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*Original Article*

# Clinical efficacy of ultrasound-guided ultra-micro needle knife combined with PVP in elderly patients with OVCF: a retrospective study

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**Abstract:** Objective: To compare the clinical efficacy of ultrasound-guided super micro needle knife combined with percutaneous vertebroplasty (PVP) versus PVP alone for senile osteoporotic vertebral compression fractures (OVCF). Methods: We conducted a retrospective analysis of 104 elderly OVCF patients. The study group received the combined treatment, while the control group received PVP only. Outcomes including clinical results, imaging findings, pain scores, and complications were compared. Results: The results showed that compared with the simple PVP group, the combined treatment group had significantly shorter postoperative ambulation time and hospitalization stay, a lower incidence of short-term complications within 3 months, and a higher clinical success rate at 6 months based on the minimal clinically important difference (MCID) criteria (all $P < 0.05$). The combined treatment group demonstrated significantly greater improvement in imaging indices, including anterior vertebral height ratio, local kyphosis angle, and vertebral wedge angle, at both 3 and 6 months postoperatively (all $P < 0.05$). Furthermore, the combined treatment group exhibited significantly lower visual analog scale (VAS) scores at all postoperative time points (3 days, 7 days, 1, 3, and 6 months), as well as lower Oswestry Disability Index (ODI) and Quality of Life Questionnaire of the European Foundation for Osteoporosis (Qualeffo-41) scores at 3 and 6 months (all $P < 0.05$). There was no significant difference in the incidence of re-fracture between the two groups within 12 months postoperatively ($P = 0.320$). Conclusion: Ultrasound-guided super micro needle knife combined with PVP can significantly relieve pain, improve thoracolumbar function and spinal alignment, enhance the quality of life, and promote early recovery in elderly OVCF patients.

**Keywords:** Osteoporosis, compression fracture, percutaneous vertebroplasty, needle knife, ultrasound, pain

## Introduction

Osteoporotic vertebral compression fracture (OVCF) is a major cause of chronic pain, functional impairment, and reduced quality of life in elderly patients [1]. For patients with adequate physical function who can tolerate surgery, surgical intervention is often recommended. Percutaneous vertebroplasty (PVP), which involves injecting bone cement into the vertebral body to enhance stability, is a commonly used treatment method [2]. However, some patients still experience residual pain and functional limitations postoperatively [3, 4].

As a characteristic traditional Chinese medicine therapy, the super micro needle-knife is widely used for various intractable painful conditions. By stripping and cutting lesion tissue, and releasing fascial adhesions and bursae, it can relieve soft tissue tension and exert anti-inflammatory and analgesic effects [5]. Recent studies have suggested that needle-knife therapy can effectively alleviate residual post-fracture pain, improve joint stability and range of motion, and enhance patients' quality of life [6, 7]. However, the safety of needle-knife treatment requires careful consideration. Traditional needle-knife procedures, predominantly based on anatomical landmarks, demand substantial anatomical expertise from the operator and carry inherent risks. In contrast, ultrasound-guided needle-knife techniques allow for dynamic visualization of muscles, nerves, bones,

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**Table 1.** Comparison of general patient data between the two groups [case (%)/(mean ± s)]

| Category | Research group (n = 52) | Control group (n = 52) | $t/\chi^2$ | P |
|---|---|---|---|---|
| Gender | | | 0.641 | 0.423 |
| Male | 32 (61.54) | 28 (53.85) | | |
| Women | 20 (38.46) | 24 (46.15) | | |
| Age (years) | 72.10±3.15 | 71.87±3.30 | 0.364 | 0.717 |
| BMI ($kg/m^2$) | 22.17±0.92 | 21.90±1.03 | 1.410 | 0.162 |
| Cause of injury | | | 0.767 | 0.681 |
| Fall injury | 25 (48.06) | 30 (57.69) | | |
| Traffic accident injury | 19 (36.54) | 16 (30.77) | | |
| Other | 8 (15.38) | 6 (11.54) | | |
| Involved vertebral body | | | 1.467 | 0.981 |
| T10 | 2 (3.85) | 1 (1.92) | | |
| T11 | 5 (9.62) | 4 (7.69) | | |
| T12 | 8 (15.38) | 7 (13.46) | | |
| L1 | 6 (11.54) | 8 (15.38) | | |
| L2 | 10 (19.23) | 11 (21.15) | | |
| L3 | 10 (19.23) | 12 (23.08) | | |
| L4 | 8 (15.38) | 5 (9.62) | | |
| L5 | 3 (5.77) | 4 (7.69) | | |

and the needle-knife's path, thereby minimizing potential injuries [8, 9].

