

Analysis of Proximal Humerus Fractures Treated By Locking Plates.

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Abstract: *Surgical management of proximal humerus fractures are widely accepted with locking plates. However, technical pitfalls often lead to complications which can always be avoided. We analyse the fractures of proximal humerus treated by locked plates in our institute in this study. The importance of minimal soft tissue dissection to preserve the vascularity of the head, indirect methods of reduction, and early mobilization help to achieve good results in these fractures. Patient education towards immediate post-operative rehabilitation should be emphasized.*

I. Introduction

Fractures of the proximal humerus represent approximately 4% of all the fractures and 26% of humerus fractures exclusively¹. Conservative management may be associated with non union, malunion and avascular necrosis resulting in painful dysfunction.² closed reduction with percutaneous pin fixation cannot produce optimal stability biomechanically³. Primary hemiarthroplasty is favoured by many authors but is associated with a large number of complications, and objective functional results which are disappointing⁴. The objective of the osteosynthesis is to reduce the displacement (usually rotation) of each fracture fragment and hold it in place with an implant and thus providing stable reduction and allowing early mobility of the shoulder. With the advent of locking compression plate, open reduction internal fixation (ORIF) of the proximal humerus injuries has become more popular. Proximal locking plates allow rigid fixation as they permit fixation of the displaced tubercles achieving more anatomical reduction of fragments 5. Passive mobility exercises can be started earlier with such rigid fixation. Even good anatomical results achieved at operative repair may lead to poor results unless there is meticulous post operative rehabilitation, which can be more challenging than the operative technique⁶. The indication for surgical management continues to be modified. Fixation techniques are myriad and none is ideal for all cases⁷. This study analyses the results of proximal humerus fractures treated by internal fixation with locking plates.

II. Methodology

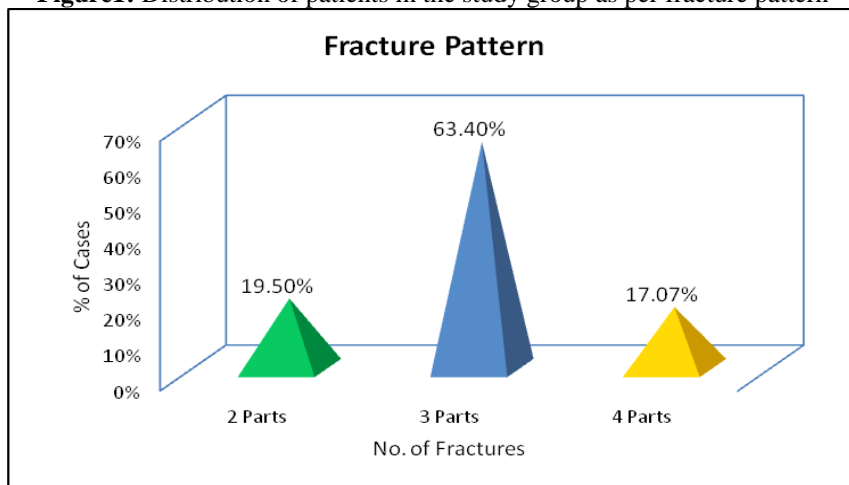
A Prospective Study of consecutive patients with proximal humerus fractures undergoing internal fixation for osteosynthesis with proximal humerus locking plates. 41 patients with proximal humerus fractures, who were willing to participate in the study during the study period, were included in the study during 2014-2016 were included in the study. Open fractures, Undisplaced fractures and Communitated fractures that were operated with hemiarthroplasty of shoulder were excluded from the group. Patient demographics, comorbidities, details of fracture type, mode of injury, associated injuries, are documented. All patients in this study were treated by open reduction and internal fixation with LCP plating. Implants used were PHILOS (Synthes), PERI-LOC (Smith & Nephew), proximal humerus locking plate (PDL Surgicals ltd.) Choice of implants was not specific to fracture pattern and was decided by the operating surgeon as per their familiarity with instrumentation.

Post-operatively limb is immobilized in arm pouch with pendulum exercises of shoulder as tolerated until suture removal at second week. From the second week, shoulder wheel exercises, gentle passive forward flexion, abduction, external and internal rotation exercises as per patient's tolerance were encouraged. If the bone was severely osteoporotic and fixation was less than rigid, motion was delayed, otherwise redisplacement of the fracture fragments could have occurred. By fourth to sixth week, active shoulder strengthening exercises were started. Patients underwent rehabilitation as per protocol. Patients were followed at 6 weeks, 3months and 6 months on OPD basis. Additionally patients were asked to review at 10th week to assess radiological union. During this period in each visit, radiological evaluation for union and clinical evaluation of pain, shoulder function and range of movements were assessed and recorded. Clinically fracture was considered to be united when there was no tenderness at the fracture site and full shoulder function is present. Radiologically fracture was regarded as united when there is no visible fracture line. Functional outcome at each follow up was evaluated by using Constant shoulder score.

