



# International Journal of Orthopaedics Sciences

E-ISSN: 2395-1958  
P-ISSN: 2706-6630  
IJOS 2021; 7(1): 1006-1015  
© 2021 IJOS  
[www.orthopaper.com](http://www.orthopaper.com)  
Received: 22-12-2020  
Accepted: 27-01-2021

**Dr. Vikram Shetty**  
Department of Orthopaedics,  
KS Hegde Medical Academy,  
Deralakatte, Mangaluru,  
Karnataka, India

**Dr. Hemant Kakarla**  
MBBS, MS (Ortho),  
Boys Hostel, KS Hedge Medical  
Academy, Deralakatte,  
Mangaluru, Karnataka, India

**Corresponding Author:**  
**Dr. Hemant Kakarla**  
MBBS, MS (Ortho),  
Boys Hostel, KS Hedge Medical  
Academy, Deralakatte,  
Mangaluru, Karnataka, India

## Functional outcome in surgically treated proximal humerus fractures with and without rotator cuff tear

**Dr. Vikram Shetty and Dr. Hemant Kakarla**

**DOI:** <https://doi.org/10.22271/ortho.2021.v7.i1o.2600>

### Abstract

Proximal humerus fractures are the second most common type of fractures in incidence among upper extremity fractures after distal radius fractures. With the relatively recent advent of locking plate technology and advances in surgical techniques, a greater proportion of the proximal humerus fractures are being treated surgically than in the past. Rotator cuff muscles are the main stabilizer of the shoulder joint and are torn in case of proximal humerus fractures. Their simultaneous repair along with the fixation of proximal humerus overcomes the need for multiple surgeries on later date. This study was a prospective observational study with an aim to find the incidence of rotator cuff injury and the functional outcome following repair in comparison to intact cuff in patients with proximal humerus fractures. The patients were subjected to MRI shoulder to know the rotator cuff status preoperatively and findings compared intra-operatively. The subjects were divided into 2 groups based on rotator cuff status. Cuff tears were repaired simultaneously while fracture fixation. The patients were asked to maintain arm pouch for a period of 6 weeks and followed by shoulder rehabilitation exercises. The functional outcome were then assessed at 12 weeks and 24 weeks post-surgery. The functional outcome was comparatively better in subjects who had intact rotator cuff, compared to torn rotator cuff in proximal humerus fractures at both 12 and 24 weeks follow-up. Complications like stiffness and pain was more common in patients with torn rotator cuff.

**Keywords:** proximal humerus fracture, rotator cuff, PHILOS plating, DASH score, ASES score

### 1. Introduction

The shoulder joint is a ball and socket type of synovial joint, in which proximal humerus forms one of its components. This joint stability depends on the skeletal framework along with coordinated musculotendinous units holding it together. Proximal humerus fractures constitute of about 4-5% of all the fractures in our body, and they account for 45% of all the various types of humeral fractures. Proximal humerus fractures are the second most common type of fractures after distal radius fractures in fractures of upper extremities [1]. When considering adults over the age of 40 years, the incidence rate of proximal humerus fractures increases to 76% [2]. These fractures have a bi-modal distribution occurring either in young people following high energy trauma or in elderly with low-velocity injuries like simple fall [3]. Most proximal humerus fractures are either un-displaced or minimally displaced and can be treated non-surgically [4]. Up to 80% of proximal humeral fractures can be treated conservatively, resulting in good satisfactory results [4]. Nonsurgical options focus on early functional exercises to achieve a functionally acceptable range of motion (ROM). For the 15% to 20% of displaced proximal humerus fractures can be benefited by surgical fixation. The incidence of proximal humerus fractures increases with age and it causes considerable morbidity among the elderly population and it consumes significant health care resources [3]. Although proximal humeral fractures are more frequently seen at advanced ages, the presence of associated chronic rotator cuff injuries has not been adequately studied [5]. With the relatively recent advent of locking plate technology and advances in surgical techniques, a greater proportion of the proximal humerus fractures are being treated surgically than in the past [1]. In proximal humerus fractures, the focus is mostly on the skeletal abnormality and its reconstruction, while the surrounding musculotendinous unit (rotator cuff) damage and its repair are often ignored because of lack of visualization of rotator cuff on plain radiograph [6].

