Int J Clin Exp Med 2019;12(1):58-66
www.ijcem.com /ISSN:1940-5901/IJCEM0073587

*Review Article*

# Meta-analysis comparing deltoid-splitting approach with deltopectoral approach for treatment of proximal humeral fractures

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Received January 28, 2018; Accepted October 9, 2018; Epub January 15, 2019; Published January 30, 2019

**Abstract:** Background: To compare the effectiveness and safety of the deltopectoral approach with the deltoid-splitting approach for proximal humeral fractures treatment. Methods: We retrieved literature published from January 2002 to July 2016 in the main medical search engines (Medline, PubMed, Embase, Cochrane Library and Wanfang Database) for RCTs and non-RCTs comparing the deltoid-splitting approach with the deltopectoral approach for proximal humeral fractures treatment. Outcomes include the Constant score, operation time, and intraoperative blood loss, as well as the rates of nerve injury, avascular necrosis and non-union. Meta-analyses were performed with Cochrane Collaboration's RevMan 5.0 software. Results: Eight articles with 635 patients were included in this meta-analysis. The deltoid-splitting approach and deltopectoral approach were used to treat 299 and 336 patients, respectively. Compared with the deltopectoral approach group, the deltoid-splitting approach group were associated with better functional scores (SMD=0.46; 95% CI 0.04 to 0.88), reduced operation time (SMD=-0.65; 95% CI -1.09 to -0.21), less intraoperative blood loss (SMD=-1.66; 95% CI -3.08 to -0.25), and a lower rate of avascular necrosis (RR=0.23; 95% CI, 0.08 to 0.64). There was no significant difference in the incidence of nerve injury (RR=4.56; 95% CI 0.53 to 39.11) and non-union (RR=0.49; 95% CI, 0.13 to 1.92). Conclusion: The deltoid-splitting approach technique shows less operative time and blood loss, a lower rate of avascular necrosis and more effective recovery of shoulder function for proximal humeral fracture treatment than does the deltopectoral approach technique. Moreover, the deltoid-splitting approach dose not increase the risk of nerve injury and non-union.

**Keywords:** Proximal humeral fractures, meta-analysis, deltopectoral approach, deltoid-splitting approach

## Introduction

Proximal humerus fractures constitute up to 5% of all adult fractures [1]. During the past several decades, the incidence of these fractures appears to be increasing with the increase in the proportion of older adults [2]. The treatment of proximal humeral fractures remains controversial. Conservative treatment is appropriate for most nondisplaced or minimally displaced proximal humeral fractures [3]. Surgery is recommended for displaced and unstable fractures, including locking plate, tension band, percutaneous K-Wire, intramedullary nails and hemiarthroplasty replacement [4]. Of these surgical techniques, internal fixation is the most commonly used technique for the majority of fractures.

Historically, the deltopectoral approach was the most common approach for plate fixation of proximal humeral fractures. The deltopectoral approach is sometimes associated with soft tissue injury and impaired blood supply to the proximal humerus [5]. This approach provides only limited access to the posterolateral aspect of the shoulder and the view of a retracted greater tuberosity fragment in this area may be restricted. As an alternative, the deltoid-splitting approach can provide good visualisation of the posterolateral aspect of the shoulder joint without extensive soft tissue dissection or fo-

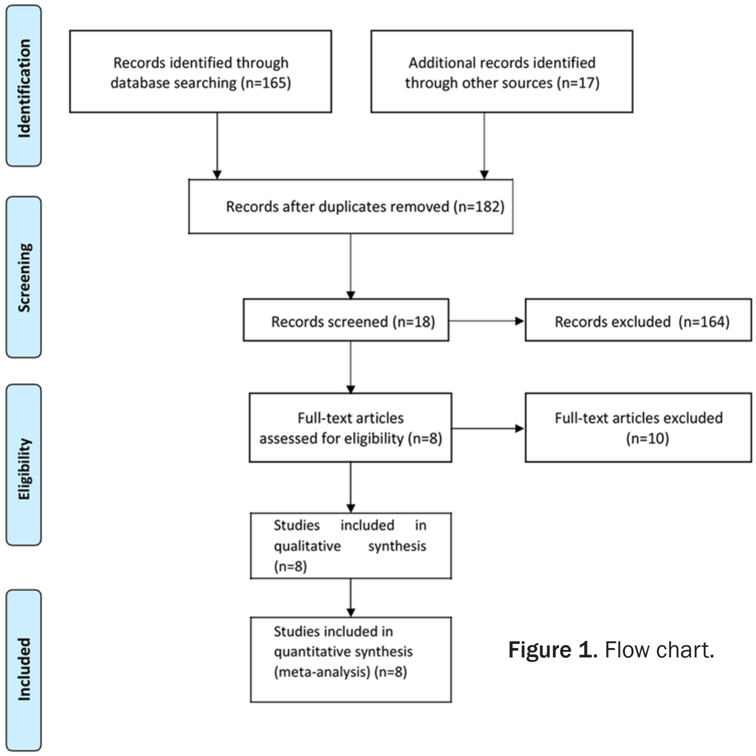


**Figure 1**. Flow chart.

rcible retraction [6]. The deltoid-splitting approach can reduce the postoperative complications and promote functional recovery of the shoulder postoperatively. However, according to some studies, the deltoid-splitting approach may injury the anterior branch of the axillary nerve [7]. Thus far, only few studies have directly compared the long-term results of deltopectoral versus deltoid-splitting approaches for the treatment of proximal humeral fractures and clear differences could not be established with respect to shoulder function, patient satisfaction, and complication rates.

