Retrospective Review

Percutaneous Vertebroplasty versus Conservative Treatment for One Level Thoracolumbar Osteoporotic Compression Fracture: Results of an Over 2-Year Follow-up

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We retrospectively compared the clinical and radiological results of percutaneous vertebroplasty with those of conservative treatment in the management of thoracolumbar osteoporotic compression fractures.

Sixty-five patients who could be followed up for more than 2 years with thoracic and lumbar spine osteoporotic compression fractures, between January 2005 and October 2010, were reviewed. The patients were divided into 2 groups according to the type of management: group 1, non-operated group treated conservatively; group 2, operated group that underwent percutaneous vertebroplasty. We assessed the clinical and radiological changes at postoperative and follow-up periods in both groups.

The male-to-female ratio and mean age of the patients were 11:54 and 73.04 years (range, 50 – 90 years), respectively. The location and number of treated vertebrae were as follows: T4 = 1, T6 = 1, T7 = 3, T8 = 1, T9 = 2, T10 = 1, T11 = 8, T12 = 11, L1 = 17, L2 = 10, L3 = 6, L4 = 3, and L5 = 1. The mean T-score was -3.37. The overall VAS score and the VAS score until 6 months post-injury were statistically more improved in group 2 than in group 1 ($P < 0.05$ and $P < 0.005$, respectively). Overall, the compression ratio was statistically more improved in group 2 than in group 1 ($P < 0.05$).

Early pain control and restoration of the compressed vertebral body are the beneficial and real effects of percutaneous vertebroplasty in patients with thoracolumbar osteoporotic compression fractures.

Key words: Osteoporosis, compression fracture, vertebroplasty, osteoplasty, comparative study, thoracic spine, lumbar spine, polymethylmethacrylate (PMMA)

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Vertebral compression fractures (VCF) have multiple causes and represent an increasingly significant public health issue in the elderly population (1,2). Osteoporosis is the most common cause of VCF (3). Traditionally, many patients with osteoporotic vertebral compression fractures (OVCF) were managed conservatively with pain management, short periods of bed rest, and bracing (4-6). In recent years, however, surgical interventions, such as vertebroplasty (VP) and kyphoplasty (KP), have been preferred.

Percutaneous cement augmentation techniques, such as the injection of polymethylmethacrylate (PMMA) into the fractured vertebral body, have been

shown to be effective in terms of early pain relief and relatively low complications (5,7-9). This technique provides pain reduction, rapid and sustained improvement in physical function, reduces pain-related visits to physicians, and improves the quality of life for most patients (3). However, there has been an ongoing controversy regarding the effective time of percutaneous cement augmentation along with various perspectives on issues like pain control, hospitalization period, quality of life, vertebral body height restoration, as well as adverse procedure-related events. Kallmes et al (10) reported that clinical improvement in patients with painful osteoporotic vertebral fractures was similar among those who underwent VP and those who did not. However, some other studies have reported significantly better vertebral height restoration and correction of spinal deformity following VP for osteoporotic vertebral fractures at the 1 – 2 month and 1 – 3 year follow-ups based on radiographic assessment (11).

A recent study demonstrated that most patients who had favorable clinical results with conservative treatment in the initial 3 weeks after the fracture also showed successful clinical results at one year after the fracture. If the patient failed conservative treatment, percutaneous cement augmentation also resulted in excellent results at one year after the trauma (5). However, the long conservative treatment period of 3 weeks has been criticized by others (5).

It is therefore very difficult to determine the effective period of percutaneous cement augmentation techniques. Furthermore, it is essential to evaluate the short- and long-term effects of percutaneous cement augmentation techniques on clinical and radiologic findings. In this study, we mainly focused on evaluation of pain and radiological preference and compared effectiveness of vertebroplasty with that of conservative management in patients with OVCF of the thoracolumbar spine.