Full-thickness cuff tears are more frequent in patients for more than 60 years old [7]. To add to it, visualization of these structures face an additional diagnostic problem as it would require extensive soft tissue stripping during surgery to see its intactness [8]. Although various surgical techniques have been described for the unstable proximal humerus fractures, proximal humeral internal locking systems (PHILOS) are increasingly popular for treating these fractures because they offer improved biomechanical properties by providing divergent and convergent fixed-angle screws that improve fixation and pull-out strength in osteoporotic bone [9]. Many factors are contributing to post-surgical joint stiffness/restriction, of which loss of integrity of the rotator cuff is one of them [10]. The integrity of the rotator cuff can be assessed by modalities like arthroscopy, USG, MRI. It would tell us the degree of tear and the status of each muscle of the rotator cuff. Few studies were done in trying to find out the prevalence of cuff tears in proximal humerus fractures by various radiological modalities [10, 11] but there are very few studies trying to find out the post-surgical functional outcome [12]. Although the importance of an intact rotator cuff has been emphasized for a good clinical outcome since the studies by Neers, the effect of rotator cuff repairs on the results has not been adequately investigated [5]. The purpose of this study is to find out the functional outcome in patients of proximal humerus fractures with rotator cuff tear and comparing it with patients with intact rotator cuff in proximal humerus fractures.

## 2. Materials and Methods

### 2.1 Study design

Prospective observational study.

### 2.2 Study population

All the patients who have attained skeletal maturity of proximal humerus and admitted to Justice K.S. Hegde charitable hospital with proximal humerus fracture.

### 2.3 Study setting

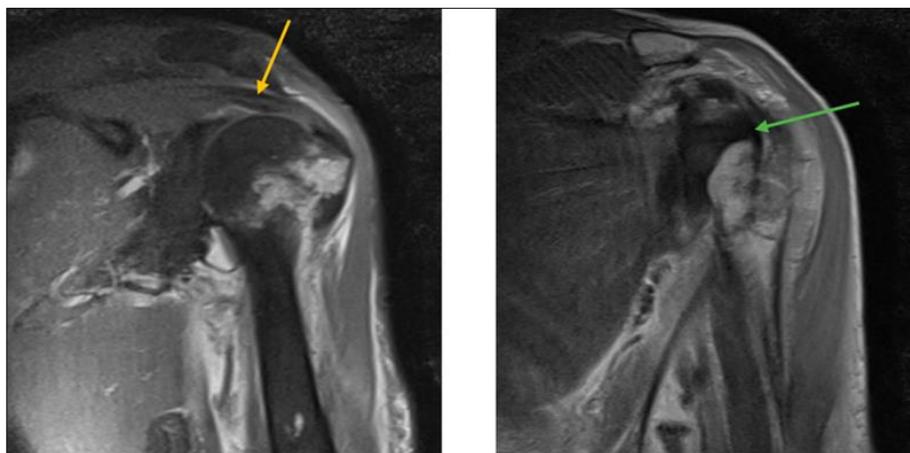
Department of orthopaedics in Justice K.S Hegde Hospital affiliated to K.S Hegde Medical Academy under Nitte (Deemed to be University). Hospital based study.

### 2.4 Study period

November 2018 – March 2020.

### 2.5 Method

All the patients diagnosed with proximal humerus fracture by radiography (x-ray) were taken up for the study after meeting the inclusion criteria. The fractures were classified into types based on Neer's classification. MRI shoulder was done to know the pre-operative rotator cuff status. These findings were verified intra-operatively. Based on the rotator cuff intactness, the patients were divided into 2 groups, group 1 were the subjects with torn cuff and group 2 were patients with an intact cuff. All the patients were taken up for surgical fixation of fracture in the form of open reduction and internal fixation with PHILOS plate by deltopectoral approach. Associated cuff tears were repaired simultaneously during the primary surgery with ethibond suture material. All the patients had similar post-operative rehabilitation protocol where arm pouch was given for 6 weeks, followed by shoulder ROM exercises were started. Functional assessment was done at 12 weeks and 24 weeks post-op by DASH and ASES scores.



**Fig 1:** Showing supraspinatus (Yellow) and subscapularis (Green) tendon tear in case 14

### 2.6 Inclusion criteria

- All skeletally mature patients presenting with proximal humerus fracture. (Age more than 19 years)
- Patients voluntarily willing to participate in the study and come for follow-up at 12, 24 weeks post-surgery.

