

# The change of sagittal balance after PKP for patients with osteoporotic vertebral compression

**Jingkun Li**

Shandong Provincial Qianfoshan Hospital, the First Hospital Affiliated with Shandong First Medical University

**Kaining Zhang**

Shandong Provincial Qianfoshan Hospital, the First Hospital Affiliated with Shandong First Medical University

**Yanjun Ren**

Shandong Provincial Qianfoshan Hospital, the First Hospital Affiliated with Shandong First Medical University

**Yingguang Wu**

Shandong Provincial Qianfoshan Hospital, the First Hospital Affiliated with Shandong First Medical University

**Yun Yang**

Shandong Provincial Qianfoshan Hospital, the First Hospital Affiliated with Shandong First Medical University

**Hong Wei**

Shandong Provincial Qianfoshan Hospital, the First Hospital Affiliated with Shandong First Medical University

**Debo Zou** (✉ [44751061@qq.com](mailto:44751061@qq.com))

Shandong Provincial Qianfoshan Hospital, the First Hospital Affiliated with Shandong First Medical Hospital

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## Research article

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# Abstract

**Purpose** To detect the postoperative change in total spinal alignment in OVCF patients after PKP.

**Methods** A total of 130 patients with vertebral compression fracture was involved in this study. The entire spine radiographs of every patients were taken pre and postoperatively. The parameters including vertebral body height, pelvic incidence (PI), sacral slope (SS), pelvic tilt (PT), lumbar lordosis (LL), sagittal vertical axis (SVA), and spinosacral angle (SSA). All the parameters were compared before and after PKP.

**Results** In the patients, the VAS score was decreased from  $8.26\pm 1.12$  preoperative to  $2.70\pm 0.90$  postoperative. And SVA decreased from  $6.82\pm 3.30$  cm to  $4.07\pm 2.77$ cm. The change in sagittal balance is related to the recovery of vertebral body height.

**Conclusion** PKP plays a role not only in improving the vertebral body height but also in rebuilding sagittal imbalance in the treatment of vertebral compression fracture.

## Introduction

Osteoporotic vertebral compression fracture (OVCF) is one of most common diseases among the ages, and it has an elevated incidence during the years (1, 2). OVCF usually cause severe pain and affect the normal life, most seriously, may result in death. To date, PKP has recently become recognized one of the most useful methods to treat OVCF (1, 3, 4). It has been proved that PKP is useful not only for dramatically relieving fracture-associated pain through injection of bone cement into the fractured vertebrae, but also for restoring the height of the destroyed vertebrae and recovering the local spinal kyphosis (5–7). However, there is no research investing if PKP is useful in restoring total spinal alignment or sagittal balance. As we all know, sagittal balance is one of the most important factors to assess the outcome of the spinal operation. And it's necessary to evaluate the influence of PKP on total spinal sagittal alignment. In this study, we will evaluate the affection of PKP on total sagittal alignment and sagittal balance in the OVCF patients prospectively.

## Materials And Methods

Ethical approval for this study was obtained from the Medical Ethics Committee of the First Hospital Affiliated with Shandong First Medical University; What's more, written informed consents from each patient included in this study were obtained.

A total of 130 patients who visited our hospital between June 2017 and March 2019 was involved and 176 vertebral bodies were treated in these patients. Of these patients, the data pertaining to 52 vertebral bodies in 52 patients, including 10 male and 42 female, treated by PKP who met the criteria described below were included in the present analysis. In all patients, full-length lateral radiographs were performed in addition to the simple dynamic lumbar radiographic imaging preoperatively. Furthermore, lumbar MR imaging were performed to determine the indication for surgery.

## **Inclusion and exclusion criteria**

The inclusion criteria were as follows: (1) severe back pain associated with single VCF refractory to analgesic medication administered for at least 2 weeks, the pain interfere with the activities of daily living; (2) Specific tender pain and percussion pain; (3) The affected vertebral body showing a high signal intensity on short T1 inversion recovery MR imaging and a low signal intensity on T1-weighted MR imaging; (4) The fracture located at T0 to L2. (5) The pain is caused by the fractured vertebra body located by MRI; (6) The patients is suffering osteoporosis.

The exclusion criteria were as follows: (1) patient who has never root or spinal injury, (2) spinal metastatic cancer, (3) patient with impaired cardiopulmonary function or coagulopathy that cannot tolerate the operation; (4) history of spinal surgery and (5) patients with more than one vertebral body fracture.

