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Original Research Article

Radiological and functional outcomes of anterior bridge plating with minimally invasive plate osteosynthesis technique for humerus diaphyseal fractures in adults

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ABSTRACT

Background: We conducted a study to evaluate radiological, functional outcomes and complications of internal fixation of humerus diaphyseal fractures by anterior bridge plating (ABP) with minimally invasive plate osteosynthesis technique.
Methods: 40 patients with humerus diaphyseal fractures operated by ABP with MIPO between August 2017 and January 2020 were included in the study. All patients were evaluated verbally, clinically, and radiologically for a minimum of 1 year.
Results: Mean time to radiological union was 13.75 weeks. Disabilities of the arm, shoulder and hand score improved from a mean of 23.45 to a mean of 5.04 at 6 months. All patients except one had an excellent Mayo Elbow Performance Score score at 6 months. The variation of mean shoulder range of motion between normal and operated side was within 5 degrees at 6 months. Visual Analogue Scale score improved from a preoperative mean of 8 to a postoperative mean of 0.5 at 6 months. Mean intraoperative blood loss was 147 ml. Two patients had a superficial wound infection, one patient had a postoperative radial nerve palsy, and one patient had a delayed union, all of which recovered without any surgical intervention.
Conclusions: ABP with MIPO technique for humerus diaphyseal fractures is a safe and effective treatment modality yielding high rates of union, excellent functional recovery, minimal biological disruption, better cosmesis, and superior patient satisfaction. Therefore, we recommend that ABP with MIPO should be considered as an alternative treatment option in patients with humerus diaphyseal fractures.

Keywords: Humerus diaphyseal fractures, Anterior bridge plating, Minimally invasive plate osteosynthesis, Functional outcome, Radiological outcome

INTRODUCTION

Fractures of the humeral shaft (diaphysis) account for approximately 1-3% of all fractures and represent 20% of all humeral fractures. The incidence is 13 to 14.5 per 1,00,000.[1-3] Primary cause of fracture includes road traffic accidents, accidental falls, or violent injury. The bimodal age distribution is seen with a peak at 3rd decade of life in males (as a result of moderate to severe trauma) and 5th - 7th decade of life in females (after simple falls).[4]

Treatment modalities have significantly changed since their first explanation in ancient Egypt (1600 BC); however essential management principles have persisted

steadily throughout the time.[5] Fractures of the humeral diaphysis have traditionally been regarded benign, with a high percentage of healing with conservative methods, using either a hanging arm cast or a functional brace.

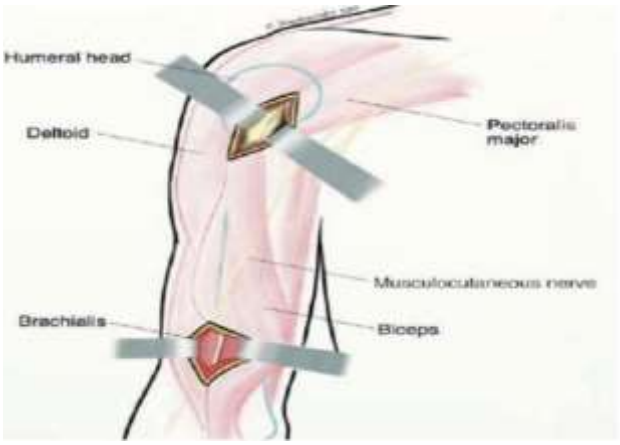

Figure 1: Approach for ABP with MIPO technique.

Figure 2: Plate fixed through proximal and distal windows.

