Cross-Sectional Analysis

Percutaneous Vertebroplasty Versus Balloon Kyphoplasty in the Treatment of Osteoporotic Vertebral Compression Fractures: Evaluating the Overlapping Meta-analyses

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Background: Numerous meta-analyses and systematic reviews have explored the differences between percutaneous vertebroplasty (PVP) and percutaneous balloon kyphoplasty (PKP) for treating osteoporotic vertebral compression fractures (OVCFs), however, their final conclusions have been inconsistent. The inconsistent conclusions drawn from these meta-analyses create uncertainty among clinicians about the best treatment approach for OVCFs.

Objective: The aim of this study was to conduct a cross-sectional analysis of overlapping meta-analyses comparing PVP and PKP treatments for OVCF in order to help clinicians have access to the best available evidence and provide treatment recommendations based on the best available evidence.

Study Design: A cross-sectional analysis of overlapping meta-analyses.

Methods: We conducted a comprehensive search of meta-analyses published up to February 2023 in PubMed, Embase, Cochrane Library and Web of Science databases to identify relevant studies. The methodological quality of these studies was assessed using the Assessment of Multiple Systematic Reviews tool (original AMSTAR) and the Oxford Centre for Evidence-based Medicine Levels of Evidence. Two researchers independently extracted the data and assessed the quality of these meta-analyses. To determine which meta-analyses represented the best evidence, we employed the Jadad decision algorithm.

Results: Seventeen meta-analyses were included in the study, with AMSTAR scores ranging from 4 to 9, with an average of 7. After rigorous scrutiny, the Zhu et al study was determined to provide the best evidence. According to their findings, both PVP and PKP effectively alleviate pain and improve function in the treatment of OVCFs, without any statistically significant differences between them. In addition, PKP can reduce the risk of polymethylmethacrylate leakage compared to PVP.

Limitations: This study analyzed published overlapping meta-analyses, inherently confining our investigation to the meta-analysis level. Furthermore, based on the AMSTAR scores, several included studies exhibited lower methodological quality.

Conclusions: Currently, the best evidence indicates that PVP and PKP are equally effective at alleviating pain and enhancing function in the treatment of OVCFs, but PKP had a lower incidence of polymethylmethacrylate leakage. However, there is still a need for high-quality randomized controlled trials to provide higher levels of evidence regarding other aspects of the differences between the 2 procedures.

Key words: Osteoporotic vertebral compression fractures, percutaneous vertebroplasty, balloon kyphoplasty, systematic review, meta-analyses

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With the rapid growth of the aging population worldwide, there is escalating concern over osteoporosis and related fractures (1). Osteoporotic vertebral compression fractures (OVCFs) have also received increasing attention as one of the most common osteoporosis-related fractures (2). Each year, the United States and Europe report an estimated 0.7 – 1.5 million vertebral compression fractures, a figure projected to rise in line with the growing elderly demographic (3,4).

Notably, while the majority of OVCFs present minimal to no symptoms, about one-third of these fractures necessitate medical intervention (5). Symptomatic OVCFs often lead to persistent back pain, a reduction in vertebral height, vertebral deformities, limited mobility, compromised pulmonary function, and even depression, especially among the elderly (6-8). The detrimental symptoms and high prevalence of OVCFs not only affect the quality of life of individuals, but also bring great challenges to society (9,10).

Currently, OVCFs are primarily treated through conservative measures or surgical interventions (11). The conservative approach involves bed rest, brace fixation, and analgesics for pain management. Although conservative treatment is widely used clinically, it also has drawbacks, such as accelerated bone loss due to prolonged bed rest, gastrointestinal complications due to painkillers, and the inability to correct kyphosis (12-14).

Minimally invasive surgical options, particularly percutaneous vertebroplasty (PVP) and percutaneous balloon kyphoplasty (PKP), have gained attention due to their evident effectiveness for treating OVCFs (12,15,16). Numerous meta-analyses have assessed the efficacy and safety of both PVP and PKP for treating OVCFs. However, the differences between PVP and PKP in clinical effectiveness, radiographic outcomes, and associated surgical complications remain controversial (12,16-31). The inconsistent conclusions drawn from these meta-analyses create uncertainty among clinicians about the best treatment approach for OVCFs.

