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Original Article

Effectiveness of bone-filled mesh bag technology and angle vertebroplasty in the treatment of osteoporotic thoracic vertebral compression fractures in the elderly

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Abstract: Objective: To evaluate the effectiveness, pain level, and lung function in elderly patients with osteoporotic thoracic vertebral compression fractures using bone filling mesh bag technology compared to curved vertebroplasty. Methods: This retrospective analysis reviewed 72 elderly patients with osteoporotic thoracic vertebral compression fractures treated at Xindu District People's Hospital of Chengdu between February 2021 and January 2022. The patients were separated into two groups according to surgery approach: an observation group using bone filling mesh bag technology and a control group using curved vertebroplasty. The overall response rate, pain degree, pulmonary function, life quality grades, surgical indicators, and bone cement leakage rates of the two groups were evaluated. Results: The variation in overall response rate (P=0.420), pain degree (P=0.270), pulmonary function (peak expiratory flow: P=0.660, forced expiratory volume in the first second: P=0.775, forced vital capacity: 0.062), and life quality grades (physical health: P=0.949, social function: P=0.935, physiological function: P=0.970, vitality: P=0.778) between the observation group and the control group after treatment was not statistically meaningful. The Cobb angle (P<0.001) and vertebral height (P<0.001) of patients in the observation group were significantly higher than those in the control group after therapy. The leakage rates of bone cement (intervertebral disc leakage, paravertebral vein leakage, paravertebral soft tissue leakage) of patients in the observation group were notably lower than those in the control group after therapy (P=0.029). Conclusion: Bone filling mesh bag technology offers significant improvements in Cobb angle and vertebral height for treating elderly patients with osteoporotic thoracic vertebral compression fractures, and reduced the leakage rate of bone cement. This technique achieves comparable therapeutic outcomes to curved vertebroplasty.

Keywords: Bone filling mesh bag technology, curved vertebroplasty, senile osteoporotic thoracic vertebral compression fractures, curative effect, degree of pain, pulmonary function

Introduction

As China's population ages, more senior people are experiencing osteoporotic thoracic vertebral compression fractures. The main clinical symptom of this disease is obvious pain in the thoracolumbar region, which severely impacts the daily life of patients [1, 2]. This is a systemic disease mainly caused by the reduction of bone mass, bone microstructure degradation and the decrease of bone strength [3, 4]. Elderly people, due to the relatively weaker physical function and lower bone mass and bone mineral density than younger population, are prone to thoracic vertebral compression fractures, resulting in obvious postoperative pain that seriously affects their quality of life [5, 6].

At present, the primary therapy for osteoporotic thoracic vertebral compression fracture in elderly patients is percutaneous vertebroplasty. However, this operation demands high proficiency and technical expertise from the operators. Imbalances in bone cement filling of both sides can lead to internal vertebral instability [7]. Minimally invasive surgeries, such as vertebroplasty and kyphoplasty, offer new treatment options, but these procedures often result in complications like bone cement extravasation during operation, pulmonary embolism and spinal stenosis after operation, which greatly

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affect the outcome and recovery [8, 9]. A novel approach in this field is bone filling mesh bag technology, noted for its excellent ductility and compressibility [10, 11]. The curved vertebroplasty is a simplified and improved version of percutaneous vertebroplasty, which facilitates a more balanced distribution of bone cement in the responsible vertebral body [12, 13]. Both approaches derive from percutaneous kyphoplasty (PKP), the most commonly performed surgery for these fractures. Studies have shown that bone filling mesh container vertebroplasty is comparable to PKP in terms of functional recovery, operation duration, number of fluoroscopy, and complication rates [14]. However, curved vertebroplasty, a relatively new treatment method, has obvious advantages in terms of safety and convenience and effective bone cement diffusion and low leakage rate [15, 16].

Despite these advancements, clinical studies on these methods are limited, and reports comparing the two modalities for the treatment of osteoporotic fractures are scarce. Also, each surgical method has unique technical characteristics, and different patients have different fracture degrees and bone conditions. In cases where the posterior wall is fractured, connecting the vertebral canal to the vertebral body, PKP can lead to bone cement leakage into the vertebral canal along the damaged part of the posterior wall of the vertebral body, causing spinal cord and nerve injury and compromising results [17]. Thus, the choice of surgical methods should be tailored to the individual's conditions and preference.

