Clinical Article

Lateral-Opening Injection Tool Used in Percutaneous Vertebroplasty to Treat Asymptomatic Osteoporotic Vertebral Burst Fractures: A Retrospective Study

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Objective: The adequate management of asymptomatic osteoporotic vertebral burst fractures (OVBFs) was still controversial. Percutaneous vertebroplasty (PVP) could achieve quick recovery with minor trauma, but there were certain safety problems by traditional bone cement injection method. Thus, the aim of this study was to assess the efficacy of lateral-opening injection tool used in PVP treating patients with asymptomatic OVBFs.

Methods: This was a retrospective study of OVBFs treated in our institute from March 2016 to March 2020. A total of 66 patients (mean age 72.10 ± 7.98 years, with 21 men and 45 women) who were diagnosed with acute asymptomatic OVBFs with mild spinal canal compromise were treated with PVP by using a lateral-opening injection tool. Two puncture needles were simultaneously placed transpedicularly in the fractured vertebra, and the inner core was removed, and the lateral-opening injection tool was inserted. The adjustment of lateral hole was to improve the distribution height of bone cement and avoid the entry of bone cement into the posterior wall of vertebral body. Related clinical outcomes and images were assessed, including back pain (visual analog scale [VAS]), vertebral height ratio (fractured vertebral height/average adjacent nonfractured vertebral height), kyphosis Cobb angle, union of the fractured vertebral posterior wall, distribution of bone cement, surgical data, and complications.

Results: The average follow-up time of all cases was 21.23 ± 9.35 months. The mean amount of bone cement was 3.28 ± 0.35 ml in the vertebrae and the mean operative time was 34.02 ± 5.23 min. There were 60 cases of bone cement that contacted the upper and lower endplates on at least one side. There was no cement leakage into the spinal canal or fracture displacement of the posterior wall of the vertebral body in all cases. The VAS scores were 3.78 ± 0.42 at 1 day postoperatively and 0.53 ± 0.40 at the last follow-up, significantly lower than 8.40 ± 0.48 preoperatively (p < 0.05). The average height ratio of anterior, middle, and posterior vertebral body in all cases. The postoperative kyphosis angle decreased (p < 0.05). At 6 months follow-up, there was no significant height loss of the vertebral body. Computed tomography examination 3 months postoperatively showed that the fracture of posterior vertebral wall healed well in all cases. There were

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seven cases of bone cement leakage without clinical symptoms and two adjacent vertebral fractures caused by falling. There were no cases of deep vein embolism, lower limb muscle atrophy, pneumonia, decubitus.

**Conclusion:** The lateral opening tool can be safely and effectively used in the PVP treatment on asymptomatic OVBFs with mild spinal canal compromise.

**Key words:** bone cement; fracture healing; lateral-opening injection tool; osteoporotic vertebral burst fractures; percutaneous vertebroplasty

### Introduction

Osteoporotic vertebral compression fractures (OVCFs) are prevalent in older people\(^\text{1,2}\). Many patients with OVCFs have asymptomatic posterior vertebral wall disruption or spinal canal compromise\(^\text{3,4}\). According to the Denis classification, this fracture type involves two columns (anterior and middle) of injury and should be classified as a vertebral burst fracture, specifically the osteoporotic vertebral burst fractures (OVBFs)\(^\text{3-9}\). OVBFs can cause persistent deep back pain, impaired gait, and progressive kyphosis, and there is a high risk of nerve compression caused by inappropriate treatment, leading to further nerve dysfunction and even death\(^\text{10}\).

Until now, the adequate management of OVBFs were still controversial\(^\text{11-13}\). Surgical pedicle internal fixation treatments have been reported previously\(^\text{13,14}\). However, many older individuals have contraindications or a high risk of accidents during the perioperative period, owing to their poor basic physical condition\(^\text{13,14}\). Conservative treatment can also be used as an alternative treatment\(^\text{12,15}\). However, conventional treatment usually requires a more extended period of bed rest; however, the risk of complications related to bed rest is high in older patients\(^\text{15}\). Moreover, conservative treatment might be highly troublesome, owing to poor patient compliance, and nerve injury might result from fracture fragment displacement. Regardless of the kind of treatment undertaken, the incidence of fracture nonunion is still high in older patients\(^\text{16}\).

