RESEARCH PAPER

Functional Outcomes of Proximal Humerus Fractures: Clinical Recovery, Fracture Complexity, and Treatment Strategy

Dr. Amit B Patil[1*], Dr. Rellu Sarath Chandra[2], Abhilash Dinesh Shetty[3], Arjun Gopal[4]
[1*]Senior Resident, Mandya Institute of Medical Sciences, Mandya
[2]Senior Resident, Guntur Medical College, Guntur
[3]Orthopaedic Resident / Junior Resident, Mandya Institute of Medical Sciences, Mandya
[4]Orthopaedic Resident / Junior Resident, Mandya Institute of Medical Sciences, Mandya
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ABSTRACT

Background: Proximal humerus fractures constitute a major cause of upper-limb disability, particularly in older adults, and uncertainty persists regarding the relationship between fracture morphology, treatment strategy, and subsequent shoulder function. This study evaluated functional recovery after proximal humerus fracture and examined clinical and fracture-related predictors of an unfavorable outcome.

Methods: A prospective observational cohort study was performed in adults with acute proximal humerus fractures. Ninety-two patients received nonoperative treatment, locking-plate fixation, or reverse shoulder arthroplasty according to clinical indications. Shoulder function was assessed at 6 weeks and 3, 6, and 12 months using the Constant-Murley Score (CMS), Disabilities of the Arm, Shoulder and Hand (DASH) score, visual analogue scale for pain, and range-of-motion measurements. Multivariable logistic regression identified independent predictors of a poor 12-month functional outcome, defined as CMS <60.

Results: Eighty-four patients completed 12-month assessment. Mean CMS improved from 31.4 ± 10.8 at 6 weeks to 70.6 ± 13.9 at 12 months ($p<0.001$), while mean DASH decreased from 58.6 ± 14.7 to 17.9 ± 12.8 ($p<0.001$). Twelve-month CMS was significantly higher for two-part fractures than three- or four-part fractures (77.8 ± 10.5, 68.9 ± 12.0, and 54.0 ± 13.1, respectively; $p<0.001$). Four-part morphology (aOR 4.62; 95% CI 1.42-15.02), treatment-related complications (aOR 5.11; 95% CI 1.48-17.63), increasing age (aOR 1.63 per decade; 95% CI 1.06-2.52), and mobilization delayed beyond three weeks (aOR 2.84; 95% CI 1.01-8.00) independently predicted poorer function. Treatment category itself was not an independent predictor.

Conclusion: Most patients demonstrated substantial functional improvement during the first year after injury. Fracture complexity, complications, age, and delayed rehabilitation were more strongly related to outcome than treatment modality alone, supporting individualized treatment and early structured rehabilitation.

Keywords: proximal humerus fracture; functional outcome; Constant-Murley Score; DASH; locking plate; reverse shoulder arthroplasty; conservative treatment; shoulder fracture

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INTRODUCTION

Proximal humerus fractures (PHFs) represent a clinically important component of adult skeletal trauma and are particularly common among older women following low-energy falls. Population-based studies have demonstrated a pronounced age-related increase in incidence, reflecting the combined influence of osteoporosis, impaired balance, and increasing longevity [1]. PHFs account for approximately 5%-6% of adult fractures and rank among the commonest fragility fractures after fractures of the hip and distal radius [1,2]. Their clinical significance extends beyond fracture union because persistent pain, weakness, restricted elevation, and impaired activities of daily living may continue after radiographic healing.

Fracture morphology varies from minimally displaced injuries to highly unstable three- and four-part patterns involving the surgical neck, tuberosities, and articular segment. The Neer classification remains one of the most widely recognized systems for describing displacement and fragment number [3], although interobserver limitations have been documented. Vascular integrity is also relevant in complex intracapsular injuries; disruption of the medial hinge, short metaphyseal head extension, and specific fracture configurations have been associated with humeral-head ischemia [4]. These anatomical characteristics partly explain the greater risk of malunion, osteonecrosis, fixation failure, and functional impairment observed after complex fractures.

Functional outcome cannot, however, be inferred solely from radiographic appearance. Shoulder recovery reflects pain control, restoration of movement and strength, rotator-cuff function, patient age, comorbidity, pre-injury independence, rehabilitation, treatment complications, and expectations. The Constant-Murley Score integrates pain, activities of daily living, range of motion, and strength and remains extensively used in outcome studies [5]. Patient-reported measures such as DASH provide complementary information regarding disability during daily upper-extremity activity.