Methods

Study Design and Patients

For evaluation of the long-term effect, 65 patients who could be followed up for more than 2 years with thoracolumbar osteoporotic compression fractures, between January 2005 and October 2010, were reviewed. The inclusion criteria were as follows: only one level osteoporotic fracture with 5 – 20% canal encroachment and bone mineral density (BMD) of less than -3.0. Exclusion criteria included combined neurological deficits, pathological fractures, and unstable vertebral fractures involving the middle or posterior column of the spine. We divided the patients into 2 groups, according to the type of management: group 1, non-operated group treated conservatively and group 2, operated group that underwent percutaneous VP. We reviewed clinical data such as BMD, hospitalization period, changes in the visual analogue scale (VAS) score, and rate of refracture. We also reviewed the radiographs at 1, 2, and 3 weeks, and at 6, 12, and 24 months after the injury to evaluate vertebral body compression ratios and kyphotic angles.

Patients in both groups were given bed rest for 2 weeks, then all patients began ambulation with thoracolumbosacral orthosis. If there was increased height loss, kyphotic change, or pain aggravation, we did VP. However, if the patient was older than 80 years, had severe DM (diabetic mellitus), CRF (chronic renal failure), pneumonia, or thrombophlebitis, we did VP without 2 weeks bed rest.

Pain medication was optimized according to the individual needs of the patients. In ascending order of pain control, the patients were treated with acetaminophen, opiate derivatives, or other specific pain killers. To optimize analgesic use, first the daily dose of prescribed analgesics was regulated and then the class of pain medication was adjusted. Some patients received bisphosphonates, calcium supplementation, and vitamin D. Furthermore, all patients underwent preoperative postural reduction using a soft pillow under the compressed level for a few days. All study protocols received full approval from Local Ethical Committee

Vertebroplasty Technique

The surgery was performed with the patients in the prone position. An 11-gauge VP needle was inserted via a transpedicular approach using the SIREMOBIL Iso-C3D (Siemens Medical Solutions, Erlangen, Germany). The needle was advanced through the pedicle, sloping anteriorly, medially, and caudally. The needle tip was placed at the anterior one-third of the vertebral body. Once the needle was placed inside the vertebral body, the liquid and powder components of PMMA were mixed and injected steadily through the pedicle needle under fluoroscopic guidance. Cement injection was performed under continuous fluoroscopic monitoring in the lateral view, with close attention to the posterior margin of the vertebral body and the epidural space. During the PMMA injection, frequent fluoroscopic controls were required to ensure that the material re-