In this study, we perform a meta-analysis of the included studies to evaluate clinical results comparing the deltoid-splitting approach with the deltopectoral approach for the treatment of proximal humeral fractures. We combine the data from all available studies to access the best evidence currently.

## Materials and methods

*Search strategy*

We perform a search of the literature on proximal humeral fracture published from January 2002 to July 2016 in Medline, PubMed, Embase, Cochrane library and Wanfang Database. The search for pertinent studies is conducted with the following terms: 'proximal humeral fracture', 'deltoid-splitting approach', 'deltopectoral approach', 'ORIF', and 'Minimally invasive'. No language is restricted. The search process is shown in **Figure 1**. Only studies performed on adult populations is included.

*Inclusion and exclusion criteria*

Studies are included in the meta-analysis if they met the following criteria: (1) published RCTs and non-RCTs on proximal humeral fractures; (2) a minimum case of 10 patients; (3) acute fracture (i.e., within 14 days after trauma); (4) outcomes include operation time, intraoperative blood loss, Constant score and complication rate; and (5) at least twelve months of follow-up. Studies are excluded if the studies contain (1) conservative treatment data, or (2) open fractures.

*Data extraction*

Search result screening and data extraction are conducted by two independent reviewers, and the corresponding authors of these studies are consulted to gain complete data when necessary. The data extracted are participant sample size and characteristics, the tests used and results.

*Statistical analysis*

Study data are pooled together and analysed with Cochrane Collaboration's RevMan 5.0 software. Relative risk (RR) with 95% confidence intervals (CIs) is calculated for dichotomous outcomes. Continuous data are summarised using the standard mean differences (SMD) and respective 95% confidence intervals (95% CI). Heterogeneity among studies is evaluated by Cochran's Q-statistic and $I^2$ parameter testing. Additionally, $P<0.05$ or $I^2>50\%$ is considered to indicate a heterogeneous nature.

**Table 1.** Characteristics of included studies

| Study | Study design | No. of patients | | Mean age (years) | | Sex (M/F) | | Mean Follow-up (months) | Fracture type | Quality assessment score | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | DS | DP | DS | DP | DS | DP | | | Jadad | Minors |
| Hepp 2008 | P | 39 | 44 | 64 | 65.5 | 12/27 | 7/37 | 12 | Neer: Two part, three part and four part | - | 20 |
| Wu 2010 | R | 28 | 32 | 58.6 | 57.7 | 9/19 | 6/26 | 32.4 | AO/ASIF: A, B, C | - | 18 |
| Martetschläger 2012 | R | 37 | 33 | 59 | 56 | 13/24 | 21/12 | 33 | Neer: Two part, three part and four part | - | 19 |
| Buecking 2014 | RCT | 60 | 60 | 69 | 67 | 12/48 | 16/44 | 12 | Neer: Two part, three part and four part | 4 | - |
| Lin 2014 | R | 43 | 43 | 63 | 61 | 16/27 | 12/31 | >12 | AO/ASIF: A, B, C | - | 16 |
| Liu 2015 | R | 39 | 52 | 60.2 | 61.7 | 17/22 | 25/27 | 24 | Neer: Two part, three part and four part | - | 19 |
| Liu 2016 | R | 33 | 42 | 50.3 | 52.1 | 12/21 | 16/26 | 14.2 | Neer: type II, type III | - | 18 |
| Fischer 2016 | P | 20 | 30 | 57.6 | 60.6 | 6/14 | 10/20 | 21.5 | AO/ASIF: A, B, C | - | 20 |

RCT: Randomized controlled trial; P: Prospective comparative study; R: Retrospective cohort study; DS: Deltoid-splitting approach; DP: Deltopectoral approach.

When substantial heterogeneity is detected, a random-effects model analysis is used. If heterogeneity is not detected, the pooled estimate is presented in the fixed effect model. Subgroup analysis is conducted to find the source, if possible, under significant heterogeneity.

*Assessment of methodological quality and publication bias*

The modified Jadad scale is applied to assess the quality of RCTs, and a score ≥4 was considered a high-quality article [8]. For non-RCTs, we assess methodological quality using methodological index for non-randomised studies (MINORS) scale [9].

Possible publication bias regarding to the primary outcome functional score is evaluated by the Begg's rank correlation test and the Egger's regression test. Both analyses are performed using STATA 10.0 software. All statistical tests are two-sided, and a *P* value <0.05 is considered statistically significant.

