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Meta-analysis of the efficacy of reverse total shoulder arthroplasty and open reduction and internal fixation in the treatment of proximal humerus fractures

YUAN LI*, MENG-XUAN NIU*, FANG-ZHENG HE, XIN QIN, WEI-WEI WANG and PENG-FEI HAN

Department of Orthopedics, Heping Hospital Affiliated to Changzhi Medical College, Changzhi, Shanxi 046000, P.R. China

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Abstract. A proximal humerus fracture (PHF) is a common type of fracture that mostly occurs in middle-aged and elderly individuals and is often caused by indirect trauma. Severe pain typically occurs at the fracture site, accompanied by soft tissue swelling around the injured area, a limited range of motion in the shoulder joint, and visible shoulder deformity. Surgical intervention is a common treatment approach. Reverse total shoulder arthroplasty (RTSA) and open reduction and internal fixation (ORIF) are commonly used surgical methods; however, their effects on patients vary. The present meta-analysis compares their intraoperative and postoperative outcomes to assist surgeons in making informed decisions and improving patient treatment outcomes. The aim of the present study was to compare the intraoperative and postoperative outcomes of RTSA and ORIF in the treatment of PHFs. Literature on the treatment of PHFs by RTSA and ORIF published in databases, such as Pubmed, Embase, Cinahl, Cochrane Library, CNKI and Wanfang was retrieved. A total of 232 relevant articles were retrieved, and finally, 7 studies were included. The quality of the studies was evaluated according to the Cochrane systematic review methodology. After extracting the data, meta-analysis was performed using Review Manager 5.4 software. In the treatment of PHF, the postoperative forward flexion and abduction angles and the operation duration of ORIF were lower than those of RTSA, and the differences were statistically significant [95% confidence interval (CI) (18.64, 36.94), P<0.00001; 95% CI (0.20, 30.15), P=0.05; [95% CI (13.44, 37.65), P<0.0001]. In addition, there were no statistically significant differences between the two groups in terms of external rotation angle, DASH score, Constant score, and other outcome measures. In conclusion, in the treatment of PHF, RTSA offers improved postoperative forward flexion and abduction angles, while ORIF has the advantage of shorter operation duration. Therefore, the choice between the two surgical approaches should be based on the individual patient's condition.

Correspondence to: Dr Peng-Fei Han, Department of Orthopedics, Heping Hospital Affiliated to Changzhi Medical College, 110 South Yan'an Road, Changzhi, Shanxi 046000, P.R. China
E-mail: 18003551149@163.com

