An updated systematic review and meta-analysis comparing deltoid-split approach with deltopectoral approach for proximal humerus fractures

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Received November 23, 2022; Accepted March 15, 2023

DOI: 10.3892/etm.2023.11995

Abstract. The present review and meta-analysis aimed to summarize the currently available data and to compare the important clinical and functional outcomes in patients with proximal humerus fractures who were treated using deltoid split (DS) or deltopectoral (DP) surgical approaches. The PubMed, EMBASE, Scopus and Cochrane Central Register of Controlled Trials databases were systematically searched for randomized controlled trials or observational studies that reported functional outcome data of patients with fracture of proximal humerus who were surgically treated using DS and DP approaches. A total of 14 studies were included in the present meta-analysis. The duration of surgery [min; weighted mean difference (WMD), -16.44; 95% CI, -(25.25-7.63)], amount of blood loss [ml; WMD, -57.99; 95% CI, -(102.74-13.23)] and time to bone union [weeks WMD, -1.66; 95% CI, -(2.30-1.02)] was comparatively lower in patients that underwent DS. There were no statistically significant differences in the pain and quality of life scores, range of movement and risk of complications between the DS and the DP groups. Patients in the DS group had improved shoulder function and constant shoulder score (CSS) at 3 months post-surgery (WMD, 6.36; 95% CI, 1.06-11.65). No differences were observed between the two groups in terms of CSS and disabilities of the arm, shoulder and hand scores at 12 and 24 months post-operatively. The activity of daily living (ADL) score was significantly improved in the DS group at 3 (WMD, 1.23; 95% CI, 0.40-2.06), 6 (WMD, 0.99; 95% CI, 0.72-1.25) and 12 months (WMD, 0.83; 95% CI, 0.18-1.47) after the surgery. The present results suggested that DS and DP surgical approaches were associated with similar clinical outcomes. The DS approach was associated with certain perioperative benefits, as well as reduced time to bone union, improved shoulder function in the early post-operative period and improved ADL scores. These benefits may be considered while choosing between these two surgical approaches.

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Key words: proximal humerus fracture, deltoid split approach, deltopectoral approach, clinical outcomes, meta-analysis

Introduction

Proximal humerus fracture has a prevalence of 5-10% and is among the 10 most frequent fractures in the adult population (1-3). Proximal fracture of the humerus comprises humeral head fracture, fractures of the anatomical as well as surgical neck, and fractures of the greater and lesser tubercles (4). More severe and complex fracture cases may involve all of these parts of the humerus and are coupled with subluxation of the humeroscapular joint (4,5). These types of fracture are largely caused by low-intensity trauma and are more common in older women due to underlying osteoporosis (6,7).

Current treatment strategies for proximal humerus fracture range from conservative treatment to surgical management comprising open reduction along with internal fixation, arthroplasty, intramedullary nailing and minimal invasive percutaneous plate osteosynthesis (8-10). It has been indicated that quality of life (QOL)-related outcomes are improved with surgical management, compared to conservative treatment. However, the comparative efficiency of various surgical modalities has remained to be determined (11). The deltopectoral (DP) approach is one of the most common methods of open reduction and internal fixation. However, this approach involves substantial dissection of the soft tissue and retraction of the muscle to gain access to the lateral aspect of the humerus (12,13). As an alternative approach, deltoid splitting (DS) is comparatively less invasive; however, studies suggested that the DS approach may be associated with an increased risk of damage to the blood supply of the humerus and on certain occasions, may also injure the axillary nerve (8,10,14). Schematics illustrating these two surgical approaches are provided in Fig. 1.

There is still no consensus regarding which of these two surgical modalities is more clinically efficacious and associated with fewer complications. A systematic review by Xie *et al* (15) that included six studies [three randomized

controlled trials (RCTs) and three prospective follow-up studies] indicated that the risk of avascular necrosis (AVN) of the humeral head was significantly lower in patients receiving DS surgery. Furthermore, the duration of surgery was lower in the DS group as compared to the DP approach. No statistically significant differences were reported for other outcomes, such as the complication rate and functional outcome. The present study conducted a comprehensive search and included all the contemporary studies relevant for this review. The intent was to provide a reliable and updated evidence on the issue at hand. The review by Xie *et al* (15) included only six studies whereas the present study identified and included 14 studies. Some of these studies have been conducted after the review by Xie *et al* (15) was published (n=5) and some of them were published before the review by Xie *et al* (15) but the review did not include those studies. Relevant details of the included studies have been presented later in the manuscript. Additionally, the present study also provided pooled estimates on important outcomes that were not considered in the review by Xie *et al* (15), such as the range of movement and time to bone union. There is a need to provide updated evidence on this issue and, therefore, the main goal of the current meta-analysis was to include all relevant studies comparing outcomes of DP and DS surgeries in patients with proximal humerus fracture.

