

## A PROSPECTIVE STUDY IN FUNCTIONAL OUTCOME OF COMMINUTED PROXIMAL HUMERUS FRACTURES WITH PHILOS PLATING

Jagadeesh Kumar M<sup>1</sup>, G Niranjana<sup>2</sup>, D Vishnu Kumar<sup>3</sup>, Rambabu Kemsarapu<sup>4</sup>

Received : 02/05/2024  
Received in revised form : 14/07/2024  
Accepted : 30/07/2024

**Keywords:**

Bone plates; fracture fixation, humerus/injuries; shoulder fractures; PHILOS.

Corresponding Author:

**Dr. Rambabu Kemsarapu,**

Email: ramkemsarapu87@gmail.com

DOI: 10.47009/jamp.2024.6.4.65

Source of Support: Nil,

Conflict of Interest: None declared

*Int J Acad Med Pharm*  
2024; 6 (4); 326-331



<sup>1</sup>Junior Resident, Department of Orthopaedics, Gandhi Medical College and Hospital, Secunderabad, Telangana, India.

<sup>2</sup>Assistant Professor, Department of Orthopaedics, Gandhi Medical College and Hospital, Secunderabad, Telangana, India.

<sup>3</sup>Assistant Professor, Department of Orthopaedics, Gandhi Medical College and Hospital, Secunderabad, Telangana, India.

<sup>4</sup>Assistant Professor, Department of Orthopaedics, Gandhi Medical College and Hospital, Secunderabad, Telangana, India.

### Abstract

**Background:** Fractures of the proximal humerus is still unsolved fractures in many ways. Proximal humeral fractures account for approximately 5% of all fractures. New plating techniques have been developed to improve stability. **Aim and objectives:** The aim of study is to analyze the functional outcomes of patients with proximal humerus fracture with PHILOS plate fixation. To evaluate the functional outcome of Proximal Humerus Locking Plate for Displaced fracture of proximal humerus, improve stability in osteoporotic humeral bones. **Materials and Methods:** This is a prospective study, conducted at Gandhi Medical College & Hospital, Secunderabad in the Department of Orthopedics & Traumatology on those who were admitted with fracture of Proximal Humerus. The PHILOS plate was used for internal fixation of displaced proximal humeral fractures in 27 patients. According to the Neer classification, 3 (11.10%), 8 (29.60%), and 15 (55.55%) patients had displaced 2-, 3-, or 4-part fractures, respectively. All patients received a similar physical therapy program following internal fixation with the PHILOS plate. Functional outcome was assessed using the Constant Murley score adjusted for age and gender. **Results:** 27 patients with closed displaced proximal humerus fractures were treated by open reduction and internal fixation with a PHILOS plate. The majority of the patients were male's i.e.77.78% and 22.22% were females. In the majority of 16 (59.26%) cases, the mode of injury was RTA. In our study, we had 3 cases (11.10%) with 2 part fracture surgical neck humerus and 8 (29.60%) cases with 3 part fractures.15 (55.55%) cases with 4-part fractures. In our study, 8 (29.63%) cases had an excellent result, 8 (29.63%) had a good result and 4 (14.82%) had a Moderate result. 3 (11.11%) had a poor result. **Conclusion:** To conclude, the PHILOS locking plate is an advantageous implant in proximal humeral fractures due to angular stability, particularly in comminuted fractures and in osteoporotic bones in elderly patients, thus allowing early mobilization.

## INTRODUCTION

The field of orthopaedic surgery has been on the front line in creating new information, establishing new principles of treatment and solving both new and old problems of the musculoskeletal system.<sup>[1]</sup> Fractures of the proximal humerus are still unsolved fractures in many ways. Disagreement exists regarding the reliability of the classification system. The indication for surgical management continues to be modified.<sup>[2]</sup> Fixation techniques are myriad and

none is ideal for all cases. Fractures of proximal humerus are not uncommon, especially in the older age group. Proximal humeral fractures account for approximately 5% of all fractures.<sup>[3]</sup> Within the last three decades, the age-adjusted incidence of proximal humeral fractures increased by 15% per year.<sup>[4]</sup> Increased incidence of proximal humeral fractures is associated with more complications. Be treated nonoperatively, resulting in satisfactory results. However, different techniques have been described for the fixation of comminuted and

