Coronal Imaging Changes Associated with Recollapse of Injured Vertebrae After Percutaneous Vertebroplasty or Percutaneous Kyphoplasty Treatment for Osteoporotic Thoracolumbar Fracture

Liehua Liu[1], Qian Wang[2], Shiming Cheng[3], Jiangang Wang[4], Ying Li[5], Qiang Liang[1], Qiang Zhou[6], Weidong Jin[1], Zili Wang[1]

■ OBJECTIVE: **To observe coronal imaging changes associated with recollapse of injured vertebrae after percutaneous vertebroplasty or percutaneous kyphoplasty for osteoporotic thoracolumbar fracture (OTLF).**

■ METHODS: **Fifty-four cases were retrospectively divided into 2 groups according to the Arbeitsgemeinschaft für Osteosynthesefragen/Association for the Study of Internal Fixation (AO/ASIF) classification of thoracolumbar fracture: group A, type A1 fracture ($n = 26$); group B, type A3.1 fracture ($n = 28$). Visual analog scale, Oswestry Disability Index, local scoliotic Cobb angle, and coronal wedge angle of the injured vertebrae were observed preoperatively, on postoperative day 3, and at final follow-up.**

■ RESULTS: **The average follow-up time was 19.17 $\pm$ 6.30 months. At final follow-up, the visual analog scale score and the Oswestry Disability Index score were significantly greater in group B than in group A (both $P < 0.05$). At final follow-up, loss of correction of scoliotic Cobb angle and coronal wedge angle was significantly higher in group B than in group A ($P < 0.05$).**

■ CONCLUSIONS: **Percutaneous vertebroplasty or percutaneous kyphoplasty was effective in both type A1 and type A3.1 OTLF. However, coronal imaging changes after percutaneous vertebroplasty or percutaneous kyphoplasty were more obvious in type A3.1 OTLF than in type A1. Moreover, clinical outcomes in type A3.1 OTLF were slightly inferior to those in type A1.**

INTRODUCTION

In 1984, Galibert et al.[1] for the first time injected polymethacrylate, commonly known as bone cement, into a second cervical vertebral hemangioma, obtaining a good analgesic effect and setting a percutaneous vertebroplasty (PVP) precedent. In 1998, Garfin et al.[2] completed the first case of percutaneous kyphoplasty (PKP) for osteoporotic vertebral fracture. The basic goal of this technique was to use a balloon to lift the endplate of the fractured vertebrae, restoring the height of the vertebral body and correcting the kyphosis. At the present time, the main surgical indication of PVP or PKP is osteoporotic vertebral fracture, and a large number of clinical studies have confirmed the effectiveness of PVP or PKP in the treatment of osteoporotic vertebral fracture, with advantages including minimal invasion, obvious pain relief, less bleeding, early movement, and shorter recovery time.[3-9]

Key words
- Coronal recollapse
- Imaging change
- Osteoporotic vertebral fractures
- Percutaneous kyphoplasty
- Percutaneous vertebroplasty

Abbreviations and Acronyms

AO/ASIF: Arbeitsgemeinschaft für Osteosynthesefragen/Association for the Study of Internal Fixation
BMD: Bone mineral density
CWA: Coronal wedge angle
ODI: Oswestry Disability Index
OTLF: Osteoporotic thoracolumbar fracture
PKP: Percutaneous kyphoplasty
PVP: Percutaneous vertebroplasty
SCA: Scoliotic Cobb angle
VAS: Visual analog scale

From the [1]Department of Spinal Surgery, General Hospital of Ningxia Medical University, Yinchuan, China; [2]Hillsborough Community College, Tampa, Florida, USA; [3]Department of Orthopedics, Chongqing Dongnan Hospital, [4]Department of Orthopedics, No. 13 People's Hospital of Chongqing, [5]Department of Radiology, Southwest Hospital, The Army (Third Military) Medical University, and [6]Department of Spine Surgery, The Third Affiliated Hospital of Chongqing Medical University (Gener Hospital), Chongqing, China

To whom correspondence should be addressed: Zili Wang, B.S.; Qiang Zhou, Ph.D.; Weidong Jin, M.D.
[E-mail: wangzlnx@126.com; zq_tlh@163.com; dr.jin_weidong@163.com]

Liehua Liu, Qian Wang, and Shiming Cheng are co—first authors.

Citation: World Neurosurg. (2018) 120:e737-e744.
https://doi.org/10.1016/j.wneu.2018.08.154

Journal homepage: www.WORLDNEUROSURGERY.org

Available online: www.sciencedirect.com

Evaluation of the operative effects of PVP or PKP at follow-up mainly includes clinical and radiologic indicators.[10] The main clinical indicators include the visual analog scale (VAS) and Oswestry Disability Index (ODI), and the radiologic indicators mainly incorporate the changes in the vertebral recollapse in the sagittal view, such as the loss of anterior vertebral height and the kyphotic Cobb angle.[11,12] Yi et al.[11] reported that the Cobb angles of kyphosis in 35 cases of PVP were 11.2° ± 6.8° preoperatively, 9.7° ± 7.4° at 1 week postoperatively, and 13.3° ± 9.1° at 2 years postoperatively and that the vertebral compression ratios were 33.8%, 23.9%, and 27.3%,. Chou et al.[12] reported 13 cases requiring revision surgery after PVP, in which Cobb angles were 23.67° before PVP, 15.90° after PVP, and 30.92° before revision surgery. Furthermore, the authors found that vertebral recollapse in the coronal view exhibited noticeable imaging changes. However, there have been few reports on these changes. Therefore, we retrospectively observed the coronal imaging changes of recollapse of the injured vertebrae after PVP or PKP treatment for osteoporotic thoracolumbar fracture (OTLF), and we report these changes for the first time in the present study.

