

# Comparison of Percutaneous Kyphoplasty and Percutaneous Pedicle Screw Fixation for the Treatment of Osteopenic Thoracolumbar Vertebral Compression Fractures

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## Research article

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# Abstract

**BACKGROUND:** Osteoporotic vertebral compression fractures (OVCFs) have a high incidence, which have attracted wide attention from society. However, few scholars have conducted researches on osteopenic vertebral compression fractures (osteopenic VCFs). Our research has compared the clinical and imaging effects of percutaneous kyphoplasty (PKP) and percutaneous pedicle screw fixation (PPSF) in the treatment of Osteopenic thoracolumbar vertebral compression fractures (Osteopenic VCFs).

**METHODS:** From December 2018 to September 2020, 70 patients with osteopenic VCFs who had undergone PKP and PPSF surgeries at our medical center were reviewed retrospectively. All patients were divided into PKP group (n=38) and PPSF group (n=32). Clinical data including clinical and radiological evaluation results were performed pre- and postoperatively.

**RESULTS:** The operation time, bleeding volume, postoperative bedtime, and hospitalization period in PKP group were lower than those in PPSF group ( $P<0.05$ ). The visual analogue scale (VAS) and Oswestry Disability Index (ODI) of two groups in the last follow-up were lower than those before the operation ( $P<0.05$ ). On the 3rd day after the operation, VAS and ODI in PPSF group were higher than those in PKP group ( $P<0.05$ ). The anterior height of injured vertebrae (AH) of two groups was recovered compared with that before the operation. Compared with two groups in each period, there was no obvious difference in AH or the height restoration of injured vertebrae (HR) ( $P>0.05$ ). The anterior height ratio of injured vertebrae (AHR) of PPSF group was higher than that of PKP group after the operation ( $P<0.05$ ). The kyphosis angle (KA) in PPSF group was smaller than PKP group after the operation ( $P<0.05$ ). All patients in PPSF group have achieved bony healing at the last follow-up.

**CONCLUSIONS:** Both PPSF and PKP can achieve satisfactory clinical results in the treatment of Osteopenic VCFs. The short-term clinical effect of PKP is better than that of PPSF, but the latter has better long-term results, including the correction and maintenance of vertebral height and the acquisition of osseous fusion.

## Introduction

Thoracolumbar vertebral compression fractures, especially osteoporotic thoracolumbar compression fractures, will lead to chronic low back pain, kyphosis, limited posture, and secondary fatigue of low back muscles, which will seriously affect the quality of life and physical and mental health of patients[1]. Some studies have shown that about 70% of bone strength is determined by bone mineral density[2], the probability of fractures increases significantly with the decrease of bone mineral density and the increase of age[3]. The detection of bone mineral density has a high indicative effect on the risk of fracture. The bone mineral density decreased by 1 standard deviation, and the relative risk of fracture increased by 1.63 times[4]. For osteopenic patients between the ages of 55 and 65, the probability of fracture was 4.6%~10.4% for men and 6.7%~19.3% for women. Therefore, age and bone mass loss are high-risk factors for fracture[5]. Although osteoporosis is one of the important risk factors of vertebral compression fractures,

not all vertebral compression fractures have obvious osteoporosis[6]. In the course of clinical diagnosis and treatment, there are still some patients with thoracolumbar compression fractures whose bone mineral density has not yet reached the diagnostic criteria of osteoporosis and is only in a state of osteopenia. And the treatment of this type of fractures is still controversial.

At present, there are two main surgical methods for vertebral compression fractures, namely percutaneous kyphoplasty (PKP) and percutaneous pedicle screw fixation (PPSF). PKP inserts the balloon into the injured vertebrae through percutaneous puncture, and pressurizes the balloon to reset the collapsed vertebrae, then fills with bone cement, which can quickly relieve pain while correcting the kyphotic deformity[7], and the clinical effect is satisfactory. Therefore, PKP is becoming the first choice for the treatment of OVCFs[8]. However, compared with OVCFs, the harder bone of osteopenic VCFs can limit the ability of PKP to correct kyphosis and restore vertebral height. In addition, there are risks such as bone cement leakage, non-bony healing, adjacent vertebral fractures, and so on[9]. With the development of minimally invasive technology, PPSF is widely used in the treatment of spinal fractures. PPSF inserted pedicle screws into the injured vertebrae and adjacent vertebrae to restore the height of vertebral body through longitudinal traction, and then fix the fracture site to enhance the local strength. It provides a stable environment for the bony healing of the vertebral body[10]. However, for patients with osteopenia, there is a risk of screw loosening and internal fixation failure[11]. Therefore, PPSF is mainly used in non-osteoporotic traumatic fractures. At present, there is no broad consensus on the treatment of osteopenic vertebral compression fractures.

In this study, we compared the clinical and imaging efficacy of PKP and PPSF in treating osteopenic vertebral compression fractures, in order to provide evidence for the decision of clinical surgery.

