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SuperPATH versus traditional hip replacement in efficacy and safety: an updated systematic review and meta-analysis

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Abstract

Background Hip replacement is a popular orthopedic surgery. The methods include SuperPATH and traditional hip replacement. The efficacy and safety of SuperPATH vs. traditional hip replacement might be an intriguing topic.

Methods The SuperPATH vs. traditional hip replacement comparison for the operation characteristics, hospitalization duration, postoperative pain and hip scores were set for the current systematic review and meta-analysis, which can help us determine the differences in the operation characteristics, hospitalization duration, postoperative pain severity and postoperative hip function between the 2 groups. Only randomized controlled trials (RCT) were eligible and 9 RCTs (299 patients with the superPATH, and 379 patients with traditional hip replacement) were enrolled. We focused on the operation characteristics, hospitalization duration, pain, and hip function after orthopedic surgery.

Results The meta-analytic results showed that SuperPATH might be associated with a significantly shorter incision length and hospitalization duration. In addition, the postoperative pain severity was lower and the postoperative hip function was better in the SuperPATH group when compared to traditional hip replacement.

Conclusions The SuperPATH might be beneficial for patients with hip replacement surgery when compared to the traditional hip replacement from the perspective of incision length, hospitalization, pain severity, and hip function. Further RCT studies with a more homogeneous study design and a greater sample size might be warranted in the future.

Keywords Hip replacement, SuperPATH, Incision length, Hospitalization duration, Postoperative pain severity, Postoperative hip function

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Today's world is facing the issue of aging population, which might be associated the increasing incidence and prevalence of hip joint problems [1, 2]. When the clinicians managed the aging hip joint, the hip arthroplasty will be an important option to treat the arthritis or fracture of hip joint. Within the multiple modalities of hip arthroplasty, the minimally invasive approach and traditional hip replacement surgery will be the major categories. In recent years, the orthopedic clinicians spend a lot of efforts to advance the skill and technique of minimally invasive and small-incision hip arthroplasty [1, 3, 4] to treat the inevitable of degenerative hip joint pathology in a world of the increasing aging population. However, the superior advantages of minimally invasive hip arthroplasty surgery are still inconclusive due to the inconsistent results of previous meta-analysis [5–7].

Among the minimally invasive hip arthroplasty approaches, a kind of new and promising approach, supercapsular percutaneously assisted approach in total hip

arthroplasty (SuperPATH), has been applied in the treatment of hip joint diseases in recent years [8]. The previous case series reported that SuperPATH approach is simple in operation with a short incision length and less trauma. In addition, the shorter hospitalization days with lower hospitalization costs, and better hip joint function has been mentioned [9]. The later randomized clinical trial (RCT) also demonstrated the decreased of hospitalization length, recovering time, and pain intensity of this approach when compared to traditional hip replacement surgery [10]. It suggested that the SuperPATH approach might provide the additional benefits when compared to the traditional approach. Several previous meta-analyses compared SuperPATH approach to traditional approach and showed the benefits of SuperPATH approach for the shorter incision length, less early pain intensity [11], less intraoperative blood loss, better hip function scores [12], the accelerated functional recovery, and less surgical trauma [13]. However, Ramadanov et al.'s [11, 12] and Zhao et al.'s [13] meta-analyses included the RCTs not reported in the international scientific journals and might have ethnic bias due to the fact that the included RCTs were almost all from China. Therefore, the current meta-analysis aimed to include the RCTs published in the international scientific journals from Western and Eastern Hemispheres to delineate the potential differences between SuperPATH and conventional approaches in efficacy and safety.

In the current systematic review and meta-analysis, we focused on the RCTs with the study design to compare the SuperPATH approach with traditional hip replacement. According to the above literature, we hypothesized that the SuperPATH approach might be superior to the traditional approach in several dimensions, such

as the operation characteristics, hospitalization duration, postoperative pain intensity, and postoperative hip joint function.

