

Original Research Article

Radiological parameters in the evaluation of functional outcomes following locking plate fixation of comminuted proximal humerus fractures

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ABSTRACT

Background: The incidence of PHF is about 5% of all fractures that are clinically treated and is more common in elderly females. Locking plates are commonly used for fracture stabilization and provide stable fracture management. But some problems like reduction loss and varus malunion can have a great effect on functional outcomes. This study aimed to assess the role of radiological parameters-neck-shaft angle (NSA) and humeral head height (HHH)-in predicting functional outcomes in comminuted PHF treated with locking plates.

Methods: A retrospective study was done on 50 patients who were treated at Pradyumna Bal Memorial Hospital, KIMS from July 2018 to July 2019 with a minimum followup of one year. The Constant Shoulder Score (CSS) was used to assess functional outcomes. Radiographic parameters were assessed at 1 month, 3 months, 6 months and 1 year after surgery. Data was analysed using Jamovi software version 2.3.28.

Results: The mean age of the study participants was 54 +/- (19) years, which included 29 (58%) males and 21 (42%) females. The fracture union was obtained in 44 (88%) patients and 6 (12%) patients needed revision surgery. The postoperative NSA was 130° (range 120° to 140°) and was found to be related to the higher CSS scores. Patients with optimal NSA and HHH (44 patients, 88%) had significantly better functional outcome (CSS ~85), while patients with nonunion or suboptimal alignment had lower scores (CSS ~60, p<0.05).

Conclusions: Radiological alignment plays an important role in functional outcome following PHF treated with locked plates. A large NSA (>125°) and adequate humeral head height prevent varus malunion and improve shoulder function after surgery. Optimum recovery will be achieved with careful surgical planning and restoration of anatomical alignment.

Keywords: Constant shoulder score, Humeral head height, Locking plate fixation, Neck-shaft angle, Proximal humerus fracture, Varus malunion

INTRODUCTION

Proximal humerus fractures (PHF) make up about 5% of all clinically treated fractures and are especially prevalent among elderly women as a result of osteoporosis and the increased risk of low-energy trauma.¹ The prevalence of

PHF has been increasing over the past few decades, due to the growing elderly population and increasing life expectancy.² PHF may cause severe pain, limited shoulder range of motion and chronic disability, compromising the patient's quality of life.

Locking plates have become one of the most popular surgical procedures in comminuted proximal humerus fracture. The angular stability provided by locking plates provides improved fixation especially in osteoporotic bone, and allow early mobilization. This technique has been proven to be satisfactory in various studies.³ However, after surgical treatment, there are concerns about loss of reduction, failure to fixate, screw cut-out, and varus malunion.

Of these complications, varus malunion caused by loss of reduction in the postoperative period is strongly correlated with poor functional results. Fractures healing with a humeral head-shaft angle of less than 120° have shown to have a higher risk of shoulder dysfunction.⁴⁻⁵ Furthermore, older age correlates screw cutouts. Changes in the height of the humeral head likewise can have a negative impact on shoulder biomechanics and functional outcome. Hence, the radiological parameters like neck-shaft angle (NSA) and humeral head height (HHH) may be useful indicators of postoperative results.⁶⁻⁸

The objective of the present study was to assess the correlation between these radiological parameters with functional results in patients with comminuted proximal humerus fractures treated with locking plate fixation and to determine factors associated with reduction loss and varus malunion.

METHODS

A retrospective observational study was carried out in Pradyumna Bal Memorial Hospital (PBMH), Kalinga Institute of Medical Sciences (KIMS), Bhubaneswar, Odisha. Patients with comminuted proximal humerus fractures (PHF) treated with locking plate fixation were included in the study.

Clinical data of patients treated from July 2018 to July 2019 were analysed. Patients with a follow-up period of more than one year after surgery were included in-order to ensure adequate assessment of fracture healing and functional results. Follow-up data were available up to 2020 or beyond. A total of 50 patients meeting these criteria were included in the study. Patients with pathological or open fractures, associated ipsilateral upper limb injuries, pre-existing shoulder pathology, or polytrauma were excluded. Patients with incomplete clinical records or follow-up of less than one year were also excluded from the study.

The primary objective of the study was to assess the effects of radiological parameters on the functional results after locking plate fixation for comminuted proximal humerus fractures. Functional outcome was measured by the Constant Shoulder Score (CSS), a validated scoring tool that measures pain, activities of daily living, range of motion and shoulder strength. The CSS scores lie between 0 and 100, with higher scores representing higher shoulder

function. Scores were categorized as excellent (86-100), good (71-85), fair (56-70), and poor (<56).