To resolve this uncertainty, our study evaluates the methodology and reporting quality of overlapping meta-analyses comparing PVP and PKP for treating OVCFs. Our objective was to select the best available evidence, determine the differences between PVP and PKP for treating OVCF, and provide treatment recommendations based on the best available evidence. To accomplish this, we meticulously investigated previously published overlapping meta-analyses on the subject and undertook a cross-sectional analysis of these studies.

Methods

The design of this study is consistent with previously published similar studies and followed the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) statement (32-35).

Search Strategy

We conducted a comprehensive search of the PubMed, Embase, Cochrane library and Web of Science databases to identify pertinent studies. This search was last updated in February 2023. The search keywords were: “compression fracture,” “osteoporotic fracture,” “osteoporotic vertebral compression fracture,” “vertebroplasty,” “kyphoplasty,” “systematic review,” and “meta-analysis”. Two researchers independently sifted through the articles. In cases of disagreements, a third researcher intervened to achieve consensus. To ensure a comprehensive review, we also examined the reference lists of the included articles to identify any additional relevant studies.

Inclusion and Exclusion Criteria

For inclusion in this study, studies had to meet the following criteria: 1) they should involve patients diagnosed with OVCFs; 2) be a meta-analysis written in English; 3) aim to compare PVP and PKP for treating OVCFs; 4) provide at least one variable outcome (e.g., visual analog scale [VAS] scores, Oswestry Disability Index [ODI]) scores, radiological characteristics, or complication rate).

Studies were excluded if they were merely reviews, systematic reviews without a meta-analysis, or lacked sufficient information and methodological descriptions.

The study selection process was performed by 2 researchers working independently. They first assessed titles and abstracts to eliminate clearly unsuitable studies. Subsequently, an in-depth review of the remaining studies was conducted to conclusively determine whether they met the inclusion criteria. Any disagreements between the 2 researchers were settled through consultation with a third investigator.

Data Extraction

Two investigators independently reviewed the full text of the included studies and extracted relevant data. When disagreements arose, consensus was sought between the 2. If a resolution was not achieved, a third investigator was consulted for a final decision. Extracted data covered the first author's surname, publication year, journal name, search databases, language restrictions, date of the last search, included studies, heterogeneity, and meta-analysis results. Meta-analysis results included VAS scores, ODI scores, vertebral height, kyphosis angle, the volume of polymethylmethacrylate (hereafter referred to as bone cement) injected, surgery duration, incidence of bone cement leakage, adjacent vertebral fracture (AVF), and nonadjacent vertebral fracture.

Quality Assessment

As a methodological assessment tool, the Assessment of Multiple Systematic Reviews (original AMSTAR) tool is often used to evaluate the methodological quality of systematic reviews or meta-analyses (36-38). It comprises 11 items, each assigned a score of one, with higher scores denoting superior quality., The Oxford Centre for Evidence-based Medicine Levels of Evidence (39) serve as a hierarchy, offering a streamlined guide for busy clinicians and researchers to source the most probable top-tier evidence. Both methods are widely recognized for their utility in assessing the quality of systematic reviews (33-35). Two investigators independently utilized the Oxford Levels of Evidence and the AMSTAR instrument to assess the methodological quality of the included studies. Any disagreements were discussed until a consensus was reached.

Heterogeneity Assessment

The I^2 statistic quantifies the proportion of total variation attributable to heterogeneity, producing values between 0% and 100%. An I^2 value of 0% signifies no observed heterogeneity, while higher values indicate increasing levels of heterogeneity (40). According to the Cochrane Handbook, for an I^2 less than or equal to 50%, heterogeneity across studies is considered acceptable in a systematic review or meta-analysis (41). If significant heterogeneity was observed among studies for a variable, we documented whether the included meta-analyses investigated its source. Concurrently, we also noted if these studies conducted sensitivity analyses and assessed publication bias.

Application of Jadad Decision Algorithm

The Jadad decision algorithm is a method for determining the best evidence from overlapping meta-analyses (42). The algorithm explores the differences between overlapping meta-analyses through question formulation, search strategy, inclusion and exclusion criteria, inclusion of studies, data extraction, heterogeneity assessment, data synthesis techniques, and trial quality assessment. For our study, 2 investigators independently employed this tool to determine which meta-analysis provided the best evidence. Disagreements were addressed through dialogue until consensus was achieved. For this research, we followed the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) statement (32) to uphold the reporting and methodological quality. Given that all data were sourced from previously published meta-analyses, there was no need for ethical approval or informed patient consent.