Methods

Search and selection keywords

The following keywords were used: “SuperPATH”, “supercapsular percutaneously-assisted total hip”, “hip” or “replacement” or “arthroplasty” or “care” or “intervention” or “postoperative” or “pain” or “hip joint function”, “orthopedic” or “randomized” or “clinical” or “trials” or “patients” or “surgery” or “bone”, “comparison” or “versus” to search and collect the related articles in the ScienceDirect, PubMed, Web of Science, Goggle Scholar, EmBase, and the Cochrane Central Register of Controlled Trials (CENTRAL). The search and selection were focused on the publications before April 2024.

The inclusion criteria of this study were: (1) The SuperPATH vs. traditional hip replacement study design (2) The studies involved with operation characteristics, hospitalization duration, postoperative pain scores, and postoperative hip joint function scores. (3) English language publications in the journals of science citation index database. (4) RCT. The exclusion criteria were: (1) No postoperative data, such as the postoperative pain and hip function scores (2) The studies without the research design with the comparisons between SuperPATH and traditional hip replacement for the patients receiving orthopedic surgery. (3) The articles were not RCTs, such as the observation study, retrospective study, chart review, case report, case series, cohort study, or review articles.

Risk of bias assessment and data extraction

The risk of bias assessment of the included RCT was assessed as ‘low’, ‘uncertain’, or ‘high’ risk of bias according to the Cochrane Collaboration Revised Risk of Bias tool for RCT (RoB 2.0, version 22 August 2019). Blinding of participants was impossible for surgical interventions, and the blinding step was not considered. The meta-analysis was performed based on the Cochrane Handbook method. The results were reported based on the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines [14].

The following data were extracted from the eligible studies: First, the operation characteristics for the SuperPATH and traditional hip replacement groups in each eligible study. Second, the hospitalization duration for the SuperPATH and traditional hip replacement groups of each eligible study. Third, the postoperative pain severity scores for the SuperPATH and traditional hip replacement groups of each eligible study. Fourth, the postoperative hip joint function scores for the SuperPATH and traditional hip replacement groups of each

eligible study. Fifth, the total patient number in each kind of hip replacement surgery.

The statistics in the meta-analysis step

We used Reviewer Manager version 5.4 (Cochrane, <https://training.cochrane.org/online-learning/core-software>) to perform the meta-analysis step. The SuperPATH group and traditional approach group were compared to determine if SuperPATH treatment can be with the better operation characteristics and hospitalization duration. In addition, the relief of postoperative pain and the improvement of postoperative hip function would be focused. The mean, standard deviation, and group sample size of SuperPATH approach group and traditional approach group of each included RCT were input in the Reviewer Manager file. The overall effect size from the mean and standard deviation of operation characteristics, hospitalization duration, postoperative pain severity scores, and postoperative hip function scores was calculated as the weighted average of the inverse variance for the study-specific estimates. The weighted standardized mean difference was used to estimate numerical variables for the continuous variables due to the variability and heterogeneity of operation characteristics, hospitalization duration, postoperative pain severity scores, and postoperative hip function scores. The synthesized results were obtained by pooling the data and using a random effects model meta-analysis. The forest plot was used to demonstrate the meta-analysis would favor SuperPATH approach or traditional approach for the better operation characteristics, a shorter hospitalization duration, less postoperative pain, and better postoperative hip function. We applied the χ^2 [2] distribution test, Higgins I [2] index, Cochran's Q, and Tau square test to estimate the heterogeneity. The exact heterogeneity estimator in the Reviewer Manager version 5.4 was the DerSimonian-Laird estimator. At last, the test for overall effect was calculated to produce the Z value and the significance of *p*-value was also produced.

Results

The included studies and the selection process

The selection process for enrolled studies has been presented in Fig. 1. The final nine studies entered the qualitative and quantitative synthesis [10, 15–22]. The risk of bias was also evaluated (Fig. 2). The publication bias of Egger's test was not significant ($P=0.427$).

