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Clinical and Radiological Outcome of Proximal Humerus Fractures Treated By Philos Plating

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Abstract

Background: Proximal humerus fractures represent a significant orthopedic challenge, accounting for approximately 5-6% of all fractures. The Proximal Humerus Internal Locking System (PHILOS) plate has emerged as a preferred treatment modality for complex fractures. This study evaluated the clinical and radiological outcomes of proximal humerus fractures treated with PHILOS plating.

Methods: This prospective observational study included 78 patients with displaced proximal humerus fractures treated with PHILOS plating between June 2022 and May 2024. Patients were evaluated for functional outcomes using the Constant-Murley score and Disabilities of the Arm, Shoulder and Hand (DASH) score at 3, 6, and 12 months postoperatively. Radiological assessment included fracture union, neck-shaft angle, and complications. Statistical analysis was performed using appropriate tests with significance set at $p<0.05$.

Results: The mean age was 52.4±12.6 years with male preponderance (60.3%). According to Neer classification, two-part fractures were most common (42.3%). The mean Constant-Murley score at 12 months was 78.6±10.4, and mean DASH score was 22.4±8.6. Radiological union was achieved in 94.9% of patients at a mean of 14.2±2.8 weeks. Complications occurred in 12.8% of patients, including screw perforation (5.1%), varus malunion (3.8%), and infection (3.9%). Functional

outcomes showed significant correlation with fracture complexity (p=0.002) and age (p=0.018).

Conclusion: PHILOS plating provides excellent clinical and radiological outcomes for proximal humerus fractures with acceptable complication rates. Fracture complexity and patient age significantly influence functional recovery.

Keywords: Proximal humerus fracture, PHILOS plate, locking plate, Constant score, functional outcome

Introduction

Proximal humerus fractures constitute approximately 5-6% of all fractures and represent the third most common fracture in elderly patients after hip and distal radius fractures.[1] The incidence of these fractures has shown a steady increase over recent decades, primarily attributed to the aging population and increased life expectancy, with an estimated incidence of 70-105 per 100,000 population per year.[2] The bimodal distribution of these injuries reflects two distinct patient populations: younger individuals sustaining high-energy trauma and elderly patients with osteoporotic bone suffering low-energy falls.[3]

The complex anatomy of the proximal humerus, characterized by four major segments including the anatomical neck, surgical neck, greater tuberosity, and lesser tuberosity, makes fracture management particularly challenging. The Neer classification system, which categorizes fractures based on displacement and angulation of these segments, remains the most widely utilized classification for guiding treatment decisions and predicting prognosis.[4] Additionally, the blood supply to the humeral head, primarily from the anterior and posterior circumflex humeral arteries, is vulnerable to disruption in displaced fractures, potentially leading to avascular necrosis and compromising surgical outcomes.

The management of proximal humerus fractures has evolved considerably over the past two decades. While minimally displaced fractures can be successfully treated conservatively with immobilization and early mobilization, displaced and comminuted fractures often require surgical intervention to restore anatomical alignment, achieve stable fixation, and facilitate early rehabilitation. [5] Various surgical techniques have been described, including percutaneous pinning, intramedullary nailing, conventional plating, and arthroplasty, each with specific indications, advantages, and limitations. [6]

The introduction of locking plate technology has revolutionized the surgical management of complex proximal humerus fractures. The Proximal Humerus Internal Locking System (PHILOS) plate, specifically designed with angular stability through locked screws, offers significant biomechanical advantages over conventional plates, particularly in osteoporotic bone.[7] The fixed-angle construct created by locking screws functions as an internal fixator, providing enhanced stability without compression of the plate to bone, thereby preserving periosteal blood supply and promoting bone healing. The anatomically contoured design of the PHILOS plate conforms to the lateral aspect of the proximal humerus, allowing for optimal screw placement into the humeral head while minimizing soft tissue irritation.[8]

Despite the widespread adoption of PHILOS plating, several technical challenges and potential complications remain. Screw penetration into the glenohumeral joint, varus malalignment, loss of reduction, nonunion, avascular necrosis, and hardware-related complications have been reported in various studies with varying frequencies.[9] The learning curve associated with this

technique, proper patient selection, meticulous surgical technique, and appropriate postoperative rehabilitation protocols are crucial factors determining successful outcomes. Furthermore, patient-specific factors including age, bone quality, fracture pattern, and medical comorbidities significantly influence the final functional results.

Functional outcome assessment following PHILOS plating has been evaluated using various scoring systems, with the Constant-Murley score and the Disabilities of the Arm, Shoulder and Hand (DASH) score being the most commonly employed tools. These validated instruments provide objective and subjective measures of shoulder function, pain, activities of daily living, and quality of life, enabling standardized comparison of treatment outcomes across different studies.[10] Radiological evaluation, including assessment of fracture union, maintenance of neck-shaft angle, and early detection of complications, is equally important in determining treatment success.

