Retrospective Study

# Percutaneous Kyphoplasty Alleviates Pain Occurring Distal to the Fracture Area Caused by Stage I and II Kümmell Disease

Yuye Zhang, BS, Wenhong Yang, BS, Wenxiang Tang, MD, Xiaomei Song, BS, Jun Hua, PhD, Yongming Sun, PhD, Xiaozhong Zhou, PhD, and Fanguo Lin, MD

From: Second Affiliated Hospital of Soochow University, People's Republic of China

Address Correspondence:
Fanguo Lin, MD
Second Affiliated Hospital of Soochow University
People's Republic of China
E-mail: fancoolin@163.com

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**Background:** Kümmell disease (KD)—a rare and relatively complex spinal condition—is a type of posttraumatic osteoporotic vertebral compression fracture manifesting as a delayed collapse of a vertebral body. Although most patients with KD present with pain in the fracture area, some present with pain in the rib region or distal lumbosacral region, without pain in the fracture area, which poses challenges for diagnosing and treating KD.

**Objective:** We aimed to explore whether percutaneous kyphoplasty can alleviate pain distal to the fracture area caused by either Stage I or Stage II KD.

**Study Design:** A retrospective study.

**Setting:** This study was conducted at a university-affiliated hospital.

**Methods:** We conducted a retrospective analysis on patients with Stage I or Stage II KD who underwent surgical treatment in our hospital from December 2021 through October 2023. All patients were accompanied by pain distal to the fracture area (i.e., pain in the rib region or the distal lumbosacral region). All patients underwent percutaneous kyphoplasty. Postoperative follow-up thoracic or lumbar x-rays confirmed polymethylmethacrylate diffusion and vertebral reduction. Pain distal to the fracture area and functional impairment were evaluated at presurgery and at postsurgery one day, one week, and one month. In addition, the anterior, middle, and posterior vertebral heights and the Cobb angle were measured at pre- and postsurgery.

**Results:** A total of 42 patients were enrolled; 39 (92.9%) were women. Their average age was 73.48 ± 8.81 years. The fracture segments with KD and pain distal to the fracture area were as follows: T7 (9 cases, 21.4%); T10 (9 cases, 21.4%); and T8 (8 cases, 19.0%). The common location of pain distal to the fracture area was the rib region (30 cases, 71.4%). The preoperative Visual Analog Scale score of pain distal to the fracture area and the Oswestry Disability Index scores were significantly higher than those at postsurgery one day, one week, and one month. The heights of the anterior, middle, and posterior edges of the vertebrae on x-ray were significantly higher postoperatively than preoperatively. The Cobb angle of the fractured vertebrae was also higher postoperatively than preoperatively.

**Limitations:** Our study was conducted at a single center; single-center studies may introduce bias. Our study also had a relatively short follow-up time.

**Conclusion:** Patients with Stage I or Stage II KD may experience pain distal to the fracture area, which may effectively be alleviated by percutaneous kyphoplasty.

**Key words:** Percutaneous kyphoplasty, Kümmell disease, pain distal to the fracture area

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Kümmell disease (KD), a rare and relatively complex spinal disorder, is a type of osteoporotic vertebral compression fracture (OVCF) manifesting as a posttraumatic delayed collapse of a vertebral body. Patients with osteoporotic vertebral compression fractures experience a period of relief in their lower back pain, but their pain worsens after a few weeks or months.

The main imaging manifestation of KD is intravertebral vacuum cleft (1-3). KD can further cause persistent severe pain and functional impairment due to vertebral instability caused by nonunion of vertebral fractures. Li, et al (4) classified KD in stages based on the degree of vertebral compression and spinal cord compression. Treatment is aimed at alleviating pain and rebuilding spinal stability in patients with Stage I or Stage II KD. Surgical methods include percutaneous vertebroplasty, percutaneous kyphoplasty, or combined pedicle screw fixation to prevent cement detachment (5-7). Due to kyphosis and spinal cord compression, patients with Stage III KD undergo spinal canal decompression and deformity correction through anterior and posterior surgery (8-10).

An "all-clear" diagnosis of KD before treatment is imperative. While most patients with KD present with pain in the fracture area, some experience pain distal to the fracture area. Pain distal to the fracture area is defined as pain away from the injured vertebra, which is off-axis pain rather than midline pain, occurring in areas such as the low back, pericostal, around the iliac crest, or hip (11).

