Percutaneous mesh-container-plasty for osteoporotic thoracolumbar burst fractures: A prospective, nonrandomized comparative study

Chengxuan Tang, Xiaojun Tang, Wei Zhao Zhang, Minghai Dai, Maoxiu Peng, Shaoqi He

Department of Orthopedic Surgery, Third Affiliated Hospital of Wenzhou Medical University, Wenzhou, Zhejiang, China

ABSTRACT

Objective: This study aimed to compare the clinical and radiological results of percutaneous mesh-container-plasty (PMCP) versus percutaneous kyphoplasty (PKP) in the treatment of osteoporotic thoracolumbar burst fractures.

Methods: A prospective study of 122 patients with osteoporotic thoracolumbar burst fractures was conducted. The patients were nonrandomly assigned to receive PKP (62: 16 men, 46 women) and PMCP (60: 14 men, 46 women). The epidemiological data, surgical outcomes, and clinical and radiological features were compared between the 2 groups. Cement leakage, height restoration, deformity correction, canal compromise, and cement distribution were calculated from the radiographs. Visual pain analog scale [VAS], the Oswestry disability index [ODI], and short-form 36 health survey domains role physical [SF-36 rp] and bodily pain [SF-36 bp] were calculated before surgery and immediately and 2 years after surgery.

Results: Although VAS, ODI, SF-36 bp, and SF-36 rp scores improved from 7 (6-9), 71.28±16.38, 22 (0-32), and 25 (0-50) preoperatively to 2 (1-3), 20.02±8.97, 84 (84-84), and 75 (75-100) immediately postoperatively in the PKP group (p<0.05) and from 7 (6-9), 71.46±13.52, 22 (10.5-31.75), and 25 (0-50) preoperatively to 2 (1-3), 21.78±11.21, 84 (84-84), and 75 (75-100) immediately postoperatively in the PKP group (p<0.05), there was no difference between the 2 groups. The mean cost in the PKP group was less than that in the PMCP group ($5109±231 vs. $6699±201, p<0.05). Anterior, middle, and posterior vertebral body height ratios in the PMCP group were greater than those in the PKP group postoperatively (88.64%±3.76% vs. 81.10%±11.78%, 86.15%±3.59% vs. 82.30%±11.82%, and 93.01%±3.01% vs. 91.43%±6.71%, respectively, p<0.05). The Cobb angle in the PMCP group was lower than that in the PKP group postoperatively (6.67°±4.39° vs. 8.99°±4.06°, p<0.05). Cement distribution in the PMCP group was higher than that in the PKP group (30.48%±5.62% vs. 91.43%±6.71%, respectively, p<0.05). Cement leakage was observed to be lesser in the PKP group (2/60) than in the PMCP group (10 vs. 62, p<0.05).

Conclusion: Both PKP and PMCP treatments seem to have significant ability in pain relief and functional recovery. Despite its higher cost, PMCP treatment may have a better inhibition ability of cement leakage, cement distribution, height restoration, and improvement in segmental kyphosis than PKP treatment for osteoporotic thoracolumbar burst fractures.

Level of Evidence: Level II, Therapeutic Study

Introduction

Because of the demographic development toward an older society, the annual incidence of osteoporosis and its associated fractures is prevalent. Osteoporotic vertebral fractures (OVFs) can affect the patient’s quality of life, including chronic back pain, functional limitations, depression, and disability, which have grown to be an important health issue (1).

Osteoporotic thoracolumbar burst fractures are severe type of OVFs. The management of osteoporotic thoracolumbar burst fractures has not been properly coded to date. However, the surgical treatment of these fractures seems to reduce pain and mobilize the patients more quickly; therefore, the hospital stay is shorter in this case. Many patients with osteoporotic thoracolumbar burst fractures without neurologic deficit have recently undergone kyphoplasty with good clinical and radiological results (2, 3). However, there have been some complications, including cement leakage, loss of the restored height, and kyphotic alignment after balloon deflation before cement injection (4-6). The risk of cement leaking into the spinal canal is greater when the posterior wall has been damaged.

