BRIDGE PLATING OF HUMERUS SHAFT FRACTURES BY MINIMALLY INVASIVE PLATE OSTEOSYNTHESIS TECHNIQUE VERSUS OPEN REDUCTION AND PLATE FIXATION: A SHORT-TERM STUDY

Mohamed H. Hashem[1], Mohamed O. Hegazi[2], Nagi Z. Sabet[3], Mohamed A. Sayed[3]*

Article History: Received: 10.05.2023 **Revised:** 20.06.2023 **Accepted:** 30.06.2023

ABSTRACT

Background: Plate osteosynthesis has been the treatment of choice for humeral shaft fractures when surgical intervention is indicated. Biological fixation of humeral shaft fractures with soft tissue preservation and near acceptable reduction is becoming more acceptable. Anterior bridge plating with minimally invasive technique is reported as an acceptable, less invasive and reproducible procedure over the conventional plate technique.

Objective: To compare the clinical, radiological and functional outcomes of the minimal invasive plating osteosynthesis technique versus traditional open reduction and plate fixation for humerus shaft fractures management.

Patients and Methods: 30 patients were included in the study. They were randomly divided in two groups, 15 patients for each group. Patients were selected from the emergency department, suffering from recently displaced humeral shaft fracture

Results: Our results, in both groups, fracture healing occurred in all patients, and the functional outcomes were also excellent based on the Mayo and UCLA scoring system. Therefore, we believe that both techniques are safe and effective method for humeral shaft fractures treatment. In the present study, no cases had postoperative iatrogenic radial nerve palsy in both groups. So, we think that humeral MIPO is a safe method in terms of radial nerve safety.

Conclusion: We can conclude that both techniques are reliable treatment options for humeral shaft fracture, although MIPO is less time consuming, exposes the patient to less soft tissue damage and less blood loss making it a more appealing option, taking in consideration that all safety measures for radiation exposure should be taken.

Keywords: humerus shaft fracture, Open reduction and internal fixation, minimally invasive plate osteosynthesis

1 Department of Orthopedic Surgery, Faculty of Medicine - Helwan University
2 Department of Orthopedic Surgery, Faculty of Medicine – Banha University
3 Department of Orthopedic Surgery, Faculty of Medicine - Misr University for Science and Technology
*** Corresponding author:** Mohamed Ahmed Mohamed Sayed, **Email:** dr.mohamed_86@hotmail.com

INTRODUCTION

Humeral shaft fractures are common injuries with various management strategies [1,2]. Many surgeons consider nonoperative management as the standard of care; [3]. Operative intervention is indicated in special conditions including failure of closed reduction, intra-articular extension, neurovascular compromises, floating elbow, pathological fractures, open fractures, bilateral humeral shaft fractures, and polytraumatized patients [4,5]. Operative management includes open reduction and internal fixation through a variety of exposures, intramedullary nail fixation, and external fixation[6].

Open reduction and internal fixation (ORIF) was considered the gold standard for operative treatment. The advantages include anatomical reduction of fractures and less interference to elbow and shoulder function [7,8]. The major disadvantages of this technique are extensive soft tissue stripping and disruption of periosteal blood supply, which increase the risk of nonunion and iatrogenic radial nerve palsies [9,10,11].

Biological fixation of humeral shaft fractures with soft tissue preservation and near acceptable reduction is becoming more acceptable [12]. Despite the need for high surgical expertise and time taken for adaptation of the procedure, anterior bridge plating with minimally invasive technique is reported as an acceptable, less invasive and reproducible procedure over the conventional plate technique [13]. The purpose of this study is to compare the clinical, radiological and functional outcomes of the minimal invasive plating osteosynthesis technique versus traditional open reduction and plate fixation for humerus shaft fractures management.

PATIENTS AND METHODS

Patients:

Study sample: Two groups of patients were assigned randomly, using closed envelopes:

Group A: patients were treated surgically with MIPO.

Group B: patients were treated surgically with ORIF.

Sample size: 30 patients were selected from the emergency department, suffering from recently displaced humeral shaft fracture. They were randomly divided in two groups, 15 patients for each group

Inclusion criteria: Recent displaced fracture; > 20° anterior angulation, > 30° varus, valgus angulation and > 3 cm shortening. Age of patient: 18- 55 years. Closed fracture. No neurovascular compromised.

Exclusion criteria: Patients with open fractures, old fracture or with pathological fractures were excluded.

Group 1: There were 10 males and 5 females with an average age of 35 years (range 20-55). The fracture was in the right side in 9 cases and on the left side in 6 cases. The mechanism of injury was RTA in 11 cases, and fall from height in 4 cases. Fracture was classified according to AO classification of humeral shaft fracture. 4 cases were A1, 2 cases were A2, 3 cases were A3, 1 case was B1, 2 cases were B2, 2 cases were C1 and 1 case was C2.

Group 2: There were 11 males and 4 females with average age 39 years (range 22 – 53). The fracture was in the right side in 6 cases and in the left side in 9 cases. The mechanism of injury was RTA in 10 cases, and fall from height in 5 cases. Fracture was classified according to AO classification of humeral shaft fracture. 4 cases were A1, 1case was A2, 5 cases were A3, 2 cases were B1, 2 cases were B2, and 1 case was C3.

Technique of MIPO

A-Position of the patient: The patients were positioned supine on the operating table with the arm abducted to 90° and the forearm in full supination. The image intensifier was placed on the same side of the operating table as the arm to be operated. [4, 15] **(Fig 1).**

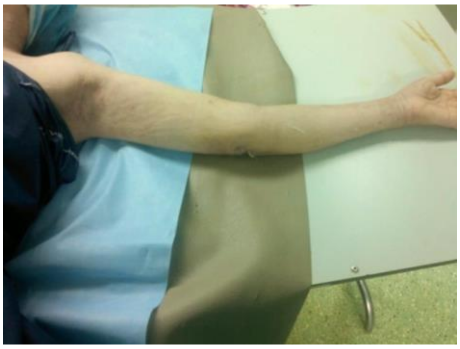

Fig. (1): Supine position of the patient in MIPO

Incision: The site of incision was confirmed under the image intensifier and altered if necessary to be as far as possible from the fracture site. First, the interval between the lateral border of the proximal part of the biceps and the medial border of the deltoid muscle was palpated; a 3 cm proximal incision was then made approximately 6 cm distal to the anterior part of the acromion process and dissection carried down to the proximal humerus **(Fig 2).** Distally, a 3 cm incision was made along the lateral border of the biceps muscle approximately 5 cm proximal to the flexion crease of the elbow **(Fig 2).**