MATERIALS AND METHODS

Clinical Materials

This research project was reviewed and approved by the Scientific Research Ethics Committee of Ningxia Medical University General Hospital. From April 2015 to December 2016, 60 cases of single OTLF were managed with PVP or PKP; 6 cases were excluded: 1 patient died of pulmonary infection 3 months after surgery, 2 patients had adjacent vertebral fractures, and 3 patients were lost to follow-up. Thus, 54 cases were included in the study and were divided into 2 groups according to the Arbeitsgemeinschaft für Osteosynthesefragen/Association for the Study of Internal Fixation

Table 1. Demographic Data and Surgical Details

	Group A	Group B	*P*	Total
Sex			0.196*	
Male	8	4		12
Female	18	24		42
Age, years	72.19 ± 9.74	70.43 ± 5.95	0.422	71.28 ± 7.98 (55—89)
Fractured vertebrae			0.800*	
T12	8	10		18
L1	6	9		15
L2	7	5		12
L3	5	4		9
AO-ASIF type				
Type A1	26	0		26
Type A3.1	0	28		28
Vertebral sagittal compression			0.027*	
≤1/3	16	8		22
>1/3 and ≤1/2	10	20		32
Onset time, days	5.30 ± 2.57	5.14 ± 1.94	0.790	
Surgical method			0.000*	
PVP	24	12		36
PKP	2	16		18
Time of operation, minutes	40.08 ± 9.90	52.36 ± 14.70	0.004	45.93 ± 13.73 (28—80)
Volume of bone cement, mL				
Left	1.85 ± 0.32	1.99 ± 0.32	0.086	1.92 ± 0.32 (1.0—3.0)
Right	1.84 ± 0.26	2.01 ± 0.49	0.390	1.93 ± 0.40 (1.2—3.2)
Total	3.69 ± 0.46	4.00±0.75	0.113	3.85 ± 0.64 (2.8—6.0)

Values are presented as number or mean ± SD.
AO/ASIF, Arbeitsgemeinschaft für Osteosynthesefragen/Association for the Study of Internal Fixation; PVP, percutaneous vertebroplasty; PKP, percutaneous kyphoplasty.
*Two-tailed Fisher exact test.

Table 2. Clinical and Radiologic Indicators at 3 Time Points

	Preoperative	Postoperative Day 3	Final Follow-Up	P_1	P_2
VAS	7.30 ± 1.00	2.87 ± 0.70	2.56 ± 0.60	0.000	0.060
ODI	39.11 ± 3.01	19.65 ± 3.08	10.46 ± 1.28	0.000	0.000
SCA, °	5.11 ± 1.78	3.97 ± 1.60	4.58 ± 2.38	0.003	0.227
CWA, °	3.87 ± 1.33	2.42 ± 1.42	3.09 ± 1.56	0.000	0.079

P_1 represents the preoperative time point vs. postoperative day 3, and P_2 represents the postoperative day 3 time point vs. final follow-up.

VAS, visual analog scale; ODI, Oswestry Disability Index; SCA, scoliotic Cobb angle; CWA, coronal wedge angle.

(AO/ASIF) classification of thoracolumbar fracture: group A comprised type A1 fractures ($n = 26$), and group B comprised type A3.1 fractures ($n = 28$). Demographic data of patients and surgical details are shown in Table 1. The main concomitant diseases were hypertension in 13 cases, chronic obstructive pulmonary disease in 9 cases, coronary heart disease in 4 cases, and diabetes in 4 cases. The inclusion criteria were as follows: 1) fresh, single primary OTLF; 2) back pain caused by trauma and the spinous process tenderness point and percussion pain point consistent with the fractured vertebrae verified by x-ray[13]; 3) anteroposterior and lateral x-rays indicating upper vertebral or upper vertebral and midvertebral compressive changes; 4) thoracolumbar fractures identified as type A1 or type A3.1, according to AO-ASIF, by imaging examination[14]; 5) ≤3 weeks from the onset time to the operation day; and 6) follow-up time ≥12 months. The following patients were excluded: 1) patients with major trauma; (2) patients with symptomatic nerve damage, such as sensory abnormalities and lower extremity or sphincter muscle power decrease; (3) patients with vertebral bone destruction resulting from tumor or infection; (4) patients who experienced acute refracture of the operated vertebrae and fracture of adjacent vertebrae during follow-up; 5) patients with mental disorders; and (6) patients with other serious diseases resulting in complete incapacitation.