Current clinical research on the combination of ultrasound-guided super micro needle-knife and PVP for treating elderly OVCF patients remains insufficient. Therefore, this study aims to evaluate the efficacy of this combined regimen compared to PVP alone, seeking to provide a more optimized treatment option that offers comprehensive and sustained clinical outcomes for elderly OVCF patients, and to contribute evidence-based support for clinical decision-making.

## Materials and methods

### *General information*

A total of 104 elderly OVCF patients from January 2019 to January 2024 were selected from Beijing Tongzhou District Hospital of Integrated Traditional Chinese and Western Medicine. Based on the surgical procedure they received, the patients were divided into two groups: the control group (underwent PVP alone, n = 52) and the experimental group (underwent ultrasound-guided super micro needle knife combined with PVP, n = 52). There was no significant difference in general information between the groups (P > 0.05), as shown in **Table 1**. This retrospective study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee (Approval Number: 2024-LH-KY-073). The requirement for informed consent was waived by the ethics committee due to the anonymous and retrospective nature of the study.

As a single-center retrospective study, the sample size was not predetermined by a power calculation. Instead, we aimed to include all consecutive eligible patients who met the inclusion and exclusion criteria during the defined study period (January 2019 to January 2024) to maximize the statistical power and representativeness of our analysis. A post-hoc power analysis was performed using G*Power software (version 3.1.9.7) based on the primary outcome of visual analog scale (VAS) score at 6 months (mean difference = 0.38, SD = 0.30, $\alpha = 0.05$). The result indicated that the achieved sample size (n = 104) provided a statistical power of > 95%, confirming the adequacy of the sample for detecting clinically significant differences between the groups.

### *Inclusion criteria*

1. Aged ≥ 60 years. 2. Diagnosed with primary osteoporosis (Bone mineral density T-score ≤ -2.5 SD at the lumbar spine or femoral neck). 3.

Clinical presentation of acute onset low back pain with a clear history of minor trauma. 4. A single-level, fresh OVCF confirmed by X-ray and Magnetic Resonance Imaging (MRI), with the affected vertebra showing a T1-weighted low-signal, and T2-weighted/Short-Tau Inversion Recovery (STIR) high-signal intensity indicative of bone marrow edema. 5. The fracture time was within 2 weeks, and the vertebral body height loss was between 20% and 70%. 6. Patients with persistent pain (VAS score ≥ 4) despite conservative treatment for at least 48 hours.

*Exclusion criteria*

1. Fractures caused by high-energy trauma or pathological fractures due to spinal tumors, infection, or metabolic bone diseases other than osteoporosis. 2. Patients with severe cardiopulmonary, hepatic, or renal insufficiency who could not tolerate the prone position or the surgical procedure. 3. Presence of concurrent spinal conditions that could confound outcomes, such as severe spinal stenosis, spondylolisthesis, scoliosis, or radiculopathy. 4. MRI evidence of a posterior vertebral wall defect, spinal canal compromise, or retropulsion of bone fragments. 5. Known allergy to bone cement (Polymethylmethacrylate [PMMA]) or its components. 6. Coagulation disorders or ongoing use of anticoagulant therapy that could not be safely managed perioperatively. 7. Patients with cognitive impairment, mental illness, or other conditions preventing reliable assessment of pain and functional outcomes.

*Treatment methods*

The control group was treated with PVP. The patient was in the prone position. The target vertebral body and pedicle surface projection points were determined through C-arm X-ray fluoroscopy. A sterile drape was applied, and local infiltration anesthesia was performed. The puncture needle was placed at the positioning point up to the anterior 1/3 of the vertebral body, the needle core was removed, and the location of the needle tip was confirmed by anteroposterior and lateral fluoroscopy. After the polymethyl methacrylate bone cement was prepared, at the later stage of stringing (paste to jelly), the bone cement was slowly bolused into the vertebral body through the working channel. The diffusion status of the bone cement was observed under fluoroscopy, and the pushing action was stopped immediately when the bone cement diffused to the edge of the vertebral body. Note that after the bone cement was slightly cured, the catheter was pulled out, the puncture site was oppressed, and a sterile dressing was applied at the end of the surgery. After surgery, the patient was observed in bed for 1-2 hours. After the vital signs were stable, a brace could be worn to move around on the ground. After surgery, standardized anti-osteoporosis drug treatment was performed. Moreover, patients who experienced pain were given 200 mg of celecoxib orally 2 times/d and 2 times/d. One week was one course of treatment.