Results

Literature Search and Screening

A comprehensive search across the PubMed, Embase, Cochrane library and Web of Science databases yielded 660 articles. After removing duplicates, 312 articles remained. A review of titles and abstracts deemed 289 of these articles irrelevant, leaving 23 for full-text assessment. Upon applying the inclusion and exclusion criteria, 6 articles were excluded because no meta-analysis was performed, resulting in 17 eligible articles being included in this study (12,16-31). The literature search process is illustrated in Fig. 1.

Study Characteristics

Table 1 presents the characteristics of the included meta-analyses. These studies were published from 2011 through 2023. The patient count across these meta-analyses varied from 619 to 3,274. Fifteen of these studies provided data on the sample sizes for patients undergoing PVP and PKP. In total, 9,737 patients underwent PVP and 9,643 underwent PKP. The number of included studies in these meta-analyses ranged from 6 to 32. Altogether, 13 randomized controlled trials (RCTs) were included in these analyses; the details of each RCT from these meta-analyses are itemized in Table 2.

Search Methodology

Of the 17 included meta-analyses, 6 had no language restrictions during their database search (16,18,22,27,29,31), 3 restricted their search to English (19,26,30), 2 narrowed it to English and Chinese (12,25), one limited the search to English and French (17), and the remaining 5 did not specify any language restrictions (20,21,23,24,28). All 17 meta-analyses undertook

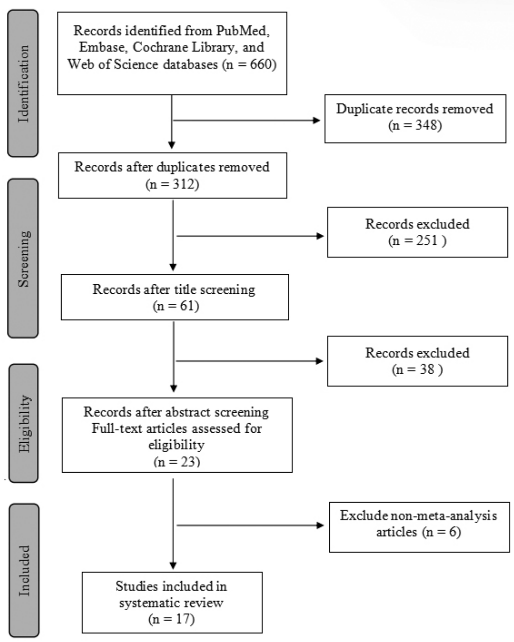

Fig. 1. *Study selection flow chart.*

comprehensive searches for original studies in PubMed. Additionally, 15 of the studies searched the Embase database and 14 searched the Cochrane Library. Other databases, such as Web of Knowledge, Google Scholar, Ovid, and Science Direct, were sporadically utilized. The specific databases employed in the literature searches for each meta-analysis are detailed in Table 3.

Methodological Quality

Methodological quality was assessed for the included 17 meta-analyses. Of them, 2 included only RCTs (19,20), while the others included both RCTs and cohort studies.

Using the Oxford Levels of Evidence for assessment, 2 meta-analyses qualified as Level I evidence (19,20), and the rest met Level II evidence criteria.

Regarding research methodologies among the 17 meta-analyses, 8 stated that they employed the PRISMA guidelines during their research process (17-20,24,26,28,29), one utilized the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) criteria (29). More detailed methodological specifics can be found in Table 4. Table 5 showcases the AMSTAR outcomes of the 17 included meta-analyses. The AMSTAR scores ranged between 4 and 9; 7was the average. Specifically, 3 meta-analyses received a score of 9 (20,28,29), 4 received a score of 8 (22,24,26,30)and another 4 received a score of 7 (17,19,21,31), 3 received a score of 6 (12,23,25), 2 received a score of 5 (27,31), and one received a score of 4 (18).

Heterogeneity Assessment and Publication Bias

Among the 17 meta-analyses, 10 utilized a Funnel plot and Egger's test for identifying publication bias (12,20,22-25,27-30). Additionally, 14 of these meta-analyses employed the I^2 value as a metric to gauge heterogeneity among studies (12,16-21,23,25-30); the specific I^2 values for each are detailed in Table 6. The majority of these 14 meta-analyses exhibited high heterogeneity ($I^2 > 50\%$). Moreover, 10 of the meta-analyses conducted a sensitivity analysis to determine if altering assumptions would lead to qualitative changes in the results (16,18,20,22,24-26,28-30).