Data on demographics, operative findings and radiological information were retrieved from hospital records. Radiological parameters assessed were neck-shaft angle (NSA), humeral head height (HHH) and fracture union status. These parameters were measured on conventional postoperative radiographs taken at 1 month, 3 months, 6 months and 1 year. These serial evaluations allowed for the evaluation of fracture alignment, fracture reduction and fracture healing over time.

Statistical analysis

Data was entered and analysed using Jamovi software (Version 2.3.28). Data was presented as mean and standard deviation for continuous variables and frequencies and percentages for categorical variables. Demographic, radiological and functional outcome data were summarized using descriptive statistics. Repeated measures analysis of variance (ANOVA) was used to determine differences in neck-shaft angle (NSA), humeral head height (HHH) and Constant Shoulder Score (CSS) between the various follow-up intervals. P value of <0.05 was deemed statistically significant.

RESULTS

A total of 50 patients with comminuted proximal humerus fractures treated with locking plate fixation were included in the study. The mean age of the patients was 54±19 years (range: 24-91 years), with 29 males (58%) and 21 females (42%).

Table 1: Demographic characteristics of study participants (n=50).

Characteristics	Values
Mean age (years)	54±19 (range 24-91)
Male, N (%)	29 (58)
Female, N (%)	21 (42)
Follow-up duration	Minimum 1 year
Fracture type	Comminuted proximal humerus fracture

The fracture union was obtained in 44 patients (88%) within 1 year, while 6 patients (12%) were diagnosed with non-union and underwent revision (Table 2). The union rate was 90%, with no change at final follow up, most fractures having united by the third postoperative month.

The mean neck-shaft angle (NSA) at surgery was 130°±6° (range, 120°-140°) and remained at this level during follow-up (Table 3). Functional outcome was better in those who underwent near-anatomical NSA. Pre- and postoperative humeral head-shaft angles are depicted in representative radiographs in Figure 1 and 2, respectively.

Likewise, humeral head height (HHH) was found to be correlated with shoulder function as shown in Figure 3.

Table 2: Union vs. Non-Union rates at 1, 3, 6 months, and 1 year.

Follow-up intervals	Union status	Count	Percentage (%)
1 month	Non-union	50	100.0
3 months	United	45	90.0
	Non-union	5	10.0
6 months	United	44	88.0
	Non-union	6	12.0
1 year	United	44	88.0
	Non-union	6	12.0

Table 3: Statistical summary (mean, SD, percentiles, range and p value).

Variables*	Mean	Standard deviation	25th Percentile (Q1)	Median (Q2)	75th Percentile (Q3)	Minimum	Maximum	P value**	F value**
NSA_1m	130°	6	125	130	135	120	140	***-----	***-----
NSA_3m	130 °	6	125	130	135	120	140		
NSA_6m	130 °	6	125	130	135	120	140		
NSA_1yr	130 °	6	125	130	135	120	140		
HHH_1m	12mm	2	11	12	14	7	18	0.310	F (3,147) =1.20
HHH_3m	12mm	2	11	12	14	7	18		
HHH_6m	12mm	2	11	12	14	7	18		
HHH_1yr	12mm	2	11	12	14	7	18		
CSS_1m	54	4	52	54	56	40	60	<0.001	F (3,147) =1008.97
CSS_3m	64	6	61	64	68	50	74		
CSS_6m	76	7	74	78	80	58	86		
CSS_1yr	86	8	86	89	90	61	92		

*NSA: Neck shaft angle; HHH: Humeral head height; CSS: Constant shoulder score; **Repeated measures ANOVA done. NSA p value and F value; ***NSA showed no variation across follow-up intervals; therefore, repeated-measures ANOVA was not applicable and no F-statistic or p value was calculated

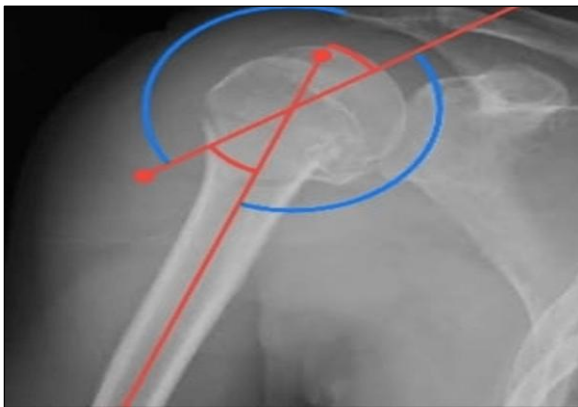


Figure 1: Preoperative radiograph demonstrating proximal humerus fracture with humeral head-shaft angle of 144°.