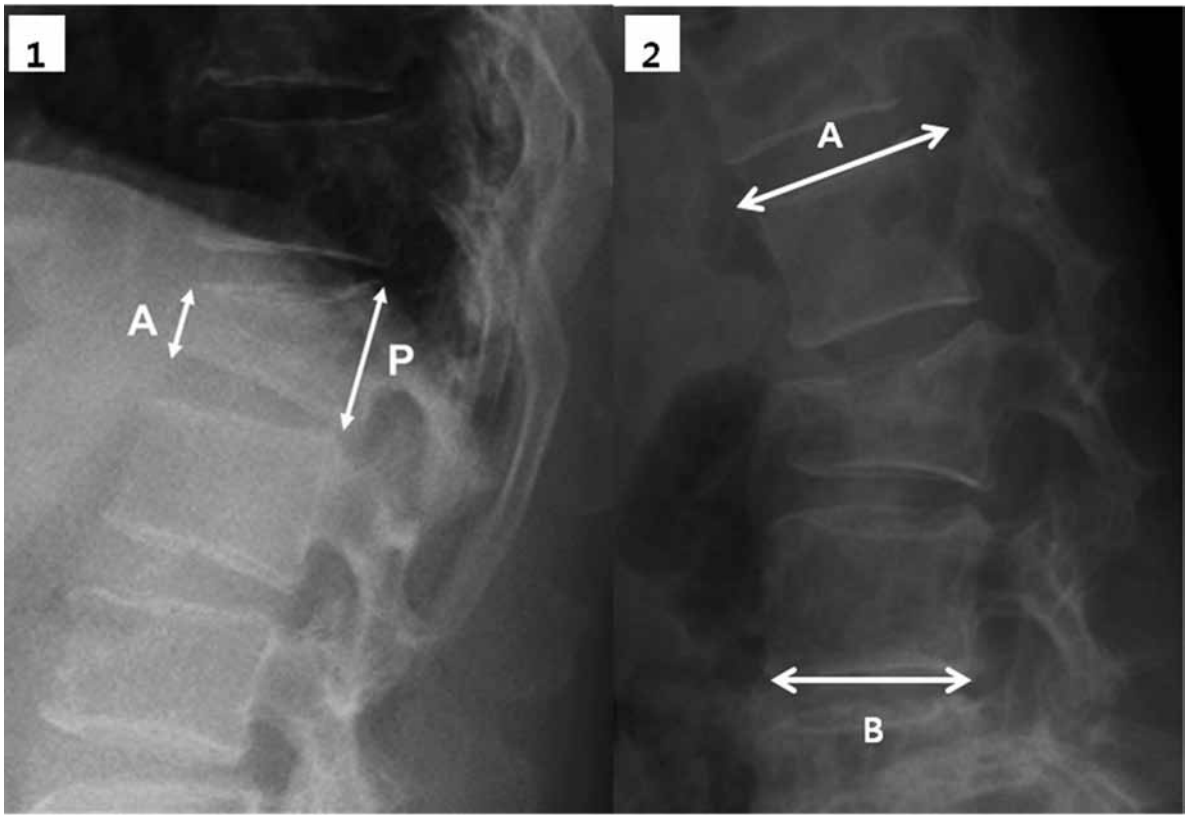

Fig. 1. *Measured factors. A: Compression ratio (A: anterior, P: posterior). The anterior-posterior (AP) ratio of the fractured vertebra calculated as the height of the anterior wall (A) divided by that of the posterior wall (P). A smaller AP ratio implies a greater degree of compression or wedge deformity. B: Vertebral wedge angle (kyphotic angle). The angle between the superior endplate of the vertebral body above and the inferior endplate of the vertebral body below the fractured vertebra on the lateral radiograph.*

mained within the vertebral body without migrating into the surrounding venous plexus. After the VP, the patients rested in the supine position for 3 – 4 hours.

Imaging Assessment

We measured vertebral body compression ratios by calculating the anterior-posterior (AP) ratio (Fig. 1) and wedge angle (kyphotic angle), which was determined by measuring the angle between the superior endplate of the vertebral body above and the inferior endplate of the vertebral body below the fractured vertebra on the lateral radiograph in a standing position (Fig. 1). Follow-up radiography was performed at 1, 2, and 3 weeks and 6, 12, and 24 months after fracture diagnosis in group 1, and at 1, 2, and 3 weeks and 6, 12, and 24 months after the procedure in group 2.

Statistical Analysis

The SAS (version 9.3, SAS Institute Inc., Cary, NC, USA) statistical package was utilized for statistical analyses. Data were represented as mean ± standard deviation (SD) and P values < 0.05 were considered statistically significant. The Chi-square test, Student t-test, or Wilcoxon rank sum test were used for the analysis as appropriate. The generalized estimating equation (GEE) adjusted by age and duration of hospitalization was used to analyze the changes in the 2 groups. The differences between the visual analogue scale (VAS) and other parametric changes were noted, and ANCOVA adjusted by age and duration of hospitalization was used to analyze these differences in changes between the 2 groups in the VAS and other radiological measurements at 1, 2, and 3 weeks and 6, 12, and 24