displaced proximal humeral fractures, including sutures, cerclage wires, K-wires, screws and plates, intramedullary devices, and shoulder arthroplasty.<sup>[5]</sup> The complication rate can be as high as 50% or higher. Several complications have been reported, such as cut-out or back-out of the screws and plates, nonunion, avascular necrosis, nail migration, rotator cuff impairment and impingement syndrome.<sup>[6]</sup> Even shoulder arthroplasty in proximal humeral fractures may yield functionally poor results.<sup>[7]</sup> To decrease the incidence of complications, particularly fixation failure and loss of stability, and to improve stability and enable early postoperative mobilization, new plating techniques such as the Proximal Humeral Internal Locking System (PHILOS, Synthes, Solothurn, Switzerland) have been developed. Since there is a high correlation between the holding capacity of screws and regional bone morphology (e.g. cortical thickness and bone mineral density), osteoporotic bone is implicated in the occurrence of complications in proximal humeral fractures.

#### **Aim and objectives**

The study aims to analyse the functional outcomes of patients with proximal humerus fracture with PHILOS plate fixation. To evaluate the functional outcome of the Proximal Humerus Locking Plate for the displacement of the fracture of the proximal humerus and to improve stability in osteoporotic humeral bones. To preserve the biological integrity of the humeral head and to secure an anatomical reduction with multiple locking screws with angular stability and shoulder stiffness and to achieve good functional shoulder range.

## **MATERIALS AND METHODS**

Source of the data: Adults (>19yrs) with proximal humerus fractures admitted to Gandhi Hospital, Secunderabad, Telangana

Method of Study: Prospective Study

Sample size and Duration of Study: Sample size of 27 cases, for 18 months.

This is a prospective study, conducted at Gandhi Medical College & Hospital, Secunderabad in the Department of Orthopedics & Traumatology on those who were admitted with fracture of Proximal Humerus from December 2021 to May 2023. Before including them in this study, informed consent was obtained from them in the language in which they were well-versed, and ethical committee clearance was obtained for the same.

#### **Method of collection of data**

The study's purpose is to include patients with proximal humerus fractures admitted and examined according to protocol, and associated injuries noted. Clinical and Radiological evaluations were done. Fractures are classified using Neer's classification. Predictor of humeral head ischemia by Hertel's criteria Routine investigation carried out to get fitness for surgery. Patients will undergo Open

reduction internal fixation with PHILOS plate Post-operative physiotherapy followed according to protocol, to evaluate the functional outcome. Patient functional results were calculated using constant and Murley scores. Patients will be followed up at 6 weeks, 12 weeks and at 6 months A minimum of 30 cases will be studied without any sampling procedure.

#### **Inclusion Criteria**

All skeletally mature patients present with displaced proximal humerus fractures according to NEER two, three and four-part fractures. skeletally matured patients with closed fracture proximal humerus with displacement >1 cm and varus angulation of >45 degrees. Patients with associated dislocation of the shoulder.

#### **Exclusion Criteria**

Pathologic fractures from primary or metastatic tumours Patients age less than 19 years Open fractures Poly trauma Failure of conservative treatment. Four-part fracture in elderly (>65 years) on admission of the patient, a careful history was elicited from the patients and or attendants of injury and the severity of trauma. The patients were then assessed clinically to evaluate their general condition and the local injury. The general condition of the patient and the vital signs were recorded. A methodical examination was done to rule out.

#### **Surgical Approaches**

The surgical approach used is the Deltopectoral approach. Deltopectoral approach: Incision starts just above the corocoid process, which is palpated in the deepest point in the clavicular concavity distally towards the acromioclavicular joint. An 8 to 10cm incision started from just above the coracoid process advanced following the line of deltopectoral groove. The inter-nervous plane is between the deltoid muscle, which is supplied by the axillary nerve and the pectoralis major muscle, which is supplied by the medial and lateral pectoral nerves. Retract pectoralis major medially and deltoid laterally, splitting the two muscles apart. The vein is retracted either medially or laterally. The short head of the biceps and the coracobrachialis must be displaced medially before access can be gained to the anterior aspect of the shoulder joint. Beneath the tendons lie the transversely running fibres of the subscapularis muscle. Apply external rotation to the arm to stretch the subscapularis, bringing the muscle belly into the wound and making its superior and inferior borders easier to define. Pass a blunt instrument between the capsule and the subscapularis, then divide the subscapularis from insertion onto the lesser tuberosity of the humerus. Incise the capsule longitudinally to enter the joint wherever the selected repair must be performed.

