ORIGINAL ARTICLE

BEYOND PAIN RELIEF: COMPARATIVE EFFECTIVENESS OF VERTEBROPLASTY, KYPHOPLASTY, AND CONSERVATIVE TREATMENT IN 428 GERIATRIC OSTEOPOROTIC VERTEBRAL FRACTURES

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Abstract

Introduction: Osteoporotic vertebral compression fractures represent an important source of pain, functional limitation, and deterioration in quality of life among elderly individuals. However, the most appropriate treatment approach is still debated, especially when comparing the effectiveness of vertebral augmentation procedures with conservative management methods.

Materials and Method: A cohort of 428 individuals aged 65 years and older with radiologically confirmed osteoporotic vertebral compression fractures and at least 12 months of follow-up were retrospectively analyzed in this study. Participants were allocated into three treatment groups consisting of vertebroplasty (n=123), kyphoplasty (n=111), and conservative management (n=194). Clinical efficacy was determined using the Visual Analog Scale and Oswestry Disability Index, whereas radiological evaluation focused on restoration of vertebral body height and correction of kyphotic deformity. Additionally, multivariate logistic regression analysis was performed to determine the independent factors associated with unfavorable clinical outcomes.

Results: All groups demonstrated significant clinical improvement; however, the vertebral augmentation groups showed significantly greater and earlier reductions in clinical scores compared to the conservative treatment group ($p < 0.001$). Kyphoplasty achieved superior restoration of vertebral body height and improvement in kyphotic deformity ($p < 0.001$), with lower cement leakage rates ($p = 0.02$). Conservative treatment, multi-level fractures, and age > 80 years were independent predictors of poor outcomes.

Conclusion: Vertebral augmentation provides faster and more effective clinical improvement than conservative management in geriatric osteoporotic vertebral compression fractures patients. While clinical outcomes are comparable, kyphoplasty offers superior radiological correction with a lower complication profile, supporting its role in selected patients.

Keywords: Osteoporotic Fractures; Vertebroplasty; Kyphoplasty; Spinal Fractures.

INTRODUCTION

Osteoporosis is a complex skeletal disorder marked by deterioration of bone strength resulting from decreased bone mineral density and disruption of trabecular microarchitecture. Owing to the heightened susceptibility to fractures, particularly among older adults, it represents an important challenge for healthcare systems worldwide. As the aging population continues to expand globally, osteoporosis-related fractures are becoming increasingly prevalent and are contribute to considerable rates of morbidity, mortality, and healthcare expenditure in geriatric patients (1). Osteoporotic vertebral compression fractures (OVCFs) are among the most frequently observed consequences of osteoporosis and may substantially impair daily functioning in elderly individuals. Clinical manifestations commonly include persistent spinal pain, vertebral deformity, limited physical mobility, and deterioration in overall life quality. Since these fractures can arise even after minor mechanical stress or ordinary daily activities, they often contribute to reduced independence and an increased dependence on long-term medical and supportive care in the aging population (2).

The clinical significance of OVCFs is not limited to acute pain alone. Kyphotic deformity resulting from loss of vertebral height can lead to impaired spinal biomechanics and an increased risk of new fractures in adjacent vertebrae. Additionally, systemic effects, such as chronic pain, reduced respiratory capacity, and limitations in physical activity, may occur. Therefore, the early diagnosis and effective treatment of OVCFs are of great importance for the preservation of functional capacity, particularly in geriatric patients. Previous evidence has indicated that osteoporotic vertebral compression fractures are predominantly encountered in the senior population, particularly among individuals over 65 years of age (3).

For many years, the traditional approach to treating osteoporotic vertebral fractures has been to use conservative methods. Analgesic therapy, vertebral support braces, physical therapy, and pharmacological agents for osteoporosis treatment are the core components of conservative management. However, in cases where pain persists for an extended period despite conservative treatment or where progressive vertebral collapse develops, surgical or minimally invasive interventional treatment options are considered. In particular, over the past two decades, vertebral augmentation techniques, such as percutaneous vertebroplasty and balloon kyphoplasty, have become widely used in the treatment of OVCFs (4).