Main Treatment

VAS and ODI scores were obtained for all cases after admission. Subsequently, relevant examinations and nonsurgical treatments (e.g., strict bed rest, pain medications, antiosteoporosis treatment) were performed. Furthermore, the physician informed the patient of the advantages and disadvantages of various treatment methods (nonsurgical treatment, PVP, PKP, and open surgery). Indications for PVP included ineffective nonsurgical treatment, patient intolerance of severe pain, unstable vertebral fracture, and tolerance of PVP surgery by a patient unsuitable for long-term bed rest.[15] Indications of PKP mainly included vertebral height compression greater than 1/3 and voluntary choice of PKP. Surgeons were the main members of the research team. The main surgical steps were as follows. With the patient in a prone position and administration of local anesthesia, a puncture was created at the skin surface projection of the pedicle. The position of the guide pin was determined through C-arm x-ray, and the dilation tube and the working sleeve were penetrated to the anterior one third of the injured vertebral body to establish surgical access. During penetration, the puncture direction angle between the needle and the median sagittal plane was 5°–10°. Bone cement in the wire drawing period was injected into both sides of the vertebral body and closely monitored by x-ray to prevent bone cement leakage. The vertebral body was filled with as much bone cement as possible, with a typical volume of 3–5 mL per vertebra, as appropriate.[16] In PKP surgery, before the bone cement was injected, the balloon was successively implanted into both sides of the vertebral body to expand the injured vertebrae. Usually, the patient was out of bed on the first postoperative day, and x-ray imaging was performed on postoperative day 3. Antiosteoporosis treatment (alendronate, calcium, and active vitamin D) was recommended on discharge and during follow-up. Thoracolumbar brace fixation was postoperatively suggested for 4–6 weeks for type A3.1 fractures.

Observation of Indicators and Data Measurement

Clinical and radiologic indicators were observed. The clinical indicators included VAS score, ODI score, and surgery satisfaction. All imaging examinations were performed by professional and technical personnel using the same methods. Preoperatively, on postoperative day 3, and at final follow-up, function (VAS, ODI) and coronal imaging of the injured vertebra were evaluated. At follow-up, bone mineral density (BMD) was measured, and the patients were asked about their satisfaction with surgery according to Odom's standard, which includes 4 grades: excellent, good, fair, and poor.[17] Coronal radiologic indicators of the injured vertebrae included local scoliotic Cobb angle (SCA) and vertebral coronal wedge angle (CWA). SCA was formed between the upper endplate of the upper normal vertebrae adjacent to the injured vertebrae and the inferior endplate of the lower normal vertebrae adjacent to the injured vertebrae. CWA was formed between the upper edge of the injured vertebrae and the lower edge of the injured vertebrae. In principle, regular follow-up was required at 1, 3, 6, 12, 18, and 24 months postoperatively and once a year thereafter. Imaging data were independently measured by 1 radiologist and 2 clinicians, and the average was taken. If the measurement error was large, the 3 personnel came together for a discussion. The correction of SCA = preoperative SCA − SCA on postoperative day 3. The loss of correction of SCA = SCA at the final follow-up − SCA on postoperative day 3. Similarly, the correction of CWA = preoperative CWA − CWA on postoperative day 3. The loss of correction of CWA = CWA at the final follow-up − CWA on postoperative day 3.

Statistical Methods

Data were processed using IBM SPSS Version 19.0 (IBM Corp., Armonk, New York, USA), and measurement data were processed using mean ± SD. The statistics included 2 sections. In section 1, all cases were not divided into groups. One-way analysis of variance was used to compare the parameters at 3 time points: preoperative, postoperative day 3, and final follow-up. Whether the loss of correction of SCA was related to fracture type, surgical method, total volume of bone cement, preoperative SCA, correction degree of SCA, preoperative CWA, correction degree of CWA, loss of correction of CWA, or BMD was analyzed through