## Materials And Methods

### Patients

The patients with thoracolumbar compression fractures treated in our hospital from December 2018 to September 2020 were analyzed retrospectively. The inclusion criteria are as follows: 1. Fresh vertebral compression fractures were diagnosed by X-ray, CT, and MRI scan, and the clinical symptoms and signs were consistent with the imaging data; 2. The T-scores of lumbar spine bone mineral density ranged from - 1.0 to - 2.5; 3. The degree of compression should be less than 70% of vertebral height; 4. All patients had low back pain and no neurological symptoms of lower extremities; 5. The follow-up time was more than 1 year and the data should be completed. The exclusion criteria are as follows: 1. Pathological vertebral fracture caused by tumors or other infectious diseases, the destruction of the posterior vertebral body is obvious; 2. Combined with spinal cord and nerve compression; 3. With obvious kyphosis; 4. There were obvious surgical taboo signs in the preoperative examination, such as severe cardiovascular and cerebrovascular diseases, mental disorders, severe malnutrition and so on. According to the surgical methods, the patients were divided into the PKP group and the PPSF group. There were 38 patients (male 14, female 24) in the PKP group, the age was ranged from 55 to 65, the average age was  $60.03 \pm 2.92$ ,

and the bone mineral density (BMD) of lumbar vertebrae was  $-1.0 \sim 2.5SD$  (mean  $1.76 \pm 0.44SD$ ). There were 32 patients (11 males and 21 females) in the PPSF group, aged from 56 to 65, with an average of  $59.56 \pm 3.04$ . The BMD of the lumbar vertebrae was  $-1.2 \sim 2.4 SD$ , mean  $-1.77 \pm 0.40SD$ . In the PKP group, 13 cases were located in the thoracic vertebrae and 25 cases in the lumbar vertebrae. The PPSF group had 10 cases of thoracic vertebrae and 22 cases of lumbar vertebrae.

## Surgical procedures

Patients in PKP group were taken a prone position, abdominal suspension, real-time dynamic ECG monitoring. The minimally invasive puncture equipment and balloon provided by Weigao Company (Shandong, China) were used. Routine disinfection and towel laying were performed after locating the injured vertebrae. Local anesthesia was performed along with the puncture point. Under the guidance of the "C" arm X-ray machine, percutaneous puncture through the pedicles of the vertebrae into the injured vertebra, and under the guidance of the guide needle, the hollow drill was drilled into the injured vertebra to establish a hollow working channel for 4.5 mm. Then, the balloon was sent into the anterior 3/4 cancellous bone of the injured vertebra through the working channel. The contrast medium was slowly injected by the high-pressure pump to dilate the balloon slowly and restore the injured vertebra to a certain height. After observing and confirming the correction of kyphosis and the recovery of vertebral height, the pressure and volume were measured, the contrast medium was extracted, and the balloon was withdrawn to vacuum. After the balloon was removed, the same volume of bone cement was injected into the collapsed vertebrae. The working channel was extracted after the bone cement was filled by the "C" arm X-ray machine, and the operation was finished. At the same time, the contralateral puncture was performed. Patients are required to stay in bed for 24 hours.

Patients in PPSF group took the prone position and the abdomen was suspended. "C" arm X-ray machine was used to locate the injured vertebrae. After successful induction of general anesthesia, routine disinfection and towel laying were performed, a 1.5 cm longitudinal incision was made along the mark. The skin, subcutis, and deep fascia were cut open, and the articular process and transverse process were bluntly separated from the gap between the multifidus muscle and the longest muscle. First of all, under the guidance of the X-ray machine in the anterior and posterior position, the needle tip was placed on the outer edge of the pedicle projection, and the parallel endplate was tilted  $10^\circ \sim 15^\circ$  inwardly into the vertebral body. Start puncturing parallel to the endplate, fluoroscopy confirmed that the tip of the puncture needle did not break through the medial cortex of pedicle after the puncture needle was punctured into bone 2 cm, then changed the lateral fluoroscopy to confirm that the puncture needle was parallel to the endplate and continued to puncture to the posterior edge of the vertebral body for 0.5-1.0 cm, to pull out the inner core, insert the guidewire, and remove the puncture needle. Through the guidewire, the enlarged tube and protective cannula were introduced successively, and the screw path was enlarged with hollow wire, then the pedicle screw was screwed into the vertebral body through the guidewire, and the guidewire was removed. "C" arm X-ray machine confirmed whether the internal position was good. Install the rod placement device, place the fixation rod into the tail groove of pedicle screws in turn, screw the fixation

nut in turn, tighten the upper nut, then use the distractor to open and restore under the fluoroscopy, tighten all the fixed nuts after the height of the vertebral body is satisfied, and suture the incision layer by layer.

## Effectiveness evaluation

Clinical outcome: Operation time, Blood loss, Postoperative bedtime, Hospitalization period, VAS scores, ODI scores, and complications.

Imaging outcome: The AH, AHR, HR and KA were evaluated on the anteroposterior and lateral films of the standing thoracolumbar spine before the operation, after the operation, and at the last follow-up. The time of bony healing, the rate of bony healing, and screw loosening were evaluated by CT scan after the operation in PSF group. The method of Bridwell[12] was used to grade osseous fusion. The methods used to measure the loss of vertebral height and angulation of the thoracolumbar fractures are shown in Fig. 1.

## Statistical Analysis

All analyses were performed using IBM SPSS Statistics for Windows, version 25.0 (IBM Corp., Armonk, NY, USA). The measurement data were expressed as mean  $\pm$ SD. The independent sample t-test was used to compare measurement data between groups and the paired T-test was used for intra-group comparison. The Chi-square test was used to compare the disordered counting data.

