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Clinical effect of unilateral balloon infusion of low dose bone cement in PKP for osteoporotic thoracolumbar compression fractures in the elderly

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Abstract. – OBJECTIVE: The study was undertaken to determine the clinical effectiveness of percutaneous kyphoplasty (PKP) with unilateral balloon infusion of low dose of bone cement for treatment of osteoporotic vertebral compression fractures (OVCFs) in the elderly.

PATIENTS AND METHODS: A retrospective study was carried out. A total of 36 patients with OVCFs treated by PKP from August 2019 and August 2020 were included. Patients were divided into two groups according to the amount of bone cement infused into the vertebral body. The amount of cement in conventional-dose group was 3.5-6.0 mL and the amount of cement in small-dose group was 1.8-3.0 mL. Pain relief before and after the operation were evaluated, and the leakage of bone cement in the two groups was also observed.

RESULTS: Two groups of patients have obtained a good clinical efficacy. Pain has significant differences before and after the operation ($p < 0.05$). More importantly, compared with conventional-dose group, small-dose group has lower bone cement leakage rate ($p < 0.05$).

CONCLUSIONS: PKP with small-dose bone cement infusion can obtain the same clinical effects of conventional-dose, but the incidence of bone cement leakage is lower and safe.

Key Words:
Osteoporosis, Vertebral compression fracture, Kyphoplasty, Bone cement, Dosage.

Introduction

Osteoporotic vertebral compression fracture (OVCF) in the elderly result from reduced bone mass and bone strength and can occur following mild violence or during performance of daily activities. The incidence of OVCF is increasing every year due to aging of the population, and it is now a common cause of morbidity and mortality in the elderly. Early and effective treatment is important as OVCF causes pain, body changes and damage, decline in social and psychological function, and increase in risk of mortality[1]. Nonsurgical treatment of OVCF is with pain medications, braces, and bed rest. However, strict bed rest can result in further loss of bone mass and lead to a vicious circle, while also increasing the risk for cardiopulmonary dysfunction, urinary tract infection, and bedsores. Traditional open surgery is associated with large trauma, high surgical risk, likelihood of damage to the spinal cord and nerve roots, screw rupture, and high internal fixation failure rate[2]. For OVCF in the elderly, treatment with open reduction and pedicle screw fixation is still controversial as there is high possibility of serious complications, such as loosening and sinking of the screw, and early extraction of the screw[3].

In the 1980s, percutaneous vertebroplasty (PVP) was introduced as a treatment for OVCF. This technique includes perfusion of bone cement into the compressed vertebral body through the pedicle (or *via* an extra-pedicle approach)[4]; the injected cement stabilizes the fracture and rapidly relieves pain *via* its thermal effect[5]. However, because the low-viscosity cement is infused into the enclosed space of the vertebral body under high pressure, bone cement leakage is a very common

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complication[6]. In severe cases, limb function paralysis may result, as a consequence, preventing bone cement leakage is of vital importance. To minimize the risk of cement leakage, a modified technique – percutaneous balloon dilatation kyphoplasty or percutaneous kyphoplasty (PKP) – was proposed. In this method, balloon dilatation is first performed to form a cavity within the diseased vertebral body (fracture or metastatic tumor) and cause low pressure. Subsequently, the bone cement was infused into the vertebral body through a fixed device. This new minimally invasive treatment can relieve pain and restore vertebral body height, while reducing the risk of bone cement leakage[7,8]. PKP is now widely used for treatment of OVCFs. However, there is controversy about the amount of cement to be injected. While some scholars believe that injection of larger amounts provides better relief of clinical symptoms, others claim that the amount of bone cement infused has nothing to do with the clinical efficacy[9]. Does the bone cement infusion dose and bone cement leakage exist? Direct correlation is also a hot spot in clinical research.

This retrospective study aimed to determine whether the amount of bone cement infused was associated with treatment response and risk of leakage.

Patients and Methods

A retrospective analysis of the clinical data of 36 patients with OCVF treated with balloon dilatation PKP at our hospital between August 2019 and August 2020 were retrospectively reviewed. Ethical approval of this study was obtained by Institutional Review Board (IRB), and consent was obtained from all participants after the study aims were explained.