The optimal management of displaced PHF continues to generate debate. Nonoperative treatment with sling support followed by progressive mobilization remains

appropriate for many fractures. Operative options include open reduction and internal fixation (ORIF), intramedullary fixation, hemiarthroplasty, and reverse shoulder arthroplasty (RSA). High-quality evidence has challenged the assumption that anatomical surgical reconstruction necessarily produces superior patient-reported function. The PROFHER randomized trial found no clinically important advantage of surgery over nonsurgical care for most displaced surgical-neck fractures [7], and subsequent systematic reviews have reached broadly similar conclusions [6,8]. Conversely, selected complex fractures in older patients may achieve more predictable elevation after RSA than after fixation or hemiarthroplasty.

Consequently, contemporary management increasingly emphasizes patient-specific factors rather than fracture classification in isolation. The present study was designed to describe the trajectory of functional recovery during the first year following PHF and to determine whether fracture complexity, treatment strategy, complications, patient characteristics, and rehabilitation timing were independently associated with 12-month functional outcome.

MATERIALS AND METHODS

Study design

A prospective observational cohort study was conducted. Adults with acute radiographically confirmed proximal humerus fractures were consecutively evaluated for eligibility and were followed through standardized clinical and functional assessments.

Participants

Adults aged 18 years or older with an acute radiographically confirmed proximal humerus fracture who presented within 14 days of injury were considered eligible. Patients were included when they had an isolated unilateral PHF and were capable of participating in clinical assessment and rehabilitation. Patients with pathological or periprosthetic fractures, previous major surgery or severe functional impairment of the affected shoulder, open high-grade fractures, polytrauma preventing standardized shoulder rehabilitation, major pre-existing neurological impairment of the affected limb, or cognitive impairment precluding reliable functional assessment were excluded.

Fracture assessment and treatment

Standard anteroposterior and scapular-Y radiographs were obtained in all patients, and computed tomography was performed when fracture anatomy required additional definition. Fractures were classified according to the Neer system [3]. Treatment was individualized according to displacement, fracture morphology, bone quality, physiological age, pre-injury activity, comorbidity, and reconstructability. Nonoperative treatment consisted of sling immobilization followed by staged pendulum and active-assisted exercises. Operatively managed reconstructable fractures predominantly underwent ORIF with an angular-stable proximal humeral locking plate. RSA was performed for selected unreconstructable complex fractures in older patients. Physiotherapy was progressed according to fracture stability, radiographic healing, pain, and treatment-specific precautions.

Outcome assessment

The primary outcome was the Constant-Murley Score at 12 months [5]. The score ranged from 0 to 100, with higher values indicating superior shoulder function. Secondary outcomes included DASH score, pain on a 10-point visual analogue scale, active forward flexion, abduction, external rotation, radiographic union, complications, and reoperations. Assessments were performed at approximately 6 weeks and 3, 6, and 12 months. Range of motion was measured using a standard goniometer. Complications included symptomatic malunion, clinically important stiffness, infection, screw penetration, avascular necrosis, neurological deficit, implant failure, and requirement for secondary surgery.

Ethical considerations

Ethical approval was obtained from the Institutional Ethics Committee before recruitment. Written informed consent was obtained from all participants. Study procedures were conducted according to the principles of the Declaration of Helsinki.

Statistical analysis

Continuous variables were summarized as mean ± standard deviation or median with interquartile range, according to distribution. Categorical variables were presented as frequencies and percentages. Continuous outcomes among independent groups were compared using analysis of variance or the Kruskal-Wallis test, as appropriate, while categorical variables were compared using chi-square or Fisher exact testing. Change in functional scores over follow-up was evaluated using repeated-measures modeling. A poor functional outcome was predefined as a 12-month CMS below 60. Variables considered clinically relevant or demonstrating univariable associations at $p<0.10$ were entered into multivariable logistic regression. Adjusted odds ratios with 95% confidence intervals were calculated. Statistical significance was defined as a two-sided $p<0.05$. Analyses were performed using IBM SPSS Statistics, version 29.0.

RESULTS

A total of 104 patients were assessed for eligibility, of whom 92 satisfied the study criteria. The mean age was 64.8 ± 12.6 years, and 58 patients (63.0%) were women. Low-energy falls accounted for 71.7% of injuries. Two-part fractures constituted the largest subgroup (47.8%), followed by three-part (33.7%) and four-part fractures (18.5%). Forty-eight patients were treated nonoperatively, 34 underwent locking-plate ORIF, and 10 underwent primary RSA. Eight patients did not complete final evaluation, leaving 84 patients for the 12-month functional analysis.