### 2.7 Exclusion criteria

- Patients more than 80 years of age.
- Isolated GT fractures of proximal humerus diagnosed radiologically.
- Patients with previous h/o injury/illness/surgery to the affected shoulder.
- Patient with low intensity injury leading to fracture of proximal humerus (Suspecting Pathological fracture).
- Presence of prior neurological deficits in the upper limb

to be assessed.

- Patients not willing to participate in the study and any loss of follow-up.

## 3. Results and Discussion

All the subjects who meet the inclusion criteria and diagnosed with proximal humerus fracture were taken for the study. They underwent pre-operative MRI to know the rotator cuff status and later cross-verified intra-operatively. Group allocation was done based on the rotator cuff intactness. Group-1 were subjects with proximal humerus fractures and torn rotator cuff, while group-2 were subjects with proximal humerus fractures and intact rotator cuff. Statistical analysis was done using SPSS software.

### 3.1 Age distribution

The age was divided into 2 groups with age less than 50 years in one group and above 50 years in another. It was noticed from the study that most of the subjects with rotator cuff tears belonged to age group more than 50 years with a mean age group of 60.80 years. Most of the subjects in group 2 had age of less than 50 years with a mean age group of 48 years.

### 3.2 Incidence

A total of 24 subjects were included in the study by the end of study period of which 10 patients had rotator cuff injury which was noted intra-operatively. Hence from our study it can be concluded that the incidence rate of rotator cuff tears in proximal humerus fractures is 41.6%.

In comparison to another study done by Nanda R, Goodchild L, Gamble A, Campbell RSD, Rangan A [4]. They studied 85 proximal humerus fractures of which 43 patients had rotator cuff tear, with an incidence rate of 41.7%.

Choo A, Sobol G, Maltenfort M, Getz C, Abboud J [1] conducted a study to find out the prevalence of rotator cuff tears in proximal humerus fractures and it was found out that the rate was 8.6%.

### 3.3 Mode of injury

The study groups were divided based on 3 different modes of injuries which included fall from height, Road traffic accidents (RTA) and slip and fall. Even though slip and fall was the most common mode of injury in both group 1 and group 2, RTA was the mode of injury which lead to rotator cuff tears in younger subjects.

In comparison to one of the studies done by Rocco Erasmo, Giovanni Guerra, Luigi Guerra [13] which included 82 study subjects it was found that most of them had slip and fall as the most common mode of injury followed by RTA. It was concluded from the study that high velocity injury was the cause for rotator cuff tears in younger age groups.

Another study done by Gaheer, Rajinder singh, Hawkins [14] studied the functional outcome of 3 and 4 part fractures fixed by PHILOS plating. It was found in their study that RTA was the most common mode of injury followed by slip and fall.

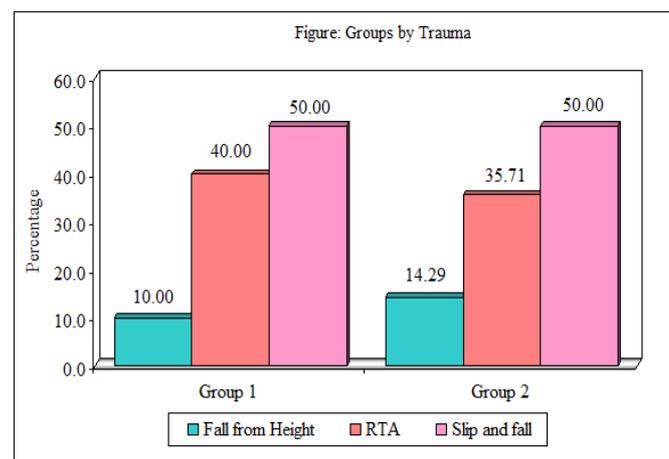


Fig 2: Bar graph depicting different modes of injury

### 3.4 Arm affected

All the subjects in the study group were right hand dominant. From the study it was found that most of the subjects in group 1 had left arm affected, constituting about 60%. Most of the subjects in group 2 had right hand affected, which constituted about 71.43%.

### 3.5 Neer's classification of fractures

All the patients were radiographically assessed and they were classified according to Neer's classification into 2-part, 3-part and 4-part fractures. There were total of 8 (2-part) fractures, 10 (3-part) fractures and 6 (4-part) fractures. Most of the subjects in group 1 had 3-part fractures whereas group 2 had 2 part fractures. In our study it was noted that severity of fractures increased with age along with increased incidence of rotator cuff injury. In young subjects 3 and 4 part fractures were due to high velocity injuries like RTA.