## Results

A total of 182 potentially relevant articles have been selected. By reviewing the abstract and the full text, one RCT [10], two prospective comparative studies [11, 12] and five retrospective cohort studies [6, 13-16] meet the eligibility criteria for the meta-analysis. All studies are published in English. **Table 1** shows the basal line of patient characteristics. The sample size ranges from 50 to 120. Buecking 2014 [10] reports a low risk of selection bias, as allocation concealment is based on presealed randomisation envelopes; and this study is not blind. The Jadad score is 4. Seven studies that included prospective or retrospective comparative studies are assessed with MINORS score. Two studies score 20, two scored 19, two scored 18, and one scored 16. Two prospective comparative studies achieved higher scores than others. The follow-up period ranges from 12 to 33 months. There is little evidence of publication bias regarding primary outcome functional score in relation to risk of intervention, as indicated by the Begg's test (P=1) and Egger's test (P=0.538). **Table 2** presents the clinical outcomes.

Functional outcomes with Constant score are reported in eight studies. As we find significant heterogeneity (P<0.00001, $I^2$=85%) between studies, a random-effect model is used. The Constant scores in the deltoid-splitting approach group are superior to those in the deltopectoral approach group with a significant difference (SMD=0.46; 95% CI 0.04 to 0.88). A subgroup analysis according to RCT and non-RCT is conducted to find possible heterogeneity. The subgroup analysis of the non-RCT group has shown better functional recovery in the deltoid-splitting approach group (SMD=0.26; 95% CI 0.08 to 0.43, P=0.80, $I^2$=0%) (**Figure 2**).

Six studies with 515 patients report data on operative time. The overall outcomes are based on a random-effect model when significant heterogeneity is found (P<0.0001, $I^2$=83%). Comparing with the deltopectoral approach, the deltoid-splitting approach can significantly decrease the operative time (SMD=-0.65; 95% CI -1.09 to -0.21). A subgroup analysis according to RCT and non-RCT is carried out. The subgroup analysis of the non-RCT group has shown better functional recovery in the deltoid-split-

**Table 2.** Outcomes of included studies

| Study | Operative time (minutes) | | Blood loss (ml) | | Constant score | | Nerve injury | | AVN | | Nonunion | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DS | DP | DS | DP | DS | DP | DS | DP | DS | DP | DS | DP |
| Hepp 2008 | 66.5±17.8 | 85.9±28.1 | NR | NR | 81±22.3 | 73.1±13.6 | 0 | 0 | 1 | 3 | NR | NR |
| Wu 2010 | 123.8±39.6 | 114.6±31.3 | 121.1±68.5 | 137.6±101.7 | 78.3±11.0 | 76.9±13.1 | 0 | 0 | 0 | 3 | 1 | 1 |
| Martetschläger 2012 | NR | NR | NR | NR | 75.1±17.5 | 72.8±19.6 | 0 | 0 | 1 | 6 | 1 | 1 |
| Buecking 2014 | 62±2.9 | 67±3.8 | NR | NR | 81±3.8 | 73±4.9 | 0 | 0 | 0 | 0 | NR | NR |
| Lin 2014 | 71.0±8.7 | 79.0±11.7 | 126.0±54.8 | 213.0±68.4 | 72.5±12 | 71.2±14 | 1 | 0 | NR | NR | 0 | 0 |
| Liu 2015 | 81.8±18.3 | 91.0±18.4 | 172±54.2 | 205±73.6 | 81.0±5.0 | 79.2±7.6 | 0 | 0 | 0 | 1 | 0 | 1 |
| Liu 2016 | 50.60±12.18 | 58.84±16.22 | 130.20±20.07 | 326.28±50.80 | 86.7±6.06 | 81.8±11.82 | 2 | 0 | 0 | 4 | 0 | 3 |
| Fischer 2016 | NR | NR | NR | NR | 81.6±16.1 | 76.3±18.6 | 0 | 0 | 0 | 1 | 0 | 0 |

NR: Not reported; D-S: Deltoid-split approach; D-P: Deltopectoral approach.

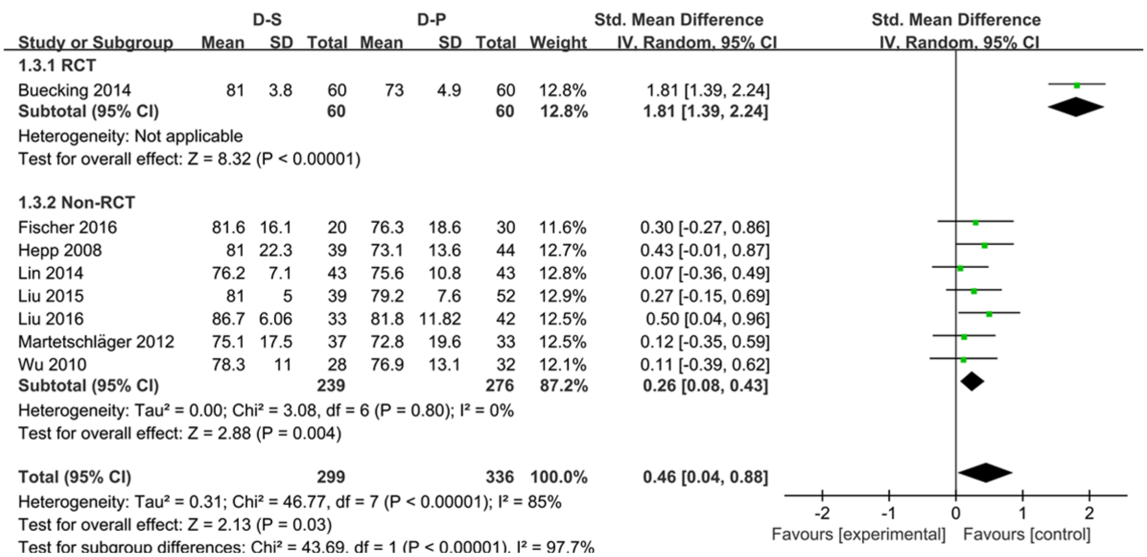


**Figure 2.** Meta-analysis of Constant score.

ting approach group (SMD=-0.49; 95% CI -0.84 to -0.14, P=0.02, $I^2$=66%) (**Figure 3**).