## Results

### Demographics

There was no significant difference in age, sex, bone mineral density, lesion location between PKP group and PPSF group (Age:  $P = 0.542$ ; Sex:  $P = 0.562$ ; Bone density:  $P = 0.801$ ). The operation time in PKP group ( $30.2 \pm 2.78$  min) was lower than that in PPSF group ( $93.09 \pm 8.63$  min) ( $P < 0.05$ ). The postoperative bedtime and hospitalization period in PKP group ( $1.24 \pm 0.43$  days,  $4.13 \pm 0.62$  days) were lower than PPSF group ( $1.66 \pm 0.83$  days,  $5.03 \pm 0.81$  days). The follow-up time was  $12.95 \pm 0.69$  months in PKP group and  $12.97 \pm 0.82$  months in PPSF group, there was no significant difference between two groups ( $P = 0.728$ ) (Table 1).

Table 1  
General data of patients in 2 groups

Characteristic	PKP	PPSF	Value <i>P</i>
Case	38	32	
Age (years old)	60.03 ± 2.92	59.56 ± 3.04	<i>P</i> > 0.05
Sex (male/female)	14/24	11/21	<i>P</i> > 0.05
BMD (lumbar)	-1.76 ± 0.44	-1.77 ± 0.40	<i>P</i> > 0.05
Thoracic vertebral	13	10	<i>P</i> > 0.05
Lumbar vertebral	25	22	<i>P</i> > 0.05
Operative time (minutes)	30.2 ± 2.78	93.09 ± 8.63	<i>P</i> < 0.05
Blood Loss (ml)	12.42 ± 5.92	66.98 ± 6.09	<i>P</i> < 0.05
Postoperative-bedtime(days)	1.24±0.43	1.66±0.83	<i>P</i> < 0.05
Hospitalization-period (days)	4.13±0.62	5.03±0.81	<i>P</i> < 0.05
Complication (Cases)	3	4	<i>P</i> > 0.05
The mean follow-up time (month)	12.95 ± 0.69	12.97 ± 0.82	<i>P</i> > 0.05
Values are mean ± SD, number of participants, or as otherwise indicated; BMD, Bone Mineral Density; PKP, Percutaneous kyphoplasty; PPSF, Percutaneous pedicle screw fixation.			

## Clinical Assessment

Both groups experienced obvious pain relief and the improvement of quality of life. The VAS scores in PKP group were  $4.87 \pm 0.74$  before the operation, which decreased to  $2.37 \pm 0.88$  immediately after operation ( $P < 0.05$ ). There was no difference in VAS scores between 3 days after the operation and the last follow-up (VAS:  $1.68 \pm 0.57$ ,  $1.60 \pm 0.49$   $P = 0.083$ ) in PKP group. In PPSF group, the VAS scores decreased from  $5.13 \pm 0.66$  before the operation to  $2.75 \pm 0.95$  ( $P < 0.05$ ) immediately after the operation, to  $2.78 \pm 0.66$  ( $P < 0.05$ ) at 3 days after the operation. The VAS scores of the last follow-up was  $1.58 \pm 0.72$ , which was remarkably different from that at 3 days after the operation ( $P < 0.05$ ). There was no difference in VAS scores before the operation, immediately after the operation, and at the last follow-up between PKP group and PPSF group ( $P = 0.134$ ;  $P = 0.086$ ;  $P = 0.066$ ). The VAS scores in PKP group were lower than that in PPSF group 3 days after the operation ( $P < 0.05$ ). The ODI scores in PKP group decreased from  $68.15 \pm 4.33$  before the operation to  $21.10 \pm 2.64$  ( $P < 0.05$ ) on 3 days after the operation, and the last follow-up was  $14.05 \pm 3.59$  ( $P < 0.05$ ). In PPSF group, the ODI scores decreased from  $69.30 \pm 3.22$  before the operation to  $34.30 \pm 3.24$  ( $P < 0.05$ ) at 3 days after the operation and  $14.86 \pm 3.18$  ( $P < 0.05$ ) at the last follow-up, and the ODI score at 3 days after the operation and at the last follow-up was lower than that in PPSF group ( $P < 0.05$ ). There was no difference in VAS and ODI scores before operation between the two groups (VAS:  $P = 0.134$ ; ODI:  $P = 0.207$ ), and there was no difference in VAS and ODI scores in the last follow-up between two groups (VAS:  $P = 0.066$  ODI:  $P = 0.328$ ) (Table 2,3).

Table 2  
Comparison of the VAS scores between 2 groups.

Group	n	Preoperatively	Immediately after surgery	3 days after surgery	Final follow-up
PKP	38	4.87 ± 0.74	2.37 ± 0.88*	1.68 ± 0.57*,▲	1.60 ± 0.49*,▲,Δ
PPSF	32	5.13 ± 0.66	2.75 ± 0.95*	2.78 ± 0.66*,▲	1.58 ± 0.72*,▲,#
Statistics		t=-1.516, P=0.134	t=-1.739, P=0.086	t=-7.441, P=0.000	t=-1.866, P=0.066
*, Compared with Preoperatively, P<0.05; ▲, Compared with Immediately after surgery, p<0.05; #, Compared with 3 days after surgery, P<0.05; Δ, Compared with 3 days after surgery, P>0.05; PKP, Percutaneous kyphoplasty; PPSF, percutaneous pedicle screw fixation; VAS, Visual Analogue Scale.					