#### **Procedure**

All patients received a prophylactic dose of 4.5 gm of piperacillin-tazobactam intravenously preoperatively. The operation was done in a supine position with a small sandbag under the shoulder, under general anaesthesia. Through the

deltopectoral approach, the fracture was exposed and reduced with minimal soft tissue dissection. Briefly, the anatomical relationship between the humeral head and greater tuberosity was reduced and fixed temporarily with K wires. In case of obvious rotation or displacement of the humeral head, a joystick technique was used. Then the shaft fragment was reduced by abduction, traction and rotation of the arm. The reduction was checked under an image intensifier. Definitive fixation with the locking plate was done with the plate positioned lateral to the bicipital groove-sparing tendon of the long head of the biceps and 1cm distal to the greater tuberosity. The screws were chosen according to preoperative planning, and all four head screws were supposed to be inserted into the head fragment. The inferior screws supporting the humeral head were considered critical. Proximal locking screws were inserted to hold the humeral head, which are multidirectional screws with the tips of the screws staying 5–10 mm away from the articular surface. All proximal locking screws were placed in a unicortical fashion through an external guide and confirmed to be within the humeral head with intraoperative fluoroscopy. AP (internal and external rotation) views and axillary views 90 degrees to each other were used to visualize screw placement. The distal shaft screws were placed bicortically. A minimum of three bicortical screws were used. Fluoroscopic images were taken to confirm satisfactory fracture reduction, plate positioning and proper length of screws in the humeral head. In case of severe comminution or instability, the rotator cuff, the greater tuberosity, and the lesser tuberosity were fastened to the plate using non-absorbable sutures. The range of motion of the shoulder was checked on the table for impingement. The wound was closed under negative suction, which was removed after 48 hours.

#### Post-operative management

All patients are immobilized in an arm pouch with a cuff and collar sling. Appropriate antibiotics and analgesics were used.

Immediate post-operative radiographs were taken to determine the bone alignment and maintenance of reduction. Sutures are removed by the 12th day. Passive range of motion and pendulum exercises are begun immediately depending on pain.

#### Follow up

All patients were followed up at 6 weeks, 12 weeks and at 6 months.

#### Exercise regime post philos plating

POD 1 TO 3 Weeks: Post-operatively arm pouch was applied for all patients for 3 weeks. Post-op day 1 patients were started on pendulum exercises with an arm pouch.

3 Weeks TO 6 Weeks: At 3 weeks arm pouch was removed and started on active assisted external rotation to neutral and active assisted flexion.

After 6 Weeks: Patients were allowed full range of movements.

Functional results

Final results are assessed using the Constant and Murley scoring system.

#### Constant and Murley scoring system

This scoring system consists of four variables that are used to assess the function of the shoulder. The right and left shoulders are assessed separately the subjective variables are pain and ADL (sleep, work, recreation/sport) which give a total of 35 points. The objective variables are a range of motion and strength, which give a total of 65 points. Altogether a total of 100 points.

#### Difference between both the shoulders are calculated and it is graded accordingly

• <11 Excellent • 11-20 Good • 21-30 Fair • >30 Poor



Figure 1: PHILOS instruments-(1)5,6,7,8,10,12 hole PHILOS plate, (2) locking and cortical screws, (3) depth gauge, (4) drill sleeve, (5) drill bit, (6) locking and nonlocking screwdriver, (7) sleeve guide

#### Intra-operative images



2(a)



2(b)





2(c)



2(d)



2(e)

**Figure 2:** 2(a)Position of patient with bump under ipsilateral shoulder & draped; 2(b)Skin incision for deltopectoral approach; 2(c)Cephalic vein in deltopectoral groove; 2(d)Fixed with screws proximally and distally; 2(e)Final construct with philos plate for proximal humerus fracture

## RESULTS

27 patients with closed displaced proximal humerus fractures were treated by open reduction and internal fixation with a PHILOS plate. The following

observations were made from the data collected during this study. The majority of the patients i.e. 11 (40.76%) were from the age group of 41-50 years followed by 9 patients (33.34%) in 51-60 years followed by 3 patients (11.10%) in 31-40 and 61-70 years and 1 patients (3.70%) in 18-30 age group. The average age of the patient was 42.6 years. The majority of the patients were male's i.e.77.78% and 22.22% were females. Male: Female sex ratio is 3.5:1. [Table 1]