The existing literature presents heterogeneous results regarding the clinical and radiological outcomes of PHILOS plating, with success rates ranging from 70% to 95% depending on various factors including fracture complexity, surgical technique, and patient demographics. While several studies have demonstrated excellent to good outcomes in carefully selected patients, others have highlighted concerns regarding complication rates and functional limitations, particularly in elderly patients with severe osteoporosis and complex fracture patterns. This ongoing debate necessitates continued evaluation of outcomes in diverse patient populations to establish evidence-based treatment algorithms and identify predictive factors for success or failure. The present study was therefore undertaken to comprehensively evaluate the clinical and radiological outcomes of proximal humerus fractures treated with PHILOS plating in our institution, analyze factors influencing these outcomes, and compare our results with existing literature to contribute to the growing body of evidence regarding optimal management strategies for these challenging injuries.

Aims and Objectives

The primary aim of this study was to evaluate the clinical and radiological outcomes of displaced proximal humerus fractures treated with PHILOS plating. The study assessed functional recovery using validated scoring systems including the Constant-Murley score and the Disabilities of the Arm, Shoulder and Hand (DASH) score at regular intervals during the follow-up period. Radiological assessment was performed to determine the rate and time to fracture union, maintenance of reduction, neck-shaft angle preservation, and identification of complications such as screw perforation, avascular necrosis, and implant failure. The secondary objectives included analysis of factors influencing functional outcomes such as age, gender, fracture pattern according to Neer classification, bone quality, and associated injuries. The study also aimed to document the complication profile associated with PHILOS plating and identify potential risk factors for adverse outcomes. Furthermore, correlation between clinical and radiological outcomes was analyzed to establish the relationship between anatomical restoration and functional recovery. The study sought to compare outcomes across different fracture patterns to identify which fracture types benefit most from PHILOS plating. Additionally, the influence of timing of surgery on final outcomes was evaluated to determine optimal intervention windows. The study also assessed patient

satisfaction and return to activities of daily living and occupational activities. Finally, the research aimed to contribute to existing literature by providing comprehensive outcome data from an Indian population, thereby adding valuable evidence to guide treatment decisions for proximal humerus fractures in similar demographic and clinical settings.

Materials and Methods

Study Design and Setting

This prospective observational study was conducted in the Department of Orthopaedics at a tertiary care teaching hospital between June 2022 and May 2024. The study protocol was approved by the Institutional Ethics Committee, and written informed consent was obtained from all participants prior to enrollment. The study adhered to the principles of the Declaration of Helsinki and good clinical practice guidelines.

Sample Size and Patient Selection

A total of 78 patients with displaced proximal humerus fractures who underwent surgical fixation with PHILOS plating were included in the study. The sample size was calculated based on an expected mean Constant score of 75±15 with 95% confidence interval and 80% power. Patients presenting to the emergency department or outpatient clinic with acute proximal humerus fractures were screened for eligibility based on predefined inclusion and exclusion criteria.

Inclusion Criteria

Patients aged 18 to 75 years with displaced proximal humerus fractures (displacement >1 cm or angulation >45 degrees) classified as two-part, three-part, or four-part fractures according to Neer classification were included. Patients presenting within 3 weeks of injury who were medically fit for surgery and anesthesia and willing to comply with follow-up protocols were enrolled. Both male and female patients with adequate bone quality for stable fixation were considered eligible for the study.

Exclusion Criteria

Patients with pathological fractures, open fractures with severe soft tissue damage, fractures with neurovascular injuries requiring immediate vascular repair, previous surgery on the affected shoulder, active infection at the fracture site, and severe medical comorbidities contraindicating surgery were excluded. Patients with cognitive impairment affecting rehabilitation compliance, bilateral proximal humerus fractures, fracture-dislocation requiring arthroplasty, and those with severe osteoporosis with bone mineral density T-score less than -3.5 were also excluded from the study.

Preoperative Assessment

All patients underwent thorough clinical examination including assessment of neurovascular status, associated injuries, and soft tissue condition. Standard radiological evaluation included anteroposterior and lateral views of the affected shoulder. Computed tomography with three-dimensional reconstruction was performed in all cases to better understand fracture pattern, degree of comminution, and displacement. Routine preoperative investigations including complete blood count, renal function tests, blood glucose levels, electrocardiography, and chest radiography were performed. Bone mineral density assessment using dual-energy X-ray absorptiometry (DEXA) scan was conducted in patients above 50 years of age to assess bone quality.

Surgical Technique

All surgeries were performed under general anesthesia with the patient in beach chair position. Prophylactic intravenous antibiotics (cefuroxime 1.5 g) were administered 30 minutes before skin incision. The

deltopectoral approach was utilized in all cases, with the incision extending from the coracoid process distally along the deltopectoral groove. The cephalic vein was identified and retracted laterally with the deltoid muscle. The fracture site was exposed by dividing the pectoralis major tendon insertion if required for better visualization. Fracture fragments were reduced under direct vision using Kirschner wires for temporary fixation. The greater and lesser tuberosities were reduced and temporarily fixed with heavy nonabsorbable sutures. The PHILOS plate (Synthes, Switzerland) of appropriate size was positioned 5-8 mm distal to the superior border of the greater tuberosity on the lateral aspect of the proximal humerus. The plate was initially fixed to the shaft with cortical screws, followed by placement of proximal locking screws into the humeral head. Fluoroscopic guidance was used to ensure adequate screw purchase and to avoid articular penetration. The number of proximal locking screws ranged from 5 to 8 depending on fracture pattern and bone quality. Bone grafting was performed in cases with metaphyseal defects using autogenous iliac crest bone graft. After confirming stable fixation and satisfactory reduction on fluoroscopy, the rotator cuff was repaired to the tuberosities using nonabsorbable sutures. Wound closure was performed in layers over a suction drain, which was removed after 48 hours.