To avoid these complications, a mesh container was developed with advantages of cement leakage, height restoration, and kyphotic angle reduction (7). During the cement injection process, continuous cement injection makes the mesh container produce a pressure; thereafter, the cement leaks outside of the mesh container and enters the bone trabeculae. Therefore, better inhibition ability of cement leakage can be achieved. The mesh container remains within the newly created vertebral cavity, and the balloon can be removed after deflation while preventing the vertebral body from collapsing. Thus, virtually, the physiological vertebral body height and shape might be restored and preserved.

On the basis of these previous studies, we hypothesize that there will be differences in the clinical efficacy and safety of percutaneous mesh-container-plasty (PMCP) and percutaneous kyphoplasty (PKP) for treatment of osteoporotic thoracolumbar burst fractures. To test this hypothesis, we compared the clinical and radiological results of PMCP and PKP for treatment of osteoporotic thoracolumbar burst fractures.
Materials and Methods

Study design

Ethical approval for this prospective, nonrandomized study was provided by the ethics committee of the authors’ institute. The patients were given sufficient explanation of the study goals, and they signed a consent form. The inclusion criteria were as follows: 1) elderly (≥60 years), 2) thoracolumbar (T10 to L2) single fresh burst fractures [type A3 or A4 according to the AOspine thoracolumbar spine injury classification system] (9), 3) minor injury or no history of trauma without neurological deficit, 4) constant ache and fatigue in the thoracolumbar vertebrae that can significantly affect daily life, and 5) diagnosed with osteoporosis according to the T value of dual-energy X-ray absorptiometry (DXA) less than −2.5. The exclusion criteria were as follows: 1) symptoms of neurological deficits, 2) polytraumatized patients, 3) patients with pre-existing spinal deformity or previous spinal operation, 4) clinical or imaging evidence of the metastatic bone tumor or multiple myeloma, 5) asymptomatic fractures, 6) systemic or local infections and severe bleeding disorders, and 7) other OVF types.

From January 2016 to December 2017, 170 consecutive patients who sustained the osteoporotic thoracolumbar burst fractures without neurologic deficit were included in this study. After a comprehensive explanation of this study and expected benefits and risks, 32 patients refused to participate in the study. After applying the exclusion criteria, we analyzed 122 patients who underwent PKP (PKP group, n=62) and PMCP (PMCP group, n=60). The differences between PKP and PMCP were explained to all the patients before surgery, and the surgical methods were selected according to patient preference.

Preoperatively, standard clinical examination and evaluation, including the medical history, physical examination of percussion pain, assessment of the pain intensity (visual analog scale [VAS]) and activity level (Oswestry disability index [ODI]) (9), and short-form 36 health survey domains role physical (SF-36 rp) and bodily pain (SF-36 bp) (10) were evaluated. X-rays of the relevant spinal region in 2 planes, computed tomography (CT) scan, magnetic resonance imaging (MRI) (T1-weighted and T2-weighted sequences including short tau inversion recovery sequences), and DXA were performed.

All the patients underwent operations within 4 days of admission to relieve pain, restore the vertebral body height, and correct the segmental kyphosis. All patients received a calcium supplementation (1,000 mg of elemental calcium daily), vitamin D (600 UI daily), and alendronate (70 mg weekly).

Surgical technique

All surgical procedures were performed under local anesthesia. The patients were positioned in a prone position on 4 bolsters placed on a radioisolant operating table with the abdomen freely 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 at the fractured vertebra through pedicular approach 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. Inflation continued until the balloon pressure reached 300 psi. The anteroposterior radiograph showed that the balloon size exceeded the midline of the vertebra. Then, the balloon was deflated and removed. If the balloon does not exceed the midline of the vertebra, a bilateral puncture is required.