SuperPATH vs. traditional hip replacement: operation characteristics

In the random effects model of operation characteristics, the differences of operation time, intraoperative blood loss, and postoperative hemoglobin were not statistically significant. The only significant operation

characteristic was the incision length. The standardized mean difference of the incision length of the included 9 studies of SuperPATH vs. traditional hip replacement was -5.78 cm [95% confidence interval (CI): $-7.84 \sim -3.73$, $Z=5.52$, $P<0.00001$], which suggested significantly shorter incision length in the SuperPATH group. However, a substantial heterogeneity was noted (Fig. 3).

SuperPATH vs. traditional hip replacement: hospitalization duration

In the random effects model, the standardized mean difference of the hospitalization duration of SuperPATH vs. traditional hip replacement was -0.97 day [95% confidence interval (CI): $-1.67 \sim -0.27$, $Z=2.73$, $P=0.006$], which suggested significantly a shorter hospitalization duration in the SuperPATH group. However, a substantial heterogeneity was noted (Fig. 4).

SuperPATH vs. traditional hip replacement: postoperative pain severity

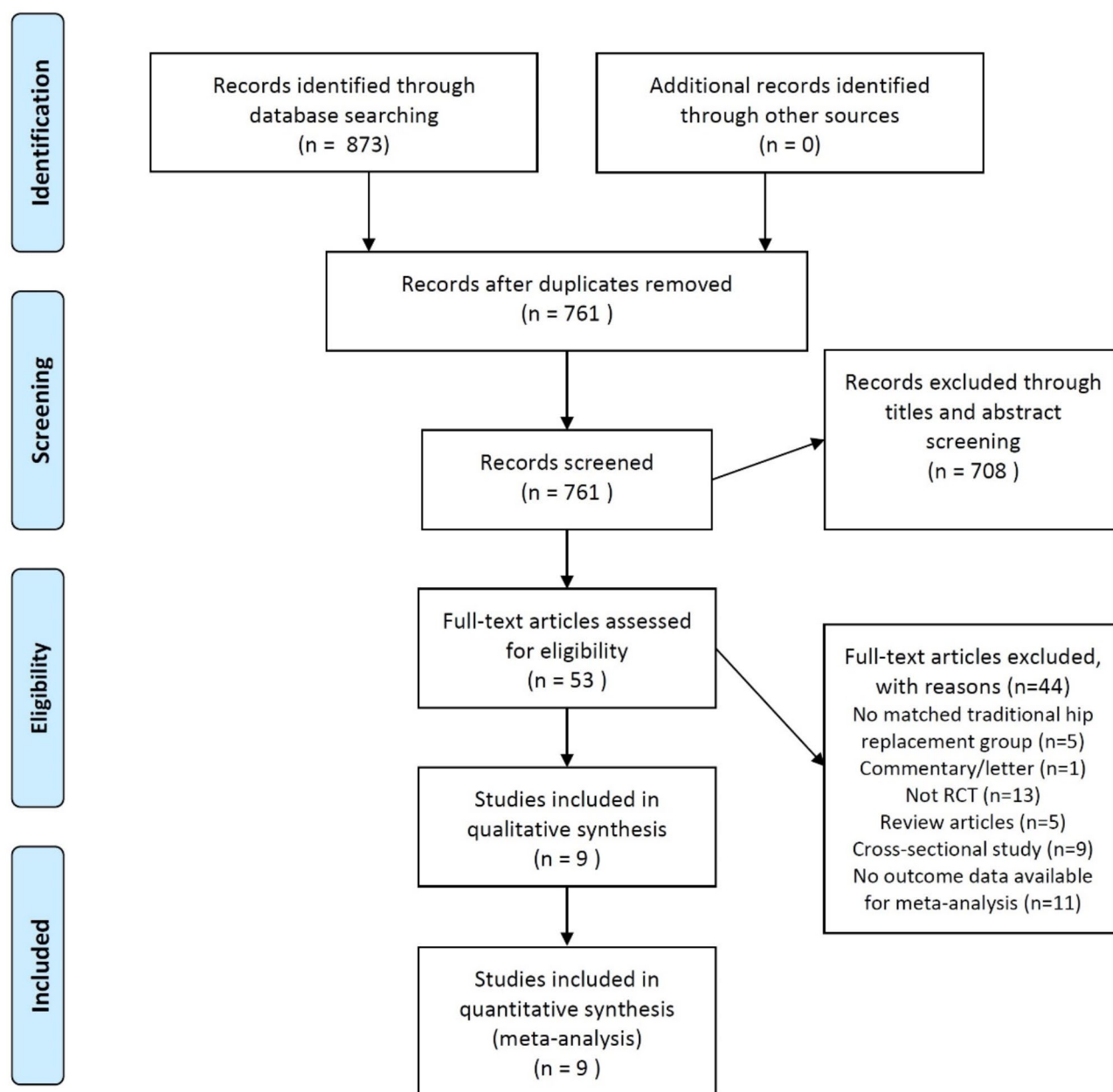
In the random effects model, the standardized mean difference of the 3-month postoperative pain scores of SuperPATH vs. traditional hip replacement was -0.28 [95% confidence interval (CI): $-0.51 \sim -0.06$, $Z=2.50$, $P=0.01$], which suggested significantly lower 3-month postoperative pain severity in the SuperPATH treatment group. However, a moderate heterogeneity was noted (Fig. 5).