Based on the above background, this study compared the effectiveness of curved vertebroplasty and bone filling mesh bag technologies, as well as pain degree and lung function of elderly patients with osteoporotic thoracic vertebral compression fractures, hoping to provide more theoretical references for the treatment of this patient population.

Methods

Study design and patients

A retrospective analysis was performed on 72 elderly patients with osteoporotic thoracic vertebral compression fractures who were treated in Xindu District People's Hospital of Chengdu between February 2021 and January 2022. These patients were divided into two groups according to the surgical approach: a control group (curved vertebroplasty, n=42) and an observation group (bone filling mesh bag technology, n=30). This study was approved by the institutional review board of the Xindu District People's Hospital of Chengdu (2023CYFYIRB-BA-Nov12, date: 20231112).

Inclusion criteria: (1) Diagnosis of osteoporotic thoracic vertebral compression fractures; (2) Suitability for both treatment methods; (3) Age ≥60 years old; (4) Presence with single segment fracture; (5) Clinical symptoms included sudden or persistent pain in thoracic vertebrae of varying degrees; (6) Availability of complete clinical files. Exclusion criteria: (1) Age under 60 years old; (2) Presence of surgical contraindications; (3) Coagulation dysfunction; (4) Presence of other serious fractures; (5) Allergy to cement or other factors affecting the operation; (6) Incomplete clinical files. The flow chart of study process is shown in **Figure 1**.

Surgical methods

The control group was treated with curved vertebroplasty [18]: the patients completed various basic examinations such as cardiopulmonary examination before the operation, and the existing underlying diseases were stabilized. The vertebral condition was confirmed through X-ray, CT and other examinations. In the prone position, a surface mark was made at the protrusion of pedicle of the responsible vertebral body, and then local anesthesia was performed. The damaged vertebra was penetrated straight through the pedicle of the vertebral arch with the use of C-arm fluoroscopy. The needle tip was positioned about 5 mm in front of the posterior edge of the vertebral body. After positioning the needle correctly, the punctured pillow core was removed and the angle conveying device was inserted. This device ensured the tip traversed the midline of the vertebral body in the anteroposterior view and was positioned in the anterior and middle third of the vertebral body in the lateral view. Then, the angle conveying device was extracted from the metal core. The "needle withdrawal method" was used to inject bone cement into the responsible vertebral body at multiple points, then the wound was cleaned, and the