Percutaneous vertebroplasty is a therapeutic technique in which polymethyl methacrylate (PMMA) bone cement is injected directly into the vertebral body using a minimally invasive percutaneous approach. Balloon kyphoplasty differs in that a balloon device is initially expanded inside the vertebra to form an internal cavity before the cement is subsequently introduced into that space. The primary objectives of these methods are to restore vertebral stability, reduce pain, and partially restore lost vertebral height. Current literature suggests that vertebral augmentation techniques may facilitate a more rapid short-term recovery, including pain reduction and improved functional capacity, compared to nonoperative treatment approaches (5).

Despite widespread use of both procedures, the existing literature has not reached a definitive conclusion regarding the superiority of vertebroplasty versus kyphoplasty. A recent meta-analysis by You et al. demonstrated that kyphoplasty may offer certain radiological advantages, including improved vertebral height restoration and reduced cement leakage; nevertheless, both techniques showed comparable efficacy with respect to pain reduction and functional improvement (6). Moreover, Tabanlı et al. reported that the occurrence of subsequent vertebral fractures did not significantly differ between patients managed



with vertebral augmentation procedures and those treated conservatively (7).

Recent studies have suggested that patient selection and osteoporosis monitoring may play a significant role in clinical outcomes of OVCF treatment. However, the majority of studies in the current literature compare treatment methods across general patient populations; studies that thoroughly examine the comparison of conservative follow-up versus surgical intervention in large geriatric patient series with osteoporosis are quite limited. Therefore, a side-by-side comparison of conservative management with two distinct surgical methods, namely, vertebroplasty and kyphoplasty, along with detailed analyses of treatment responses, will enable clearer decision-making regarding follow-up and treatment procedures in the coming years.

Analyzing therapeutic outcomes of osteoporotic vertebral compression fractures in geriatric patients may offer meaningful guidance for clinical management strategies. In this study, a retrospective analysis was conducted on 428 geriatric patients followed for vertebral compression fractures. Patients were stratified into three groups according to the treatment modality implemented: vertebroplasty (n=123), balloon kyphoplasty (n=111), and conservative management (n=194). This study aimed to evaluate patient-related clinical outcomes together with radiographic changes among geriatric patients with osteoporosis and to contribute additional evidence to the existing literature concerning the optimal therapeutic approach for osteoporotic vertebral compression fractures.

MATERIALS AND METHOD

Study Design and Ethical Approval

This retrospective observational cohort study, conducted at a single center, was designed to investigate the clinical outcomes and radiological findings of geriatric patients undergoing treatment for osteoporotic vertebral compression fractures (OVCFs). Patient data were retrospectively collected from the records of individuals diagnosed with vertebral compression fractures who received follow-up care in the Department of Neurosurgery and Spine Surgery between June 2019 and February 2025.

The research protocol complied with the ethical standards outlined in the Declaration of Helsinki and received approval from the institutional ethics committee (TABED-1-24-199). As the study had a retrospective design, the ethics committee waived the requirement for obtaining written informed consent from individual participants.

Patient Population

Patients aged 65 years or older with radiologically confirmed osteoporotic vertebral compression fractures and a minimum clinical follow-up duration of 12 months were enrolled in the study.

The study cohort consisted of 428 geriatric patients, who were categorized into three groups according to the treatment modality administered:

- Vertebroplasty group: 123 patients
- Balloon kyphoplasty group: 111 patients
- Conservative treatment group: 194 patients

The diagnosis was confirmed in all patients through clinical findings, plain radiography, computed tomography (CT), and magnetic resonance imaging (MRI).