In the PKP group, poly-(methyl methacrylate) (PMMA) cement was injected into the defect of the fractured body through the cannula under continuous fluoroscopic monitoring. The PMMA insertion was considered complete when it reached the posterior third of the vertebral body or had a potential tendency of cortical, epidural, and anterior venous cement leakage. In the PMCP group, a mesh container (Shandong Guanlong Medical Utensils Co., Ltd.) was advanced into the cavity. The mesh container was made of polyethylene terephthalate. Thereafter, the PMMA cement was manually injected into the mesh container within the treated vertebral body by applying a cement perfusion apparatus under fluoroscopic guidance. With the continuous injection of PMMA, the mesh container was inflated, and the height of the fractured vertebra was restored. At a certain injection amount, the PMMA cement leaked outside of the mesh container from the meshes and entered the bone trabeculae (Figure 1 and Supplementary figure 1).

A neurologic examination was performed soon 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 fracture, improvement in the segmental kyphosis, and functional recovery.

HIGHLIGHTS

- Both PKP and PMCP treatments seem to have significant ability in pain relief and functional recovery.
- PMCP treatment may have a better inhibition ability of cement leakage, cement distribution, height restoration, improvement in segmental kyphosis than PKP treatments for osteoporotic thoracolumbar burst fractures.
- The cost of PMCP treatment is higher than that of PKP treatment.
tal kyphosis, and distribution of the cement. Operation time, estimated blood loss, cost, hospital stay, cement volume, and complications (cement leakage, cerebrospinal fluid leakage, and infection) were also noted. Back pain intensity was recorded on VAS (0=no pain, 10=worst pain). Functional outcome was evaluated using ODI, SF-36 rp, and SF-36 bp. All the patients were postoperatively followed up clinically and radiologically immediately; at 1, 3, and 6 months; and at 1 and 2 years.

The Cobb angle and the anterior, middle, and posterior vertebral body height ratios (AVBHr, MVBHr, and PVBHr, respectively) were measured using the lateral radiograph as described in a previous study (11, 12) Cement distribution and canal compromise were calculated using the CT images (Figure 2). Cement leakage was determined using the CT images of all the sections of the fractured vertebra.

Furthermore, 2 independent blinded spine surgeons performed the clinical evaluation of patients. Additionally, 3 other independent blinded spine surgeons assessed the radiographs.

Statistical analysis
Statistical analysis was performed using the Statistical Package for the Social Sciences version 18.0 software IBM SPSS Corp.; Armonk, NY, USA). The numerical variables were presented as means±standard deviation or median (interquartile range). The Student’s t 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, SF-36, AVBHr, MVBHr, PVBHr, and the Cobb angle preoperatively, postoperatively, and 2 years postoperatively. The nominal variables (sex, distribution of the fractured vertebra, fracture type, and cement leakages) were presented as numbers (percentages) and compared using the chi-square test. A two-sided p-value of <0.05 was considered statistically significant.

Results
The clinical characteristics of the 122 patients are summarized in Table 1. There were no statistical differences in the demographic data including age, sex, distribution of the fractured vertebra, fracture type, T-score, body mass index, and injury time between the 2 groups. The mean cost in the PKP group was less than that in the PMCP group ($5109±231 vs. $6699±201, p<0.05). There were no significant differences in the blood loss, operation time, and hospital stay between the 2 groups. The details are shown in Table 2.