In the majority of 16 (59.26%) cases, the mode of injury was RTA. These were high-energy trauma directly or indirectly to the shoulder. 9 (33.34%) of the cases were due to falls and 2 (7.40%) was due to assault. The fracture occurred right in 18 patients (66.66%) and left side in 9 patients (33.34%). This is because of right-handedness and can be attributed to left-side driving on the roads and subsequent RTAs. In our study, we had 3 cases (11.10%) with 2-part fracture surgical neck humerus and 8 (29.60%) cases with 3 part fractures.15 (55.55%) cases with 4-part fractures, and one (11.10%) case with 2-part - greater tuberosity. [Table 2]

Out of 27 patients, 2 (7.40%) patients with diabetes, one is hypertensive, one is a heart disease patient and one is suffering from rheumatoid arthritis. All patients were treated operatively with a proximal humerus locking plate. Method of treatment: All patients underwent open reduction and internal fixation with a philos plate.

Time of surgery: The average interval between admission and surgery was 2.06 days.

Stay in hospital: The average hospital stay in our study was 7 days.

15 (55.55%) patients were operated under c-arm guidance and rest without it. 17 (62.96%) patients were operated on through the deltopectoral approach and 5 (18.50%) were through the deltoid splitting approach. The average duration of surgery is about 103 minutes ranging from 50 minutes to 155 minutes. The average blood loss is about 202 ml ranging from 50 ml to 300 ml. The average day of surgery from incident of injury is about 28 days ranging from 2 days to 51 days. No intra-operative anaesthetic complications. No neurological deficit due to anaesthetic complication.

In our study, 8 (29.63%) cases had an excellent result, 8 (29.63%) had a good result and 4 (14.82%) had a Moderate result. 3 (11.11%) had a poor result and there was 4 (14.81%) lost follow-up.

Out of the 27 patients followed up, 8 patients had excellent scores, 8 had good scores, 4 had moderate scores and 3 had poor outcome scores. The mean constant score is 76.6 (range 38- 91 points). The mean constant score for the Neer two-part fracture was 85 (range 72 – 91), for Neer's three-part fracture, was 78.5 (range 57 – 86) and for Neer's four-part fracture was 66.30 (range 38 – 91). The mean constant score for the middle age group (18-40) was 85 (range 72 – 91), for the old age group (41-60) was 71.35 (range 38 – 91) and for the very old age group (>60) was 60.0 (50- 70).

**Table 1: Age Distribution**

Age in year	Male	Female	N (%)
18-30	1 (3.70%)	-	1 (3.70%)
31-40	3 (11.10%)	-	3 (11.10%)
41-50	8 (29.60%)	3 (11.10%)	11 (40.76%)
51-60	7 (25.90%)	2 (7.40%)	9 (33.34%)

61-70	2 (7.40%)	1 (3.70%)	3 (11.10%)
Total	21 (77.78%)	6 (22.22%)	27 (100%)

**Table 2: Mode of Injury and Type of Fractures**

	Number of Patients
<b>Mode of injury</b>	
Assault	2 (7.40%)
Fall	9 (33.34%)
RTA	16 (59.26%)
The fracture occurred	
Right side	18 (66.66%)
Left side	9(33.34%)
<b>Mode of injury</b>	
Two part - surgical neck	3 (11.10%)
Two part - greater tuberosity	1 (3.70%)
Three-Part Fracture	8 (29.60%)
Four Part Fracture	15 (55.55%)

**Table 3: Results according to constant and Murley score**

Result - Outcome	Numbers (%)
Excellent	8 (29.63%)
Good	8 (29.63%)
Moderate	4 (14.82%)
Poorer	3 (11.11%)
Lost follow up	4 (14.81%)

## DISCUSSION

Operative treatment of comminuted and displaced proximal humeral fractures, especially in osteoporotic bone, has been a complex and challenging problem. Different techniques have been described for the fixation of comminuted and displaced proximal humeral fractures.<sup>[8-10]</sup> All these techniques have been associated with a varying rate of complications such as cut-out or back-out of the screws and plates, nonunion, avascular necrosis, and fractures distal to the plate.<sup>[11]</sup> Functional outcome not only depends on the quality of bone stock but also the stability provided by the implant. In an internal locking system like the PHILOS plate, all forces are transmitted from the bone via the locking head screws to the blade, and vice versa. Hence, the principle of fixed angle plates enables a gain in torsional stiffness and stability, and may therefore promote a superior outcome.<sup>[12]</sup>

The present study was conducted to evaluate clinical outcomes following PHILOS plate fixation and to assess potential complications during the follow-up. To date, early results of locking plate fixation of proximal humeral fractures have been reported.<sup>[13,14]</sup> In our study, 8 (29.63%) cases had an excellent result, 8 (29.63%) had a good result and 4 (14.82%) had a Moderate result. 3 (11.11%) had a poor result and there was 4 (14.81%) lost follow-up. Despite some inhomogeneity, our results are comparable with those reported for the PHILOS plate.<sup>[15]</sup> We found that in the majority 16 (59.26%) of cases, the mode of injury was RTA.