*Contributed equally

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Introduction

A proximal humerus fracture (PHF) is a type of bone trauma caused by external forces, such as direct or indirect impact to the shoulder (1). This kind of injury leads to a series of symptoms, including persistent pain at the fracture site, especially when the shoulder is moved or the injured area is touched, which intensifies the pain Local swelling may occur due to soft tissue damage, leading to the exudation of blood and tissue fluid. Additionally, shoulder joint mobility becomes limited, and patients have difficulty lifting, abducting, or rotating the arm normally (2,3). Severe cases may also involve deformities of the shoulder appearance, such as local protrusion or depression, which are asymmetrical to the opposite shoulder (4,5). Proximal humeral fractures account for ~4-5% of all fractures in the body, 26% of shoulder fractures, and up to one-third of fractures in older adults (6). Its incidence rate is second only to that of the hip and distal radial fractures. It is more common in the elderly population, particularly in postmenopausal women. The increased incidence of PHFs is closely related to several factors. For example, osteoporosis reduces bone strength and toughness of the bones decrease, and even a slight external force can easily cause fractures (7,8). In addition, because the risk of shoulder injury increases among people engaged in high-intensity physical labor or extreme sports, the incidence rate of proximal humeral fractures also increases. With the intensification of the aging global population, its incidence is expected to continue rising (9,10). In the treatment of PHFs, the existing options include conservative treatment and surgical treatment (11,12). Surgical intervention has become the primary treatment modality for most patients (13,14). Therefore, selecting an appropriate surgical approach is critical, as different techniques vary substantially in terms of operative time, length of hospital stay, and postoperative rehabilitation (15). Among the available surgical options, open reduction and internal fixation (ORIF) and reverse total shoulder arthroplasty (RTSA) are the two most commonly employed procedures. ORIF involves surgical exposure of the fracture site, followed by anatomical reduction and stabilization using internal fixation devices such as plates and screws. It is generally indicated for relatively simple fractures with limited displacement and allows the restoration of anatomical continuity and mechanical stability (16,17). By contrast, RTSA is typically indicated for complex fracture patterns, including comminuted fractures, osteoporotic fractures and humeral head necrosis (18). By replacing the native joint with a prosthesis, RTSA enables the restoration of shoulder function. Although RTSA is technically more demanding and may entail a longer operative time than ORIF, it provides improved articular surface reconstruction and may facilitate earlier functional rehabilitation in selected patients (19). Although both RTSA and ORIF are commonly used to treat PHFs, current literature presents inconsistent conclusions regarding their relative effectiveness. Previous studies have reported inconsistent findings regarding the comparative efficacy of ORIF and RTSA. Some studies suggested that ORIF may be associated with a shorter operative time (20), whereas others indicated that RTSA may provide superior improvements in postoperative forward flexion and abduction (21). These discrepancies underscore the need for a comprehensive and systematic comparison of the two surgical approaches; therefore, the present meta-analysis was conducted to compare the clinical outcomes of RTSA and ORIF in the treatment of proximal humeral fractures. By synthesizing evidence from multiple studies, the aim of the present study was to provide more robust evidence to inform surgical decision-making in clinical practice. It was aimed to provide reliable, evidence-based guidance for surgeons in selecting the most appropriate surgical plan, ultimately improving treatment outcomes and patient quality of life.

Materials and methods

Retrieval strategy. Search databases such as PubMed, Embase, CINAHL, Cochrane Library, CNKI (China National Knowledge Infrastructure) and Wanfang. Relevant literature was retrieved from all databases. The search strategy was: ('RTSA' OR Reverse Total Shoulder Arthroplasty) AND ('ORIF' OR 'Open Reduction and Internal Fixation') AND ('Proximal Humeral Fractures' OR 'Proximal Humerus Fracture').

Inclusion and exclusion criteria. Inclusion criteria were as follows: i) Research subjects: Patients diagnosed with PHF requiring surgery; ii) Intervention measures: The experimental group received RTSA, and the control group received ORIF; iii) Outcome indicators: Six items including angles of forward flexion, abduction, external rotation, DASH score, Constant score and operation duration; iv) Study design: Clinical controlled trials. Exclusion criteria were as follows: i) Treatment involving shoulder hemiarthroplasty; ii) Reviews, systematic reviews, case reports, letters, or duplicate publications; iii) non-case-control studies; iv) Incomplete outcome data or irrelevant studies.

Data extraction. Two independent researchers extracted data using a standardized protocol. Any disagreements were resolved through discussion or reviewed by senior researchers until consensus was reached. The included studies were assessed using the Newcastle-Ottawa Scale (NOS). In the outcome assessment, a follow-up time of ≥1 year and a loss to follow-up rate of ≤15% were considered acceptable. Study quality was categorized as low (<5 points), moderate (5-7 points), or high (8-9 points).

Statistical methods. All meta-analyses were performed using Review Manager (RevMan version 5.4; Cochrane Collaboration). Dichotomous outcomes were expressed as odds ratios (ORs) with 95% confidence intervals (CIs), whereas continuous outcomes were expressed as mean differences (MDs) or standardized mean differences (SMDs) with 95% CIs. Statistical significance was defined as a two-sided $P \leq 0.05$. Heterogeneity among studies was assessed using the I^2 statistic. When the heterogeneity was low ($I^2<50\%$), a fixed-effects model was applied; otherwise ($I^2>50\%$), a random-effects model was used. Sensitivity and subgroup analyses were conducted to explore potential sources of heterogeneity. Sensitivity analysis was performed by sequentially excluding individual studies to evaluate the stability of the results. Publication bias was assessed using funnel plots.