Intraoperative blood loss is accessed across four studies. A random-effect model is used when there is significant heterogeneity (P<0.00001, $I^2$=96%). We find lower intraoperative blood loss in the deltoid-splitting approach group than in the deltopectoral approach group (SMD=-1.66; 95% CI -3.08 to -0.25) (**Figure 4**).

Eight studies provide data on nerve injury resulting from the deltoid-splitting approach or deltopectoral approach, including 3 of 299 and 0 of 336, respectively. No significant differences are found between the two groups (RR=4.56; 95% CI 0.53 to 39.11; P=0.74, $I^2$=0%). A subgroup analysis according to RCT and non-RCT is carried out. The subgroup analysis of the non-RCT group has shown no significant difference between the two interventions (RR=4.56; 95% CI 0.53 to 39.11; P=0.74, $I^2$=0%) (**Figure 5**).

Seven studies provide data on the rate of avascular necrosis. Pooled results show that the rate in the deltopectoral approach group is significantly higher than that in the deltoid-splitting approach group (6.1% vs. 0.8%, respectively; RR=0.23; 95% CI, 0.08 to 0.64; P=0.97, $I^2$=0). A subgroup analysis according to RCT and non-RCT is carried out. The subgroup analysis of the non-RCT group has shown a higher rate of avascular necrosis in the deltopectoral approach group (RR=0.23; 95% CI, 0.08 to 0.64; P=0.97, $I^2$=0) (**Figure 6**).

Six studies report data on the rate of non-union. There is no significant heterogeneity (P=0.80, $I^2$=0). This study uses a fixed-effect model, and no significant difference is found between the