Fig. (2): Proximal and distal incision of MIPO

The interval between the biceps brachii and the brachialis was identified. The biceps was retracted medially to expose the musculocutaneous nerve lying on the brachialis. The brachialis was then split longitudinally along its midline to reach the periosteum of the anterior cortex of the distal humerus. The musculocutaneous nerve was retracted together with the medial half of the split brachialis, while the lateral half served as a cushion to protect the radial nerve

C- Application of the plate

A sub-brachialis extraperiosteal tunnel was then created. Conventional DCP or locked plate was passed deep to the brachialis from the distal to the proximal incision **(Fig 3)** plate type was chosen according to bone quality and fracture comminution. Some difficulty may be encountered during the passage of the plate at the proximal part of the tunnel due to the intimate blending of the fibers of the brachialis and deltoid muscles along the lateral aspect of the tunnel at this point.

Fig. (3): Passage of the plate from distal to proximal incision in MIPO

After preparation of the anterior sub-brachialis tunnel; the plate position and reduction was visualized by the image intensifier. Manual traction was applied to restore length and correct varus or valgus angulation and rotation. The plate was temporary fixed to the bone with 2 mm K-wires **(Fig 4).**

Fig. (4): Fixing plate to bone temporary by k-wire

After ensuring that the position of the plate on the distal fragment was central, it was fixed with a locking screw and, similarly, the proximal fragment was also fixed. After confirmation of the reduction alignment on image intensifier**,** other screws were inserted to complete the fixation. **(Fig 5, 6)**

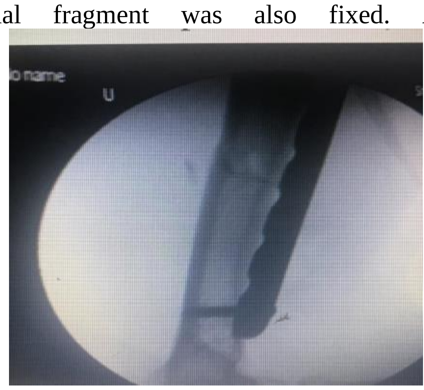

Fig. (5): Lateral image of fracture site and distal screw in MIPO

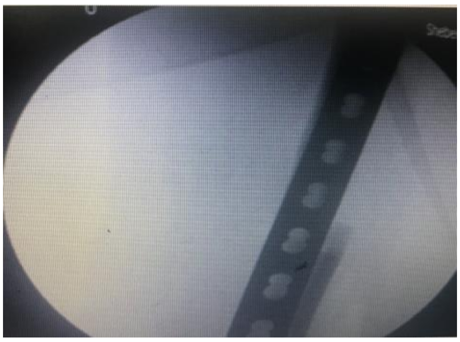

Fig. (6): AP image of fracture site in MIPO

Lastly wound was closed with sutures without drain **(Fig 7).**

Fig. (7): Closure of the wound in MIPO

Technique of ORIF

Position of the patients: The patient was placed in supine position for anterolateral approach; the arm to be operated on was carefully supported on the table **(Fig 8).** And the patient was placed in lateral position for posterior approach and the injured arm supported with adequate padding [14] **(Fig 9).**

Fig. (8): Supine position of the patient in anterolateral approach

Fig. (9): Lateral position of the patient in post approach

Approach:

Anterolateral approach to the humerus: The incision started over the tip of the coracoid process extending distally and laterally in the line of the deltopectoral groove which is identified by cephalic vein, following the lateral border of the biceps muscle. The incision extended as needed according to fracture site and geometry. **(Fig 10).** The lateral cutaneous nerve of the forearm was identified distally and the radial nerve was identified deeper in the interval between biceps and brachioradialis, and followed proximally as the incision was developed. The biceps and brachialis was retracted medially, and the brachioradialis laterally in order to identify radial nerve.

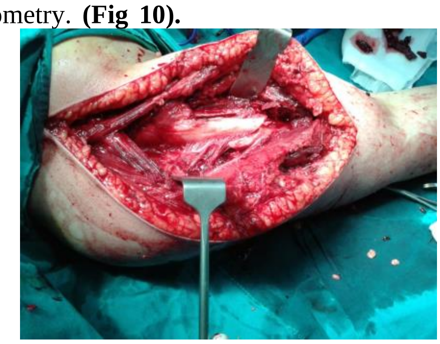

Fig. (10): Anterolateral approach of humerus

Posterior approach to the humerus: Skin was incised beginning at the tip of the olecranon process. The incision runs proximally in a straight line along the posterior midline of the arm. The interval between the lateral and long heads of the triceps was identified by palpation with a finger; the radial nerve was identified beneath the triceps as it crosses the humerus by retracting the lateral head laterally and the long head medially. Within the spiral groove the radial nerve was identified accompanying profunda brachii artery **(Fig 11)**. Distally, the common triceps tendon was split, along the line of the skin incision by sharp dissection. The medial head of triceps was released from the humerus proximally, and was incised distally in line with the humeral shaft. The muscle was released from the bone only as much as needed.

Fig. (11): Posterior approach of humerus

Methods of reduction: The fracture was reduced anatomically using blunt reduction forceps on each side of fracture fragments. A small bone lever was used to reduce transverse or short oblique fractures. Reduction of overlapping short oblique fractures was achieved by twisting a reduction forceps, thereby lengthening the fracture. In unstable reduction, the plate was fixed to one fragment and then the other fragment was reduced onto the plate.

Application of the plate

Plate location: For proximal fractures an anterolateral plate location and anterolateral surgical exposure was used. For mid shaft and distal fractures a posterior plate location was used through a posterior approach.

Plate fixation

Planning for lag screw: The lag screws were used to achieve compression and absolute stability, they were usually used for the fixation of simple fractures such as a spiral or oblique fracture also they were used under specific circumstances to compress large fracture fragments of a multifragmentary fracture in order to secure added stability. It was placed centrally across the plane of the fracture and perpendicularly to it. Lag screw location and the screw heads were done outside the chosen area for the plate**.** When the lag screw was to be applied through the plate, the proposed location of the screw and its chosen hole was considered before applying the plate. The center of the plate was over the fracture site.