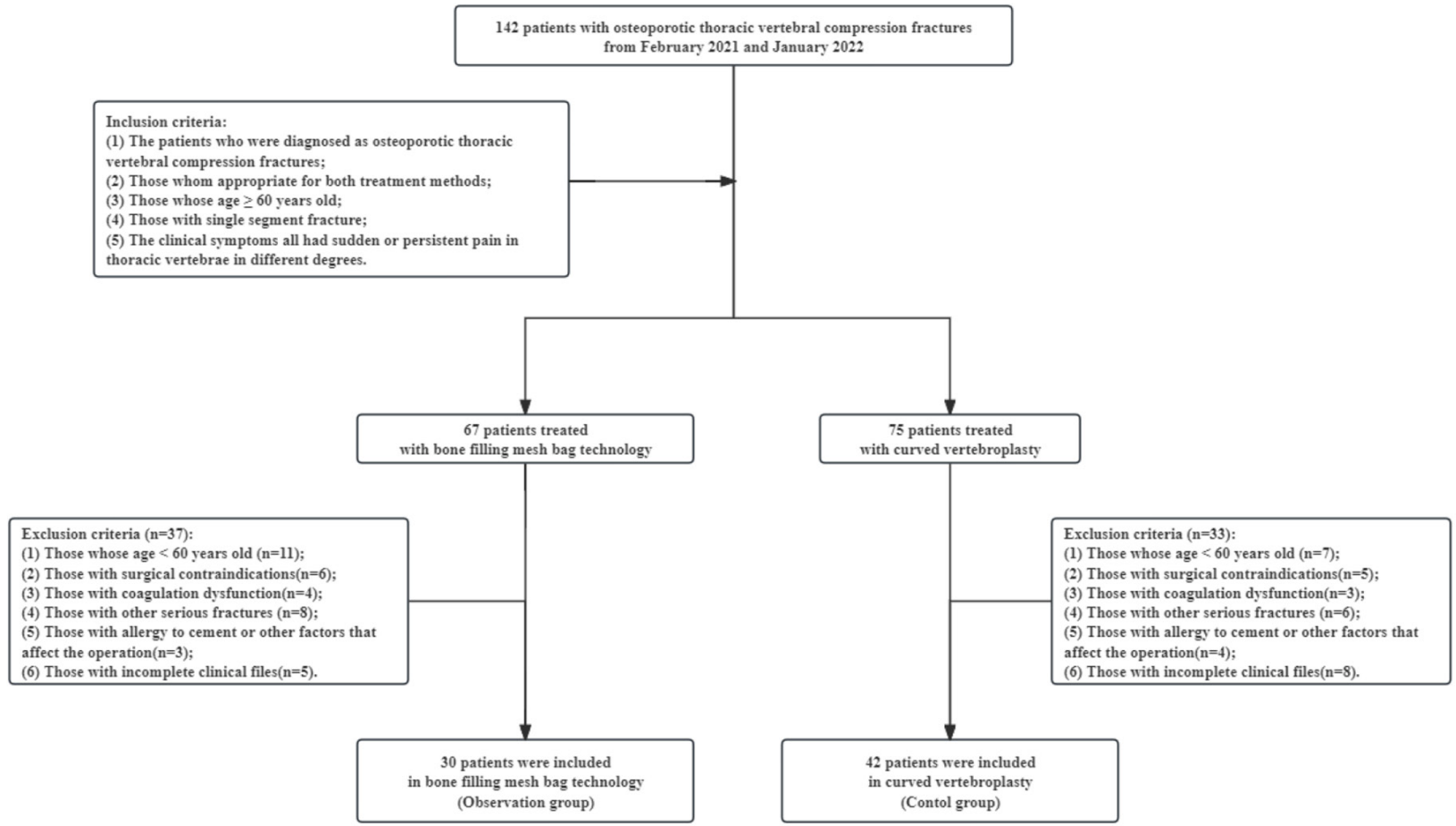

Figure 1. Study flow chart.

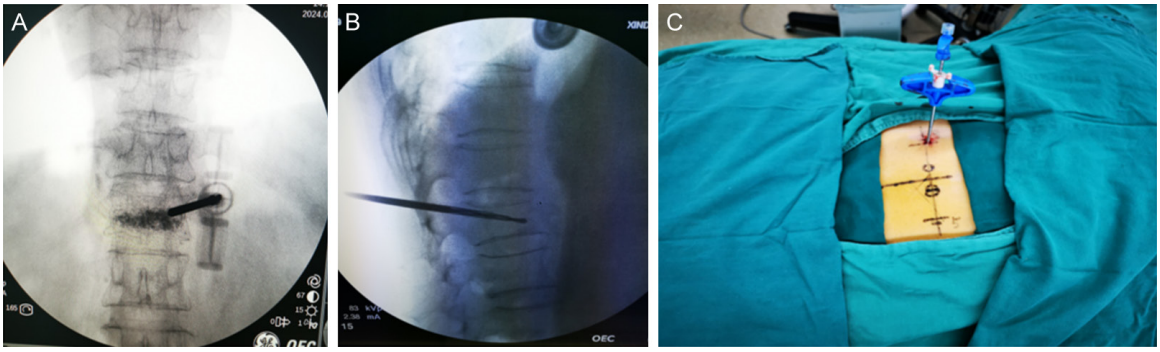

Figure 2. Surgical images of the two methods. A. Bone cement injection process by Curved vertebroplasty. B. Bone cement injection process by Bone-filled mesh bag technology. C. Use of expansion orthoses on surgical sites.

changes of vital sign indicators of patients were observed. After the bone cement hardened, the patients were sent to the ward. Following surgery, the patients' vital signs were monitored, and antibiotics were administered as needed. Patients were encouraged to mobilize within 2-8 hours post-surgery, depending on individual recovery, and appropriate functional exercise were recommended, and ongoing treatment for osteoporosis was provided.