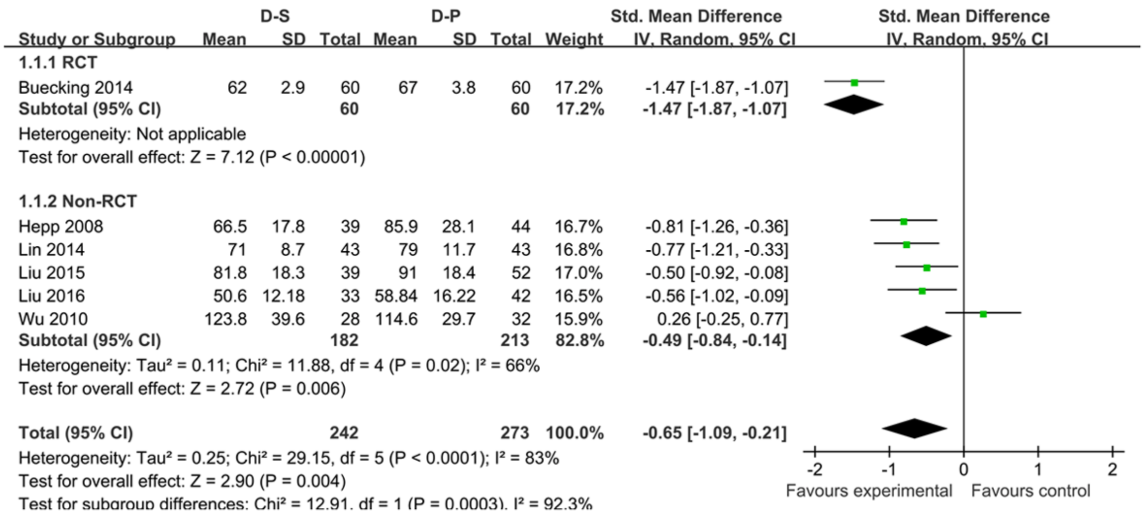


**Figure 3.** Meta-analysis of operative time.

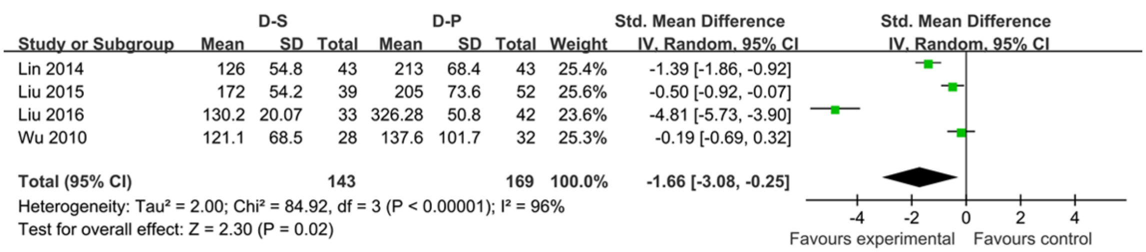


**Figure 4.** Meta-analysis of intraoperative blood loss.

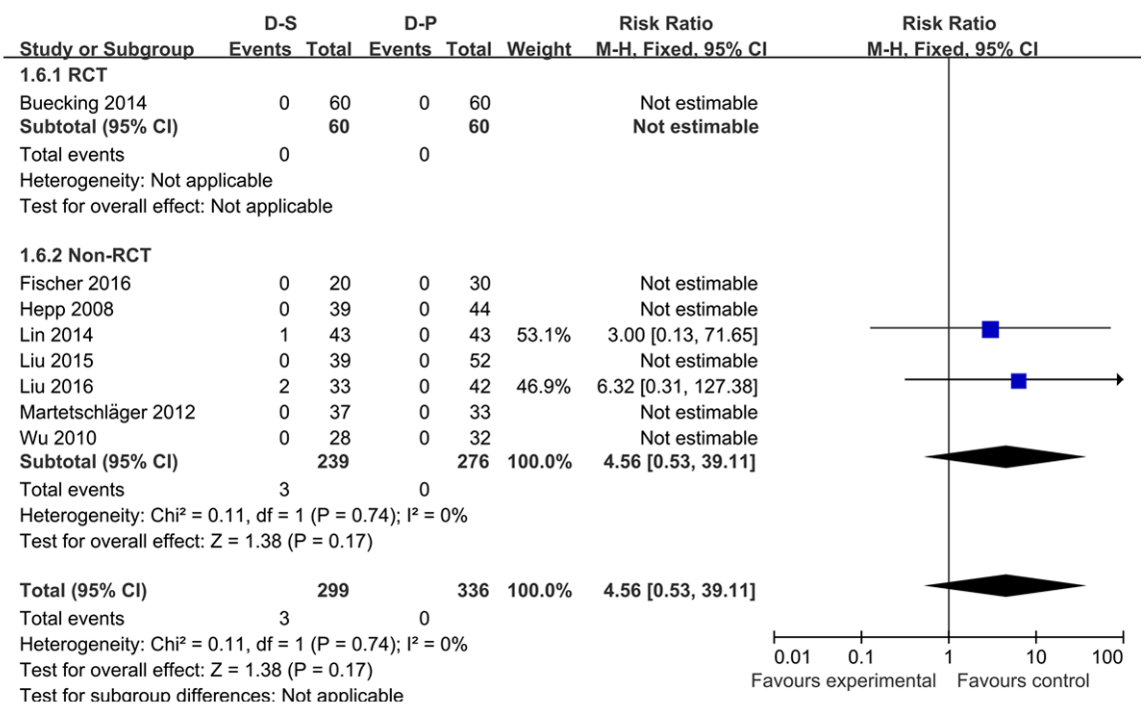


**Figure 5.** Meta-analysis of rate of nerve injury.

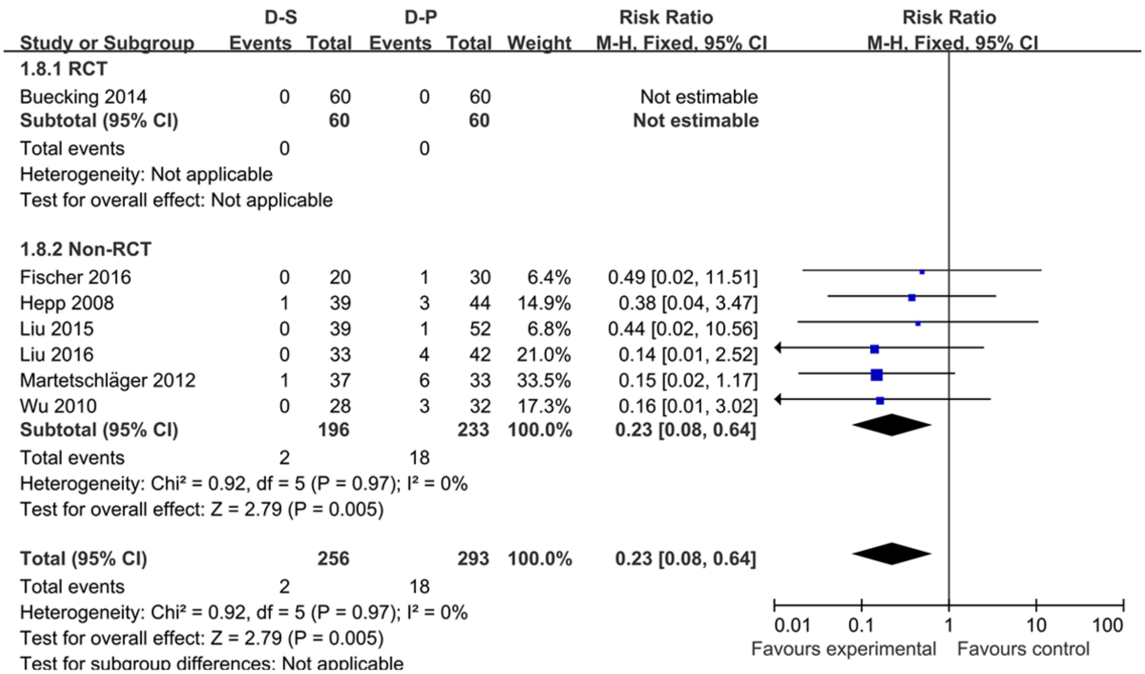


**Figure 6.** Meta-analysis of rate of avascular necrosis.

deltoid-splitting approach group and deltopectoral approach group regarding the rate of non-union (RR=0.49; 95% CI, 0.13 to 1.92) (**Figure 7**).

