Analysis of percutaneous kyphoplasty or short-segmental fixation combined with vertebroplasty in the treatment of Kummell disease

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Abstract

Background: In recent years, short segment internal fixation combined with vertebroplasty (SSF + VP) has provided a new option for the treatment of Kummell disease (KD). The purpose of this study is to evaluate the efficacy of percutaneous kyphoplasty (PKP) and SSF + VP, to provide evidence-based medical support for the decision-making process when treating KD patients without neurological deficits.

Methods: Databases including MEDLINE (PubMed) and EMBASE (Ovid) (1947 to April 6, 2019) were searched for PKP and short-segmental fixation combined with vertebroplasty (SSF + VP) to treat Kummell disease in randomized controlled trials (RCTs) or cohort studies. Two investigators independently evaluated the eligibility of the studies retrieved from the databases based on the predetermined selection criteria. The postoperative evaluation indexes included operation time, bleeding volume, visual analog scale (VAS) score, Oswestry Disability Index (ODI) score, local vertebral Cobb angle, and cement leakage. When the data were significant, a random-effects model was used for analysis. In contrast, when the results showed no statistical heterogeneity, a fixed-effects model was used to estimate the overall effect sizes.

Results: Three retrospective case-control studies were included in the final analysis. The differences in the bleeding volume and operation time were statistically significant, and the combined weighted mean differences (WMDs) (95% CI) were −0.204.46 (−210.97, −197.93) and −98.98 (−141.63, 56.32), respectively. The combined data showed that the differences in VAS score, ODI score, local vertebral Cobb angle, and cement leakage were not statistically significant.

Conclusions: This analysis demonstrates that the PKP and SSF + VP methods are safe and effective in treating Kummell disease patients without neurological symptoms. However, PKP can shorten the operation time and reduce the volume of blood loss.

Keywords: Kyphoplasty, Vertebroplasty, Fixation, Kummell disease
Background
Kummell disease (KD) was first reported by Steel in 1951 and occurs in middle-aged and elderly people with osteoporosis. KD presents as a delayed vertebral compression fracture and is characterized by the following common characteristics: a history of minor trauma, after which the pain disappears, but the symptoms recur or worsen, and a kyphosis deformity occurs months or years later [1, 2]. The affected vertebra is usually located in the lower thoracic or upper lumbar region (T8–L4), owing to the well-known prevalence of vertebral fractures at the thoracolumbar junction. In the majority of cases, only a single vertebra is involved [2].

The main diagnostic imaging finding of KD is characterized by an intravertebral vacuum cleft on plain radiograph, which is better appreciated on the anteroposterior view of computed tomography (CT) or magnetic resonance imaging (MRI) scans [3]. However, imaging cannot be used as a specific basis for diagnosis. KD is surrounded by hardened bone and cannot self-heal. At present, there is no standard treatment for KD [1, 4].

In terms of surgical treatments, different methods are adopted according to the presence of neurological symptoms. If the patients are neurologically impaired, the aim of surgery is to decompress the spinal canal, restore the spinal curvature, and maintain spinal stability. The surgical modes include anterior, posterior, or combined anterior and posterior approaches. If the patients do not have neurological symptoms, the purpose of surgery is to preserve the maximum amount of movement of the injured vertebra and to restore vertebral height and sagittal alignment. Therefore, the percutaneous kyphoplasty (PKP) and percutaneous vertebroplasty (PVP) techniques have been widely used to treat KD [5, 6]. However, there have been reports of loosening and displacement of the bone cement, further loss of vertebral height, and even secondary paralysis following PKP or PVP [7–10]. Therefore, short-segmental fixation combined with vertebroplasty (SSF + VP) has also been used to treat KD in recent years. This technique has been reported to have certain positive effects on pain relief and functional recovery [1, 11, 12].

However, no consensus has been reached on the optimal treatment method for KD patients without neurological deficits. Thus, we performed an analysis to evaluate the efficacy of PKP and SSF + VP and to provide evidence-based medical support for the decision-making process when treating KD patients without neurological deficits.