Percutaneous vertebroplasty (PVP) and percutaneous kyphoplasty (PKP), two minimally invasive procedures that involve the injection of polymethyl methacrylate (PMMA) bone cement into the vertebral bodies to restore the stability of fractured vertebral bodies and reduce pain, are widely applied for the treatment of OVCFs\(^\text{17}\). Although some surgeons have tried to treat OVBFs with PVP or PKP and achieved certain results, the risks of this treatment have not been solved\(^\text{13,16,17,18,19}\). The most critical issue is that bone cement might leak into the spinal canal through the fractured posterior wall or push the burst fracture fragments backward, ultimately causing nerve compression\(^\text{11}\). However, effective solutions to this problem have rarely been reported in previous papers. In addition, because the posterior wall of the vertebral body is damaged in a burst fracture, the stability of the middle column of the spine decreases\(^\text{8,9}\). How to guarantee the safety during the PVP or PKP treatment and stability of vertebrae with burst fracture after treatment has not been solved.

Recently, an intriguing new method for treating OVCFs\(^\text{20}\), vesselplasty (vertebral augmentation using Vessel-X bone filler), using a new device, the Vessel-X bone-filling mesh container, was produced. Instead of using a balloon to create a cavity, vesselplasty uses a polyethylene terephthalate Vessel-X container to restore the height of the vertebral body, enabling further injection of PMMA cement\(^\text{20-22}\). Theoretically, because of the restriction of the container, vesselplasty can reduce the chance of bone cement leakage if the posterior wall ruptures, and a number of studies have reported the safety and effectiveness of this technology for OVBFs\(^\text{21,22}\). However, for economic reasons, the application of vesselplasty was limited in many hospitals.

Because during the conventional PVP treatment of vertebral fracture, the bone cement can only flow out through the front hole of the puncture tube. When the distribution of bone cement cannot meet the requirements of safety and stability, the outlet position of bone cement is difficulty adjusted only by repeated puncturing or moving the puncture tube back and forth. In clinical work, we found that a lateral-opening injection tool (03.702.218S, Vertecem V, DePuy Synthes, Raynham, MA, USA) can make the outflow of bone cement only through a lateral hole, which may reduce the risk of cement leakage and displacement of burst fracture fragments by adjusting the direction of the lateral opening. Therefore, by the retrospective review of our previous cases, this study aims to: (i) evaluate the safety of using the lateral-opening injection tool in PVP treatment; (ii) evaluate the efficacy of this method for patients with asymptomatic OVBFs.

### Materials and Methods

#### Patients

All patients met the following criteria: (i) single-segment OVBFs from T10 to L5; (ii) spinal canal occupational ratio \(\leq 20\%\); (iii) older than 60 years but younger than 85; (iv) no neurological dysfunction; (v) history of trauma &lt;7 days; (vi) low signal on T1-weighted magnetic resonance imaging (MRI) and high signal on short tau inversion recovery (STIR) MRI sequences in the fractured vertebra, with no evidence of complex posterior ligamentous injury.
Additionally, patients with the following phenomena were excluded: (i) pathological fractures; (ii) long-term chronic low back pain; (iii) long-term use of hormone therapy or chemotherapy. The study protocol was approved by the ethics committee of our hospital (No. SH9H-2021-T258-2).

A total of 66 patients with single-segment acute OVBFs in vertebrae from T10 to L5 with a spinal canal occupational ratio under 20% were treated by PVP with lateral opening hole in our operative group between March 2016 and March 2020. Basic data of all patients included age, sex, injury mechanism of fracture, bone density, and spinal canal occupational ratio. The spinal canal occupational ratio was assessed by computed tomography (CT) of the spine using the following equation:

\[
\frac{1 - A}{(B + C)/2} \times 100
\]

where \(A\) is the diameter of the spinal canal at the fractured level, \(B\) is the diameter of the spinal canal at the superior nonfractured level, and \(C\) is the diameter of the spinal canal at the inferior nonfractured level. According to Schnake’s morphological osteoporotic fracture classification, all patients in our study met the criteria for type II of osteoporotic fracture: Deformation without or with only minor involvement of the posterior wall (<1/5). All patients underwent X-ray (GE Healthcare, MA, Boston, USA), CT (Revolution CT, GE Healthcare), and MRI (Achieva 3.0TX, Philips, Amsterdam, Netherlands) before PVP.