A progressive and clinically substantial improvement in shoulder function occurred throughout follow-up. Mean CMS increased from 31.4 ± 10.8 at 6 weeks to 47.9 ± 12.6 at three months, 61.8 ± 13.4 at six months, and 70.6 ± 13.9 at one year ($p<0.001$). Correspondingly,

DASH disability declined from 58.6 ± 14.7 to 17.9 ± 12.8. Forward flexion improved from approximately 72 degrees at six weeks to 139 degrees at 12 months. Improvement was greatest during the first six months, although measurable functional gains continued between six and 12 months.

Fracture complexity showed a stronger association with final function than crude treatment category. Patients with two-part fractures achieved a mean 12-month CMS of 77.8, compared with 68.9 after three-part fractures and 54.0 after four-part fractures ($p<0.001$). Unadjusted CMS did not differ significantly among nonoperative, ORIF, and RSA groups, although treatment selection reflected baseline fracture severity.

Fourteen patients developed clinically relevant complications; complications were more frequent after operative treatment. In multivariable analysis, four-part morphology, complications, older age, and delayed mobilization remained independently associated with CMS <60, whereas treatment modality did not.

Table 1. Baseline characteristics of the study cohort

Characteristic	Value (n=92)
Age, years, mean ± SD	64.8 ± 12.6
Female sex	58 (63.0%)
Low-energy fall	66 (71.7%)
Dominant arm involved	39 (42.4%)
Documented osteoporosis	35 (38.0%)
Diabetes mellitus	17 (18.5%)
Current smoker	18 (19.6%)
Neer two-part fracture	44 (47.8%)
Neer three-part fracture	31 (33.7%)
Neer four-part fracture	17 (18.5%)
Nonoperative treatment	48 (52.2%)
Locking-plate ORIF	34 (37.0%)
Reverse shoulder arthroplasty	10 (10.9%)

The cohort reflected the typical demographic profile of proximal humerus fracture, with a predominance of women and low-energy injury mechanisms. Nearly one-half of fractures were two-part injuries, whereas approximately one-fifth were complex four-part fractures. Slightly more than half of patients were managed without surgery. The distribution of ORIF and RSA demonstrated selective operative management rather than uniform treatment according to displacement alone, permitting assessment of recovery across a clinically heterogeneous fracture population.

Table 2. Functional recovery during 12 months of follow-up

Outcome	6 weeks	3 months	6 months	12 months	p value
Constant-Murley Score	31.4 ± 10.8	47.9 ± 12.6	61.8 ± 13.4	70.6 ± 13.9	<0.001
DASH score	58.6 ± 14.7	39.7 ± 13.5	25.8 ± 12.9	17.9 ± 12.8	<0.001
VAS pain	5.1 ± 1.6	3.4 ± 1.5	2.2 ± 1.3	1.6 ± 1.2	<0.001
Forward flexion, degrees	72 ± 21	102 ± 24	127 ± 23	139 ± 22	<0.001
Abduction, degrees	64 ± 20	91 ± 23	116 ± 24	128 ± 24	<0.001

Functional improvement was continuous across the first post-fracture year, with the steepest recovery occurring between six weeks and six months. The increase in CMS was accompanied by substantial reductions in patient-reported disability and pain, indicating concordant objective and subjective recovery. Although improvement slowed after six months, both shoulder elevation and composite functional scores continued to increase through 12 months. These findings suggest that patients may appropriately be counseled to expect recovery beyond early radiographic union.

Increasing fracture complexity was associated with a clear deterioration in one-year function, higher disability, and greater complication burden. In contrast, crude comparison by treatment category showed no statistically significant difference in CMS or DASH. This apparent similarity should not be interpreted as treatment equivalence because operative treatment had preferentially been selected for more complex injuries. The findings instead emphasize fracture severity as a major determinant of prognosis and the limitations of unadjusted treatment comparisons in observational cohorts.