Clinical evaluation
The VAS scores decreased from preoperative 7 (6-9) to postoperative 2 (1-3) in the PMCP group (p<0.05) and from preoperative 7 (6-8) to postoperative 2 (1-3) in the PKP group (p<0.05). The ODI scores decreased from preoperative 71.28±16.38 to postoperative 20.02±8.97
Table 1. Basic characteristics and comparative analysis between PKP and PMCP for the treatment of the 122 patients with osteoporotic thoracolumbar burst fractures in this study (x±s or median [interquartile range])

| Fracture type | PKP (n=62) | PMCP (n=60) |
|---------------|------------|-------------|
| Age (years)   | 71.37±12.04 | 71.38±6.63 |
| Male/female   | 16/46      | 14/46       |
| Distribution  | 1.01±0.03  | 1.00±0.03   |
| T10           | 5          | 5           |
| T11           | 6          | 8           |
| T12           | 17         | 12          |
| L1            | 20         | 24          |
| L2            | 14         | 11          |
| T-score       | −2.96±0.38 | −3.04±0.46 |
| BMI           | 23.77±4.25 | 23.51±3.71 |
| Injury time   | 4±2.31     | 4.30±2.21  |

PKP: percutaneous kyphoplasty; PMCP: percutaneous mesh-container-plasty; BMI: body mass index.

Table 2. Comparison of perioperative parameters between the PKP and PMCP groups for the treatment of the 122 patients with osteoporotic thoracolumbar burst fractures in this study (x±s or median [interquartile range])

| Fracture type | PKP (n=62) | PMCP (n=60) | t or Z | p |
|---------------|------------|-------------|-------|---|
| Operation time (min) | 31.71±6.23 | 32.47±5.57 | −0.843 | 0.401 |
| Blood loss (mL) | 6.34±1.87 | 6.20±1.18 | 0.038 | 0.700 |
| Hospital stay (days) | 4.24±1.51 | 4.37±1.83 | 0.411 | 0.662 |
| Cost (dollar) | 5199±921 | 6699±201 | −40.477 | <0.001 |
| Cement leakage | 10/62 | 0/60 | χ²=6.629 | 0.018 |
| Cement volume (mL) | 7.5 | 7.5 | Z=−0.348 | 0.727 |

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

Table 3. Clinical comparisons between the PKP and PMCP groups for the treatment of the 122 patients with osteoporotic thoracolumbar burst fractures in this study (x±s or median [interquartile range])

| Fracture type | PKP (n=62) | PMCP (n=60) | t or Z | p |
|---------------|------------|-------------|-------|---|
| VAS Preoperative | 7 (6–8) | 7 (6–9) | Z=0.547 | 0.584 |
| Postoperative | 2 (1–3)* | 2 (1–3)* | Z=−0.451 | 0.652 |
| 2 years postoperative | 2 (1–2)* | 2 (1–2)* | Z=−3.05 | 0.652 |
| ODI Preoperative | 71.40±13.52 | 71.28±16.38 | t=0.043 | 0.996 |
| Postoperative | 21.78±11.21* | 20.02±8.97* | t=0.953 | 0.342 |
| 2 years postoperative | 16.02±7.76* | 16.13±7.27* | t=−0.085 | 0.932 |
| SF-36 bp Preoperative | 84 (84–84)* | 84 (84–84)* | Z=0.158 | 0.114 |
| Postoperative | 84 (84–91.5)* | 84 (84–94)* | Z=−0.109 | 0.913 |
| SF-36 rp Preoperative | 22 (10–31.75) | 22 (0–32) | Z=0.547 | 0.584 |
| Postoperative | 84 (84–84)* | 84 (84–94)* | Z=0.158 | 0.114 |
| 2 years postoperative | 84 (84–91.5)* | 84 (84–94)* | Z=−0.109 | 0.913 |

*Repeated measures variance analysis was used for the statistical analysis. There were significant differences (p<0.05) between the postoperative or 2 years postoperative and preoperative values of these 2 groups.

PKP: percutaneous kyphoplasty; PMCP: percutaneous mesh-container-plasty; VAS: visual pain analog scale; ODI: Oswestry disability index; SF-36: short-form 36 health survey.