Notably, some patients also present with pain in the rib region or distal lumbosacral region, without pain in the fractured area. This poses challenges for the diagnosis and treatment of KD. At present, there is no relevant research on pain distal to the fracture area caused by KD. The present study explored whether percutaneous kyphoplasty can alleviate pain distal to the fracture area caused by Stage I or Stage II KD.

## Methods

### Patient Population

This study was approved by the ethics committee of the Second Affiliated Hospital of Soochow University, People's Republic of China. Patients with KD admitted to our hospital from December 2021 through October 2023 were retrospectively reviewed. After admission, all patients underwent spinal x-rays, spinal computed tomography, and spinal magnetic resonance imaging examinations.

The inclusion criteria were: 1) a diagnosis of Stage I or Stage II KD (verified by magnetic resonance imaging or computed tomography that showed vertebral osteonecrosis with intravertebral vacuum cleft) (12,13); 2) pain distal to the fracture area (i.e., pain in the rib region or pain in the distal lumbosacral region); 3) rib pain or distal lumbosacral pain with a Visual Analog Scale (VAS) score $\geq 5$; 4) a t value of $\leq -2.5$; 5) signed, informed consent.

The exclusion criteria were vertebral destruction caused by spinal tumor, spinal infection, tuberculosis, brucellosis, or other systemic or local infections.

### Surgical Techniques

With the patient prone, general anesthesia was administered. C-arm fluoroscopy was used to locate and mark the pedicle on both sides of the fractured vertebra. The puncture needle was inserted along the upper quadrant outside the marked point and inserted into the vertebral fissure. The work sleeve was then inserted and the liquid was extracted from the crack. A balloon with contrast medium was inserted in the appropriate position and then the vertebra was spread. When the polymethylmethacrylate was in the late stage of wire drawing, it was pushed under the C-arm fluoroscopy through bilateral working sleeves.

### Postoperative Management and Follow-Up

All patients completed the surgery and began functional exercise at one day postsurgery. Postoperative follow-up thoracic or lumbar x-rays were conducted to visualize polymethylmethacrylate diffusion and vertebral reduction. All patients underwent routine postsurgery antiosteoporosis treatment.

Pain distal to the fracture area and functional impairment were evaluated at presurgery and at postsurgery one day, one week, and one month. The VAS was used to assess pain distal to the fracture area but not midline pain. The Oswestry Disability Index (ODI) was used to score functional impairments. In addition, the anterior, middle, and posterior vertebral heights and Cobb angle were measuredat pre- and postsurgery. Measurements were made by 3 spine surgeons who each had more than 5 years of work experience. The average of the measurements taken by the 3 surgeons is the final data.

### Data Analysis

All data were statistically processed using IBM

SPSS Statistics 26.0 (IBM Corporation). Continuous variables are represented as mean ± SD. For nonnormally distributed data, the Friedman test was expressed by 50% percentile (25%, 75%). Normally distributed variables were compared using the paired sample t test. A repeated measures analysis of variance (ANOVA) was used to compare mean differences of normally distributed, independent, and homogeneous data. A *P* value of < 0.05 was considered statistically significant.

## Results

A total of 66 patients diagnosed with either Stage I or Stage II KD were recruited. The flow diagram of patient recruitment and study procedures is detailed in Fig. 1. Among them, 48 patients had pain distal to the fracture area. Among these 48 patients, 6 patients experienced pain relief after a facet joint block. Forty-two patients were included in the final analysis, of whom 39 (92.9%) were women. The average age was 73.48 ± 8.81 years. Detailed patient baseline information is displayed in Table 1.

There were 29 cases (69.05%) of Stage I KD and 13 cases (30.95%) of Stage II KD. The fracture segments with KD and pain distal to the fracture area were as follows: T7 (9 cases, 21.4%), T10 (9 cases, 21.4%), T8 (8 cases, 19.0%), T6 (5 cases, 11.9%), L1 (5 cases, 11.9%), T9 (3 cases, 7.14%), T11 (3 cases, 7.14%), T12 (3 cases, 7.14%), and L2 (one case, 2.38%). Thirty-eight patients had single segment fractures and 4 had multiple segment fractures. Ten patients (23.81%) only had pain distal to the fracture area and no local pain in the fracture. The common location of pain distal to the fracture area was the rib region (30 cases, 71.43%).

