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Functional and Radiological Outcome in the Management of Diaphyseal Humeral Shaft Fracture Using the Minimally Invasive Percutaneous Plate Osteosynthesis (MIPO) Technique

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ABSTRACT

Introduction: Minimally invasive percutaneous plate osteosynthesis (MIPO) is gaining preference nowadays compared to other treatment modalities for diaphyseal fracture of the humerus. We have evaluated the functional and radiological outcome of diaphyseal humeral shaft fracture with the MIPO technique.

Methods: A hospital-based prospective study was conducted on 23 adult patients with diaphyseal fracture of the humerus and treated with the Minimally Invasive Percutaneous Plate Osteosynthesis (MIPO) technique. In all cases, 4.5mm locking compression plates were applied. Clinical and radiological evaluation was done at 6 weeks, 3 months, and 6 months.

Results: Out of 23 patients, the mean age of patients was 40.3 years. The maximum number of cases were caused due to road traffic accidents 14 (60.9%). The left side was commonly affected with a maximum number of them being Type A fracture 13 (56%) as per AO/OTA classification. The mean operative time was 106 minutes and fracture union was achieved in all patients by the end of 20 weeks (mean 14.83 weeks). In the study group, 1 patient had superficial infection with no evidence of iatrogenic radial nerve injury or implant failure. Shoulder and elbow ROM was restored to normal range.

Conclusion: MIPO is a safe and effective technique for the management of diaphyseal humerus fractures, with early fracture healing, less risk of complications such as superficial or deep infection, implant failure, and iatrogenic radial nerve injury, along with a cosmetically acceptable scar.

Keywords: *Bone Plate; Fracture Healing; Humerus; Radial Nerve*

INTRODUCTION

Humerus shaft fractures constitute around 1-2% of all fractures and 14% of the entire humeral fractures.[1]Incidence rates reveal a bimodal age distribution.[2]It occurs due to high

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and low energy trauma in younger and elderly individuals respectively.[3]Radial nerve injury is commonly encountered during diaphysis fractures.[4]

Most cases undergo conservative management but with limitations.[5]Surgical indications include failed nonsurgical treatment, polytrauma, open fractures, floating elbow, bilateral humerus injuries, and pathological fractures.[6]Open reduction and internal fixation (ORIF) with compression plate and intramedullary nails are widely accepted but involve extensive surgical dissection with the rate of non-union between (3-20)% with the additional risk of infection and iatrogenic radial nerve injury.[7,8] Nowadays preservation of soft tissues and fracture hematoma along near acceptable alignment is considered better than stable mechanical fixation.[9] The disadvantage of rigid fixation led to a shift toward the concept of biological plate osteosynthesis with secondary bone healing.[10]An alternative method is minimally invasive percutaneous plate osteosynthesis (MIPO) based on relative stability promoting secondary bone healing using the principle of biological fixation.[11]

This study aims to evaluate the radiological and clinical outcome of MIPO in diaphyseal fracture of humerus in adults.

METHODS

A hospital-based prospective study was conducted in the Department of Orthopaedics, Manipal Teaching Hospital, from May 2019 to May 2021. A total number of 23 patients with diaphyseal fractures of the humerus attending the OutPatient Department and the Emergency Department of Orthopaedics, who met the inclusion criteria outlined below were included in the study. Inclusion criteria included patients in the age group of 18-61 years. Fractures within 14 days of injury, closed fracture of diaphysis of the humerus (a fracture located at least 5cm distal to the surgical neck of the humerus and 5cm proximal to olecranon fossa), and medically stable patients who could undergo post-operative rehabilitation were included. Exclusion criteria included open fractures of diaphysis of humerus, polytrauma involving the same limb, medically unfit patient for surgery, fracture with associated neurovascular injury, pathological fractures of diaphysis of humerus, and patient with known alcohol and drug dependency. Routine pre-operative clinical and radiological evaluation was done, which included radiographs in anteroposterior (AP) and lateral (LAT) views of the humerus. The fractures were classified as per AO-ASIF trauma classification. All the patients were operated on within 7 days of the injury by the same surgeon. The implant used to fix these fractures was a 4.5mm narrow locking compression plate (LCP). Informed written consent was obtained from each patient before participation in the study.

Ethical clearance for this study was taken and approved by the Ethical Committee of Manipal Teaching Hospital.