SuperPATH vs. traditional hip replacement: postoperative hip joint function

In the random effects model, the standardized mean difference of 1-month postoperative hip joint function scores of SuperPATH vs. traditional hip replacement was 1.29 [95% confidence interval (CI): $0.19 \sim 2.38$, $Z=2.30$, $P=0.02$], which suggested significantly better postoperative hip joint function in SuperPATH group. However, a substantial heterogeneity was noted (Fig. 6).

Discussion

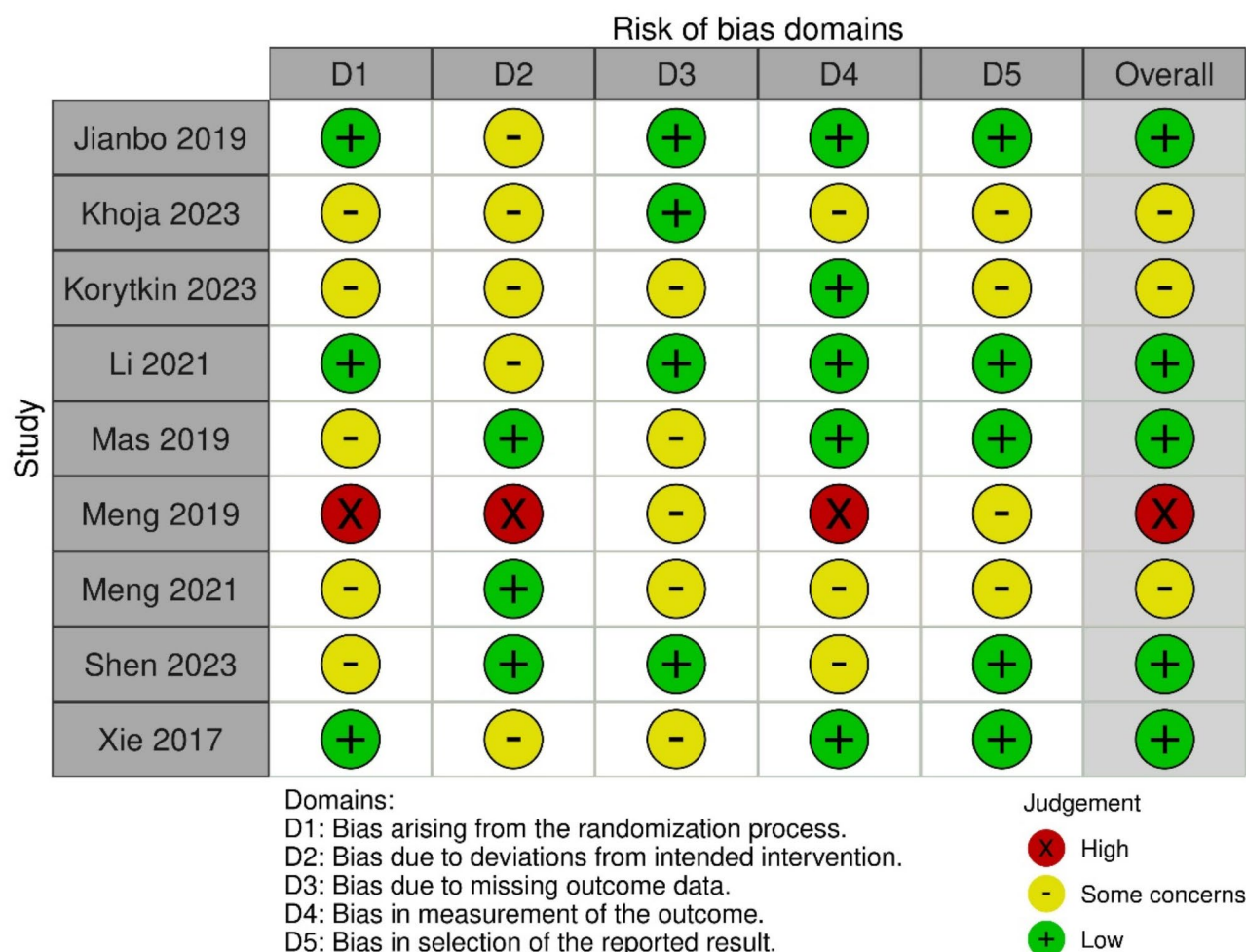
In the current meta-analysis of RCTs, the authors demonstrated that SuperPATH might be superior to the traditional hip replacement in several dimensions. In the operation characteristics, the shorter incision length