Table 3  
Comparison of the ODI scores between 2 groups.

Group	n	Preoperatively	3 days after surgery	Final follow-up
PKP	38	68.15 ± 4.33	21.10 ± 2.64*	14.05 ± 3.59*,#
PPSF	32	69.30 ± 3.22	34.30 ± 3.24*	14.86 ± 3.18*,#
Statistics		T=-1.274, P=0.207	T=-18.772, P=0.000	T=-0.986, P=0.328
*, Compared with Preoperatively, P<0.05; #, Compared with 3 days after surgery, P<0.05; PKP, Percutaneous kyphoplasty; PPSF, percutaneous pedicle screw fixation; ODI, Oswestry Disability Index				

## Radiological Assessment

In PKP group, the AH increased from 13.56 ± 2.52 before the operation to 22.33 ± 1.77 (P < 0.05) after the operation, and there was no significant difference between the last follow-up (22.12 ± 1.97) and postoperative comparison (P = 0.051). In PPSF group, it increased from 13.93 ± 2.57 preoperatively to 21.83 ± 0.99 postoperatively (P < 0.05), and there was no significant difference between the last follow-up (21.58 ± 1.07) and the post-operation (P = 0.055). In PKP group, AHR increased from 54.00±10.48 to 88.88±6.59(P < 0.05)after the operation, and then decreased to 87.89±6.98 (P < 0.05) at the last follow-up. In PPSF group, the AHR increased from 59.73±11.23 before the operation to 91.29±3.75(P < 0.05)after the operation, and decreased to 91.07±4.13 (P < 0.05) at the last follow-up. There was no significant difference in AHR between two groups before the operation (P > 0.05), but AHR in the PPSF group was significantly higher than that in the PKP group after the operation and at the last follow-up. In PKP group, the postoperative HR was 8.82±2.36 and decreased to 8.58±2.55 (P < 0.05) at the last follow-up. In PPSF group, the postoperative HR was 7.58±3.08 and decreased to 7.32±3.04 (P < 0.05) at the last follow-up. There was no difference in postoperative and last follow-up HR between the two groups (P = 0.220; P = 0.223). In PKP group, KA decreased from 14.66 ± 2.58 preoperatively to 8.55 ± 2.55(P < 0.05)

postoperatively, and the last follow-up was  $8.67 \pm 2.56$  ( $P < 0.05$ ). In PPSF group, KA decreased from  $13.76 \pm 1.91$  preoperatively to  $6.35 \pm 1.63$  ( $P < 0.05$ ) postoperatively, and the last follow-up was  $6.57 \pm 1.63$  ( $P < 0.05$ ). There was no difference in KA between two groups before the operation ( $P = 0.156$ ). However, the KA of postoperative and last follow-up was higher than that of PPSF group ( $P < 0.05$ ). The time of bony healing in the PPSF was  $4.34 \pm 0.72$  (months). Among the 32 patients in PPSF group, 28 patients were grade I fusion and 4 patients were grade II fusion. The rate of bony healing in PPSF was 100% (Table 4 ~ 7).

Table 4  
Comparison of the Anterior Height between 2 groups.

Group	n	Preoperatively	Post-operatively	Final follow-up
PKP	38	$13.56 \pm 2.52$	$22.33 \pm 1.77^*$	$22.12 \pm 1.97^{*,\#}$
PPSF	32	$13.93 \pm 2.57$	$21.83 \pm 0.99^*$	$21.58 \pm 1.07^{*,\#}$
Statistic		$T = -0.602, P = 0.54$	$T = 1.473, P = 0.164$	$T = 1.473, P = 0.146$
*, Compared with Preoperatively Group, $P < 0.05$ ; #, Compared with Post-operatively Group, $P > 0.05$ ; PKP, Percutaneous kyphoplasty; PPSF, percutaneous pedicle screw fixation; AH, the anterior height of the injured vertebral body.				

Table 5  
Comparison of the Anterior Height Ratio (AHR) between 2 groups.

Group	n	Preoperatively	Post-operatively	Final follow-up
PKP	38	$54.00 \pm 10.48$	$88.88 \pm 6.59^*$	$87.89 \pm 6.98^{*,\#}$
PPSF	32	$59.73 \pm 11.23$	$91.29 \pm 3.75^*$	$91.07 \pm 4.13^{*,\#}$
Statistic		$T = -2.206, P = 0.031$	$T = -2.995, P = 0.004$	$T = -2.261, P = 0.027$
*, Compared with Preoperatively $P < 0.05$ ; #, Compared with Post-operatively, $P < 0.05$ ; PKP, Percutaneous kyphoplasty; PPSF, percutaneous pedicle screw fixation; AHR, the height ratio of the anterior edge of injured vertebra.				

Table 6  
Comparison of the Height Restoration (HR) between 2 groups.