However, loss of reduction in the plaster cast invariably leads to malunion. Hence now, with better implant design and surgical method, operative treatment of humerus diaphyseal fractures is preferred over conservative management. The advantages of operative treatment are early mobilization and patient comfort. Operative treatment can be accomplished via external fixation, intramedullary nails or plate-and-screw constructs.[1,6] Conventional open plating (COP) provides satisfactory results but requires extensive dissection and meticulous radial nerve protection. Intramedullary nailing is advantageous in being a less invasive surgery, an undisturbed fracture hematoma and the use of load-sharing device support. However, the phenomenal success of interlocking nailing in long bones like femur and tibia is not seen in the humerus. According to recent studies, the preferred method of fixation of humeral diaphyseal fractures is by dynamic compression plate.[7,8]

Anterior bridge plating (ABP) which utilizes minimally invasive plate osteosynthesis (MIPO) technique can be said to be the latest entrant in the management of humerus diaphyseal fractures.[9-13] The ABP is designed to combine the best features of these two techniques: therefore, it is minimally invasive and cosmetic friendly and causes minimal manipulation of vital structures. This technique has benefits of minimal soft tissue dissection and avoids the need to expose the radial nerve; thus, little risk of iatrogenic palsies.[10-14] Considering the review of literature, we found that there is a paucity of studies on anterior humerus bridge plating with MIPO technique, in developing countries like India. The few Indian studies in literature do talk about radiological and functional outcomes of this technique but clinical outcomes in terms of pain, influence of gender on outcome, surgical time and blood loss have not been evaluated in detail. Hence, we conducted a single centre open study to understand the outcomes to help us plan a larger study later, which could be multicentric, double blinded and compared with posterior humerus plating as well as intramedullary humerus nailing.

METHODS

40 patients with humerus diaphyseal fractures were admitted in the department of orthopaedics of our tertiary care hospital (Grant Medical College and Sir J. J. Group of Hospitals, Mumbai) between August 2017 and January 2020. They were operated with anterior bridge plating with minimally invasive plate osteosynthesis and were included in this study after obtaining approval from the Institutional Ethics Committee (prospective cohort study- Level of evidence-II). All patients were operated on and evaluated by the same senior surgeon.

Inclusion criteria

Patients with humeral diaphyseal fractures aged 18 years and above, and skeletally mature. All patients having a minimum 1 year of follow-up at the time of the study.

Exclusion criteria

Proximal humeral shaft fractures extending to the humeral head and fractures extending to distal humerus. Open fractures and pathological fractures. Patients with pre-existing shoulder and elbow problems. Ipsilateral upper limb trauma/neurovascular insult or any other major injuries elsewhere which had the potential to jeopardize the patient rehabilitation. History of old humeral fractures on the same side. Patients with brachial plexus injury, who were unable to do the active flexion-extension of the elbow

Primary treatment

All patients underwent a primary survey and hemodynamic stabilization in the emergency department. The presence of other fractures, assessment of the neurovascular status of the limb and systemic evaluation was done subsequently on the secondary survey. Standard

anteroposterior (AP) and lateral views of the affected arm including ipsilateral shoulder and elbow joint were obtained for diagnosis and the limb was immobilized in plaster of paris (POP) U-slab. All patients were informed about the study procedure, purpose and risk. A written informed consent was obtained.

Surgical procedure

All surgeries were performed under regional anaesthesia with the patient in supine position. Scrubbing, painting and draping were done under aseptic conditions and the shoulder was abducted to 30°–60°, the elbow was flexed to about 90° and the forearm was supinated throughout the procedure to decrease the tension on the brachialis muscle.

The minimal access anterior approach to the humerus that utilizes two soft-tissue windows, proximal and distal were used (Figure 1). The advantage of this approach is the preservation of the blood supply to the fracture zone. The disadvantage is that the fracture is not exposed, which makes it difficult to achieve and assess the reduction. A 3-4 cm longitudinal incision beginning 5 cm distal to the acromion, was made in the line of the deltopectoral groove to create a proximal window. A second 3-4 cm longitudinal incision overlying the lateral border of the biceps brachii in the distal third of the arm extending to, within 5 cm proximal to the flexion crease, was made to create a distal window. Proximally, the anterior minimal access approach utilizes the plane between the deltoid muscle (axillary nerve) and the pectoralis major muscle (lateral and medial pectoral nerves). Distally, the plane lies between the medial half of the brachialis muscle supplied by the musculocutaneous nerve and the lateral half of the brachialis muscle supplied by the radial nerve. The biceps and underlying neurovascular bundle was retracted medially and the lateral part of the split brachialis muscle protected the radial nerve. An undue forceful retraction was avoided to prevent neuropraxia.