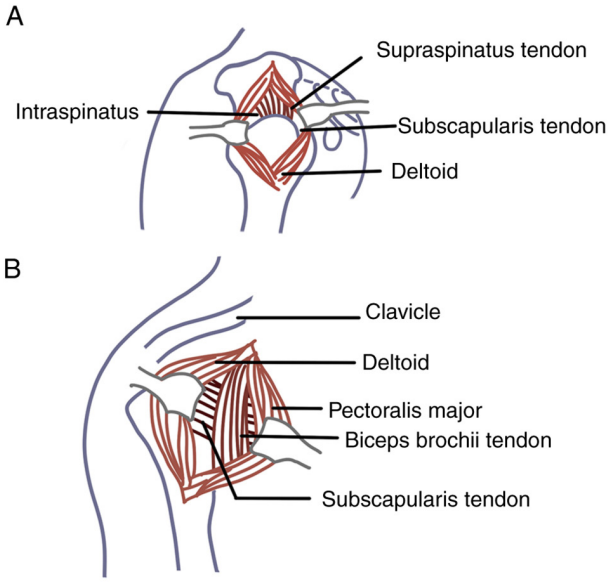

Figure 1. Schematic representation of the two surgical approaches. (A) Deltoid split approach showing access to the proximal humerus by splitting through the deltoid muscle and (B) deltopectoral approach showing access to the proximal humerus by creating a window between the deltoid and pectoral muscle.

Materials and methods

Search strategy. The protocol of the study was registered in the International Prospective Registry of Systematic Reviews (registration no. CRD42021290759). The Preferred Reporting Items for Systematic Reviews and Meta-analyses 2020 guidelines were followed while conducting the literature review (16). A systematic thorough search, using a pre-defined and pilot-tested search strategy, was performed in the PubMed, Scopus, EMBASE and Cochrane Central Register of Controlled Trials databases for papers published in the English language until 31 January 2023. The following search strategy was used: 'deltoid-split approach OR deltopectoral approach' AND 'humerus fracture OR proximal humerus fracture' AND 'outcomes OR functional outcomes OR complications OR blood loss OR operative time'. Studies that compared the outcomes of interest among patients with proximal humerus fractures that were managed using DS and DP approaches were identified. The primary outcome of interest included functional outcomes such as constant shoulder score (CSS) and disabilities of the arm, shoulder and hand (DASH) score. Secondary outcomes of interest included risk of complications, range of movement in the postoperative period, pain, QOL, activities of daily living (ADL) score, duration of surgery, blood loss during surgery, length of hospital stay and time required for bone union.

Selection criteria and methods. The studies identified by the literature search were retrieved and duplicates were removed. Titles and abstracts were then screened by two authors, followed by a review of the full texts of the remaining studies. Disagreements were resolved through discussions among the authors. Reference lists of the included studies were also reviewed to identify additional relevant manuscripts.

The inclusion criteria were as follows: i) RCT and observational studies including case-control studies; ii) studies with prospective follow-ups and retrospective studies that analysed data using clinical records; iii) studies that involved patients with fracture of the proximal humerus and reported relevant outcomes based on DS and DP surgical approaches.

Exclusion criteria were as follows: i) Case-reports or review articles; ii) studies that did not report findings based on the two management modalities (DS and DP); iii) studies that did not report the outcomes of interest.

Data extraction and quality assessment. Data from the included studies were extracted independently by two authors using a pretested data extraction sheet. The quality of the included studies was assessed independently by two authors using the Newcastle-Ottawa Quality Assessment Scale for observational studies (17).

Statistical analysis. STATA version 16.0 (StataCorp LP) was used for statistical analysis. Pooled relative risk (RR) was used for categorical outcomes. For continuous outcomes, weighted mean difference (WMD) was used where the outcomes were reported on the same scales. In instances where outcomes were reported based on assessment using different tools/scales, e.g. pain scores, standard mean difference (SMD) was used to report pooled effect sizes. All effect sizes were reported along with 95% CIs. For all the analyses, I^2 was used to measure heterogeneity. In cases of I^2 >40%, the random-effects model was used (18). P<0.05 was considered to indicate a statistically significant difference. Egger's test was used to detect publication bias (19).