Table 1. *Baseline characteristics.*

	Group 1 (n = 30)	Group 2 (n = 35)	*P*-value†
Gender (male:female)	7 : 23	4 : 31	0.2019
Age (yr ± SD)	69.5 ± 12.3	76.1 ± 8.0	0.0145
Hospital stay (day)	21 (12-49)	11 (5-19)	**0.0030***
Decubitus ulcer (n, %)	2 (6.7)	2 (5.7)	0.1601
Pneumonia (n, %)	0(0)	0(0)	0.0000
Thrombophlebitis (n, %)	1 (3.3)	1 (2.9)	0.1807
Cardiovascular complications (n, %)	0 (0)	0 (0)	0.0000
Mortality (%)	0	0	0.0000

Values are number of patients (%), mean ± SD or median (interquartile range) unless otherwise indicated.
* Hospital stay means period of stay at hospital after 2 weeks conservative treatment.
† *P*-Values values are calculated by Chi-square test, Student t-test, or Wilcoxon rank sum test as appropriate.
yr: year, SD: standard deviation, min: minimum, max: maximum
*: statistically significant

Table 2. *Comparison of the visual analogue scale by the time in the both groups.*

VAS	Group 1 (n = 30)		Group 2 (n = 35)		*P*-value†
	Mean	SD	Mean	SD	
Day of fractured	7.2	± 1.2	6.1	± 1.5	0.0043*
1 week	5.9	± 1.2	3.4	± 1.8	< 0.0001*
2 weeks	4.8	± 1.4	3.0	± 1.5	< 0.0001*
3wks	3.9	± 1.2	2.6	± 1.4	0.0003*
6 months	3.4	± 1.4	2.2	± 1.1	0.0037*
1 year	2.6	± 1.0	2.4	± 1.7	0.7212
2 years	2.2	± 1.0	1.9	± 1.3	0.5747

Values are mean ± SD.
† *P*-values are calculated by ANCOVA adjusted by age and duration of hospitalization.
*: statistically significant

months after fracture diagnosis in group 1, and at 1, 2, and 3 weeks and 6, 12, and 24 months after the procedure in group 2.

Results

Male-to-female patient ratio was 11:54, and the mean age of the patients was 73.04 years (range, 50 – 90 years). The location and number of the treated vertebrae were as follows: T4 = 1, T6 = 1, T7 = 3, T8 = 1, T9 = 2, T10 = 1, T11 = 8, T12 = 11, L1 = 17, L2 = 10, L3 = 6, L4 = 3, and L5 = 1. Mean T-score was -3.37. The number of patients in group 1 was 30 (46.1%) and in group 2 was 35 (53.9%). Baseline characteristics of the 2 groups were statistically different in age and admission period ($P < 0.05$) but, other factors (gender, age, decubitus ulcer, pneumonia, thrombophlebitis, cardiovascular complication, mortality) did not have statistical significance (Table 1). The mean VAS scores of groups 1 and 2 were 7.2 (± 1.2) and 6.1 (± 1.5) at onset, 5.9 (± 1.2) and 3.4 (± 1.8) at one week post-injury, 4.8 (± 1.4) and 3.0 (± 1.5) at 2 weeks post-injury, 3.9 (± 1.2) and 2.6 (± 1.4) at 3 weeks post-injury, 3.4 (± 1.4) and 2.2 (± 1.2) at 6 months post-injury, 2.6 (± 1.0) and 2.4 (± 1.7) at one year post-injury, and 2.2 (± 1.2) and 1.9 (± 1.3) at 2 years post-injury, respectively. The overall VAS score was statistically more improved in group 2 than in group 1. With respect to time, the change in the VAS score until 6 months post-injury was also statistically more improved in group 2 than in group 1 (Table 2).