III. Results

Of the 42 patients included in the study, one patient was excluded as the fixation was converted to hemiarthroplasty following immediate fixation failure on 3rd post-operative. In our series of forty one patients, eight were in the age group of less than 45 years (19.5%), fifteen in the age group of 45-60 years (36.5%), seventeen in the age group of 60-75 years (41.4%) and one in the age group of greater than 75 years (4.7%). Mean age of the study group is 55.9 years. The common type of fracture observed in our series was three part fracture (Figure 1).

Figure1: Distribution of patients in the study group as per fracture pattern



In our study, choice of implant was not based on fracture pattern and was solely operating surgeon’s decision basing upon financial constraints of the patient and orientation with instrumentation (Table 1).

Table 1: Distribution of type of implant used in the study group

Implant Used	No. of Cases	Percentage
PDL – Prox humerus locking plate	25	60.90%
Synthes- PHILOS	11	26.8%
S & N – Peri-Loc	5	12.1%
Total	41	

Basing on intra operative finding of the void significance, we have used allograft in our patients. Five (11.9%) of the 41 patients were grafted. Three (11.5%) of twenty six patients with 3-part proximal humerus fracture and two of seven patients with 4-part (28.5%) proximal humerus fracture were grafted. The average time taken for radiological union was 10.97 weeks (Range: 8-32 weeks). One patient had non union. At fifth month, patient underwent autologous bone grafting at fracture site from ipsilateral iliac crest and the fracture united. At 3 months of follow up, Constant shoulder score was observed to be poor in six patients (14.6%), fair in twelve patients (29.2%), good in seventeen patients (41.4%) and six (14.6%) patients had excellent outcome. At 6 months of follow up, Constant shoulder score was observed to be poor in six patients (14.6%), fair in eight patients (19.5%), good in twenty patients (48.7%) and seven (17%) patients had excellent outcome. Mean Constant shoulder score in this study group is 66. Patients younger than 45 years have better outcome as compared to older patients in our study group. But there is no significant relation of age with functional outcome (p=0.117). [table 2]

Fracture Pattern (Neer`s Classification)	Functional Outcome – Constant Shoulder Score				Total
	Poor	Fair	Good	Excellent	
2 Parts	0	1	4	4	9
3 Parts	4	5	13	3	25
4 Parts	2	2	3	0	7
Total	6	8	20	7	41

Table 2 : Funtional outcome at 6 months vs Fracture pattern.

Four patients in our study had primary fixation along with allograft. Two of the five patients had union in 10 weeks and three of the five patients had union in 12 weeks. There is no significant relation of usage of allograft with radiological union in our study group ($p=0.369$). In our study group, we have encountered complications in nine patients. Six patients (14.6%) had stiffness of shoulder with poor outcome. Two patients had varus malunion (4.87%). One patient had non union (2.43%). One patient had aseptic necrosis of humerus head (2.43%) and one patient had screw cut through out of the medial sub chondral bone (2.43%). Loss of passive movements of shoulder was noted among six patients in our study group resulting in poor functional outcome. None of them had fixation failure. One patient had non-union leading to severe pain and had to be grafted, but developed stiffness of shoulder. The joint was manipulated at the time of bone grafting, but the patient had poor outcome at final follow up of 6 months. One patient had minimal pain and good range of motion and the clinical result (good) did not correlate with the radiological picture of aseptic necrosis of the humeral head, therefore no hardware removal was required. This patient had 3-part humerus fracture and was operated one day after injury with good reduction after open reduction and internal fixation with locking plate. X ray on 6th week was satisfactory and no sign of medial head collapse was evident. At 3 months follow up medial resorption of humeral head was seen. At 6 months of follow up, patient had minimal pain and good functional outcome. She was followed until 1 year and there was no further progress of aseptic necrosis and no limitation of function of shoulder. At 3rd month of follow up, one patient had pain and x ray showed screw penetrating the medial subchondral bone. Patient had screw removal done and she improved symptomatically. The same patient had varus collapse that healed with varus malunion. Both the two patients who had varus malunion in our study group had medial comminution at injury. One patient had good functional outcome and was not symptomatic (varus = 117^0), while the other patient had fair outcome and was complaining of pain. No revision procedure was performed in either of the case.