Results

Selection of articles, study characteristics and quality of the included studies. A total of 288 citations were identified by

Table I. Characteristics of the studies included in the meta-analysis.

First author(s), year	Study design	Country	Participant characteristics	Sample size	Timing of reporting of outcomes/follow-up period	(Refs.)
Borer *et al*, 2020	Prospective follow-up	Switzerland	-Median age, 64 years -Females, 75% -Majority with two- or three-parts fracture, 85% -Mean BMI, 26.6 kg/m^2	DS (n=39); DP (n=23)	Outcomes reported at minimum 1-year follow-up Median follow-up, 47 months	(30)
Büyükkuşcu *et al*, 2020	Prospective follow-up	Turkey	-Mean age, 48 years -Males, 60%	DS (n=21); DP (n=27)	Mean follow-up,18 months	(29)
Rouleau *et al*, 2020	RCT	Canada	-Mean age, 62 years -Females, 78% -Varus displacement, 70% -Mean BMI, 21 kg/m^2	DS (n=44); DP (n=41)	Mean follow-up, 26 months	(32)
Vijayvargiya *et al*, 2016	Prospective follow-up	India	-Mean age, 46 years -Majority were males, (58%) -Time between injury and operation, ~7 days Neer's type 3 fracture, 46%	DS (n=13); DP (n=13)	Minimum follow-up, ≥6 months	(27)
Bandalović *et al*, 2014	Prospective follow-up	Croatia	-Patients aged >65 years -All with closed proximal humerus fracture	DS (n=25) DP (n=42)	Mean follow-up, 14.7 months	(24)
Bhayana *et al*, 2021	Prospective follow-up	India	-Mean age, 45 years -Majority were males, 66% -Patients with either Neer's type 3 or 4 fracture	DS (n=42) DP (n=42)	Mean follow-up, 23 months	(33)
Buecking *et al*, 2014	RCT	Germany	-Mean age, ~68 years; -Females, 77% -Neer's type 3 or 4 fracture, 75%	DS (n=60) DP (n=60)	Mean follow-up, 12 months	(23)
Zhao *et al*, 2017	RCT	China	-Mean age, 64 years -Male, 58.3% -Mean BMI, 25.9 kg/m^2 -All with either Neer's type 2 or 3 fracture	17 DS 19 DP	Mean follow-up, 12 months	(28)
Martetschläger *et al*, 2012	RCT	Germany	-Mean age, ~58 years -Male, 49% -Neer's type 3 or 4 fracture (87%)	DS (n=37) DP (n=33)	Mean follow-up, 33 months	(22)
Hepp *et al*, 2008	Prospective	Germany	-Median age, 65 years -Female, 77% -Majority with Neer's type 2 or 3 fracture -Right upper limb was affected in the majority of cases	DS (n=39) DP (n=44)	Follow-up at 3, 6 and 12 months post-operatively	(20)
Fischer *et al*, 2016	Prospective	Germany	-Mean age, ~60 years -Females, 65% -AO fracture classification, B/C (78%)	DS (n=20) DP (n=30)	Follow-up, ~24 months	(26)
Kim *et al*, 2020	Retrospective analysis of medical records	South Korea	-Mean age, 68 years -Females, 85% -All with either Neer type 2 or 3 fracture	DS (n=39) DP (n=38)	Mean follow-up, ~16 months Outcomes assessed at 12 months post-operative period	(31)

Table I. Continued.

First author(s), year	Study design	Country	Participant characteristics	Sample size	Timing of reporting of outcomes/follow-up period	(Refs.)
Siripong *et al*, 2015	Retrospective analysis of medical records	Thailand	-Age range, 50-60 years -Females, 57% -All with either Neer type 2 or 3 fracture	DS (n=12) DP (n=16)	Follow up period not reported in the study	(25)
Wu *et al*, 2011	Retrospective analysis	Taiwan	-Mean age, 58 years; -Females, 75% -With high energy injury, ≥60% -Type C fracture, 42%	DS (n=28) DP (n=32)	Minimum follow-up, 24 months Mean follow-up, 32 months	(21)

Values are expressed as the mean ± standard deviation. DS, deltoid split; DP, deltopectoral; RR, risk ratio; AVN, avascular necrosis; DASH, disabilities of the arm, shoulder and hand score; CSS, constant shoulder score; QOL, quality of life score; VAS, visual analog scale; RCT, randomized controlled trial; ADL, activities of daily living.