seemed to be the crucial characteristic of SuperPATH surgery. In spite of the non-significant differences in the operation time, intraoperative blood loss, and postoperative hemoglobin, SuperPATH approach might offer the advantage of a shorter incision length, which might be an important concern for the cosmetic issue. In addition, the decreased duration of hospitalization might be another advantage of SuperPATH surgery when compared to the traditional hip replacement. The shorter hospitalization duration might accompany with other advantages, such

**Fig. 1** The PRISMA flowchart of our meta-analysis

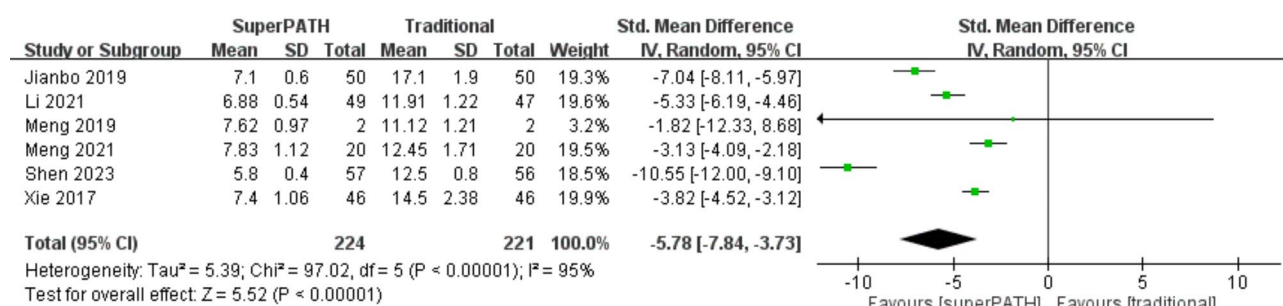
The selection, exclusion, qualitative, and quantitative analysis of enrolled RCTs

