Minimally invasive plate osteosynthesis for humerus diaphyseal fractures

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ABSTRACT

Background: Minimally invasive plate osteosynthesis (MIPO) technique is reported as a satisfactory procedure for the treatment of humeral shaft fractures by the anterior approach by several authors. However, none of the published reports had a significant follow-up nor have they reported patient outcomes. We evaluated the clinical, radiographic, and functional outcome over a minimum follow-up of 2 years using the same MIPO technique to humeral shaft fracture.

Materials and Methods: 32 adult patients with diaphyseal fractures of the humerus treated with MIPO between June 2007 and October 2008 were included in the study. Patients with metabolic bone disease, polytrauma, and Gustilo and Anderson type 3 open fractures with injury severity score >16 were excluded from the study. All cases were treated with closed indirect reduction and locking plate fixation using the MIPO technique. The surgery time, radiation exposure, and time for union was noted. The shoulder and elbow function was assessed using the UCLA shoulder and Mayo elbow performance scores, respectively.

Results: Of the 32 patients in the study, 19 were males and 13 were females. The mean age was 39 years (range: 22–70 years). Twenty-seven of the thirty-two patients (84.3%) had the dominant side fractured. We had eight cases of C2 type; five cases of C1 and A2 type; four cases of B2 type; three cases each of B3, B1, and A1 type; and one case of A3 type of fracture. The mean surgical time was 91.5 minutes (range: 70–120 minutes) and mean radiation exposure was 160.3 seconds (range: 100–220 seconds). The mean radiological fracture union time was 12.9 weeks (range: 10–20 weeks). Shoulder function was excellent in 27 cases (84.3%) and good in remaining 5 cases (15.6%) on the UCLA score. Elbow function was excellent in 26 cases (81.2%), good in 5 cases (15.6%), and fair in 1 case (3.1%) who had an associated olecranon fracture that was fixed by tension band wire in the same sitting.

Conclusion: MIPO of the humerus gives good functional and cosmetic results and should be considered one of the management options in the treatment of humeral diaphyseal fractures.

Key words: Minimally invasive plate osteosynthesis, diaphyseal fracture, humerus

INTRODUCTION

The conflict between the need for absolute anatomical reduction and, at the same time, the desire for soft tissue preservation has been going on for a long time. Not just solid healing, but immediate and continuous function of the limb is now a leading goal. However, precise reduction and absolute stable fixation has its biological price.[1] There has been evidence to show the superiority of biological fixation over a stable mechanical fixation.[2] This led to the development and improvement in the techniques of biological fixation for fractures and also the development of stabilization systems that help in achieving a biological fixation.[3,4]

Treatment of diaphyseal humeral fracture has evolved from the conservative cast and brace[5,6] to internal fixation with plate and screws[7] and intramedullary nailing;[7] each of these techniques has its own complications[7-10] and there is no definite data that shows the superiority of one over the other. The minimally invasive plate osteosyntesis (MIPO) of humerus shaft fracture has shown promising results recently.[11-14]

We evaluated the clinical, radiographic, and functional outcomes over a minimum follow-up of 2 years using the same MIPO technique to humeral shaft fracture.

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MATERIALS AND METHODS

32 diaphyseal fractures of humerus were treated with MIPO technique, in a prospective study between June 2007 and October 2008 at our centre. The cases were followed up for a minimum period of 2 years. The fractures were classified as per the AO-ASIF trauma classification.[15] These fractures were fixed with 4.5-mm narrow locking compression plate (LCP) (Synthes India Pvt. Ltd.,Gurgaon.). All patients were operated by the same surgeon (AK). This study was approved by the Institutional Ethical Committee.

The inclusion criterion was displaced diaphyseal fracture of humerus between 21 and 75 years and who consented to participate in the study. The operative procedure was performed within 5 days of the injury. Exclusion criteria included coexisting medical disorders (such as a malignant tumor and hyperparathyroidism), vascular insufficiency of the upper limb, polytrauma patients with an injury severity score[16] of >16 points, patients with known alcohol or drug dependency, and those participating in other clinical trials.

A routine preoperative clinical evaluation of the affected arm was carried out noting the swelling, abrasions, contusion, puckering of skin and distal neurovascular deficit, including the status of the radial nerve. Standardized anteroposterior (AP) and lateral (Lat) radiographs of the humerus, with the patient supine, arm abducted to 30° at the shoulder, elbow extended, and forearm supinated, were taken [Figure 1]. These radiographs were also used to template the appropriate length of implant and planning the number and position of screws and their order of insertion.