Jadad Decision Algorithm Results

The consolidated findings from all included meta-analyses are depicted in Fig 2. Two researchers worked independently, utilizing the Jadad decision algorithm, to determine which of the included meta-analyses offered the best evidence for guiding treatment recommendations for patients with OVCFs. According to the Oxford Levels of Evidence (38), Zarza, et al (19) and Zhu, et al (20) strictly included only RCT studies, leading to their classification as level I evidence. Notably, the AMSTAR scores of Ma, et al (29), Xing, et al (28), and Zhu, et al (20) ranked the highest among all studies. Therefore, when applying the Jadad decision algorithm, we selected the meta-analysis of Zhu, et al (20) as the best evidence.

Discussion

With the aged population increasing, treating OVCFs has garnered significant attention. Both PVP and PKP have become widely adopted clinical interventions for OVCFs.

Through an exhaustive search and rigorous screening process, the present study identified 17 overlapping meta-analyses comparing the differences between PVP and PKP for treating OVCFs. However, we found that the conclusions of these meta-analyses varied widely, and some were even contradictory. For example, 11 meta-analyses reported that PKP effectively reduce bone cement leakage (12,16,17,20,23,24,26-29,31); 3 meta-analyses found no significant difference in bone cement leakage between the 2 techniques (18,19,30); and one reported that PVP holds a distinct advantage

Table 1. *Included meta-analyses characteristics.*

Study, Year	Journal	Date of Last Literature Search	Search Language	Date of Publication	Number of included studies	Number of Included RCTs	Number of patients	Number of PVPs	Number of PKPs
Han S 2011 (30)	International Orthopaedics	Oct, 2010	English	Jun, 2011	8	1	848	NR	NR
Ma X 2012 (29)	European Spine Journal	Mar, 2012	No restrictions	Jul, 2012	12	1	1081	455	626
Xing D 2013 (28)	Journal of Clinical Neuroscience	May, 2012	NR	Feb, 2013	10	1	783	317	466
Yang H 2013 (27)	International Journal of Spine Surgery	Sep, 2012	No restrictions	Dec, 2013	15	1	1151	627	524
Chang X 2014 (25)	International Orthopaedics	Jul, 2014	English and Chinese	Sep, 2014	20	6	1429	732	697
Xiao H 2014 (16)	European Journal of Orthopaedic Surgery and Traumatology	Apr, 2014	No restrictions	Jul, 2014	19	2	1787	887	900
Wang H 2015 (26)	Pain Physician	Apr, 2014	English	2015	8	1	836	440	396
Gu C 2015 (23)	Journal of Neurointerventional Surgery	Nov, 2014	NR	May, 2015	29	3	2838	1454	1384
Liang L 2016 (31)	Annals of Saudi Medicine	Aug, 2015	No restrictions	2016	32	4	3274	1621	1653
Zhao D 2016 (22)	American Journal of Therapeutics	NR	No restrictions	2016	10	1	821	444	377
Zhao G 2016 (24)	Osteoporosis International	NR	NR	Apr, 2016	11	1	869	411	458
Chen C 2017 (21)	Orthopade	Oct, 2016	NR	Aug, 2017	10	3	902	NR	NR
Wang B 2018 (12)	Journal of Orthopaedic Surgery and Research	Jan, 2018	English and Chinese	Oct, 2018	14	1	1432	785	647
Zhu Y 2019 (20)	Medicine (Baltimore)	Aug, 2019	NR	Nov, 2019	7	7	877	440	437
Zarza W 2022 (19)	Coluna/ Columna	Mar, 2019	English	2022	7	7	919	450	469
Zhu H 2022 (18)	Alternative Therapies in Health and Medicine	Apr, 2022	No restrictions	Jul, 2022	6	1	664	380	284
Daher M 2023 (17)	World Neurosurgery	Jun, 2022	English and French	Mar, 2023	8	2	619	294	325

NR, not reported

in minimizing this complication (25). Meta-analyses are widely regarded as the pinnacle of statistical evidence to guide clinical decision making (43). The disparate conclusions from overlapping meta-analyses on the same topic may have a negative effect on guiding clinical decision making (44). Such conflicting findings undoubtedly perplex clinicians, hindering the establishment of a standardized therapeutic protocol.