Radiologic evaluation

The AVBHr, MVBHr, PVBrh, and Cobb angle scores improved from preoperative (66.72±5.35, 67.81±5.04, 87.31±3.30, and 13.31±6.46, respectively) to postoperative (88.44±3.76, 86.15±3.50, 89.11±3.01, and 6.67±4.39, respectively) in the PMCP group (p<0.05) and from preoperative (65.69±10.51, 68.34±12.74, 86.69±6.78, and 11.88±4.28, respectively) to postoperative (81.10±11.78*, 67.81±5.04, 86.15±3.5*, and 5.28±0.012, respectively) in the PKP group (p<0.05). The Cobb angle in the PKP group was lower than that in the PMCP group postoperatively (p<0.05). Therefore, although both PKP and PMCP treatments had a significant ability for pain relief and functional recovery postoperatively and at 2 years postoperatively, there was no difference between the 2 groups.

Therefore, although both PKP and PMCP treatments had a significant ability for pain relief and functional recovery postoperatively and at 2 years postoperatively, there was no difference between the 2 groups.
Therefore, PKP and PMCP treatments could significantly restore the height and improve the segmental kyphosis of the fractured vertebral body. The PMCP group had significantly higher height restoration, improvement in the segmental kyphosis, and cement distribution than the PKP group, which indicated that PMCP treatment had a better ability to treat the vertebral body than PKP treatment.

### Surgical complications

After the surgeries, CT was performed immediately to assess PMMA cement leakage. PMMA cement leakage was observed in 16% (10/62) patients of the PKP group (2 anterior to the vertebral body, 1 lateral to the vertebral body, and 7 into the disk without sequela) and in 3.33% (2/60) of patients in the PMCP group (1 anterior to the vertebral body and 1 into the disk without sequela) (p<0.05) (Table 2). Furthermore, cement leakage was observed in 6.67% (2/30) patients of the PKP group and 3.70% (1/27) patients of the PMCP group of fracture type A3 (p<0.05) and 25% (8/32) patients of the PKP group and 3.03% (1/33) patients of the PMCP group of fracture type A4 (p<0.05) (Table 5). All the cement leakages were asymptomatic, and no surgical intervention was required to remove the extravasated cement. Postoperative complications, such as neurological functional aggravation, hemorrhage, wound healing abnormalities, infection, and pulmonary embolism, were not observed during the 2-year follow-up period. These analyses indicate that PMCP treatment had better safety than PKP treatment for A4 fractures.

### Discussion

Osteoporosis and associated fractures are prevalent in clinics. A standardized treatment strategy for osteoporotic thoracolumbar burst fractures does not exist at present (2, 13-16). PKP has been increasingly used in older people currently because it is a minimally invasive treatment. However, the major disadvantages of PKP are cement leakage and loss of the restored height and kyphotic alignment after balloon deflation before cement injection. Therefore, the mesh container was developed (7).

This research showed that PMCP treatment had better safety than PKP treatment in terms of cement leakage, ability in cement distribution, height restoration, and improvement in the segmental kyphosis. Cementoplasty involves risks of complications, including pulmonary embolism, intradiscal cement leakage, neurological deficit, and even paraplegia (4, 6, 17). The cavity created in PKP treatment may decrease the cement perfusion pressure as well as the possibility of cement leakage. A4 fractures are complete burst fractures involving the posterior wall with an increased risk of cement leakage into the vertebral canal during the classical vertebroplasty and kyphoplasty interventions. The mesh container in PMCP treatment keeps the PMMA cement inside the container, and only partial cement leaks outside from the mesh to the bone trabecula. In this study, cement leakage was observed in 6.67% (2/30) patients of the PKP group and 3.70% (1/27) patients of the PMCP group of fracture type A3 (p<0.05) and 25% (8/32) patients of the PKP group and 3.03% (1/33) patients of the PMCP group of fracture type A4 (p<0.05) (Table 5). The possible mechanism for height restoration and improvement in the segmental kyphosis of the treated fractured vertebral body and the clinical outcome (pain reduction) (18, 19). In this study, height restoration and improvement in the segmental kyphosis in the PMCP group were both higher than those in the PKP group. However, the clinical outcome was not significantly different between these 2 groups. Previous studies indicated that PKP was not useful for height restoration and improvement in the segmental kyphosis. The improvement in segmental kyphosis was attributed to postural reduction with cement strengthening. The most significant factors affecting the improvement in segmental kyphosis were the fracture type and the volume of cement injected (11, 20, 21). This study showed that improvement in the segmental kyphosis in the PMCP group was higher than that in the PKP group with respect to both A3 and A4 fractures (Supplementary Table 1). The possible mechanism for height restoration and kyphosis correlation is the inflation of the mesh container.