The mean compression ratios of groups 1 and 2 were 24.7 (± 16.7) and 33.8 (± 13.1) at onset, 28.0 (± 18.3) and 23.9 (± 8.2) at one week post-injury, 32.9 (± 19.5) and 25.3 (± 9.8) at 6 months post-injury, 32.9 (± 17.9) and 28.4 (± 9.0) at one year post-injury, and 36.2

Table 3. *Changes of the Compression compression ratio in the both groups.*

Compression ratio	Group 1 (n = 30)		Group 2 (n = 35)		*P*-value*	*P*-value**	*P*-value***
	Mean	SD	Mean	SD			
Day of fractured	24.7	± 16.7	33.8	± 13.1	0.7205	0.0003	< 0.0001
1 week	28.0	± 18.3	23.9	± 8.2			
6 months	32.9	± 19.5	25.3	± 9.8			
1 year	32.9	± 17.9	28.4	± 9.0			
2 years	36.2	± 19.4	27.3	± 10.3			

Values are n, mean ± SD.
* *P*-value is for a group effect with Generalized Estimating Equation (GEE) adjusted by age and duration of hospitalization.
** *P*-value is for a time effect with Generalized Estimating Equation (GEE) adjusted by age and duration of hospitalization.
*** *P*-value is for an interaction effect between time and group with Generalized Estimating Equation (GEE) adjusted by age and duration of hospitalization.

Table 4. *Changes of the kyphotic angle in the both groups.*

Kyphotic angle	Group 1 (n = 30)		Group 2 (n = 35)		*P*-value*	*P*-value**	*P*-value***
	Mean	SD	Mean	SD			
Day of fractured	13.3	± 8.8	11.2	± 6.8	0.4923	0.0036	0.1034
1 week	12.1	± 8.3	9.7	± 7.4			
6 months	13.4	± 8.7	10.8	± 8.1			
1 year	12.6	± 7.9	8.9	± 6.3			
2 years	14.6	± 9.5	13.3	± 9.1			

Values are n, mean ± SD.
* *P*-value is for a group effect with Generalized Estimating Equation (GEE) adjusted by age and duration of hospitalization.
** *P*-value is for a time effect with Generalized Estimating Equation (GEE) adjusted by age and duration of hospitalization.
*** *P*-value is for an interaction effect between time and group with Generalized Estimating Equation (GEE) adjusted by age and duration of hospitalization.

(± 19.4) and 27.3 (± 10.3) at 2 years post-injury, respectively. Overall, the compression ratio was statistically more improved in group 2 than in group 1. However, with respect to time, the changes in the compression ratio between the 2 groups were not statistically different (Table 3).

The mean kyphotic angles of groups 1 and 2 were 13.3 (± 8.8) and 11.2 (± 6.8) at onset, 12.1 (± 8.3) and 9.7 (± 7.4) at one week post-injury, 13.4 (± 8.7) and 10.8 (± 8.1) at 6 months post-injury, 12.6 (± 7.9) and 8.9 (± 6.3) at one year post-injury, and 14.6 (± 9.5) and 13.3 (± 9.1) at 2 years post-injury, respectively. With respect to overall changes, the kyphotic angle was not statistically improved in the both groups (Table 4).

Discussion

VCFs due to osteoporotic degeneration, metastatic disease, primary tumor, or trauma of the spine represent an increasingly significant public health problem (3). Osteoporosis is the most common cause of VCF (12). VCF is associated with chronic back pain in 84% of symptomatic patients (13), increased rates of new VCF, other osteoporotic fractures (14), height loss, kyphosis, loss of mobility, and depression, as well as pulmonary dysfunction -(15,16), therefore mortality is also higher (17). Medical management, including bed rest, postural reduction, and bracing, may help to reduce pain over weeks or months; however, in frail elderly patients, long periods of inactivity are associated with higher rates of pneumonia, decubitus ulcers, venous thromboembolism, and even death (18). On the other hand, open surgery also poses a significant risk in these patients.

The debate is still ongoing about the effect of VP for pain relief and reduction of kyphosis (5,10,19,20). But we wanted to investigate the long-term follow-up effect for more than 2 years. There are not many articles about relations between osteoporotic compression fractures with pain and restoration of compressed vertebral bodies over the long term. So we focused on the long-term follow-up effects of VP.