The study group was treated with an ultrasound-guided ultramicro-needle knife combined with PVP. The PVP method was the same as that used for the control group. Before PVP surgery, ultrasound-guided ultramicro-needle-knife treatment was performed under local infiltration anesthesia. With the patient in the prone position, a high-frequency linear ultrasound probe was used to clearly show the paravertebral soft tissues of the target vertebral segment. Under ultrasound guidance, a disposable ultramicro Hanzhang needle knife (0.8 mm * 80 mm) was used to subcutaneously puncture the target muscle-fascial junction, and longitudinal incision and lateral stripping were performed to release the local muscle tissue and fascial tissue to relieve compression. With respect to nerve tissue, the fracture lesion was found, and the lesion in the fracture area usually covered the fractured vertebral body and the bilateral paravertebral regions of 1 to 2 segments between the upper and lower sides (**Figure 1**). If necessary, drug injection intervention with the small needle knife technique was given. After the expected loosening effect was achieved, the needle knife was removed, and local pressure was applied to stop the bleeding. Immediately afterward, PVP surgery was performed, and the operation was the same as that of the control group. Ultramicro-needle knife treatment was continued for 1 week after surgery to release the acupoints and Ashi acupoints on the thoracolumbar region and back. Under ultrasound guidance, the ultramicro-needle knife was inserted into the marking points sequentially, and the needle was gradually inserted into the bone surface for longitudinal and transverse

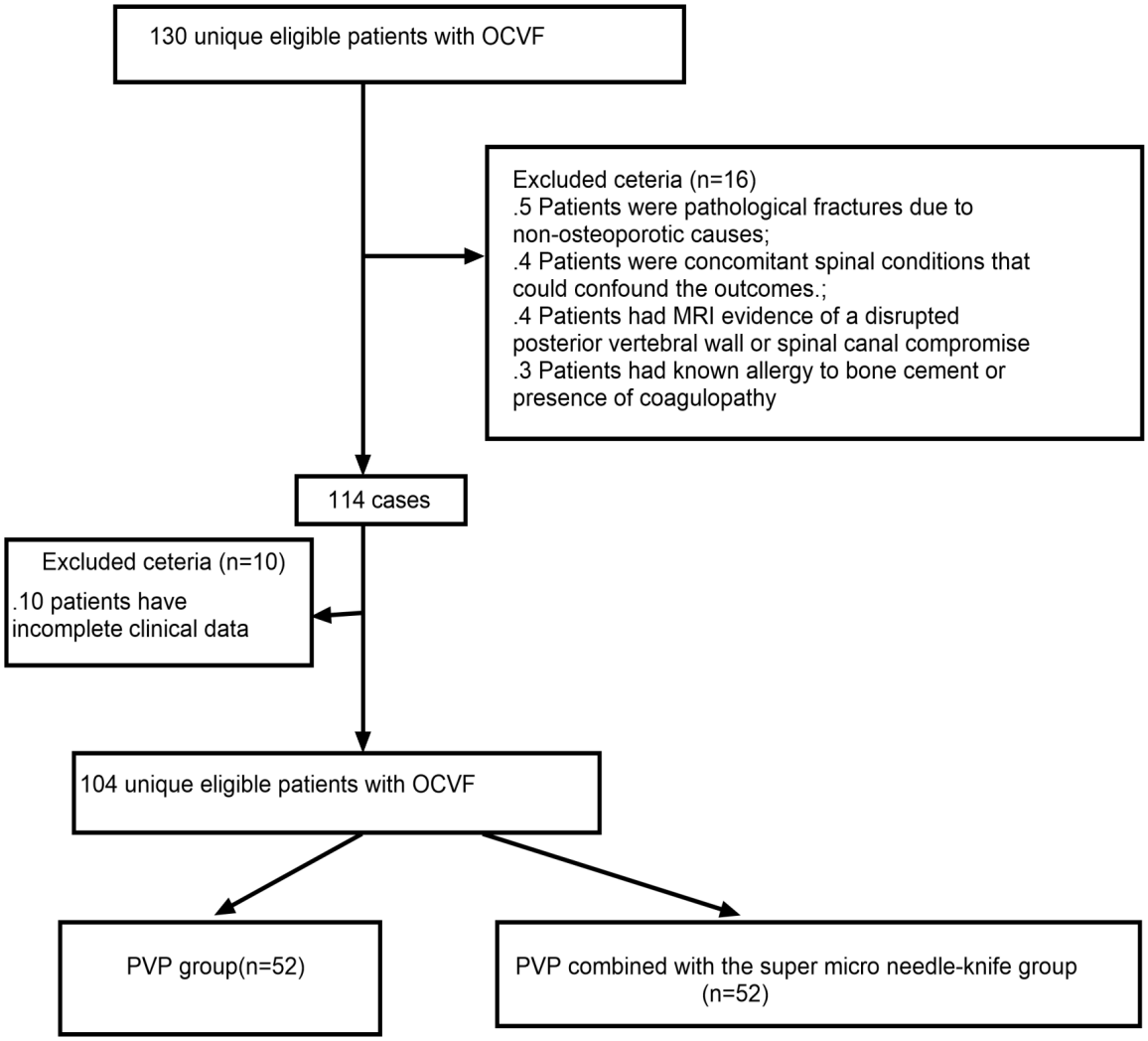


**Figure 1.** Patient flowchart of the study. This flowchart illustrates the patient selection and allocation process. Of 130 initially screened patients with osteoporotic vertebral compression fractures (OVCF), 16 were excluded based on predefined exclusion criteria and 10 were excluded due to incomplete clinical data. The remaining 104 eligible patients were divided into two groups: the percutaneous vertebroplasty (PVP) group (n = 52) and the PVP combined with super micro needle-knife group (n = 52).