### Treatment Strategies

All PVPs in all patients were performed by two surgeons. All procedures were performed under intermittent C-arm fluoroscopic guidance.

### Anesthesia and Position

The patients were placed in the prone position on the operating table. The iliac and chest cushions under the body were used to make the spinal hyperextended position to help partial reduction of fractures. After local anesthesia, marks were made on the skin and a small incision was made by a scalpel blade.

### Puncturing and Injecting

All patients were treated with PVP via bilateral approach. Two 10G bone puncture needles (03.702.218S, Vertecem V+, DePuy Synthes, Raynham, MA, USA) were simultaneously placed transpedicularly in the fractured vertebra. On each side, the required volume of high-viscosity 15% hydroxyapatite and PMMA composite bone cement (07.702.016S, Vertecem V+, DePuy Synthes, Raynham, MA, USA) was determined as \(\approx 1.5-2.0\) ml for the T10 to L5 segments. After puncturing the vertebral body, the outer cannula was retained, and the inner core was removed. Then the lateral-opening injection tool (03.702.218S, Vertecem V+, DePuy Synthes, Raynham, MA, USA) was inserted and the bone cement flowed out only through the side opening hole, which can help to adjust the injection direction (Figures 1 and 2A,B). In order to increase the longitudinal height of bone cement distribution in the vertebral body, the bone cement was injected close to the upper and lower endplates as much as possible. On the other hand, in order to prevent the bone cement from entering the posterior wall or spinal canal, the bone cement injection was controlled between the first quarter and the second third of the vertebral body, as viewed laterally (Figure 2C–E). When cement had infiltrated into the anterior quarter or posterior quarter of the vertebrae, as viewed laterally, the needle was repositioned for further injection, or the injection procedure stopped.
Postoperative Treatment
All patients were observed in the supine position for 4 h after the PVP operation in the ward, and an overnight hospital stay was required. The patients were discharged the next day. All patients were prescribed systematic anti-osteoporosis treatment that included bisphosphonates and vitamin D analogs.

One day after PVP, X-ray and CT were used to assess the bilateral longitudinal height of the bone cement in the treated vertebral body, as well as cement leakage. Following the work of Hou et al., if the minimum distances of bone cement from the upper and lower endplates were both zero, “contacted” bone cement distribution was declared; other conditions were considered to be “uncontacted” bone cement distribution. If the bone cement contacted at least one side, small amounts of physical activity with brace protection for 1 month were recommended. If the bone cement was uncontacted bilaterally, physical activity with brace protection was recommended after absolute bed rest for 3 weeks. Regular activities of the extremities were encouraged during the period of best resting, such as active ankle movement. The time of increased activity was determined by the healing of posterior vertebral wall in CT images. The operative vertebral segments, operative time, and amounts of injected bone cement were recorded for all patients.

Effectiveness Evaluation
To evaluate the therapeutic effect of this operation, patients were followed up for at least 12 months. Visual analog scale (VAS), radiological assessments, and complications were recorded. The VAS is a commonly used questionnaire for quantification of pain. The intensity of pain experienced by the patient was gauged on a scale that went from “no pain” (score of 0) to “unbearable pain” (score of 10). The following evaluated pain using the VAS scores have been recommended: no pain, 0; mild pain, ≤3; moderate pain, 4–6; and severe pain, 7–10. In this study, back pain was assessed according to the VAS preoperatively, 1 day; 1, 3, and 6 months postoperatively, and also at the final follow-up.

Fracture Healing
The vertebral fractures were examined 1 and 3 months postoperatively by CT in all patients. In this study, the disappearance of the fracture line of the posterior wall of the vertebral body in images of CT scan and two-dimensional reconstruction was considered to be the healing of the vertebral fracture of the middle column.

