Locking Plate Fixation versus Hemiarthroplasty for Complex Proximal Humeral Fractures: an Updated Systematic Review and Meta-analysis

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Abstract

Background

This updated systematic review and meta-analysis was performed to compare clinical efficacy and safety of locking plate fixation (LPF) and hemiarthroplasty (HAP) for surgical treatment of complex proximal humeral fractures (PHFs).

Methods

Five electronic databases (PubMed, EMBASE, CNKI, Wanfang database and the Cochrane Library) were searched from their start dates to July 2020 to identify all relevant studies. Our main endpoints were Constant–Murley score (efficacy), and method-related complications and revisions (safety). Cochrane Collaboration's RevMan 5.3 was used for meta-analysis.

Results

Sixteen retrospective trials and one randomized controlled trial involving a total of 936 patients (506 patients in the LPF group and 430 patients in the HAP group) were included in this analysis. The Constant–Murley score was significantly higher with LPF than with HAP [SMD=0.73, 95%CI: (0.23, 1.22)]. In subgroup analysis however, there was no significant difference in Constant-Murley score between LPF and HAP for four-part fractures [SMD=0.35, 95%CI (-0.07, 0.77)] or for subjects over 60 years of age [SMD=0.54, 95%CI: (-0.45, 1.52)]. Revision rate [OR=3.61, 95%CI (1.99, 6.56)] and postoperative complications [OR=1.80, 95%CI (1.24, 2.61)] were significantly lower with HAP than with LPF.

Conclusions

In general, for treatment of complex PHFs, LPF was superior to HAP in postoperative shoulder joint function assessed by the Constant–Murley score. However, there was no significant difference in efficacy for patients with four-part fractures or those older than 60 years of age. Since LPF was associated with significantly higher revision and postoperative complications rates, we suggest that HAP should be considered the preferred procedure for patients older than 60 years with four-part proximal humeral fractures.

Introduction

Proximal humeral fracture (PHF) is one of the most frequent fractures in adults, especially elderly women [1–2]. Its incidence rate increases with age and numbers are increasing yearly as the population ages [3–4]. It is closely associated with osteoporosis and falls [1,3–4], and is the third most common osteoporotic nonvertebral fracture type after hip and forearm fractures [1, 3, 5].

Most simple PHFs are non-displaced or minimally displaced fractures, and can be treated conservatively with good outcomes [6]. Complex PHFs, however, are often complicated by injury to the humeral head

blood supply, to the rotator cuff and to other soft tissues, and surgical treatment is necessary if the patient's condition allows it. There are several operative techniques, all with different advantages and disadvantages, including pinning, locking plate fixation (LPF), hemiarthroplasty (HAP) and reverse shoulder arthroplasty.

With the recent development of prosthetic/fixation devices and improvements in surgical techniques, LPF and HAP have become widely used for the surgical treatment of complex PHFs [7]. The clinical effects of these two surgical techniques have been compared in retrospective studies and randomized controlled trials (RCTs), but with no firm conclusion that one was better or safer than the other [8–24]. The purpose of this meta-analysis was to evaluate these two methods for effectiveness and post-surgical complications including the need for revision surgery.

Materials And Methods

Meta-analyses principles

The meta-analysis followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses, <https://osf.io/2v7mk/>) guidelines [25] and was registered at International Prospective Register of Systematic Reviews (number: CRD42020204883).

Search strategy

Published studies were retrieved from five databases (PubMed, EMBASE, CNKI, Wanfang database, and the Cochrane Library) from their start dates to June 2020. Search terms including “proximal humerus fracture”, “internal fixation”, “locking plate fixation”, “hemiarthroplasty”, and “arthroplasty” were used individually and in combination. There were no restrictions on publication language.

Study selection

The inclusion criteria were: (i) closed PHFs treated with LPF or HAP; (ii) age ≥ 21 years old; (iii) X-ray or CT to confirm the diagnosis of the complex PHFs (three-/four-part); (iv) follow-up for at least six months with complete clinical data. The exclusion criteria were: (i) open, obsolete, oncologic/pathologic, and other types of PHFs; (ii) closed PHFs not treated with LPF or HAP; (iii) fixation with allograft strut augmentation; (iv) age < 21 years old; (v) reviews, meta-analyses, case reports, letters, editorial articles and retracted papers.