Group	n	Postoperatively	Final follow-up
PKP	38	8.82±2.36	8.58±2.55▲
PPSF	32	7.58±3.08	7.32±3.04▲
Statistic		T = 1.861, P = 0.068	T = 1.881 P = 0.064
▲, Compared with Postoperatively, P> 0.05; PKP, Percutaneous kyphoplasty; PPSF, percutaneous pedicle screw fixation;			
HR, the restoration of the anterior height of injured vertebra .			

Table 7  
Comparison of the Kyphotic Angle (KA) between the 2 groups.

Group	n	Preoperatively	Post-operatively	Final follow up
PKP	38	14.66±2.58	8.55±2.55*	8.67±2.65*,#
PPSF	32	13.76±1.91	6.35±1.63*	6.57±1.63*,#
Statistic		T = 1.686, P = 0.096	T = 4.364, P = 0.000	T = 4.051, P = 0.000
*, Compared with Preoperatively Group, P<0.05; #, Compared with Post-operatively Group, P>0.05; PKP, Percutaneous kyphoplasty; PPSF, percutaneous pedicle screw fixation. KA, the Kyphotic Angle .				

## Complications

In PKP group, there was 1 case of new vertebral fracture and 2 cases of asymptomatic bone cement leakage. In PPSF group, 1 case was complicated with transient lower limb radiation pain, 2 cases with incision fat liquefaction, and 1 case with pulmonary infection. All the above patients recovered after active symptomatic treatment. In the PPSF group, there was no screw loosening, nail breaking and so on (Typical cases are shown in Fig. 2, 3).

## Discussion

This study found that the operation time, bleeding volume, postoperative bedtime, and hospitalization period in PKP group were lower than those in PPSF group, which indicated that PKP had less surgical trauma than PPSF. Despite this, our study did not find any significant difference in the VAS score

immediately after operation between PKP group and PPSF group. The possible reasons are as follows: (1) PKP can quickly relieve clinical symptoms by stabilizing small fractures in injured vertebrae and restoring biomechanical properties[13], the exothermic reaction of bone cement solidification destroys pain nerve endings[14], toxic destruction of bone cement destroys sensory nerve endings and partial decompression of spinal nerve roots. (2) due to the enhanced recovery after surgery (ERAS) and reasonable analgesia program carried out in our hospital, the pain feedback after PPSF is reduced to the minimum. However, VAS scores in PKP group was lower than PPSF group 3 days after operation, which may be related to the discontinuation of painkillers after operation. There was no difference in VAS scores between two groups at the last follow-up, which also showed that both PKP and PPSF were effective in relieving pain in patients with osteopenic VCFs. At the same time, we found that the postoperative ODI scores in PKP group was lower than PPSF group, which may be due to some damage to the soft tissue during the placement of nails and rods during PPSF operation. However, there was no obvious difference in the last follow-up, which may be related to the recovery of muscle and soft tissue injury at the end of follow-up. Undeniably, compared with other surgical methods, PKP has a strong efficacy in rapidly relieving clinical symptoms. This is crucial for elderly patients with underlying diseases, which means it can improve the quality of life of them and reduce the risk of bedridden complications.

In this study, it was found that the AH of injured vertebrae in both groups recovered significantly after the operation, and lost to some extent during the follow-up period, but there was no difference in AH between two groups at the last follow-up. This result is different from the previous research view that PPSF has stronger kyphosis correction ability[15, 16]. By analyzing the characteristics of the cases included in our study, we found that more patients with lumbar fractures were included into PKP group, especially male patients. Considering the differences in vertebral height of different genders and different segments of the spine, we introduced the concept of Anterior Height Ratio (AHR), that is, the anterior height of the injured vertebra / the average anterior height of the upper and lower vertebrae adjacent to the injured vertebra. The results also showed that the AHR in PPSF group was higher than PKP group after operation and in the last follow-up, indicating that PPSF could better restore the height of injured vertebrae. The KA in PPSF group was lower than that in PKP group after operation and in the last follow-up, which confirmed that PPSF had higher kyphosis correction ability than PKP.

Previous studies have suggested that the holding force of pedicle screws may be weakened due to bone loss. Through a series of biomechanical studies, Lukas[17] et al. considered that the stability of pedicle screws may be obviously insufficient when the bone mineral content of thoracolumbar vertebrae is less than  $80 \text{ mg/cm}^3$ , so it is necessary to apply additional measures to enhance the stability of screws. At the same time, the study found that longer bed rest time will accelerate bone mass loss, and eventually lead to disused osteoporosis[18]. Although the patients included in our study had osteopenia, no implant-related complications such as screw loosening were found, which may be due to: (1) The age of patients is not old enough (average age:  $59.56 \pm 3.04$ , which indicated that the loss of bone mass may not severe. (2) PPSF is beneficial to the bony healing of injured vertebrae. Once bony healing is achieved, the incidence of screw loosening is low. (3) All patients with PPSF wore lumbar brace after the operation.