In a study conducted by Gaheer, Rajinder Singh, Hawkins [14] it was noted that RTA was the most common mode of injury and severity of fracture increased with increasing age and the functional outcome was better in younger subjects compared to elderly. It was also inferred from the study that valgus angulation had a better outcome compared to varus angulation of humeral head post-surgical fixation and associated complications were also more in varus than valgus head.

In another study conducted by Halfen, Tobias, Siebenbürger [15] all the 2-part fractures were taken in the study and functional outcome between intramedullary nailing and PHILOS plating was studied. In their study it was noted that most of the subjects had age group less than 50 years and there was no significant difference in the functional outcome during 6 and 12 months follow-up. It also showed that they all had better outcomes and less disability following surgery.

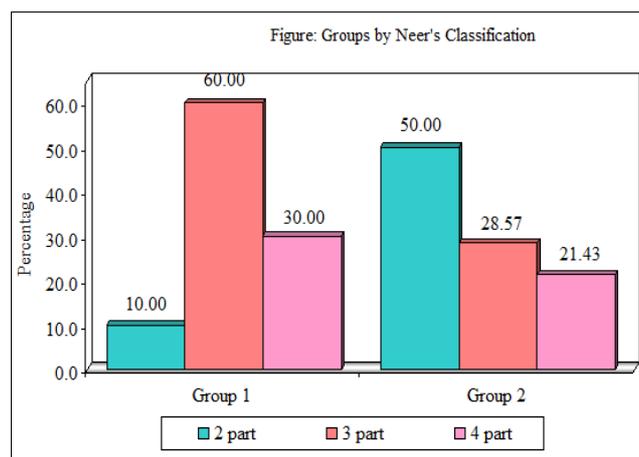


Fig 3: Bar graph showing Neer's classification of fractures

### 3.6 DASH scores

All the subjects were assessed by DASH scores at 12 weeks and 24 weeks follow-up to know their functional outcome, pain and disability due to fracture and to know any difference between subjects from group 1 and group 2. It was observed from the study that both the groups had improved DASH scores from 12 weeks to 24 weeks but the group 2 had better scores compared to group 1 at both 12 and 24 weeks. Statistically it was a significant co-relation with a p-value of 0.0001. It can be concluded from the study that rotator cuff integrity plays a role in deciding the functional outcome of surgically treated proximal humerus fractures by ORIF and Intact rotator cuff has better outcome compared to torn cuff.

In line with a study done by Neslihan AKSU, Ömer ASLAN, Ayhan Nedim KARA [2] where simultaneous repair of rotator cuff was done during fracture fixation and were followed up (mean follow-up period of 17 months). It was concluded from the study that there was no significant difference in functional outcome between both the groups (i.e. between simultaneous repair group and intact cuff group).

In Another study done by Tang Ying Ji, Tao Z, Li J, Yin Z [16]. They compared the functional outcome between simultaneous repair and delayed repair (>3 months following fracture fixation) of rotator cuff in subjects with proximal humerus fractures. Simultaneous repair was done by open

method and delayed repair by arthroscopic method. It was concluded from the study that simultaneous repair subjects had a better outcome compared to delayed repair (assessed by constant murphy score and UCLA scores).

**Table 1:** DASH scores of subjects

Time period	Groups	Mean	SD	SE	t-value	P-value
12 weeks	Group 1	39.38	13.86	4.38		
	Group 2	19.08	7.66	2.05	4.6083	0.0001*
24 weeks	Group 1	21.93	13.45	4.48		
	Group 2	8.57	4.18	1.16	3.3862	0.0029*
Changes	Group 1	15.71	6.73	2.24		
	Group 2	9.80	3.90	1.08	2.6109	0.0167*

**3.7 ASES scores**

All the subjects were followed up at 12 and 24 weeks follow-up. It was observed from the study that both the groups had improved ASES scores from 12 weeks to 24 weeks but the group 2 had better outcome compared to group 1 at both 12 and 24 weeks. Statistically it was a significant co-relation with a p-value of 0.0006. It can be inferred from the study that intact rotator cuff subjects had less disability and better functional outcome compared to subjects with torn and

repaired rotator cuff.