cuts. Each treatment cos ~$3, based on the degree of soreness felt by the patient. The needle-knife treatments were performed 2 times a week for a total of 4 weeks.

*Observation indicators*

*Primary outcomes:* The primary outcomes were pain intensity and functional status, assessed as follows:

Pain intensity: Evaluated using the VAS ranging from 0 (no pain) to 10 (worst imaginable pain). Patients scored their pain at the thoracolumbar fracture site within the preceding 24 hours. Assessments were conducted preoperatively and at 3 days, 7 days, 1 month, 3 months, and 6 months postoperatively [10].

Functional status: Assessed using the Oswestry Disability Index (ODI). The index score is calculated as (total score/(number of items * 5)) * 100%, with lower scores indicating better lumbar function. Evaluations were performed preoperatively and at 3 months and 6 months postoperatively [11].

*Secondary outcomes:* Secondary outcomes included surgical details, clinical efficacy, imaging findings, and quality of life, measured at the following time points:

**Table 2.** Comparison of surgical outcomes and postoperative recovery between the two groups (mean ± s)

| Groups | n | Operative time (min) | Intraoperative blood loss (mL) | Volume of bone cement injection (mL) | Time of getting out of bed (h) | Duration of hospitalization (d) |
|---|---|---|---|---|---|---|
| Research group | 52 | 33.06±6.18 | 12.69±3.51 | 4.96±0.67 | 2.28±0.69 | 6.51±1.27 |
| Control group | 52 | 34.18±6.57 | 13.74±4.12 | 5.13±0.71 | 3.05±0.74 | 7.26±1.45 |
| t | | 0.895 | 1.399 | 1.256 | 5.627 | 2.867 |
| P | | 0.373 | 0.165 | 0.212 | < 0.001 | 0.005 |

Surgical and recovery parameters: Recorded intraoperatively and during the hospital stay, including surgical time, intraoperative blood loss, bone cement injection volume, time to ambulation, and length of hospitalization.

Clinical efficacy: Assessed at 6 months postoperatively based on the minimal clinically important difference (MCID) for ODI and VAS scores. Clinical success was defined as a reduction of ≥ 30% in ODI score and/or a reduction of ≥ 50% in VAS score from baseline, in accordance with established thresholds for spinal conditions [10]. This approach provides a more objective and standardized evaluation of functional recovery and pain relief in OVCF patients.

Imaging parameters: Measured on spinal radiographs or CT scans preoperatively and at 3 and 6 months postoperatively. Parameters included the local kyphosis angle, vertebral wedge angle, and the anterior vertebral body height ratio (calculated as: [actual anterior height of the injured vertebra/estimated original anterior height] × 100%).

Quality of life: Assessed using the Quality of Life Questionnaire of the European Foundation for Osteoporosis (Qualeffo-41).

Statistics on the incidence of complications and refractures, including bone cement leakage, residual back pain, and incision infections, within 3 months after surgery. All patients were followed up for 12 months to measure the incidence of second fracture.

*Statistical methods*

The database was created using Excel 2019, and the Chinese version of SPSS 27.0 was used to process the database. The measurement data fit a normal distribution (mean ± s), and the difference between groups was analyzed using a t test. Repeated measures analysis of variance (ANOVA) was used to analyze the multitime point data. First, the interaction effect of time and treatment factor was tested. If the interaction effect was significant, further analysis of simple effects was needed; if the interaction effect was not significant, further analysis was performed. Analysis of main effects. The count data are expressed as n (%), and the $\chi^2$ test was performed. $P < 0.05$ was considered to indicate statistical significance.

## Results

*Comparison of demographic and clinical data*

The two groups showed no significant differences in baseline characteristics (see **Table 1**).

*Comparison of surgical outcomes and postoperative recovery between the two groups*

There was no significant difference in the operative time, amount of intraoperative blood loss, or amount of bone cement injection between the two groups (P > 0.05), and the duration of ambulation and hospitalization in the experimental group were shorter than those in the control group (P < 0.05). See **Table 2** and **Figure 2**.