Methods
Search strategy and data sources
We searched MEDLINE (PubMed) and EMBASE (OVID) (1947 to April 6, 2019) for randomized controlled trials (RCTs) or cohort studies that investigated PKP and SSF + VP to treat KD. There were no restrictions regarding language or type of publication. The search terms used were the following: (i) kummell [Title/Abstract] OR avascular osteonecrosis of vertebral body [Title/Abstract] OR vertebral osteonecrosis [Title/Abstract] OR vertebral pseudarthrosis [Title/Abstract] OR intravertebral vacuum cleft [Title/Abstract] OR delayed vertebral collapse [Title/Abstract] OR compression fracture nonunion [Title/Abstract]; AND (ii) kyphoplasty [Title/Abstract] OR vertebroplasty [Title/Abstract] OR bone cement augment [Title/Abstract] OR fixation [Title/Abstract]. The retrieval strategy was formulated according to a professional retrieval process, and we also searched the bibliographies of relevant articles to identify any additional studies.

Study selection
The inclusion criteria were as follows: (1) presented original data from a cohort study or case-control study; (2) included patients definitively diagnosed with KD; (3) used two comparator groups in which one group was treated with a PKP strategy, and the other group was treated with an SSF + VP strategy; (4) included patients with monosegmental lesions who did not have neurological deficits and for whom conservative treatment was invalid; and (5) had sufficient data for analysis.

The exclusion criteria were as follows: (1) included patients with metastatic spinal tumors, infections, primary bone tumors, multiple myeloma or bisegmental and multisegmental lesions; (2) included patients with neurological symptoms; (3) included patients with defects of the posterior wall of the vertebral body or those that occupied the vertebral canal; and (4) included non-human study subjects. If the data were duplicated or the same population was used in more than one study, we chose the most recent or complete study.

Data extraction and quality assessment
Two investigators (Wei Lu/Zhaowei Teng) independently evaluated the eligibility of the studies retrieved from the databases based on the predetermined selection criteria. In addition, a cross-reference search for eligible articles was conducted to identify studies not identified from the computerized search. These two authors independently extracted the following data: the first author's name; year of publication, study regions, cohort size, operative time, bleeding volume, visual analog scale (VAS) score, Oswestry Disability Index (ODI) score, local vertebral Cobb angle, cement leakage, and statistical adjustments for confounding factors. Any disagreements were resolved either by discussion or in consultation with the corresponding author (Sheng Lu). Finally, the eligible studies were included in the meta-analysis.
Statistical analyses
Data analysis was performed using Stata 14.0 software (StataCorp., USA). The Cochran $Q$ and $I^2$ value were used together to test heterogeneity. When the $p$ value was < 0.1 and the $I^2$ value was > 50%, the data were considered to be heterogeneous, and a random-effects model was used for the meta-analysis. Otherwise, when the results showed no statistical heterogeneity, a fixed-effects model was used to estimate the overall effect sizes.

Results
Literature search and study characteristics
A total of 329 articles were initially identified from the PubMed and EMBASE databases. There were no additional studies from other sources. After removing the duplicate articles, 73 studies were included for further assessment. We reviewed the titles, abstracts, and full texts of all retrieved articles using the defined criteria. Finally, there were three articles that met the inclusion criteria. Figure 1 shows the flow diagram of the selection process. The characteristics of the included studies are shown in Table 1. All three articles were retrospective case-control studies from China [13–15].

Analysis
The data of the three included articles were summarized and analyzed. Two indicators obtained from the forest map were statistically significant, namely, the volume of blood loss during surgery and the operation time. Since the specific volume of blood loss was not provided in one paper (Chen, China) [14], we combined the data of the other two papers, as shown in Fig. 2a. The combined weighted mean difference (WMD) (95% CI) was $-0.204.46 (-210.97, -197.93)$, and the combined results were statistically significant.

The operation time data of the three references were combined. As shown in Fig. 2b, the combined WMD (95% CI) was $-98.98 (-141.63, -56.32)$, and the combined results were statistically significant.