Cement is the key factor for stabilizing the injured vertebrae by filling the bone cavity. When the cement volume (22) remains constant, the more extensive cement distribution leads to better surgical outcomes (23-25). In this study, cement distribution in the PMCP group was higher than that in the PKP group. An extensive cement distribution can improve the kyphotic angle and vertebral height effectively, without causing cement leakage or adjacent vertebral fractures (25). High distribution of the cement in the vertebral body in the PMCP group could possibly affect height restoration and improvement in the segmental kyphosis of the treated fractured vertebral body and the rate of new fracture.

In this study, although both PKP and PMCP treatments had significant ability in pain relief and functional recovery for the treatment of osteoporotic thoracolumbar burst fractures, there was no difference between the 2 groups. Previous studies also found that there was no significant difference of clinical outcome between shield kyphoplasty, vertebroplasty, and balloon kyphoplasty (26).

For patients using PMCP as our preceding operative method, the average cost is relatively higher than that for patients using PKP.

The major shortcomings of this study are that the results were available from a small patient population and a short follow-up duration. Another limitation of this study is its nonrandom nature. Prospective, randomized controlled studies enrolling more patients with long-term follow-ups are needed to evaluate the clinical and radiographic efficiency of PMCP more reliably and objectively.

In conclusion, both PKP and PMCP treatments seem to have significant ability in pain relief and functional recovery. Despite higher cost, PMCP treatment may have a better inhibition ability of cement leakage, cement distribution, height restoration, and improvement in the segmental kyphosis than PKP treatment for osteoporotic thoracolumbar burst fractures.

**Supplementary Table 1. Comparison of the Cobb angle (°) between the PKP and PMCP groups with respect to the fracture type**

| Fracture type | PKP (n=62) | PMCP (n=60) | t   | p     |
|--------------|------------|-------------|-----|-------|
| A3 Preoperative | 11.45±4.37 | 12.77±4.08 | -1.823 | 0.074 |
| Postoperative | 8.68±4.13  | 7.77±4.24  | 1.756 | 0.085 |
| % Changes     | 23.66±12.73| 20.68±13.69| -0.168| <0.001|
| 2 years postoperative | 9.2±4.19  | 5.05±2.81  | 1.272 | 0.209 |
| % Changes     | 20.95±12.7 | 24.3±8.81  | -0.183| <0.001|
| A4 Preoperative | 12.27±4.08 | 12.77±4.81 | -0.358 | 0.722 |
| Postoperative | 8.92±3.98  | 6.49±4.41  | 2.333 | 0.023 |
| % Changes     | 28.22±15.98| 50.68±16.76| -5.527| <0.001|
| 2 years postoperative | 9.81±4   | 7±5.8     | 2.634 | 0.011 |
| % Changes     | 20.68±13.69| 44.04±22.15| -5.132| <0.001|