To connect the two windows, an epiperiosteal plane was developed on the anterior surface of the humerus using a blunt elevator. After the humerus is exposed through the proximal and distal window, the fracture was reduced and the plate was placed on the bone such that the appropriate part of the plate was on the fracture site i.e., the middle part of the DCP plate without holes. As described by Wang et al 15° of angulation in any plane and 1 cm migration of fracture ends were the threshold of acceptability and anything more than that merited a second attempt for reduction.[15] The cortical step sign and diameter difference sign described by Krettek et al were used to minimize malrotation during fixation.[16]

The longest possible 4.5-mm dynamic/locking compression plate (DCP/LCP) was chosen depending on the humeral anatomy (Figure 2). During insertion of the distal screws on the anterior surface, care was taken to avoid the of the radial nerve laterally and brachial artery and musculocutaneous nerve medially. Simple cortical screws were used in all cases (at least two proximally and two distally) except when the bone was extremely osteoporotic where locking screws were used. For calculating the blood loss, the following method was used: We used the same size surgical mop intraoperatively in all cases.

The blood soaked surgical mop was weighed postoperatively and the dry weight of the surgical mop (that was taken preoperatively) was subtracted from the wet weight. Blood loss in surgical mop was calculated considering 1gm of blood equal to 1 ml of blood. Blood loss in suction bottle=Total fluid in the suction bottle at the end of the surgery minus volume of irrigation fluid used intraoperatively.

Post operative protocol

Postoperatively a compression bandage was applied and a broad arm pouch was given. Parenteral antibiotics were given for 24 hours postoperatively. The wound was inspected on the 3rd post-operative day. Sutures were removed between the 10th and 12th postoperative days. Pendulum exercises and elbow, wrist, and hand range of motion (ROM) exercises were started from postoperative day 1 as tolerated by the patient. Active and active-assisted shoulder ROM exercises were started under the supervision of a physiotherapist 2 weeks after surgery. Active abduction beyond 90° and active rotation was allowed at 3-4 weeks after surgery. The patient was allowed to gradually resume preoperative activities with muscle strengthening and return to the full spectrum of activities at 9-12 weeks after surgery.

Follow-up evaluation

All the patients were followed up at monthly intervals till fracture union and once in 6 months till the completion of the study. They were evaluated verbally, clinically and radiologically for the outcome of surgery at every follow-up. The age, sex, occupation, side of injury, time of injury, mode of injury and type of fracture pattern was noted. Clinical examination was done to assess the status of the surgical wound, pain, tenderness, range of motion of shoulder and elbow, stability of the fracture and clinical union. Roentgenograms were taken in AP and Lateral views to look for signs of the radiological union. In our study, clinically, the bone was said to be united when the fracture site had become stable and pain-free. The union was confirmed radiologically when plain X-rays showed bony trabeculae or cortical bone crossing fracture site on at least three surfaces on orthogonal radiograms. The time taken for the clinical and radiological union was noted. Any complication occurring during the course of the treatment was also noted. Patients with no signs of radiographic/clinical union at more than 180 days or 6 months after surgery, were subsequently treated for non-union. Functional evaluation was made by Disabilities of the arm, shoulder and hand (DASH) scoring, Mayo Elbow

Performance Score (MEPS), Visual Analogue Scale(VAS) and Shoulder Range of Motion at 6 weeks, 3 months and 6 months.

Statistical analysis

The data was compiled into Microsoft Office Excel worksheet 2013 version and statistical analysis for significance was done using student's t-test and one-way ANOVA test. A probability value $p<0.05$ was considered significant.