Fortunately, Jadad, et al (42) developed a method to address the challenge posed by conflicting conclusions drawn from overlapping meta-analyses on the same topic. They developed a decision algorithm for clinical practice that identifies the most reliable evidence among conflicting systematic reviews or meta-analyses. Our study aimed to conduct a cross-sectional analysis of overlapping meta-analyses comparing PVP with PKP for treating OVCFs. The goal was to determine which meta-analysis provides the most credible

Table 2. *The primary RCTs included in each meta-analysis.*

Study, Year	Liu 2010	Kumar 2010	Endres 2012	Volg 2013	Omidi 2013	Dohm 2014	Yang 2014	Wang 2015	Liu 2015	Zhou 2015	Li 2015	Evans 2016	Chang 2020
Han S 2011 (30)	+												
Ma X 2012 (29)	+												
Xing D 2013 (28)	+												
Yang H 2013 (27)	+												
Chang X 2014 (25)	+		+	+	+								
Xiao H 2014 (16)	+			+									
Wang H 2015 (26)	+												
Gu C 2015 (23)	+					+						+	
Liang L 2016 (31)	+		+			+	+						
Zhao D 2016 (22)		+											
Zhao G 2016 (24)	+												
Chen C 2017 (21)	+							+				+	
Wang B 2018 (12)	+												
Zhu Y 2019 (20)	+		+			+			+	+	+	+	
Zarza W 2022 (19)	+		+	+	+	+		+	+				
Zhu H 2022 (18)													+
Daher M 2023 (17)	+			+									

Table 3. *The databases searched by each meta-analysis.*

Study, Year	PubMed	Embase	Cochrane Library	Web of Knowledge	Ovid	Science Direct	Google Scholar	EBSCO	Scopus	Springer Link	Others
Han S 2011 (30)	+			+	+						
Ma X 2012 (29)	+	+	+		+	+	+				+
Xing D 2013 (28)	+	+	+		+	+					+
Yang H 2013 (27)	+	+	+	+		+		+	+	+	+
Chang X 2014 (25)	+	+	+	+							+
Xiao H 2014 (16)	+	+	+	+		+		+		+	
Wang H 2015 (26)	+	+	+	+	+	+	+				+
Gu C 2015 (23)	+	+		+							+
Liang L 2016 (31)	+	+	+								
Zhao D 2016 (22)	+	+	+	+							+
Zhao G 2016 (24)	+	+	+								+
Chen C 2017 (21)	+	+									+
Wang B 2018 (12)	+	+	+								+
Zhu Y 2019 (20)	+	+	+								
Zarza W 2022 (19)	+	+	+								+
Zhu H 2022 (18)	+	+	+								+
Daher M 2023 (17)	+		+				+				+

Table 4. *The methodological information of the meta-analyses.*

Study,Year	Design of included studies	Level of Evidence	Solfware	Heterogeneity	GRADE Use	Sensitivity Analysis	Publication Bias	PRISMA Use
Han S 2011 (30)	RCT and cohort study	Level II	STATA 11.0	Yes	No	Yes	Yes	No
Ma X 2012 (29)	RCT and cohort study	Level II	RevMan 5.1	Yes	Yes	Yes	Yes	Yes
Xing D 2013 (28)	RCT and cohort study	Level II	RevMan 5.1	Yes	No	Yes	Yes	Yes
Yang H 2013 (27)	RCT and cohort study	Level II	RevMan 5.0	Yes	No	No	Yes	No
Chang X 2014 (25)	RCT and cohort study	Level II	RevMan 5.2	Yes	No	Yes	Yes	No
Xiao H 2014 (16)	RCT and cohort study	Level II	RevMan 5.0	Yes	No	Yes	No	No
Wang H 2015 (26)	RCT and cohort study	Level II	RevMan 5.1	Yes	No	Yes	No	Yes
Gu C 2015 (23)	RCT and cohort study	Level II	Comprehensive Meta-analysis V.2.2	Yes	No	No	Yes	No
Liang L 2016 (31)	RCT and cohort study	Level II	STATA 12.0	Yes	No	No	No	No
Zhao D 2016 (22)	RCT and cohort study	Level II	STATA 12.0	Yes	No	Yes	Yes	No
Zhao G 2016 (24)	RCT and cohort study	Level II	STATA 10.0	Yes	No	Yes	Yes	Yes
Chen C 2017 (21)	RCT and cohort study	Level II	RevMan 5.2	Yes	No	No	No	No
Wang B 2018 (12)	RCT and cohort study	Level II	STATA 10.0	Yes	No	No	Yes	No
Zhu Y 2019 (20)	RCT	Level I	RevMan 5.3	Yes	No	Yes	Yes	Yes
Zarza W 2022 (19)	RCT	Level I	R 3.5.1	Yes	No	No	No	Yes
Zhu H 2022 (18)	RCT and cohort study	Level II	RevMan 5.3	Yes	No	Yes	No	Yes
Daher M 2023 (17)	RCT and cohort study	Level II	RevMan 5.4	Yes	No	No	No	Yes