PKP: percutaneous kyphoplasty; PMCP: percutaneous mesh-container-plasty
11. Xu C, Liu HX, Xu HG. Analysis of related factors on the deformity correction of balloon kyphoplasty. AJNR Am J Neuroradiol 2014; 35: 202-6. [Crossref]
12. Thaler M, Lechner R, Nagler M, Göttinger M, Bach C. Surgical procedure and initial radiographic results of a new augmentation technique for vertebral compression fractures. Eur Radiol 2018; 28: 806-16. [Crossref]
13. Ender SA, Eschler A, Ender M, Merk HR, Kayser R. Fracture care using percutaneously applied titanium mesh cages (OsseoFix®) for unstable osteoporotic thoracolumbar burst fractures is able to reduce cement-associated complications—results after 12 months. J Orthop Surg Res 2015; 10: 175. doi: 10.1186/s13018-015-0322-5. [Crossref]
14. Bakhsheshian J, Dahdaleh NS, Fakurzadeh S, Scheer JK, Smith ZA. Evidence-based management of traumatic thoracolumbar burst fractures: a systematic review of nonoperative management. Neurosurg Focus 2014; 37: E1. [Crossref]
15. Song X, Wang W, Yan Y, Zuo J, Yao N, Lin H. Clinical effect evaluation of percutaneous vertebroplasty combined with the spinal external fixator for the treatment of osteoporotic compressive fractures with posterior vertebral defect. Eur Spine J 2014; 23: 2711-7. [Crossref]
16. He S, Lin L, Tang X, et al. The treatment of osteoporotic thoracolumbar severe burst fractures with short pedicle screw fixation and vertebroplasty. Acta Orthop Belg 2014; 80: 493-500.
17. Hong SJ, Lee S, Yoon JS, Kim JH, Park YK. Analysis of intradiscal cement leakage during percutaneous vertebroplasty: multivariate study of risk factors emphasizing preoperative MR findings. J Neuroradiol 2014; 41: 195-201. [Crossref]
18. Feltes C, Fountas KN, Machinis T, et al. Immediate and early postoperative pain relief after kyphoplasty without significant restoration of vertebral body height in acute osteoporotic vertebral fractures. Neurosurg Focus 2005; 18: e3. [Crossref]
19. McKiernan F, Faciszewski T, Jensen R. Does vertebral height restoration achieved at vertebroplasty matter. J Vasc Interv Radiol 2005; 16: 973-9. [Crossref]
20. Hiwatashi A, Westesson PL, Yoshizuka T, et al. Kyphoplasty and vertebroplasty to produce the same degree of height restoration. AJNR Am J Neuroradiol 2000; 30: 669-73. [Crossref]
21. Kanayama M, Oha F, Iwata A, Hashimoto T. Does balloon kyphoplasty improve the global spinal alignment in osteoporotic vertebral fracture. Int Orthop 2015; 39: 1137-43. [Crossref]
22. Nieuwenhuijze MJ, Bollen L, van Erkel AR, Dijkstra PD. Optimal intravertebral cement volume for osteoporotic vertebral compression fractures: an analysis of clinical data. AJNR Am J Neuroradiol 2017; 38: 1431-6. [Crossref]
23. Liang D, Ye LQ, Jiang XB, et al. Biomechanical effects of cement distribution in the fractured area on osteoarticular compression fractures: a three-dimensional finite element analysis. J Surg Res 2015; 195: 246-56. [Crossref]
24. Zhang L, Wang Q, Wang L, Shen J, Zhang Q, Sun C. Bone cement distribution in the vertebral body affects chances of recompression after percutaneous vertebroplasty treatment in elderly patients with osteoporotic vertebral compression fractures. Clin Interv Aging 2017; 12: 421-6. [Crossref]
25. He X, Li H, Meng Y, et al. Percutaneous kyphoplasty evaluated by cement volume and distribution: An analysis of clinical data. Pain Physician 2016; 19: 499-506. [Crossref]
26. Endres S, Badura A. Shield kyphoplasty through a unipedicular approach compared to vertebroplasty and balloon kyphoplasty in osteoporotic thoracolumbar fracture: A prospective randomized study. Orthop Traumatol Surg Res 2012; 98: 334-340. [Crossref]