Constant Shoulder Score (CSS) functional outcomes showed a significant improvement with time ($p<0.001$) (Table 3). The mean CSS increased from 54 ± 4 at one month to 86 ± 8 at one year. Patients who had union of the fracture with good radiological alignment had better

functional scores while patients with non-union and varus malalignment had worse scores. Complications seen at follow-up included 12% non-union, 8% shoulder stiffness, and 4% patients experienced a transient nerve palsy.

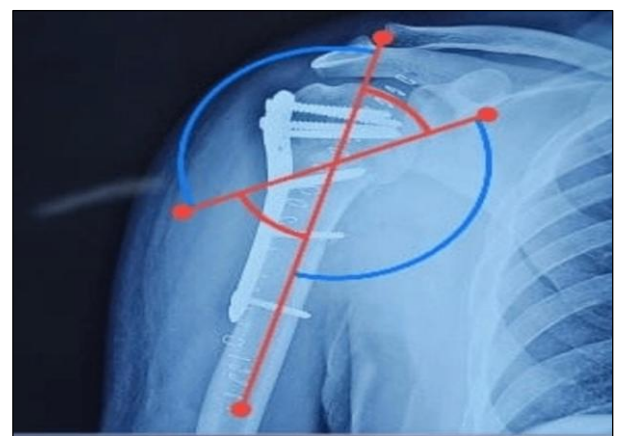


Figure 2: Post operative radiograph following locking plate fixation showing restoration of humeral head-shaft angle to 129°.

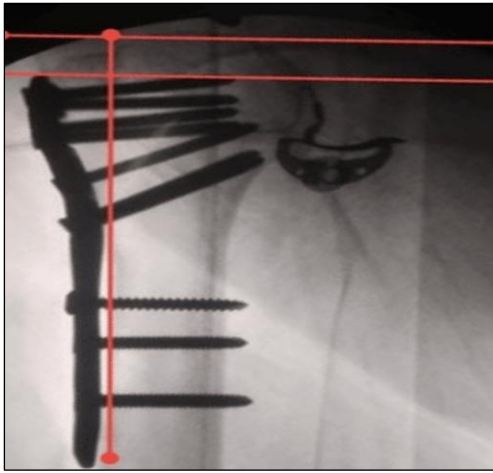


Figure 3: Radiographic measurement of Humeral Head Height (HHH) demonstrating maintained postoperative alignment (2.2mm).

DISCUSSION

Osteoporotic proximal humerus fractures present considerable surgical difficulties because poor bone quality reduces implant stability and increases the likelihood of reduction loss, fixation failure, and humeral head osteonecrosis. Locking plate fixation is widely used for managing displaced and comminuted fractures, while augmentation with calcium phosphate cement may enhance fixation strength. Despite these advances, complications such as osteonecrosis remain problematic and are influenced by factors including patient age, fracture configuration, and vascular compromise. In severely comminuted fractures, the addition of bone allograft to locking plate fixation has shown encouraging outcomes, emphasizing the importance of tailoring surgical management to individual fracture characteristics.⁹⁻¹²

The proximal humerus fracture (PHF) is a significant and increasing clinical problem especially in the elderly. Of these fractures, about 90% occur in individuals older than 60 years, where natural decline in bone density predisposes older individuals to fractures, even after a low-energy fall.¹³⁻¹⁵ The incidence of PHFs is rising and they are now the third most common fracture in older cohorts after femoral and distal radius fractures.¹⁶ Our patients had a mean age of 54 years (range 24-91 years), and a male preponderance (58%). This demographic profile partially differs from the classic epidemiological description of PHFs as predominantly affecting elderly females, which may reflect a higher proportion of higher-energy mechanisms at a tertiary orthopaedic centre.¹⁷

