone trabeculae, and as a result, the bone trabeculae are strengthened and stabilized. In this study, the leakage rate of bone cement in the PKP group was 36% (18/50) compared with 16% (7/44) in the PMCP group; therefore, PMCP has a better ability to inhibit cement leakage than PKP for the treatment of metastatic spinal compression fractures.

Furthermore, cement is a key factor in stabilizing the vertebral body, and the wider the distribution of cement, the better the surgical outcome, provided that the amount of cement[23] remains constant.[24-26] Moreover, a reasonable cement distribution can reduce the risk of recompression after vertebroplasty.[27] Adequate contact between the cement and the upper and lower endplates has been shown to better restore the strength of the vertebral body, maintain the height of the vertebral body, and reduce the risk of vertebral body recompression and long-term pain.[28] Cement distribution in the PMCP group was higher than that in the PKP group (44.30% ± 10.25% vs. 32.54% ± 11.76%, $P < .05$). An extensive cement distribution can improve the kyphotic angle and vertebral height effectively and reduces the risk of cement leakage or adjacent vertebral fractures.[24]

In addition, the recovery of vertebral body height and improvement of segmental kyphosis after treatment are important parameters in assessing the clinical efficacy of minimally invasive techniques. Previous studies found no correlation between the restoration of vertebral body height and improvement in clinical outcomes (e.g., pain reduction and functional recovery).[29,30] In this study, the recovery of vertebral body height and improvement in segmental kyphosis were higher in the PMCP group than in the PKP group. However, no statistically significant differences in clinical outcomes were noted between the 2 groups. Not all patients have significant vertebral compression changes and increased segmental kyphosis, considering that metastatic tumors of the spine are different from vertebral compression fractures. Therefore, satisfactory results in the correction of vertebral body height and segmental kyphosis were achieved in both the PKP and PMCP groups, and no statistically significant differences were noted.

Although PMCP has a greater advantage over PKP in the treatment of metastatic spinal compression fractures, caution is still required even with the mesh-container technique. In this study, 16% (7/44) of patients of PMCP group experienced cement leakage postoperatively (2 anterior to the vertebral body, 2 lateral to the vertebral, and 3 into the disk). The mesh container only delays the distribution of cement and reduces the risk of cement leakage but does not eliminate the possibility of cement leakage. Premature leakage of cement out of the mesh bag and into the spinal canal or vasculature can occur when the cement is injected too thinly and too quickly, with catastrophic consequences, as cement can diffuse outside the mesh bag through the mesh holes. In this study, 2 cases with anterior leakage of the vertebral body, 2 cases with lateral leakage to the vertebral body, and 3 cases with intervertebral leakage were present, but no symptoms, such as neural compression, were observed. Therefore, careful handling under C-arm surveillance is still required to inject the cement slowly into the vertebral body during the drawing phase and to stop the injection as soon as the cement diffuses into the posterior third of the vertebral body, or a potential trend of cement leakage from the cortex, epidural, and anterior veins is noted.

This study has certain limitations. It was a retrospective study, with all the inherent biases. The sample size was small and from a single center. Prospective, randomized controlled studies enrolling more patients with long-term follow-up are needed in the future to evaluate the clinical and radiographic efficiency of PMCP more reliably and objectively.

In conclusion, both PKP and PMCP have significant abilities in functional recovery, height restoration, and segment kyphosis improvement. Percutaneous mesh-container-plasty may have a better ability to relieve pain, inhibit cement leakage, and improve cement distribution than PKP in the treatment of metastatic spinal compression fractures. However, PMCP requires a relatively longer procedure time and is more expensive than PKP.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of Third affiliated Hospital of Wenzhou Medical University (Approval No: YJ2020006).

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Author Contributions: Concept - S.H.; Design - Y.L., S.H.; Supervision - S.H.; Materials - X.Z., Y.Q.; Data Collection and/or Processing - Y.Q., G.S.; Analysis and/or Interpretation - X.Z., G.S.; Literature Review - Y.L., S.H.; Writing - Y.L.; Critical Review - Y.L., S.H.