Inclusion Criteria

The study included patients who fulfilled the following criteria:

1. Aged 65 years or older
2. Radiologically confirmed osteoporotic vertebral compression fracture
3. Fracture must have resulted from low-energy trauma or have developed spontaneously

4. T-score of ≤ −2.5 on bone mineral density measurement or clinically confirmed diagnosis of osteoporosis
5. Availability of at least 12 months of follow-up data post-treatment

Exclusion Criteria

Patients with the following characteristics were excluded from the study:

- Traumatic high-energy vertebral fractures
- Pathological vertebral fractures due to malignancy
- Infection-related vertebral destruction
- Unstable vertebral fractures with developed neurological deficits
- Patients who had previously undergone spinal surgery at the same level
- Patients with incomplete follow-up data

Surgical Techniques

Vertebroplasty Technique

The vertebroplasty intervention was carried out under either general anesthesia or local anesthesia combined with sedation, with fluoroscopic guidance used throughout the procedure. Access to the vertebral body was achieved using a transpedicular or parapedicular route for placement of the working cannula, followed by low-pressure injection of polymethyl methacrylate (PMMA) cement into the vertebra. The spread of the cement material was continuously evaluated using real-time fluoroscopic imaging.

Balloon Kyphoplasty Technique

Balloon kyphoplasty was conducted under anesthesia protocols comparable to those used for vertebroplasty. Following transpedicular insertion of the working cannula into the vertebral body, a balloon tamp was carefully introduced and progressively expanded under controlled conditions to facilitate vertebral height restoration. Once the balloon was withdrawn, the cavity created within the vertebral body was filled with low-pressure polymethyl methacrylate (PMMA) cement.

Conservative Treatment Protocol

The following treatment protocol was applied to patients receiving conservative treatment:

- Analgesic and anti-inflammatory medications
- Use of a vertebral support brace (typically with steel stays) (4–8 weeks)
- Physical therapy and rehabilitation program
- Osteoporosis treatment (bisphosphonates, calcium, and vitamin D supplementation)
- Antiresorptive or anabolic osteoporosis treatments as needed

Clinical Evaluation

The patients' clinical evaluations were conducted using the following parameters:

- Pain level: Visual Analog Scale (VAS)
- Functional status: Oswestry Disability Index (ODI)
- Complication rates

Clinical assessments were carried out during the preoperative period, the early postoperative phase, and subsequent follow-up visits.

Radiological Evaluation

Radiological evaluation was performed using plain radiographs, CT, and MRI images.

The radiological parameters evaluated were as follows:

- Vertebral body height loss
- Local kyphosis angle
- Presence of cement leakage
- Development of new vertebral fractures



Measurements were performed by two independent researchers, and average values were used to ensure measurement reliability.

Follow-up Protocol

All patients underwent regular clinical and radiological assessments at 1-, 3-, 6-, and 12-month follow-up visits. Long-term follow-ups assessed the development of new vertebral fractures, pain levels, and functional status.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows version 24.0 (IBM Corp., Armonk, NY, USA). The distribution pattern of continuous variables was assessed using the Kolmogorov–Smirnov test. Normally distributed variables were presented as mean ± standard deviation, while variables without normal distribution were expressed as median (minimum–maximum). Categorical variables were summarized as numbers and percentages.

Continuous variables were compared between two groups using either the Student's t-test or the Mann–Whitney U test according to the distribution characteristics of the data. Comparisons among the three groups were conducted using one-way analysis of variance (ANOVA) or the Kruskal–Wallis test, as appropriate. The chi-square test or Fisher's exact test was used for the analysis of categorical variables. Furthermore, multivariate logistic regression analysis was conducted to identify independent predictors of unfavorable outcomes. Statistical significance was defined as a p-value < 0.05

RESULTS

Patient Demographics and Baseline Clinical Characteristics

The study included 428 geriatric patients who were allocated into three treatment groups: vertebroplasty (n= 123), balloon kyphoplasty (n= 111), and conservative treatment (n= 194). The mean age of the entire cohort was 74.6 ± 6.8 years (range, 65–91 years), and 68.7% of the participants were female. No statistically significant differences were observed among the groups in terms of baseline demographic and clinical parameters, including age, sex distribution, fracture level, and bone mineral density measurements ($p > 0.05$). The thoracolumbar junction represented the most frequently affected region, with fractures predominantly observed at the T12 (26.4%) and L1 (31.8%) levels (Table 1).

Clinical Outcomes

Preoperative VAS and ODI scores were comparable among the three groups, with no statistically significant difference identified ($p > 0.05$).