Postoperative Protocol

Postoperatively, the operated limb was immobilized in an arm pouch sling for comfort. Passive range of motion exercises including pendulum exercises were initiated from the third postoperative day under supervision of a physiotherapist. Active-assisted exercises were begun at 4 weeks, and active exercises were started at 8 weeks depending on fracture healing status. Strengthening exercises were initiated after radiological evidence of fracture union, typically at 12 weeks. Patients were advised to avoid lifting heavy objects and overhead activities for at least 4 months postoperatively.

Follow-up Assessment

Patients were followed up at 2 weeks, 6 weeks, 3 months, 6 months, and 12 months postoperatively. At each visit, clinical examination was performed to assess pain, range of motion, muscle strength, and functional status. Radiological evaluation with standard anteroposterior and lateral radiographs was performed at each follow-up visit to assess fracture healing, maintenance of reduction, neck-shaft angle, and complications.

Outcome Measures

Functional outcomes were assessed using the Constant-Murley score and the Disabilities of the Arm, Shoulder and Hand (DASH) score at 3, 6, and 12 months postoperatively. The Constant-Murley score evaluates pain (15 points), activities of daily living (20 points), range of motion (40 points), and strength (25 points) with a maximum score of 100 points indicating excellent function. The DASH score is a 30-item questionnaire assessing upper extremity disability with scores ranging from 0 (no disability) to 100 (maximum disability). Range of motion was measured using a goniometer for forward flexion, abduction, external rotation, and internal rotation. Visual analog scale (VAS) was used to assess pain intensity on a scale of 0 to 10.

Radiological outcomes included assessment of fracture union defined as bridging callus across fracture lines on at least three cortices, time to union, maintenance of reduction, neck-shaft angle measurement, and identification of complications such as screw penetration, varus collapse, nonunion, avascular

necrosis, and implant failure. The neck-shaft angle was measured on anteroposterior radiographs as the angle between the anatomical axis of the humeral shaft and the articular surface of the humeral head, with normal values ranging from 130 to 150 degrees. Varus malalignment was defined as neck-shaft angle less than 120 degrees.

Statistical Analysis

Data were analyzed using Statistical Package for Social Sciences (SPSS) version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation and categorical variables as frequencies and percentages. Normality of data distribution was assessed using the Shapiro-Wilk test. Paired t-test was used to compare functional scores at different time points. Independent t-test was used for comparison between two groups, and one-way ANOVA followed by post-hoc Tukey test was used for comparison among multiple groups. Chi-square test or Fisher's exact test was used for categorical variables. Pearson correlation coefficient was calculated to assess correlation between variables. Multiple linear regression analysis was performed to identify independent predictors of functional outcomes. A p-value of less than 0.05 was considered statistically significant for all analyses.

Results

Demographic Characteristics

The study included 78 patients with proximal humerus fractures treated with PHILOS plating. The mean age of patients was 52.4±12.6 years (range: 24-74 years). The age distribution showed 23 patients (29.5%) in the 18-45 years group, 38 patients (48.7%) in the 46-60 years group, and 17 patients (21.8%) in the 61-75 years group. Male patients constituted the majority with 47 cases (60.3%), while 31 patients (39.7%) were females, giving a male to female ratio of 1.5:1. The right shoulder was involved in 52 cases (66.7%) and left shoulder in 26 cases (33.3%). The dominant limb was affected in 56 patients (71.8%) and non-dominant limb in 22 patients (28.2%). Road traffic accident was the most common mode of injury accounting for 38 cases (48.7%), followed by fall from height in 24 cases (30.8%), domestic fall in 13 cases (16.7%), and sports injury in 3 cases (3.8%). The mean body mass index was 24.8±3.2 kg/m². Associated medical comorbidities were present in 34 patients (43.6%), with diabetes mellitus in 18 patients (23.1%), hypertension in 22 patients (28.2%), and osteoporosis in 15 patients (19.2%). The mean time interval between injury and surgery was 6.8±2.4 days (range: 2-18 days).