Data extraction

A standardized selection protocol was designed and two investigators (Xu-gang Li and Xiao-yang Qi) independently extracted the data to identify studies meeting the inclusion criteria. Any disagreements were resolved through discussion with a third investigator (Xu-sheng Qiu). The following parameters were extracted from the final list of studies included: first author, publication year, age range, country, research

design, number of cases, average age, gender, intervention, outcomes and follow-up. The main efficacy outcome included was the Constant-Murley score [26], a measure of shoulder function.

Quality assessment and publication bias

Two investigators (Xu-gang Li and Xiao-yang Qi) independently evaluated the methodological qualities and risk of bias of the non-RCTs according to Methodological Index for Nonrandomized Studies (MINORS) [27]. The methodological quality and risk of bias of the RCTs were evaluated as described in the Cochrane Handbook for Systematic Reviews [28].

Statistical analyses

The Cochrane Collaboration’s RevMan 5.3 software was used to perform the statistical analysis and to establish forest plots. Continuous variables are expressed as mean differences (MDs) or standard mean differences (SMDs) with 95% confidence intervals (CIs). For publications that provided only medians and ranges, the method reported by Hozo et al. [29] was used to calculate means and standard deviations. Dichotomous variables are presented as odds ratios (ORs) with 95% CIs. Inter-study heterogeneity was calculated from Cochran's Q test and I² value. When the heterogeneity was low (I² < 50%, P > 0.05), the fixed effect model was used, otherwise, the random effect model was used. When the I² value was inconsistent with the P value, the model used was based on the P value. Differences were considered statistically significant at P < 0.05.

Results

Search results

A total of 503 studies were initially retrieved from the five databases. 234 repeated studies were excluded. A further 128 studies were excluded based on information in the title and abstract. Of the remaining 141 studies, 21 met the inclusion and exclusion criteria, and four were excluded because of data problems. Finally, 17 studies were selected for the analysis. The flow chart for study inclusion and exclusion is shown in Fig. 1.

Study characteristics

There was a total of 936 patients (506 in the LPF group and 430 in the HAP group) enrolled in the included studies. The characteristics of the final 17 included studies are presented in Table 1.

Table 1: Characteristics of included studies

Author	Country	Cases (LPF/HAP)	Test type	Follow-up (months)	Age (Years)	Age range (Years)	Sex (M/F)	Fracture type
Dietrich 2008 ^[8]	Germany	52/59	Retrospective study	12	80.9	>70	17/94	Three-/four-part
Solberg 2009 ^[9]	USA	38/48	Retrospective study	36	66.5	>55	26/60	Three-/four-part
Wang 2009 ^[10]	China	12/10	Retrospective study	20	49	21-75	14/18	Three-/four-part
Wild 2011 ^[11]	USA	42/15	Retrospective study	35	59.4	29-90	15/42	Three-/four-part
Spross 2012 ^[12]	Switzerland	22/22	Retrospective study	30	75.5	42-93	7/37	Neer VI
Cai 2012 ^[13]	China	13/19	RCT	24	71.1	>67	5/27	Four-part
Xu 2012 ^[14]	China	36/27	Retrospective study	20	66	>55	26/37	Three-/four-part
You 2013 ^[15]	China	20/12	Retrospective study	18	71.5	61-85	10/22	Three-/four-part
Zhao 2015 ^[16]	China	24/30	Retrospective study	19	71	>65	23/31	Three-/four-part
Celik 2016 ^[17]	Turkey	35/23	Retrospective study	47	51	25-76	39/19	Three-/four-part
Huang 2016 ^[18]	China	44/35	Retrospective study	12	69	65-77	24/55	Three-/four-part
Shen 2017 ^[19]	China	32/12	Retrospective study	29	78	58-89	21/23	Four-part
Xue 2017 ^[20]	China	20/20	Retrospective study	12	67	60-83	13/27	Three-/four-part
Wei 2018 ^[21]	China	22/13	Retrospective study	8	67.3	51-79	14/21	Three-/four-part
Hao 2018 ^[22]	China	42/55	Retrospective study	6	57	54-69	52/45	Three-/four-part
Qu 2020 ^[23]	China	22/13	Retrospective study	14	69	>60	13-22	Four-part
Ye 2020 ^[24]	China	30/19	Retrospective study	>12	69	>60	21/28	Three-/four-part