## **Operation procedure**

All patients were operated on by one doctor. All patients were placed in the prone position and then local anesthesia was performed. In all cases, balloon PKP was performed through the transpedicular route on both sides by placement of working cannulas bilaterally by using standard PKP equipment. In the vertebral body, the balloons on each side were inflated to create a space for injection of the bone cement, and then the balloons were deflated and removed. The polymethylmethacrylate (PMMA) mixture was also injected into the vertebral body from both sides. During the bone cement injection, fluoroscopic monitoring was conducted in both planes with a C-arm unit. After the bone cement injection, the surgery was completed by withdrawing the needle.

## **Data collection and image analysis**

Visual analogue scale (VAS) score and Oswestry dysfunctional index (ODI) score of all the patients were recorded before and after operation to evaluate the clinical outcomes.

All patients underwent a standing lateral radiograph of the whole spine with the arms in the fists-on-clavicles position with their knees and hips fully extended before operation and 2 days 1 year after operation. The following parameters were measured on the lateral whole spine standing radiographs: (1) sagittal vertical axis (SVA): distance between the C7 plumb line and

the posterior corner of the sacrum; (2) spinosacral angle (SSA): angle formed between the line drawn from the front side of T1 to the middle of sacrum and the line passing through the sacral plateau; (3) Lumbar lordosis (LL): angle between the superior endplate of L1 and the superior endplate of S1 using Cobb method. (4) Pelvic tilt (PT): angle formed by a line drawn from the midpoint of the sacral endplate to the center of the bicoxofemoral axis and vertical plumb line. (5) relative height of front of the fracture body: height of the front edge/average height of adjacent two bodies $\times$ 100% ; (6) local kyphosis: angle between the superior endplate of upper vertebral body and the lower endplate of the inferior vertebral body.(Fig. 2)

## Statistical Analysis

All the data are presented as the means $\pm$ SD. Statistical analyses were performed by using Student's t-test and two-way analysis of variance (ANOVA) with Prism software followed by the Student-Newman-Keuls post hoc test. Differences were considered to be statistically significant if the p-value <0.05 (\* or #) or 0.01 (\*\* or ##).

## Results

### General situation

All the patients operated successfully, and no complication including never injury and pulmonary embolism has happened (8). The average operation time is (27.7 $\pm$ 6.5) minutes, the average injection volume of PMMA cement is (4.40 $\pm$ 1.74)ml, and the average amount of bleeding is (5.61 $\pm$ 2.11)ml.

### Clinical outcome

In our study, the average VAS score was (8.26 $\pm$ 1.12) and ODI score was (81.20 $\pm$ 6.70) before operation; the VAS score improved to (2.70 $\pm$ 0.90) and ODI score improved to (30.09 $\pm$ 6.34) two days after operation. It means the operation could dramatically release the pain and approve the activities of daily living. In the follow-up one year after operation, VAS score was (2.09 $\pm$ 0.88) and ODI score was (24.32 $\pm$ 8.20), has no obvious change compared with the scores that two days after operation. (Table 1 and Table 2) The results mean that PKP can dramatically relieve fracture-associated pain; at the same time, in the case of no new fracture, the patients' back pain is not significantly increased within one year.

### Imaging results pre- and post-operation

In the present study, the results showed that, before operation, the local kyphosis angle was (22.97  $\pm$  4.04) ° and the relative height of the anterior edge of the vertebral body was (62.32  $\pm$  7.66)%; and two days after operation, the local kyphosis angle was (13.96  $\pm$  3.04) ° and the relative height of the anterior edge of the vertebral body was (84.74  $\pm$  7.85)%, all of which were statistically significant (P < 0.05); and at the last follow-up, the local kyphosis angle was (13.96  $\pm$  2.65) ° and the relative height of the anterior edge of the vertebral body were (P < 0.05) at the last follow-up The difference was (83.85  $\pm$  8.07)%, which was statistically significant (P < 0.05)

The SVA of the patients before operation was (6.82  $\pm$  3.30) cm, which indicated that there was spinal sagittal imbalance in different degrees in OVCF patients. After PKP, the SVA of the patients improved to (4.47  $\pm$  2.77) cm; at the same time, the SSA of the patients increased to (110.7  $\pm$  12.6) ° from (103.4  $\pm$  10.3) ° before operation, and II increased to (43.4  $\pm$  17.0) ° from (40.5  $\pm$  15.5) ° before operation, which was statistically different from that before operation. On the other hand, at the last follow-up, we found that SVA, SSA and II were significantly improved compared with those before operation, but compared with the imaging examination at 2 days after operation, SVA increased to some extent, while SSA and II decreased.(Table 2)