Vertebral body cement augmentation procedures

such as VP and KP provide significant, immediate, and sustained pain relief in the vast majority of patients suffering from painful compression fractures due to osteoporosis or malignancy. They reduce pain immediately and provide rapid and sustained improvement in physical function, reduce pain-related visits to physicians, and improve the quality of life for most patients (11).

However, the effectiveness of VP and KP in comparison with conservative treatment is controversial. Boonen et al (21) showed that in the short term, these benefits have been shown to be significantly greater with VP and KP as compared to optimal medical management in other studies (11). At a longer-term (6 – 12 months) follow-up, as patients managed conservatively gradually improve, the relative advantage of augmentation over medical management is considered to be diminished. However, recently published level 1 data showed significant benefits from vertebral augmentation in pain, quality of life, deformity correction for up to 3 years (11,21). Klazen et al (22) stated that in patients with acute osteoporotic vertebral fractures who have persistent severe pain, VP performed at a mean of 5.6 weeks after onset of symptoms resulted in quicker and greater pain relief than conservative treatment. Notably, in more than half of the patients who initially qualified for the study, the pain spontaneously decreased to bearable levels. After VP, patients had significant pain relief and used a lower class of drugs than those receiving conservative treatment. In contrast, with conservative treatment, pain relief was slower and lesser, and the extent of pain treatment required tended to increase during the first month (22). Lee et al (5) showed that both balloon KP and conservative treatment led to well-controlled pain and improved quality of life at the one-year follow-up after acute OVCF. In fact, balloon KP showed more rapid improvement in pain and disability than conservative treatment, with significant differences in VAS and Oswestry Disability Index (ODI) scores between the treatment groups up until the first month. However, these differences diminished, and there were no significant differences between the 2 groups after one month throughout the one-year follow-up period (5). Our study revealed that patients who underwent VP showed immediate improvement in pain after the procedure, especially in the acute stage. Therefore, early phase VP could be effective in pain control and thus, from this point of view, it should be considered as a treatment procedure as early as possible.

Vertebral augmentation has many adverse effects. Adjacent segment fractures and cement leakage have been found to occur (23). Cement leakage was presumed to be a significant complication of VP, and to a lesser extent, of KP. However, with current developed techniques and devices, the rate of symptomatic cement leakage with both procedures is very low (24,25).

In some of the imaging studies, factors like compression ratio and kyphotic angle show varying results. We revealed differences in compression ratio changes between the operative and non-operative groups. However, there were no significant differences in the kyphotic angle. We think that the kyphotic angle worsens with time and the difference between the 2 groups is not statistically significant.

The limitations of this study include the following: (1) We were not able to conduct a randomized control study (RCT) and poorly designed non-RCTs are more likely to suffer from various types of bias; (2) Patients from group 1 fall into group 2 because of persisting or worsening of the pain which biased the study even more. The Korean public health insurance system allows osteoplasty when there is persistent pain despite medical treatment and bed rest care over 2 weeks. So, our first treatment choice is group 1, and then if we did osteoplasty, it could be group 2. But we did our best in order to avoid duplicating groups (3). This study possessed only one level thoracolumbar osteoporotic VCF. Therefore, changes of the kyphotic angle between both groups were not significant. But, if we checked other sagittal imbalance radiologic factors, like pelvic incidence, pelvic tilt, lumbar lordosis, and thoracic kyphosis, we might have been able to get more meaningful results (4). In this study, only pain and radiologic factors were considered (5); no economic outcomes were reported. Further prospective studies should be undertaken to elucidate the differences in the cost-effectiveness between conservative management and percutaneous VP in patients with thoracolumbar VCF.

Conclusion

Our study showed that percutaneous VP has a beneficial effect on pain relief, especially in the early stage. We also revealed differences in compressive ratio changes between the operative and non-operative groups. Therefore, we think that early pain control and restoration of the compressed vertebral body are real effects of percutaneous VP. Further prospective studies should be undertaken to elucidate the differences in the cost-effectiveness between conservative management and percutaneous VP in patients with thoracolumbar OCVF.