The observation group was treated with bone filling mesh bag technology [14]: the patients were positioned supine on a hard bed with the injured vertebrae extended. Pedicle positions and other landmarks on both sides of the responsible vertebrae were determined by C-arm fluoroscopy. The operation area was routinely disinfected, and local infiltration anesthesia was performed with 1% lidocaine. The needle was inserted at 10 o'clock and 2 o'clock on the left and right sides of the pedicle, respectively. The needle core was extracted when the needle tip reached the inner margin of the pedicle in the anteroposterior view and the posterior edge of the vertebral body in the lateral view. Based on the perspective of the C-arm machine, the solid vertebral drill was inserted in a slow and rotating manner until the midline of the pedicle was reached in the anteroposterior view and exceeded two thirds of the vertebral body in the lateral view, so as to establish the working channel and replace the working sleeve. Via the working path, an expansion orthosis was placed in the first third of the vertebral body, and the instrument was slowly rotated until the vertebral body was restored, then the instrument was retracted. Under continuous fluoroscopy guidance, wire drawing bone cement was slowly poured into the mesh bag placed in the front quarter of the vertebral body along the working channel. During injection, the filling of the mesh bag bone cement and the dispersion within the vertebral body were closely observed. Injection was stopped once the bone cement gradually exuded and reached the edge of the mesh bag. After the cement solidified, the sleeve and working passage were pulled out, and the wound was disinfected and bandaged. Patients were required to remain in bed initially, with close monitoring of the bone cement reaction. Functional exercise could be carried out one day after the operation, and suitable activities could be carried out within three days after the operation. At the same time, medications were used to improve the osteoporosis conditions. The surgeries for both groups are shown in **Figure 2**.

Data collection

Preoperative data of eligible patients, including age, gender, body mass index (BMI), bone mineral density (BMD) score, disease course were collected from the patient records. X-ray and CT films in the anteroposterior and lateral view were reviewed to record the preoperative Cobb angle and vertebral height.

Postoperative data of patients included the overall response rate, pain degree (1 day and 1 week after operation), pulmonary function (peak expiratory flow, forced expiratory volume in the first second, forced vital capacity), quality of life scores (physical health, social function, physiological function and vitality score), surgical indicators (Cobb angle and vertebral height before and after operation), and bone cement leakage rates (intervertebral disc leak-

Table 1. Baseline data of the patients

Group	Gender (male/female)	Age (years)	BMI ($kg·m^{-2}$)	BMD score	Disease course (years)
Observation group	13/17	70.65±4.53	28.19±4.72	-3.72±0.48	3.76±1.12
Control group	23/19	70.79±4.37	28.01±4.18	-3.73±0.45	3.75±1.20
χ^2/t	0.914	0.132	0.171	0.090	0.036
P	0.339	0.895	0.865	0.928	0.972

Table 2. Comparison of clinical treatment effectiveness between the two groups (%)

Group	Markedly effective	Effective	Invalid	Overall response rate
Observation group	17 (56.67)	10 (33.33)	3 (10.00)	27 (90.00)
Control group	22 (52.38)	13 (30.95)	7 (16.67)	35 (83.33)
χ^2	-	-	-	0.650
P	-	-	-	0.420

age, paravertebral vein leakage, paravertebral soft tissue leakage).

Outcome measures

Primary outcome was the overall response rate of clinical treatment. Markedly effective was defined as complete disappearance of clinical symptoms and client indicators after treatment; Effective was defined as dramatic enhancement in clinical manifestations and indicators; Invalid was defined as unchanged or even worsened symptoms following therapy. The overall response rate = (markedly effective cases + effective cases)/total number of cases × 100%.

Secondary outcomes included pain level, pulmonary function and quality of life. The degree of pain was assessed on day 1 and 7 after therapy with a visual analogue scale (VAS) ranging from 0-10. Higher scores indicate greater pain. Pulmonary function (peak expiratory flow, forced expiratory volume in the first second, forced vital capacity) was assessed using a ST-150 pulmonary function tester provided by Shanghai Yimu medical device Co., Ltd. Quality of life was evaluated in four domains: physical health, social function, physiological function and vitality score. Each domain was scored out of 100 points on the life quality short scale, with higher scores reflecting better quality of life.