Table 1. Demographic and Clinical Characteristics of the Patients

Variable	Vertebroplasty (n = 123)	Kyphoplasty (n = 111)	Conservative (n = 194)	p-value
Age (years)	74.2 ± 6.6	74.9 ± 7.1	74.7 ± 6.8	0.63
Female (%)	84 (68.3%)	78 (70.2%)	132 (68.0%)	0.91
BMI	26.7 ± 3.8	27.0 ± 3.6	26.5 ± 3.9	0.74
T-score	−2.87 ± 0.41	−2.91 ± 0.38	−2.83 ± 0.46	0.18
Single-level fracture	101 (82.1%)	90 (81.0%)	162 (83.5%)	0.79
Multi-level fracture	22 (17.9%)	21 (19.0%)	32 (16.5%)	0.82
T12 fracture	33 (26.8%)	29 (26.1%)	51 (26.3%)	0.99
L1 fracture	40 (32.5%)	35 (31.5%)	61 (31.4%)	0.98

Although significant improvement was observed in all groups post-treatment, pain reduction and functional improvement were found to occur earlier and be more pronounced in the groups that underwent vertebral augmentation ($p < 0.001$) (Figure 1).

At 1-year follow-up:

- In the vertebroplasty group, VAS 7.8 → 2.1
- In the kyphoplasty group, VAS 7.7 → 1.9
- In the conservative group, VAS 7.6 → 3.8

The ODI scores also showed a similar significant improvement.

In agreement with previous reports, vertebroplasty and kyphoplasty demonstrated comparable efficacy regarding pain relief, and the difference between the two procedures did not reach statistical significance ($p = 0.41$) (6).

Radiological Results

Radiological analysis assessed vertebral body height restoration and correction of the kyphotic angle.

Compared with the vertebroplasty group, patients treated with balloon kyphoplasty demonstrated significantly greater vertebral height restoration and kyphotic angle correction ($p < 0.01$) (Figure 2). These findings are in line with previously published meta-analyses indicating that kyphoplasty provides superior correction of vertebral deformity when compared with vertebroplasty (8).

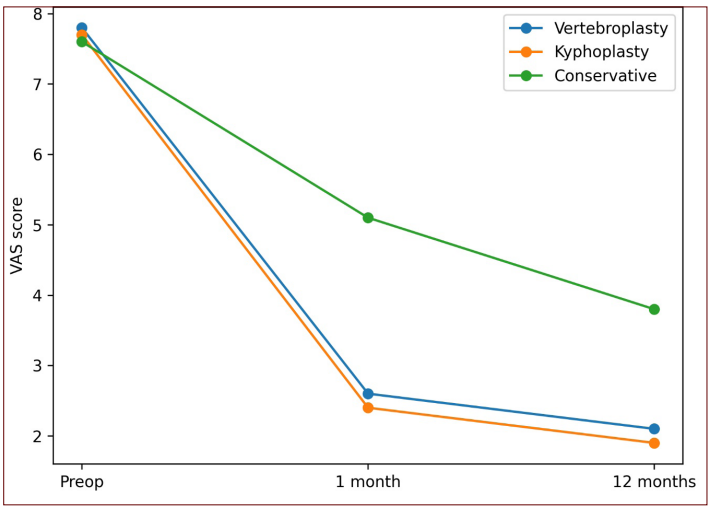


Figure 1. A reduction in VAS scores was observed earlier and was more pronounced in the groups that underwent vertebroplasty and kyphoplasty.