*Comparison of clinical success rates based on MCID*

At the 6-month follow-up, the clinical success rate, defined as achieving a reduction of ≥ 30% in ODI score and/or ≥ 50% in VAS score, was significantly higher in the research group (90.4%, 47/52) compared to the control group (73.1%, 38/52), and the difference was statistically significant ($\chi^2$ = 5.429, P = 0.020) (**Table 3**).

*Comparison of the imaging index scores before and after surgery*

Repeated measures analysis of variance revealed significant interaction, time, and inter-

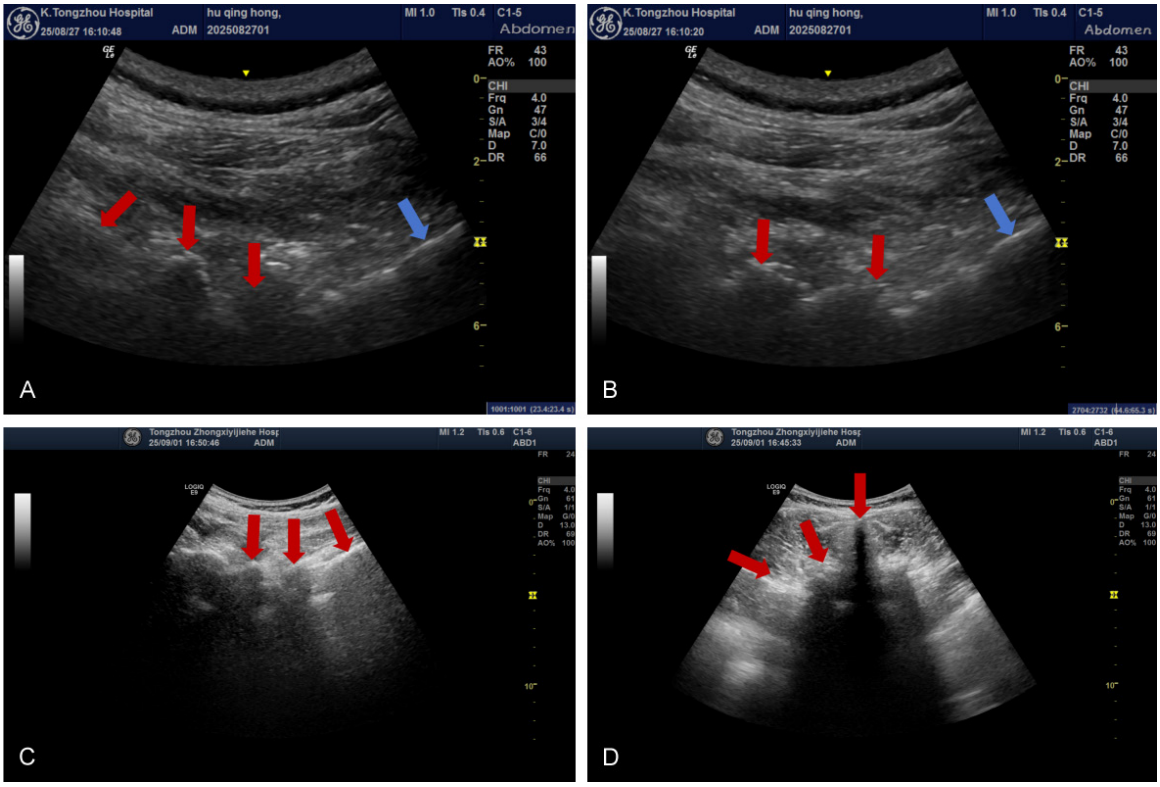


**Figure 2.** Ultrasound-guided micro-needle-knife release technique for osteoporotic vertebral compression fractures. A. Longitudinal ultrasound view showing the sacral slope (blue arrow) and facet joints (red arrows). The probe is positioned 2-3 cm lateral to the spinous processes, identifying the S1 vertebral slope and the hill-shaped facet joints. B. Longitudinal scan demonstrating the L4/L5 facet joint and L5/S1 facet joint (red arrows) with sacrum (blue arrow). The micro-needle-knife is inserted perpendicular to the skin to release the superficial fascia before reaching the bone surface of the facet joint. C. Repositioned probe showing the superior articular processes of L4, L5, and S1 (red arrows). The micro-needle-knife is used to release the medial branch of the posterior ramus by scraping along the base of the superior articular process. D. Transverse ultrasound view displaying the spinous process (vertical red arrow), facet joint (oblique red arrow), and transverse process (horizontal red arrow). The micro-needle-knife is maneuvered along the junction between the facet joint and transverse process to release the lateral branch of the posterior ramus.