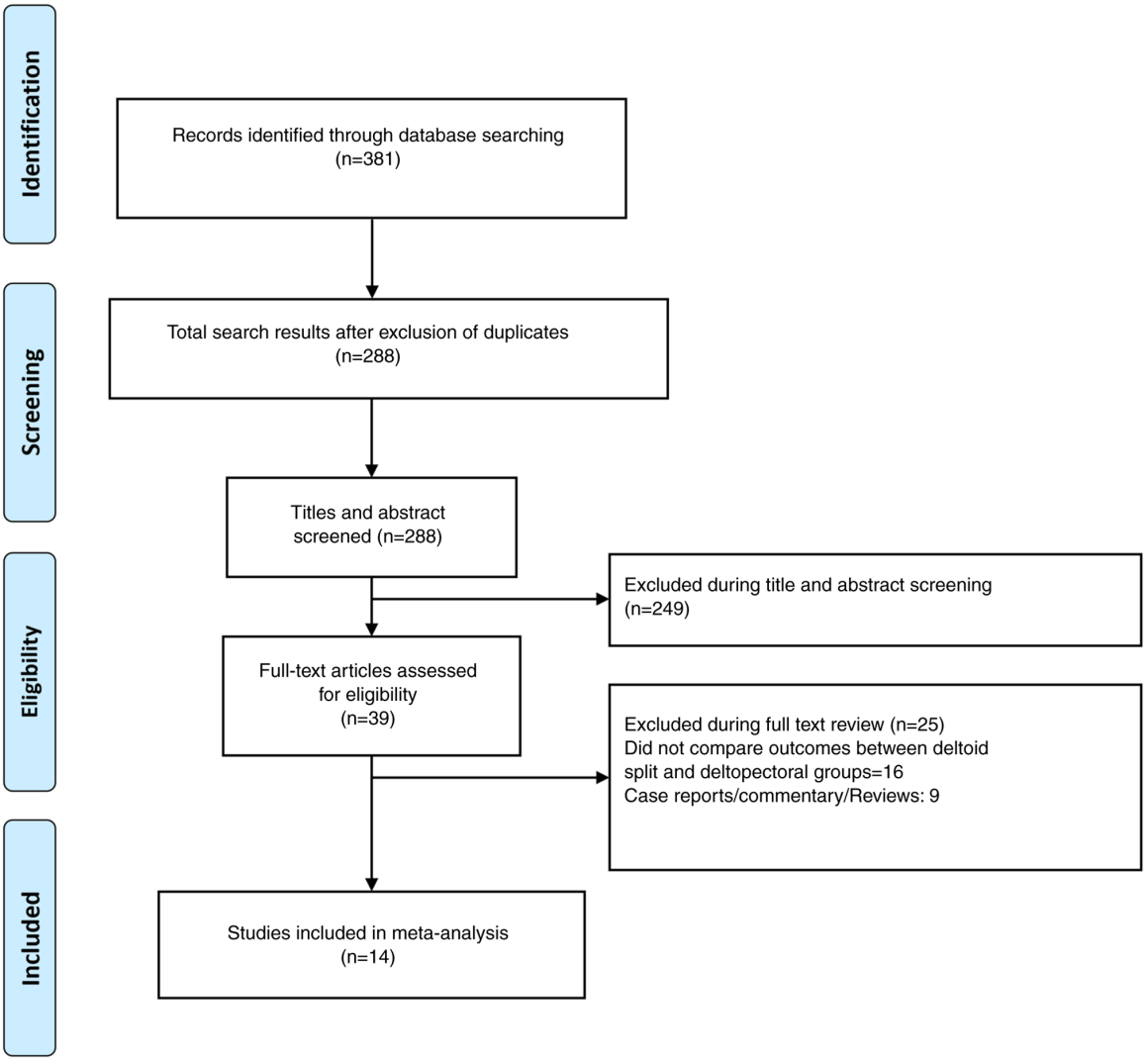

Figure 2. Selection process of the studies included in the review.

the systematic literature search after removing any duplicates (Fig. 2). An additional 249 citations were excluded based on the screening of the titles and abstracts. Full texts of the remaining 39 studies were read and 25 studies were excluded. Finally, a total of 14 studies were considered for inclusion (20-33). The details of the 14 studies included are presented in Table I.