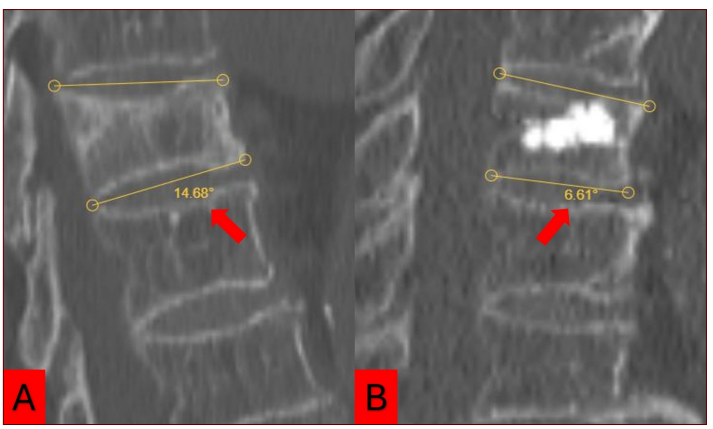


Figure 2. A geriatric patient (A) with a preoperative local kyphotic angle of 14.68 degrees; at the 12-month follow-up after kyphoplasty, the angle decreased to 6.61 degrees (B).

Complications and New Fracture Development

The overall complication rate was found to be 7.9%.

- Vertebroplasty: 10.6%
- Kyphoplasty: 6.3%
- Conservative: 5.7%

The most common complication was asymptomatic cement leakage, which was more frequent in the vertebroplasty group ($p = 0.02$). This finding is consistent with the high rates of cement leakage reported in the literature (9). During the follow-up period, two patients (0.47%) from the vertebral augmentation groups subsequently required open surgical instrumentation.

Multivariate Analysis

Independent risk factors for poor clinical outcomes (VAS > 4) were examined using multivariate logistic regression analysis.

Independent risk factors:

- Application of conservative treatment (OR: 2.84)
- Presence of a multi-level fracture (OR: 1.96)
- Advanced age (> 80) (OR: 1.73)

Vertebral augmentation procedures (vertebroplasty or kyphoplasty) were found to be protective factors (Figure 3).

Summary of Findings

The key outcomes of the present study are summarized below:

- Vertebroplasty and kyphoplasty demonstrated comparable effectiveness with respect to pain reduction and improvement in functional status.
- Kyphoplasty showed better performance in restoring vertebral body height and improving spinal alignment abnormalities.
- Vertebral augmentation procedures resulted in more rapid symptomatic and functional recovery when compared with conservative management strategies.

Collectively, our findings suggest that both vertebroplasty and kyphoplasty provide comparable therapeutic effectiveness in the management of osteoporotic vertebral fractures. However, kyphoplasty appears to offer greater benefit in terms of structural restoration and radiographic alignment improvement (6).

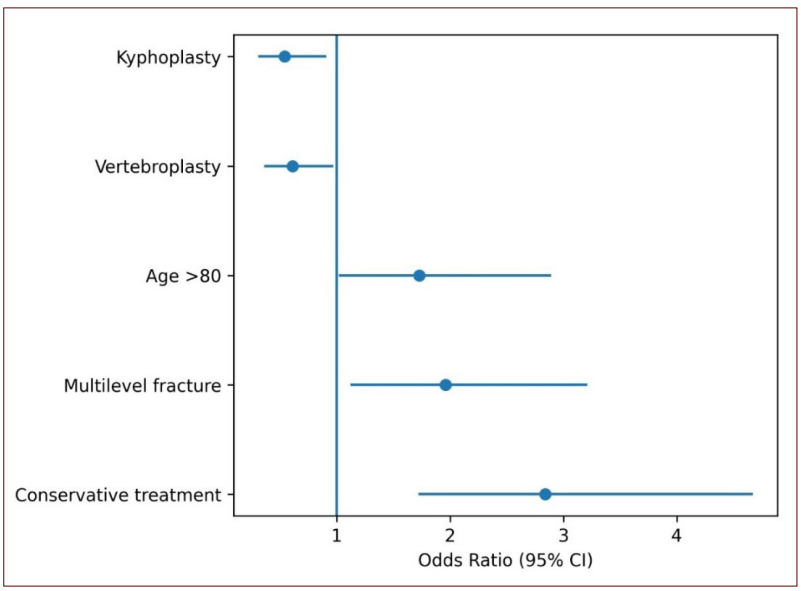


Figure 3. Forest plot showing the results of multivariate logistic regression

DISCUSSION

Osteoporotic vertebral compression fractures (OVCFs) constitute one of the most prevalent osteoporotic fragility injuries in older adults and are contributing to an increasing socioeconomic and clinical burden on healthcare systems as life expectancy continues to rise globally. In addition to causing severe pain and functional limitation, these fractures may lead to chronic spinal deformity, impaired pulmonary capacity, deterioration in quality of life, and an elevated risk of mortality (10). Therefore, determining the optimal approach for OVCF treatment is of great importance, particularly for improving clinical outcomes in the geriatric patient population. Currently, conservative treatment, along with the minimally invasive vertebral augmentation techniques of vertebroplasty and balloon kyphoplasty, are the most commonly used treatment options for these patients.