Bone mineral density is an important factor in the correction of vertebral kyphosis after PKP[19], and lower bone mineral density often means better correction of wedge angle and kyphosis angle after operation[20]. Heini et al[21, 22]. found in vitro experiments that lower bone mineral density is more conducive to the penetration and dispersion of bone cement in the trabecula. A series of clinical and basic studies have shown that there is a good positive correlation between bone mineral density and fracture compression force and vertebral stiffness[23]. Therefore, we believe that the lower the bone mineral density, the more definite the surgical indications of PKP. During the follow-up, we found that there was a case of vertebral re-fracture in PKP group. We analysed that the patient was a postmenopausal woman with a T value of -2.4 before the first operation, which was close to the diagnosis of osteoporosis, and the patient was not given continuous BMD-monitoring and regular anti-osteoporosis treatment after discharge, so there was a high risk of bone mass loss. This result also reminds us that the effective detection of bone mineral density and timely and regular anti-osteoporosis treatment are of great significance for patients with osteopenic vertebral compression fractures. There was no significant difference in the overall incidence of complications between two groups during the follow-up period, and all complications were cured after active treatment, which confirmed the safety of both PPSF and PKP in the treatment of osteopenic compression fractures.

## Conclusions

In summary, this study showed that both PPSF and PKP can achieve satisfactory clinical results in the treatment of osteopenic thoracolumbar compression fractures. Although PKP and PPSF have a similar incidence of complications, imaging effects, and long-term clinical effects, in view of the long survival time of the patients, the risk of recurrent vertebral fracture, kyphosis caused by PKP may be higher in the long term. Meanwhile, PPSF can achieve bony healing of the injured vertebrae by stabilizing the posterior column of the spine. In a word, PPSF can achieve bony union by minimally invasive internal fixation, which may be more beneficial to patients with osteopenic thoracolumbar vertebral compression fractures.

## List Of Abbreviations

**PKP** Percutaneous Kyphoplasty

**PPSF** Percutaneous Pedicle Screw Fixation

**Osteopenic VCFs** Osteopenic vertebral compression fractures

**VAS** Visual Analogue Scale

**ODI** Oswestry Disability Index

**AH** The anterior height of the vertebra

**AHR** The anterior height ratio of injured vertebra

**HR** The height restoration of the injured vertebra

**KA** The kyphosis angle

## **Declarations**

## **Ethics approval and consent to participate**

This retrospective study was approved by the Ethics Committee of Chongqing Medical University, and all participants agreed and signed informed consent forms

## **Consent for publication:**

Not applicable

## **Availability of data and materials:**

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

## **Competing interests:**

The authors declare that they have no competing interests.

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## **Authors' contributions:**

YZ, WWY, and BL conceived and designed the experiment. ZY and HQX collected the patient samples. ZY and HYL analyzed and interpreted the data. YZ and WWY prepared the manuscript. YZ, ZJY, and FH reviewed the manuscript. YZ, WWY, HQX, and HYL are responsible for the integrity of the data. YZ and BL approved the final version of the manuscript. All authors have read and approved the final submitted manuscript.