Table 3. Twelve-month outcome according to fracture complexity and management

Subgroup	n	CMS, mean ± SD	DASH, mean ± SD	Complications
Two-part fracture	41	77.8 ± 10.5	12.1 ± 8.8	3 (7.3%)
Three-part fracture	28	68.9 ± 12.0	18.9 ± 10.4	5 (17.9%)
Four-part fracture	15	54.0 ± 13.1	32.0 ± 15.2	6 (40.0%)
p value	-	<0.001	<0.001	0.008
Nonoperative	44	72.1 ± 13.0	16.4 ± 11.6	4/48 (8.3%)*
ORIF	31	70.4 ± 13.7	18.1 ± 12.2	8/34 (23.5%)*
RSA	9	64.2 ± 17.1	24.3 ± 17.0	2/10 (20.0%)*
p value	-	0.22	0.29	0.12

Table 4. Multivariable predictors of poor 12-month function (CMS <60)

Predictor	Adjusted odds ratio	95% CI	p value
Age, per 10-year increase	1.63	1.06-2.52	0.026
Female sex	1.21	0.40-3.62	0.74
Three-part vs two-part fracture	2.18	0.70-6.80	0.18
Four-part vs two-part fracture	4.62	1.42-15.02	0.011
Any treatment-related complication	5.11	1.48-17.63	0.010
Mobilization delayed >3 weeks	2.84	1.01-8.00	0.048
Operative vs nonoperative treatment	0.89	0.30-2.65	0.84

Multivariable analysis demonstrated that prognosis depended principally on fracture complexity and the subsequent clinical course. Four-part morphology increased the adjusted odds of poor function more than fourfold, while occurrence of a complication increased the odds approximately fivefold. Increasing age and delayed mobilization also retained independent associations. Once these factors had been considered, operative treatment itself was not associated with poor outcome. The model therefore supported individualized decision-making focused on biological and mechanical risk rather than surgery as an isolated prognostic determinant.

FIGURE 1. DISTRIBUTION OF PROXIMAL HUMERUS FRACTURES BY NEER CLASSIFICATION

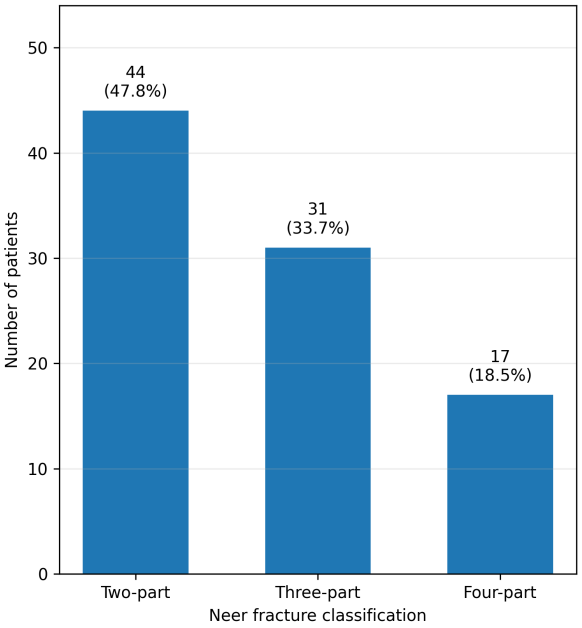
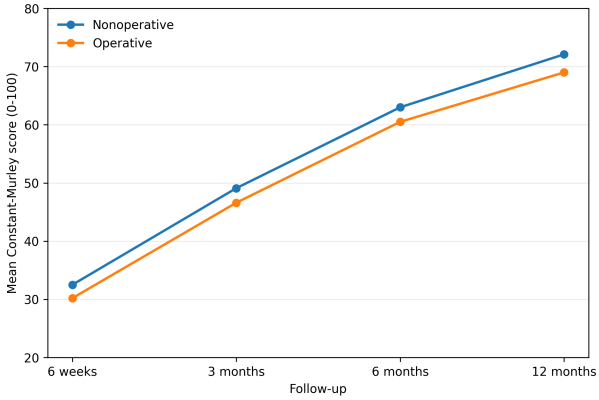


Figure 1 demonstrates that two-part fractures constituted the largest proportion of the cohort, followed by three-part fractures, while four-part injuries were least frequent. This distribution is clinically relevant because it indicates that simpler fracture patterns predominated, yet a meaningful proportion of patients still presented with complex fractures associated with poorer prognosis. The figure visually reinforces the cohort's heterogeneity and provides context for subsequent subgroup comparisons of functional outcome.

FIGURE 2. FUNCTIONAL RECOVERY TRAJECTORY ACCORDING TO TREATMENT STRATEGY



Both treatment groups displayed a broadly parallel increase in mean CMS throughout follow-up. Improvement was rapid during the first six months and continued at a slower rate thereafter. The nonoperative group maintained slightly higher unadjusted scores, but this difference should be interpreted in the context of treatment selection, because surgically managed patients contained a greater proportion of complex fractures. The trajectory supports the concept that biological recovery and structured rehabilitation contribute substantially to functional improvement regardless of definitive treatment strategy.