In comparison to study conducted by Neslihan AKSU, Ömer ASLAN, Ayhan Nedim KARA [2] where simultaneous repair of rotator cuff was done during fracture fixation and were followed up (mean follow-up period of 17 months). It was concluded from the study that there was no significant difference in functional outcome between both the groups (i.e. between simultaneous repair group and intact cuff group).

**Table 2:** ASES scores of subjects

Time period	Groups	Mean	SD	SE	t-value	P-value
12 weeks	Group 1	41.75	14.71	4.65		
	Group 2	65.98	9.72	2.60	-4.8714	0.0001*
24 weeks	Group 1	67.06	14.74	4.91		
	Group 2	85.00	5.05	1.40	-4.0932	0.0006*
Changes	Group 1	-23.63	8.33	2.78		
	Group 2	-18.05	5.94	1.65	-1.8398	0.0807

**3.8 Co-relation between MRI and intra-OP rotator cuff status**

All the subjects were assessed pre-operatively by MRI to know the rotator cuff status and it was cross verified intra-operatively. Group 1 had subjects with rotator cuff tear, which included both partial and complete tears of rotator cuff. MRI showed 3 subjects with complete tear which was cross verified intra-operatively and was true. While 10 subjects had partial tear on MRI, only 7 were noted intra-operatively and rest 3 had intact cuff.

For the final assessment and group allocation intra-operative rotator cuff status was considered. In total there were 3 subjects with complete tear, 7 subjects with partial tear and 14 subjects with intact rotator cuff. All the subjects with partial tear had supraspinatus tear in them and associated tears, where 4 had infraspinatus and 1 had teres minor and 1 with subscapularis tear.

Coming to sensitivity of detection of cuff tears pre-operatively by MRI imaging, it was noted that 3 patients who were found to have partial tear on MRI had intact cuff, when cross verified intra-operatively. From our study it was found that the sensitivity of MRI imaging was 70%.

In comparison to a study done by Gallo RA, Altman DT, Altman GT [5], it was observed that MRI had a sensitivity of 94% and it was better than Ultrasound scan which had a sensitivity of 82%.

From the data gathered from the study, DASH scores and ASES scores of group1 (i.e. simultaneous repair of torn rotator cuff during fracture fixation) at 12 weeks and 24 weeks follow-up were compared with similar scores at same

time period of surgically treated proximal humerus fractures without rotator cuff repair. It was observed that the scores were better in group with repair than non-repair at both 12 and 24 weeks, showing better functional outcome and reduced disability following surgery. The following tables show the scores from various studies which were found on PubMed search engine. Hence from this data it can be concluded that simultaneous repair of rotator cuff improves the overall functional outcome of surgically treated proximal humerus fractures.

**Table 3:** DASH scores comparing between repair and non-repair groups

Study	Mean DASH score 12 weeks	Mean DASH score 24 weeks
Plath <i>et al.</i> [17]	52.0	45.0
Hengg <i>et al.</i> [18]	31.0	19.6
Helfen <i>et al.</i> [19]	47.2	40.1
Our study	28.3	14.8

**Table 4:** ASES scores comparing between repair and non-repair groups

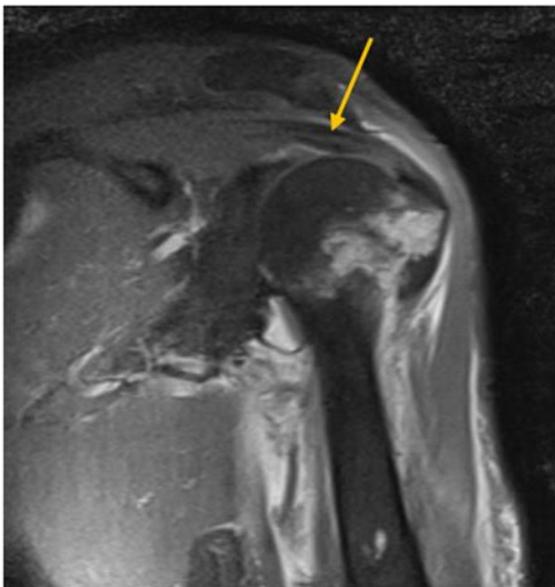
Study	Mean ASES score 12 weeks	Mean ASES score 24 weeks
Helfen <i>et al.</i> [15]	47.6	64.3
Our study	55.8	76.21