Patients were eligible for inclusion if: (1) they were aged ≥65 years; (2) preoperative imaging (spinal radiography, CT, and MRI) showed wedged-shaped, biconcave, or flat vertebral body, with compression of >70%; (3) MRI or ECT confirmed fresh vertebral body compression fracture (i.e., low signal on T1-weighted imaging, high signal on T2-weighted imaging or other signals, and high signal on short tau inversion recovery MRI images); (4) dual energy x-ray bone densitometer confirmed osteoporosis; (5) there were no symptoms of spinal nerve damage; (6) they received PKP surgery; and (7) they were willing to attend regular clinical follow-up. The exclusion criteria were: (1) poor coagulation and cardiopulmonary function; (2) infection of vertebral body and surrounding soft tissues, or poor local skin condition; (3) occupation of primary benign, malignant and metastatic tumors; (4) spinal cord compression; (5) nerve function disorders; or (6) allergy to contrast material.

The included patients were divided into two groups according to the amount of bone cement infused into the vertebral body. The amount of cement in conventional-dose group was 3.5-6.0 mL and the amount of cement in small-dose group was 1.8-3.0 mL. Degree of pain relief, restoration of vertebral body height, and bone cement leakage were compared between the groups. A visual analog scale (VAS) that ranged from 0 (indicating no pain) to 10 (indicating unbearable pain) evaluated the degree of pain in patients. Bone cement leakage was assessed on routine lateral radiographs. If evident bone cement leakage occurred during the procedure, CT was performed postoperatively.

All patients underwent unilateral puncture. For the procedure, the patient was placed in a prone position and the abdomen was suspended. The location of the diseased vertebral body and target pedicle was accurately determined using C-arm x-ray fluoroscopy, and the skin puncture site was marked. Then, 1% lidocaine was infiltrated into the full thickness of soft tissue from the skin up to the pedicle. The upper part of the pedicle shadow (eleven o'clock on the left side of the pedicle projection and two eleven o'clock on the right side) was selected as the puncture point. The needle was inserted at an angle of 10°-25° to the sagittal plane and slowly advanced until the tip penetrated the pedicle; the needle was then carefully advanced into the vertebral body. When the needle tip advanced into one-third of the vertebral body, the stylet was withdrawn, and a dilator was used to expand the tunnel to the front of the vertebral body to reach the middle of the vertebral body. Then, the balloon was passed along the puncture needle sleeve under fluoroscopy. Contrast medium was injected into the balloon to observe the recovery of vertebral height. The balloon was then withdrawn, and the bone cement was injected in the drawing phase under the whole perspective. After the injected bone cement had solidified, the push rod and working sleeve were pulled out. The incision was sutured, and a sterile dressing was applied.

After the procedure, intravenous fluids and inhaled oxygen were routinely administered, and vital signs were monitored. Sensory and motor function

of the lower extremities were checked and, if any sensory/motor dysfunction was noted, the patient was sent for immediate CT scan. If CT showed leakage of bone cement into the spinal canal and compression of the spinal cord, emergency vertebral canal decompression surgery was performed.

On the first day after PKP, the patient was allowed to sit up under the protection of the waist, and then walked slowly. A review radiograph was obtained on the second day after surgery. Patients were discharged 3-4 days after surgery, with advice to continue usual anti-osteoporosis treatment and attend follow-up regularly.

Measurement data were summarized as the mean ± standard deviation. The *t*-test was used to analyze the significance of change in pain after operation and to compare pain relief between the two groups. $p < 0.05$ was considered statistically significant. Statistical analysis was performed using SPSS 17.0 (SPSS Inc., Chicago, IL, USA).

Results

A total of 36 patients with OVCFs were selected in this study. The procedure was uneventful in all patients. Operation time for each vertebral body was ~38 minutes.

The pain relief degree of the two groups of patients treated with PKP was significantly higher than that of the control group ($p < 0.05$) (Table I). No patient developed symptoms of spinal cord or nerve root compression after the operation. Among them, 30 patients had no evident pain after going to the ground after operation; 6 patients had pain after going to the ground, and relieved after 1-3 months of analgesic and anti-osteoporosis treatment.

In the low-dose group, bone cement leakage occurred through the upper and lower end plates into the intervertebral spaces in 2 patients; no neurological dysfunction occurred in any patient. In the conventional dose group, bone cement leakage occurred in 8 patients; while 5 patients had leakage into the interstitial space, 2 patients had exudation of cement through the anterior wall of the vertebral body, and 1 patient had exudation of cement into the paravertebral venous system. No neurological dysfunction occurred in any patient. The difference between the two groups in the incidence of bone cement leakage was statistically significant ($p < 0.05$). Typical cases are shown in Figure 1 and Figure 2.