RESULTS

Total 40 patients with humerus diaphyseal fracture were operated with ABP with MIPO technique in a tertiary care hospital between August 2017 and January 2020. Out of the original 46 patients included in the study, two declined to continue participation, two were lost to follow-up and two died due to unrelated causes (one due to a motor vehicle accident and one due to a cardiac arrest). Demographic details with respect to age, gender, occupation, side affected, mode of injury, location of the humerus shaft fracture, and AO classification have been tabulated and presented in (Table 1). One patient was a chronic tobacco chewer and two were chronic smokers. Bimodal age distribution was observed with 15 patients aged less than 30 years and 16 patients aged above 50 years. The mean delay in surgery was 2.5 days. The minimum operative time was 60 minutes and the maximum was 120 minutes with a mean operative time of 79 minutes. It was also noted that surgical time decreased as the surgeon became more and more familiar with the operative procedure.

Figure 3: Case 1, (a, b): Preoperative X-ray Humerus AP/Lateral Postoperative X ray, (c, d): Day 1, (e, f): 3 months, (g, h): 6 months.

Minimum intra-operative blood loss was 120 ml and maximum blood loss was 210 ml with a mean blood loss of 147 ml. All except one patient has radiological union within 4.5 months with a mean time to the radiological union being 13.75 weeks. One patient had a delayed union that got completely united at 1 year (Figure 3-5). The mean MEPS score, DASH score and VAS score are summarised in (Table 2, Figure 6-7).

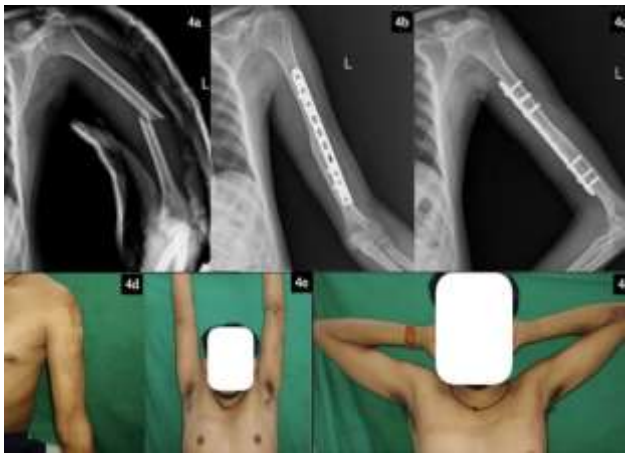

Figure 4: Case 2, (a): Preoperative X-ray Humerus, (b, c): Postoperative X-ray 6 months and (d-f): Clinical images showing shoulder range of motion.

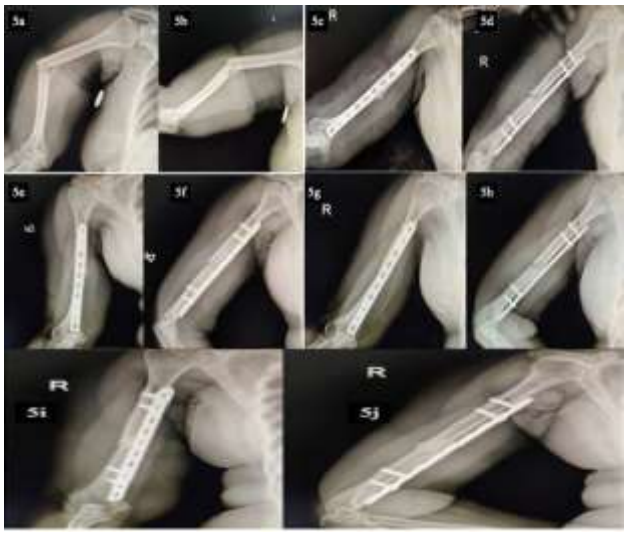

Figure 5: Case 3, (a, b): Delayed union- preoperative X-ray Humerus, (c, d): Postoperative X-ray Day 1, (e, f): 3 months, (g, h): 6 months, (i, j): 1 year.