Vertebral Body Height
Anterior–posterior and lateral spinal radiography was tested on day 1 and 1, 3, and 6 months after PVP treatment. The anterior, middle, and posterior vertebral heights were measured from lateral radiographs for the treated vertebra and the adjacent nonfractured vertebrae. The vertebral height ratio was determined by dividing the height of the fractured
Cobb Angle
The kyphosis Cobb angle was measured based on a method proposed by Kuklo et al.26. Briefly, the Cobb angle is the angle between the extension line of the upper endplate of the upper vertebra and the extension line of the lower endplate of the lower vertebra, with the affected vertebra at the center.

Complications
Complications and adverse events were recorded in all patients during follow-up, including cement leakage, postoperative adjacent vertebra fracture, infection, deep vein thrombosis, muscle atrophy, joint stiffness, hypostatic pneumonia, and decubitus ulcers.

Statistical Analysis
SPSS version 19.0 software (SPSS, IBM Corporation, Chicago, Illinois, USA) was used to analyze all data. The quantity results were expressed as mean ± SD, and were analyzed using paired-sample t tests, including pain score on the VAS, vertebral height ratio, and kyphosis Cobb angle at the preoperative and postoperative follow-up time points. The quality results were also evaluated, including the causes of OVBFs, segments of fractured vertebrae, and complications. Significance was set at p < 0.05.

Results
General Patient Information
Our study included 66 patients (mean age 72.10 ± 7.98 years, with 21 men and 45 women). The causes of the OVBFs included traffic accidents (16 cases), high falls (18 cases), low falls (22 cases), and flat falls (10 cases). The mean T score was −2.91 ± 0.35. The mean spinal canal occupational ratio was 12.64% ± 3.28%. There were T10–T11 (13 cases), T12–L1 (36 cases), and L2–L5 (17 cases) fractures. The average follow-up duration was 21.23 ± 9.35 months after surgery.

Surgical Parameters
The mean amount of bone cement was 3.28 ± 0.35 ml in the vertebrae. The mean operative time was 34.02 ± 5.23 min. A total of 44 patients showed a “contacted” bone cement distribution bilaterally; 16 patients showed a “uncontacted” bone cement distribution unilaterally, and six patients showed “uncontacted” bone cement distribution bilaterally.

Clinical Improvement
One day after the operation, all patients obtained obvious relief of back pain (p < 0.05). During the follow-up, the pain scores gradually declined. The scores of VAS were 8.40 ± 0.48 preoperatively, 3.78 ± 0.42 1 day postoperatively, 2.19 ± 0.38 1 month postoperatively, 1.60 ± 0.38 3 months postoperatively, 1.05 ± 0.41 6 months postoperatively, and 0.53 ± 0.40 at last follow-up.

Radiographic Improvement
The radiological outcomes were shown in Table 1. The mean anterior, middle, and posterior vertebral height ratio were significantly increased after PVP compared with the preoperative values in all patients (p < 0.05). With the prolonged follow-up, although the anterior, middle, and posterior vertebral height ratio was slightly decreased, these values still were significantly higher than the preoperative values (p < 0.05). The values of anterior vertebral height ratio were 68.73 ± 3.94% preoperatively, 85.37 ± 3.10% 1 day postoperatively, and 83.43 ± 2.91% 6 months postoperatively. The values of middle vertebral height ratio were 81.32 ± 3.30% preoperatively, 88.65% ± 2.92% 1 day postoperatively, and 87.45% ± 2.87% 6 months postoperatively, respectively. The values of posterior vertebral height ratio were 93.43% ± 2.78% preoperatively, 94.68% ± 2.49% 1 day postoperatively, and 94.00% ± 2.47% 6 months postoperatively. By contrast, the kyphosis Cobb angle was significantly decreased after PVP compared with preoperative values in all patients (p < 0.05). With the prolonged following-up, although the Cobb angle was slightly increased, these values still were significantly lower than the preoperative values (p < 0.05). The values of kyphosis Cobb angle were 14.50° ± 1.04° pre-operatively, 11.38° ± 0.94° 1 day postoperatively, 11.59° ± 0.90° 1 month postoperatively, 11.71° ± 0.92° 3 months postoperatively, and 11.89° ± 0.94° 6 months postoperatively.