Other identified outcomes are insufficient for this meta-analysis. For example, Liu 2016 reports a significantly shorter length of incision in the deltoid-splitting approach group. Hepp 2008 finds no significant difference in pain, activities of daily living, power and DASH score between groups.

## Discussion

To our knowledge, this is the first systematic review and meta-analysis comparing the deltopectoral approach with the deltoid-splitting approach for the treatment of proximal humeral fractures. A total of 565 patients from seven studies are included in this meta-analysis. Compared with the deltopectoral approach, the deltoid-splitting approach is associated with better functional score, less operation time and intraoperative blood loss, and lower rate of avascular necrosis. There is no significant difference in the incidence of nerve injury and non-union.

One RCT, two PCTs and five CCTs meet the inclusion criteria of meta-analysis and have been published since 2008. All included studies show comparable baseline data without providing the intention to treat analysis. When pooled results show significant heterogeneity, a subgroup analysis according to RCT and non-RCT is performed in this paper to determine the possible source.

Currently, the deltopectoral approach is widely used as a standard 'workhorse' [17]. Using this approach, surgeons benefit from the excellent exposure of the anterior structures, including the humeral head and lesser tuberosity. The lack of a need to dissect any vascular structures and no risk to the axillary nerve make this approach popular with most orthopaedic surgeons [18]. However, excessive soft tissue stripping destroys the local blood supply and integrity of the deltoid, which may increase the risk of avascular necrosis and restrict postoperative functional recovery [19]. Moreover, more difficult visualisation of greater tuberosity fragment has been noted.

The deltoid-splitting approach offers an alternative option for proximal humeral fracture fixation, as it provides more direct visualisation of the greater tuberosity fragment with less soft tissue dissection and periosteal stripping [20]. Gardner et al [5] concludes that plating through

| Study or Subgroup | D-S Events | D-S Total | D-P Events | D-P Total | Weight | Risk Ratio M-H, Fixed, 95% CI |
|---|---|---|---|---|---|---|
| Fischer 2016 | 0 | 20 | 0 | 30 | | Not estimable |
| Lin 2014 | 0 | 43 | 0 | 43 | | Not estimable |
| Liu 2015 | 0 | 39 | 1 | 52 | 20.3% | 0.44 [0.02, 10.56] |
| Liu 2016 | 0 | 33 | 3 | 42 | 48.5% | 0.18 [0.01, 3.38] |
| Martetschläger 2012 | 1 | 37 | 1 | 33 | 16.6% | 0.89 [0.06, 13.70] |
| Wu 2010 | 1 | 28 | 1 | 32 | 14.6% | 1.14 [0.07, 17.44] |
| **Total (95% CI)** | | **200** | | **232** | **100.0%** | **0.49 [0.13, 1.92]** |
| Total events | 2 | | 6 | | | |

Heterogeneity: Chi² = 1.00, df = 3 (P = 0.80); I² = 0%
Test for overall effect: Z = 1.02 (P = 0.31)

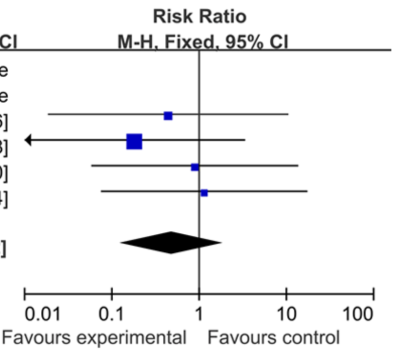


**Figure 7.** Meta-analysis of rate of non-union.

a minimally invasive anterolateral acromial approach allows direct access to the appropriate plating zone, a bare spot between the humeral head-penetrating vessels from the anterior and posterior circumflex system. In our meta-analysis, the deltoid-splitting approach seems superior to the deltopectoral approach with less operation time and intraoperative blood loss. Explicit exposure and convenient surgery result in decreased surgery duration and blood loss, as shown in our meta-analysis.

Functional outcomes are evaluated with Constant score. The analysis of Constant score has shown better functional recovery in the deltoid-splitting approach group, and the result is consistent with subgroup analysis in the non-RCT group. Hepp et al [11] hypothesised that more extensive dissection and the resultant more extensive scar in the deltoid muscle produced more deltoid atrophy in the deltopectoral approach than in the mini-open repair group. Moreover, the deltoid-splitting approach is able to distinctly expose the displaced greater tuberosity, thereby facilitating reduction and fixation with a locking plate. Anatomic reduction of the greater tuberosity is important for the recovery of shoulder function [21]. Liu [15] reported a quicker shoulder function recovery in the deltoid-splitting approach group.