Fixation of the plate: No periosteal stripping was done either for plate fixation or screw placement, but there was adequate soft tissue exposure to provide sufficient area for the plate. The plate was positioned so that three to four screws were used in each of the proximal and distal segment **(Fig 12, 13)**. Insertion of the second screw eccentrically was done then tightening of screws to compress the fracture, and then the lag screw was inserted.

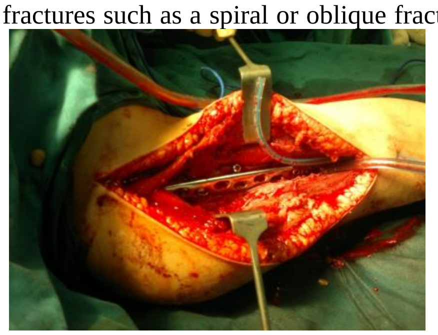

Fig. (12): Application of the plate in anterolateral approach

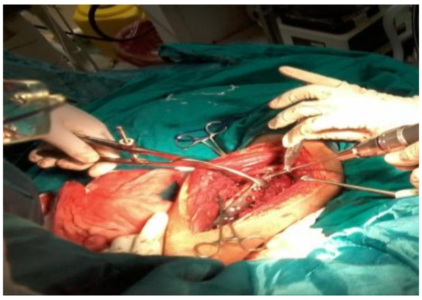

Fig. (13): Application of the plate in posterior approach

Alignment of the humerus and reduction of the fragments were confirmed with fluoroscopy. The wound was sutured after placing drain submuscular **(Fig 14).**

Fig. (14): Closure of wound in post approach

Postoperative follow up: The arm was supported in a sling. Carefully radial nerve function and vascularity was examined. Gentle use of hand and elbow usually begun as soon as the patient's comfort permits. Forceful use of the arm was discouraged, but gently assisted range of motion for shoulder and elbow was added quickly. The patients came for a weekly follow up during the first 2 weeks; stitches were removed at 2 weeks, then follow up monthly for next 6 months. All visits consisted of radiographic and clinical evaluations to assess the union and recovery of elbow and shoulder movements and function and detect any complications.

The operative time, intraoperative radiation exposure, intraoperative blood loss, union time, postoperative complications, and shoulder and elbow functions were recorded. Shoulder function was assessed by the UCLA scoring system, and elbow function was assessed by the Mayo elbow performance index. Operative time was defined as the time from skin incision to closure. Union was defined as the absence of pain and the presence of bridging callus in three of the four cortices on anteroposterior and lateral radiographic views of the humerus. Nonunion was defined as the absence of fracture union at 6 months postoperatively. Postoperative complications were categorized as infection, nonunion, and radial nerve injury

Statistical Methods

Data were analyzed using IBM© SPSS© Statistics version 26 (IBM© Corp., Armonk, NY) and MedCalc® Statistical Software version 20 (MedCalc Software Ltd, Ostend, Belgium; https://www.medcalc.org; 2021). Categorical variables are presented as counts and percentages and intergroup differences are compared using the Pearson chi-squared test or Fisher's exact test. Ordinal data are compared using the chi-squared test for trend. Numerical variables are presented as mean and standard deviation and intergroup differences are compared with the unpaired t-test. Time to event analysis is done using the Kaplan-Meier method. The log-rank test is used to compare Kaplan-Meier curves. P-values <0.05 are considered statistically significant.

RESULTS

Table (1): Demographic characteristics of both groups

Variable	MIPO (n=15)	ORIF (n=15)	Difference				P-value
			Mean	SE	Lower 95% CI	Upper 95% CI	
Age (years), mean ± SD	37.6 ± 10.4	40.0 ± 10.6	-2.4	3.8	-10.3	5.4	0.532†
Sex, F/M	5/10	4/11					>0.999‡

†. Unpaired t-test.
‡. Pearson chi-squared test.
SD = standard deviation, SE = standard error, 95% CI = 95% confidence interval.

Table (2): Characteristics of the fracture in both groups

Variable	MIPO (n=15)	ORIF (n=15)	P-value
Operated side			0.273†
Left	6 (40.0%)	9 (60.0%)	
Right	9 (60.0%)	6 (40.0%)	
Mechanism of injury			1.000‡
RTA	11 (73.3%)	10 (66.7%)	
FFH	4 (26.7%)	5 (33.3%)	
AO classification			0.788‡
A1	4 (26.7%)	4 (26.7%)	
A2	2 (13.3%)	1 (6.7%)	
A3	3 (20.0%)	5 (33.3%)	
B1	1 (6.7%)	2 (13.3%)	
B2	2 (13.3%)	2 (13.3%)	
C1	2 (13.3%)	0 (0.0%)	
C2	1 (6.7%)	0 (0.0%)	
C3	0 (0.0%)	1 (6.7%)	

†. Pearson Chi-squared test.
‡. Fisher's exact test.
FFH= fall from height, RTA= road traffic accident

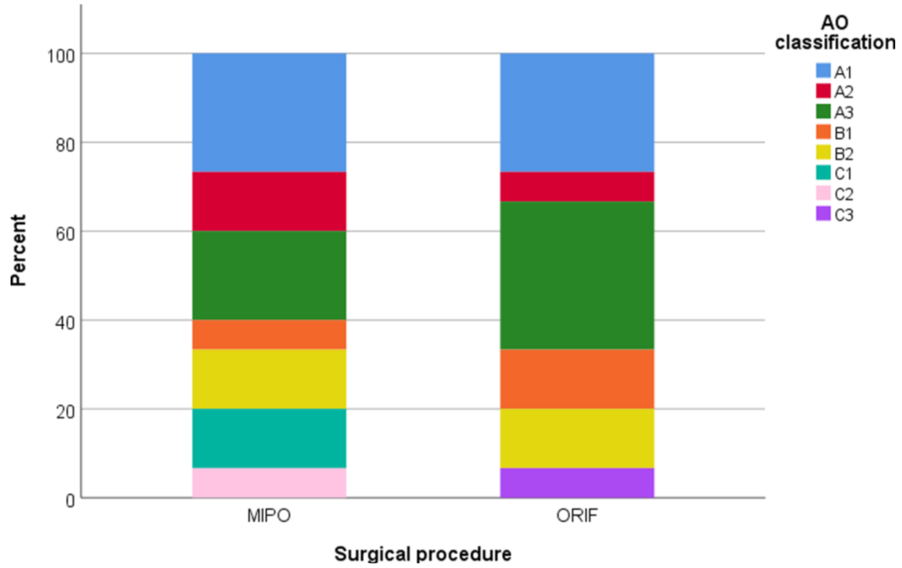

Fig. (15): AO classification of the fracture in both study groups.