Results

Retrieval results. A total of 232 relevant studies were retrieved from the databases. After applying the inclusion and exclusion criteria, 7 studies were included in the analysis.

Basic information of the included literatures. Among the included studies, 5 reported forward flexion angles, 4 reported abduction angles, 5 reported external rotation angles, 4 reported DASH scores, 3 reported Constant scores, and 4 reported operation duration. In total, 514 patients were included: 257 received the RTSA, and 257 received the ORIF. The study selection process is shown in Fig. 1, and basic study characteristics are presented in Table I (22-28).

Quality evaluation of the included literatures. A total of seven retrospective cohort studies were included in this meta-analysis. The NOS was used to assess methodological quality. Specifically, two studies scored 8 points, indicating high methodological quality, two scored 7 points, and another two scored 6 points, resulting in four studies with moderate methodological quality. One study scored 4 points, indicating low methodological quality.

Results of meta-analysis

Comparison of postoperative indicators. Postoperative outcomes included forward flexion, abduction and external rotation angles, as well as Disabilities of the Arm, Shoulder, and Hand (DASH) and Constant scores. Five studies compared forward flexion between RTSA and ORIF. Moderate heterogeneity was observed ($I^2=65\%$); therefore, a random-effects model was used. The pooled analysis demonstrated that forward flexion was significantly greater in the RTSA group than in the ORIF group (MD=27.70; 95% CI: 18.46 to 36.94; $P<0.00001$; Fig. 2A). Four studies reported abduction. Given the substantial heterogeneity ($I^2=89\%$), a random-effects model was used. The results indicated that abduction was significantly improved in the RTSA group

Table I. Basic characteristics of the included studies.

First author/s, year	Research type	Country	Surgical approach	Number of cases (n)	Average age/year	Sex (male/female)	Outcome	Quality evaluation (NOS)	(Refs.)
Repetto *et al*, 2017	Retrospective cohort study	Italy	RTSA ORIF	27 19	71..2±7.5 65.3±12.4	7/20 6/13	(1) (2) (3) (4)	7	(22)
Giardella *et al*, 2017	Retrospective cohort study	Italy	RTSA ORIF	21 23	63.7±8.4 68.2±7.3	8/13 9/14	(1) (2) (3) (5)	7	(23)
Tong *et al*, 2023	Retrospective cohort study	Hong Kong	RTSA ORIF	25 25	77.0±7.14 75.2±6.79	3/22 3/22	(1) (2) (3) (4) (5) (6)	8	(24)
Lanzetti *et al*, 2023	Retrospective cohort study	Italy	RTSA ORIF	72 66	73.00±10.00 63.00±14.00	18/54 20/46	(1) (2) (3) (4) (5) (6)	8	(25)
Samborski *et al*, 2022	Retrospective cohort study	USA	RTSA ORIF	24 23	77.30±9.50 67.10±5.50	1/23 5/18	(1) (3)	6	(26)
Ott *et al*, 2022	Retrospective cohort study	Germany	RTSA ORIF	71 90	82.20±6.10 82.00±6.50	18/53 17/73	(6)	4	(27)
Jaekel *et al*, 2025	Retrospective cohort study	Germany	RTSA ORIF	17 17	77.8±5.9 75.3±6.3	1/16 3/14	(4) (6)	6	(28)

Outcome indicators: (1) Forward flexion; (2) Abduction; (3) External rotation; (4) DASH score; (5) Constant score; (6) Operation duration. RTSA, reverse total shoulder arthroplasty; ORIF, open reduction and internal fixation; NOS, Newcastle-Ottawa Scale.