Fracture Healing
There were 60 cases of bone cement contacted the upper and lower endplates on at least one side. Obvious callus formation of the posterior wall of the treated vertebral body was found 1 month after PVP among those 60 cases. Among the other six patients with both sides of bone cement uncontacted the upper endplate, the bone cement contacted the adjacent nonfractured vertebrae bilaterally.

| TABLE 1 | Changes in vertebral height ratio during follow-up |
|---------|--------------------------------------------------|
|         | Pre-operation (%) | Postoperative 1 day (%) | Postoperative 1 month (%) | Postoperative 3 months (%) | Postoperative 6 months (%) |
| AVHR    | 68.73 ± 3.94     | 85.37 ± 3.10 *           | 84.91 ± 3.05               | 84.22 ± 3.00               | 83.43 ± 2.91               |
| MVHR    | 81.32 ± 3.30     | 88.65 ± 2.92 *           | 88.48 ± 2.86               | 87.89 ± 2.86               | 87.45 ± 2.87               |
| PVHR    | 93.43 ± 2.78     | 94.68 ± 2.49 *           | 94.54 ± 2.49               | 94.20 ± 2.45               | 94.00 ± 2.47               |

Values = mean ± SD.; Abbreviations: AVHT, anterior vertebral height ratio; MVHT, middle vertebral height ratio; PVHT, posterior vertebral height ratio.; * p < 0.05 versus pre-operation.
and lower endplates, there was slight callus formation of the posterior wall, but no obvious fracture displacement of the posterior wall on the CT scans 1 month postoperatively. The vertebral fractures of all cases healed according to CT results 3 months postoperatively. No patients suffered refractures of the treated vertebral body. Typical X-rays and CT scans at different time points are shown in Figures 3–5.

Complications
Cement leakage was observed in seven patients, but none of these patients suffered any clinical symptoms. The cement leakages included lateral venous (two cases), anterior fracture (two cases), lateral fracture (two cases), and disk (one case) leakage. All patients with asymptomatic cement leakage were recommended to follow-up. New adjacent vertebral fractures (two cases) and nonadjacent vertebral fractures (one case) caused by flat falling occurred at 13, 15, and 16 months postoperatively and these cases recovered well after PVP treatment again. During bed rest, one patient suffered an infection of the urinary system, and recovered after antibacterial therapy. No patients suffered deep vein thrombosis, muscle atrophy, joint stiffness, hypostatic pneumonia, or decubitus ulcers.

Discussion
For older patients who suffered vertebral body fractures with posterior wall disruption, namely OVBFs, treatments were aimed at reducing back pain and promoting healing of vertebral fractures, thus avoiding further fractured fragment displacement leading to nerve compression. The mechanical stability of the fractured vertebral body is one of the most critical factors affecting union of the fracture. Therefore, we attempted to inject bone cement as close as possible to the endplate by a lateral-opening injection tool; this procedure helped provide mechanical stability of the fractured vertebral body. The bone cement was symmetrically and evenly distributed in the anterior to middle part of the vertebral body, increasing the stability of the vertebra while reducing the risk of bone cement leakage into the spinal canal. All patients got significant back pain relief after treatment and most patients achieved early movement out of bed. The bone fragments of posterior vertebral wall healed in all patients.

The Potential Treatment for OVBFs by PVP
Some attempts have been made to use PVP or PKP to treat OVBFs, with satisfactory results. For example, Nakano et al. first performed PVP using calcium phosphate cement to treat patients with thoracolumbar burst fractures without neurological deficits. Then Hiwatashi and Westesson found that patients with OVBFs and spinal canal compromise could be safely treated using PVP, and that this treatment could reduce pain, decrease the wedge angle, and increase the vertebral body height. Furthermore, other authors reported that PKP is an effective and safe method for treating patients with OVBFs with spinal canal compromise, achieving obvious kyphotic angle reduction and vertebral height restoration and further leading to good pain relief and functional improvement.