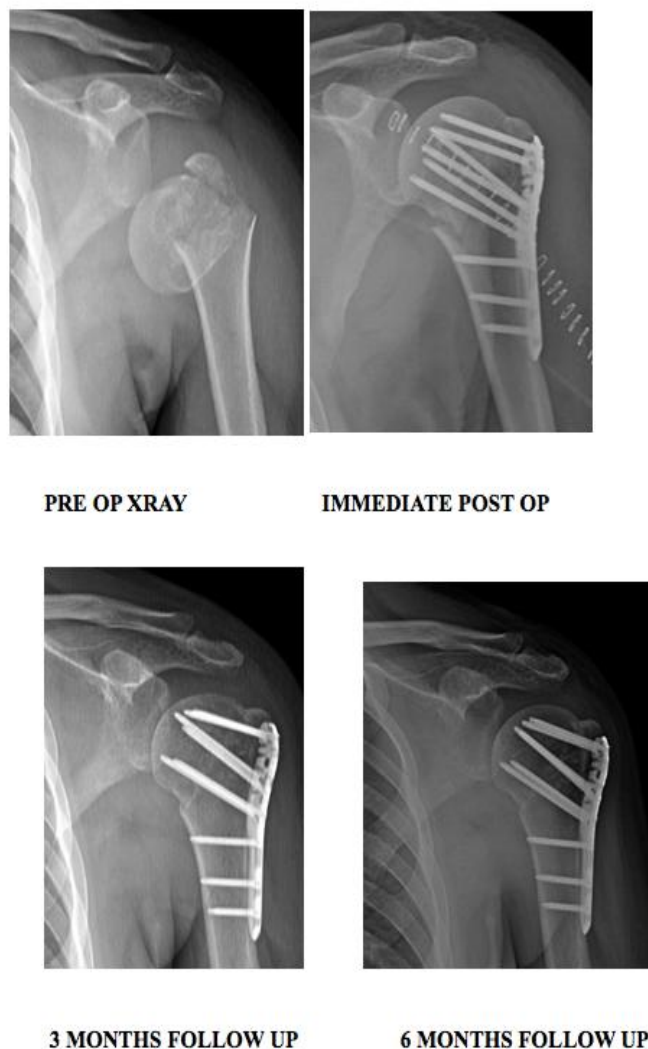


Figure 2: Avascular Necrosis Of Hemurus Head At 3 Months Follow Up

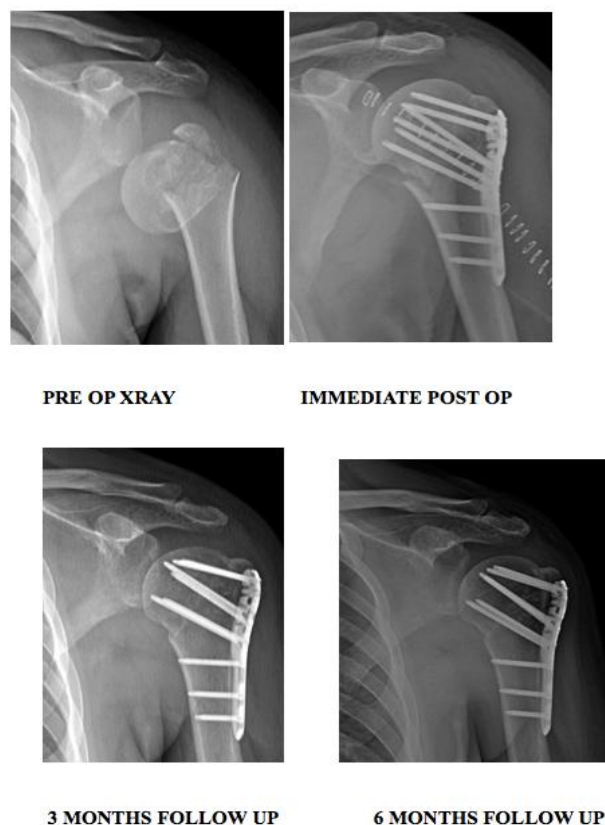


Figure 3: 6 months follow up of a case treated with proximal humerus locking plate with excellent outcome.