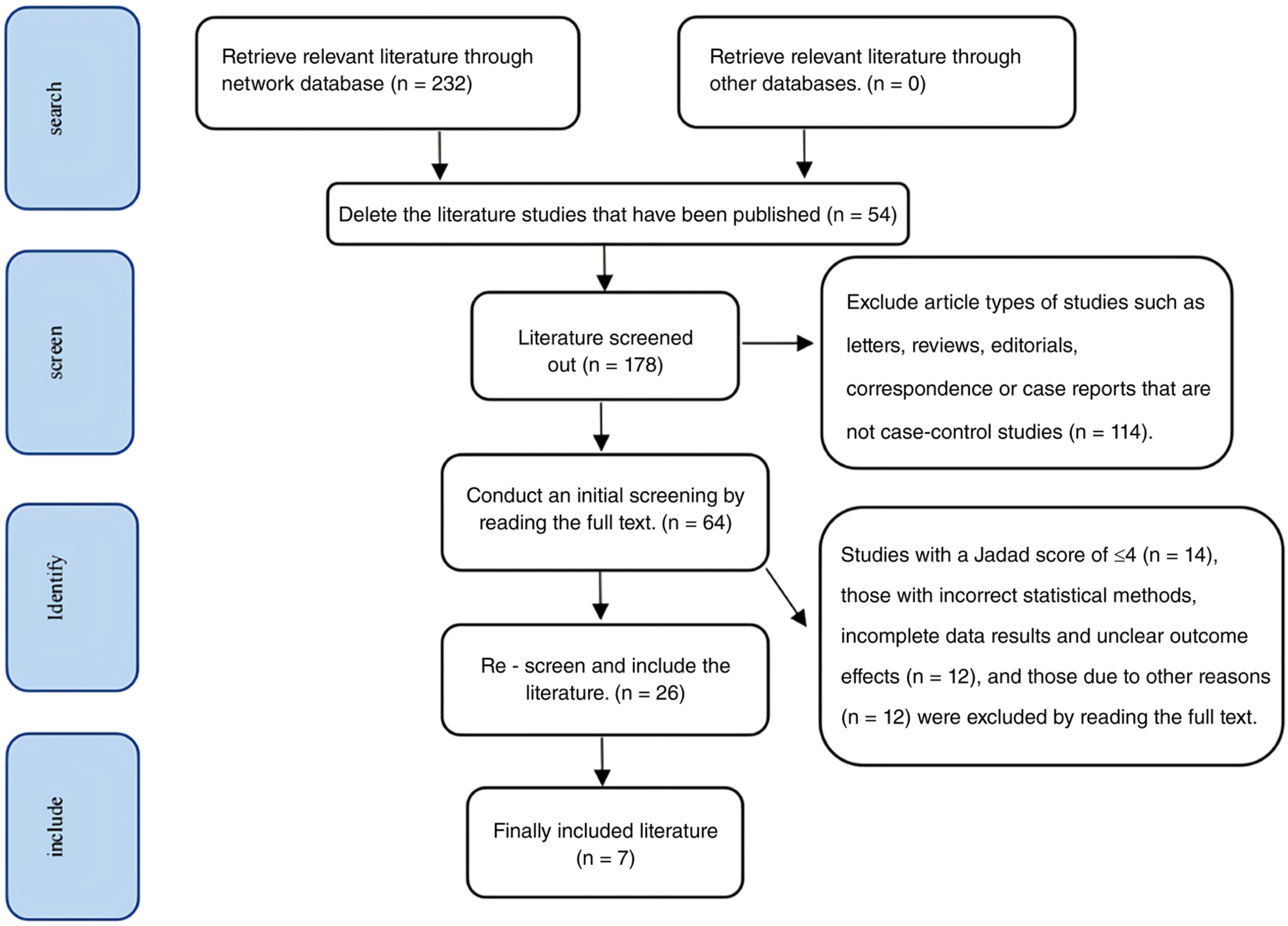

Figure 1. Flow chart of literature screening.