**Table 3.** Comparison of clinical success rates based on MCID criteria at 6 months postoperatively [n (%)]

| Groups | n | Achieved MCID | Did not achieve MCID | Clinical Success Rate | $\chi^2$ | P |
|---|---|---|---|---|---|---|
| Research group | 52 | 47 (90.4) | 5 (9.6) | 47 (90.4) | 5.429 | 0.020 |
| Control group | 52 | 38 (73.1) | 14 (26.9) | 38 (73.1) | | |

group effects for all imaging indicators (all $P < 0.001$, **Table 4**). Post-hoc analysis with paired t-tests demonstrated that both treatment groups showed significant improvements from preoperative values at both 3 and 6 months postoperatively (all $P < 0.001$). Specifically, the local kyphosis angle and vertebral wedge angle significantly decreased, while the anterior vertebral height ratio significantly increased within each group over time. Furthermore, the research group achieved superior restoration compared to the control group, as evidenced by significantly lower local kyphosis and vertebral wedge angles, and a greater anterior vertebral height ratio at both postoperative time points (all $P < 0.05$) (**Figure 3**). See **Table 4**.

*Comparison of VAS scores between the two groups before and after surgery*

Repeated measures ANOVA identified statistically significant interaction, time, and inter-

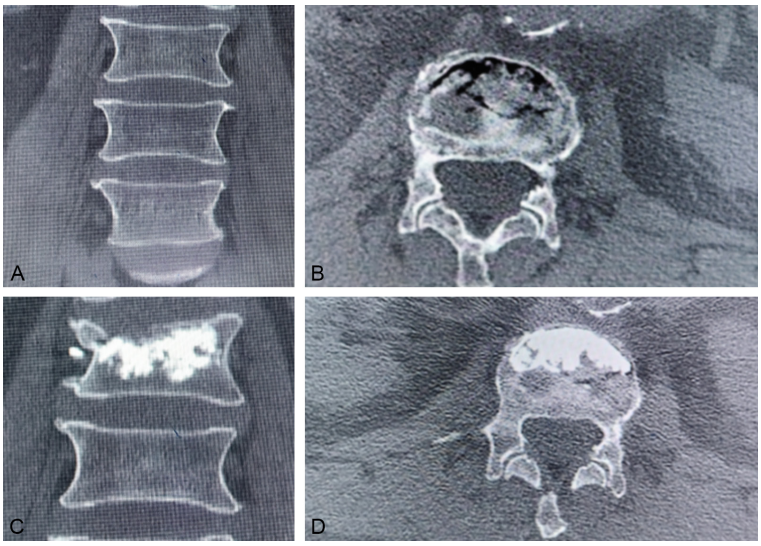


**Figure 3.** Representative CT images showing vertebral compression fractures before and after treatment. A, B. Preoperative CT images demonstrate osteoporotic vertebral compression fractures in sagittal and axial views. C, D. Postoperative CT images show bone cement distribution within the fractured vertebrae after percutaneous vertebroplasty treatment in sagittal and axial views.

group effects for VAS scores (all $P < 0.001$, **Table 5**). Paired t-tests confirmed that VAS scores decreased significantly from baseline at all postoperative time points within both the research and control groups (all $P < 0.001$). While there was no significant difference in preoperative VAS scores between the groups ($P > 0.05$), the research group consistently reported significantly lower VAS scores (indicating less pain) than the control group at 3 days, 7 days, 1 month, 3 months, and 6 months after surgery (all $P < 0.05$), demonstrating a more rapid and pronounced analgesic effect of the combined treatment. See **Table 5**.

*Comparison of ODI and Qualergo-41 scores between the two groups before and after surgery*

The repeated measures ANOVA showed significant interaction, time, and intergroup effects for both ODI and Qualeffo-41 scores (all $P < 0.001$, **Table 6**). Post-hoc paired t-tests revealed that scores for both functional and quality-of-life measures decreased significantly from preoperative levels at 3 and 6 months within each group (all $P < 0.001$), indicating substantial functional improvement. Preoperative scores were comparable between the two groups ($P > 0.05$). However, at both 3 and 6 months postoperatively, the research group exhibited significantly lower ODI and Qualeffo-41 scores than the control group (all $P < 0.05$), reflecting better functional recovery and quality of life in patients receiving the combined therapy. See **Table 6**.

*Comparison of postoperative complication rates between the two groups*

Within 3 months after surgery, the total incidence of complications in the experimental group was lower than that in the control group ($P < 0.05$). See **Table 7**.

*Comparison of the incidence of second fracture between the two groups*

The patients were followed up for 12 months after surgery. The patients were lost to follow-up after the 8th month. Three patients in the control group were lost to follow-up, and 2 patients in the study group were lost to follow-up. Among the patients who completed the follow-up, the incidence of refracture in the control group was 14.29% (7/49), the incidence of refracture in the experimental group was 8.00% (4/50), and the incidence of refracture in the experimental group was compared with that in the control group, and the difference was not statistically significant ($\chi^2 = 0.990$, $P = 0.320 < 0.05$).