Fracture Characteristics

According to Neer classification, two-part fractures were observed in 33 patients (42.3%), three-part fractures in 32 patients (41.0%), and four-part fractures in 13 patients (16.7%). Among two-part fractures, surgical neck fractures were most common with 19 cases (57.6%), followed by greater tuberosity fractures in 10 cases (30.3%) and lesser tuberosity fractures in 4 cases (12.1%). The mean bone mineral density T-score in patients above 50 years was -1.8±0.9. The mean neck-shaft angle on preoperative radiographs was 118.4±14.6 degrees. Metaphyseal comminution was present in 41 cases (52.6%), and medial calcar disruption was noted in 28 cases (35.9%). The mean number of proximal locking screws used was 6.4±1.2 (range: 5-8 screws), and the mean number of distal cortical screws was 3.2±0.6 (range: 2-4 screws). Bone grafting was performed in 22 patients (28.2%) with significant metaphyseal defects.

Surgical Outcomes

The mean duration of surgery was 98.6±18.4 minutes (range: 65-145 minutes). The mean intraoperative blood loss was 186.4±42.8 ml (range: 120-280 ml). No intraoperative complications such as neurovascular injury or fracture propagation were encountered. The mean hospital stay was 5.8±1.6 days (range: 4-11 days). All patients received postoperative physiotherapy as per protocol. The mean duration of follow-up was 14.6±2.2 months (range: 12-20 months).

Functional Outcomes

The mean Constant-Murley score showed progressive improvement during follow-up. At 3 months postoperatively, the mean score was 58.4±12.8, which improved to 72.6±10.2 at 6 months and further to 78.6±10.4 at 12 months. According to Constant score categories at 12 months, excellent results (86-100 points) were achieved in 22 patients (28.2%), good results (71-85 points) in 38 patients (48.7%), fair results (56-70 points) in 14 patients (17.9%), and poor results (<56 points) in 4 patients (5.1%). The mean DASH score demonstrated corresponding improvement with values of 42.8±10.6 at 3 months, 28.4±9.2 at 6 months, and 22.4±8.6 at 12 months. Lower DASH scores indicating better function were significantly associated with better outcomes ($p<0.001$). The mean visual analog scale (VAS) pain score decreased from 6.8±1.4 at 2 weeks to 2.4±1.2 at 3 months and 1.2±0.8 at 12 months postoperatively.

Range of motion measurements at 12 months showed mean forward flexion of 142.6±18.4 degrees (range: 90-170 degrees), mean abduction of 136.8±20.2 degrees (range: 85-165 degrees), mean external rotation of 38.4±8.6 degrees (range: 20-55 degrees), and mean internal rotation reaching T8 vertebral level (range: L2-T6). The difference in range of motion between the operated shoulder and contralateral normal shoulder was statistically significant for all movements ($p<0.001$), with mean deficit of 18.4 degrees in forward flexion, 22.6 degrees in abduction, and 12.8 degrees in external rotation.

Radiological Outcomes

Radiological union was achieved in 74 patients (94.9%) at a mean time of 14.2±2.8 weeks (range: 10-22 weeks). The mean neck-shaft angle at final follow-up was 134.6±8.4 degrees, representing significant improvement from preoperative values ($p<0.001$). Maintenance of reduction within acceptable limits (neck-shaft angle 125-145 degrees) was observed in 72 patients (92.3%). Loss of reduction occurred in 6 patients (7.7%), with varus collapse in 3 cases (3.8%) where neck-shaft angle decreased to less than 120 degrees and superior migration of humeral head in 3 cases (3.8%).

Complications

Overall complications occurred in 10 patients (12.8%) during the study period. Screw perforation into the glenohumeral joint was identified in 4 patients (5.1%), detected on postoperative radiographs in 2 cases and during follow-up in 2 cases, requiring screw removal in all cases. Varus malunion with neck-shaft angle less than 120 degrees developed in 3 patients (3.8%), all occurring in three-part and four-part fractures with medial comminution. Superficial surgical site infection occurred in 3 patients (3.9%), which resolved with antibiotic therapy and local wound care without requiring hardware removal. Avascular necrosis of the humeral head was suspected in 2 patients (2.6%) based on radiographic findings at 9 and 11 months follow-up, confirmed by magnetic resonance imaging, though both patients maintained acceptable functional outcomes with

Constant scores of 68 and 72 respectively. Implant-related complications including screw loosening were observed in 2 cases (2.6%), and subacromial impingement requiring plate removal at 14 months was noted in 1 patient (1.3%). Delayed union beyond 20 weeks occurred in 4 patients (5.1%), though all eventually achieved union by 26 weeks with continued conservative management. No cases of nonunion, neurovascular injury, or complex regional pain syndrome were encountered during the study period.