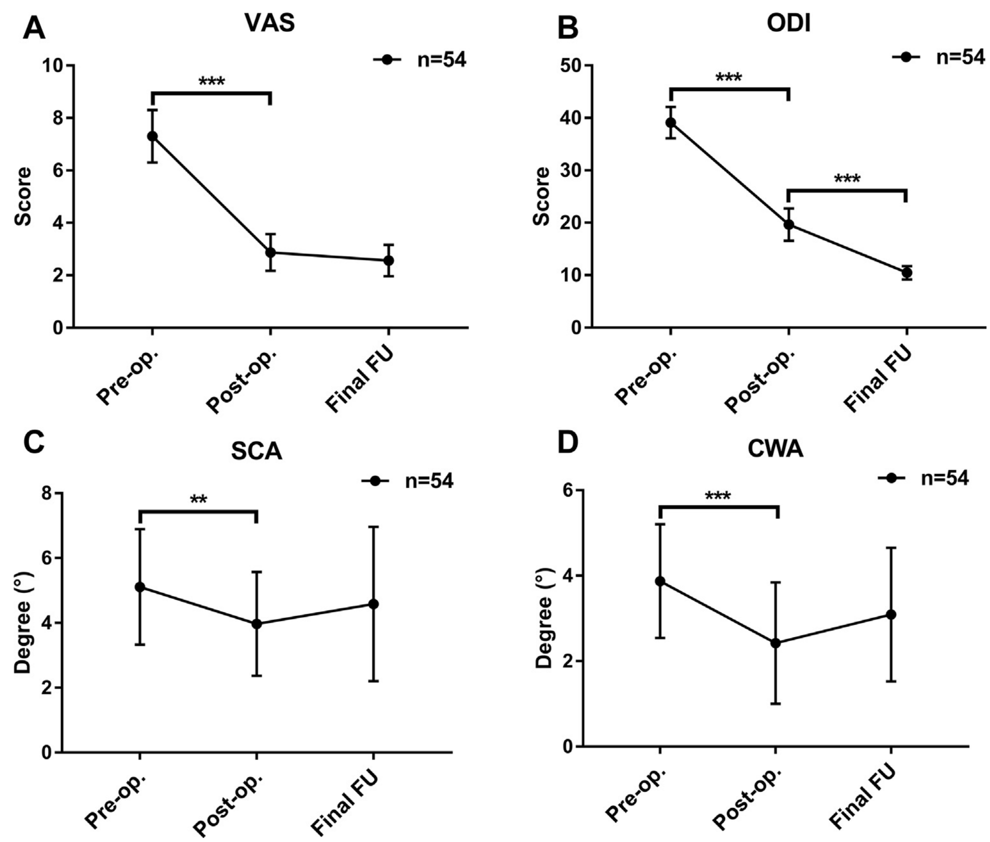

Figure 1. (**A**—**D**) Visual analog scale, Oswestry Disability Index, scoliotic Cobb angle, and coronal wedge angle for all cases preoperatively, on postoperative day 3, and at final follow-up. VAS, visual analog scale; ODI, Oswestry Disability Index; SCA, scoliotic Cobb angle; CWA, coronal wedge angle; Pre-op., preoperative; Post-op., postoperative; FU, follow-up. **$P < 0.01$; ***$P < 0.001$.

multivariate linear stepwise regression. Whether the loss of correction of CWA was related to fracture type, surgical method, total volume of bone cement, preoperative CWA, correction degree of CWA, or BMD was analyzed through multivariate linear stepwise regression. If the measurement data were not normally distributed, the data were logarithmically transformed.

In section 2, all cases were divided into group A ($n = 26$) and group B ($n = 28$). If the measurement data were normally distributed, an unpaired t test was used to compare the difference between the 2 groups; if not, a Mann-Whitney test was used. Fisher exact test was used to compare the constituent ratio of surgery satisfaction between the 2 groups. $P < 0.05$ was considered statistically significant.

RESULTS

Clinical and Radiologic Indicators for All Cases

The average follow-up time was 19.17 ± 6.30 months (range, 12—32 months). The results of statistical section 1 were as follows. The clinical and radiologic indicators preoperatively, on postoperative day 3, and at the final follow-up are shown in Table 2 and Figure 1. On postoperative day 3, VAS and ODI scores were less than the values observed preoperatively, and the differences between the 2 time points were statistically significant ($P < 0.001$). At the final follow-up, there was no significant difference in VAS score compared with postoperative day 3 ($P > 0.05$), but the ODI score at the final follow-up was lower than on postoperative day 3, and the difference between the 2 time points was statistically significant ($P < 0.001$). At the final follow-up, excellent and good ratings of satisfaction according to Odom's criteria accounted for 85.18% of all ratings (Table 3). On postoperative day 3, SCA and CWA were lower than the preoperative values, and the difference between the 2 time points was statistically significant ($P < 0.05$). At the final follow-up, SCA and CWA were greater than on postoperative day 3, but the differences were not significant ($P > 0.05$). The loss of correction of SCA was related to the preoperative CWA and the loss of correction of CWA ($R^2 = 0.313$, $P < 0.001$). The loss of correction of CWA was related to the fracture type and surgical method ($R^2 = 0.310$, $P < 0.001$).

Clinical and Radiologic Indicators in Groups A and B

The results of statistical section 2 were as follows. There was no significant difference between the 2 groups in sex, age, fractured vertebrae, onset time, volume of injected bone cement, follow-up

Table 3. Surgery Satisfaction at Final Follow-Up

	Group A ($n = 26$)	Group B ($n = 28$)	Total ($n = 54$)
Excellent	15 (57.69%)	13 (46.43%)	28 (51.85%)
Good	8 (30.77%)	10 (35.71%)	18 (33.33%)
Fair	3 (11.54%)	5 (17.86%)	8 (14.82%)
Poor	0	0	0
P		0.759*	

*Two-tailed Fisher exact test.

time, or BMD at the final follow-up ($P > 0.05$), but there was a significant difference between the 2 groups in vertebral sagittal compression, surgical method, and time of operation ($P < 0.05$). The clinical and radiologic indicators between the 2 groups are shown in Table 4 and Figure 2. The VAS and ODI scores in group B were greater than the scores in group A preoperatively and on postoperative day 3, but the differences were not statistically significant ($P > 0.05$). At the final follow-up, the VAS score in group B was greater than the score in group A, but the difference was not statistically significant ($P > 0.05$). However, the ODI score in group B was greater than the score in group A, which was statistically significant ($P < 0.05$). The Odom standard excellent and good ratings of surgery satisfaction in groups A and B were 88.46% and 82.14%, respectively (Table 3). There was no significant difference in the constituent ratio of surgery satisfaction between the 2 groups ($P > 0.05$). Typical cases are shown in Figure 3. The SCA in group B was greater than the SCA in group A preoperatively, on postoperative day 3, and at the final follow-up, but the differences were not statistically significant ($P > 0.05$). However, the loss of correction of SCA in group B was significantly greater than that in group A ($P < 0.05$). At the final follow-up, the CWA and the loss of correction of CWA in group B were greater than in group A, and the difference was significant ($P < 0.05$).

