The Impact of Reduction on Survivorship and Outcomes following Locked Plate Fixation of Proximal Humerus Fractures

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INTRODUCTION:

Proximal humerus fracture management remains controversial at present day. Several surgical treatment options exist, and the modality selected may be influenced by a multitude of factors including fracture pattern, patient age, bone quality, and surgeon expertise. There is evidence to suggest that open reduction and internal fixation (ORIF) with locked plating can lead to excellent outcomes. However, mixed results have been reported in some studies. Variables that impact outcome following locked plate fixation, including fracture reduction, require further elucidation. The objectives of this study were to evaluate survivorship and outcomes in a large series of proximal humerus fractures treated with locked plating and to discern the association between fracture reduction and outcome.

METHODS:

This retrospective study included 147 patients from a single institution's orthopaedic trauma registry treated with locked plate fixation for unstable proximal humerus fractures during the period of 2008-2018. Demographic, case-specific, and surgical data were collected. Preoperative fracture pattern, reduction parameters, fixation characteristics, maintenance of reduction, and failure were evaluated on radiography. Follow-up data were collected from charts. Surveys were used to collect patient-reported outcome measures (PROMs). Signs of radiographic failure (new changes suggestive of osteonecrosis, arthritis, nonunion, failure of fixation, hardware fracture, instability, and screw penetration into the joint) and history of reoperation were documented. Analysis was performed on 134 patients with ≥12 months follow up. Survivorship free from revision surgery was calculated using the Kaplan-Meier method. Independent t-tests and chi-squared tests were used to evaluate the association of variables with radiographic failure.

RESULTS:

Mean age was 58±15 years and 97 were female (66%). Baseline patient and fracture characteristics are outlined in **Table 1**. Fracture patterns in 147 patients included 72 four-part fractures (49%), 53 three-part fractures (36%), and 22 two-part fractures (15%), 16 head splits (11%), and 16 fracture-dislocations (11%). Following ORIF, coronal alignment was 135.5±9.84°; 133 fractures were fixed with adequate coronal alignment of 120-150° (90%) and 83 fractures were fixed with neutral coronal alignment of 130-140° (56%). Sagittal reduction was neutral in 138 (88%) and the head was noted to be tilted posteriorly in 9 (6%). The medial column was restored in 114 (78%). Mean follow-up duration was 5±3 years.

Survivorship free from revision surgery was 95% at 1 year, 93% at 2 years, and 89% at 5 years. Revision surgery for failure was performed in 14 patients (10%). Procedures included arthroplasty for posttraumatic arthritis or osteonecrosis in 8 (5%), screw removal for joint penetration in 3 (2%), repair nonunion in 2 (1%), and Latarjet procedure for instability in 1 (1%). Radiographic evidence of failure included avascular necrosis in 11 (7%), arthritis in 10 (7%), nonunion in 3 (2%), screw penetration in 3 (2%), failure of fixation in 2 (1%), and instability in 1 (1%). Preoperative factors associated with postoperative failure included female gender, fracture with head split, and fracture-dislocation ($p<0.05$; **Table 2**). With respect to reduction, a sagittal malreduction with the head tilted posteriorly was associated with failure ($p=0.006$; **Table 3**), while malreduction with coronal alignment outside of 120-150° and calcar malreduction appeared to be associated with failure although statistical significance was not found ($p=0.12$ and $p=0.11$, respectively). Outcomes including range of motion (forward flexion 148±28°) and PROMs (ASES 83±21; QuickDASH 16±19); (**Table 3**).

DISCUSSION AND CONCLUSION:

Survivorship and outcomes following locked plate fixation of proximal humerus fractures were very good in this large series of proximal humerus fractures. Factors associated with failure included fracture pattern (fracture-dislocation and head-splitting fractures) and reduction (sagittal alignment). Locked plate fixation continues to be a viable option for management of unstable proximal humerus fractures.

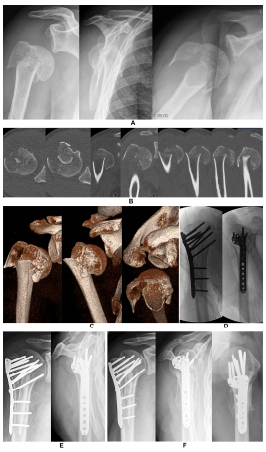

Figure 1

A 58-year old male was referred for definitive treatment following a skiing accident. Radiographs (A) demonstrated a varus impacted 3-part proximal humerus fracture-dislocation involving the anatomic neck and greater tuberosity and significant medial calcar displacement. 2D- and 3D-CT scan images (B,C) further demonstrate the anatomic neck fracture and medial comminution. Open reduction and internal fixation was performed (D) with preparation and insertion of an endosteal fibula allograft for support of the humeral head fragment and a proximal humerus locking plate; including a medial calcar screw into the subchondral bone and dissc to the calcar cortex with an acceptable reduction. Follow-up radiographs at one month (E) demonstrated maintenance of reduction, alignment and fixation. Radiographs at 8 months (F) revealed a healed proximal humerus fracture with maintenance of fixation and reduction.