Table II. Outcomes in subjects undergoing deltoid-splitting approach, compared to deltopectoral approach.

Outcome	Number of studies	Pooled effect size	I^2, %
Duration of surgery, min	10	WMD -16.44 (95% CI, -25.25 to -7.63)[a]	98.0
Duration of hospital stay, days	4	WMD -0.04 (95% CI, -0.28 to 0.21)	49.6
Blood loss, ml	5	WMD -57.99 (95% CI, -102.74 to -13.23)[a]	87.3
Time to union, weeks	4	WMD -1.66 (95% CI, -2.30 to -1.02)[a]	94.4
QOL (physical component), 24 months	3	WMD 2.10 (95% CI, -4.81 to 9.01)	82.9
QOL (mental component), 24 months	2	WMD 0.52 (95% CI, -10.93 to 11.97)	87.5
Range of movement (degrees) at latest follow-up			
External rotation	4	WMD 0.09 (95% CI, -0.31 to 0.48)	9.3
Internal rotation	3	WMD 0.33 (95% CI, -0.08 to 0.75)	0.0
Abduction	3	WMD -1.73 (95% CI, -5.83 to 2.38)	97.2
Activity of daily living score			
Within 3 months	2	WMD 1.23 (95% CI, 0.40 to 2.06)[a]	44.2
At 6 months	2	WMD 0.99 (95% CI, 0.72 to 1.25)[a]	0.0
At 12 months	2	WMD 0.83 (95% CI, 0.18 to 1.47)[a]	38.5
At 24 months	1	WMD 0.00; 95% CI, (-0.30 to 0.30)	-

[a]P<0.05. QOL, quality of life score; WMD, weighted mean difference.

There were seven prospective studies, four RCTs and three retrospective studies. A total of four studies were conducted in Germany, two in India and one each in Switzerland, Turkey, Canada, Croatia, China, South Korea, Thailand and Taiwan. The mean follow-up period ranged from 12-47 months. The results of the quality evaluation indicated that the studies were of modest to good quality (Table SI).

Functional outcomes. Compared with patients treated using the DP approach, those treated with the DS approach had an improved shoulder function, as indicated by the CSS at 3 months post-surgery (WMD 6.36; 95% CI, 1.06 to 11.65; n=2; I^2=30.6%) (Fig. 3). There was no significant difference between the DP and the DS groups in the CSS at 6 (WMD 1.52; 95% CI, -4.27 to 7.31; n=2; I^2=82.0%], 12 (WMD 1.27; 95% CI, -1.67 to 4.22; n=6; I^2=85.5%) and 24 months (WMD 3.25; 95% CI, -1.88 to 8.38; n=5; I^2=86.6%) after the surgery (Fig. 3). Furthermore, there were no statistically significant differences in the DASH scores between the two groups at 3 (WMD -2.90; 95% CI, -8.74 to 2.94; n=1), 12 (WMD 0.29; 95% CI, -0.62 to 1.19; n=3; I^2=57.8%) and 24 months (WMD 3.27; 95% CI, -2.87 to 9.41; n=4; I^2=73.8%) post-surgery (Fig. 3). The ADL score was significantly improved in the DS group, compared with that in the DP group, at 3 (WMD 1.23; 95% CI, 0.40 to 2.06; n=2; I^2=44.2%), 6 (WMD 0.99; 95% CI, 0.72 to 1.25; n=2; I^2=0.0%) and 12 months (WMD 0.83; 95% CI, 0.18 to 1.47; n=2; I^2=38.5%) after the operation (Table II). At 24 months, there was only one study reporting the ADL score, and it did not indicate any difference between the two groups of patients. The pooled effect size for the range of movement (degrees) at the latest follow-up (the reported mean follow-up was 12-26 months in the included studies) was comparable between the two groups in terms of external rotation (WMD 0.09; 95% CI, -0.31 to 0.48; n=4; I^2=9.3%), internal rotation (WMD 0.33; 95% CI, -0.08 to 0.75; n=3; I^2=0.0%) and abduction (WMD -1.73; 95% CI, -5.83 to 2.38; n=3; I^2=97.2%) (Table II). Similarly, no significant differences were noted between the two groups in physical (WMD 2.10; 95% CI, -4.81 to 9.01; n=3; I^2=82.9%) and mental components (WMD 0.52; 95% CI, -10.93 to 11.97; n=2; I^2=87.5%) of the