Table 4. Clinical and Radiologic Indicators Between Groups

	Group A ($n = 26$)	Group B ($n = 28$)	*P*
VAS			
Preoperative	7.04 ± 1.11	7.54 ± 0.84	0.068
Postoperative day 3	2.69 ± 0.74	3.04 ± 0.64	0.072
Final follow-up	2.38 ± 0.64	2.68 ± 0.55	0.074
ODI			
Preoperative	38.77 ± 3.44	39.43 ± 2.57	0.432
Postoperative day 3	19.08 ± 2.92	20.18 ± 3.17	0.192
Final follow-up	10.08 ± 1.09	10.82 ± 1.36	0.036*
SCA, °			
Preoperative	4.71 ± 1.96	5.49 ± 1.52	0.156*
Postoperative day 3	3.72 ± 1.87	4.20 ± 1.28	0.203*
Final follow-up	3.91 ± 1.87	5.20 ± 2.66	0.082*
Correction	0.99 ± 1.09	1.28 ± 1.10	0.264*
Loss of correction	0.19 ± 0.19	1.00 ± 1.98	0.011*
CWA, °			
Preoperative	3.44 ± 0.94	4.27 ± 1.52	0.050*
Postoperative day 3	2.08 ± 1.06	2.74 ± 1.65	0.156*
Final follow-up	2.30 ± 1.00	3.61 ± 1.75	0.005*
Correction	1.36 ± 0.69	1.55 ± 0.77	0.842*
Loss of correction	0.22 ± 0.21	0.88 ± 0.72	0.000*
BMD at final follow-up	−4.16 ± 0.98	−4.57 ± 0.87	0.109
Follow-up time, months	18.04 ± 6.71	20.21 ± 5.82	0.226*

VAS, visual analog scale; ODI, Oswestry Disability Index; SCA, scoliotic Cobb angle; CWA, coronal wedge angle; BMD, bone mineral density.
*Mann-Whitney test.

DISCUSSION

Recollapse of injured vertebrae after PVP or PKP is mainly related to the vertebral pathologic factor and the filler material.[18] The anterior one third of the vertebral body fracture might lead to the rupture of the medullary arterioles, resulting in avascular osteonecrosis of the vertebral body.[19] Bone cement could induce osteonecrosis as well as stress concentrated at the bone cement—cancellous bone interface owing to the high elastic modulus of bone cement, leading to failure of the interface, aseptic loosening of the implant, and progressive collapse.[20] Previous studies have reported sagittal imaging changes associated with the recollapse of injured vertebrae, which mainly included anterior vertebral height decrease and local kyphotic Cobb angle increase.[11,12] As the sagittal imaging changes indicating the recollapse of injured vertebrae were obvious, we could not ignore the coronal image changes. To the best of our knowledge, this is the first study to focus on the coronal imaging changes associated with the recollapse of injured vertebrae after PVP or PKP treatment.

Liebschner et al.[16] found that vertebral unilateral load could cause spinal instability through a three-dimensional finite element model and that unilateral perfusion of bone cement could cause the cement to move from the side of the perfusion to the side of the nonperfusion, which is consistent with the theory that the internal instrument of the spine requires balanced fixation on both sides.[21] Therefore, in this study, both cases were punctured and perfused with bone cement bilaterally to prevent the uneven distribution of cement in the vertebral body or uneven lateral force on the vertebral body.

This study found that VAS score recovery was faster than ODI score recovery in all cases because ODI includes more parameters, and some patients also present with systemic diseases, such as heart disease, lung disease, and endocrine disease. Therefore, the recovery of ODI score was slower than that of the simple pain score. The cancellous bone around the bone cement after PVP or PKP gradually collapsed without obvious acute pathologic changes in the vertebral body, such as edema and hemorrhage; thus, most patients had no obvious pain or aggravated pain. From the