The VAS score of pain distal to the fracture area, the ODI score, and the heights of the fractured vertebra pre- and postoperative are depicted in Table 2. The preoperative VAS score for pain away from the fracture area was 7 (6, 8). The VAS score on the first postoperative day was 2 (1, 2), 1 (1, 1) at one week, and 0.5 (0, 1) at one month. The difference was statistically significant ($P < 0.001$).

The ODI was 74.9 ± 3.06 preoperative, 24.90 ± 3.11 one day postsurgery, 16.40 ± 2.08 one week postsurgery, and 13.74 ± 1.96 one month postsurgery. The difference was statistically significant ($P < 0.001$).

Four patients had multisegment fractures. Thus, 46 vertebrae were measured for the height of the anterior, middle, and posterior edges. The heights of the anterior, middle, and posterior edges of the vertebrae on x-ray were significantly higher one day postoperatively than preoperatively (13.42 [11.90, 17.22] vs 17.84 (15.23, 20.22) mm, 13.6 ± 3.88 vs 17.7 ± 3.25 mm, 19.93 (16.63, 23.25) vs 21.49 (19.01, 25.07) mm). The difference was statistically significant ($P < 0.001$).

The Cobb angles of the fractured vertebrae

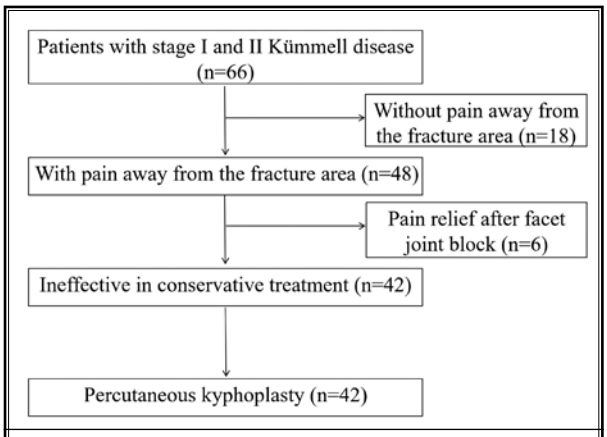


Fig. 1. *Flow diagram of patient recruitment and study procedures*

Table 1. *Summary of demographic characteristics and surgical related information*

| Characteristic | Possible values |
|---|---|
| Mean age (yrs) (x ± s) | 73.48 ± 8.81 |
| Female gender (%) | 39 (92.9%) |
| BMI | 22.86 ± 2.70 |
| Stage I Kümmell disease | 29 (69.05%) |
| Surgical level (%) | |
| T6 | 5 (11.9%) |
| T7 | 9 (21.4%) |
| T8 | 8 (19.0%) |
| T9 | 3 (7.14%) |
| T10 | 9 (21.4%) |
| T11 | 3 (7.14%) |
| T12 | 3 (7.14%) |
| L1 | 5 (11.9%) |
| L2 | 1 (2.38%) |
| Fracture pattern (%) | |
| Single segmental fracture | 38 (90.48%) |
| Multiple segment fractures | 4 (9.52%) |
| Without pain in the fractured area (%) | 10 (23.81%) |
| Location of pain away from the fracture area (%) | |
| Rib region | 30 (71.43%) |
| Distal lumbosacral region | 12 (28.57%) |

BMI: body mass index

were also higher postoperatively than preoperatively (-13.50° (-10.00°, -16.25°) vs -8.50° (-4.75°, -12.00°). The difference was statistically significant ($P < 0.001$).

The images of patients aged 90-99 years with KD of L1 are shown in Fig. 2. Preoperative imaging suggests an intravertebral vacuum cleft in the lumbar vertebra. Postoperative imaging showed good diffusion of polymethylmethacrylate without leakage. The cleft is fully filled with polymethylmethacrylate. The preoperative and postoperative measurements of the anterior, middle, and posterior vertebral heights and Cobb angles are shown in Fig. 3. The height of the anterior, middle, and posterior edges of the vertebrae, as well as the Cobb angle, improved significantly after surgery.