evidence and to formulate treatment recommendations based on this evidence.

Jadad, et al (42) identified multiple factors contributing to discordance among meta-analyses. These factors include formulating the clinical question, the criteria for selecting and including studies, data extraction techniques, study quality assessment, and evaluating the potential for combining studies and the statistical approaches used in data synthesis. Currently, this algorithm has been widely used to determine the best evidence in overlapping meta-analyses of inconsistent conclusions (45-47).

In our present study, the algorithm was applied to 17 included meta-analyses. The meta-analyses conducted by Zarza, et al (19) and Zhu, et al (20), which exclusively incorporated RCTs, were both assigned a Level I rating according to the Oxford Levels of Evidence (38). Moreover, the studies by Ma, et al (29), Xing, et al (28), and Zhu, et al (20) achieved the highest scores on the AMSTAR scale. Ultimately, the Jadad decision tool led to the selection of Zhu et, al (20) as the highest quality meta-analysis for comparing PVP with PKP for treating OVCFs. This distinction is due to its stringent selection of primary trials and the overall methodological excellence of the meta-analysis.

To the best of our knowledge, our study represents the first cross-sectional analysis of overlapping meta-analyses comparing PVP with PKP for treating OVCFs. Drawing from the findings of Zhu, et al (20), we concluded that PKP offers a reduced rate of bone cement leakage compared to PVP. However, when assessing pain alleviation and functional recuperation, no discernible differences were observed between the 2 techniques.

Patients with OVCFs commonly experience persistent dorsal pain and reduced mobility, often leading them to consider surgical interventions (48). In the included 17 meta-analyses, a significant majority of these used VAS and ODI scores to evaluate pain relief and improvement in lumbar function pre- and posttreatment. It is encouraging to note that there was a unanimous consensus from these meta-analyses that both PVP and PKP substantially reduce pain and improve lumbar functionality in patients with OVCF. While there's ongoing contention about PKP's superiority over PVP in terms of pain reduction and functional improvement, both immediate and extended follow-up results consistently highlight PKP's ability to either match or surpass PVP in relieving pain and elevating function in patients with OVCF.

Table 5. *The AMSTAR score of each meta-analysis.*

Items	Han S 2011 (30)	Ma X 2012 (29)	Xing D 2013 (28)	Yang H 2013 (27)	Chang X 2014 (25)	Xiao H 2014 (16)	Wang H 2015 (26)	Gu C 2015 (23)	Liang L 2016 (31)	Zhao D 2016 (22)	Zhao G 2016 (24)	Chen C 2017 (21)	Wang B 2018 (12)	Zhu Y 2019 (20)	Zarza W 2022 (19)	Zhu H 2022 (18)	Daher M 2023 (17)
1. Was an a priori design provided?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Was there duplicate study selection and data extraction?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3. Was a comprehensive literature search performed?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4. Was the status of publication (i.e., grey literature) used as an inclusion criterion?	0	1	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0
5. Was a list of studies (included and excluded) provided?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6. Were the characteristics of the included studies provided?	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
7. Was the scientific quality of the included studies assessed and documented?	1	1	1	0	1	1	1	0	0	1	1	1	0	1	1	0	1
8. Was the scientific quality of the included studies used appropriately in formulating conclusions?	1	1	1	0	1	1	1	0	0	1	1	1	0	1	1	0	1
9. Were the methods used to combine the findings of studies appropriate?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10. Was the likelihood of publication bias assessed?	1	1	1	1	1	0	0	1	0	1	1	0	1	1	0	0	0
11. Was the conflict of interest stated?	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	0	1
Total scores	8	9	9	5	6	7	8	6	5	8	8	7	6	9	7	4	7