Statistical analysis for significance was done using the student's t-test and was found to be statistically significant ($p<0.05$) showing a lower DASH scores and higher MEPS score at 3 months and 6 months. The data were also checked for significance using a one-way ANOVA test and was found to be significant with a p value less than 0.05. The majority of the patients had a fair to good MEPS score at 1.5 months that improved to an excellent score at 6 months in all patients except one. One patient had a good score at 6 months (Table 2). The shoulder range of motion of the operated side was compared to the normal side at 6 months. The variation of mean range of motion between normal and operated sides was within + 5 degrees (Figure 4). Statistical analysis for significance using student's t-test was also performed to see the effect of age, gender,

side of injury and associated comorbidities on the rate of healing (time taken for radiological union).

Figure 6: Mean DASH scores at different time intervals.

Table 1: Demographic details with respect to age, gender, occupation, side affected, mode of injury, location of the humerus shaft fracture, and AO classification (n=40).

Parameters	N (%)
Mean age (years)	38.8±13.96
Gender	
Male	26 (65)
Female	14 (35)
Occupation	
Involving overhead activities	25 (62.5)
Athletes	8 (32.0)
Labourers	17 (68.0)
Not involving overhea activities	15 (37.5)
Entrepreneurs	8 (53.3)
Clerks	7 (46.7)
Side affected (Right/Left)	32 (80)/8 (20)
Mode of injury	
Road traffic accident	30 (75)
Fall from height	8 (20)
Assault	2 (5)
Location of humerus shaft fracture	
Middle third	24 (60)
Proximal third	10 (25)
Distal third	6 (15)
AO classification	
12-A1	8 (20)
12-A2	15 (37.5)
12-A3	12 (30)
12-B1	3 (7.5)
12-B2	2 (5)
12-C	0 (0)

It was found out that age, gender and side of injury did not have any effect on the rate of healing. Mean time to radiological union was 15.22±3.63 weeks in patients (9 patients) with at least one associated medical comorbidity (diabetes mellitus, hypertension, ischemic heart disease, etc) and mean time to radiological union was 13.32±1.47 weeks in patients (31 patients) without any associated medical comorbidity.

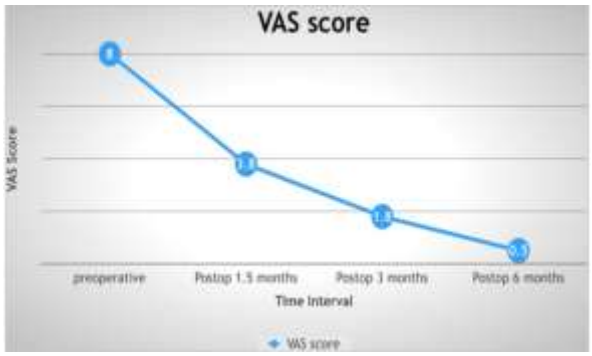

Figure 7: Mean VAS scores at different time intervals.

Statistical analysis for significance was done using an independent t-test and it was found that the difference was statistically significant among the study population ($p<0.05$). Out of 40 patients, 4 (10%) patients had complications. Two patients who were known cases of diabetes mellitus and hypertension developed superficial wound infection that got healed with daily dressing and intravenous antibiotics over 2 weeks. One patient developed radial nerve palsy postoperatively that recovered completely in 6 weeks. One patient who was a known case of hypertension and diabetes mellitus had delayed union that got completely united in 1 year without any need of re-operation.

Table 2: Distribution of patients according to Mayo elbow performance score at different time intervals

Time interval	1.5 months	3 months	6 months
Poor (<60)	2	0	0
Fair (60-74)	18	2	0
Good (75-89)	20	16	1
Excellent (90-100)	0	22	39

DISCUSSION

Fractures of the humeral shaft have traditionally been regarded benign, with a high percentage of healing with conservative methods, using either a hanging arm cast or a functional brace. Sir John Charnley has said, "Humerus is possibly the easiest of the foremost long bones to manage by conservative means".[17] However, loss of reduction in the plaster cast invariably leads to malunion. Hence, now with better implant design and surgical method, operative treatment of humeral diaphyseal fractures is preferred over conservative management, the advantages of operative management being early mobilization and patient comfort. Plating provides satisfactory results and is the preferred method of fixation of a humeral fracture.