Surgery was performed on a radiolucent operating table with the patient in the supine position and injured arm in 60 degrees abduction and full supination using an image intensifier. Proximal and distal, two separate skin incisions were made. A 3 cm proximal skin incision was made in between the proximal part of the biceps and the medial border of the deltoid muscle and a 3 cm distal skin incision was made lateral to the biceps approximately 4-5cm proximal to the elbow crease. [Figure 1]

Figure 1: Proximal and distal skin incision of the left arm

Biceps were retracted medially to expose the brachialis with the musculocutaneous nerve lying on the muscle. By blunt dissection, the brachialis muscle was split and retracted with the medial part cushioning the musculocutaneous nerve and the lateral part cushioning the radial nerve. From the distal to the proximal incision a tunnel was made sub-muscularly by a tunneling instrument, in our case, a 4.5mm locking compression plate was used. The plate was then passed close to the bone and exited from the proximal site. Under the image intensifier, the plate was positioned on the anterior surface of the bone and temporarily fixed by two 1.5 mm K-wires in each segment. The reduction was checked under the image intensifier. The elbow was flexed at 90° to relax the brachialis muscle, aiding the reduction. A long eight to twelve-hole narrow locking compression plate (LCP) was then inserted below the brachialis extra-periosteally from proximal to distal. The plate position and reduction were checked under the image intensifier. The distal-most screw was inserted first. Manual traction and indirect reduction techniques were used to restore the length, correcting the varus and valgus angulation and rotation. Three to four screws were inserted in each fracture fragment.

Incisions were then sutured in layers using interrupted sutures. No patients needed the use of bone grafting or bone substitute in the primary surgery. The radial nerve was not explored in any of the cases.

After surgery, the involved arm was kept in an arm sling pouch. Elbow and shoulder movement was initiated immediately from the third postoperative day to avoid any stiffness, and edema and to promote circulation. Arm sling pouch was continued till 6 weeks from the day of operation, which was put off during the time of shoulder and elbow exercises.

The follow-up of the patients was done at an interval of two weeks, six weeks, three months, and six months with the suture removed two weeks following the surgery. The patients were assessed subjectively for pain at the fracture site and clinically for any stiffness, tenderness, or signs of infection.

The fracture union was clinically assessed by the absence of tenderness and the presence of three bridging cortices on images in two orthogonal planes. For this, anteroposterior and lateral views were obtained at, six weeks, three months, and six months in all followed up cases. The functional outcomes of the shoulder and elbow were analyzed using the UCLA Shoulder and MEPS scoring system respectively at 3 months and 6 months follow up.

UCLA shoulder score categories include “active forward flexion” (maximum of 5 points and physician completed), “strength of forward flexion” (maximum of 5 points and physician completed), “pain” (maximum of 10 points and patient completed), “satisfaction” (maximum of 5 points and patient completed), and “function” (maximum of 10 points and patient completed). Scores range from 0 to 35 with a score of 0 indicating worse shoulder function and 35 indicating excellent shoulder function. The MEPS measures elbow function across four domains: pain (45 points), stability (10 points), range of motion (20 points), and daily functional tasks (25 points).Scores are categorized as 90-100 = excellent, 75-89 = good, 60-74 = fair, 0-59 = poor.Scoring for shoulder and elbow was done for different fracture groups i.e (AO A,B,C) and statistically analyzed for p-value. A P-value of less than 0.05 was considered statistically significant.