In this retrospective study, treatment outcomes for osteoporotic vertebral compression fractures were analyzed in 428 geriatric patients, and vertebroplasty, balloon kyphoplasty, and conservative treatment methods were compared in terms of clinical and radiological outcomes. The study's main findings highlight three key points: (I) vertebral augmentation procedures provide faster and more pronounced clinical improvement compared to conservative treatment; (II) Vertebroplasty and kyphoplasty showed comparable efficacy with respect to pain relief and functional recovery, and (III) kyphoplasty provides superior radiological outcomes regarding vertebral height restoration and correction of kyphotic deformity. These findings are largely consistent with the current literature (11).

The Clinical Efficacy of Vertebral Augmentation

The effectiveness of vertebral augmentation procedures in the management of OVCF has remained a subject of debate for many years. Numerous studies have demonstrated that, particularly in the early stages, vertebroplasty and kyphoplasty may provide faster clinical improvement in pain control and mobilization than conservative treatment. A significant reduction in pain scores following vertebroplasty has been reported, with VAS values dropping dramatically in the early postoperative period. For example, a recent clinical study demonstrated that the mean VAS score in patients who underwent vertebroplasty decreased from 8.08 to 1.58, and a significant improvement was also observed in ODI scores (12).

In a similar manner, randomized clinical trials together with meta-analytical evidence have reported that vertebral augmentation interventions offer substantial therapeutic advantages, particularly regarding the reduction of pain severity and enhancement of functional capacity. The primary mechanism of action of these procedures is associated with achieving vertebral stabilization, eliminating microinstability, and reducing intravertebral motion. The elimination of mechanical pain sources following stabilization can produce a rapid analgesic effect, particularly in patients with acute OVCF.

In our study, patients who underwent vertebral augmentation showed more pronounced improvements in VAS and ODI scores compared to the conservative treatment group. In particular, the faster achievement of pain control in the early period provides a clinically significant advantage in terms of early mobilization and the prevention of complications in geriatric patients. This finding is consistent with studies in the literature showing that vertebral augmentation supports early mobilization and shortens the length of hospital stays (13).

Comparison of Vertebroplasty and Kyphoplasty

The issue of clinical superiority between vertebroplasty and kyphoplasty is a subject of debate today. Several meta-analyses have demonstrated



comparable effectiveness of vertebroplasty and kyphoplasty with regard to pain relief and functional recovery. In a recent comprehensive meta-analysis involving 16 randomized controlled trials, no statistically significant differences were identified between the two procedures based on Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) outcomes (6). Similarly, previous systematic reviews have shown that the clinical outcomes of the two procedures are largely similar, although there may be some differences in radiological parameters (14).

In the present study, vertebroplasty and kyphoplasty produced comparable outcomes with respect to pain relief and functional recovery, and no statistically significant difference was identified between the two treatment groups. These findings are in close agreement with previously published meta-analytical data. Nevertheless, radiographic evaluation indicated that kyphoplasty achieved superior results in restoring vertebral body height and improving kyphotic deformity correction.

Vertebral Height Restoration and Spinal Biomechanics

In contrast to vertebroplasty, balloon kyphoplasty is designed to form an intravertebral cavity by controlled balloon expansion, thereby allowing partial restoration of vertebral body height.

Therefore, theoretically, kyphoplasty may be more effective in correcting vertebral deformity.