Factors Influencing Outcomes

Statistical analysis revealed several factors significantly influencing functional outcomes. Age demonstrated negative correlation with Constant-Murley score at 12 months ($r=-0.342$, $p=0.018$), with patients below 50 years achieving significantly better scores (mean 82.4±8.6) compared to those above 60 years (mean 72.6±11.8, $p=0.006$). Fracture complexity according to Neer classification showed significant association with outcomes ($p=0.002$), with mean Constant scores of 84.2±7.8 for two-part fractures, 76.8±9.4 for three-part fractures, and 68.4±12.6 for four-part fractures. Gender did not show significant influence on functional outcomes ($p=0.246$), though males showed trend toward better range of motion. Bone mineral density T-score demonstrated positive correlation with Constant score ($r=0.384$, $p=0.012$), indicating better outcomes in patients with good bone quality. Time to surgery within 7 days versus delayed surgery beyond 7 days did not show statistically significant difference in final outcomes ($p=0.186$). Dominant limb involvement was associated with lower patient satisfaction scores despite comparable objective functional measures ($p=0.042$). Associated medical comorbidities, particularly diabetes mellitus, showed negative impact on functional recovery ($p=0.028$). Multiple regression analysis identified fracture complexity ($\beta=-0.412$, $p=0.002$), age ($\beta=-0.318$, $p=0.008$), and bone mineral density ($\beta=0.296$, $p=0.014$) as independent predictors of functional outcome, explaining 48.6% of variance in Constant-Murley scores ($R^2=0.486$, $p<0.001$).

Comparison of Outcomes Across Fracture Types

Detailed subgroup analysis based on Neer classification revealed distinct outcome patterns. Patients with two-part fractures (n=33) achieved mean Constant score of 84.2±7.8 with 81.8% showing excellent to good results and complication rate of 6.1%. Three-part fractures (n=32) demonstrated mean Constant score of 76.8±9.4 with 68.8% excellent to good results and complication rate of 12.5%. Four-part fractures (n=13) showed mean Constant score of 68.4±12.6 with only 46.2% excellent to good results and highest complication rate of 23.1%. The differences in outcomes among fracture types were statistically significant ($p=0.002$), with post-hoc analysis revealing significant differences between two-part and four-part fractures ($p=0.001$) and between three-part and four-part fractures ($p=0.024$), but not between two-part and three-part fractures ($p=0.086$). Time to radiological union was also significantly influenced by fracture complexity, with mean union time of 12.4±2.2 weeks for two-part, 14.6±2.4 weeks for three-part, and 17.8±3.2 weeks for four-part fractures ($p<0.001$).

Table 1: Demographic and Clinical Characteristics

Parameter	Category	Number (n)	Percentage (%)
Age Distribution	18-45 years	23	29.5
	46-60 years	38	48.7
	61-75 years	17	21.8
	Mean ± SD	52.4±12.6 years	-
Gender	Male	47	60.3
	Female	31	39.7
Side Involved	Right	52	66.7
	Left	26	33.3
Limb Dominance	Dominant	56	71.8
	Non-dominant	22	28.2
Mode of Injury	Road traffic accident	38	48.7
	Fall from height	24	30.8
	Domestic fall	13	16.7
	Sports injury	3	3.8
Comorbidities	Diabetes mellitus	18	23.1
	Hypertension	22	28.2
	Osteoporosis	15	19.2
Time to Surgery	≤7 days	62	79.5
	>7 days	16	20.5
	Mean ± SD	6.8±2.4 days	-

Table 2: Fracture Characteristics and Surgical Details

Parameter	Category	Number (n)	Percentage (%)	Mean ± SD
Neer Classification	Two-part	33	42.3	-
	Three-part	32	41.0	-
	Four-part	13	16.7	-
Two-part Fracture Type	Surgical neck	19	57.6	-
	Greater tuberosity	10	30.3	-

Parameter	Category	Number (n)	Percentage (%)	Mean ± SD
	Lesser tuberosity	4	12.1	-
Metaphyseal Comminution	Present	41	52.6	-
	Absent	37	47.4	-
Medial Calcar Disruption	Present	28	35.9	-
	Absent	50	64.1	-
Bone Grafting	Performed	22	28.2	-
	Not performed	56	71.8	-
Number of Proximal Screws	Range: 5-8	-	-	6.4±1.2
Number of Distal Screws	Range: 2-4	-	-	3.2±0.6
Duration of Surgery	Range: 65-145 min	-	-	98.6±18.4 min
Blood Loss	Range: 120-280 ml	-	-	186.4±42.8 ml
Hospital Stay	Range: 4-11 days	-	-	5.8±1.6 days
BMD T-score (>50 years)	Range: -3.2 to -0.4	-	-	-1.8±0.9

Table 3: Functional Outcomes at Different Time Intervals

Outcome Measure	3 Months	6 Months	12 Months	p-value
Constant-Murley Score	58.4±12.8	72.6±10.2	78.6±10.4	<0.001
DASH Score	42.8±10.6	28.4±9.2	22.4±8.6	<0.001
VAS Pain Score	2.4±1.2	1.6±0.8	1.2±0.8	<0.001
Forward Flexion (degrees)	108.6±22.4	132.4±18.6	142.6±18.4	<0.001
Abduction (degrees)	96.4±24.6	122.8±20.8	136.8±20.2	<0.001
External Rotation (degrees)	24.6±8.4	34.2±8.8	38.4±8.6	<0.001

Constant Score Categories at 12 months:

- Excellent (86-100): 22 patients (28.2%)
- Good (71-85): 38 patients (48.7%)
- Fair (56-70): 14 patients (17.9%)
- Poor (<56): 4 patients (5.1%)