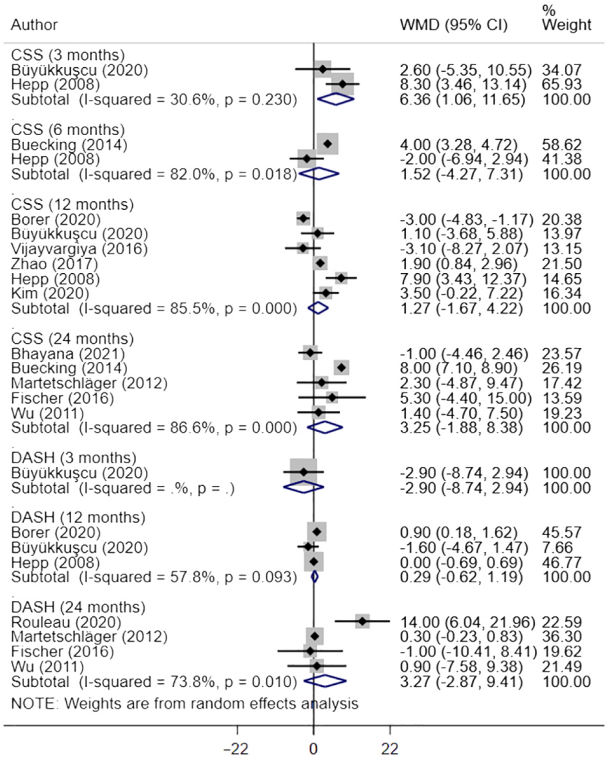

Figure 3. CSS and DASH in patients undergoing the deltoid-splitting approach compared with those undergoing the deltopectoral approach. WMD, weighted mean difference; CSS, constant shoulder score; DASH, disabilities of the arm, shoulder and hand score.

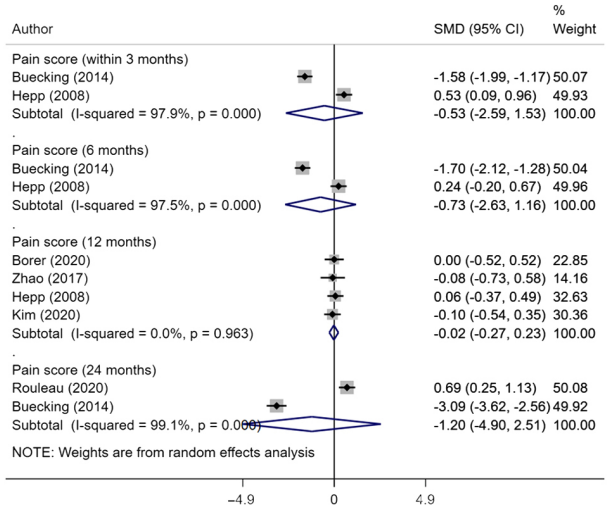

Figure 4. Pain score in patients undergoing the deltoid-splitting approach compared with those undergoing the deltopectoral approach. SDM, standard mean difference.

QOL score 24 months after the surgery (Table II). Publication bias was not detected for any of the functional outcomes (P>0.05; data not shown) using Egger's test.

Additional outcomes. The DS approach was associated with a comparatively lower duration of surgery (in minutes) (WMD -16.44; 95% CI, -25.25 to -7.63; n=10; I^2=98.0%) and the amount of blood loss (in ml) (WMD -57.99; 95% CI, -102.74 to -13.23; n=5; I^2=87.3%) (Table II). Time to bone union (in weeks) (WMD -1.66; 95% CI, -2.30 to -1.02; n=4; I^2=94.4%) was also lower in the patients that received the DS approach treatment. The duration of hospital stay (in days) (WMD -0.04; 95% CI, -0.28 to 0.21; n=4; I^2=49.6%) was similar in both groups (Table II). There were no statistically significant differences in the pain scores between the two groups at 3 (SMD -0.53; 95% CI, -2.59 to 1.53; n=2; I^2=97.9%), 6 (SMD -0.73; 95% CI, -2.63 to 1.16; n=2; I^2=97.5%), 12 (SMD -0.02; 95% CI, -0.27 to 0.23; n=4; I^2=0.0%) and 24 months (SMD -1.20; 95% CI, -4.90 to 2.51; n=2; I^2=99.1%) post-surgery (Fig. 4). We found no statistical evidence of publication bias for the above-mentioned outcomes on Egger's test (P>0.05; data not shown).