DISCUSSION

The principal finding of this study was that substantial functional recovery occurred during the first year after proximal humerus fracture, but the magnitude of recovery varied markedly according to fracture complexity, age, complications, and rehabilitation timing. Two-part fractures produced the most favorable results, while four-part injuries remained associated with substantial residual disability. Importantly, treatment modality did not independently predict poor function after adjustment, suggesting that the clinical context in which treatment is selected may be more consequential than a simple operative-versus-nonoperative distinction.

These findings are consistent with the PROFHER trial, in which Rangan et al. reported no clinically important advantage of surgery over nonsurgical treatment for the majority of displaced surgical-neck fractures [7]. Similar conclusions emerged from the NITEP trial of displaced two-part fractures, where locking-plate fixation did not improve functional outcomes compared with nonoperative treatment [11]. The NITEP three- and four-part trial likewise failed to demonstrate clinically important superiority of locking plates or hemiarthroplasty over nonoperative management in older adults [12]. Cochrane and contemporary meta-analytic evidence has reinforced the conclusion that routine surgery cannot be justified solely on the basis of displacement [6,8].

Not all trials have been entirely concordant. Olerud et al. observed numerical functional and quality-of-life

advantages following locking-plate fixation of displaced three-part fractures, although these gains occurred alongside a substantial additional-surgery rate [9]. Fjalestad et al. similarly found no compelling long-term functional superiority of angular-stable plating for complex fractures [10]. In four-part fractures, Olerud et al. reported improved health-related quality of life with hemiarthroplasty but no significant advantage in Constant score or range of motion [13]. Such findings emphasize that modest gains in selected domains may be counterbalanced by procedural morbidity.

The role of arthroplasty is particularly relevant in unreconstructable fractures. Fraser et al. demonstrated superior two-year Constant scores with RSA compared with plate fixation in patients aged 65-85 years with selected displaced fractures [14]. Laas et al. also reported better anterior elevation and Constant scores with RSA than hemiarthroplasty [15]. Conversely, Lopiz et al. found relatively limited overall benefit of RSA over nonoperative treatment among very elderly patients with three- and four-part fractures [16]. Thus, RSA may provide predictable elevation in appropriately selected complex injuries, but these findings should not be generalized to every displaced PHF.

The strong association between complications and poor function in the present study is biologically plausible. Locked-plate fixation can fail through screw penetration, varus collapse, avascular necrosis, stiffness, or loss of reduction. A large systematic review of PHILOS plate fixation reported an appreciable burden of complications and reinterventions [17]. Osterhoff et al. identified calcar comminution as a negative prognostic factor [19], while Sudkamp et al. demonstrated that local complications and varus deformity adversely influenced one-year Constant scores [20]. Ong et al. similarly showed poorer function after three- and four-part fractures than after simpler fracture patterns [18].

The association between delayed mobilization and worse outcome should be interpreted cautiously because patients with less stable injuries may deliberately have undergone prolonged protection. Nevertheless, prolonged immobilization can contribute to capsular stiffness, muscle wasting, impaired proprioception, and fear-mediated restriction of use. Functional rehabilitation should therefore balance mechanical protection with the earliest safe restoration of motion. Collectively, the present findings and prior trials favor treatment decisions that integrate reconstructability, bone quality, physiological age, functional demand, and rehabilitation capacity rather than radiographic displacement alone.

Several limitations must be acknowledged. The observational design permitted confounding by indication, particularly because complex fractures were disproportionately represented among surgically treated patients. The sample size restricted subgroup precision, especially for RSA. The CMS included examiner-dependent components, and pre-injury shoulder scores were unavailable. Follow-up was limited to one year, precluding evaluation of late osteonecrosis, post-traumatic arthritis, implant failure, or long-term arthroplasty survival. Larger multicenter prospective studies using standardized patient-reported outcomes and stratification by fracture morphology, frailty, bone quality, and rehabilitation exposure are warranted.

CONCLUSION

Proximal humerus fractures demonstrated substantial but heterogeneous functional recovery during the first year after injury. Fracture complexity, treatment-related complications, increasing age, and delayed mobilization were more strongly associated with poor functional outcome than treatment modality alone. Two-part fractures generally achieved favorable shoulder function, whereas four-part injuries remained clinically challenging despite contemporary management. These findings support an individualized treatment strategy that integrates fracture reconstructability, physiological age, functional demand, complication risk, and the capacity for structured rehabilitation rather than relying on displacement or operative intervention in isolation.

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