Discussion

OVCFs are the most common type of fractures in the elderly and can severely affect the quality of life. The clinical manifestations of OVCF are low back pain, spinal deformity, and motor dysfunction. Conservative measures or minimally invasive percutaneous vertebroplasty can be used to treat OVCFs. Conservative management includes bed rest, analgesics, and brace protection. However, conservative treatment is associated with complications, such as bedsores, deep vein thrombosis of the lower extremities, lung infection, and depression. PKP causes relatively little trauma, and is simple, safe, and effective. It can quickly relieve pain and restore the vertebral body morphology[10], and therefore, it has been widely used in recent years.

Rapid pain relief is the greatest advantage of PKP. In the present study, patients in both groups had rapid relief of low back pain. There are various mechanisms by which PKP relieves pain. The injected bone cement increases vertebral strength and enhances vertebra stability. The solidified bone cement in the vertebra bears a considerable part of the axial force, reducing stress on the endplates of the fractured vertebral body and the intervertebral joints, and minimizing stimulation of peripheral nerve endings. Restoration of vertebral body height also helps reduce the pain due to kyphosis. In addition, the heat generated by the polymerization reaction after bone cement injection may destroy the sensory nerves in the

Table I. Comparison of visual analog scale score and bone cement Leakage between the two groups (Mean ± SD).

Groups	Visual analog scale score			Bone cement Leakage, n / (%)
	Preoperative	At 3 days after surgery	At last follow-up	
Low-dose group (n = 16)	8.56 ± 2.63	2.78 ± 2.57*	1.67 ± 2.32*	2 (12.5%)
Conventional-dose group (n = 20)	8.45 ± 2.56	2.53 ± 2.39*	1.58 ± 2.16*	8 (40%)

*$p < 0.05$ (Compared with preoperative, $p < 0.05$).