Complications. There were no statistically significant differences in the risk of 'any' complication (RR 0.93; 95% CI, 0.65 to 1.34; n=8; I^2=0.0%), AVN (RR 0.88; 95% CI, 0.46 to 1.68; n=9; I^2=0.0%), non-union (RR 1.22; 95% CI, 0.32 to 4.64; n=4; I^2=0.0%), malunion (RR 0.92; 95% CI, 0.49 to 1.73; n=5; I^2=0.0%) and infection (RR 0.58; 95% CI, 0.16 to 2.12; n=5; I^2=0.0%) between the DS and the DP group (Fig. 5). All of the studies that reported on outcomes related to axillary nerve found no axillary nerve damage in the two groups of patients. The risk of screw-related perforation (RR 0.69; 95% CI, 0.35 to 1.36; n=6; I^2=0.0%), subacromial impingement (RR 1.16; 95% CI, 0.55 to 2.46; n=3; I^2=0.0%), need for reoperation (RR 1.10; 95% CI, 0.66 to 1.83; n=4; I^2=0.0%) and implant failure (RR 1.03; 95% CI, 0.68 to 1.58; n=6; I^2=0.0%) was also similar in both groups (Fig. 6). Egger's test did not indicate

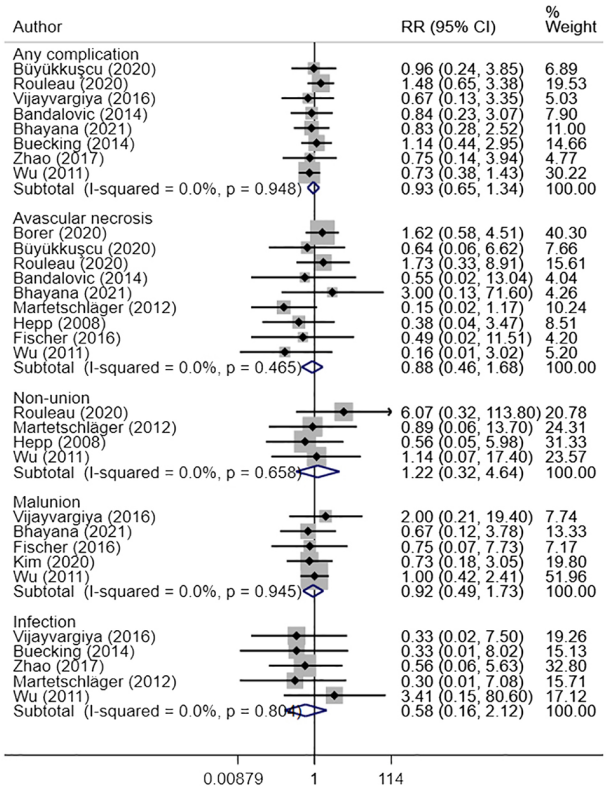

Figure 5. Risk of complications (any, avascular necrosis, non-union, malunion, infection) in subjects undergoing deltoid-splitting approach compared with those undergoing deltopectoral approach. RR, relative risk.

the presence of publication bias for any of the complications mentioned above (P>0.05; data not shown).

Discussion

The current meta-analysis aimed to provide updated evidence on two surgical methods, DP and DS, for the management of proximal humerus fracture, and to compare clinical and functional outcomes associated with these approaches. The time to bone union was comparatively lower in patients who underwent surgery using the DS approach. Furthermore, the DS approach was associated with improved shoulder function at 3 months but not at 12 and 24 months after the surgery. The ADL in patients treated with the DS approach was significantly improved at the 3-, 6- and 12-month follow-ups as compared with that in the DP group. There were no statistically significant differences in the pain and QOL scores, as well as in the ranges of movement and risk of complications between the two groups. Although the duration of surgery and amount of blood loss were lower in the DS group, this difference was not statistically significant.