Table (3): Operative data in both groups

Variable	MIPO (n=15)		ORIF (n=15)		Difference				P-value
	Mean	SD	Mean	SD	Mean	SE	Lower 95% CI	Upper 95% CI	
Operative time (min)	90.3	14.2	130.3	12.3	-40.0	4.9	-50.0	-30.0	<0.001
Intraoperative radiation time (s)	85.3	11.9	9.1	6.1	76.2	3.4	69.0	83.4	<0.001
Operative blood loss (ml)	110.0	10.0	340.0	54.6	-230.0	14.3	-260.6	-199.4	<0.001

†. Unpaired t-test. SD = standard deviation, SE = standard error, 95% CI = 95% confidence interval.

Table (4): Time to bone union and time to resume normal daily activity in both groups

Variable	MIPO (n=15)		ORIF (n=15)		Difference				P-value
	Mean	SD	Mean	SD	Mean	SE	Lower 95% CI	Upper 95% CI	
Time to bone union (weeks)	15.1	2.2	16.3	2.7	-1.2	0.9	-3.1	0.7	0.195
Time to resume normal daily activity (months)	3.8	0.5	4.1	0.7	-0.3	0.2	-0.8	0.2	0.188

†. Unpaired t-test. SD = standard deviation, SE = standard error, 95% CI = 95% confidence interval.

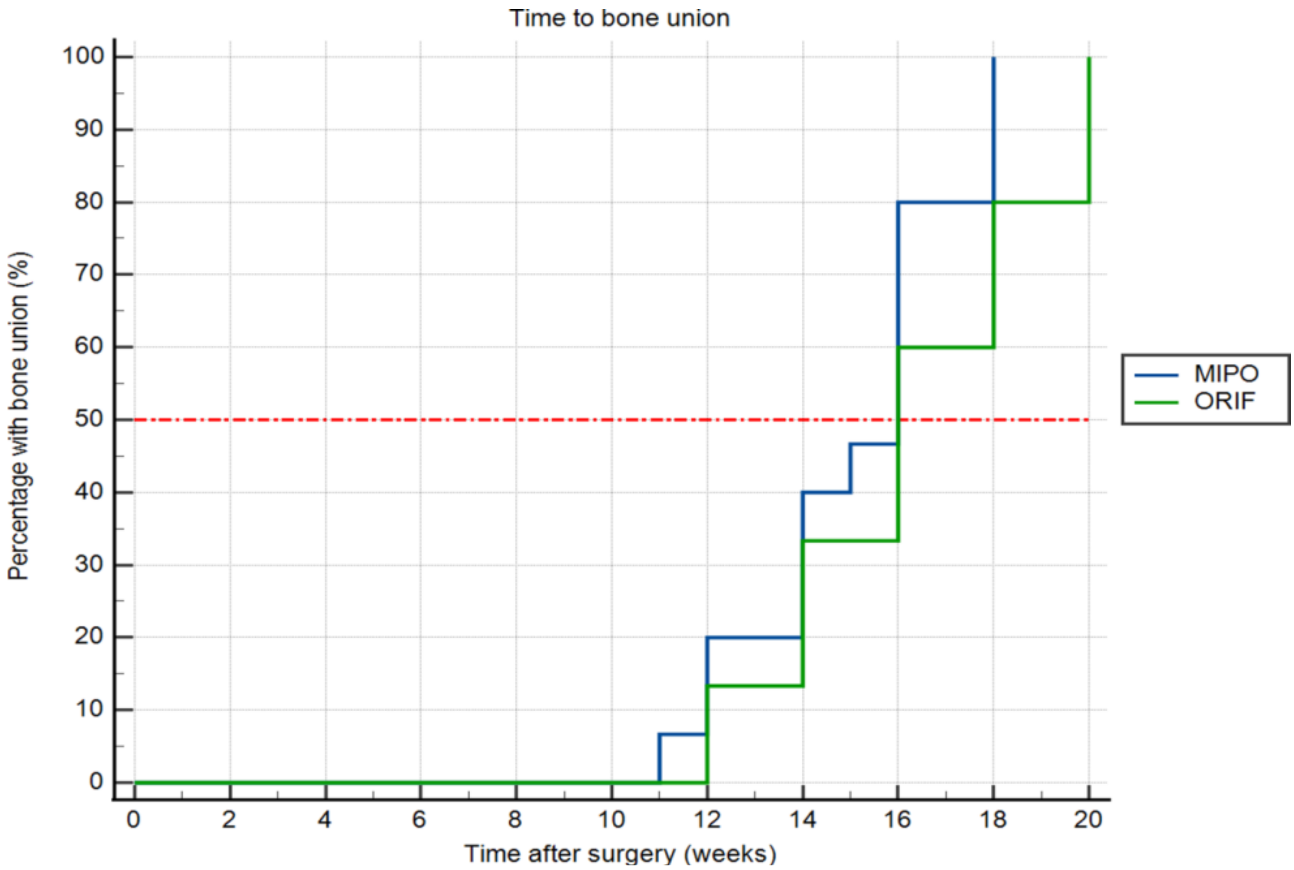

Fig. (16): Kaplan-Meier curves for time to union in both study groups. Median time to union = 16 weeks in both study groups. Incidence rate ration (IRR, MIPO/ORIF) = 2.13 (95% CI = 0.82 to 5.51). difference between both Kaplan-Meier curves is not statistically significant (Log-rank test chi-squared = 2.431, df = 1, p-value = 0.119).