The deltoid-splitting approach has the potential risk of causing injury to the anterior branch of the axillary nerve during the muscle splitting [10]. Several anatomical studies report that the axillary nerve proceeds in a predictable way [22, 23]. Apaydin et al [24] finds the distance from the nerve to the tip of the acromion is approximately 5-7 cm. Therefore, the current opinion agrees with Smith et al [25] that the approach is a safe choice when correctly implemented with palpating or visualising the nerve before plate insertion and using the longer 5-hole PHILOS plate to insert the screws a certain distance above and below the lateral branch of the axillary nerve. In our meta-analysis, there is no significant difference in the incidence of nerve injury between the deltopectoral approach with deltoid-splitting approach. The deltoid-splitting approach requires familiarity with the anatomy of the proximal humerus and much more experience. Although the approach theoretically places fewer anatomic structures at risk for iatrogenic injury, care must be taken to avoid over-retraction and soft-tissue injury while performing this exposure.

Decreased soft tissue stripping favours the blood supply of local tissue, which is also important for successful clinical outcome [26]. In our meta-analysis, the deltopectoral approach group reports a higher rate of avascular necrosis after locking plate osteosynthesis compared with the deltoid-splitting approach technique. It is concluded that the deltoid-splitting approach is more protective of the blood supply of the humeral head.

Although satisfactory operative results (better functional score, less operation time and intraoperative blood loss) and low rate of avascular necrosis are achieved with the deltoid-splitting approach, it should be noted that not all proximal humeral fractures are suited for this incision. This approach is unable to distinctly expose the anteromedial region of the proximal humerus in the 4-part fracture with displacement and separation of lesser tuberosities and medial cortex, making it difficult to reconstruct the medial column [27] and causing severe complications, such as malreduction and Varus fracture collapse [28]. Sohn et al [29] recommends a neck-shaft angle >120° that cannot be obtained using the MIPO technique through the deltoid-splitting approach for 4-part fractures of the proximal humerus. Despite the involvement of 4-part fractures, this meta-analysis reports satisfactory clinical outcomes in the deltoid-splitting approach group. Specific subgroup analyses according to different fracture types are required in the future.

Our analysis indicates that the deltoid-splitting approach is superior to the deltopectoral approach for the treatment of proximal humeral fractures. However, this study has several limitations. (1) Only eight reports are included, and the sample size of each study is small, which would influence the results. (2) Seven non-RCTs are included in this meta-analysis; thus, the evidence is lowered. (3) A subgroup analysis according to RCT and non-RCT is conducted to find possible heterogeneity. Data heterogeneity is also from patient population, fracture type and outcome measures. (4) Three of the included studies reported only the median, range, and the size of the trials when we need the mean value and the standard deviation to pool the data. A simple method was used according to Hozo et al [30] to calculate the SDs and certainly caused data bias. This available method widely improved the inclusiveness of all trials for the meta-analyses studies, and this bias can be lower with large samples.

The systematic review is the first to evaluate the safety and efficiency of the deltoid-splitting approach compared with those of the deltopectoral approach for the treatment of proximal humeral fracture. High-quality RCTs and well-designed studies are still needed to detect clinical benefit or other adverse effects in the future.

## Conclusion

The deltoid-splitting approach technique shows less operative time and blood loss, a lower rate of avascular necrosis and more effective recovery of shoulder function for the treatment of proximal humeral fractures than does the deltopectoral approach group. Moreover, the deltoid-splitting approach dose not increase the risk of nerve injury and non-union.

## Acknowledgements

Key Discipline Construction Project of Pudong Health Bureau of Shanghai (PWZx2014-17).

## Disclosure of conflict of interest

None.

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## References

[1] Neer CS 2nd. Displaced proximal humeral fractures. I. Classification and evaluation. J Bone Joint Surg Am 1970; 52: 1077-1089.
[2] Palvanen M, Kannus P, Niemi S and Parkkari J. Update in the epidemiology of proximal humeral fractures. Clin Orthop Relat Res 2006; 442: 87-92.
[3] Iyengar JJ, Devcic Z, Sproul RC and Feeley BT. Nonoperative treatment of proximal humerus fractures: a systematic review. J Orthop Trauma 2011; 25: 612-617.
[4] Murray IR, Amin AK, White TO and Robinson CM. Proximal humeral fractures: current concepts in classification, treatment and outcomes. J Bone Joint Surg Br 2011; 93: 1-11.
[5] Gardner MJ, Voos JE, Wanich T, Helfet DL and Lorich DG. Vascular implications of minimally invasive plating of proximal humerus fractures. J Orthop Trauma 2006; 20: 602-607.
[6] Lin T, Xiao B, Ma X, Fu D and Yang S. Minimally invasive plate osteosynthesis with a locking compression plate is superior to open reduction and internal fixation in the management of the proximal humerus fractures. BMC Musculoskelet Disord 2014; 15: 1-15.
[7] Esenyel CZ, Dedeoğlu S, Imren Y, Kahraman S, Cakar M and Oztürk K. Relationship between axillary nerve and percutaneously inserted proximal humeral locking plate: a cadaver study. Acta Orthop Traumatol Turc 2014; 48: 553-557.
[8] Oremus M, Wolfson C, Perrault A, Demers L, Momoli F and Moride Y. Interrater reliability of the modified Jadad quality scale for systematic reviews of Alzheimer's disease drug trials. Dement Geriatr Cogn Disord 2001; 12: 232-236.