as the less hospitalization expenses or less risk of hospitalization infection. For the elderly patients, the shortening of hospitalization duration would be a significant point to consider due to the less risk of hospitalization infection. The shorter incision length and hospitalization duration might represent the superiority of SuperPATH approach in safety when compared to the traditional hip replacement. For the efficacy, the postoperative pain severity and hip joint function would be the significant focus. SuperPATH approach seemed to provide the advantage of decreased pain severity even at 3 months

after surgery. In addition, the postoperative hip joint function seemed to be more improved at one month after SuperPATH surgery. The advantages of postoperative pain severity and hip joint function might represent the superiority of SuperPATH approach in the efficacy of hip replacement surgery. The results suggested the long-term efficacy of SuperPATH approach in the dimensions of postoperative pain and hip joint function. However, the substantial heterogeneity should be considered in current meta-analysis results. The clinical heterogeneity, methodological, and statistical heterogeneity might contribute

**Fig. 2** Bias risk assessment

The risk of bias assessment version 2 (ROB v2) was used to report the assessment of bias risk

**Fig. 3** The forest plot for the incision length [SuperPATH vs. traditional hip replacement]

The SuperPATH was with a shorter incision length when compared to traditional hip replacement

to the substantial heterogeneity. The clinical heterogeneity might include the variations in SuperPATH approach, traditional hip replacement, patient populations, and outcome measurements. The methodological heterogeneity might include the variations of study design and risk of bias. The statistical heterogeneity might include the variability in the intervention effects being evaluated

in the different studies. The risk of bias has been evaluated and no significant risk of bias was observed in the included studies. Therefore, the issues of clinical heterogeneity and statistical heterogeneity should be considered in the current meta-analysis. Compared to the previous meta-analyses, our results replicated the findings of Ramadanov et al.'s meta-analyses, such as shorter incision

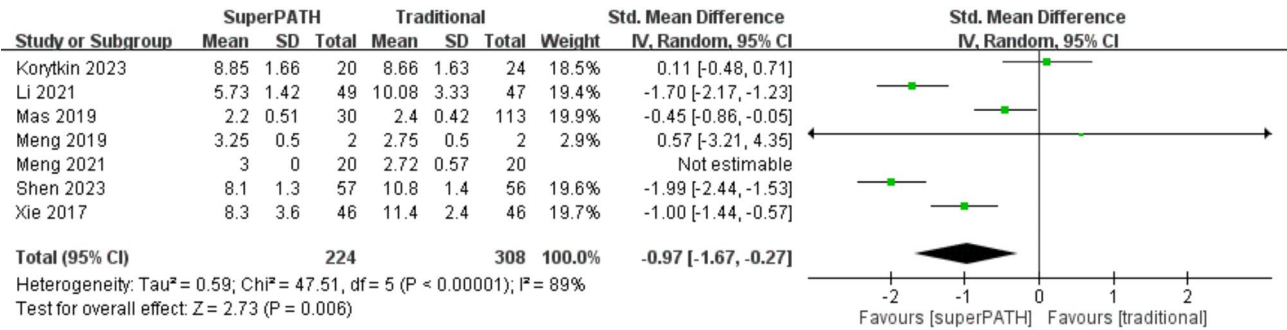


Fig. 4 The forest plot for the hospitalization duration [SuperPATH vs. traditional hip replacement]
The SuperPATH was with a shorter hospitalization duration when compared to traditional hip replacement