In the typical case in Figure 1, we can see that the SVA of the patients after PKP was significantly reduced and the SSA and II were significantly increased compared with those before PKP. However, compared with the two days and one year after PKP, the SVA was increased, while the SSA and II were continuously decreased. (Fig. 1)

## Discussion

PKP has been proved to be one of the most useful methods to treat OVCF (1–4). In the previous studies, many reports show that the vertebral body height restoration and kyphotic changes are very significant. As a result, PKP could not only stable the fractured vertebra body and reveal the severe pain immediately, but also restore the vertebral body height and correct the local kyphosis by inflating of the balloon(6, 9, 10). However, there is no study investigate the influence of PKP on the spinopelvic alignment or sagittal balance of the entire spine. Sagittal imbalance of spine is becoming one of the most important factors in assessing degree of spinal deformity. If PKP could improve sagittal imbalance of spine, and if the clinical outcome is associated with the sagittal imbalance improvement are still unknown.

Previous studies have proved that sagittal balance of entire spine plays important roles in the spinal function and outcomes of many spinal operations(11). Healthy adults tend to stand in negative sagittal balance as determined by the SVA, as human grow older, adults tend to stand in positive sagittal balance. What's more, lumbodorsal muscles tend to atrophy and center of gravity move forward with ages, these may result in increased pressure of the anterior column and tension of the posterior column, all of these points may lead to backache and compression fractures of vertebral body(12–14). In patients with severe sagittal imbalance of entire spine, posterior rotation of the pelvis around the hip joint takes place to compensate for sagittal imbalance even to a small extent and that this compensatory mechanism leads to a decrease in sacral slope and an increase in pelvic tilt. And then, flexion of the knee joints and hyperextension of the hip joints are involved in the compensatory mechanism. These compensatory mechanisms serve as factors responsible for dysfunction of the lower limbs and low quality of life(15). Recovery of the sagittal balance will dramatically improve the health-related quality of life (16). Therefore, it is desirable that spinal operation associated with any pathologic condition be designed to correct sagittal imbalance.

As we all know, SVA is one of the most important index in evaluation of sagittal balance. In healthy adults, SVA usually is minus or smaller than 4 centimeters, sagittal imbalance of spine happens the when SVA is more than 4 centimeters(17). On the other hand, VCF patients show significant decrease of sacral slope and increase of pelvic tilt and SVA compared to healthy adults. This kind of sagittal imbalance may related to Age-related spinal degeneration and the aggravation of kyphosis caused by vertebral collapse and the pain avoiding posture caused by patients' pain(15). When PKP was performed in OVCF patients, SVA decreased, thus resulting in partial correction of the sagittal imbalance. After PKP treatment, SVA of patients decreased, which may be due to the relief of back pain, the recovery of back activity unit function, and the ability to maintain a relatively natural posture. But more importantly, the height of pathological vertebral body recovered to a certain extent, and the local kyphosis angle decreased, which

is also a reason for SVA reduction. On the other hand, the changes of II and SSA mean that the overall sagittal balance of the spine is improved significantly. This shows that PKP can not only relieve the patients' back pain, but also improve the patients' sagittal imbalance in the treatment of OVCF, so as to improve the patients' quality of life.

In this study, within 2 days after PKP, SVA decreased, II and SSA increased, but after long-term follow-up, we found that with the increase of patients' age, SVA increased gradually, but there was no significant change in VAS score and ODI score, which indicated that sagittal kyphosis can be a natural trend of human degeneration(13). Nevertheless, with the SVA increases and the body leans forward, the pressure on the anterior column of the spine increases, and then the possibility of secondary vertebral fractures may increase significantly (18). Therefore, in the process of PKP, it is necessary to restore the height of vertebral body and local kyphosis angle as much as possible to further improve SVA, thus to reduce the risk of vertebral fracture, and end the vicious circle of fracture.

## Conclusion

PKP can not only alleviate the low back pain of OVCF, but also improve the sagittal balance of spine. However, whether there is a correlation between the improvement of symptoms and the reduction of SVA still needs further study. The purpose of PKP should not only improve the symptoms of patients, but also restore the height of fracture vertebral body as much as possible.