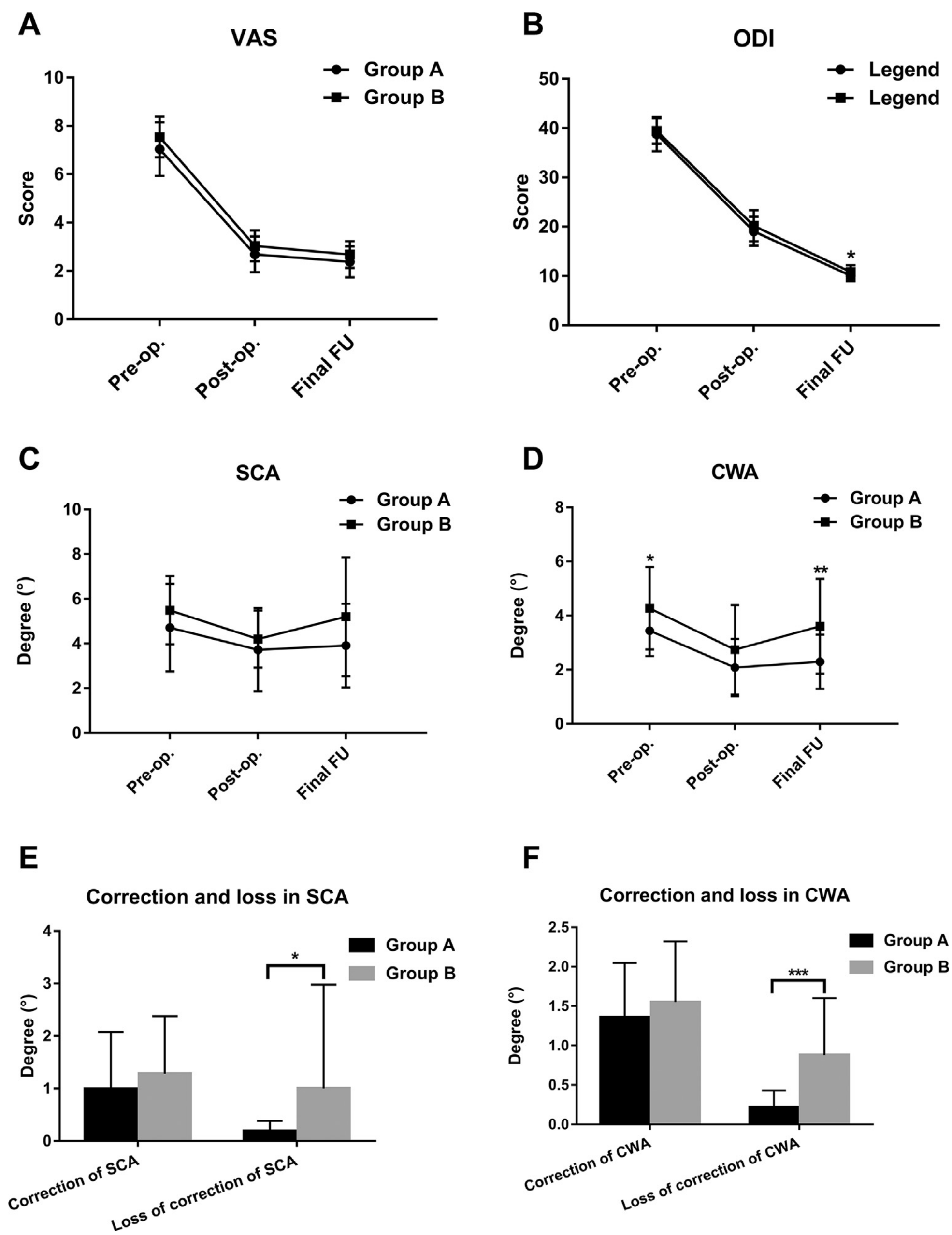

Figure 2. (**A**–**D**) Visual analog scale, Oswestry Disability Index, scoliotic Cobb angle, and coronal wedge angle in group A and group B preoperatively, on postoperative day 3, and at final follow-up. (**E** and **F**) Correction and loss of scoliotic Cobb angle and coronal wedge angle. VAS, visual analog scale; ODI, Oswestry Disability Index; SCA, scoliotic Cobb angle; CWA, coronal wedge angle; Pre-op., preoperative; Post-op., postoperative; FU, follow-up. $*P < 0.05$; $**P < 0.01$; $***P < 0.001$.

perspective of radiologic parameters, PVP or PKP could effectively correct part of the coronal deformity of the injured vertebrae, but there was a certain loss of correction of SCA and CWA during the follow-up period. Overall, patients had satisfactory function and quality of life during the follow-up period of 19.17 months.

Multiple linear regression indicated that the loss of correction of SCA was related to the preoperative CWA and the loss of correction of CWA. Because CWA was greater, SCA would be followed by a corresponding change. In other words, CWA presence was more common in the follow-up, and the loss of SCA was greater.