Frankhauser et al,<sup>[16]</sup> evaluated 29 proximal humeral fractures in 28 patients treated with the Locking Proximal Humerus Plate. They observed no nonunion and reported a low incidence of reoperation (n=2). The mean Constant-Murley score

was 74.6 after 12 months. They suggested that the outcome could be improved by enhanced positioning of the plate on the humeral shaft and placing the locking screws to avoid redislocations, malunions, and implant-related impingement. In a retrospective study, Björkenheim et al,<sup>[17]</sup> reviewed 72 patients treated with the PHILOS plate. At final controls, 36 patients had a good or excellent functional outcome according to the Constant-Murley score, 31 patients had a moderate score, and five patients had a poor outcome. The authors advocated the use of the PHILOS plate, especially in osteoporotic bone.

In a series of 20 consecutive patients, Koukakis et al,<sup>[18]</sup> showed favourable early results with surgical treatment of proximal humeral fractures using the PHILOS plate. After a mean follow-up of 16 months, the mean Constant score was 76.1. In our study, the majority of the patients i.e. 11 (40.76%) were from the age group of 41-50 years. Hente et al,<sup>[19]</sup> studied 31 patients with displaced 3 and 4-part fractures of the proximal humerus treated with the PHILOS plate. In our study, we had 3 cases (11.10%) with 2-part fracture surgical neck humerus and 8 (29.60%) cases with 3 part fractures.15 (55.55%) cases with 4-part fractures.

Furthermore, their strength measurements included patients who were not able to hold their arm in 90° abduction, whereas we rated these patients as zero as suggested by Bankes et al.<sup>[20]</sup> Since strength is a major determinant of the total Constant- Murley score and varies with the measurement method (i.e. lever arm), it is of utmost importance to standardize the measurement method, as previously described. 15 (55.55%) patients were operated under c-arm guidance and rest without it. 17 (62.96%) patients were operated on through the deltopectoral approach and 5 (18.50%) were through the deltoid splitting

approach.<sup>[21]</sup> The average duration of surgery is about 103 minutes ranging from 50 minutes to 155 minutes. The average blood loss is about 202 ml ranging from 50 ml to 300 ml. The average day of surgery from incident of injury is about 28 days ranging from 2 days to 51 days. No intra-operative anaesthetic complications. No neurological deficit due to anaesthetic complication Based on our observations, inadequate positioning of the implant resulted in reduced functional outcome.

Out of the 27 patients followed up, 8 patients had excellent scores, 8 had good scores, 4 had moderate scores and 3 had poor outcome scores. The mean constant score is 76.6 (range 38- 91 points). The mean constant score for the Neer two-part fracture was 85 (range 72 – 91), for Neer's three-part fracture, was 78.5 (range 57 – 86) and for Neer's four-part fracture was 66.30 (range 38 – 91).<sup>[22]</sup>

## CONCLUSION

To conclude, the PHILOS locking plate is an advantageous implant in proximal humeral fractures due to angular stability, particularly in comminuted fractures and in osteoporotic bones in elderly patients, thus allowing early mobilization.