LPF locking plate fixation, HAP hemiarthroplasty, M male, F female

Methodological quality and publication bias

Of the 17 included studies, 16 were retrospective studies and one was a RCT. The methodological quality and risk of bias for each study were evaluated as described in Methods (Fig. 2; Table 2). MINORS scores greater than 12 were included in the study ^[27], and the quality index scores of the non-RCTs were 13–18 points (13 for one study, 16 for eleven studies, 17 for one study, and 18 for three studies), indicating a moderate risk of bias. A funnel plot for method-related complications (Fig. 3) showed no obvious bias.

However, the analysis did include a majority of Chinese studies and so publication bias cannot be excluded.

Table 2
MINORS appraisal scores for the included non-RCTs studies.

Study	Methodological items												Total
	A	B	C	D	E	F	G	H	I	J	K	L	
Dietrich 2008	2	2	0	1	0	2	0	0	2	0	2	2	13
Solberg 2009	2	2	0	2	0	2	0	0	2	2	2	2	16
Wang 2009	2	2	0	2	0	2	0	0	2	2	2	2	16
Wild 2011	2	2	0	2	0	2	0	0	2	2	2	2	16
Spross 2011	2	2	0	2	0	2	2	0	2	2	2	2	18
Xu 2012	2	2	0	2	0	2	1	0	2	2	2	2	17
You 2013	2	2	0	2	0	2	0	0	2	2	2	2	16
Zhao 2015	2	2	0	2	0	2	0	0	2	2	2	2	16
Celik 2016	2	2	0	2	0	2	0	0	2	2	2	2	16
Huang 2016	2	2	0	2	0	2	0	0	2	2	2	2	16
Shen 2017	2	2	0	2	0	2	2	0	2	2	2	2	18
Xue 2017	2	2	0	2	0	2	0	0	2	2	2	2	16
Wei 2018	2	2	0	2	0	2	2	0	2	2	2	2	18
Hao 2018	2	2	0	2	0	2	0	0	2	2	2	2	16
Qu 2020	2	2	0	2	0	2	0	0	2	2	2	2	16
Ye 2020	2	2	0	2	0	2	0	0	2	2	2	2	16
MINORS Methodological index for nonrandomized studies.													

A: A clearly stated aim; B: inclusion of consecutive patients; C: prospective collection of data; D: endpoints appropriate to the aim of the study; E: unbiased assessment of the study endpoint; F: follow-up period appropriate to the aim of the study; G: loss to follow-up that is < 5%; H: prospective calculation of the study size; I: an adequate control group; J: contemporary groups; K: baseline equivalence of groups; L: adequate statistical analyses. The items were scored as “0” (not reported), “1” (reported but inadequate), or “2” (reported and adequate)

Results of the meta-analysis

Efficacy (Constant–Murley score)

The Constant–Murley score was recorded in the 10 retrospective studies [8–12,15–17,20,24], and included 263 cases in the LPF group and 235 cases in the HAP group. There was significant heterogeneity ($P < 0.00001$, $I^2 = 84\%$) and so a random effect model was used. In this analysis, the Constant-Murley score was significantly greater in the LPF treated group than in the HAP treated group [SMD = 0.73, 95%CI: (0.23, 1.22), Fig. 4] suggesting that LPF resulted in a better clinical outcome in treatment of PHFs. However, in a subgroup analysis there was no significant difference [SMD = 0.54, 95%CI: (-0.45, 1.52), Fig. 5] in patients more than 60 years old. A subgroup analysis on the fracture type showed a significantly greater Constant–Murley score with LPF compared with HAP in 3-part fractures [SMD = 1.52, 95%CI (1.07, 1.98)] but not in 4-part fractures [SMD = 0.35, 95%CI (-0.07, 0.77), Fig. 6].