## Discussion

While PVP is a standard procedure for treating OVCFs in the elderly, effectively stabilizing the spine and alleviating pain [12-15], it often fails to address concomitant paravertebral soft tissue injuries. This limitation can lead to persistent postoperative pain and functional impairment, highlighting the need for comprehensive treatment strategies that manage both vertebral instability and associated soft tissue damage.

The super micro needle-knife, a characteristic therapy in traditional Chinese medicine, has demonstrated significant efficacy in managing pain and dysfunction resulting from soft tissue

**Table 4.** Comparison of imaging indicators before and after surgery between the two groups (mean ± SD)

| Indicator | Group | Preoperative | 3 Months Postop | t-value (vs. Preop) | *P*-value (vs. Preop) | 6 Months Postop | t-value (vs. Preop) | *P*-value (vs. Preop) |
|---|---|---|---|---|---|---|---|---|
| Local kyphosis angle (°) | Research Group | 15.13±3.29 | 6.95±1.37 | 18.25 | < 0.001 | 6.87±1.40 | 18.51 | < 0.001 |
| | Control Group | 14.56±3.11 | 7.82±1.65 | 15.71 | < 0.001 | 7.75±1.59 | 15.89 | < 0.001 |
| Vertebral wedge angle (°) | Research Group | 19.22±2.65 | 9.36±1.84 | 25.41 | < 0.001 | 9.18±1.79 | 25.92 | < 0.001 |
| | Control Group | 18.67±2.84 | 10.59±1.92 | 19.87 | < 0.001 | 10.47±1.85 | 20.12 | < 0.001 |
| Anterior vertebral height ratio (%) | Research Group | 69.85±6.71 | 80.42±5.49 | -11.89 | < 0.001 | 81.30±5.24 | -12.56 | < 0.001 |
| | Control Group | 70.43±7.08 | 77.81±5.86 | -8.34 | < 0.001 | 78.15±5.73 | -8.21 | < 0.001 |

Notes: SD: Standard Deviation; Postop: Postoperative. *P*-value derived from paired-samples t-test comparing postoperative scores with preoperative baseline within the same group. Repeated measures ANOVA results: Local kyphosis angle: Fintergroup = 59.680, P < 0.001; Ftime = 110.35, P < 0.001; Finteraction = 81.231, P < 0.001. Vertebral wedge angle: Fintergroup = 38.569, P < 0.001; Ftime = 92.104, P < 0.001; Finteraction = 64.223, P < 0.001. Anterior vertebral height ratio: Fintergroup = 25.687, P < 0.001; Ftime = 98.621, P < 0.001; Finteraction = 55.820, P < 0.001.

**Table 5.** Comparison of VAS scores before and after surgery between the two groups (mean ± SD)

| Group | n | Preoperative | 3 Days Postop | t-value (vs. Preop) | *P*-value (vs. Preop) | 7 Days Postop | t-value (vs. Preop) | *P*-value (vs. Preop) | 1 Month Postop | t-value (vs. Preop) | *P*-value (vs. Preop) | 3 Months Postop | t-value (vs. Preop) | *P*-value (vs. Preop) | 6 Months Postop | t-value (vs. Preop) | *P*-value (vs. Preop) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Research Group | 52 | 6.84±1.22 | 3.78±0.75 | 16.95 | < 0.001 | 3.12±0.65 | 21.45 | < 0.001 | 2.41±0.60 | 26.18 | < 0.001 | 2.25±0.53 | 28.64 | < 0.001 | 1.45±0.28 | 35.92 | < 0.001 |
| Control Group | 52 | 6.59±1.14 | 4.65±0.83 | 11.89 | < 0.001 | 3.74±0.72 | 16.52 | < 0.001 | 3.16±0.68 | 19.87 | < 0.001 | 3.01±0.64 | 21.54 | < 0.001 | 1.83±0.31 | 30.15 | < 0.001 |

Notes: VAS: Visual Analogue Scale; SD: Standard Deviation; Postop: Postoperative. *P*-value derived from paired-samples t-test comparing postoperative scores with preoperative baseline within the same group. Repeated measures ANOVA results: Fintergroup = 22.301, P < 0.001; Ftime = 86.300, P < 0.001; Finteraction = 52.398, P < 0.001.