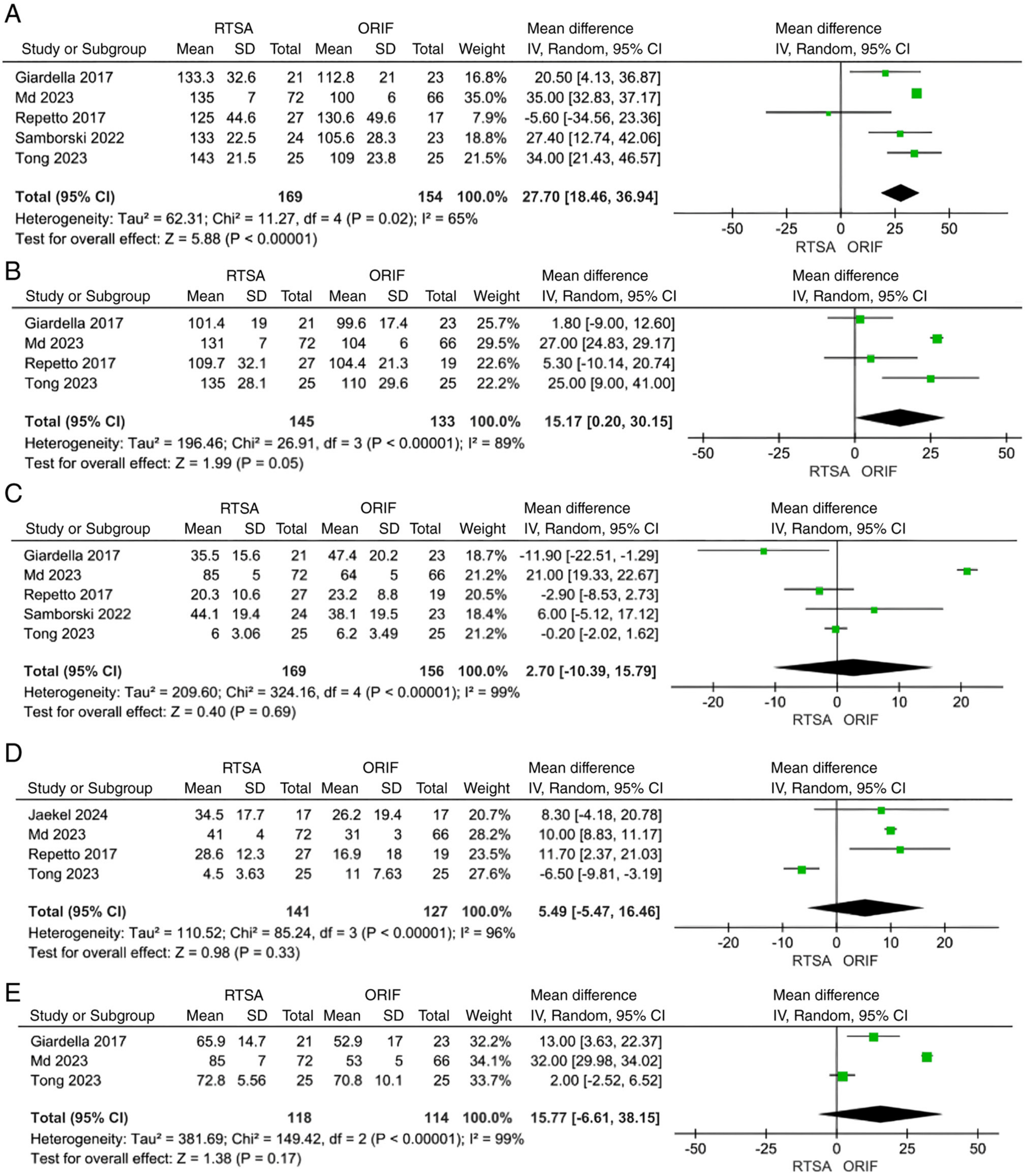

Figure 2. Meta-analysis of postoperative indicators of reverse total shoulder arthroplasty and open reduction and internal fixation for the treatment of proximal humerus fractures. (A) Forward flexion. (B) Abduction. (C) External rotation. (D) DASH score. (E) Constant score. RTSA, reverse total shoulder arthroplasty; ORIF, open reduction and internal fixation; CI, confidence interval.