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## Figures

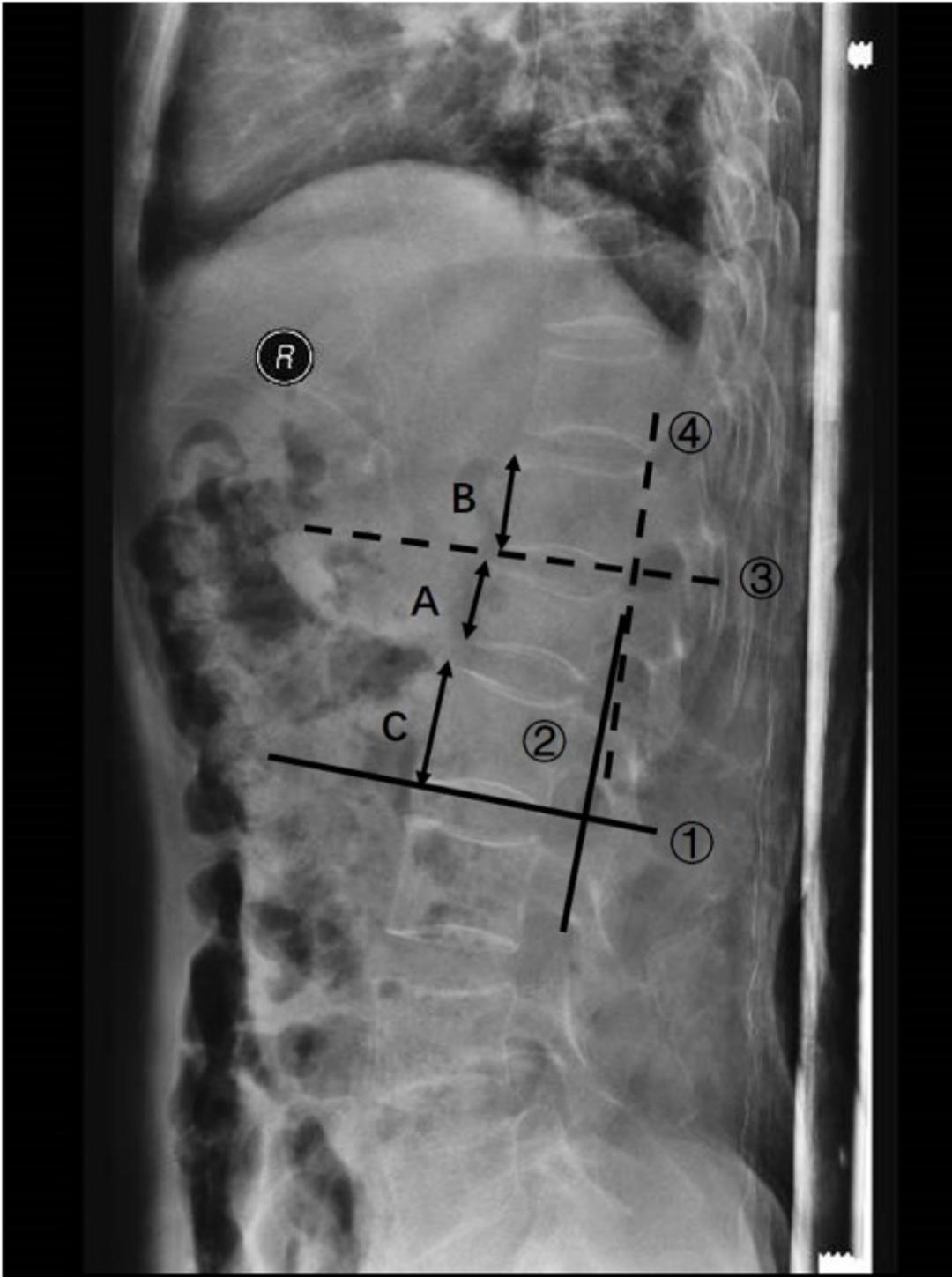
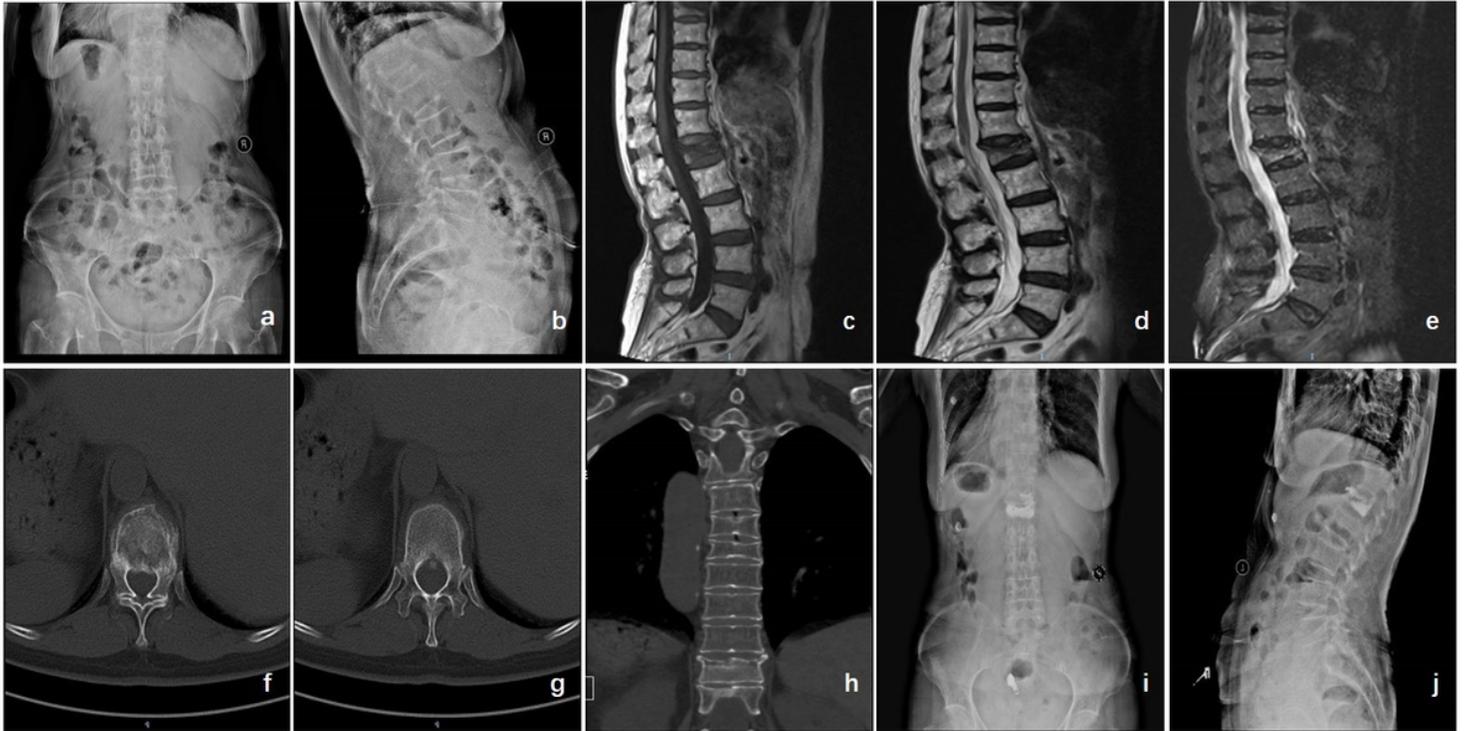