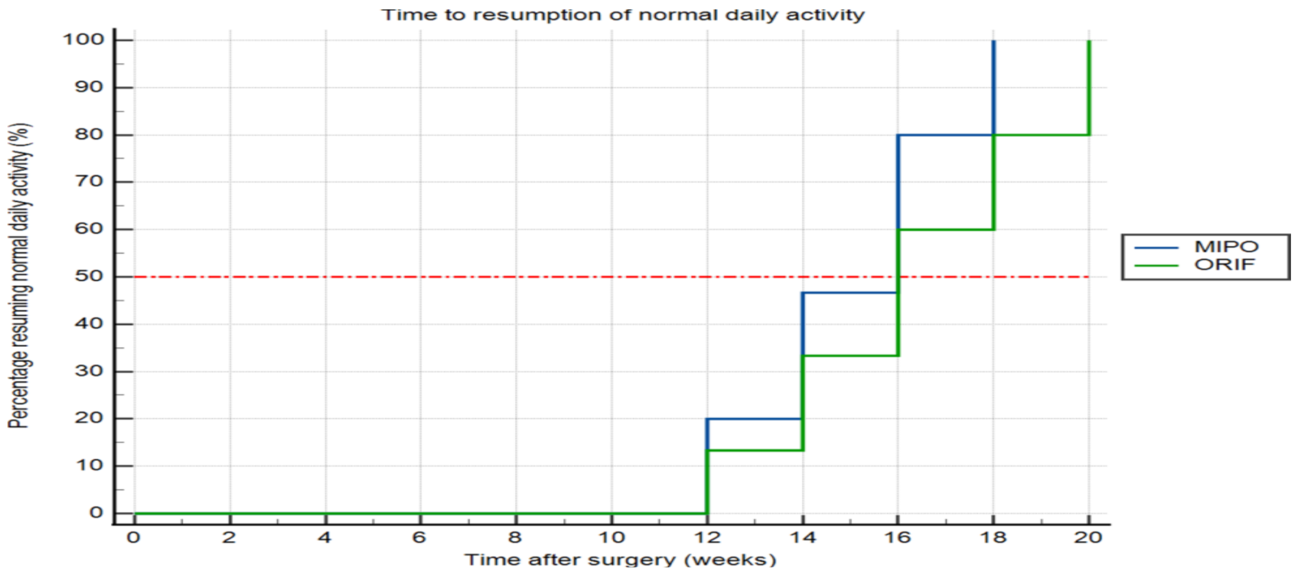

Fig. (17): Kaplan-Meier curves for time to resume normal daily activity in both study groups. Median time to resume normal daily activity = 16 weeks in both study groups. Incidence rate ration (IRR, MIPO/ORIF) = 2.17 (95% CI = 0.82 to 5.72). Difference between both Kaplan-Meier curves is not statistically significant (Log-rank test chi-squared = 2.426, df = 1, p-value = 0.119).

Table (5): Functional outcome in both study groups

Score	MIPO (n=15)	ORIF (n=15)	P-value†
MEPI score, n (%)			0.581
Fair	1 (6.7%)	2 (13.3%)	
Good	7 (46.7%)	7 (46.7%)	
Excellent	7 (46.7%)	6 (40.0%)	
UCLA score, n (%)			0.622
Poor	0 (0.0%)	1 (6.7%)	
Fair	1 (6.7%)	1 (6.7%)	
Good	8 (53.3%)	7 (46.7%)	
Excellent	6 (40.0%)	6 (40.0%)	

†. Chi-squared test for trend.

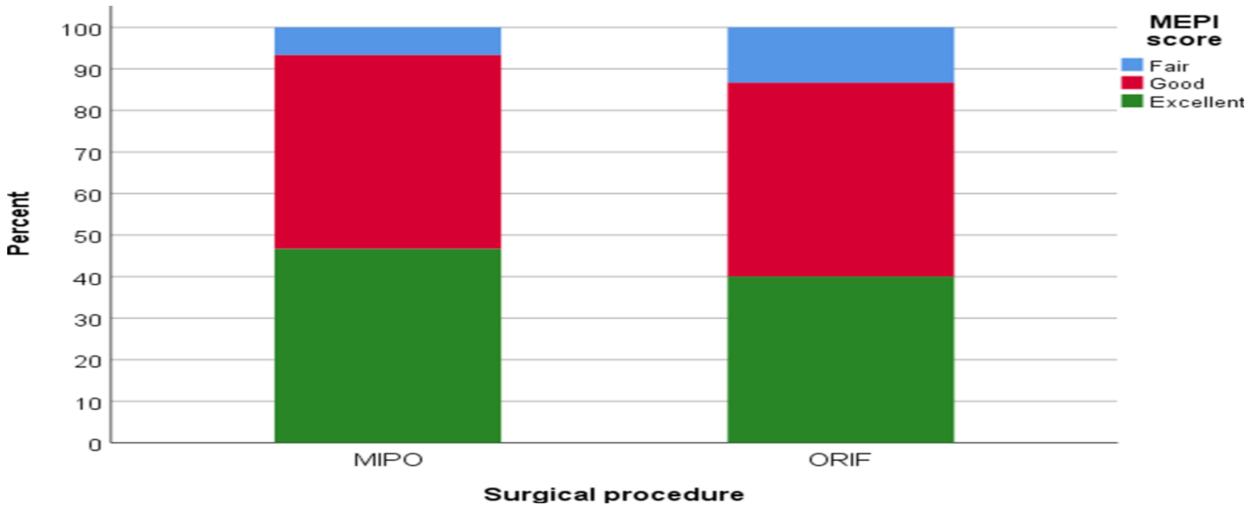

Fig. (38): MEPI score in both study groups. Error bars represent the 95% confidence interval (95% CI).