Data from the three included studies regarding the VAS score, ODI score, and local vertebral Cobb angle of the
| Author, year, location | Study design | Number of patients | Operative time (min) | bleeding volume (ml) | VAS score | ODI score | Local vertebral Cobb angle | Cement leakage |
|------------------------|-------------|--------------------|---------------------|---------------------|-----------|-----------|-----------------------------|---------------|
| Liang Chen, 2015, China | Retrospective cohort | 31 23 | 128 76 (60–95) | Minimal 245 | Pre78 ± 0.9 | ND | Pre 247 ± 92 | 11 5 |
| | | | 76 (95–165) | | POM 3.3 ± 1.0 | ND | POM 145 ± 5.3 | |
| | | | | Fin 2.9 ± 0.9 | | Fin 15.5 ± 52 | |
| Yan-Sheng Huang, 2018, China | Retrospective cohort | 32 28 | 43.1 ± 7.1 | 115.9 ± 10.0 | 9.9 ± 2.7 | 2143 ± 17.5 | Pre 75.3 ± 50 | 3 3 |
| | | | 115.9 ± 10.0 | 9.9 ± 2.7 | 2143 ± 17.5 | Pre 74.4 ± 5.1 | Fin 15.1 ± 46 | |
| | | | | Pre 8.1 ± 08 | POM 28 ± 08 | Fin 2.9 ± 1.2 | Pre 229 ± 3.9 | POM 145 ± 3.8 | Fin 15.1 ± 46 | |
| Hou-Kun Li, 2017, China | Retrospective cohort | 25 21 | 43.2 ± 21.8 | 230.6 ± 87.1 | 5.3 ± 3.1 | 2150 ± 170.2 | Pre 72.5 ± 100 | 2 1 |
| | | | 230.6 ± 87.1 | 5.3 ± 3.1 | 2150 ± 170.2 | Pre 228 ± 7.4 | POM 149 ± 8.2 | |
| | | | | Pre 8.1 ± 08 | POM 28 ± 08 | Fin 2.9 ± 1.2 | Pre 217 ± 36 | POM 150 ± 67 | Fin 165 ± 28 | |

Abbreviations: PKP percutaneous kyphoplasty, SSF short-segmental fixation, VP vertebroplasty, VAS visual analog scale, ODI Oswesty Disability Index, Pre preoperative, POM postoperative 1 month, Fin final follow-up, ND no data
two different surgical methods PKP and SSF + VP were extracted and combined. We combined the VAS score data in the preoperative period, at 1 month postoperative and at the final follow-up. As shown in Fig. 2c–e, the combined WMDs (95% CI) were 0.12 (−0.35, 0.58), 0.72 (−1.62, 0.17), and −0.10 (−0.58, 0.38) in the preoperative period, at 1 month postoperative and at the final follow-up, respectively. The combined data showed no statistical significance.

We combined the local vertebral Cobb angle data in the preoperative period, at 1 month postoperative and at the final follow-up, as shown in Fig. 2f–h. The corresponding WMDs (95% CI) were 0.17 (−1.66, 2.01), 0.31 (−1.24, 1.85), and 0.55 (−0.99, 2.10); the combined data were not statistically significant.

Because (Chen, China) [14] did not provide ODI scores, the ODI scores in the preoperative period and at the postoperative final follow-up of the two remaining papers were combined, as shown in Fig. 2i, j. The WMDs (95% CI) in the preoperative period and at the postoperative final follow-up were −1.48 (−7.25, 4.20) and 1.28 (−0.81, 3.36), respectively; the combined data were not statistically significant.