**Illustrations of cases – No. 1 (Case 5)**



**Pre-operative X-ray**

**Partial Cuff tear - SS**



**MRI showing Partial SS tear (Red arrow)  
and Post-op images after PHILOS plating.**

## Functional outcome at 24 weeks follow-up



**Restricted abduction**

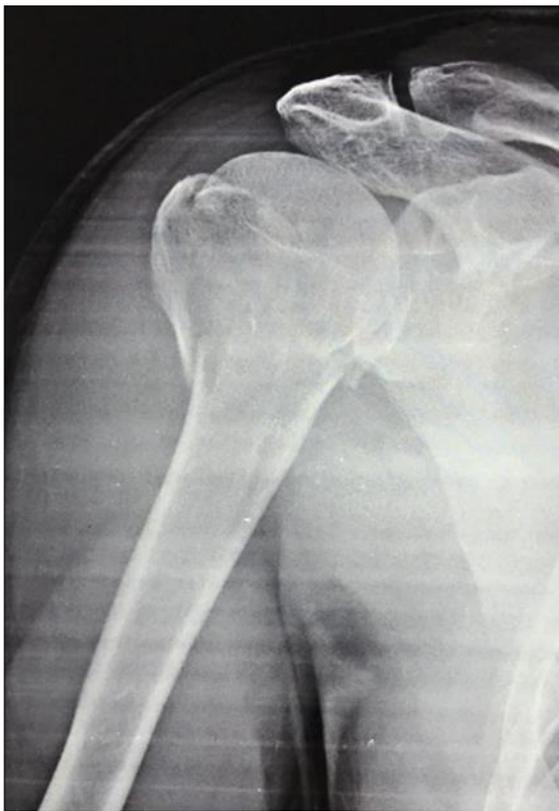
**Restricted forward flexion**



**ILLUSTRATION NO.2 (Case No. 12)**



**Intra-op images showing partial tear of SS & IS (A); Repair of same and PHILOS plating (B)**

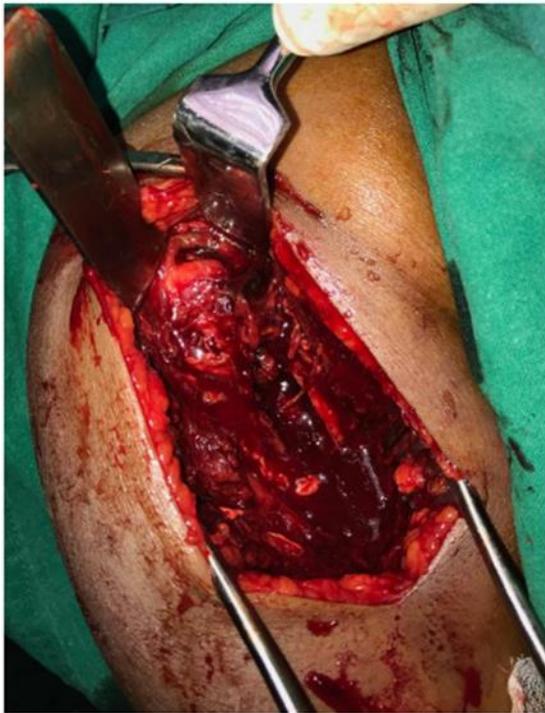


**Pre-op Image**



**Post-op Image**

### ILLUSTRATION No. 3 (Case No. 3)



**Intra-op image with complete tear of cuff & Post-op PHILOS Plating**



**Functional outcome at 24 weeks follow-up  
With restricted flexion, abduction and internal rotation**

Table 5: Master chart

Sl. No.	IP No.	Date of Sx	Age	Gender	Trauma	Affected hand	Dominant hand	Neer's Classification	MRI RC status	Intra-op RC status	DASH scoring	DASH scoring	ASES scoring	ASES scoring	Complications
											12 weeks	24 weeks	12 weeks	24 weeks	
1	18076037	08-11-2018	64	Male	Slip and fall	Left	Right	4 part	Partial tear	Intact	28.3	12.2	53.34	67.3	
2	18083239	29-11-2018	46	Female	Slip and fall	Right	Right	2 part	Intact	Intact	17.5	6.7	58.3	83.3	
3	18088685	19-12-2018	30	Male	Fall from height	Left	Right	3 part	Complete tear	Complete tear	47.5	20.8	31.6	68.3	Stiffness
4	18095498	06-01-2019	40	Male	RTA	Left	Right	4 part	Intact	Intact	13.3	5	74.9	91.6	
5	18096554	11-01-2019	60	Female	RTA	Left	Right	3 part	Partial tear – SS	Partial Tear – SS	40	15	48.3	83.32	
6	18098791	17-01-2019	28	Male	Fall from Height	Right	Right	2 part	Intact	Intact	10.8	5.8	78.3	89.9	
7	18098946	18-01-2019	50	Female	Slip and fall	Right	Right	3 part	Intact	Intact	20.8	9.2	69.9	81.6	Pain
8	18116356	14-03-2019	33	Male	RTA	Right	Right	2 Part	Intact	Intact	18.3	8.3	69.3	88.3	
9	18121916	30-03-2019	44	Male	RTA	Left	Right	4 part	Partial tear – SS	Intact	20.6	9.8	68.3	82.3	
10	19012669	09-05-2019	70	Female	Slip and fall	Right	Right	2 part	Intact	Intact	35.8	20	50	73.3	
11	19021186	04-06-2019	66	Female	Slip and fall	Right	Right	2 part	Intact	Intact	30	13.3	51.6	81.6	
12	19024418	13-06-2019	76	Male	Slip and fall	Right	Right	3 part	Partial tear - SS, IS and Minor	Partial Tear – SS, IS	55	34.9	26.6	53.2	