IV. Discussion

The goal of proximal humerus fixation is anatomic reduction of all fracture fragments, reestablishment of the native neck shaft angle (between 130° and 140°), restoration of the medial calcar, and stable fixation, which will allow early motion and return to function⁸. Open reduction and internal fixation of the proximal humerus fractures has increased in frequency with the development of locking plate and angular stable technology. Locking plate technology allows load to be evenly distributed throughout the length of the plate, countering the impact of the humeral head's poor bone quality on plate stability and limiting the risk of screw pull-out and fixation failure.

The most serious concern in proximal humeral fracture fixation has been the high rate of avascular necrosis of the humeral head, with reported rates as high as 45% when traditional plating was used.⁹ In our study avascular necrosis was noted in one patient, a rate consistent with the low incidence reported in other studies where locking plates were used (range: 4.5–16%).¹⁰ Avascular head necrosis is initiated by the fracture pattern itself that almost unavoidably damages the delicate blood supply of the humeral head.¹¹ However, humeral head vascular supply may be further compromised by the rather extensive soft tissue dissection required in order to achieve adequate reduction and fracture fixation with conventional plates.¹⁰ In that respect the use of locking plates, which act as a locked internal fixator, requires considerably less soft tissue and periosteal stripping, thus minimising further iatrogenic damage to the already compromised blood supply of the humeral head.¹² If reduction of the necrotic humeral head is preserved, fracture healing can be achieved leading to an acceptable clinical result that does not necessarily correlate with radiological findings of severe humeral head damage.⁹ It has been proposed that even re-vascularisation of the humeral head is possible when a stable fixation is provided.¹³ In our series, one patient had a 3-part fracture with primary fracture line along anatomical neck and was fixed with locking plate (PDL proximal humerus locking plate). Signs of aseptic necrosis were noted radiologically at 3rd month follow up. By then patient had radiological union of fracture and had good functional outcome with Constant shoulder score of 77. Probably as the fracture united, there was no functional limitation to the patient even at 1 year of follow up.

Early loss of fixation has been another serious concern in the surgical treatment of proximal humeral fractures, with reported rates ranging from 25%^{14,15} It appears that the overall rate of loss of fixation has significantly decreased after the introduction of locking plates instead of traditional plates in the treatment of this fractures.^{16,17} This is supported by our findings, as loss of reduction was recorded in only one patient in this

series (Patient was excluded from the study as it was converted to hemiarthroplasty). Traditional non-locking screws and plates rely on friction between the plate and bone for stability. In osteoporotic bone, this construct is more prone to failure because of bone resorption underneath the plate and high rotational forces. Additionally, the screws may not obtain sufficient purchase in the cancellous and osteoporotic humeral head, leading to high failure rates. Since locking plates rely on an angular-stable interface between the screw head and plate, the 'classic' failure of screw back-out or screw-breakage at the screw head/plate interface is far less common.¹⁴ Locking plates usually fail as a complete 'monoblock' by pulling out of the humeral head or shaft.

In a multicentre study conducted by Agudelo et al with a relatively large cohort of patients treated by locking plates, it was found that varus malreduction (head shaft angle $<120^{\circ}$) was significantly associated with early loss of fixation.¹⁶ In our series, one patient with malreduction (117.4°) and no medial buttress had the fracture united without any complication. Another case with medial comminution had varus collapse with penetration of screw on 3rd month follow up. However, this patient had screw removal after varus malunion and patient improved symptomatically. Björkenheim et al.²¹ reported 26.3% of the Fractures Having 2, 3 And 4-Part United in slightly varus position after open reduction and internal fixation with locking plate. As reported by Pinkas et al.¹⁸ select types of malunion of the proximal humerus have been shown to be well tolerated in an elderly, low-demand patient population as like in our series.

Screw perforation of the humeral head is the most common complication, with reported rates of up to 17 % in fractures treated without fixation augmentation.²⁰ Königshasen et al. reported that nearly half (42 %) of their study's complications were attributed to screw perforation of the humeral head.²⁰ Postoperative radiographs should be monitored periodically for signs of perforation at each visit. The shoulder should be taken through an arc of motion for evaluation of crepitus or catching to suspect screw perforation clinically. Screws should be removed in a timely manner to limit injury to the articular surface of the glenoid, if fracture fixation is not negatively impacted by screw removal. There was only one case of screw perforation in our series. Placement of screws within 5-10 mm of subchondral bone and avoiding drill of subchondral bone beyond the point of screw tract can prevent these complications of screw perforation. The case which had screw perforation had severe medial comminution with loss of medial buttress upon fixation which lead to varus collapse, thereby leading to screw perforation.