## REFERENCES

- Chao EY, Lim J. Virtual Interactive Musculoskeletal System (VIMS) in orthopaedic translational research. *Journal of Orthopaedic Translation*. 2013;1(1):25-40.
- Patel AH, Wilder JH, Ofa SA, Lee OC, Iloanya MC, Savoie III FH, Sherman WF. How age and gender influence proximal humerus fracture management in patients older than fifty years. *JSES international*. 2022;6(2):253-8.
- Patel AH, Wilder JH, Ofa SA, Lee OC, Savoie III FH, O'Brien MJ, Sherman WF. Trending a decade of proximal humerus fracture management in older adults. *JSES international*. 2022;6(1):137-43.
- Iglesias-Rodríguez S, Domínguez-Prado DM, García-Reza A, Fernández-Fernández D, Pérez-Alfonso E, García-Piñeiro J, Castro-Menéndez M. Epidemiology of proximal humerus fractures. *Journal of orthopaedic surgery and research*. 2021;16(1):402.
- Calori GM, Colombo M, Bucci MS, Fadigati P, Colombo AI, Mazzola S, Cefalo V, Mazza E. Complications in proximal humeral fractures. *Injury*. 2016;47: S54-8.
- Erasmus 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: S43-8.
- Sirveaux F, Roche O, Molé D. Shoulder arthroplasty for acute proximal humerus fracture. *Orthopaedics & Traumatology: Surgery & Research*. 2010;96(6):683-94.
- Cecere AB, Toro G, De Cicco A, Braile A, Paoletta M, Iolascon G, Panni AS. How to improve the outcomes of surgically treated proximal humeral osteoporotic fractures? A narrative review. *Orthopedic Reviews*. 2020;12(2).
- Ratajczak K, Szczepny G, Małydk P. Comminuted fractures of the proximal humerus—principles of the diagnosis, treatment and rehabilitation. *Ortopedia Traumatologia Rehabilitacja*. 2019 ;21(2):77-93.
- Song JQ, Deng XF, Wang YM, Wang XB, Li X, Yu B. Operative vs. nonoperative treatment for comminuted proximal humeral fractures in elderly patients: a current meta-analysis. *Acta Orthopaedica et Traumatologica Turcica*. 2015;49(4):345-53.
- McMillan TE, Johnstone AJ. Primary screw perforation or subsequent screw cut-out following proximal humerus fracture fixation using locking plates: a review of causative factors and proposed solutions. *International Orthopaedics*. 2018; 42:1935-42.
- Lill, H., Hepp, P., Komer, J. et al. Proximal humeral fractures: how stiff should an implant be? A comparative mechanical study with new implants in human specimens. *Arch Orthop Trauma Surg* 2003;123: 74–81 (2003).
- Brunner F, Sommer C, Bahrs C, Heuwinkel R, Hafner C, Rillmann P, Kohut G, Ekelund A, Muller M, Audigé L, Babst R. Open reduction and internal fixation of proximal humerus fractures using a proximal humeral locked plate: a prospective multicenter analysis. *Journal of orthopaedic trauma*. 2009;23(3):163-72.
- Leonard M, Mokotedi L, Alao U, Glynn A, Dolan M, Fleming P. The use of locking plates in proximal humeral fractures: Comparison of outcome by patient age and fracture pattern. *International journal of shoulder surgery*. 2009;3(4):85.
- Kettler M, Biberthaler P, Braunstein V, Zeiler C, Kroetz M, Mutschler W. Treatment of proximal humeral fractures with the PHILOS angular stable plate: Presentation of 225 cases of dislocated fractures. *Der Unfallchirurg*. 2006; 109:1032-40.
- Fankhauser F, Boldin C, Schippinger G, Haunschmid C, Szyszkowitz R. A new locking plate for unstable fractures of the proximal humerus. *Clinical Orthopaedics and Related Research*. 2005; 430:176-81.
- Björkenheim JM, Pajarinen J, Savolainen V. Internal fixation of proximal humeral fractures with a locking compression plate A retrospective evaluation of 72 patients followed for a minimum of 1 year. *Acta Orthopaedica Scandinavica*. 2004;75(6):741-5.
- Koukakis A, Apostolou CD, Taneja T, Korres DS, Amini A. Fixation of proximal humerus fractures using the PHILOS plate: early experience. *Clinical Orthopaedics and Related Research*. 2006; 442:115-20.
- Hente R, Kampshoff J, Kinner B, Füchtmeier B, Nerlich M. Treatment of dislocated 3-and 4-part fractures of the proximal humerus with an angle-stabilizing fixation plate. *Der Unfallchirurg*. 2004;107(9):769-82.
- Banks MJ, Crossman JE, Emery RJ. A standard method of shoulder strength measurement for the Constant score with a spring balance. *Journal of Shoulder and Elbow Surgery*. 1998;7(2):116-21.
- Guo HL, Han YJ. Deltoid-splitting approach and deltopectoral approach in the repair of proximal humeral fracture: a meta-analysis. *Chinese Journal of Tissue Engineering Research*. 2014;18(35):5723.
- Charles s neer II. Displaced proximal humeral fractures: Part II. Treatment of three-part and four-part displacement. *JBJS*. 1970;52(6):1090-103.