Table 3: Comparison of functional and radiological outcomes of various studies.

Study	Operative technique / study aim	N	Mean Operative time (minutes)	Time to radiological union	Outcome and follow up	Remarks
Present Study	MIPO	40	79	13.75	At 6 months Mean DASH-5.04, Mean MEPS: 96.5, Complication Rate: 10%	High rate of union, excellent functional recovery and patient satisfaction.
Sanjeevaiah et al.[24]	MIPO	42	52	Mean of 14 weeks	Blood loss 84 ml	MIPO technique is safe, doesnot require special tools and implants.
Zogaib et al.[28]	MIPO	22	-	Mean: 2.7 months	DASH score ranged from 0 to 12.5 (mean 5.45)	MIPO technique is easy, safe and effective for the treatment of fractures of humeral shaft.
Mahajan et al.[29]	MIPO in Patients Predominantly Involved in Overhead Activities	48	95	45 days	Mean MEPS: 95.94±6.74, mean DASH score:1.56 ±3.15, Compli-cation rate 11%	ABP yields high rates of union, excellent functional recovery, minimal biological disruption and better cosmesis.
Shetty et al.30	MIPO	32	91.5 (range: 70-120)	Mean: 12.9 weeks (range: 10-20 weeks).	-	MIPO of the humerus gives good functional and cosmetic results.
Zhiquan et al.[10]	MIPO vs. COP	33	MIPO-92.35±57.68 and COP-103.12±31.08	MIPO-15.29±4.01 weeks and COP-21.25±13.67 weeks	-	MIPO advantages: Reduced incidence of iatrogenic radial nerve palsies, accelerated fracture union and similar functional outcome
Kim et al.[31]	COP vs MIPO	68	COP-116, MIPO-105	COP-mean 15.8 weeks, MIPO-mean 14.6 weeks	No complications in MIPO group	Both MIPO and COP has high overall rate of union and excellent functional outcomes.
An et al.[19]	COP vs. MIPO	40		MIPO- 17.06 (12-32) weeks, COP-16.11 (8-58) weeks	The MEPS in these two groups: MIPO-99.44 (90-100), COP- 99.74 (95-100) points	MIPO technique has advantages to not expose the radial nerve and to decrease the occurrence of iatrogenic radial nerve palsies.
Oh et al.[21]	COP vs. MIPO	59	MIPO (110), ORPO (169 min)	MIPO-mean 17.3 weeks, COP-16.7 weeks	Difference of union rates and union times was not significant.	MIPO can achieve comparable radiological and functional results while reducing the operative time and perioperative complications
Niall et al.[8]	COP	49		Nean time to union of 9 week	union rate of 96% at 14 weeks	ORIF with plating is the treatment of choice for non-pathological humeral shaft fractures.
McCormack et al.[7]	IMN vs COP	44	-	-	IMN can lead to problems with shoulder ROM probably because of damage to the rotator cuff.	Fixation by IMN is technically more demanding and has a higher rate of complications.