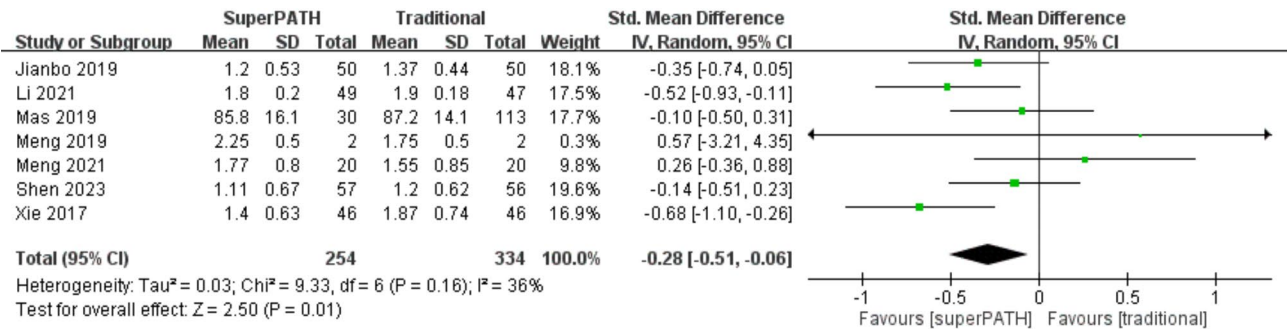


Fig. 5 The forest plot for the postoperative pain [SuperPATH vs. traditional hip replacement]
The SuperPATH was with the decreased 3-month postoperative pain severity when compared to traditional hip replacement

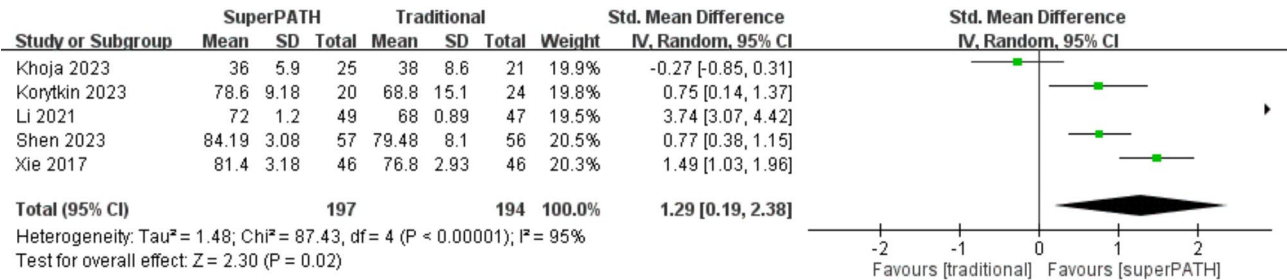


Fig. 6 The forest plot for the postoperative hip function [SuperPATH vs. traditional hip replacement]
The SuperPATH was with the improved postoperative hip function after 1 month when compared to traditional hip replacement

length, less postoperative pain intensity, and better hip function scores [11, 12]. In addition, our results indicated the potential benefit to decrease the hospitalization duration. However, our results failed to replicate the findings of Zhao et al's meta-analysis [13].

For the incision length, our meta-analysis replicated the results of the previous meta-analysis [6]. We also observed the similar phenomenon of a shorter incision length in the SuperPATH approaches when compared to traditional approach. In addition, the incision length is shorter in our meta-analysis, which might suggest that the improved method, skill or technique of SuperPATH approach in the recent years. For hospitalization duration, our results showed a near one day shorter of SuperPATH approach when compared to traditional hip

replacement. Our result was similar with the result of the previous meta-analysis focused on the minimally-invasive hip arthroplasty [7]. However, the recent meta-analysis failed to find the advantage of a shorter hospitalization duration in the SuperPATH approach [6].

The previous meta-analysis failed to find the significant difference of hip joint function scores between minimally invasive surgery and standard open surgery of hip arthroplasty [7]. In addition, the recent meta-analysis including most not-science citation index studies found a short-term effects for hip joint function of SuperPATH approach within 7 days and no significant long-term effects were observed [6]. In addition, another recent network meta-analysis study supported the potential benefit for the hip joint function by the SuperPATH approach

[23]. Our meta-analysis study proved the potentially long-term benefits of SuperPATH approach for the patients after hip arthroplasty to obtain the better profile of hip joint function. For the postoperative pain severity, our meta-analysis found the pain-relief effects might be persistent till 3 months after SuperPATH approach when compared to traditional hip replacement. However, previous meta-analytic studies [6, 7] failed to the short-term and long-term effects of pain relief for the SuperPATH approach.