13	19039961	25-07-2019	44	Male	RTA	Left	Right	4 part	Partial tear	Partial tear	21.7	6.7	58.3	86.6	
14	19040867	01-08-2019	71	Female	RTA	Right	Right	3 Part	Partial tear – SS, IS and Sub	Partial tear – SS, IS and Sub	39.2	25.8	41.6	64.9	Stiffness
15	19042194	05-08-2019	75	Female	Slip and fall	Left	Right	3 part	Complete tear	Complete tear	40	24.2	40	58.3	
16	19046671	14-08-2019	60	Female	Slip and fall	Right	Right	4 part	Partial tear - SS, IS and Minor	Partial Tear – SS and IS	33.3	15	38.3	59.9	
17	19048442	20-08-2019	42	Male	Slip and fall	Right	Right	2 part	Intact	Intact	17.5	5.8	68.3	88.3	
18	19052504	31-08-2019	30	Female	RTA	Left	Right	2 part	Partial tear – SS and Minor	Intact	15.8	6.7	63.3	84.99	
19	19067798	13-10-2019	71	Female	Slip and fall	Right	Right	4 part	Complete tear	Complete tear	38.3	30.8	39.9	58.33	Stiffness
20	19077482	12-11-2019	56	Female	RTA	Right	Right	3 part	Intact	Intact	17.5	8.3	63.3	81.6	
21	19077807	14-11-2019	54	Male	Fall from height	Right	Right	3 part	Intact	Intact	11.7	8.3	76.6	89.9	
22	19110344	01-03-2020	54	Male	RTA	Left	Right	2 part	Partial tear – SS	Partial Tear – SS	16.3	8.3	71.3	82.3	
23	20001082	25-03-2020	49	Male	Slip and fall	Right	Right	3 part	Intact	Intact	9.2	4.2	78.3	88.33	
24	20002605	28-03-2020	67	Female	Slip and fall	Left	Right	3 part	Partial tear – SS and Sub	Partial Tear – SS	62.5	50.8	21.6	41.6	Stiffness
25	19062241	26-09-2019	61	Male	Slip and fall	Left	Right	4 part	Partial tear	Intact	28.3		53.34		Plate backout
26	19076610	10-11-2019	76	Male	Slip and fall	Right	Right	3 part	Partial tear - SS, IS and Minor	Partial Tear – SS, IS	55		26.6		Died

Abbreviations	
ASES	American Shoulder and Elbow Surgeons Standardized Shoulder Score.
DASH	Disability of Arm, Shoulder and Hand score.
IS	Infraspinatus
Minor	Teres Minor
RC	Rotator cuff
RTA	Road Traffic Accident
SS	Supraspinatus
Sub	Subscapularis

**4. Conclusion**

Pre-operative assessment of rotator cuff status and thorough intra-operative observation for cuff damage and simultaneous repair during fracture fixation has better functional outcome and limitation of disability in surgically treated proximal humerus fractures.

**5. References**

1. Choo A, Sobol G, Maltenfort M, Getz C, Abboud J.

Prevalence of Rotator Cuff Tears in Operative Proximal Humerus Fractures. Orthopedics 2014;37(11):e968–74.