The main advantage of compression plate fixation for humeral diaphysis fractures is that it is a very rigid stabilization technique. Conventional open plating (COP) has the advantage of anatomical reduction but also has a variety of disadvantages, including potential injury to the radial nerve, the risk of infection and nonunion caused by extensive soft tissue stripping. Disruption of the periosteal blood supply and poor cosmetic scarring also add to the list of disadvantages. Intramedullary nailing is minimally invasive and preserves the fracture hematoma but has the disadvantage of postoperative rotator cuff impingement and a lower success rate. Our technique of AHB with MIPO technique combines the advantages and avoids the complications concerned with the above mentioned methods. Several authors have reported that MIPO of humeral diaphyseal fractures is an effective and safe method.[11,12,18] It is minimally invasive, cosmetic friendly and causes minimal manipulation of vital structures. This technique has the benefits of fewer soft tissue dissection and escapes the need to expose the radial nerve; thus, minimizing the risk of iatrogenic palsies. In the present study, we have evaluated the functional and radiological outcome of internal fixation of diaphyseal fractures of humerus operated by anterior bridge plating with the MIPO technique. The results of our study and various other similar studies are summarised in (Table 3). In our study, humerus shaft fractures were more common in males as compared to females. There was a bimodal age distribution and road traffic accident was the most common mode of injury. The middle third humerus shaft was the most common location of the fracture. These findings are consistent with the previous studies.[1-4]

The minimum operative time was 60 minutes and the maximum was 120 minutes with a mean operative time of 79 minutes. The operative time range of 52 to 110 mins for MIPO has been described in previous similar studies.[19-23] This parameter primarily depends on the technique used and the skill of the surgeon to that specific technique performed. MIPO has small incisions and is relatively safer with no extensive soft tissue and minimal blood loss compared to COP. In the study by Sanjeevaiah et al the mean blood loss was 85 ml for the MIPO group.[24] In the study by Lu et al mean blood loss for the ORIF group was 278.33 ml.[23] In our study, minimum intraoperative blood loss was 120 ml and a maximum blood loss was 210 ml with a mean blood loss of 147 ml, which is an acceptable surgical blood loss and significantly lesser than the blood loss in COP. The functional outcome was assessed using DASH score, MEPS, VAS scores and shoulder range of motion. At 6 months follow up, the mean DASH score was 5.04 and the mean MEPS was 96.5. Compared to the normal opposite side used as a reference, most patients recovered their original ROM at 6 months. The functional outcome achieved in our study is comparable to the functional outcome in other similar studies on this topic.[19-22,25-27] In our study, the fracture healed in all patients with a mean time to radiological union of 13.75 weeks with only one case of a delayed union at 24 weeks. Statistical analysis was also performed to see the effect of age, gender, side of injury and associated comorbidities on the rate of healing (time taken for radiological union). It was found that age, gender and side of injury did not have any effect on the rate of healing. However, the time taken for the radiological union was longer in patients with at least one associated medical comorbidity (diabetes, hypertension, IHD, etc.) as compared to those without any associated medical comorbidities.

The complication rate in our study was 10%. One patient had radial nerve palsy (2.5%), one patient had delayed union (2.5%) and 2 patients had a superficial wound infection (5%). There was no incidence of any shoulder pain, shoulder stiffness, elbow stiffness, implant failure or nonunion. Zhiquan An et al established a bigger incidence of iatrogenic radial nerve palsy in the ORIF with plating group than MIPO group and concluded that as compared to COP, MIPO is advantageous in terms of the decreased incidence of iatrogenic radial nerve palsies and faster fracture union.[19] Even in simple fractures, MIPO showed an excellent union rate, which may have potentially resulted from the biological superiority with less stripping and the preservation of vascularity.

Limitations

The limitations of our study include it being a single centre, open study with no comparative arm. The encouraging results of this study need to be further validated by doing a randomised controlled trial in the future, ensuring validity and reproducibility of these results. Furthermore, we also plan to study outcomes of MIPO plating in complex fracture patterns.

CONCLUSION

In conclusion, ABP with MIPO technique for humerus diaphyseal fractures has advantages of reducing the operative time and perioperative complications. It is a safe and effective treatment modality yielding high rates of union, excellent functional recovery, minimal biological disruption, better cosmesis and superior patient satisfaction, thereby making it a cost-effective option. Therefore, we recommend that anterior bridge plating with minimally invasive plate osteosynthesis should be considered as an alternative treatment option in patients with humerus diaphyseal fractures.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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