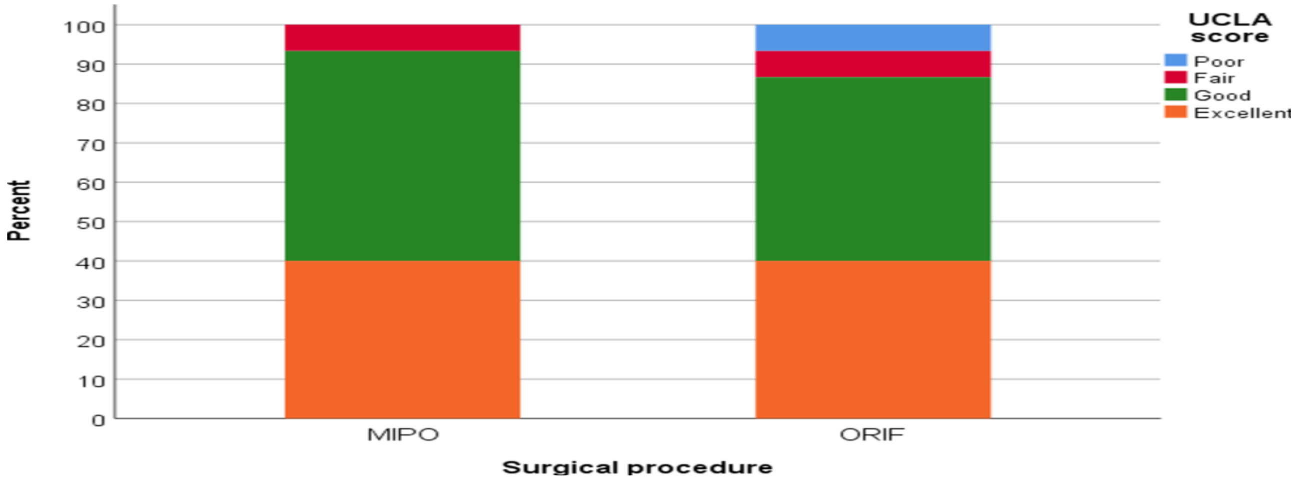

Fig. (18): UCLA score in both study groups. Error bars represent the 95% confidence interval (95% CI

Table (6): Incidence of complications in both study groups

Complication	MIPO (n=15)	ORIF (n=15)	P-value†
Infection, n (%)	0 (0.0%)	2 (13.3%)	0.483
Iatrogenic nerve injury, n (%)	0 (0.0%)	0 (0.0%)	NC
Non-union, n (%)	0 (0.0%)	0 (0.0%)	NC
Delayed union, n (%)	0 (0.0%)	1 (6.7%)	1.000
Malunion, n (%)	0 (0.0%)	0 (0.0%)	NC
Need for bone graft, n (%)	0 (0.0%)	1 (6.7%)	1.000

‡. Fisher's exact test.
NC = not calculable.

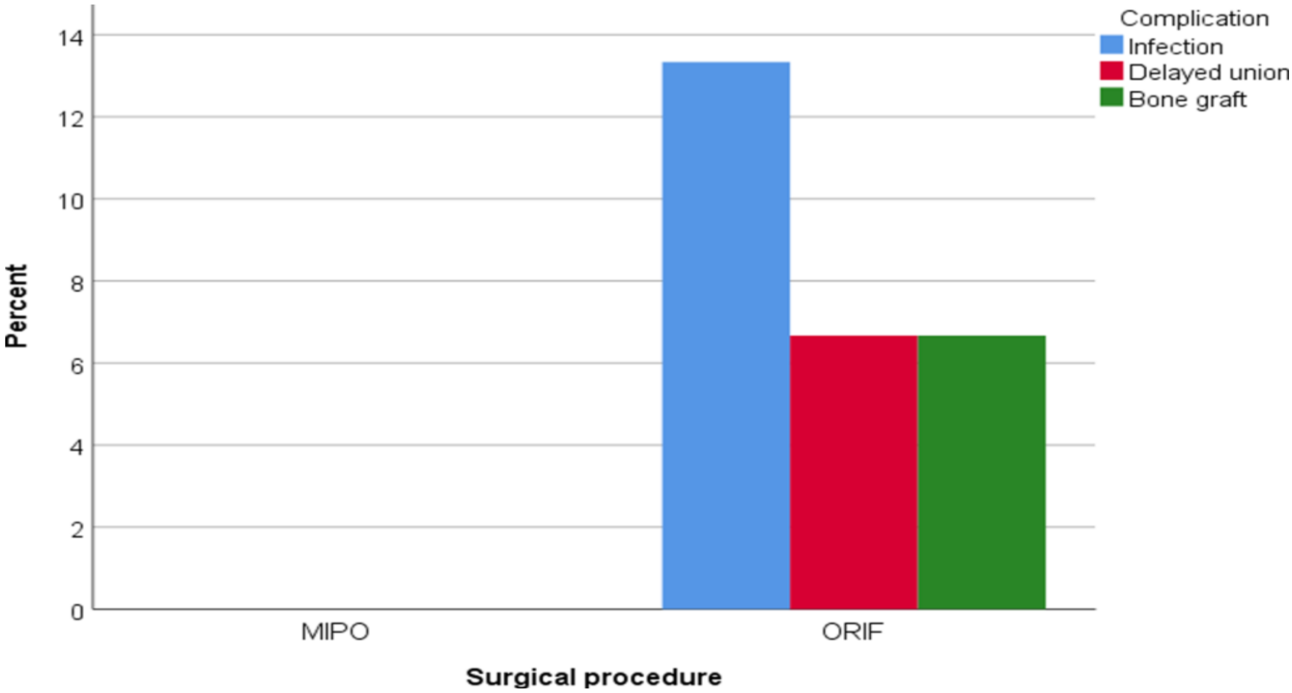

Fig. (19): Incidence of complications in both study groups

DISCUSSION

Plate osteosynthesis has been the treatment of choice for humeral shaft fractures when surgical intervention is indicated [10, 11]. However, complications such as problems of healing, infection and iatrogenic radial nerve injury have been documented. Therefore; plate osteosynthesis of comminuted humeral fracture is a challenging operation, which requires surgical experience and meticulous dealing with the periosteum, nerves and muscles. MIPO is an emerging technique for treatment fractures of the humeral shaft [13]. One of the main benefits of MIPO is that it keeps soft tissue and the periosteal circulation, which enhances fracture healing [14].

According to the study results, the MIPO group has some advantages over the ORIF group, with a markedly shortened postoperative recovery time. Our results revealed that MIPO can restore limb length, correct deformity, restore the axis angle, requires a smaller incision, and leaves smaller and less disfiguring scars. MIPO conforms to the principle of biological treatment of fracture, promotes stability and reconstruction of the local blood supply, which may reduce the incidences of infection or delayed union, and enhances recovery of patients' shoulder joint function. In this study, all patients had united fractures; this may be due to small sample size.

In the present study, 15 patients of humeral shaft fractures were surgically treated by MIPO (Group A) and other 15 patients were surgically treated by ORIF (Group B).

The mean operative time was 90.3 min (range 70 – 120 min) in MIPO group and 130.3 min (range 120 – 150 min) in ORIF group which was highly significant. Operative time for the procedures was calculated from skin incision to wound closure. In all cases of MIPO group we use intraoperative fluoroscopic control to evaluate the reduction and to have an acceptable alignment. The mean time of intraoperative radiation exposure was 85 seconds (range 70 -100 sec). C-arm was not routinely used in ORIF group. We use intraoperative fluoroscope to evaluate reduction after fixation in some cases with mean exposure time 9 sec (range 0-15 sec).