Operative procedure

The procedure was done in the supine position under general anesthesia, with the arm abducted to 90° and the forearm in full supination. The image intensifier was positioned on the same side of the operating table as the arm to be operated. A 3-cm incision between the proximal biceps and the medial border of deltoid, 6 cm distal to the anterior part of the acromion process was made. Dissection was carried to the humerus. Distally, a 3-cm incision was made along the lateral border of the biceps, approximately 5 cm proximal to the flexion crease. The site of incision was confirmed under the image intensifier and altered, if necessary, to be as far as away as possible from the fracture site. The biceps was retracted medially to expose the musculocutaneous nerve, which overlies the brachialis muscle. The brachialis muscle was split and the musculocutaneous nerve retracted medially, and the radial nerve was protected by the lateral half of the brachialis muscle.

A sub-brachialis, extra-periosteal tunnel was created by passing an artery forceps, used as a tunneling instrument, deep to the brachialis muscle from the distal to the proximal incision. Care was taken to pass the tunneling instruments anteriorly or anteromedially to avoid the chances of injury to the radial nerve. After creating the tunnel, the LCP of the template length was passed through the tunnel. The plate position and reduction was visualized on the image intensifier. Manual traction was applied to restore length and correct varus/valgus angulation and rotation. The plate was temporally fixed to the bone with 2.0-mm K-wires. 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, the fixation was completed with a minimum of two screws in both fragments. Care was taken to pass the tunneling instruments anteriorly or anteromedially to avoid the chances of injury to the radial nerve. Deciding the appropriate amount of force to be used for manual traction to achieve adaptation of the fragments was not easy at first; this was something we had to slowly master as the study progressed. The rotational deformity was minimized using the 'cortical step sign' and the 'diameter difference sign' described by Krettek.[17] None of the patients required bone grafting or bone substitute at primary surgery. The operative time (defined as the time, from the skin incision to wound closure) and duration of radiation exposure (in seconds) was recorded though the doses were not calculated.

Postoperatively, arm was immobilized in a neck-wrist sling. The standard protocol of mobilization exercises were started from day 2, as far as the patient's pain permitted. The time to union, the need for secondary procedure, and complications were noted [Figures 1 and 2].

The patients were followed up and reviewed by an independent surgeon (MSS), monthly for the first 6 months, then once every 3 months till 1 year and,

Figure 1A: (a) Preoperative X-ray of arm (anteroposterior and lateral view) showing fracture shaft of humerus (AO 1.2.A.2); follow-up X-ray (b) anteroposterior view and (c) lateral view at 6 months followup showing good union

Figure 1B: Postoperative clinical photographs of same patient showing (a) elbow flexion (b) elbow extension with healed surgical scars (c) shoulder abduction (d) shoulder internal rotation

Figure 2A: (a) Intraoperative image with two incisions and the template plate; (b) Intraoperative fluoroscopy image showing fracture shaft of humerus (AO 1.2.C.1); (c) Intraoperative fluoroscopy image showing manipulation technique to achieve reduction
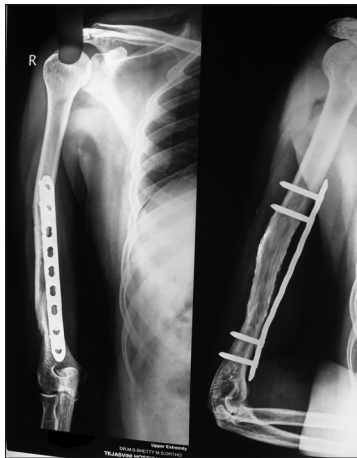

Figure 2B: One-year follow-up X-ray of a patient showing good union but a varus alignment of 5°

Figure 2C: Clinical photograph showing in spite of the varus alignment, the patient has a good range of motion at the elbow

union or for any potential loss of fracture reduction. Union was defined as the absence of pain and the presence of bridging callus in three of the four cortices seen on the anteroposterior and lateral radiographs.

RESULTS

The mean age was 39 years (range 22–70 years). Nineteen (59.3%) were males and 13 (40.6%) females. Twenty-seven cases (84.3%) had injury in their dominant arm. We had eight cases of C2 type; five cases of C1 and A2 type; four cases of B2 type; three cases of B3, B1, and A1 type; and one case of A3 type of fractures. Road traffic accident was the most common mode of injury, being reported by 26 (81.2%) cases; the rest sustained injury following fall on an outstretched hand (four cases) and direct trauma (two cases).

after that, once every 6 months till 2 years. The patients' shoulder and elbow function were assessed using the UCLA shoulder score[18] and the Mayo elbow performance score (MEPS).[19] The UCLA shoulder score was graded into excellent (34–35 points), good (29–33 points), fair (21–28 points), and poor (0–20 points).[20] Function of elbow was graded on the basis of MEPS into excellent (≥90 points), good (75–89 points), fair (60–74 points), or poor (<60 points).