## Discussion

KD is a complication of osteoporotic vertebral compression fracture and often occurs in clinical practice in middle-aged adults. With the aging population, its incidence has been increasing yearly (14-16). The most common sites of occurrence are the thoracic vertebrae and thoracolumbar segments.

Previous studies have suggested that the mechanism underlying KD is the interruption of blood supply to the anterior one-third of the vertebra after vertebral fracture, leading to local ischemic bone necrosis of the fractured vertebra. The local cavity left after the absorption of necrotic bone is the intravertebral vacuum cleft on imaging (17-19). Based on clinical practice, we believe that local ischemic necrosis of a fractured vertebra is only a partial cause of KD. KD is often caused by minor trauma; patients sometimes exhibit no clear history of trauma. The patient's local pain is not very severe, especially for patients with thoracic vertebral fractures, which are less pronounced due to rib support. Hence, the patient does not receive sufficient conservative treatment methods such as bed rest and waist circumference fixation after vertebral fracture and directly engages in daily activities, resulting in repeated compression and tension of the fractured area. Repeated compression

Table 2. *VAS of pain distal to the fracture area, ODI score, and the heights of the fractured vertebra pre- and postoperative*

| | Preoperative | 1 Day Postoperative | 1 Week Postoperative | 1 Month Postoperative | *P* |
|---|---|---|---|---|---|
| VAS | 7 (6, 8)$_a$ | 2 (1, 2)$_b$ | 1 (1, 1)$_c$ | 0.5 (0, 1)$_d$ | < 0.001 |
| ODI | 74.9±3.06$_e$ | 24.90±3.11$_f$ | 16.40±2.08$_g$ | 13.74±1.96$_h$ | < 0.001 |
| The heights of the fractured vertebra (mm) | | | | | |
| anterior | 13.42 (11.90, 17.22) | 17.84 (15.23, 20.22) | | | < 0.001 |
| middle | 13.6±3.88 | 17.7±3.25 | | | < 0.001 |
| posterior | 19.93 (16.63, 23.25) | 21.49 (19.01, 25.07) | | | < 0.001 |
| Cobb (°) | -13.50 (-10.00, -16.25) | -8.50 (-4.75, -12.00) | | | < 0.001 |

VAS: visual analog scale; ODI: oswestry disability index; a, b, c, d, e, f, g, h means the differences across the four were statistically significant

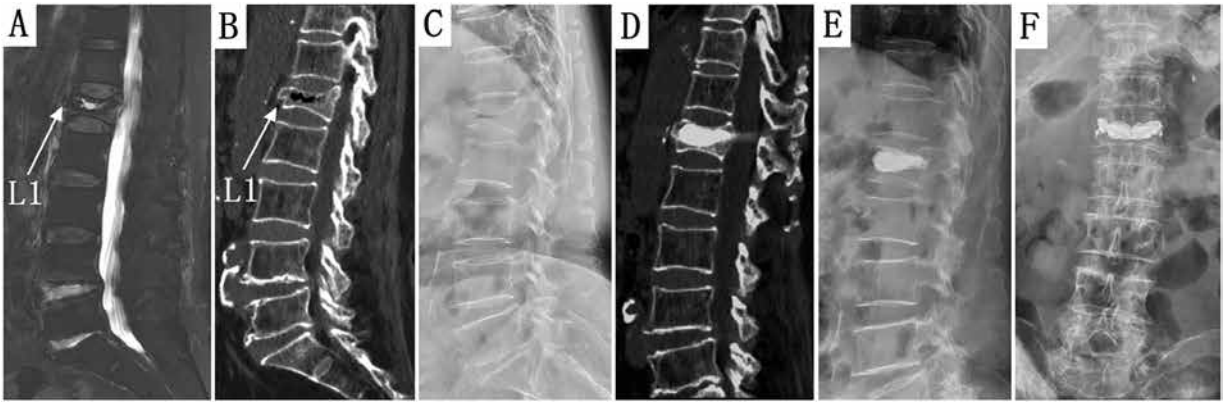


Fig. 2. *The imaging data of a patient with Kümmell's disease (L1) are shown in the figure. A: preoperative MRI, B: preoperative CT, C: preoperative lateral x-ray, D: postoperative CT, E: postoperative posterior x-ray, F: postoperative anteroposterior x-ray.*

and tension lead to nonunion and osteonecrosis. Finally, local fluid accumulation and bone defects are formed in the vertebral fracture. This is the intravertebral vacuum cleft manifested on imaging.