compared with the ORIF group (MD=15.18; 95% CI: 0.20 to 30.15; P=0.05; Fig. 2B). No statistically significant differences were observed between the two groups in external rotation (MD=2.70; 95% CI: -10.39 to 15.79; P=0.69; Fig. 2C), DASH score (MD=5.50; 95% CI: -5.47 to 16.46; P=0.33; Fig. 2D), or Constant score (MD=15.77; 95% CI: -6.61 to 38.15; P=0.17; Fig. 2E).

Comparison of intraoperative efficacy indicators. Operative time was evaluated as an intraoperative outcome. Four studies compared operative time between RTSA and ORIF. Substantial heterogeneity was observed (I^2=73%); therefore, a random-effects model was used. The pooled analysis demonstrated that operative time was significantly longer in the RTSA group than in the ORIF group (MD=25.55; 95% CI: 13.44 to 37.65; P<0.0001) (Fig. 3).

Publication bias and sensitivity analysis. Review Manager 5.4 statistical software was used to perform publication bias analysis for six outcome measures in the treatment of PHF,

Study or Subgroup	RTSA Mean	RTSA SD	RTSA Total	ORIF Mean	ORIF SD	ORIF Total	Weight	Mean difference IV, Random, 95% CI
Jaekel 2024	97	56	17	78	21	17	12.5%	19.00 [-9.43, 47.43]
Md 2023	90	18	72	60	18	66	36.9%	30.00 [23.99, 36.01]
Ott 2022	87.3	25.2	71	73	30.2	90	33.8%	14.30 [5.74, 22.86]
Tong 2023	133	52.2	25	89.7	25	25	16.7%	43.30 [20.61, 65.99]
Total (95% CI)			**185**			**198**	**100.0%**	**25.54 [13.44, 37.65]**

Heterogeneity: Tau² = 93.92; Chi² = 11.29, df = 3 (P = 0.01); I² = 73%
Test for overall effect: Z = 4.13 (P < 0.0001)

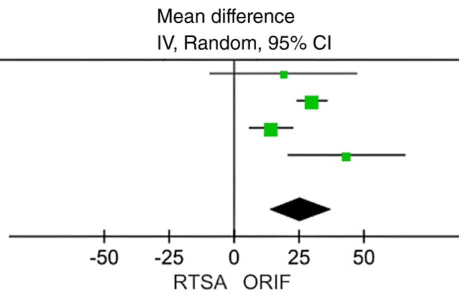

Figure 3. Meta-analysis of intraoperative efficacy indicators of reverse total shoulder arthroplasty and open reduction and internal fixation for the treatment of proximal humerus fractures. RTSA, reverse total shoulder arthroplasty; ORIF, open reduction and internal fixation; CI, confidence interval.