Managing and Healing of the Fracture Posterior Wall of the Vertebral Body
However, none of these reports specifically mentioned how to deal with the posterior wall of the fractured vertebral bodies and healing of the fractured posterior wall; this is a fundamental issue behind the controversy over using PVP or PKP to treat OVBFs. In clinical practice, we found that there were some risks when using traditional anterior opening bone cement injection tools for OVBFs. On the one hand, it was difficult to inject sufficient bone cement to increase the stability of the fractured vertebral body. On the other hand, using the traditional tool, the bone cement flowed out through an anterior opening. As a result, the bone cement may flow directly along the fracture gap or trabecular space to the posterior wall of burst vertebral fracture, which might lead to a leakage of bone cement into the spinal canal through the fractured posterior wall or push the burst fracture fragments backward, ultimately causing nerve compression. In this study, the bone cement was injected and controlled directly via a lateral opening and kept away from the fractured posterior wall of the vertebral body. Thus, the safety during the operation could be ensured, and the amount of injected bone cement could be reached on demand. In addition, the lateral-opening injection tool could be used to minimize the amount of bone cement in the central area of the vertebral body, which might reduce the blood supply to the fractured areas to some extent. We suggested that the union of the posterior vertebral wall in OVBFs could increase the stability of the fractured vertebral body, further reducing the risk of bone cement leaking into the spinal canal and nerve compression resulting from bone cement loosening. In addition, the displacement of bone cement to the spinal canal after PVP or PKP is usually due to incomplete healing of the posterior wall of the vertebral body. Therefore, we specifically observed the bone healing of the posterior wall of the fractured vertebral body. The bone cement in our patients was distributed at some distance from the fractured posterior fragments, to avoid the bone cement obstructing the blood supply of the bone fragments and provide the possibility of observing bone healing during imaging follow-up. One month after the operation, CT showed callus formation at the posterior wall of the fractured vertebral body, which was a clear sign of bone healing. Three months after the operation, CT showed that the bone fragments of the posterior fractured vertebral body had healed in all cases. In addition, there was no significant loss of vertebral height at 6 months postoperatively, compared with 1 day, 1, or 3 months postoperatively. No patients complained of nerve dysfunction symptoms caused by bone cement loosening in the long-term follow-up. These results proved that the posterior stability of the fractured vertebral body in OVBFs was important for long-term prognosis and suggested that our...
surgical procedures were helpful for the union of fractures in the posterior vertebral wall.

**The Height of Bone Cement in the Fractured Vertebral Body**
The distance between the bone cement and the endplate is a crucial risk factor for the stability of the treated vertebrae after PVP or PKP. The closer the bone cement was to the upper and lower endplates, the better the stability of the longitudinal support of the vertebral body. In addition, an even cement distribution in the fractured vertebral body might be optimal for providing better stability than bulky bone cement. Symmetrical bilateral injection of bone cement might promote even cement distribution.

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**Fig. 3** Typical case 1: A 68-year-old woman with asymptomatic OVBFs treated using our method. (A) Anterior–posterior and lateral spinal X-rays, preoperatively and 1 day postoperatively. There was a contacted bone cement distribution and obvious anterior and middle vertebral height ratio restoration after PVP. (B) Transverse axial CT scans at different time points. There was continuous callus formation of the posterior wall of the treated vertebral body 1 month postoperatively. The fracture had healed by 3 months postoperatively. (C) Corresponding sagittal reconstruction images of CT scans preoperatively and 3 months postoperatively. There was obvious bone healing of the posterior wall of the treated vertebrae. OVBFs, osteoporotic vertebral burst fractures; PVP, percutaneous vertebroplasty.
Fig. 4 Typical case 2: A 67-year-old woman with asymptomatic OVBFs treated using our method. (A) Anterior–posterior and lateral spinal X-rays, preoperatively and 1 day postoperatively. (B) Transverse axial CT scans, preoperatively and 3 months postoperatively. (C) Corresponding sagittal reconstruction images of CT scans, preoperatively and 3 months postoperatively. OVBFs, osteoporotic vertebral burst fractures.
Fig. 5 Typical case 3: A 82-year-old woman with asymptomatic OVBFs treated using our method. (A) Anterior–posterior and lateral spinal X-rays, preoperatively and 1 day postoperatively. (B) Transverse axial CT scans, preoperatively and 3 months postoperatively. (C) Corresponding sagittal reconstruction images of CT scans, preoperatively and 3 months postoperatively. OVBFs, osteoporotic vertebral burst fractures.
posterior wall of the vertebral body was damaged in patients with OVBFs, to reduce the risk of bone cement leakage into the spinal canal many surgeons would inject bone cement only into the anterior three-quarters of the vertebrae. If the patients want to get out of bed early, the vertical support provided by the bone cement in the anterior three-quarters of the vertebral body is essential to share the vertical load on the posterior wall of the fractured vertebral body to avoid nonunion or displacement of bone fragments. Using a lateral-opening bone cement injection tool, the direction of the lateral opening can be adjusted to control the distribution of the bone cement to be as close as possible to the upper and lower endplates. Meanwhile, this method could reduce the bulkiness of the injected bone cement and make more longitudinal height of bone cement distribution in the vertebral. In our study, 60/66 cases demonstrated a contacted bone cement distribution on at least one side, and the bone cement distribution was symmetrical and even between the anterior quarter and posterior two-thirds of the vertebrae, providing adequate mechanical support for the fractured vertebral body. This is helpful for the healing of posterior bone fragments.