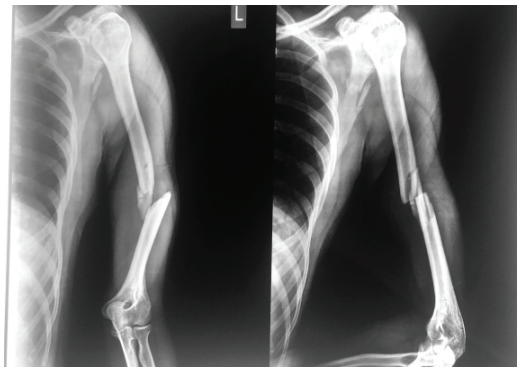

Figure 2: Pre-operative Xray: Anteroposterior and lateral views

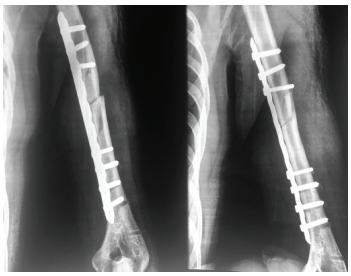

Figure 3: Post-operative follow-up X-ray

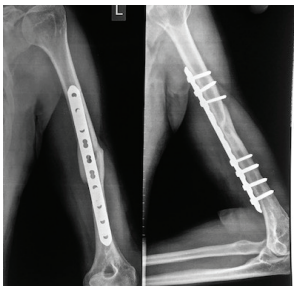

Figure 4: Final follow-up X-ray

RESULTS

Out of 23 patients, 11 (47.8%) were males and 12 (52.2%) were females. In our study, the age group ranged from 18 to 61 years, with a mean age of 40 years. The fracture was common in the age group of 36-45 years, which account for 7(33%) of the case. In total, fourteen patients were affected on the left side and nine patients on the right side. A road traffic accident was the most common mode of injury in 14 patients (60.9%), followed by falls from height 6 (26.1%) and domestic falls 3 (13%). According to the AO classification, four cases were A1 (17.4%), four cases were A2 (17.4%), five cases were A3 (21.7%), five cases were B1 (21.7%), four cases were B2 (17.4%) and a single case of C1 (4.3%). The duration of surgery depends upon the type of fracture, with a mean surgical time of 106 minutes. Fracture union was achieved in all the patients by the end of 20 weeks (mean of 14.83 weeks) Figure (2, 3, 4).

UCLA shoulder assessment score at 6 months post-operative follow-up classified 2 patients (8.69%) as excellent (34-35), 15 patients (65.21%) as good (28-33), 6 patients (26%) as fair (22-27). It was observed that the majority of the cases had excellent and good UCLA scores as shown in Tables 1 and 2. According to the Mayo Elbow Performance Scoring system at six months post-operative follow-up 8 patients (34.5%) had an excellent result, and 15 patients (65.2 %) had a good result.

Comparing the bleeding volume, operative time, and hospital stay duration between different AO groups showed no significant differences ($p>0.05$). Similarly, bone union time, UCLA score, and MEPS between different AO groups at six months follow-ups also showed no significant differences ($p>0.05$) as shown in Table 3. Shoulder and elbow movement showed no limitation when compared to the normal side (Figure 5, 6). Superficial infection was noted in one case (4.34%) which responded to daily betadine dressing and seven days course of oral antibiotics. No complications such as screw loosening, screw breakage, or implant failure were noted. None of the patients had iatrogenic radial nerve palsy. All malalignments noted were less than 10 degrees and did not affect the function of the shoulder or elbow joint.

Figure 5: Range of movement (flexion of the elbow) at final follow-up

Figure 6: Range of movement (extension of the elbow) at final follow-up

Table 1: Comparisons of related indicators

AO/OTA classification	Number of patients	Mean Bleeding volume(ml)	Mean Operative time(min)	Mean hospital stay (days)	Mean Time to union (weeks)
A1	4	95	114	6.25	15.03
A2	4	91.25	103.75	5.75	14.33
A3	5	93	95.4	6.20	15.14
B1	5	96	105.6	6.2	14.66
B2	4	95	107.25	5.75	14.67

AO: Arbeitsgemeinschaft für Osteosynthesefragen; OTA: Orthopaedic Trauma Association

Table 2: Statistics for the Study

Parameter	Range	Mean
Age(in Years)	18-61	40.3
Surgery time(in minutes)	80-128	106
Union(in weeks)	13-16.4	14.83
UCLA score(points)	27-34	29.6
MEPS (points)	75-96	84.7

UCLS: University of California at Los Angeles Shoulder Score;
MEPS: Mayo elbow performance score

Table 3: Comparisons of different related indicators

Parameters	AO Type A	AO Type B	AO Type C (single case)	p-value
Bleeding Volume(ml) mean	93.08	95.5	80	0.931
Operative time(min)mean	104.3	106.42	110	0.338
HSD(days)	6.06	5.975	9	0.585
BH(weeks)	14.83	14.66	15.2	0.878
UCLA score	29.9	29.02	30	0.965
Mayo elbow score	85.01	87.175	79	0.907