2. Aksu N. Simultaneous repair of chronic full-thickness rotator cuff tears during fixation of proximal humerus fractures and clinical results. Acta Orthopaedica et Traumatologica Turcica 2010, 173–9.

3. Fjalestad T, Hole MØ, Blücher J, Hovden IAH, Stiris MG, Strømsøe K. Rotator cuff tears in proximal humeral fractures: an MRI cohort study in 76 patients. Archives of

- Orthopaedic and Trauma Surgery 2010;130(5):575–81.
4. Nanda R, Goodchild L, Gamble A, Campbell RSD, Rangan A. Does the presence of a full-thickness rotator cuff tear influence outcome after proximal humeral fractures? *J Trauma* 2007;62(6):1436–9.
  5. Gallo RA, Altman DT, Altman GT. Assessment of Rotator Cuff Tendons After Proximal Humerus Fractures: Is Preoperative Imaging Necessary? *The Journal of Trauma: Injury, Infection, and Critical Care* 2009;66(3):951–3.
  6. Rouleau DM, Laflamme GY, Mutch J. Fractures of the greater tuberosity of the humerus: A study of associated rotator cuff injury and atrophy. *Shoulder Elbow* 2016;8(4):242–9.
  7. Bahrs C, Rolaufts B, Stuby F, Dietz K, Weise K, Helwig P. Effect of proximal humeral fractures on the age-specific prevalence of rotator cuff tears. *J Trauma* 2010;69(4):901–6.
  8. Zhang J, Huang Q. [Reverse total shoulder arthroplasty for the treatment of comminuted fracture of proximal humerus in elderly patients with rotator cuff injury]. *Zhongguo Gu Shang* 2019;32(1):17–21.
  9. Moda SK, Chadha NS, Sangwan SS, Khurana DK, Dahiya AS, Siwach RC. Open reduction and fixation of proximal humeral fractures and fracture-dislocations. *J Bone Joint Surg Br* 1990;72(6):1050–2.
  10. Kim YG, Park KH, Kim JW, Oh JK, Yoon JP, Kim HJ *et al.* Is minimally invasive plate osteosynthesis superior to open plating for fixation of two-part fracture of the proximal humerus? *J Orthop Surg (Hong Kong)* 2019;27(2):2309499019836156.
  11. Osterhoff G, Ossendorf C, Wanner GA, Simmen HP, Werner CM. The calcar screw in angular stable plate fixation of proximal humeral fractures--a case study. *J Orthop Surg Res* 2011;24(6):50.
  12. Pawaskar AC, Lee KW, Kim JM, Park JW, Aminata IW, Jung HJ *et al.* Locking plate for proximal humeral fracture in the elderly population: serial change of neck shaft angle. *Clin Orthop Surg* 2012;4(3):209–15.
  13. Erasmo R, Guerra G, Guerra L. Fractures and fracture-dislocations of the proximal humerus: A retrospective analysis of 82 cases treated with the Philos® locking plate. *Injury* 2014;45(S6):S43-48.
  14. Gaheer RS, Hawkins A. Fixation of 3 and 4-part proximal humerus fractures using the PHILOS plate: mid-term results. *Orthopedics* 2010;33(9):671.
  15. Helfen T, Siebenbürger G, Fleischhacker E, Gleich J, Böcker W, Ockert B. Operative treatment of 2-part surgical neck type fractures of the proximal humerus in the elderly: Cement augmented locking plate PHILOS™ vs. proximal humerus nail multiloc®. *Injury* 2020;51(10):2245–52.
  16. Tang J, Tao Z, Li J, Yin Z. [Effectiveness of simultaneous versus delayed repair of combined full-thickness rotator cuff rupture in proximal humerus fracture]. *Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi* 2019;33(9):1141–6.
  17. Plath JE, Kerschbaum C, Seebauer T, Holz R, Henderson DJH, Förch S *et al.* Locking nail versus locking plate for proximal humeral fracture fixation in an elderly population: a prospective randomised controlled trial. *BMC Musculoskelet Disord* 2019;20(1):20.
  18. Hengg C, Nijs S, Klopfer T, Jaeger M, Platz A, Pohlemann T *et al.* Cement augmentation of the proximal humerus internal locking system in elderly patients: a

multicenter randomized controlled trial. *Archives of Orthopaedic and Trauma Surgery* 2019;139(7):927–42.