Statistical methods

SPSS 23.0 was used for data analysis. The count data were expressed as n (%), and analyzed using chi-squared test or Fisher's exact test. The measurement data were expressed as mean ± standard deviation (SD), and analyzed using the independent samples t-test. Statistical significance was set at $P<0.05$.

Results

Baseline information of the two groups

The control group had an average age of 70.79±4.37 years, ranging from 60 to 78 years. The group was comprised of 23 men and 19 women. The BMI ranged from 19 to 34 $kg·m^{-2}$, with an average of (28.01±4.18) $kg·m^{-2}$. The mean BMD score was (-3.73±0.45). The disease course ranged from 0.6 to 7 years, with an average of (3.75±1.20) years. The average age of the observation group was (70.65± 4.53) years old, spanning from 60 to 81 years. This group included 13 men and 17 women. The BMI ranged from 18 to 34 $kg·m^{-2}$, with an average of (28.19±4.72) $kg·m^{-2}$. The mean BMD score was (-3.72±0.48). The disease duration varied from 0.5 to 7 years, with an average of (3.76±1.12) years. Statistical analysis revealed no significant differences between the groups for these baseline variables (all $P>0.05$). See **Table 1**.

Comparison of treatment efficacy between the two groups

After therapy, there was no statistical difference between the observation group and the control group in overall effective rate ($P= 0.420$). See **Table 2**.

Table 3. Comparison of pain degree on postoperative day 1 and week 1 between the two groups

	One day after operation	One week after operation
Observation group	5.55±1.11	2.22±0.44
Control group	5.62±1.06	2.36±0.58
t value	0.271	1.112
P value	0.787	0.270

Comparison of pain levels on post-operative day 1 and 7 between the two groups

The evaluation of pain levels 1 day and 1 week after the operation revealed no statistically significant differences between the observational group and the control group (P=0.787, P=0.270). See **Table 3**.

Comparison of post-operative lung function between the two groups

The comparisons of postoperative peak expiratory flow (P=0.660), forced expiratory volume in the first second (P=0.775), forced vital capacity (P=0.062) of patients between the two groups revealed no statistical differences between the observation group and the control group. See **Table 4**.

Comparison of post-operative life quality between the two groups

The social function (P=0.935), physical health (P=0.949), physiological function (P=0.970) and vitality score (P=0.778) of patients in the two groups after therapy were compared, and there was no statistical differences between the two groups. See **Table 5**.

Comparison of surgery outcomes between the two groups

Before operation, there was no statistical difference between the two groups in spinal height or Cobb angle. Post-treatment assessments indicated superior surgical outcomes in the observational group, with significant improvements in both Cobb angle and vertebral height monitoring values compared to the control group (P<0.001). See **Table 6**.

Comparison of bone cement leakage rates between the two groups

The leakage rates of bone cement, including intervertebral disc leakage, paravertebral vein leakage, paravertebral soft tissue leakage, in the observation group were significantly lower than those in the control group (P=0.029). See **Table 7**.

Discussion

Osteoporotic thoracic vertebral compression fractures are prevalent in elderlie people and primarily result from calcium loss in bone tissue, decreased bone mineral density and the deterioration of bone structure; it is also a frequent side effect of osteoporosis [2, 19]. Curved vertebroplasty, a modified percutaneous vertebroplasty, simplifies the procedure while assuring uniform bone cement diffusion in the affected vertebral body [2, 20]. This study compared two surgical approaches in treating osteoporotic thoracic vertebral compression fracture.