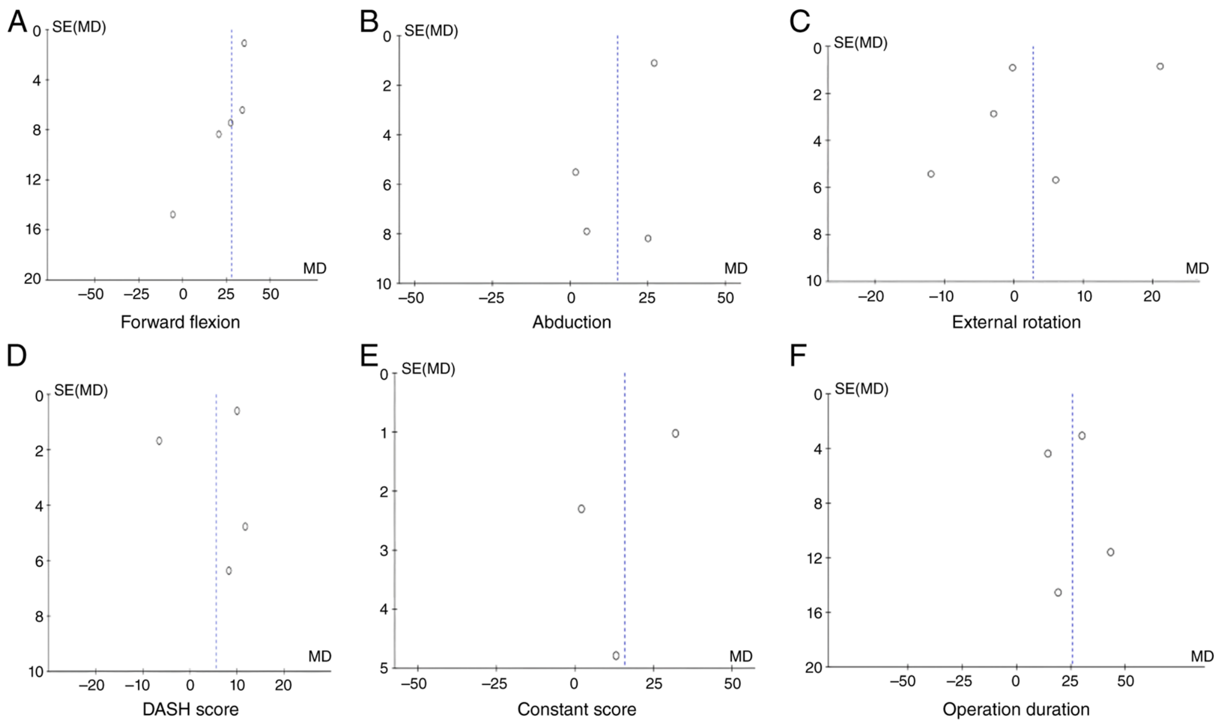

Figure 4. Funnel plots of the Meta-analysis of reverse total shoulder arthroplasty and open reduction and internal fixation for the treatment of proximal humerus fractures. (A) Forward flexion. (B) Abduction. (C) External rotation. (D) DASH score. (E) Constant score. (F) Operation duration.

including forward flexion angle, abduction angle, external rotation angle, DASH score, Constant score (corrected spelling) and operative duration. The results demonstrated that each funnel plot was symmetrical (Fig. 4), indicating the absence of significant publication bias.

Discussion

The present meta-analysis compared the clinical efficacy of RTSA with ORIF in the management of PHF. The results demonstrated significant differences in key outcome measures between the two surgical approaches, thereby providing valuable evidence for clinical surgical decision-making.

The findings of the present meta-analysis indicated that RTSA conferred distinct advantages over ORIF with respect to postoperative forward flexion and abduction angles, with statistically significant differences [95% CI (18.46, 36.94), P<0.00001; and 95% CI (0.20, 30.15), P=0.05; respectively]. This result is consistent with the outcomes of previously published relevant studies (21,29), which may be attributed to the inherent surgical characteristics of RTSA. Clinical practice has demonstrated that RTSA allows superior articular surface reconstruction and is well-suited for severe comminuted fractures or osteoporotic fractures (18), thereby facilitating improved postoperative shoulder joint range of motion. In addition, RTSA can effectively compensate for rotator cuff functional deficits. When the rotator cuff is severely impaired and unable to function normally, the prosthetic design of RTSA enables the deltoid muscle to drive shoulder joint movement directly, thereby promoting recovery of shoulder joint function (30,31). By contrast, ORIF is associated with an increased risk of complications, such as nonunion, malunion and humeral head avascular necrosis, in the management of severe fractures (16), which may limit the recovery of shoulder joint mobility and further compromise postoperative forward flexion and abduction angles. However, the extent of shoulder joint function improvement achieved with RTSA may also be influenced by factors such as the surgical technique and postoperative rehabilitation protocols, which warrant further validation through additional high-quality studies.