The constant shoulder score improved progressively and significantly from one month to one year, from a mean score of 54 to 86 ($p < 0.001$). The mean CSS for patients with optimal radiological alignment was about 85, compared to a means of about 60 for non-union and suboptimal alignment. A recent systematic review of 514

patients who received locking plate fixation for PHFs reported a mean constant score of 74 at the last follow-up and a long-term PHILOS (Proximal Humerus Internal Locking System) plate study found a mean normalised Constant Score of 88.7 ± 10.9 at a minimum follow-up of 10 years.^{3,18} These benchmarks are also largely comminuted fracture patterns and our one-year CSS of 86 compares favourably with these. There is also evidence that functional outcomes remain stable at 1 year postoperatively and do not significantly change thereafter, making 1 year a clinically relevant endpoint.¹⁹

The postoperative NSA in the current study had a mean of 130° (range 120° - 140°) and patients with a postoperative NSA near to the anatomical normal range (130° - 135°) had significantly higher Constant Shoulder Scores (CSS). The authors' results are consistent with previous literature, which showed that one of the major radiological predictors of functional outcome is NSA. At 6 months, patients with normal NSA had a mean Constant score of 76.63 which was significantly higher than the mean score seen in patients with varus NSA (60) ($p = 0.001$).²⁰ Varus malunion will have a negative effect on rotator cuff biomechanics, which in turn will lead to a decrease in subacromial space and make the deltoid muscle less efficient, thus limiting overhead motion of the shoulder. Factors which contribute to the development of a varus deformity and to adverse functional results include high fracture comminution and inability to restore a continuous medial cortex.²⁰ Moreover, varus progression and screw cutout have been linked to poor functional outcome and poorer Constant Shoulder Score.²¹

The HHH did not change at any of the follow-up times (mean 12 mm; range 7-18 mm) and maintaining the HHH is crucial to keep the tension of the rotator cuff and prevent cranialisation of the plate. Clavert et al found in their study that excessively high positioning of the plate independently worsened constant scores and a screw cutout rate of 13.7% was similarly related to poor functional results, highlighting HHH as an important intraoperative quality indicator alongside NSA.²²

The union rate was 88% and 12% of patients needed revision surgery. In a systematic review of 3422 locking plate PHF cases, the most common complications were varus collapse (6.8%) and non-union (1.5%) with a reoperation rate of 13.8%.²³ A higher non-union rate in our cohort is probably due to the purely comminuted fracture morphology and the older mean age of patients included. Around 16%-36% rates of complications associated with locking plate fixation have been well documented and are, most commonly due to reduction loss, screw perforation, osteonecrosis or metal breakage, all of which can lead to poorer outcomes.²⁴ The loss of medial cortical support shows a strong association with secondary varus collapse and augmentation strategies like calcar-directed screws, fibular allograft, or bone cement may be considered if medial comminution is large.^{9,12}

Age, bone quality and rotator cuff integrity continue to be patient-specific factors that affect the risk of reduction loss. PHFs are the third most prevalent fracture type and the incidence increases dramatically after the age of 50 years and locking screws have an inherent mechanical disadvantage in osteoporotic bone.^{25,11} Systematically using bone mineral density measurement and rotator cuff assessment in the preoperative planning to stratify the patients at risk for suboptimal radiological and functional outcome should be included in future studies.

There are a few limitations to the present study. First, the study was retrospective, single centre and had a small number of participants, thus results may not be generalizable. Second, there was no formal assessment of bone mineral density, therefore it was not possible to analyze osteoporosis as a confounding variable. Third, the Constant Shoulder Score is validated but has subjective elements which can be affected by other factors that do not affect shoulder function. Fourth, no comparator group (conservative management or arthroplasty) was used, which restricts the conclusions regarding the comparative efficacy of locking plate fixation in the comminuted PHF population. Despite these restrictions, the study offers a systematic radiological and functional data set obtained from a well characterised cohort of patients from a single centre with a structured follow-up protocol.

CONCLUSION

Radiological restoration and maintenance of proximal humerus anatomy play a major role in determining functional recovery after locking plate fixation of comminuted proximal humerus fractures. Patients in whom neck-shaft angle and humeral head height were adequately maintained demonstrated better shoulder function and higher Constant Shoulder Scores during follow-up. In contrast, loss of reduction, varus malalignment, and non-union were associated with inferior outcomes and increased postoperative complications.

The findings of the present study highlight the importance of meticulous surgical reduction, preservation of medial support, and stable fixation to minimise secondary collapse and improve fracture healing. Achieving a postoperative neck-shaft angle close to the anatomical range appears particularly important for obtaining satisfactory functional results. Although locking plate fixation remains an effective treatment option, careful attention to fracture pattern, bone quality, and patient-related factors is essential for optimising outcomes in these complex injuries.

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