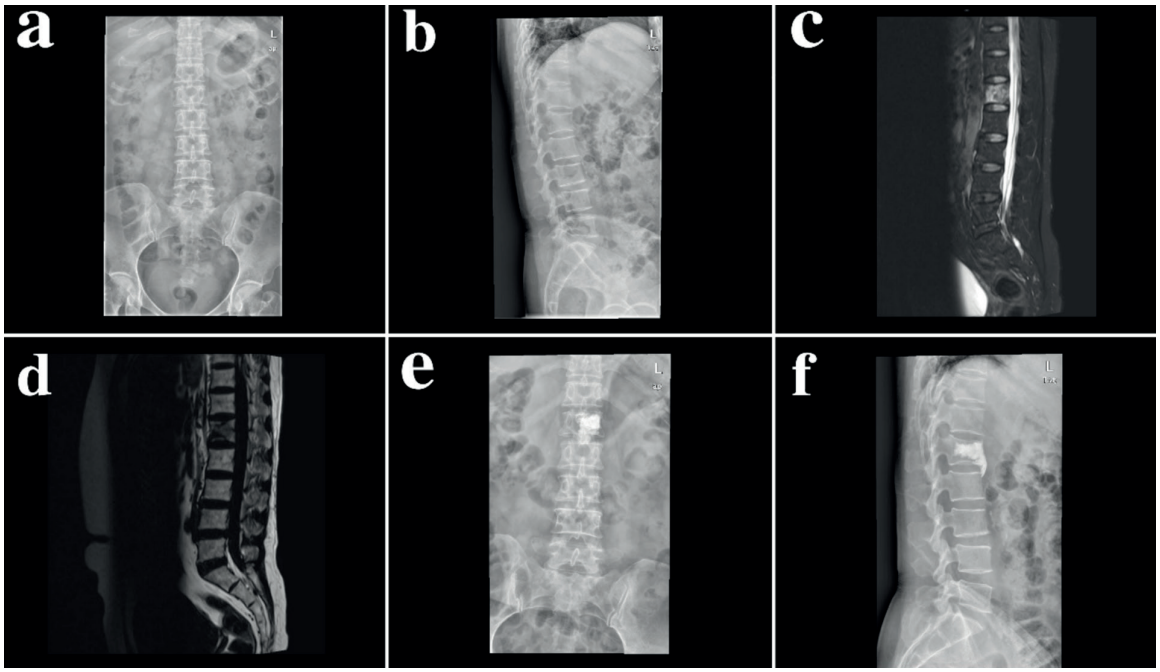

Figure 1. A 76-year-old woman was admitted to the hospital 3 days after a back injury. **a,** and **b,** preoperative lumbar spine lateral radiograph show Ll vertebral wedge shape and loss of height; **c,** and **d,** preoperative MRI shows Ll vertebral bone marrow is a fresh fracture. **e,** and **f,** L1 vertebral body was treated with PVP via unilateral pedicle puncture and injection of 5.2 mL of PMMA bone cement. Postoperative radiograph of lumbar spine shows increase in height of L1 vertebral body (compared with that before operation) and bone cement leakage into the intervertebral space.

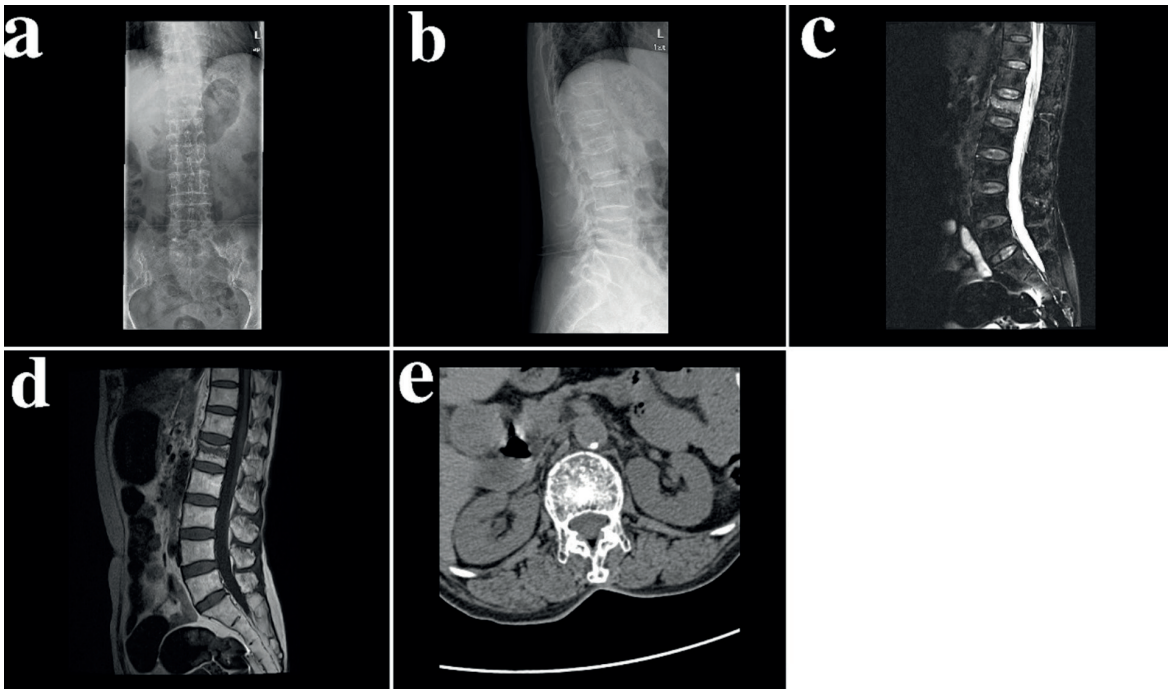

Figure 2. A 80-year-old woman was admitted to the hospital with low back pain 1 day after a fall. **a,** and **b,** Preoperative lumbar spine lateral radiograph shows L1 vertebral body wedge shape changes height. **c,** and **d,** preoperative MRI show Ll vertebral bone marrow is a fresh fracture. **e,** PVP treatment of L1 vertebral body via unilateral pedicle puncture, and injection of 2.6 mL PMMA bone cement into L1. Postoperative CT shows bone cement is well dispersed in L1, and there is no leakage of bone cement.

vertebrae and reduce pain; bone cement may also have a toxic effect on the nerve endings. Finally, bone cement may block microvascular blood flow in the vertebral body and thus reduce inflammatory factors and inflammation[11,12].