While Zhu, et al (20) did not evaluate the radiographic outcomes of PVP and PKP treatments for OVCFs, other meta-analyses indicate a marked advantage for PKP in restoring vertebral height. Six meta-analyses consistently demonstrated that PKP was superior to PVP in improving vertebral kyphosis (12,23,24,26,27,31). Contrarily, Daher, et al (17) reported no significant difference between the 2 methods in terms of improving vertebral kyphotic angles. Disparities in these findings may be influenced by a variety of factors. They include endplate subsidence, varying bone cement types or volumes, inconsistent measurement methodologies, and human errors in measurement (29). It is also worth noting that some scholars believe that correcting kyphosis largely depends on the natural healing of the fracture rather than on the treatment itself (49).

Postoperative complications following PVP and PKP are hotly discussed and debated, particularly regarding issues surrounding bone cement leakage and adjacent vertebral fractures. Bone cement leakage remains a prevalent complication in cement-augmentation techniques (50,51). Although many instances of bone cement leakage are asymptomatic, there are scenarios where it precipitates severe consequences, such as pulmonary embolism and cardiovascular blockages (52). Moreover, when bone cement intrudes into the intervertebral or spinal canal spaces, it can compress neural tissues, potentially causing significant nerve damage (53).

The meta-analysis conducted by Zhu, et al (20) reported a lower risk of bone cement leakage with PKP compared to PVP. This reduced risk may be attributed to the creation of cavities by balloon expansion during the cementing phase, which allows for the injection of denser bone cement at lower pressures. Conversely, PVP often requires higher injection pressures and a less viscous bone cement, thereby increasing the likelihood of leakage through fractures and vasculature (54). Additionally, the volume of bone cement and the integrity of the vertebral cortex also are crucial factors influencing leakage (52). Consequently, thorough preoperative computed tomography scans, vigilant intraoperative imaging monitoring, skilled surgical techniques, and accurate bone cement volume calibration are essential to minimize leakage risk (55).

Table 6. *The I^2 statistic value of every outcome effect in the meta-analyses.*

Items	Han S 2011 (30)	Ma X 2012 (29)	Xing D 2013 (28)	Yang H 2013 (27)	Chang X 2014 (25)	Xiao H 2014 (16)	Wang H 2015 (26)	Gu C 2015 (23)	Liang L 2016 (31)	Zhao D 2016 (22)	Zhao G 2016 (24)	Chen C 2017 (21)	Wang B 2018 (12)	Zhu Y 2019 (20)	Zarza W 2022 (19)	Zhu H 2022 (18)	Daher M 2023 (17)
Short-term VAS	94%	97%	94%	94%	91%		95%	NR	NR		NR	65%	NR		NR		
Middle-term VAS	NR			98%								48%	NR				
Long-term VAS	NR	98%	98%	93%	78%		51%	NR	NR		NR	0%	81%	35%	0%	36%	97%
Short-term ODI	NR	90%	90%	NR	94%		34%	NR	NR	NR	NR		NR		NR		
Middle-term ODI	83%			NR									NR				
Long-term ODI	NR	97%	94%	NR	86%		0%	NR	NR		NR		21%	84%	79%	50%	88%
Short-term SF-36							0%			NR					NR		
Middle-term SF-36																	
Long-term SF-36							0%								92%		
Surgery time			88%	NR	48%		87%	NR	NR		NR						
Cement volume				NR	88%		83%	NR	NR							97%	
Short-term kyphosis angle		NR	87%	71%	90%		72%		NR								
Long-term kyphosis angle		NR	74%		77%		0%		NR								
Kyphosis angle improvement				61%			96%	82%	NR		NR		93%				99%
Short-term anterior vertebral height				10%	95%				NR						NR		
Long-term anterior vertebral height									NR						0%		
Vertebral height restoration		NR	96%	89%				97%	NR		NR		92%				99%
Adjacent vertebral fracture	19%	2%	0%	0%	0%	0%	7%	NR	NR		NR						0%
Non-adjacent vertebral fracture						0%		NR	NR								
Polymethylmethacrylate leakage	39%	17%	0%	24%	23%	45%	43%	NR	NR		NR		39%	24%	85%	61%	36%