Method-related complications

Method-related complications were described in 15 studies [8–9,11–23], which included 457 cases in the LPF group and 397 cases in the HAP group. There was no significant heterogeneity ($P = 0.39$, $I^2 = 6\%$) and a fixed-effect model was used for analysis. There was significant difference between the LPF and HAP groups in method-related complications [OR = 1.80, 95%CI (1.24, 2.61), Fig. 7]. We got the same results [OR = 2.12, 95%CI (1.18, 3.79), Fig. 8] when we separately analyzed patients older than 60 years old based on age range.

Revision

Revision surgery was described in 11 studies [8–9,11–17,19,21], which included 329 cases in the LPF group and 274 cases in the HAP group. There was significant heterogeneity ($P = 0.61$, $I^2 = 0\%$) and a random effect model was used for analysis. There was a significantly higher rate of reoperation after LPF than after HAP [OR = 3.61, 95%CI (1.99, 6.56), Fig. 9] A significantly higher rate was also seen for patients more than 60 years old [OR = 5.66, 95%CI (1.97, 16.24), Fig. 10].

Discussion

The incidence of PHFs is increasing, and is associated with the aging of the World's population [3–4]. The nature of complex PHFs makes them difficult to manage, and it is therefore important to evaluate the postoperative outcomes (efficacy and complications) of the different treatment options for these fractures [30]. The Current surgical methods for the treatment of complex PHFs include pinning, LPF, HAP and reverse shoulder arthroplasty [31]. Pinning is a minimally invasive technique. It can minimize soft tissue damage and aid fracture repair. Pinning, however, is a suitable option only for three- and four-part fractures in patients with good bone quality [32]. Reverse shoulder arthroplasty was first proposed by Grammont et al. [33] and is suitable mainly for patients with rotator cuff joint disease and glenohumeral arthritis, and for comminuted PHFs in the elderly. It is often employed as a rescue measure after the failure of first-line treatment [34]. In this meta-analysis, we compared the two most commonly used

surgical techniques for complex PHFs ^[35], LPF and HAP, in terms of clinical efficacy (Constant–Murley score), method-related complications, and the need for revision surgery.

The main purpose of this surgery is to restore shoulder function as completely as possible. In this regard, this meta-analysis showed LPF to be significantly better than HAP in terms of the overall Constant–Murley score. This result is consistent with a previous meta-analysis by Dai et al. ^[36], though our analysis included more studies and more clinical data. We also conducted subgroup analyses on the age range of the patients and on fracture types, which showed no significant difference in Constant–Murley scores between the two procedures for patients with four-part fractures or older than 60 years. We propose these observations result mainly from fracture-specific factors (comminution and fracture pattern) and age-related deterioration in bone quality. Despite the fixed-angle screw construct created by locked plating irrespective of bone quality ^[37], bone loss combined with severe comminution of the fracture may make it difficult to accurately locate some anatomical landmarks and so affect the anatomical reduction. This is consistent with reduced bone quality as an important factor in the prognosis of PHFs ^[38–40]. Reduced patient compliance because of age and infirmity may also contribute. While based on our analysis it appears that HAP would be the preferred procedure for older subjects with four-part fractures, more data are needed. This includes the comparison of Constant–Murley scores of patients with three-part fractures who are more than 60 years old.

In addition to postoperative functional recovery, postoperative complications and revisions are also important to consider. In this analysis, there were significantly higher rates of total postoperative complications and revisions with LFP compared to HAP. Earlier meta-analyses have shown similar rates of post-operative complications and revisions with the two procedures ^[36,41–42]. We believe that this difference between analyses results from characteristics of the implant, the condition of the fractured end, and the surgeon's technique. To determine if age of the patients was a factor in this difference between studies, we performed a subgroup analysis based on age range of the patients. In patients more than 60 years old, the rates of postoperative complications and revisions were still significantly higher with LPF than with HAP. It should be noted, however, that for older patients with comorbidities and poor surgical tolerance, revision is accompanied by a higher surgical risk and therefore is less well accepted. In these cases surgeons should prioritize revision rather than postoperative function when choosing surgical strategies.