The cement leakage data were combined, as shown in Fig. 2k, with an OR (95% CI) value of 1.52 (0.61, 3.79); the combined data were not statistically significant.
In conclusion, both the PKP and SSF + VP methods are safe and effective for treating KD patients without neurological symptoms. However, PKP can shorten the operation time and reduce the bleeding volume. Moreover, the PKP method offers better pain relief and kyphosis correction due to its stability and reduced cement leakage. Further studies are needed to evaluate the long-term outcomes and cost-effectiveness of these techniques.
strenthen the credibility of this result. In addition, this study also has the following limitations: first, there was some statistical heterogeneity between the included studies. Although we used the random-effects model to balance this statistical heterogeneity in the analysis process, this heterogeneity still has some influence on the conclusions. Second, all the included studies were retrospective case-control studies, and this non-randomized controlled study was susceptible to selection bias, implementation bias, mixed bias, etc.

Abbreviations
CT: Computed tomography; Fin: Final follow-up; KD: Kümmell disease; MRI: Magnetic resonance imaging; ND: No data; ODI: Oswestry Disability Index; PKP: Percutaneous kyphoplasty; POM: Postoperative 1 month; Pre: Preoperative; PVP: Percutaneous vertebroplasty; RCTs: Randomized controlled trials; SSF: Short-segmental fixation; VAS: Visual analog score; VP: Vertebroplasty; WMDs: Weighted mean differences

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Authors’ contributions
WL and ZWT conceived the study design. WL, GHH, and CLX performed the data collection, data extraction, data interpretation, manuscript drafting, statistical analysis, and performance of the study. ZWT and WL were responsible for critical revision of the manuscript. WL, LM, JLL, RMS, and HTL were responsible for data interpretation, manuscript drafting, supervision, and critical revision of the manuscript. SL and ZWT act as the guarantors for this article and take full responsibility for this study. All authors have read and approved the final manuscript.

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Availability of data and materials
All data analyzed during this study are included in this published article.