Out of six patients who developed stiffness in the post-operative period, one had non-union and could not carry out the prescribed rehabilitation program. Rest of the five patients had poor adherence to the post-operative rehabilitation program in early post-operative period. There was no loss of reduction or screw penetration or infection in these five cases that could attribute to pain. Patient education towards rehabilitation program and its result should be emphasized. Although different implants – PHILOS (Synthes), Peri-Loc (Smith & Nephew) and proximal humerus locking plate (PDL) were used in our study, there was no significant difference among them with respect to complications, union and functional outcome. All the three implants were based on the principles of angular stability with locking mechanism and hence not much difference. The union success in our series (40/41 or 97.6%) is more favourable than the published results of both Björkenheim et al.¹⁷ and Charalambous et al.²² with the PHILOS plate, achieving union in 70/72 (97.2%) and 20/25 (80%) respectively.

Outcomes of proximal humerus internal fixation vary widely and are highly dependent on a surgeon's treatment philosophy, learning curve and preoperative presentation along with patient's factors like age, bone quality and adherence to rehabilitation program. The Constant score is an objective method of evaluating patient functional outcomes on the basis of range of motion, strength, pain, and activity level. Constant scores have ranged from 61 to 80 (max 100) with angular stable constructs in literature reviews^{64, 65} but significant variability remains. The ascending pattern of improvement in functional outcome among the study population suggests the improvement with rehabilitation program. Patients with poorer outcome do not have any improvement in outcome at subsequent follow up. Patients with poor outcome if identified early can be shifted to a vigorous rehabilitation program or educated about the same. Mean Constant shoulder score in our group at 6 months follow up was 66 and is consistent with literature. Solberg et al. (2009) and Sudkamm et al. (2011) reported poorer Constant scores in their patients presenting with varus preoperative coronal displacement, as compared with their valgus-impacted patients.^{23,25}

Patients with anatomic fracture reduction and reestablishment of the medial calcar have stable fixation less prone for failure and are hence associated with significantly better functional outcome. The increasing number of parts of the fracture did not seem to have any correlation to the final functional outcome in our study group, probably because of the small sample size. However, the complication rate did seem to increase with the increasing number of fracture parts, reflecting the difficulty of treatment of more complex fracture configurations.

Surgeon's experience is an important factor when analyzing the complication rates associated with locked plating of proximal humerus fractures, as studies have presented relatively high complication rates directly related to the surgical procedure itself. As afore mentioned, Solberg et al.²³ acknowledged the fact that they faced a significant learning curve in achieving and maintaining reduction of the humeral head as a limitation of their study. These authors also reported that 5 patients underwent revision surgery within 48 h of their initial surgery due to screw penetration.²⁵ In a study investigating the use of locked plating, Aggarwal et al.²⁶ found that they realised a greater number of complications in patients they treated earlier in the study. They attributed this greater complication rate to their experience with the operation and they concluded that the use of locked plating for proximal humerus fractures has a steep learning curve. Sudkamp et al. found that 55% of complications were a result of the surgery itself, with the most common complication being primary screw penetration.²⁵ In our study no intraoperative complications were reported. However, complications were identified in at least 9 patients (11 complications in 9 patients) in our series. Most of these complications were not surgeon controlled (5 cases of stiffness due to poor rehabilitation and one case of aseptic necrosis due to fracture pattern). Following the principles of meticulous soft tissue handling with accurate reduction of fragments including tuberosities and proper placements of screws and checking their lengths in multiple views could have cut down surgeon related complications in our study group. This study shows that good fracture stability if achieved early, allows early mobilization without compromising fracture union.

There are certain limitations in this study—the small sample size, the short follow up, and surgeon-to-surgeon variability in the surgical technique as well as in postoperative management. Important aspects of the surgical technique include placement of the plate in strict adherence to the technique, determination of appropriate length and placement of the screws with fluoroscopy, insertion of screws to the head in adequate number and position, providing medial cortex support for the prevention of varus displacement and to fix tubercle fragments, fixation of the non absorbable sutures to the locking plate at the junction of the tubercle and rotator cuff.

V. Conclusion

The main challenge in the operative treatment of proximal humeral fractures by internal fixation is to achieve effective stabilization of an adequately reduced fracture in order to maximize the functional outcome. If an adequate reduction is not achieved and medial buttressing is insufficient, especially with a varus malreduction, secondary loss of reduction and subsequent screw perforation or plate breakage is possible. The importance of minimal soft tissue dissection to preserve the vascularity of the head, indirect methods of reduction, and early mobilization help to achieve good results. Patient education towards immediate post-operative rehabilitation should be emphasized.

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