Stability of Vertebral Burst Fracture after PVP
According to the Denis three-column system, the completed middle column structure, including the posterior wall of the vertebral body, the posterior longitudinal ligament, and the posterior annulus fibrosus, was very important in maintaining the stability of the spine. Although the bone cement could increase the stability of the anterior part of the vertebral body, whether the whole vertebral body could bear the longitudinal load was not fully determined because there was a stability defect of the posterior quarter of the vertebral body. In some reports about PVP or PKP treatment for OVBFs, attention was not specifically paid to the need for bed rest, and related recommendations were not proposed. Once older patients experienced poor healing of vertebral body fractures, such as refracture and Kummel diseases, they usually need to undergo reoperations with additional financial burden. Therefore, we recommended that patients performed some simple activities with lumbar brace protection for 1 month after the operation. In addition, previous studies have suggested that the distance between the bone cement and endplate could affect the stability of fractured vertebral bodies. Therefore, for the purpose of clinical safety, we recommended that six patients with uncontacted bone cement distribution stayed in bed for 3 weeks to increase the stability of the fractured vertebral bodies in the early stage. At the 3 month follow-up, CT showed that the fractures had healed in all patients, and no patients experienced new burst fractures of the posterior wall in the treated vertebral body. Because the amount of time for bed rest was short, and moderate activities in bed were encouraged, complications from bed rest were rare in our patients, except for one patient who suffered an infection of the urinary system.

Limitations
There were some limitations in our study. First, the sample size was small; this should be expanded in further studies. Second, for clinical safety, patients with uncontacted bone cement distribution were advised to remain under absolute bed rest for 3 weeks. However, there was no evidence as to whether bed rest protection was necessary or on the appropriate length of bed rest for patients with uncontacted cement distribution. Third, it was not confirmed whether patients with a higher spinal canal occupational ratio could be treated using our method, which should be further studied.

Conclusions
In summary, using a lateral-opening injection tool in PVP procedure can improve the distribution height of bone cement and decrease the risk of bone cement into the posterior wall of vertebrae. The methods were very safe and effectively used in the PVP treatment on asymptomatic OVBFs with mild spinal canal compromise.

Author Contributions
All authors had full access to the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Conceptualization: Kangping Shen and Wenjie Jin. Methodology: Xin Sun, Jia Wang, and Wenjie Jin. Investigation: Xiang Wang, Kangping Shen, and Wenjie Jin. Formal analysis: Xin Sun, Jia Wang and Xingzhen Liu. Resources: Xin Sun, Hairong Tao, and Wenjie Jin. Writing - original Draft: Xin Sun, Jia Wang, Tong Zhu, and Wenjie Jin; Writing - review & editing, Xin Sun, Jia Wang, and Wenjie Jin; Visualization, Kangping Shen and Wenjie Jin; Supervision, Kangping Shen and Wenjie Jin; Funding acquisition, Wenjie Jin.

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