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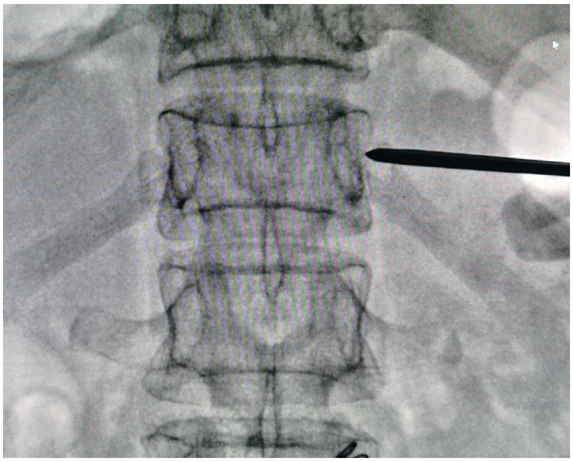
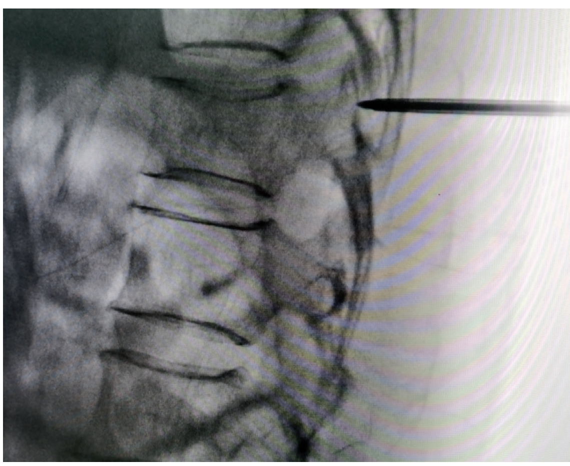
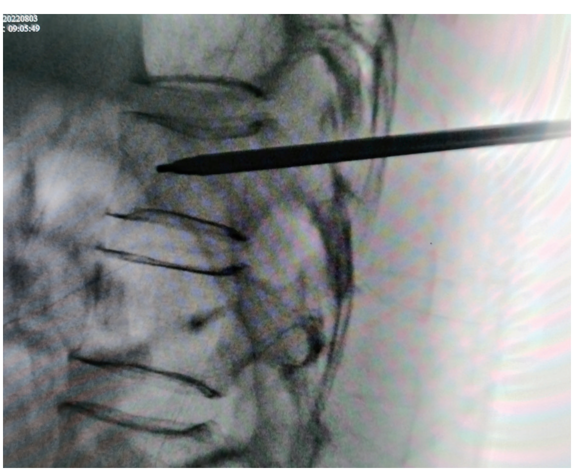


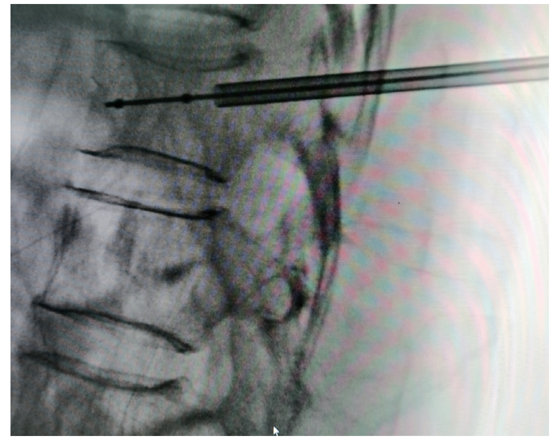
Supplementary Figure 1. Intraoperative fluoroscopic anteroposterior image demonstrating pedicle puncture of PMCP surgical procedure.



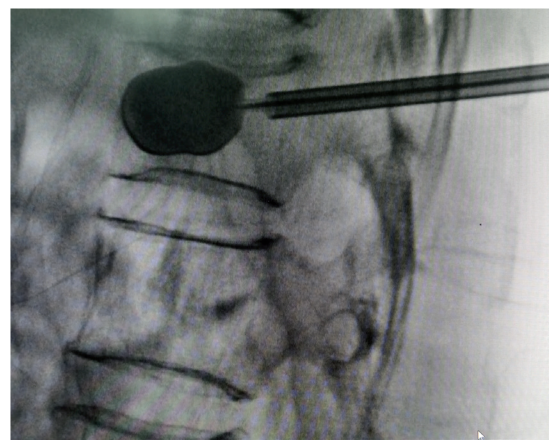
Supplementary Figure 2. Intraoperative fluoroscopic lateral image demonstrating pedicle puncture of PMCP surgical procedure.



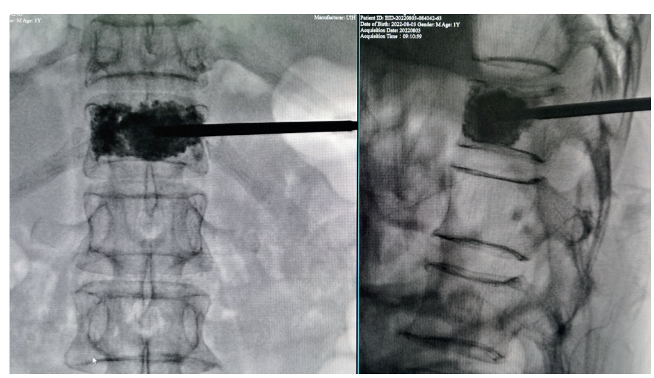
Supplementary Figure 3. Intraoperative fluoroscopic lateral image demonstrating puncture into vertebral body of PMCP surgical procedure.



Supplementary Figure 4. Intraoperative fluoroscopic lateral image demonstrating a balloon was placed into vertebral body of PMCP surgical procedure.



Supplementary Figure 5. Intraoperative fluoroscopic lateral image demonstrating balloon dilatation of PMCP surgical procedure.



Supplementary Figure 6. Intraoperative fluoroscopic anteroposterior and lateral image demonstrating bone cement injection of PMCP surgical procedure.

Supplementary Figure 7. Intraoperative view of PMCP surgical procedure.