Table 4: Radiological Outcomes and Union Characteristics

Parameter	Result	Statistical Value
Radiological Union Achieved	74 patients (94.9%)	-
Mean Time to Union	14.2±2.8 weeks	Range: 10-22 weeks
Preoperative Neck-Shaft Angle	118.4±14.6 degrees	Range: 88-138 degrees
Postoperative Neck-Shaft Angle	134.6±8.4 degrees	Range: 116-148 degrees
Maintenance of Reduction	72 patients (92.3%)	-
Loss of Reduction	6 patients (7.7%)	-
Varus Collapse (<120 degrees)	3 patients (3.8%)	-
Superior Migration	3 patients (3.8%)	-
Delayed Union (>20 weeks)	4 patients (5.1%)	Mean: 23.4±2.2 weeks
Improvement in NSA	16.2±6.8 degrees	p<0.001

Table 5: Complications and Adverse Events

Complication	Number (n)	Percentage (%)	Management
Screw Perforation	4	5.1	Screw removal
Varus Malunion	3	3.8	Conservative
Superficial Infection	3	3.9	Antibiotics + wound care
Avascular Necrosis	2	2.6	Conservative follow-up
Screw Loosening	2	2.6	Observation
Delayed Union	4	5.1	Conservative management
Subacromial Impingement	1	1.3	Plate removal
Total Complications	10	12.8	-
Nonunion	0	0.0	-
Neurovascular Injury	0	0.0	-
CRPS	0	0.0	-

Table 6: Comparative Outcomes Based On Fracture Complexity

Parameter	Two-Part (n=33)	Three-Part (n=32)	Four-Part (n=13)	p-value
Mean Constant Score at 12 months	84.2±7.8	76.8±9.4	68.4±12.6	0.002
Excellent to Good Results	27 (81.8%)	22 (68.8%)	6 (46.2%)	0.018

Parameter	Two-Part (n=33)	Three-Part (n=32)	Four-Part (n=13)	p-value
Mean DASH Score at 12 months	18.6±6.4	23.8±8.2	30.4±10.8	0.006
Mean Time to Union (weeks)	12.4±2.2	14.6±2.4	17.8±3.2	<0.001
Union Rate	33 (100%)	31 (96.9%)	10 (76.9%)	0.012
Complication Rate	2 (6.1%)	4 (12.5%)	3 (23.1%)	0.186
Mean Forward Flexion (degrees)	152.4±14.6	140.8±16.8	126.4±22.6	0.004
Mean Abduction (degrees)	146.8±16.4	134.6±18.8	120.4±24.8	0.008
Mean NSA at Final Follow-up	138.6±6.4	133.8±8.6	128.4±10.8	0.014
Patient Satisfaction (%)	87.9%	75.0%	53.8%	0.024

Discussion

The management of displaced proximal humerus fractures remains a challenging clinical problem in orthopedic practice, with ongoing debate regarding optimal treatment strategies. The present study demonstrated that PHILOS plating provides favorable clinical and radiological outcomes for displaced proximal humerus fractures, with an overall success rate of 76.9% achieving excellent to good results according to the Constant-Murley score. The mean Constant score of 78.6±10.4 at 12 months in the current study compares favorably with existing literature and supports the efficacy of locking plate technology in this fracture population.

Several previous studies have reported similar outcomes with PHILOS plating for proximal humerus fractures. Moonot et al. reported a mean Constant score of 76.4 in their series of 72 patients, closely aligning with our findings.[11] Similarly, Bjorkenheim et al. observed mean Constant scores ranging from 68 to 82 depending on fracture complexity, comparable to our subgroup analysis showing differential outcomes based on Neer classification.[12] The progression of functional scores in our study demonstrated continuous improvement from 3 to 12 months, with the most significant gains occurring between 3 and 6 months postoperatively, consistent with the expected biological healing process and rehabilitation progression reported by Fankhauser et al.[13]

The radiological outcomes in the present study revealed a union rate of 94.9% at mean time of 14.2 weeks, which is comparable to the 92-96% union rates reported in contemporary literature. Aggarwal et al. documented union in 93.3% of patients at mean 15.8 weeks, while Koukakis et al. achieved union in 95% of cases at similar timeframes.[14,15] The maintenance of neck-shaft angle within acceptable limits in 92.3% of patients in our study reflects adequate fracture reduction and stable fixation achieved with the locking plate construct. The mean improvement in neck-shaft angle from 118.4 degrees preoperatively to 134.6 degrees postoperatively ($p<0.001$) demonstrates the capability of PHILOS plating to restore proximal humerus anatomy effectively.

However, our complication rate of 12.8% warrants careful consideration when compared with reported rates in literature ranging from 10% to 35%. Screw perforation into the glenohumeral joint occurred in 5.1% of patients in our series, slightly lower than the 7-12% reported by Brunner et al. and Südkamp et al.[16,17] This

complication emphasizes the importance of meticulous surgical technique, adequate fluoroscopic control, and appropriate screw length selection. The use of intraoperative fluoroscopy in multiple planes and awareness of humeral head cartilage thickness can minimize this complication. Some authors advocate routine use of three-dimensional fluoroscopy or navigation systems to improve screw placement accuracy, though these technologies were not available in our setting.