Table 1. Baseline characteristics of the entire cohort and per group

Variables	All patients (N = 147)
Age (years); mean ± SD	58 ± 15
Age ≥65 years; N (%)	50 (34%)
Follow-up (months); mean ± SD (range)	56 ± 33 (12 – 154)
Female gender; N (%)	97 (66%)
Fracture fragments: 2	22 (15%)
3	53 (36%)
4	72 (49%)
Fracture type, AO/OTA; N (%)	
11A	26 (18%)
11A1.1	0 (0%)
11A1.2	0 (0%)
11A2.1	13 (9%)
11A2.2	1 (1%)
11A2.3	11 (7%)
11A3	1 (1%)
11B	38 (26%)
11B1.1	32 (22%)
11B1.2	6 (4%)
11C	83 (56%)
11C1.1	12 (8%)
11C1.3	0 (0%)
11C3.1	57 (39%)
11C3.2	6 (4%)
11C3.3	8 (5%)
Coronal alignment (degrees); mean ± SD	135 ± 10
Coronal alignment-angulation (type)	
Varus (<130 degrees)	62 (42%)
Neutral (130-140 degrees)	12 (8%)
Valgus (>140 degrees)	73 (50%)
Sagittal alignment (position of head to shaft)	
Anterior	4 (3%)
Neutral	56 (38%)
Posterior	87 (59%)
Head split (>20% of head involved)	16 (11%)
Fracture dislocation	22 (16%)
Medial Calcar displacement (mm); mean ± SD	11 ± 10
Metaphyseal extension (mm); mean ± SD	9 ± 11
>8mm	66 (45%)

SD indicates standard deviation; N, number

Table 2. Univariate analysis of failure with preoperative characteristics

Variables	All patients (N = 134)	No failure (N = 109)	Failure (N = 25)	P-value
Female gender; N (%)	90 (67%)	69 (63%)	21 (84%)	**0.047**
Age; mn ± SD	59 ± 15	58 ± 15	63± 16	0.095
Age over 65 years; N (%)	47 (35%)	36 (33%)	11 (44%)	0.300
Coronal alignment; mn ± SD	142 ± 37	140 ± 33	155 ± 48	0.152
Coronal alignment, N (%)				0.760
Varus (<130°)	53 (40%)	43 (39%)	10 (40%)	
Neutral (130-140°)	10 (8%)	9 (8%)	1 (4%)	
Valgus (>140°)	71 (53%)	57 (52%)	14 (56%)	
Sagittal alignment, N (%)				0.211
Anterior	4 (3%)	3 (3%)	1 (4%)	
Neutral	53 (40%)	47 (43%)	6 (24%)	
Posterior	77 (57%)	59 (54%)	18 (72%)	
AO Classification, N (%)				0.166
A	22 (16%)	21 (19%)	1 (4%)	
B	36 (27%)	29 (27%)	7 (28%)	
C	76 (57%)	59 (54%)	17 (68%)	
Number of fragments, N (%)				0.120
2	19 (14%)	18 (17%)	1 (4%)	
3	51 (38%)	43 (39%)	8 (32%)	
4	64 (48%)	48 (44%)	16 (64%)	
Head Split; N (%)	15 (11%)	8 (7%)	7 (28%)	**0.008**
Fracture dislocation; N (%)	22 (16%)	11 (10%)	11 (44%)	**<0.001**
Medial Calcar displaced; N (%)	112 (84%)	90 (83%)	22 (88%)	0.765
Medial Calcar displacement; mn ± SD	10 ± 9	9 ± 9	13 ± 9	0.094
Metaphyseal-head extension; N (%)	60 (45%)	52 (48%)	8 (32%)	0.154
Metaphyseal-head extension; mn ± SD	9 ± 12	9 ± 13	6 ± 7	0.194

N indicates number of patients; mn, mean; SD, standard deviation; IQR, interquartile range

Table 3. Univariate analysis of failure with intraoperative and postoperative characteristics

Variables	All patients (N = 134)	No failure (N = 109)	Failure (N = 25)	P-value
Coronal alignment; mn ± SD	136 ± 10	136 ± 9	137 ± 13	0.662
Coronal alignment; N (%)				0.366
Varus (<130°)	27 (20%)	26 (22%)	1 (8%)	
Neutral (130-140°)	70 (52%)	61 (50%)	9 (69%)	
Valgus (>150°)	37 (28%)	34 (28%)	3 (23%)	
Adequate coronal alignment 120-150°	123 (92%)	102 (94%)	21 (84%)	0.124
Posterior sagittal alignment, N (%)	8 (6%)	3 (3%)	5 (20%)	**0.006**
Medial Hinge integrity; N (%)	47 (35%)	40 (37%)	7 (28%)	0.411
Medial Calcar distance; mn ± SD	2 ± 3	2 ± 3	3 ± 4	0.135
Medial Calcar reduced; N (%)	73 (55%)	63 (58%)	10 (40%)	0.107
Gardner criteria; N (%)	102 (77%)	83 (77%)	19 (76%)	0.928
Use of fibula allograftx; N (%)	86 (62%)	68 (64%)	8 (32%)	0.211
>1 Calcar Screws; N (%)	56 (42%)	46 (42%)	10 (40%)	0.830
Calcar Screw distance; mn ± SD	4 ± 4	4 ± 4	4 ± 3	0.154
Calcar Screw within 5mm; N (%)	92 (69%)	73 (67%)	19 (76%)	0.380
Humeral head height reduction; mn ± SD	15 ± 7	15 ± 7	13 ± 7	0.461
VAS Pain, mn ± SD	1 ± 1	1 ± 1	2 ± 1	0.010
ASES; mn ± SD	80 ± 22	83 ± 21	65 ± 21	**0.003**
QuickDASH; mn ± SD	20 ± 22	16 ± 19	36 ± 25	**0.010**
SF-12 Physical; mn ± SD	48 ± 10	49 ± 9	44 ± 12	**0.039**
SF-12 Mental; mn ± SD	53 ± 8	53 ± 8	51 ± 9	0.363
Active forward flexion; mn ± SD	140 ± 37	148 ± 28	112 ± 52	**0.023**
Active abduction; mn ± SD	127 ± 37	133 ± 31	105 ± 48	0.096
Active external rotation; mn ± SD	50 ± 22	55 ± 21	33 ± 17	**0.001**

N indicates number of patients; SD, standard deviation; IQR, interquartile range