According to previous reports, over 90% of patients have symptom relief after PKP treatment of OVCF. Some scholars[13] suggest that if the volume of bone cement injected exceeds a certain critical value, the risk of complications increases significantly. One research showed that a small amount of bone cement (2 mL) was sufficient to increase vertebral body strength and to significantly alleviate clinical symptoms[14]. The pain of OVCFs is caused by the micromovements of the injured vertebrae. Reinforcement of the vertebral body *via* perfusion of bone cement eliminates these micromovements and relieves pain[15]. In this study, we found that pain relief was obtained with both low-dose and conventional-dose treatments.

Bone cement leakage is the main complication seen in patients receiving PKP. In severe cases, it may cause paralysis or even endanger life. Bone cement leakage has been shown to be closely related to the amount of bone cement infused, the degree of compression of the vertebral body, and the integrity of the vertebral body wall[16,17]. In the present study, compared with conventional-dose group, small-dose group has lower bone cement leakage rate, indicating that the leakage is closely related to the amount of bone cement infused. Our results are consistent with previous reports. Gandhoke et al[18] performed a retrospective cohort evaluation on a consecutive series of 162 patients over age 80 who underwent treatment for compression fractures using the balloon kyphoplasty and found the mean VAS score for back pain improved from 9 to 3.5 for the entire cohort ($p<0.0001$). Other similar studies[19,20] have also achieved satisfactory results.

In this study, our clinical experience is as follows: the operation should be carried out in local anesthesiology as much as possible. According to the preoperative X-ray film, we should choose the relatively clear side of the pedicle for puncture. X-ray monitoring should be carried out during the operation to prevent the puncture needle from entering the spinal canal. Bone cement should be injected into the vertebral body in a "viscous state" to avoid the early injection of bone cement spreading to the spinal cord or nerve. Multiple injections of 0.2-0.3 mL each can help avoid bone cement leakage. The injection of bone cement should not over-emphasize the full vertebral body, but the bone cement should be poured into the midline to better meet the biomechanical requirements of the spine.

Based on our clinical experience, we can offer some recommendations for minimizing risk of bone cement leakage. (1) Routine MRI examination before surgery is necessary to determine the number and type of compression fractures and the degree of compression of the vertebral bodies. CT should be performed for those with evident compression and suspected incomplete posterior wall, as these cases will require greater care during the procedure. (2) The puncture point must be correctly identified. On the anteroposterior X-ray image, the puncture needle was inserted from the outer upper edge of the pedicle. We used a slow hammer as much as possible to enter the needle and use less hand-held rotating puncture to avoid the gap between the needle and the surrounding bone caused by shaking and bone cement leaks retrogradely along the the gap. (3) Fluoroscopic monitoring of the lateral position should be repeated during the puncture. When the puncture needle is placed on the posterior wall of the vertebral body, the puncture needle of the positive position should be inside the center of the elliptical shadow of the pedicle to prevent puncture the inner wall of the pedicle. (4) The bone cement should ideally be injected when in a "brushed" state. At this time, it has only moderate viscosity and so is easily injected and well dispersed in the vertebral body. (5) Good imaging equipment can help identifying leakage so that injection can be immediately stopped. (6) Adequate surgical skills and correct operation technique are also important for prevention of bone cement leakage.

The present study has some limitations that should be considered. The number of subjects was relatively small, and a larger study sample may be needed for statistical assessment in the future. Selective bias might have been introduced, which may lead to errors in the results. The relatively short follow-up period is also the deficiency of this study. Besides, this study did not include the conservative treatment group which will be evaluated in a further study.

Conclusions

PKP is an effective method for treatment of OVCF in the elderly. Infusion of low doses of bone cement appears to effectively relieve pain, while reducing the risk of bone cement leakage.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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Authors' Contribution
Quan-Ming Zhao designed the study. Li-Ming Lu carried out the study and wrote the original manuscript. Xing-Yuan Zhu performed the investigation. Jie-Shi Wu and Fa-Cai Xu collected the data. Xiao-Hui Ni and Jin-Ping Ni contributed to the interpretation of the data and analyses. Wei Tan and Shi Yin wrote the final manuscript. All authors read and approved the final manuscript.