In terms of operative duration, ORIF demonstrated a significant advantage over RTSA, with a statistically significant difference [95% CI: 13.44 to 37.65; P<0.00001]. This finding is primarily attributed to the greater complexity of the RTSA procedure. Surgeons are required to accurately implant prostheses (including glenoid and humeral components), precisely prepare the bony bed to ensure optimal prosthesis position and angulation, and reconstruct the soft tissue balance and biomechanical structure surrounding the shoulder joint (32). In addition, the management and repair of soft tissues, such as the rotator cuff and the deltoid muscle, are necessary during RTSA to accommodate the new prosthesis and restore normal shoulder joint motor function (33). In particular, when addressing narrow and complex anatomical structures, such as the glenoid cavity, surgical difficulty increases, thereby prolonging the operative time. By contrast, ORIF primarily involves fixation of the fracture site using internal fixation materials such as plates and screws, following fracture reduction, with a relatively straightforward surgical procedure (16,17), resulting in a shorter operative duration.

It should be emphasized that the clinical efficacy of RTSA and ORIF is influenced by multiple factors. For patients with severe comminuted fractures, osteoporotic fractures, or concomitant rotator cuff injury, RTSA may represent a more appropriate therapeutic option as it can effectively address the challenges of fracture healing and postoperative joint function recovery. For patients with relatively simple fracture patterns and no significant displacement, ORIF can meet clinical treatment requirements, with the distinct advantage of a shorter operative time, which reduces the risk of intraoperative complications. Therefore, the selection of a surgical approach should be determined comprehensively based on individual patient characteristics, including age, fracture classification, preoperative shoulder joint function status, and other relevant clinical factors, to achieve optimal therapeutic outcomes.

The present meta-analysis has certain limitations that should be acknowledged. A paucity of randomized controlled trials was identified among the included studies, which resulted in a relatively low level of evidence. The present meta-analysis was not pre-registered on PROSPERO or any other public protocol registration platform, which might have compromised the transparency of the study design. All included studies were retrospective cohort studies, with one study achieving a NOS score of only 4 points, indicating low methodological quality. Although the sensitivity analysis, excluding this low-quality study, confirmed the robustness of the primary findings, the retrospective nature of the included studies may still introduce selection bias and indication confounding, potentially affecting the reliability of the results. High heterogeneity was observed across all outcome measures (forward flexion, I^2=65%; abduction, I^2=89%; operative duration, I^2=73%), thereby limiting the reliability and generalizability of the pooled effect estimates. Owing to the lack of relevant data in the included studies, important clinical outcomes, such as dislocation, infection, revision surgery and implant failure, were not analyzed, thereby affecting the comprehensiveness of the study. Follow-up durations varied across the included studies, and this variability may introduce bias into the comparison of functional scores, as longer or shorter follow-up periods can lead to differential evaluations of functional recovery. The number of included studies ranged from 3 to 5 for all outcome measures. The heterogeneity among these studies, coupled with variations in final follow-up times, may have affected the results. Additionally, the long-term efficacy remains unclear, and discrepancies may exist between the findings of this study and real-world clinical outcomes. Therefore, additional studies with larger sample sizes are warranted. Future publication of more high-quality clinical studies focusing on the surgical management of PHF is anticipated, which will help reduce bias and facilitate the derivation of more valid and reliable conclusions.

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Availability of data and materials

The data generated in the present study are included in the figures and/or tables of this article.

Authors' contributions

PFH, YL and MXN conceived and designed the study. FZH, XQ and WWW acquired the data. YL, MXN and PFH conducted the statistical analysis and data interpretation. YL, MXN and FZH drafted the manuscript. All authors critically revised the manuscript for important intellectual content, read and approved the final manuscript, and agree to be accountable for all aspects of the work. PFH and YL confirm the authenticity of all raw data.

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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