Figure 1

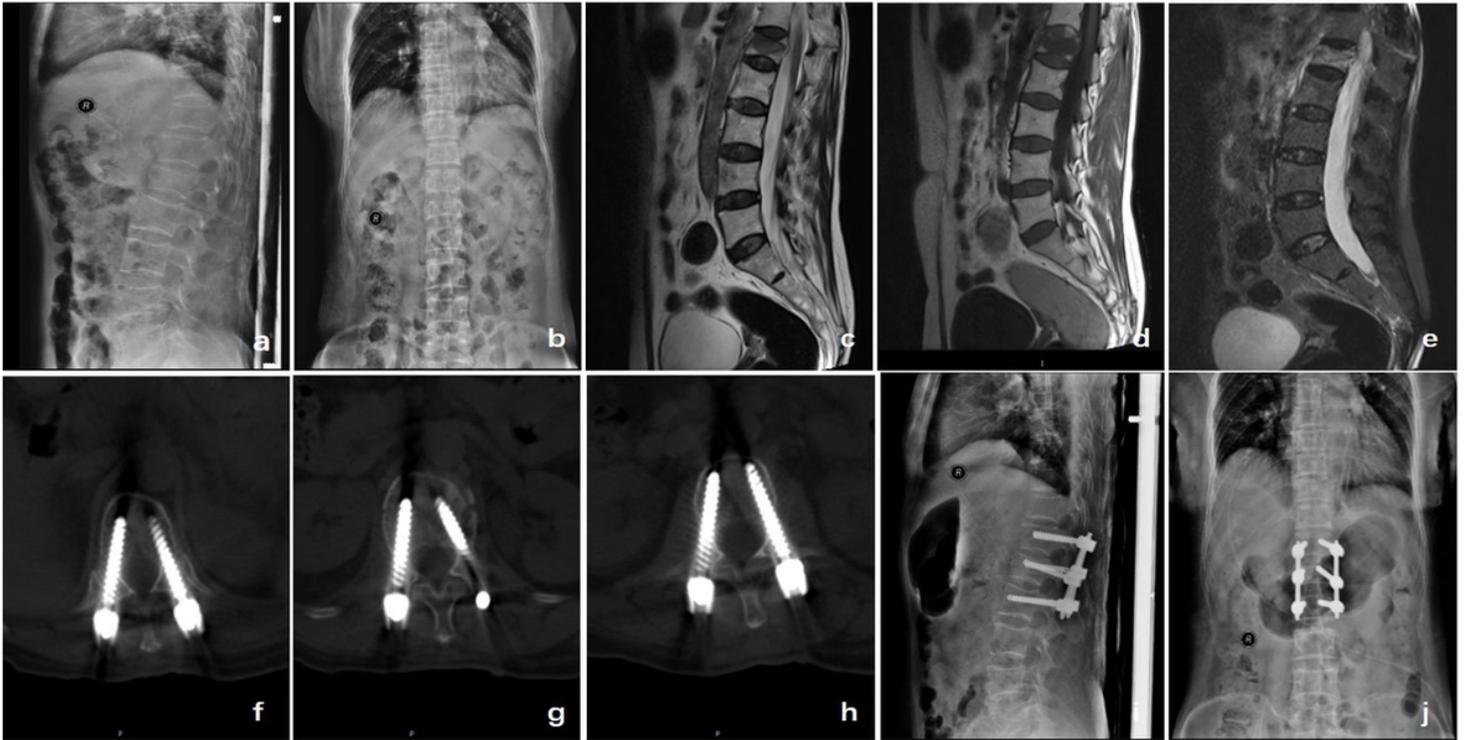
Methods for measuring anterior height (AH), anterior height ratio (AHR), height restoration (HR) and kyphotic angle (KA). The anterior height of injured vertebrae is defined as A, and the adjacent upper and lower vertebra of the injured vertebra are defined as B and C.  $AH=A$ ,  $AHR= A/\sqrt{(B+C)/2}$ ,  $HR=A$  (postoperative)-A (pre-operative). The kyphotic angle is measured by drawing a line 1 parallel to the inferior endplate of the caudal vertebra of the injured vertebra, and line 2 is perpendicular to it. Similarly,

line 3 is parallel to the inferior endplate of the superior vertebral body of the injured vertebra, and line 4 is perpendicular to it. The angle between line 2 and line 4 is the kyphotic angle (KA).



**Figure 2**

The typical case of PKP. A 65-year-old female, who fell caused back pain for 5 days, had a lumbar spine T value of -2.4 and underwent PKP surgery. The patient was diagnosed as L1 vertebral compression fracture by preoperative anterior and lateral X-ray (fig.2a, 2b), MRI (fig.2c, 2d, 2e), and CT (fig.2f, 2g, 2h). Postoperative lateral X-ray (fig.2i, 2j) showed that the filling of bone cement was good and the height of the vertebral body recovered.



**Figure 3**

The typical case of PPSF. A 59-year-old male, who underwent violent trauma to back pain for 2 days, had a lumbar spine T value of -2.2 and underwent PPSF surgery. The patient was diagnosed as L1 vertebral compression fracture by preoperative anterior and lateral X-ray (fig.3a, 3b) and MRI (fig.3c, 3d, 3e). 5 months after the operation, CT three-dimensional reconstruction showed that pedicle screws were fixed in place, and there was no obvious loosening. At the same time, partial bony healing of the L1 vertebral body could be observed (Fig. 3f - 3j).