This study has limitations. Only one RCT was included, which itself had limitations and did not have a high level of evidence. The heterogeneity of the efficacy indicator (Constant–Murley score) was relatively large ($I^2 = 84\%$). This may be due in part to differences in surgeons' surgical level and in patients' physical conditions or comorbidities, with the bias caused by these factors not being accurately assessed. So while the conclusions of this study are consistent with previous reports, they should be viewed with caution. Further large sample sized studies, ideally RCTs, are needed to resolve some of the outstanding issues and questions.

Conclusion

This meta-analysis indicates that after treatment of complex PHFs, the overall Constant–Murley score was significantly higher with LPF than with HAP, but for patients with four-part fractures or older than 60 years, there were no significant differences in Constant–Murley score between two groups. Rates of postoperative complications and revisions were significantly higher with LPF than with HAP. Hence, we suggest that HAP should be given priority to patients who are more than 60 years old and have four-part PHFs.

Abbreviations

LPF: locking plate fixation; HAP:hemiarthroplasty; PHFs:proximal humeral fractures; CIs:Confidence intervals; I^2 :Inconsistency index statistic; MD:Mean difference; SMDs:standard mean differences; ORs:Odds ratios

Declarations

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Authors' contributions

Xu-gang Li participated in conception and design of this study. Xu-gang Li and Xiao-yang Qi performed the acquisition of data and the statistical analyses. Xu-gang Li drafted the manuscript. Xu-sheng Qiu revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

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Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Conflict of Interest

None reported.

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Figures

Figure 1

The study selection and inclusion process.

Figure 1

The study selection and inclusion process.

	Random sequence generation (selection bias)
	Allocation concealment (selection bias)
	Blinding of participants and personnel (performance bias)
	Blinding of outcome assessment (detection bias)
	Incomplete outcome data (attrition bias)
	Selective reporting (reporting bias)
	Other bias
Cai 2012	<div><div>+</div></div>
	<div><div>+</div></div>
	<div><div>?</div></div>
	<div><div>?</div></div>
	<div><div>+</div></div>
	<div><div>+</div></div>
	<div><div>?</div></div>

Figure 2

Risk of bias summary of the included randomized control trial. "+": risk of bias not present; "-": risk of bias present; "?": insufficient information to judge risk of bias.

	Random sequence generation (selection bias)
	Allocation concealment (selection bias)
	Blinding of participants and personnel (performance bias)
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	<div><div>?</div></div>
	<div><div>+</div></div>
	<div><div>+</div></div>
	<div><div>?</div></div>

Figure 2

Risk of bias summary of the included randomized control trial. "+": risk of bias not present; "-": risk of bias present; "?": insufficient information to judge risk of bias.

Figure 3

Funnel plot

Figure 3

Funnel plot

Figure 4

Forest plot for Constant–Murley score between the LPF and HAP groups.

Figure 4

Forest plot for Constant-Murley score between the LPF and HAP groups.

Figure 5

Forest plot for Constant-Murley score between the LPF and HAP groups: age>60Y.

Figure 5

Forest plot for Constant-Murley score between the LPF and HAP groups: age>60Y.

Figure 6

Forest plot for Constant-Murley score between the LPF and HAP groups: three-/four-part.

Figure 6

Forest plot for Constant-Murley score between the LPF and HAP groups: three-/four-part.

Figure 7

Forest plot for method-related complications between the LPF and HAP groups.

Figure 7

Forest plot for method-related complications between the LPF and HAP groups.

Figure 8

Forest plot for method-related complications between the LPF and HAP groups: age>60Y.

Figure 8

Forest plot for method-related complications between the LPF and HAP groups: age>60Y.

Figure 9

Forest plot for revision between the LPF and HAP groups.

Figure 9

Forest plot for revision between the LPF and HAP groups.

Figure 10

Forest plot for revision between the LPF and HAP groups: age>60Y.

Figure 10

Forest plot for revision between the LPF and HAP groups: age>60Y.

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