Apart from surgical incision length, hospital stay duration, postoperative pain scores, and functional outcomes, another crucial factor of efficacy and safety is dislocation rate. Most included RCTs in the current meta-analysis didn't mention the dislocation rate, except Más Martínez et al. 2019 [19], Meng et al. 2019 [21], and Shen et al. 2023 [22], which mentioned no dislocation in both SuperPATH and traditional approach groups. The only RCT mentioned dislocation is Xie et al. 2017 [10], which mentioned a higher dislocation rate of traditional approach versus SuperPATH (4.3% vs. 2.2%). Other advanced approaches, such as piriformis-sparing approach, showed a lower risk of dislocation and mortality when compared to the conventional posterior approach [24]. Another piriformis-sparing approach, the Sparing Piriformis and Internus, Repair Externus (SPAIRE) technique, has also been reported to be associated with a lower rate of dislocation [25]. The preservation of the short external rotator (SER) approach also might reduce the dislocation rate after hemiarthroplasty of the hip joint [26]. Even the lack of data of included RCTs in the current meta-analysis makes it difficult to compare SuperPATH and traditional approaches in the dislocation rate, the above literature might hint at the potential benefit of SuperPATH in reducing the dislocation rate. The future RCTs should investigate dislocation rate to enhance the chance to complete the full meta-analysis of dislocation rate for SuperPATH vs. traditional approaches in the dislocation rate.

We acknowledged several limitations in the meta-analysis. First, the bias of different surgical levels of surgeons, implants, and bone cements in the included studies might influence our results. We aimed to pool the synthesis effects of SuperPATH approach and traditional hip replacement. The specific individual analysis for the above variables should be warranted. Second, the different underlying diseases of hip replacement in the included studies might bias our meta-analysis results. Third, the significant heterogeneity might be another confounding factor for our results. It might be related to the diversity of operating surgeons, using materials, operating room setting and the underlying diseases in the included studies. Therefore, the authors applied the random effects model analysis to decrease the impacts

from the heterogeneity and the significant results were still observed. Fourth, the statistical methods for the heterogeneity I [2] estimates need to be interpreted with caution due to that our meta-analysis only enrolled a limited number of RCTs and might be biased. Fifth, the relatively low number of enrolled subjects, the limited included studies, the variations in patient populations, and study designs should also be considered in evaluating the results of the current meta-analysis. Given the limited sample size, it may not be appropriate to definitively conclude that SuperPATH is superior to traditional approaches. Sixth, the lack of prosthesis information during the intraoperative procedures, such as cemented vs. cementless bipolar hemiarthroplasty, single wedge stem design vs. double wedge stem design, standard length stem design vs. short stem design, might limit the interpretation of our results.

Conclusion

The meta-analysis results suggested the significant advantages of SuperPATH approach vs. traditional hip replacement for the efficacy and safety. The SuperPATH demonstrated a shorter incision length and hospitalization duration for the safety issue. In addition, the SuperPATH approach might provide with the more decline in the postoperative pain severity within 3 months and the more improvement of hip joint function within 1 month. However, the heterogeneity issue might be a concern and the future research might need a homogeneous sample in the study design.

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Author contributions

Research idea and study design: HL and DS; data acquisition: HL and DS; data analysis/interpretation: HL and DS; statistical analysis: HL, DS, and FD; supervision or mentorship: YF. All authors take responsibility that this study has been reported honestly, accurately and transparently, and accept accountability for the overall work by ensuring that questions pertaining to the accuracy or integrity of any portion of the work are appropriately investigated and resolved.

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Data availability

Data available on request from the authors. Please contact the corresponding author. Dr. Feng Yang, Gastroenterology Department, The First Hospital Affiliated to Army Medical University, Chongqing 400038, China, E-mail: yangfeng@tmmu.edu.cn.

Declarations

Human ethics and consent to participate

Not applicable.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Clinical trial number

Not applicable.

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