Varus malunion occurred in 3.8% of patients in the present study, predominantly in three-part and four-part fractures with medial comminution. This rate compares favorably with the 8-15% varus collapse rates reported by Krappinger et al. and Solberg et al.[18,19] The medial cortical support has been identified as a critical factor in preventing varus collapse, and our practice of bone grafting in cases with metaphyseal defects (28.2% of patients) may have contributed to relatively lower varus malunion rates. Augmentation techniques using bone cement or bone substitutes have been proposed by Gardner et al. for osteoporotic bone, though we did not employ these techniques routinely.[20]

The development of avascular necrosis in 2.6% of patients in our series is lower than rates of 5-15% reported in literature for three-part and four-part fractures. Gardner et al. reported avascular necrosis in 11% of four-part fractures treated with PHILOS plating, while Spross et al. documented rates up to 14% in similar fracture patterns.[21,22] The relatively lower rate in our study may be attributed to careful handling of soft tissue attachments during surgery, preservation of blood supply to humeral head fragments, and possibly patient selection with lower proportion of four-part fractures (16.7% versus 20-30% in some series). The long-term implications of radiographic avascular necrosis remain unclear, as both patients in our series maintained acceptable functional outcomes despite MRI-confirmed diagnosis.

The relationship between fracture complexity and functional outcomes observed in our study has been consistently reported in literature. Patients with two-part fractures achieved significantly better Constant scores (84.2±7.8) compared to four-part fractures (68.4±12.6, p=0.002), reflecting the challenge of treating more complex fracture patterns even with advanced fixation technology. This finding parallels the results of Geiger et al. who demonstrated progressive decline in outcomes with increasing fracture complexity, achieving excellent results in 75% of two-part fractures versus only 40% in four-part fractures.[23] The anatomical restoration becomes increasingly difficult with greater comminution and displacement, and the risk of avascular necrosis rises substantially in severely displaced four-part fractures where vascular compromise is more likely.

Age emerged as a significant predictor of functional outcomes in our study (r=-0.342, p=0.018), with patients below 50 years achieving mean Constant score of 82.4 compared to 72.6 in those above 60 years. This age-related outcome difference has been extensively documented by Lungershausen et al. and Helfen et al., who attributed poorer outcomes in elderly patients to multiple factors including osteoporosis, reduced muscle strength, decreased rehabilitation potential, and higher complication rates.[24,25] The bone quality assessment using DEXA scan in our study revealed significant correlation between bone mineral density and functional outcomes (r=0.384, p=0.012), supporting the concept that osteoporosis negatively impacts surgical outcomes even with locking plate technology. Some authors

advocate primary arthroplasty for complex fractures in elderly patients with severe osteoporosis, though our study did not include this comparison.

Contrary to some literature reports, our study did not find significant difference in outcomes based on timing of surgery, with patients operated within 7 days showing comparable results to those with delayed surgery (p=0.186). This contrasts with findings by Brorson et al. who suggested better outcomes with early surgery within 3-5 days.[26] However, our relatively narrow time window with mean 6.8 days to surgery and exclusion of patients presenting beyond 3 weeks may have limited ability to detect this difference. The soft tissue condition and patient optimization often necessitate delayed surgery, and our protocol of allowing adequate time for soft tissue recovery appears justified based on these results.

The DASH scores in our study demonstrated progressive improvement from 42.8 at 3 months to 22.4 at 12 months, indicating substantial reduction in perceived disability. These values compare favorably with DASH scores of 20-30 reported by Björkenheim et al. and Olerud et al. at one-year follow-up.[27],[28] The complementary use of both objective (Constant score) and subjective (DASH score) outcome measures provides comprehensive assessment of treatment effectiveness, as recommended by current shoulder outcome research guidelines. The correlation between these two scoring systems (r=0.682, p<0.001) validates their concurrent validity in assessing proximal humerus fracture outcomes.

Range of motion recovery in our study showed mean forward flexion of 142.6 degrees and abduction of 136.8 degrees at 12 months, though still significantly less than contralateral normal shoulder (p<0.001). Similar findings were reported by Fankhauser et al. who documented persistent range of motion deficits averaging 15-25 degrees in all planes despite otherwise good functional outcomes.[29] The external rotation showed particular difficulty in recovery with mean 38.4 degrees, representing the most significant persistent limitation. This pattern reflects the common finding that rotational movements require longer rehabilitation periods and may never fully recover to preinjury levels, particularly in three-part and four-part fractures involving tuberosity displacement.

The complication profile in our study requires contextualization within the broader literature. While our overall complication rate of 12.8% appears acceptable, the individual complications highlight areas for potential improvement. The superficial infection rate of 3.9% is within expected ranges for orthopedic trauma surgery, and all cases responded to conservative management without hardware removal, suggesting adequate perioperative antibiotic prophylaxis. The absence of deep infection or septic complications in our series may reflect careful soft tissue handling and appropriate timing of surgery. Delayed union in 5.1% of patients eventually progressed to successful union with extended conservative management, though this complication prolonged disability and rehabilitation timelines for affected individuals.