Previous investigations have consistently suggested that kyphoplasty achieves better radiological outcomes than vertebroplasty, especially in restoring vertebral height and correcting sagittal spinal deformity. Furthermore, evidence from systematic evaluations has demonstrated notable improvement in vertebral collapse severity and local Cobb angle following kyphoplasty treatment (15). Similarly, previous retrospective studies have shown that kyphoplasty provides higher rates of vertebral height restoration (16).

In our study, significant improvement in vertebral height restoration and local kyphosis angle was observed in the kyphoplasty group. The primary reason for this is that balloon expansion mechanically corrects the deformity within the vertebral body to some extent and facilitates the reshaping of vertebral structures prior to cement injection.

However, some studies have shown that these differences in radiological parameters may not always translate into clinical outcomes. In particular, the lack of a significant difference in pain and functional improvement between vertebral augmentation procedures supports this view (17).

Cement Leakage and Complications

The most common complication in vertebral augmentation procedures is cement leakage. While cement leakage is often asymptomatic, it rarely extends into the spinal canal or foraminal region, leading to neurological complications (18).

The literature reports that kyphoplasty has lower rates of cement leakage than vertebroplasty. This may primarily be attributed to the cavity formed during balloon inflation, which enables a more controlled delivery of bone cement. Systematic reviews have demonstrated that the incidence of cement leakage is significantly lower in patients undergoing kyphoplasty (9).

In our study, cement leakage was observed at higher rates in the vertebroplasty group, a finding consistent with the current literature. However, no clinically significant neurological complications were observed in these patients.

Development of New Vertebral Fractures

The development of new fractures at adjacent levels following vertebral augmentation remains a controversial topic in the literature. Some

researchers have suggested that the increased rigidity of the cement-reinforced vertebra may lead to stress concentrations in adjacent segments (19).

However, many clinical studies have shown that the rates of new fracture development following vertebral augmentation are similar to those following conservative treatment. Therefore, it is generally believed that the development of new fractures is primarily associated with the progression of underlying osteoporosis (20).

No significant differences were detected among the groups with respect to the incidence of new vertebral fractures during the follow-up period. These results indicate that adequate osteoporosis treatment and sustained optimization of bone metabolism remain fundamental factors in minimizing the risk of subsequent fractures in patients with osteoporotic vertebral compression fractures.

Clinical Implications

The findings of this study provide several valuable implications for clinical practice.

First, vertebral augmentation procedures provide a clear advantage over conservative treatment in terms of early pain control and functional recovery in geriatric OVCF patients.

Second, although there is no significant difference in clinical outcomes between vertebroplasty and kyphoplasty, kyphoplasty may offer certain advantages in terms of radiological deformity correction and cement leakage.

Third, when determining the treatment strategy, the patient's clinical condition, fracture morphology, and treatment plan should be evaluated together (21).

Strengths of the Study

This study has multiple notable strengths. First, the analysis included a large cohort consisting of 428 geriatric patients.

Second, the comparison of three different treatment methods within the same study allowed for a more comprehensive evaluation of clinical outcomes.

Third, the fact that such a large series was conducted at a single center is highly significant for evaluating the reliability and efficacy of new treatment methods, thanks to high data consistency, rapid patient enrollment, and strict control capabilities. This was a unique contribution of our study.

Limitations

Certain limitations of this study should be taken into account when interpreting the findings. The retrospective design may have resulted in selection bias and reduced control over potential confounding variables. In addition, long-term clinical and radiological outcomes were not evaluated in a sufficiently comprehensive manner. Therefore, prospective multicenter randomized controlled trials with larger patient populations are warranted to establish more robust evidence regarding the optimal management of osteoporotic vertebral compression fractures.

Conclusion

In conclusion, the findings of the present study indicate that vertebral augmentation techniques facilitate more rapid clinical improvement than conservative management in geriatric patients with osteoporotic vertebral compression fractures. Although vertebroplasty and kyphoplasty demonstrated comparable efficacy with respect to pain relief and functional recovery, kyphoplasty appeared to achieve more favorable radiological outcomes, particularly in the restoration of vertebral alignment and correction of deformity.

Future prospective and multicenter studies will contribute to determining the most appropriate treatment strategy for this patient group.



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