AO: Arbeitsgemeinschaft für Osteosynthesefragen; OTA: Orthopaedic Trauma Association; UCLS: University of California at Los Angeles Shoulder Score; HSD: Hospital stays (days); BH: bone healing

DISCUSSION

Operative treatment in the form of open reduction and plate osteosynthesis (ORPO) is the treatment of choice for humeral diaphyseal fracture.[7] ORPO works in principle to maintain absolute stability at the fracture site leading to a solid union of fracture but at the expense of disruption of periosteal blood supply and extensive soft tissue dissection.[15] Moreover, local vascularization is affected leading to osteonecrosis underneath the implant, which could lead to delayed union or non-union.[16] Fracture fixation by absolute stability leading to primary bone healing in plating is weaker and may present a real risk of re-fracture after implant removal.[17] Using the MIPO technique, anatomical reduction of fracture fragments is usually not required, so it works in the principle to maintain relative stability leading to secondary bone healing. Studies have shown secondary bone healing is a more biological

form of fracture fixation having the advantage that the potential of remodeling is much higher in contrast to primary bone healing.[18,19] In MIPO, a long plate is usually preferred to distribute the bending stresses over a long segment of the plate and thus reducing the stress per unit area, correspondingly reducing the rate of plate failure.[20]

Our mean duration of surgery was 106 minutes ranging from (80-128minutes) which was comparable to the study done by Yang et al.[21] The mean time for fracture union was 14.83 weeks ranging from (13-to 16.4 weeks) and meantime of union for group C fracture was slightly higher than group A and B. Matsunaga et al. studied the first RCT comparing MIPO stabilization and functional bracing for treatment of humeral shaft fracture and found no non-union with MIPO as compared to functional bracing(15%) and less radiographic deformity in the coronal plane with MIPO compared to those managed non-operatively in a brace(15%).[22]

Esmailiejah et al. in a comparative group of 65 patients found better results in MIPO (32patients) as compared to ORIF(33 patients)with regards to iatrogenic radial nerve palsy (3% and 12% respectively), rate of infection(0 and 6% respectively and having a shorter duration of the union in MIPO group.[14] Kim et al. reported good functional outcomes without any iatrogenic nerve injury in the patient treated with MIPO which was similar to our study.[23] Benegas et al in an RCT studied 40 humeral shaft fractures to either MIPO (n=21) or IMN (n=19) and observed that surgical time was equivalent between the 2 groups, but there was significantly more use of fluoroscopy with IMN compared to MIPO and concluded that humeral shaft MIPO is a safe and effective technique that resulted in less radiation exposure for the surgeon, with comparable shoulder function.[24] Apivatthakakul et al. performed a cadaveric study to investigate the relationship of the nerve at risk to the approaches necessary to create the anterior sub-muscular tunnel and emphasized that protecting the radial nerve from the distal end of the anterior plate by maintaining the forearm in supination during the surgical procedure. During pronation, it was noted that the radial nerve moved closer to the distal part of the plate. He further described the danger zone for the radial nerve which lies 36.5%-59.2% of the humeral length above the lateral condyle of the humerus.[25]

Humeral shaft fractures in the proximal third are more difficult to control, and deltoid acts to displace the fracture site. A slight extension of the proximal approach facilitates a more anatomical reduction and the use of additional screws will augment stability. Some surgeons still consider radial nerve palsy an indication for surgical exploration and ORIF, the current consensus for the closed fracture is an expectant policy of observation and monitoring nerve injuries unless they were the direct result of an attempted maneuver.[26]

It could be said that MIPO is preferred due to the advantage of having a limited skin incision thereby offering a better cosmetic appearance along with less risk of infection and iatrogenic radial nerve injury. In addition, radiation exposure to the patient and surgeon is less with excellent shoulder and elbow function, leading to patient satisfaction.

CONCLUSION

MIPO holds genuine promise as an alternative method of humeral shaft fracture fixation. Our study favors MIPO as a method of fixation for the shaft of humerus fracture as it offers a middle ground between ORIF and IML that incorporates some of the best aspects of each. MIPO merits an overwhelming advantage compared to other treatment methods. Thus the proper selection of patients, the surgeon's acumen, and the learning curve of the surgery play an important role in the successful outcome following MIPO of the shaft of the humerus.

CONFLICT OF INTEREST

None

SOURCES OF FUNDING
None

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