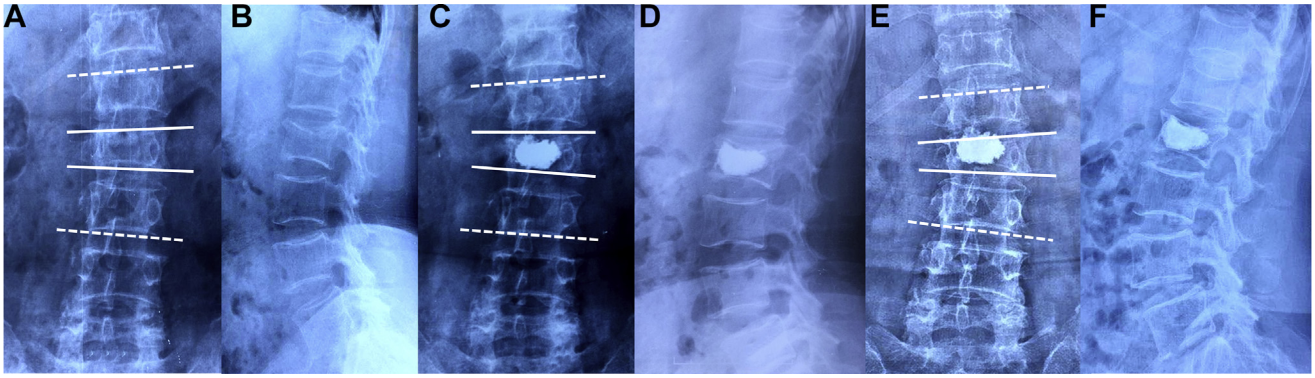

Figure 3. A 67-year-old woman with type A3.1 L2 osteoporotic fracture 29 months after percutaneous kyphoplasty. (**A** and **B**) Preoperative anteroposterior and lateral x-rays. (**C** and **D**) Anteroposterior and lateral x-rays on postoperative day 3. (**E** and **F**) Anteroposterior and lateral x-rays at final follow-up. Scoliotic Cobb angle was 6.40° preoperatively, 6.01° on postoperative day 3, and 12.18° at final follow-up (*dotted lines*). Coronal wedge angle was 5.77° preoperatively, 5.05° on postoperative day 3, and 7.22° at final follow-up.

The loss of correction of CWA was related to the fracture type and surgical method. First, the more severe the fracture type, the worse the stability. The residual CWA after surgery would continue to increase during the follow-up period. Second, regarding the more severe and unstable type A3.1 fracture, we tended to use PKP surgery (PKP-to-PVP ratio = 16:12) in the hope of achieving better recovery of the vertebral body height and better correction of spinal deformity.[22] However, the correction of spinal deformity was correspondingly lost throughout the follow-up.[20] The reason may be that it was difficult to fully infiltrate the bone cement into the compressed cancellous bone around the balloon dilation, and bone cement did not contact the upper and lower endplates of the injured vertebrae. This reasoning is consistent with that of Kim et al.[23] and Chevalier et al.[24]

In this study, some cases were burst fractures (type A3.1), and therefore we divided all cases into 2 groups according to the AO-ASIF classification. At the final follow-up, the 2 groups showed similar VAS scores, but the ODI scores in group A were superior to ODI scores in group B. The excellent and good ratings of surgery satisfaction in group A were slightly superior to those in group B. Based on the changes in SCA and CWA, the study showed that the more serious the type of fracture, the more obvious the coronal deformity of the injured vertebra. The stress of the spine postoperatively was more concentrated on the concave side, and the injured vertebra was further compressed; thus SCA and CWA increased obviously throughout the follow-up period. In this study, the clinical outcomes of group B were slightly inferior to those of group A; we suspected that the difference was related to the greater aggravation of coronal deformity in group B. Therefore, clinicians should pay attention to the coronal deformity of the injured vertebrae and try to correct it and maintain the correction, especially for type A3 OTLF.

Because of the persistence of pathologic factors associated with osteoporosis, postoperative vertebral recollapse after PVP or PKP had a certain degree of correlation with osteoporosis. Hey et al.[25] proposed that lower BMD was a risk factor for vertebral recollapse. Yoo et al.[26] noted that BMD was one of the reference indexes of vertebral recollapse after vertebral reinforcement treatment. Whether the patient received standard antiosteoporosis treatment postoperatively after PVP or PKP was related to the patient's health awareness, compliance, and financial abilities. Physicians should increase postoperative health education and emphasize the importance of regular antiosteoporosis treatment.

This study had some limitations, including a small number of cases and single-center, nonprospective design. As a next step, we will expand the sample size, striving to evaluate the same surgical method for the same fracture type.

CONCLUSIONS

PVP or PKP was effective in both type A1 and type A3.1 OTLF. However, the coronal imaging changes associated with recollapse of injured vertebrae after PVP or PKP were more obvious in type A3.1 OTLF than in type A1, which were manifested as the loss of correction of SCA and CWA. Moreover, the clinical outcomes in type A3.1 OTLF were slightly inferior to outcomes in type A1.

REFERENCES

1. Galibert P, Deramond H, Rosat P, Le Gars D. Preliminary note on the treatment of vertebral angioma by percutaneous acrylic vertebroplasty. *Neurochirurgie*. 1987;33:166-168 [in French].

2. Garfin SR, Yuan HA, Reiley MA. New technologies in spine: kyphoplasty and vertebroplasty for the treatment of painful osteoporotic compression fractures. *Spine (Phila Pa 1976)*. 2001;26:1511-1515.

3. 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.

4. Yang H, Pan J, Sun Z, Mei X, Yang Y. Percutaneous augmented instrumentation of unstable thoracolumbar burst fractures: our experience in preventing cement leakage. *Eur Spine J*. 2012;21:1410-1412 [author reply: 1413].

5. Lange A, Kasperk C, Alvares L, Sauermann S, Braun S. Survival and cost comparison of kyphoplasty and percutaneous vertebroplasty using

German claims data. *Spine (Phila Pa 1976)*. 2014;39:318-326.

6. Zhao G, Liu X, Li F. Balloon kyphoplasty versus percutaneous vertebroplasty for treatment of osteoporotic vertebral compression fractures (OVCFs). *Osteoporos Int*. 2016;27:2823-2834.

7. Yang EZ, Xu JG, Huang GZ, Xiao WZ, Liu XK, Zeng BF, et al. Percutaneous vertebroplasty versus conservative treatment in aged patients with acute osteoporotic vertebral compression fractures: a prospective randomized controlled clinical study. *Spine (Phila Pa 1976)*. 2016;41:653-660.