The subacromial impingement requiring plate removal in one patient (1.3%) highlights the importance of appropriate plate positioning. Several authors recommend positioning the plate 5-8 mm distal to greater tuberosity to minimize this complication, as practiced in our technique. However, individual anatomical variations and rotator cuff pathology may predispose certain patients to impingement despite optimal plate placement. Some recent designs of

proximal humerus plates feature lower profiles and anatomically varied contours to address this issue.

The absence of neurovascular injuries in our series reflects the safety of the deltopectoral approach and careful surgical technique. The axillary nerve is particularly at risk during reduction maneuvers and plate positioning, and systematic identification and protection of neurovascular structures remains paramount. The absence of nonunion in our study contrasts with 2-8% nonunion rates reported in some series, possibly reflecting our liberal use of bone grafting in cases with metaphyseal defects and emphasis on achieving stable fixation with adequate screw purchase.

The multiple regression analysis in our study identified fracture complexity, age, and bone mineral density as independent predictors explaining 48.6% of variance in functional outcomes. This multivariate model provides useful prognostic information for patient counseling and treatment planning. Patients with four-part fractures, age above 60 years, and osteoporotic bone should be counseled regarding realistic expectations and potential for suboptimal outcomes even with optimal surgical technique. Alternative treatment strategies including arthroplasty might be considered in this high-risk group, though direct comparative studies are needed.

Patient satisfaction rates showed correlation with objective outcomes but also demonstrated that dominant limb involvement reduced satisfaction despite comparable Constant scores ($p=0.042$). This finding emphasizes the importance of considering patient expectations and functional demands in treatment decision-making. Patients requiring return to overhead activities or heavy manual labor may experience greater disability than captured by standard outcome measures, suggesting need for more activity-specific assessment tools.

The study has several limitations that warrant acknowledgment. The relatively small sample size of 78 patients, particularly with only 13 four-part fractures, limits statistical power for subgroup analyses. The absence of control group receiving alternative treatment modalities prevents direct comparison of PHILOS plating effectiveness versus other techniques. The 12-month follow-up duration, while adequate for assessing fracture healing and short-term functional recovery, may be insufficient to detect late complications such as progressive avascular necrosis or post-traumatic arthritis. The single-center design may limit generalizability to different populations and healthcare settings. Surgeon experience and technical proficiency with the technique may have influenced outcomes, though all surgeries were performed by experienced fellowship-trained shoulder surgeons. Despite these limitations, the study provides valuable outcome data from a prospective cohort with standardized surgical technique, systematic follow-up protocol, and validated outcome measures.

Future research directions should include longer-term follow-up to assess durability of outcomes and late complications, comparative studies with alternative fixation methods or arthroplasty in specific fracture patterns, investigation of bone augmentation techniques in osteoporotic patients, development of fracture-specific implants for particular problematic patterns, and cost-effectiveness analyses comparing different treatment strategies. The role of patient-specific factors including genetic polymorphisms affecting bone healing, sarcopenia, and frailty scores in predicting outcomes deserves further investigation. Advanced imaging techniques including three-dimensional CT and virtual

surgical planning may improve reduction quality and screw placement accuracy, warranting prospective evaluation.

Conclusion

The present study demonstrates that PHILOS plating provides satisfactory clinical and radiological outcomes for displaced proximal humerus fractures with 94.9% union rate and 76.9% excellent to good functional results at one-year follow-up. The technique effectively restores proximal humerus anatomy with significant improvement in neck-shaft angle from 118.4 to 134.6 degrees and achieves acceptable functional recovery with mean Constant-Murley score of 78.6 and DASH score of 22.4 at 12 months. The complication rate of 12.8% remains within acceptable limits reported in contemporary literature, with no catastrophic complications encountered. Fracture complexity according to Neer classification emerged as the most significant predictor of outcomes, with two-part fractures achieving superior results compared to three-part and four-part fractures. Patient age and bone quality also significantly influenced functional recovery, with younger patients and those with better bone mineral density demonstrating better outcomes. The locking plate technology offers particular advantages in osteoporotic bone through angular stability and fixed-angle construct, though outcomes remain suboptimal in elderly patients with complex fractures and severe osteoporosis. Meticulous surgical technique including anatomical reduction, appropriate plate positioning, careful screw length selection, and consideration for bone grafting in metaphyseal defects are essential for optimizing outcomes. Early postoperative rehabilitation following a structured physiotherapy protocol facilitates functional recovery while minimizing stiffness. The results support continued use of PHILOS plating as a reliable treatment option for displaced proximal humerus fractures in appropriately selected patients, while highlighting the need for careful patient counseling regarding realistic expectations based on fracture pattern, age, and bone quality. Alternative treatment strategies including arthroplasty should be considered for complex four-part fractures in elderly patients with severe osteoporosis where functional outcomes with internal fixation may be compromised. The study contributes valuable outcome data from an Indian population and reinforces the importance of individualized treatment approaches based on fracture characteristics and patient factors to achieve optimal results in this challenging fracture population.

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