The mean intraoperative blood loss was 110 cc (range 100-120) and 340 cc (range 250-400) in MIPO group and ORIF group respectively which is statistically highly significant.

Mehraj et al. 2019, a study on forty patients with humerus shaft fractures managed by anterior bridge plating using the MIPO technique with dynamic compression plate fixation. The mean surgical time was 72.5 minutes (range: 45-100 minutes) and mean radiation exposure was 160 seconds (range: 100-220 seconds). [15]

Yang et al 2021, in a comparative study of conventional ORIF versus MIPO technique in the treatment of humeral shaft fractures. The study had been done on 28 patients, 14 patients for each group. Compared to the ORIF group, the intraoperative blood loss (96.07 ± 14.96 mL) was less, and the operation time (110.57 ± 21.90 min), were all significantly shorter in the MIPO group ($P < 0.05$). The number of intraoperative fluoroscopy images (20.07 ± 3.22) was significantly higher in the MIPO group ($P < 0.05$) [16]

All operative data of previous studies coincide with our study results as regards operative time, radiation and blood loss which are statistically highly significant.

As regards previously mentioned operative characteristics of the MIPO group, a reduced operative time is desirable because it decreases the risks of general anesthetic. This, along with reduced surgical trauma, may be significant in reducing postoperative morbidity in such patients. With regard to surgical blood loss, blood loss decreases due to less soft tissue dissection and less fracture exposure. Because decreased blood loss is thought to be an explanation of reduced cardiovascular complications, this may have a great clinical significance. While MIPO technique offers numerous benefits, its practice requires frequent use of intraoperative fluoroscopy with its known health hazard requiring taking proper precautions to protect the patient and the operating team.

As regards fracture union in MIPO group of this study, all cases achieved primary bony union, and this matches with previous reports on MIPO. In ORIF group there was only one case of delayed union which was managed by bone graft after 5 months and achieved complete union after 30 weeks. Average union time was 15.1 weeks and 16.3 weeks in MIPO group and in ORIF group respectively. Union time in group B is longer than group A but it is statistically not significant. Union was defined as the absence of fracture site tenderness and the presence of bridging callus in three of the four cortices seen on the antero-posterior and lateral radiographic views of the humerus**.**

Hadhoud et al 2015 reported that, all cases achieved primary bony union there was only one case of delayed union which was united after 40 weeks. In ORIF group nonunion occur in one case only which was managed by bone graft after 6 months when there was no evidence of progress of bone union. Average union time was 15.3 weeks and 16.5 weeks in MIPO group and in ORIF group respectively. [17]

Kim et al. 2015 documented that average union time was 14.6 weeks and 15.8 weeks in MIPO group and in ORIF group respectively. They observed no case of nonunion and only one delayed union in open plating, and no instance of nonunion in MIPO. This coincides with our study results. [18]

In closed and minimally invasive techniques with indirect fracture reduction, mal-alignment is a more common complication as compared with conventional open reduction. In particular, intraoperative limb length, axial alignment, and rotation must be carefully assessed to prevent malalignment. Malalignment was not observed in the MIPO group in the present study; however, the mean intraoperative radiation exposure time was 85 seconds. **Zhiquan et al** reported it was necessary to confirm the reduction states with an image intensifier repeatedly for successful results using closed reduction in MIPO. As indicated by our results, the repeated use of fluoroscopy could avoid mal-alignment, but this might increase the radiation hazard. mild varus angulation did not affect the functional outcome due to wide range of shoulder and elbow motion. [19]

In terms of functional outcomes at an average follow-up of 6 months, the functional outcomes of shoulders and elbows in this study were satisfactory in both study groups. The mean function of elbow assessed by MEPI score system was 90.3 and 87.7 in the MIPO group and ORIF group respectively. Scores are categorized as 90-100= excellent, 75-89= good, 60-74= fair and 0-59=poor. 7 patients were excellent, 7 patients were good and one patient had fair result in MIPO group while 6 patients were excellent, 7 patients were good and two patients had fair results in ORIF group. The mean UCLA score for assessment of shoulder function was 32.2 and 30.9 for MIPO group and ORIF group respectively. The maximum score is 35 points. > 27 good/ excellent indicate satisfactory results, whereas < 27 fair/ poor indicate unsatisfactory results. 6 patients were excellent, 8 patients were good, and one patient had fair result in the MIPO group. And 6 patients were excellent, 7 patients were good, 1 patient was fair and one patient had poor result of ORIF group which is consistent with previous reports on plating techniques**.**

Hadhoud et al 2015, in a comparative study of conventional ORIF versus MIPO technique in the treatment of mid-distal humeral shaft fractures the functional outcomes of shoulders and elbows were satisfactory in both study groups. The mean function of the elbow as assessed by the MEPI score system was 90.3 and 87.7 in the MIPO group and ORIF group, respectively. The mean UCLA score for shoulder function was 32.2 and 30.9 for the MIPO group and ORIF group, respectively. [17]

In a study on forty patients with humerus shaft fractures managed using the MIPO technique done by **Mehraj et al. 2019**. The mean radiological fracture union time was 13 weeks (range: 8-18 weeks). All cases achieved primary bone union. They observed no case of nonunion. Shoulder function based on the UCLA score was excellent to good in 33 cases (82.5%), fair in 6 cases (15%) [15]

As revealed by our results, in both groups, fracture healing occurred in all patients, and the functional outcomes were also excellent based on the Mayo and UCLA scoring system. Therefore, we believe that both techniques are safe and effective method for humeral shaft fractures treatment.