In our study, the results showed that bone-filling mesh bag technology and curved vertebroplasty have comparable therapeutic outcomes. Curved vertebroplasty has the dual advantages of fusing both unilateral and bilateral pedicles by straight puncture. Curved vertebroplasty, which utilizes a bent distal end of the straight puncture needle sleeve made from nitinol alloy, allows for crossing the vertebral body's sagittal midline, with a relatively small incision [21, 22]. This design ensures even distribution of bone cement across the vertebral body, with the advantage of modifying the injection point through its flexible and movable sleeve. This technique provides effective pain relief by ensuring a symmetrical cement spread [23, 24]. Conversely, bone-filling mesh bag technology has shown excellent results due to its superior biocompatibility and tensile strength, even over extended periods [6, 25]. It notably excels in encapsulation and leakage prevention [26, 27]. This method not only restores the biomechanical integrity of the compressed vertebral body but also significantly reduces the risk of adjacent vertebral fractures by increasing the vertebral height under high pressure [28, 29]. Furthermore, advancements in this technology allow bone

Table 4. Comparison of pulmonary functions between the two groups

	Peak expiratory flow (l/s)	Forced expiratory volume in the first second (L)	Forced vital capacity (L)
Observation group (n=30)	34.67±2.72	1.98±0.42	2.89±0.43
Control group (n=42)	34.24±4.80	1.95±0.45	2.70±0.41
t value	0.442	0.287	1.900
P value	0.660	0.775	0.062

Table 5. Comparison of life quality between the two groups

	Physical health	Social function	Physiological function	Vitality
Observation group (n=30)	80.97±10.12	78.65±9.89	79.15±10.05	80.06±11.05
Control group (n=42)	80.83±8.43	78.81±6.65	79.24±10.07	80.79±10.57
t	0.064	0.082	0.037	0.284
P	0.949	0.935	0.970	0.778

Table 6. Comparison of surgical indicators between the two groups

	Number of cases	Cobb angle (°)		Vertebral height (%)	
		Before operation	3 days after operation	Before operation	3 days after operation
Observation group	30	19.92±1.00	16.42±0.74	28.42±1.20	73.52±0.87
Control group	42	19.98±1.04	11.83±0.93	28.46±0.90	33.93±0.96
t		0.245	22.420	0.162	179.282
P		0.807	<0.0001	0.872	<0.0001

Table 7. Comparison of the incidence of bone cement leakage between the two groups (%)

	Intervertebral disc leakage	Paravertebral venous leakage	Paravertebral soft tissue leakage	Total incidence
Observation group (n=30)	0 (0.00)	1 (3.33)	0 (0.00)	1 (3.33)
Control group (n=42)	4 (9.52)	3 (7.14)	2 (4.76)	9 (21.42)
χ^2		-		4.791
P		-		0.029

cement to penetrate into the trabecular bone area, enhancing the stability and mechanical properties of the affected vertebrae, leading to highly effective clinical applications [30, 31].

The results also revealed that the two groups achieved comparable results in overall response rate, pain intensity, lung function, and life quality. The reason may be that in bone filling mesh container vertebroplasty, the heat generated by the polymerization of the bone cement mitigated the sensory nerve endings of the damaged vertebral body, thereby reducing pain. Moreover, the structure of the bone filling mesh container can facilitated effective injection and diffusion of bone cement, enhancing integration with the surrounding bone tissue, thereby promoting vertebral stability and improving thoracolumbar function.

After therapy, the surgical indicators, such as preoperative and postoperative Cobb angle and vertebral height, were superior in the observation group compared to the control group. The postoperative leakage rates of bone cement, including intervertebral disc leakage, paravertebral vein leakage, and paravertebral soft tissue leakage, were lower in the observational group. These findings suggest that both curved vertebroplasty and bone filling mesh bag technology are comparably effective and safe in the treatment of elderly patients with osteoporotic thoracic vertebral compression fractures. However, bone filling mesh bag tech-

nology particularly excels in reducing leakage rates of bone cement.

Our study has some limitations. It is a single-arm, retrospective study with a relatively small sample size, conducted at a single center. This confines the scope and generalizability of our findings, as the analysis could not be extensively stratified due to the limited cohort size. Therefore, the conclusions we draw need to be tested and validated by further studies in larger cohorts and more centers.

In conclusion, both angle vertebroplasty and bone-filling mesh bag technologies provide comparable therapeutic outcomes in the treatment of elderly individuals with osteoporotic thoracic vertebral compression fractures. There were no significant differences in pain degree, lung function, and quality of life between the two groups. However, bone-filling mesh bag technology does offer superior improvements in Cobb angle and vertebral body height, and it significantly reduces the rates of bone cement leakage. Therefore, the surgical intervention should be selected according to the specific clinical situations of patients.

Disclosure of conflict of interest

None.

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