**Table 6.** Comparison of ODI and Qualeffo-41 scores before and after surgery between the two groups (mean ± SD)

| Indicator | Group | n | Preoperative | 3 Months Postop | t-value (vs. Preop) | *P*-value (vs. Preop) | 6 Months Postop | t-value (vs. Preop) | *P*-value (vs. Preop) |
|---|---|---|---|---|---|---|---|---|---|
| ODI | Research Group | 52 | 78.62±5.13 | 9.11±2.29 | 104.35 | < 0.001 | 8.87±2.01 | 108.92 | < 0.001 |
| | Control Group | 52 | 77.59±5.46 | 10.24±2.43 | 92.18 | < 0.001 | 10.15±2.27 | 93.45 | < 0.001 |
| Qualeffo-41 | Research Group | 52 | 64.53±4.21 | 38.65±3.42 | 38.95 | < 0.001 | 36.81±3.27 | 42.18 | < 0.001 |
| | Control Group | 52 | 63.61±4.58 | 41.08±3.65 | 31.67 | < 0.001 | 39.67±3.50 | 32.41 | < 0.001 |

Notes: ODI: Oswestry Disability Index; SD: Standard Deviation; Postop: Postoperative. *P*-value derived from paired-samples t-test comparing postoperative scores with preoperative baseline within the same group. Repeated measures ANOVA results: ODI: Fintergroup = 19.641, P < 0.001; Ftime = 95.620, P < 0.001; Finteraction = 60.232, P < 0.001. Qualeffo-41: Fintergroup = 15.698, P < 0.001; Ftime = 101.203, P < 0.001; Finteraction = 58.462, P < 0.001.

**Table 7.** Comparison of postoperative complication rates between the two groups [n (%)]

| Groups | n | Bone cement leakage | Residual back pain | Incision infection | Total incidence |
|---|---|---|---|---|---|
| Research group | 52 | 2 (3.85) | 0 (0.00) | 0 (0.00) | 2 (3.85) |
| Control group | 52 | 3 (5.77) | 4 (7.69) | 1 (1.92) | 8 (15.38) |
| $\chi^2$ | | | | | 3.983 |
| P | | | | | 0.046 |

injuries [16, 17]. This study innovatively integrated this technique with PVP. Our findings indicate that the combined therapy group outperformed the PVP-only group in terms of time to ambulation, hospital stay, and the incidence of short-term complications. This aligns with the direction of research by Pei et al. [18], suggesting that needle-knife intervention may facilitate early mobilization and rehabilitation by releasing contracted paravertebral muscles and fascia, improving local microcirculation, and reducing soft tissue edema. Crucially, all needle-knife procedures in this study were performed under ultrasound guidance, whose dynamic visualization capabilities [19-21] ensured treatment safety without introducing additional complications.

Regarding pain relief and functional improvement, the combined group showed significantly better outcomes than the control group in VAS, ODI, and Qualeffo-41 scores at all postoperative time points. This is consistent with findings by Geng et al. [22] on the analgesic effects of needle-knife therapy. The potential mechanism is that the ultrasound-guided super micro needle-knife can precisely release tense and spasmodic soft tissues around the fractured vertebra preoperatively, alleviating compression or abnormal stimulation of peripheral nerves. Thus, on the foundation of vertebral stability provided by PVP, it further interrupts the cycle of pain at the soft tissue level, promoting functional recovery [23, 24].

Radiographic assessments revealed superior restoration of anterior vertebral height, local kyphosis angle, and vertebral wedge angle in the combined group at 3 and 6 months postoperatively. We posit that the needle-knife plays a key role in restoring paravertebral dynamic balance. By releasing abnormally tractioned soft tissues, it reduces abnormal stress on the vertebral body, thereby helping to maintain the vertebral morphology and spinal alignment achieved by PVP [25, 26]. In contrast, the control group may have experienced some loss of correction due to residual soft tissue contracture and pain affecting the effectiveness of postoperative functional exercise [27, 28].

No statistically significant difference in the incidence of re-fracture within 12 months was observed between the two groups. This could be attributed to the relatively limited sample size and short follow-up period of this study. Furthermore, the use and adherence to anti-osteoporosis medication are critical factors influencing re-fracture rates [29, 30], whose effects might have overshadowed differences attributable to the treatment modality itself. Future studies with larger sample sizes and longer follow-up are needed to validate the effect of the combined protocol on re-fracture risk.

This study has several limitations. First, its single-center, retrospective design may introduce selection bias. Second, the relatively small sample size may have underpowered the statistical analysis of secondary outcomes like re-fracture rate. Finally, the adherence to anti-osteoporosis pharmacotherapy was not precisely quantified or standardized, potentially acting as a confounding factor.

In conclusion, ultrasound-guided super micro needle-knife therapy combined with PVP represents a comprehensive treatment strategy. By addressing both skeletal stability and soft tissue repair, it offers superior pain relief, functional improvement, and quality of life for elderly patients with OVCFs, demonstrating significant clinical value worthy of broader application.

## Disclosure of conflict of interest

None.

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