VAS, Visual Analog Scale; ODI, Oswestry Disability Index; SF-36, Short Form Health Survey

The precise mechanisms underlying AVFs remain a subject of ongoing debate. Berlemann, et al (56) suggested that injecting bone cement may exert excessive stress on adjacent vertebrae, potentially increasing the risk of subsequent vertebral fractures. In comparison, the research conducted by Farrokhi, et al (57) indicated that individuals receiving conservative treatment exhibited a higher incidence of adjacent vertebral fractures compared to those undergoing PVP. In our study, each meta-analysis examining AVFs consistently found no statistically significant difference in the incidence of adjacent vertebral compression between PVP and PKP. The similar incidence of AVFs between PVP and PKP is not unexpected, given that both are vertebral augmentation techniques and that they share a common fundamental mechanism. Additionally, Baek, et al (58) reported that the most significant factors influencing AVFs were the degree of osteoporosis and the biomechanical alterations in the entire spine postfracture.

There are some limitations to our study. First, being an analysis of published overlapping meta-analyses, it confines our insights to the meta-analysis level. Second, the restriction to English-language literature may have introduced a selection bias. Finally, including numerous nonrandomized controlled studies in the meta-analyses could potentially diminish the overall quality of evidence.

Conclusion

This cross-sectional analysis of overlapping meta-

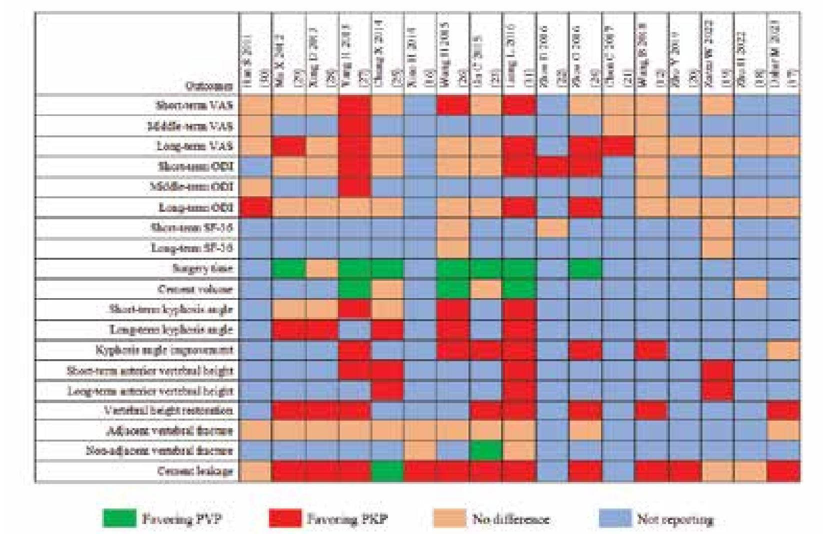

Fig. 2. *Included meta-analyses results.*

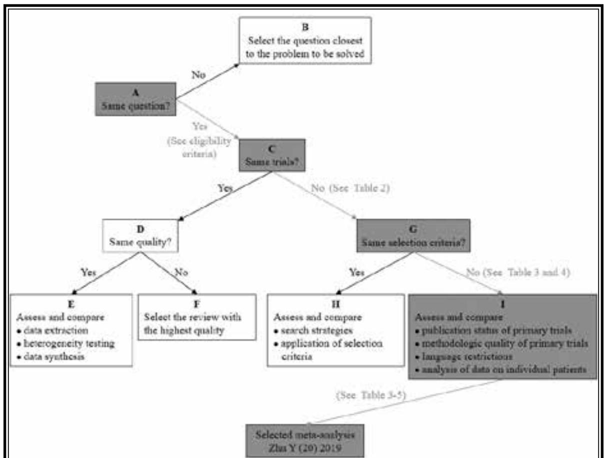

Fig. 3. *Jadad algorithm procedure in the study.*

analyses has determined that the Zhu, et al meta-analysis (20) provides the best available evidence for comparing PVP and PKP for OVCFs. The results of this meta-analysis suggest that PVP and PKP are equally effective in alleviating pain and enhancing functionality, but PKP had a lower incidence of bone cement leakage. However, there is still a need for high-quality RCTs to provide higher levels of evidence regarding other aspects of the differences between these 2 procedures.

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