## Abbreviations

OVCF	Osteoporotic vertebral compression fracture
PKP	Percutaneous kyphoplasty
SVA	Sagittal vertical axis
PI	Pelvic incidence
PT	Pelvic tilt
SS	Sacral slope
SSA	Spinosacral angle
LL	Lumbar lordosis
VAS	Visual analog scale
PMMA	Polymethylmethacrylate

## Declarations

### Ethics approval

Ethical approval for this study was obtained from the Medical Ethics Committee of the First Hospital Affiliated with Shandong First Medical University.

### Consent for publication

Written informed consent for publication was obtained from all participants.

## Availability of data and material

The datasets analysed during the current study are available from the corresponding author on reasonable request.

## Competing interests

The authors do not have any possible conflicts of interest.

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## Authors' contributions and Acknowledgements

Debo Zou: Conception and design of the study, acquisition and interpretation of data, final approval of the version to be published.

Jingkun Li: Drafting the article, acquisition of data, analysis and interpretation of data, revising the article, final approval of the version to be published.

Kaining Zhang, Yanjun Ren, Yingguang Wu, Hong Wei: Finish the Operation, analysis and interpretation of data.

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## Tables

**Table 1 Comparison of scores of OVCFs patients pre-operation, 2 days after operation and during follow-up**

	pre-operation	2 days after operation	the last follow-up
<b>VAS score</b>	8.26±1.12	2.70±0.90*	2.09±0.88*
<b>ODI score</b>	81.20±6.70	30.09±6.34*	24.32±8.20*

\* comparison with the same group  $P < 0.05$

**Table 2 Comparison of scores of OVCFs patients pre-operation, 2 days after operation and during follow-up**

	pre-operation	2 days after operation	the last follow-up
local kyphosis angle <sup>°</sup>	22.97±4.04	13.96±3.04*	13.96±2.65*
Relative height of anterior edge of vertebral body [mm]	62.32±7.66	84.74±7.85*	83.85±8.07*
<b>SVA</b> [cm]	6.82±3.30	4.07±2.77*	5.43±3.49*
<b>SSA</b> <sup>°</sup>	103.4±10.3	110.7±12.6*	106.1±13.1*
<b>LL</b> <sup>°</sup>	40.5±15.5	43.4±17.0*	42.5±16.4*
<b>PT</b> <sup>°</sup>	26.7±5.91	27.4±7.18	27.0±7.55

\* comparison with the same group  $P < 0.05$

## Figures



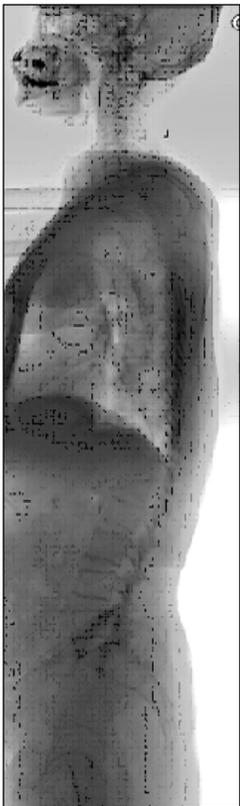
**A**



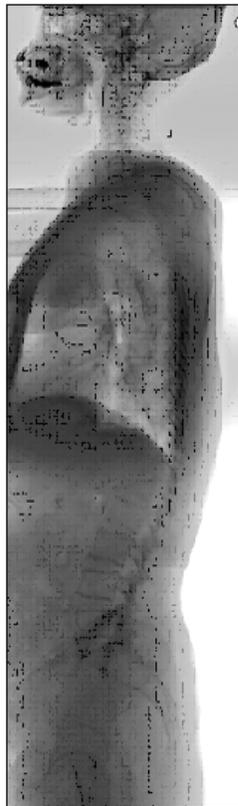
**B**



**C**



**2018.9.28**



**2018.9.29**



**2018.10.31**



**2019.9.26**

**Figure 1**

Female, 63 years old, pain 2 days after lumbar sprain. MRI showed: low signal on T1WI (A), high signal on T2WI (B) and high signal on STIR (C) of lumbar 1 vertebrae. Fracture line was found in the vertebrae, suggesting acute fracture of lumbar 1 vertebrae. And the lateral radiograph of entire spine at different times.