[9] Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y and Chipponi J. Methodological index for non-randomized studies (minors): development and validation of a new instrument. ANZ J Surg 2003; 73: 712-716.
[10] Buecking B, Mohr J, Bockmann B, Zettl R and Ruchholtz S. Deltoid-split or deltopectoral approaches for the treatment of displaced proximal humeral fractures? Clin Orthop Relat Res 2014; 472: 1576-1585.
[11] Hepp P, Theopold J, Voigt C, Engel T, Josten C and Lill H. The surgical approach for locking plate osteosynthesis of displaced proximal humeral fractures influences the functional outcome. J Shoulder Elbow Surg 2008; 17: 21-28.
[12] Fischer C, Frank M, Kunz P, Tanner M, Weber MA, Moghaddam A, Schmidmaier G and Hug A. Dynamic contrast-enhanced ultrasound (CEUS) after open and minimally invasive locked plating of proximal humerus fractures. Injury 2016; 47: 1725-1731.
[13] Wu CH, Ma CH, Yeh JJ, Yen CY, Yu SW and Tu YK. Locked plating for proximal humeral fractures: differences between the deltopectoral and deltoid-splitting approaches. J Trauma 2011; 71: 1364-1370.
[14] Liu YW, Wei XE, Kuang Y, Zheng YX, Gu XF, Zhan HS and Shi YY. Open vs. closed reduction combined with minimally invasive plate osteosynthesis in humeral fractures. Minim Invasive Ther Allied Technol 2016; 25: 215-221.
[15] Liu K, Liu PC, Liu R and Wu X. Advantage of minimally invasive lateral approach relative to conventional deltopectoral approach for treatment of proximal humerus fractures. Med Sci Monit 2015; 21: 496-504.
[16] Martetschläger F, Siebenlist S, Weier M, Sandmann G, Ahrens P, Braun K, Elser F, Stöckle U and Freude T. Plating of proximal humeral fractures. Orthopedics 2012; 35: 1606-1612.
[17] Brunner F, Sommer C, Bahrs C, Heuwinkel R, Hafner C, Rillmann P, Kohut G, Ekelund A, Muller M, Audige L and Babst R. Open reduction and internal fixation of proximal humerus fractures using a proximal humeral locked plate: a prospective multicenter analysis. J Orthop Trauma 2009; 23: 163-172.
[18] Pennington SD and Duralde XA. Locking plate fixation for proximal humerus fractures. Am J Orthop (Belle Mead NJ) 2014; 43: 302-308.
[19] Robinson CM and Murray IR. The extended deltoid-splitting approach to the proximal humerus: variations and extensions. J Bone Joint Surg Br 2011; 93: 387-392.
[20] Koljonen PA, Fang C, Lau TW, Leung F and Cheung NW. Minimally invasive plate osteosynthesis for proximal humeral fractures. J Orthop Surg (Hong Kong) 2015; 23: 160-163.
[21] Demirhan M, Kilicoglu O, Altinel L, Eralp L and Akalin Y. Prognostic factors in prosthetic replacement for acute proximal humerus fractures. J Orthop Trauma 2003; 17: 181-188; discussion 188-189.
[22] Gardner MJ, Griffith MH, Dines JS, Briggs SM, Weiland AJ and Lorich DG. The extended anterolateral acromial approach allows minimally invasive access to the proximal humerus. Clin Orthop Relat Res 2005; 123-129.
[23] Cetik O, Uslu M, Acar HI, Comert A, Tekdemir I and Cift H. Is there a safe area for the axillary nerve in the deltoid muscle? A cadaveric study. J Bone Joint Surg Am 2006; 88: 2395-2399.
[24] Apaydin N, Tubbs RS, Loukas M and Duparc F. Review of the surgical anatomy of the axillary nerve and the anatomic basis of its iatrogenic and traumatic injury. Surg Radiol Anat 2010; 32: 193-201.
[25] Smith J, Berry G, Laflamme Y, Blain-Pare E, Reindl R and Harvey E. Percutaneous insertion of a proximal humeral locking plate: an anatomic study. Injury 2007; 38: 206-211.
[26] Gardner MJ, Griffith MH, Dines JS and Lorich DG. A minimally invasive approach for plate fixation of the proximal humerus. Bull Hosp Jt Dis 2004; 62: 18-23.
[27] Weeks CA, Begum F, Beaupre LA, Carey JP, Adeeb S and Bouliane MJ. Locking plate fixation of proximal humeral fractures with impaction of the fracture site to restore medial column support: a biomechanical study. J Shoulder Elbow Surg 2013; 22: 1552-1557.
[28] Jung WB, Moon ES, Kim SK, Kovacevic D and Kim MS. Does medial support decrease major complications of unstable proximal humerus fractures treated with locking plate? BMC Musculoskelet Disord 2013; 14: 102.
[29] Sohn HS and Shin SJ. Minimally invasive plate osteosynthesis for proximal humeral fractures: clinical and radiologic outcomes according to fracture type. J Shoulder Elbow Surg 2014; 23: 1334-1340.
[30] Hozo SP, Djulbegovic B and Hozo I. Estimating the mean and variance from the median, range, and the size of a sample. BMC Med Res Methodol 2005; 5: 13.