Radiographic measurements were performed on standard anteroposterior and lateral radiographs to assess fracture

The mean surgical time was 91.5 minutes (range: 70–120 minutes) and the mean radiation exposure was for 160.3 seconds (range: 100–220 seconds). We had to use lag screw through a stab incision in two cases where the long oblique pattern of the fracture demanded screw fixation to maintain reduction. The mean follow-up of our cases was 31 months (range: 24–40 months). Union was observed at a mean period of 12.9 weeks (range: 10–20 weeks). In two cases, where there was scanty callus at 12 weeks, we infiltrated bone marrow taken from the patient's iliac crest at the fracture site, and these patients showed good union at 20 weeks. We accepted up to 5° of varus/valgus angulation intraoperatively and on following these patients up, in 25 (78.1%) of the cases the angulation had remodeled to correct alignment. In the remaining seven cases, four had 3° of varus, two had 3° valgus, and one case had 5° varus angulation at the end of 2 years; however, this did not affect their functional outcome [Table 1].

On determining the functional outcome, 27 cases (84.3%) had excellent outcome and 5 cases (15.6%) had good shoulder function on the UCLA score. With regard to elbow function, 26 cases (81.2%) had excellent outcome, 5 cases (15.6%) had good outcome, and 1 case (3.1%) (who also had an associated olecrenon fracture that was fixed with tension band wiring) had fair outcome.

We had two cases with postoperative sensory blunting over the lateral half of the forearm due to injury to musculocutaneous nerve, but this recovered within 3 months of surgery without any intervention.

DISCUSSION

Hunter (1728–1793) supported Albrecht Haller's (1708–1777) theory that bone was deposited in response to injury from the vascularity around the reparative zone.[21] This early understanding of the importance of the vascular network in fracture repair is one of the cornerstones of minimally invasive fracture surgery. Minimally invasive methods for

Table 1: Clinical details of patients

Age (in years)/sex	Type of fracture	Sx time (in minutes)	Rad time (in seconds)	F/U	Union (in weeks)	Active shoulder abd/flex (in degrees)	Active elbow flex/ext (in degrees)	UCLA	MEPS	Angulatn
56/M	A1	120	210	42	10	120/170	140/0	35	100	-
28/M	C2	90	220	42	12	120/165	130/5	35	95	-
32/F	A2	90	200	36	12	110/165	130/5	34	95	3° varus
46/M	B1	100	180	36	14	120/170	120/0	35	85	-
34/M	C2	120	210	30	20	110/160	140/5	34	95	3° varus
70/F	B3	110	220	36	10	120/165	130/0	34	90	-
22/M	A2	100	190	30	14	110/150	140/5	35	100	-
43/F	B2	120	180	36	12	120/165	130/5	34	95	3° valgus
36/M	C2	90	160	36	14	90/150	120/0	33	85	-
26/F	B2	110	170	36	16	120/150	130/5	35	100	-
30/M	C1	100	150	30	14	110/165	140/5	35	95	5° varus
27/M	A1	90	180	30	10	120/170	140/5	34	100	-
33/F	A2	90	130	30	12	110/170	120/0	32	80	-
56/M	C1	100	190	27	12	110/160	130/0	35	100	-
41/M	B3	80	140	27	14	110/165	140/0	34	100	-
49/F	C2	90	160	30	14	110/165	130/0	35	100	3° valgus
26/F	C1	100	140	30	16	100/165	130/5	35	100	-
29/M	B3	90	150	30	12	90/150	140/0	31	100	-
23/F	C2	90	180	36	10	110/160	100/0	34	70	3° varus
34/M	C1	80	180	30	10	120/165	140/0	34	95	-
39/F	B1	75	160	30	12	90/150	130/0	31	95	-
36/M	C2	85	140	36	10	100/170	130/5	34	100	-
49/M	C1	80	150	30	20	110/165	140/0	35	95	-
55/F	A1	90	150	30	14	120/150	110/0	34	80	-
63/M	B2	80	160	30	16	100/160	130/5	35	95	3° varus
42/M	C2	75	140	30	12	90/150	140/5	33	100	-
56/F	B3	90	120	24	14	110/160	130/0	34	95	-
33/M	A2	100	100	24	10	110/160	140/5	35	100	-
38/M	B2	80	110	27	12	120/170	130/0	35	100	-
48/F	C2	70	140	24	10	110/160	120/0	34	80	-
26/M	B1	75	120	24	14	120/170	140/5	32	90	-
30/F	A2	70	100	24	12	110/165	140/0	34	95	-