Patients with KD experience instability of the entire vertebra due to intravertebral vacuum cleft (20-22). During activity, anterior edge support weakens, leading to an increase in the body's weight borne by the facet joints. Due to prolonged external force stimulation, the facet joints undergo a similar degradation process to other synovial joints, such as osteoarthritis. This process involves cartilage degeneration, subchondral sclerosis, osteophyte formation, and intraarticular fluid accumulation (23,24).

Facet joint degeneration leads to Maigne syndrome. Maigne syndrome is a cause of low back pain. It primarily affects thoracolumbar joints and may cause peripheral involvement of the lateral cutaneous branch of the dorsal rami (25-28). This explains why patients with KD in our study experienced pain distal to the fracture area. After reviewing 48 patients with either Stage I or Stage II KD who experienced pain distal to the fracture area, 6 of them had pain relief with a facet joint block. This better explains that KD may cause Maigne syndrome, which in turn leads to pain distal to the fracture area.

For patients with either Stage I or Stage II KD who have failed strict conservative treatment, treatment is only aimed at alleviating pain and rebuilding spinal stability. Surgical strategies include percutaneous vertebroplasty, percutaneous kyphoplasty, or combined pedicle screw fixation to prevent cement detachment (29-32).

We believe that treating patients who have either Stage I or Stage II KD with percutaneous kyphoplasty should effectively relieve pain. During spinal stability reconstruction, the procedure should be minimally invasive and concise in order to reduce trauma. Early functional exercise and restoration of daily life should be achieved as soon as possible. Due to the presence of osteosclerosis and intravertebral vacuum cleft in KD, percutaneous vertebroplasty cannot achieve satisfactory vertebral reduction results solely based on positional reduction estimation. Meanwhile, polymethylmethacrylate is prone to leakage into the spinal canal along the fissure. Therefore, our study's analysis leads to a recommendation for a percutaneous kyphoplasty surgical approach to treat pain distal to the fracture area caused by KD. This involves partial reduction of percutaneous kyphoplasty and stabilization of the vertebra, which reduces stress on the articular processes and facet joints. This strategy can effectively alleviate pain distal to the fracture area caused by either Stage I or Stage II KD.

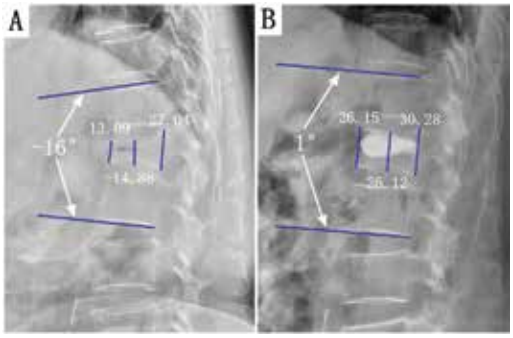


Fig. 3. *The preoperative and postoperative X-ray measurement data of the patient are shown in the figure. The preoperative x-ray (A) showed that the heights of the anterior, middle, and posterior edges of the vertebrae were 13.09 mm, 14.88 mm, and 27.04 mm. The COBB angle is -16°, and postoperative x-ray (B) showed that the heights of the anterior, middle, and posterior edges of the vertebrae are 26.15 mm, 26.12 mm, and 30.28 mm. The COBB angle is -1°.*

### Limitations

Nonetheless, our study has some shortcomings. This is a retrospective study that included patients with either Stage I or Stage II KD, which may have selection and recall biases. In addition, the overall sample size was relatively small, and the follow-up time was relatively short. Our future study will prospectively include more patients with KD and more research indicators, which may be beneficial in developing new treatment methods for pain distal to the fracture area caused by KD.

## Conclusion

In summary, patients with either Stage I or Stage II KD may experience pain distal to the fracture area, which may be effectively alleviated by percutaneous kyphoplasty, thereby expediting early functional exercise and a return to activities of daily living.

### Author Contributions

All authors contributed significantly to the planning, conduct, and reporting of the work described in the paper. Yuye Zhang, Wenhong Yang, Wenxiang Tang, and Xiaomei Song contributed equally to this paper. Yuye Zhang, Wenhong Yang, Wenxiang Tang, and Xiaomei Song are joint first authors.

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