A previous review by Xie *et al* (15) compared the outcomes of DS and DP approaches in patients with proximal humerus fracture and indicated that the risk of AVN of the humeral head was significantly lower in those patients subjected to the DS approach. In addition, they reported no significant difference in functional outcomes between the two approaches. These results were different from the outcomes observed in the present meta-analysis. The present results indicated no significant difference in the risk of necrosis between the

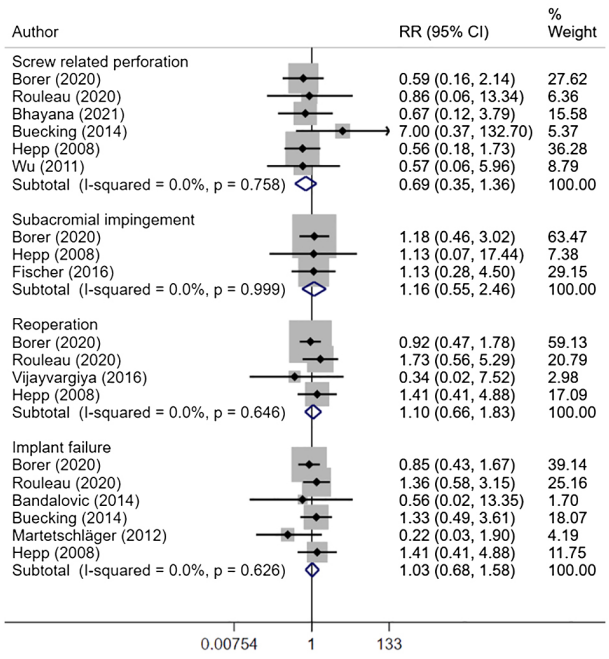

Figure 6. Risk of complications (screw-related perforation, subacromial impingement, reoperation, implant failure) in subjects undergoing deltoid-splitting approach compared with those undergoing deltopectoral approach. RR, relative risk.

two groups. At the same time, improved functional outcome was reported in patients that were managed with the DS approach, which was reflected by the CSS and ADL score. The difference in the results may be explained by the fact that the present meta-analysis included a higher number of peer-reviewed studies. Furthermore, the current study also provided pooled estimates on important outcomes that were not considered in the review by Xie *et al* (15), such as the range of movement and time to bone union. The present study suggested that patients that were managed using the DS approach had a significantly lower time to bone union compared with that in the DP group. There is still a need for studies with improved follow-up data to make strong and reliable recommendations for clinicians treating patients with proximal humerus fractures.

One possible explanation for the improved functional score in patients treated with the DS approach discovered by the present meta-analysis may be that this approach involves a lesser degree of soft tissue manipulation and injury, possibly due to the shorter duration of surgery and fairly direct access to the fracture. On the other hand, the DP approach required extensive dissection and retraction of the soft tissue (34). Furthermore, the DP approach also required a partial release of deltoid insertion and retraction of the deltoid muscle (35). This may potentially lead to functional deficits. In addition, there was a risk of damage to the anterior humeral circumflex artery, particularly the anterolateral branch (36). In general clinical practice, the traditional DP approach is commonly used and most surgeons are familiar with this technique, compared to the DS approach (4,15,23). The choice between these two surgical techniques, to a large extent, may depend on the choice and skill of the treating surgeon and the quality of healthcare facilities available.

The present meta-analysis had certain limitations. For several of the outcomes, the number of studies pooled was small, which may potentially lead to low power of the tests. This made identifying a real effect challenging, as there was limited information to aid in clinical reasoning and establish a more solid foundation for causal inferences. The majority of the included studies (n=10/14) were observational; therefore, the possibility of not having data on important confounders or the inability to adjust for them in the present analytic model could not be excluded. The clinical and functional outcomes may also depend on the nature of the fracture, e.g. the number of fractures. The included studies did not provide data stratified by the nature of fracture and therefore, such a subgroup analysis could not be performed. In addition, the majority of the included studies did not provide baseline information and characteristics of the patients in both groups. Furthermore, data on whether these variables were statistically similar or different were not provided. Therefore, it was unclear if the studies were adjusted for these baseline differences if any of or how these differences could have impacted the final effect sizes.

The current meta-analysis indicated certain advantages of the DS over the DP approach in patients with proximal humerus fracture in terms of improved functional outcomes and reduced time to bone union. There was neither a difference in the risk of complications, pain and QOL scores, nor in the range of movements between the two approaches. With the available data and findings, it was not possible to conclusively elucidate which of the two approaches had improved clinical efficacy and the choice of the procedure should largely depend on the skills of the treating surgeon. A larger number of RCTs with a robust methodology and adequate sample size would be required to provide conclusive answers on the comparative efficacy of the two approaches.

Acknowledgements

Not applicable.

Funding

No funding was received.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

ZW conceived and designed the study. ZW and WS performed the literature search and data collection. ZW and WS analysed the data. WS wrote the paper. All authors have read and approved the final manuscript. Data sharing is not applicable.

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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