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References

1) Parreira PCS, Maher CG, Megale RZ, March L, Ferreira ML. An overview of clinical guidelines for the management of vertebral compression fracture: a systematic review. Spine J 2017; 17: 1932-1938.
2) Garg B, Dixit V, Batra S, Malhotra R, Sharan A. Non-surgical management of acute osteoporotic vertebral compression fracture: A review. J Clin Orthop Trauma 2017; 8: 131-138.
3) Perovic D, Boric I. [Diagnostics and treatment of osteoporotic vertebral fractures]. Reumatizam 2014; 61: 75-79.
4) Savage JW, Schroeder GD, Anderson PA. Vertebroplasty and kyphoplasty for the treatment of osteoporotic vertebral compression fractures. J Am Acad Orthop Surg 2014; 22: 653-664.
5) Robinson Y, Olerud C. Vertebroplasty and kyphoplasty - A systematic review of cement augmentation techniques for osteoporotic vertebral compression fractures compared to standard medical therapy. Maturitas 2012; 72: 42-49.
6) Feng L, Feng C, Chen J, Wu Y, Shen JM. The risk factors of vertebral refracture after kyphoplasty in patients with osteoporotic vertebral compression fractures: A study protocol for a prospective cohort study. BMC Musculoskelet Disord 2018; 19: e195.
7) Zou D, Zhang K, Ren Y. Therapeutic effects of PKP on chronic painful osteoporotic vertebral compression fractures with or without intravertebral cleft. Int J Clin Exp Med 2015; 8: 15780-15786.
8) Karmakar A, Acharya S, Biswas D, Sau A. Evaluation of percutaneous vertebroplasty for management of symptomatic osteoporotic compression fracture. J Clin Diagnostic Res 2017; 11: RC7-RC10.
9) Zhu Y, Cheng J, Yin J, Zhang Z, Liu C, Hao D. Therapeutic effect of kyphoplasty and balloon vertebroplasty on osteoporotic vertebral compression fracture: A systematic review and meta-analysis of randomized controlled trials. Medicine (Baltimore) 2019; 98: e17810.
10) Marcia S, Muto M, Hirsch JA, Chandra RV, Carter N, Crivelli P, Piras E, Saba L. What is the role of vertebral augmentation for osteoporotic fractures? A review of the recent literature. Neuroradiology 2018; 60: 777-783.
11) Muratore M, Ferrera A, Masse A, Bistolfi A. Osteoporotic vertebral fractures: predictive factors for conservative treatment failure. A systematic review. Eur Spine J 2018; 27: 2565-2576.
12) Lamanna A, Maingard J, Kok HK, Ranatunga D, Looby ST, Brennan P, Chua M, Owen A, Brooks DM, Chandra R V., Asadi H. Vertebroplasty for acute painful osteoporotic vertebral compression fractures: An update. J Med Imaging Radiat Oncol 2019; 63: 779-785.
13) Luo J, Daines L, Charalambous A, Adams MA, Annesley-Williams DJ, Dolan P. Vertebroplasty: Only small cement volumes are required to normalize stress distributions on the vertebral bodies. Spine (Phila Pa 1976) 2009; 34: 2865-2873.
14) He S, Zhang Y, Lv N, Wang S, Wang Y, Wu S, He F, Chen A, Qian Z, Chen J. The effect of bone cement distribution on clinical efficacy after percutaneous kyphoplasty for osteoporotic vertebral compression fractures. Med (United States) 2019; 98: e18217.
15) Park YS, Kim HS. Prevention and treatment of multiple osteoporotic compression fracture. Asian Spine J 2014; 8: 382-390.
16) Yeom JS, Kim WJ, Choy WS, Lee CK, Chang BS, Kang JW. Leakage of cement in percutaneous transpedicular vertebroplasty for painful osteoporotic compression fractures. J Bone Joint Surg 2003; 85: 83-89.
17) Yang S, Chen C, Wang H, Wu Z, Liu L. A systematic review of unilateral versus bilateral percutaneous vertebroplasty/percutaneous kyphoplasty for osteoporotic vertebral compression fractures. Acta Orthop Traumatol Turc 2017; 51: 290-297.
18) Gandhoke GS, Deibert CP, Paschel E, Gerszten PC. Safety and efficacy of balloon kypholasty for compression fractures in the very elderly. Cureus 2014; 6: e161.
19) Molloy S, Mathis JM, Belkoff SM. The effect of vertebral body percentage fill on mechanical behavior during percutaneous vertebroplasty. Spine (Phila Pa 1976) 2003; 28: 1549-1554.
20) Kulcsár Z, Marosfoi M, Berentei Z, Veres R, Nyáry I, Szikora I. [Frequency of adjacent vertebral fractures following percutaneous vertebroplasty]. Orv Hetil 2009; 150: 1744-1748.