Author contributions

All authors participated in the experimental design, conduction, data analysis, and approved the final version of the paper.

Ethical approval

All study protocols received full approval from Local Ethical Committee.

Author statements

This manuscript is original, has not been submitted to or is not under consideration by another publication, has not been previously published in any language or any form, including electronic, and contains no disclosure of confidential information or authorship/patent application disputations.

References

1. Hasserius R, Karlsson MK, Jonsson B, Redlund-Johnell I, Johnell O. Long-term morbidity and mortality after a clinically diagnosed vertebral fracture in the elderly -- a 12- and 22-year follow-up of 257 patients. *Calcif Tissue Int* 2005; 76:235-242.
2. Hasserius R, Karlsson MK, Nilsson BE, Redlund-Johnell I, Johnell O. Prevalent vertebral deformities predict increased mortality and increased fracture rate in both men and women: A 10-year population-based study of 598 individuals from the Swedish cohort in the European Vertebral Osteoporosis Study. *Osteoporos Int* 2003; 14:61-68.
3. Itshayek E, Miller P, Barzilay Y, Hasharoni A, Kaplan L, Fraifeld S, Cohen JE. Vertebral augmentation in the treatment of vertebral compression fractures: Review and new insights from recent studies. *J Clin Neurosci* 2012; 19:786-791.
4. Black DM, Cummings SR, Karpf DB, Cauley JA, Thompson DE, Nevitt MC, Bauer DC, Genant HK, Haskell WL, Marcus R, Ott SM, Torner JC, Quandt SA, Reiss TF, Ensrud KE. Randomised trial of effect of alendronate on risk of fracture in women with existing vertebral fractures. Fracture Intervention Trial Research Group. *Lancet* 1996; 348:1535-1541.
5. Lee HM, Park SY, Lee SH, Suh SW, Hong JY. Comparative analysis of clinical outcomes in patients with osteoporotic vertebral compression fractures (OVCFs): Conservative treatment versus balloon kyphoplasty. *Spine J* 2012; 12:998-1005.
6. Papaioannou A, Watts NB, Kendler DL, Yuen CK, Adachi JD, Ferko N. Diagnosis and management of vertebral fractures in elderly adults. *Am J Med* 2002; 113:220-228.
7. Evans AJ, Jensen ME, Kip KE, DeNardo AJ, Lawler GJ, Negin GA, Remley KB, Boutin SM, Dunnagan SA. Vertebral compression fractures: Pain reduction and improvement in functional mobility after percutaneous polymethylmethacrylate vertebroplasty retrospective report of 245 cases. *Radiology* 2003; 226:366-372.
8. Alvarez L, Alcaraz M, Perez-Higueras A, Granizo JJ, de Miguel I, Rossi RE, Quinones D. Percutaneous vertebroplasty: Functional improvement in patients with osteoporotic compression fractures. *Spine (Phila Pa 1976)* 2006; 31:1113-1118.
9. Diamond TH, Champion B, Clark WA. Management of acute osteoporotic vertebral fractures: A nonrandomized trial comparing percutaneous vertebroplasty with conservative therapy. *Am J Med* 2003; 114:257-265.
10. Kallmes DF, Comstock BA, Heagerty PJ, Turner JA, Wilson DJ, Diamond TH, Edwards R, Gray LA, Stout L, Owen S, Hollingworth W, Ghdoke B, Annesley-Williams DJ, Ralston SH, Jarvik JG. A randomized trial of vertebroplasty for osteoporotic spinal fractures. *N Engl J Med* 2009; 361:569-579.
11. Farrokhi MR, Alibai E, Maghami Z. Randomized controlled trial of percutaneous vertebroplasty versus optimal medical management for the relief of pain and disability in acute osteoporotic vertebral compression fractures. *J Neurosurg Spine* 2011; 14:561-569.
12. Eastell R, Cedel SL, Wahner HW, Riggs BL, Melton LJ, 3rd. Classification of vertebral fractures. *J Bone Miner Res* 1991; 6:207-215.
13. Silverman SL. The clinical consequences of vertebral compression fracture. *Bone* 1992; 13:S27-31.
14. Cooper C, Atkinson EJ, O'Fallon WM, Melton LJ, 3rd. Incidence of clinically diagnosed vertebral fractures: A population-based study in Rochester, Minnesota, 1985-1989. *J Bone Miner Res* 1992; 7:221-227.
15. Ensrud KE, Thompson DE, Cauley JA, Nevitt MC, Kado DM, Hochberg MC, Santora AC, 2nd, Black DM. Prevalent vertebral deformities predict mortality and hospitalization in older women with low bone mass. Fracture Intervention Trial Research Group. *J Am Geriatr Soc* 2000; 48:241-249.
16. Schlaich C, Minne HW, Bruckner T, Wagner G, Gebest HJ, Grunze M, Ziegler R, Leidig-Bruckner G. Reduced pulmonary function in patients with spinal osteoporotic fractures. *Osteoporos Int* 1998; 8:261-267.
17. Kado DM, Duong T, Stone KL, Ensrud KE, Nevitt MC, Greendale GA, Cummings SR. Incident vertebral fractures and mortality in older women: A prospective study. *Osteoporos Int* 2003; 14:589-594.
18. Ross PD. Clinical consequences of vertebral fractures. *Am J Med* 1997; 103:30S-42S; discussion 42S-43S.
19. Papanastassiou ID, Filis A, Gerochristou MA, Vrionis FD. Controversial issues in kyphoplasty and vertebroplasty in osteoporotic vertebral fractures. *Biomed Res Int* 2014; 2014:934206.
20. Rousing R, Andersen MO, Jespersen SM, Thomsen K, Lauritsen J. Percutaneous vertebroplasty compared to conservative treatment in patients with painful acute or subacute osteoporotic vertebral fractures: Three-months follow-up in a clinical randomized study. *Spine (Phila Pa 1976)* 2009; 34:1349-1354.
21. Boonen S, Van Meirhaeghe J, Bastian L, Cummings SR, Ranstam J, Tillman JB, Eastell R, Talmadge K, Wardlaw D. Balloon kyphoplasty for the treatment of acute vertebral compression fractures: 2-year results from a randomized trial.