8. Takura T, Yoshimatsu M, Sugimori H, Takizawa K, Furumatsu Y, Ikeda H, et al. Cost-effectiveness analysis of percutaneous vertebroplasty for osteoporotic compression fractures. *Clin Spine Surg*. 2017;30:E205-E210.

9. Du JP, Liu JJ, Fan Y, Zhang JN, Huang YS, Zhang J, et al. Surgery for multisegment thoracolumbar mild osteoporotic fractures: revised assessment system of thoracolumbar osteoporotic fracture. *World Neurosurg*. 2018;114:e969-e975.

10. Ee GW, Lei J, Guo CM, Yeo W, Tan SB, Tow PB, et al. Comparison of clinical outcomes and radiographic measurements in 4 different treatment modalities for osteoporotic compression fractures: retrospective analysis. *J Spinal Disord Tech*. 2015;28:E328-335.

11. Yi HJ, Jeong JH, Im SB, Lee JK. Percutaneous vertebroplasty versus conservative treatment for one level thoracolumbar osteoporotic compression fracture: results of an over 2-year follow-up. *Pain Physician*. 2016;19:E743-750.

12. Chou KN, Lin BJ, Wu YC, Liu MY, Hueng DY. Progressive kyphosis after vertebroplasty in osteoporotic vertebral compression fracture. *Spine (Phila Pa 1976)*. 2014;39:68-73.

13. Lin J, Liu H, Yang P, Yang H. The methodology of locating painful responsible vertebrae in osteoporotic vertebral compression fractures. *Int J Clin Exp Med*. 2015;8:4686-4689.

14. Vaccaro AR, Oner C, Kepler CK, Dvorak M, Schnake K, Bellabarba C, et al. AOSpine thoracolumbar spine injury classification system: fracture description, neurological status, and key modifiers. *Spine (Phila Pa 1976)*. 2013;38:2028-2037.

15. Röllinghoff M, Zarghooni K, Schlüter-Brust K, Sobottke R, Schlegel U, Eysel P, et al. Indications and contraindications for vertebroplasty and kyphoplasty. *Arch Orthop Trauma Surg*. 2010;130:765-774.

16. Liebschner MA, Rosenberg WS, Keaveny TM. Effects of bone cement volume and distribution on vertebral stiffness after vertebroplasty. *Spine (Phila Pa 1976)*. 2001;26:1547-1554.

17. Odom GL, Finney W, Woodhall B. Cervical disk lesions. *JAMA*. 1958;166:23-28.

18. Heo DH, Chin DK, Yoon YS, Kuh SU. Recollapse of previous vertebral compression fracture after percutaneous vertebroplasty. *Osteoporos Int*. 2009;20:473-480.

19. He D, Yu W, Chen Z, Li L, Zhu K, Fan S. Pathogenesis of the intravertebral vacuum of Kümmell's disease. *Exp Ther Med*. 2016;12:879-882.

20. Yu W, Xu W, Jiang X, Liang, Jian W. Risk factors for recollapse of the augmented vertebrae after percutaneous vertebral augmentation: a systematic review and meta-analysis. *World Neurosurg*. 2018;111:119-129.

21. Dick JC, Brodke DS, Zdeblick TA, Bartel BD, Kunz DN, Rapoff AJ. Anterior instrumentation of the thoracolumbar spine. A biomechanical comparison. *Spine (Phila Pa 1976)*. 1997;22:744-750.

22. Schofer MD, Efe T, Timmesfeld N, Kortmann HR, Quante M. Comparison of kyphoplasty and vertebroplasty in the treatment of fresh vertebral compression fractures. *Arch Orthop Trauma Surg*. 2009;129:1391-1399.

23. Kim MJ, Lindsey DP, Hannibal M, Alamin TF. Vertebroplasty versus kyphoplasty: biomechanical behavior under repetitive loading conditions. *Spine (Phila Pa 1976)*. 2006;31:2079-2084.

24. Chevalier Y, Pahr D, Charlebois M, Heini P, Schneider E, Zysset P. Cement distribution, volume, and compliance in vertebroplasty: some answers from an anatomy-based nonlinear finite element study. *Spine (Phila Pa 1976)*. 2008;33:1722-1730.

25. Hey HW, Tan JH, Tan CS, Tan HM, Lau PH, Hee HT. Subsequent vertebral fractures post cement augmentation of the thoracolumbar spine: Does it correlate with level-specific bone mineral density scores? *Spine (Phila Pa 1976)*. 2015;40:1903-1909.

26. Yoo CM, Park KB, Hwang SH, Kang DH, Jung JM, Park IS. The analysis of patterns and risk factors of newly developed vertebral compression fractures after percutaneous vertebroplasty. *J Korean Neurosurg Soc*. 2012;52:339-345.

Conflict of interest statement: This work was supported by the Chongqing Municipal Health and Family Planning Commission (2016MSXM084).

Received 4 July 2018; accepted 20 August 2018

Citation: World Neurosurg. (2018) 120:e737-e744.
https://doi.org/10.1016/j.wneu.2018.08.154

Journal homepage: ***www.WORLDNEUROSURGERY.org***

Available online: ***www.sciencedirect.com***