In the preset study there was no infection in the MIPO group while there was only one superficial infection and one deep infection in ORIF group. It might be due to extensive soft tissue dissection which concurs with the previous reports. The one superficial infection that happened resolved with antibiotic treatment and frequent wound dressing. The patient who developed a deep infection responded to serial debridement and irrigation with culture-specific antibiotics. Hardware removal was not deemed necessary as no signs of loosening were present and progressive bone healing was visible on radiographs. Adequate healing with complete remission of infection was achieved. In the present study, no cases had postoperative iatrogenic radial nerve palsy in both groups. So, we think that humeral MIPO is a safe method in terms of radial nerve safety**.**

Esmailiejah et al 2015, 65 patients with humeral shaft fractures were treated using ORIF (33 patients) or MIPO (32 patients). They reported two cases of deep infection in ORIF group but the difference wasn't statistically significant. They also reported one case of iatrogenic radial nerve injury in MIPO group and 4 cases in ORIF group **(19)**

Zhao et al 2017 documented that in a met-analysis on surgical intervention to treat humeral shaft fractures. In comparison to IMN, either ORPF or MIPO significantly decreased the risk of shoulder impingement. Furthermore, the pooled results showed a significantly higher occurrence of iatrogenic radial nerve injury in the ORPF group than in the MIPO group. There were no significant differences among the three procedures in nonunion, delayed union, and infection. Hence, they concluded that the MIPO technique is the preferred treatment method for humeral shaft fractures. **(20)**

Although we luckily had no radial nerve injury in both groups, pre-existing literature demonstrates MIPO technique superiority over the conventional technique even when compared to historical control data of pre-existing literature.

CONCLUSION

We can conclude that both techniques are reliable treatment options for humeral shaft fracture, although MIPO is less time consuming, exposes the patient to less soft tissue damage and less blood loss making it a more appealing option, taking in consideration that all safety measures for radiation exposure should be taken.

REFERENCES

1. **Updegrove GF, Mourad W, Abboud JA.** Humeral shaft fractures. J Shoulder Elbow Surg. 2018; 27(4):e87-e97
2. **Mehraj M, Shah I, Mohd J, Rasool S.** Early Results of Bridge Plating of Humerus Diaphyseal Fractures by MIPO Technique. Ortop Traumatol Rehabil. 2019; 21(2):117-121.
3. **Kulkarni VS, Goyal V, Kulkarni MG, et al.** Comparison between antegrade intramedullary nailing (IMN), open reduction plate osteosynthesis (ORPO) and minimally invasive plate osteosynthesis (MIPO) in treatment of humerus diaphyseal fractures. Injury. 2017; 48 Suppl 2:S8-S13.
4. **Tetsworth K, Hohmann E, Glatt V.** Minimally Invasive Plate Osteosynthesis of Humeral Shaft Fractures: Current State of the Art. J Am Acad Orthop Surg. 2018; 26(18):652-661
5. **Schemitsch EH, Bhandari M. Fractures of the humeral shaft. In: Browner BD, Jupiter JB, Levine AM, Trafton PG, editors.** Skeletal trauma: basic science, management, and reconstruction. 3rd ed. Philadelphia: WB Saunders Company; 2003. 1487-1488.
6. **Zhao Y, Wang J, Yao W, et al.** Interventions for humeral shaft fractures: mixed treatment comparisons of clinical trials. osteoporos Int. 2017; 28(11):3229-3237.
7. **Niall DM, O′Mahony J, McElwain JP.** Plating of humeral shaft fractures - has the pendulum swung back?. Injury 2004; 35:580-586.
8. **Bhandari M, Devereaux PJ, McKee MD, Schemitsch EH.** Compression plating versus intramedullary nailing of humeral shaft fractures - a meta-analysis. Acta Orthop 2006; 77:279-284.
9. **Lim KE, Yap CK, Ong SC, Aminuddin M.** Plate osteosynthesis of the humerus shaft fracture and its association with radial nerve injury - a retrospective study in Melaka General Hospital. Med J Malaysia 2001; 56:8-12.
10. **Paris H, Tropiano P, ClouetD′orval B Chaudet H, Poitout DG.** Fractures of the shaft of the humerus: systematic plate fixation. Anatomic and functional results in 156 cases and a review of the literature. Rev Chir Orthop Reparatrice Appar Mot 2000; 86:346-359.
11. **Jawa A, McCarty P, Doornberg J Harris M, Ring D.** Extra-articular distal-third diaphyseal fractures of the humerus. A comparison of functional bracing and plate fixation. J Bone Joint Surg Am 2006; 88 :2343-2347
12. **Davies G, Yeo G, Meta M, et al.** Case-Match Controlled Comparison of Minimally Invasive Plate Osteosynthesis and Intramedullary Nailing for the Stabilization of Humeral Shaft Fractures. J Orthop Trauma. 2016; 30(11):612-617.
13. **An Z, He X, Zeng B.** A comparative study on open reduction and plating osteosynthesis and minimal invasive plating osteosynthesis in treating mid-distal humeral shaft fractures. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi. 2009; 23(1):41-4.
14. **Zhiquan A, Bingfang Z, Yeming W Chi Z, Peiyan H.** Minimally invasive plating osteosynthesis (MIPO) of middle and distal third humeral shaft fractures. J Orthop Trauma 2007; 21 :628-633

15. **Mehraj M, Shah I, Mohd M, Rasool S.** Early Results of Bridge Plating of Humerus Diaphyseal Fractures by MIPO Technique. Ortop Traumatol Rehabil. 2019. 30;21(2):117-121
16. **Yang J, Liu D, Zhang L, Lu Z, Liu T and Tao C.** Treatment of humeral shaft fractures: a new minimally-invasive plate osteosynthesis versus open reduction and internal fixation: a case control study. BMC Surg. 2021; 21: 349.
17. **Hadhoud MM, Darwish AE and Mesriga MM.** Minimally invasive plate osteosynthesis versus open reduction and plate fixation of humeral shaft fractures. Menoufia Medical Journal. 2015;28(1): 154-161
18. **Kim JW, Chang WO, Young-SB, Jung JK, MD and Ki P.** A Prospective Randomized Study of Operative Treatment for Non-comminuted Humeral Shaft Fractures: Conventional Open Plating Versus Minimal Invasive Plate Osteosynthesis. J Orthop Trauma. 2015;29(4)
19. **Esmailiejah AA, Abbasian MR, Safdari F and Ashoori K.** Treatment of Humeral Shaft Fractures: Minimally Invasive Plate Osteosynthesis Versus Open Reduction and Internal Fixation. Trauma Mon. 2015;20(3):e26271
20. **Zhao JG, Wang J, Meng XH, Zeng XT, and Kan SL.** Surgical interventions to treat humerus shaft fractures: A network meta-analysis of randomized controlled trials. journal. Pone. 2017; 12(3): e0173634.