J Bone Miner Res 2011; 26:1627-1637.

22. Klazen CA, Lohle PN, de Vries J, Jansen FH, Tielbeek AV, Blonk MC, Venmans A, van Rooij WJ, Schoemaker MC, Juttmann JR, Lo TH, Verhaar HJ, van der Graaf Y, van Everdingen KJ, Muller AF, Elgersma OE, Halkema DR, Fransen H, Janssens X, Buskens E, Mali WP. Vertebroplasty versus conservative treatment in acute osteoporotic vertebral compression fractures (Vertos II): An open-label randomised trial. *Lancet* 2010; 376:1085-1092.
23. Han S, Wan S, Ning L, Tong Y, Zhang J, Fan S. Percutaneous vertebroplasty versus balloon kyphoplasty for treatment of osteoporotic vertebral compression fracture: A meta-analysis of randomised and non-randomised controlled trials. *Int Orthop* 2011; 35:1349-1358.
24. Mirovsky Y, Anekstein Y, Shalmon E, Blankstein A, Peer A. Intradiscal cement leak following percutaneous vertebroplasty. *Spine (Phila Pa 1976)* 2006; 31:1120-1124.
25. Bhatia C, Barzilay Y, Krishna M, Friesem T, Pollock R. Cement leakage in percutaneous vertebroplasty: Effect of preinjection gelfoam embolization. *Spine (Phila Pa 1976)* 2006; 31:915-919.