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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References
1. Lee SH, Kim ES, Eoh W. Cement augmented anterior reconstruction with short posterior instrumentation: a less invasive surgical option for Kümmell’s disease with cord compression. J Clin Neurosci. 2011;18:509–14.
2. Li H, Liang CZ, Chen QX. Kümmell’s disease, an uncommon and complicated spinal disorder: a review. J Int Med Res. 2012;40:406–14.
3. Malghem J, Maldaigue B, Labaisse MA, Dooms G, Duprez T, Devoegele JP, et al. Intravertebral vacuum defect: changes in content after supine positioning. Radiology. 1999;187:483–7.
4. Hulin Y, Jun P, Genlin W. A review of osteoporotic vertebral fracture nonunion management. Spine. 2014;39:84–6.
5. Matsurara M, Fujimoto Y, Yamada N, Nakamae T. Percutaneous vertebroplasty versus balloon kyphoplasty for osteoporotic vertebral fracture with intravertebral cleft. Spine J. 2014;14:S123.
6. Huang Y, Peng M, He S, Tang X, Dai M, Tang C. Clinical efficacy of percutaneous kyphoplasty at the hyperelevation position for the treatment of osteoporotic Kümmell disease. Clin Spine Surg. 2016;29:161–6.
7. Laredo JD. Expert’s comment concerning grand rounds case entitled “Kümmell’s disease: delayed post-traumatic osteonecrosis of the vertebral body” (by R. Ma, R. Chow, F. H. Shen). Eur Spine J. 2010;19:1071–2.
8. Wagner AL, Baikart E. Refracture with cement extrusion following percutaneous vertebroplasty of a large interbody cleft. AJNR Am J Neuroradiol. 2006;27:230–1.
9. D’Orsia S, Delvecchio C, Dibenedetto M, Zizza F, Somma C. Case report of Kümmell’s disease with delayed onset myelopathy and the literature review. Eur J Orthop Surg Traumatol. 2018;28:309–16.
10. Wang HS, Kim HS, Ju CL, Kim SW. Delayed bone cement displacement following balloon kyphoplasty. J Korean Neurosurg Soc. 2008;43:212–4.
11. Park SJ, Kim HS, Lee SK, Kim SW. Bone cement-augmented percutaneous short segment fixation: an effective treatment for Kümmell’s disease? J Korean Neurosurg Soc. 2015;55:84–9.
12. Zhang QG, Gao YZ, Zheng J, Luo JP, Tang C, Chen SL, et al. Posterior decompression and short segmental pedicle screw fixation combined with vertebroplasty for Kümmell’s disease with neurological deficits. Exp Ther Med. 2013;5:517–22.
13. Li HK, Hao DJ, Yang JS, Huang DG, Yu CC, Zhang JN, et al. Percutaneous kyphoplasty versus posterior spinal fixation with vertebroplasty for Kümmell’s disease. Medicine. 2017;96:e9287.
14. Chen L, Dong R, Gu Y, Feng Y. Comparison between balloon kyphoplasty and short segmental fixation combined with vertebroplasty in the treatment of Kümmell’s disease. Pain Physician. 2015;18:373–81.
15. Huang YS, Hao DJ, Feng H, Zhang HP, He SM, Ge CY, et al. Comparison of percutaneous kyphoplasty and bone cement-augmented short-segment pedicle screw fixation for management of Kümmell disease. Med Sci Monit. 2018;24:1072.
16. Yoon ST, Qureshi AA, Heller AG. Kyphoplasty for salvage of a failed vertebroplasty in osteoporotic vertebral compression fractures: case report and surgical technique. J Spinal Disord Tech. 2005;18:529–34.
17. Yu W, Liang YZ, Qiu T, Ye L, Jiang X. The therapeutic effect of intravertebral vacuum cleft with osteoporotic vertebral compression fractures: a systematic review and meta-analysis. Int J Surg. 2017;40:17–23.
18. Fabbriani G, Pirro M, Floridi P, Callarelli L, Manfredelli MR, Scarponi AM, et al. Osteoanabolic therapy: a non-surgical option of treatment for Kümmell’s disease? Rheumatol Int. 2012;32:1371–4.
19. Garfin SR, Reiley MA. Minimally invasive treatment of osteoporotic vertebral body compression fractures. Spine J. 2002;2:76–80.
20. Kytkulov C, Molloy S, Vincis F, Alberico R, Bastian L, Zonder JA, et al. The role of cement augmentation with percutaneous vertebroplasty and balloon kyphoplasty for the treatment of vertebral compression fractures in multiple myeloma: a consensus statement from the international myeloma working group (IMWG). Blood Cancer J. 2019;9:27.
21. Phillips FM, Wetzel FT, Lichtman I, Cambebi-Hupp M. An in vivo comparison of the potential for extravertebral cement leak after vertebroplasty and kyphoplasty. Spine. 2002;27:2173–8.
22. Ha KY, Lee JS, Kim KW, Chon JS. Percutaneous vertebroplasty for vertebral compression fractures with and without intravertebral clefts. J Bone Joint Surg Br. 2006;88:629–33.
23. Kong LD, Wang P, Wang LF, Shen Y, Shang ZK, Meng LC. Comparison of vertebroplasty and kyphoplasty in the treatment of osteoporotic vertebral compression fractures with intravertebral clefts. Eur J Orthop Surg Traumatol. 2014;24(Suppl 1):S201–8.

24. Tanigawa N, Kanya S, Komemushi A, Tokuda T, Nakatani M, Yagi R, et al. Cement leakage in percutaneous vertebroplasty for osteoporotic compression fractures with or without intravertebral clefts. AJR Am J Roentgenol. 2009;193:W442–5.

25. Formica M, Zanirato A, Cavagnaro L, Basso M, Divano S, Lamartina C, et al. Vertebral body osteonecrosis: proposal of a treatment-oriented classification system. Eur Spine J. 2018;27:190–7.

26. Huang YS, Hao DJ, Wang XD, Sun HH, Du JP, Yang JS, et al. Long-segment or bone cement-augmented short-segment fixation for Kummell disease with neurologic deficits? a comparative cohort study. World Neurosurg. 2018;116:e1079–86.

27. Nardi A, Tarantino U, Ventura L, Armotti P, Resmini G, Cozzi L, et al. Domino effect: mechanic factors role. Clin Cases Miner Bone Metab. 2011;8:38–42.

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