Sx time - Surgical time, Rad time - Radiation time, F/U - Follow-up duration in weeks, abd - Abduction, flex - Flexion, ext - Extension, Angulatn - Angulation

fracture treatment continue to evolve and MIPO techniques are becoming increasingly popular. Krettek and Tscherne first reported MIPO for supracondylar femoral fractures in 1996.[22] Long plates bridging an extensive zone of fragmentation, with only short fixation on either end of the bone, will withstand considerable deformation forces. As bending stresses are distributed over a long segment of the plate, the stress per unit area is correspondingly low, which reduces the risk of plate failure. The entire construct becomes elastic and even simple fractures can be successfully bridged.[23,24]

MIPO for humeral shaft fractures has been reported earlier[11-13,25] with fair results. MIPO scores over open reduction and plate fixation of humerus fractures by decreasing the surgical trauma to the soft tissue and maintaining the periosteal circulation. Application of the plate on the bone by an open technique interferes with the local vascularization, leading to osteonecrosis beneath the implant, which can cause delayed healing or non-healing (the reported rate of nonunion being 5.8%).[26] The primary bone healing without callus formation is not very strong and there exists a real risk for refracture after removal of the implant[27,28] in the open technique. The union time for fractures in our series was 12.9 weeks (range: 10–20 weeks). This duration for bone union is better than that reported by Zhiquan *et al.*[12] for their series of MIPO humeral shaft fractures and is comparable with the reported time duration of 9–12 weeks for open reduction and plating procedures.[25,29] Union was delayed in a case of 1.2.C2 and 1.2.C1 (comminuted) fractures. Probable reasons are that the adaptation of all fragments was difficult by the indirect reduction technique or that the initial soft tissue injury might have compromised the vascularity at the fracture site. These cases responded well to bone marrow infiltration and showed union within 4–8 weeks of infiltration. Another advantage of secondary bone healing is that the potential to remodel is much higher as compared to primary bone healing. The mean surgical time with MIPO was 91.5 minutes (range: 70–120 minutes) which, in our experience, is little more than with open reduction and internal fixation of humeral shaft fracture. The duration of radiation exposure in our series was 160.3 seconds (range: 100–220 seconds), our initial cases taking a longer duration due to our learning curve. The duration of radiation documented with intramedullary nailing was 140 seconds,[10] which is close to our values. An added advantage with MIPO is that it is devoid of the entry-point problems of intramedullary nailing such as rotator cuff impingement.[8,9]

The course of the radial nerve is well described in literature[30] and texts.[31] According to Apivatthakakul *et al.*[11] when a plate is placed on the anterior side of the humeral shaft,

the mean distance from the closest part of the plate to the radial nerve is 3.2 mm. Apivatthakakul *et al.*[11] also pointed out that when the forearm was pronated, the radial nerve was noted to move medially closer to the distal end of the plate and was at risk of iatrogenic injury. For this reason, the supination position of the forearm should be maintained during the operation. In another study,[14] postoperative ultrasonographic measurement of the distance between the radial nerve and the material implanted using the MIPO technique was calculated and the authors reported that the point of greatest proximity of the radial nerve and the implant in a humeral shaft fracture was between 1.6 and 19.6 mm (mean: 9.3 mm) and in distal-third fractures it was between 1.0 and 8.1 mm (mean: 4.0 mm). The brachialis muscle covers the humerus anteriorly and protects the radial nerve from injury when a plate is inserted submuscularly through two small incisions on the anterior side of the arm away from fracture site, supporting our findings of no radial nerve palsies with the technique used in our study.

Apivatthakakul *et al.*[32] have described the danger zone for the radial nerve with respect to percutaneous locking screw placement. It lies 36.35%–59.2% of the humeral length away from the lateral epicondyle, i.e., predominantly in the middle third of the humeral shaft. We used percutaneous lag screw in two cases where, in the long oblique pattern of the fracture, the application of a precontoured locking plate with locking screws alone was contributing to distraction and angulation at the fracture site. In apprehension of delayed union or nonunion, a percutaneous lag screw was applied despite associated risks. These two cases were part of our first eight cases; after this, as the author grew in experience, the fracture apposition was achieved by manipulation and maintained with bridge plating only, avoiding the need for percutaneous lag screw.

The danger zone for the musculocutaneous nerve lies, on average, 18.37%–42.67% of the humeral length from the lateral epicondyle.[32] This gives us only the distal one-fifth of the humeral length, which is insufficient for application of the minimum of two locking screws. In our study we had two cases of neuropraxia of the musculocutaneous nerve, just above the elbow where it pierces the deep fascia before continuing as the lateral antebrachial cutaneous nerve. This injury was attributed to the excessive traction applied at the small distal incision that we had made with the intention of avoiding opening the fracture site. This nerve is best protected by retracting it under vision after medially retracting the biceps, which is not always possible in the restricted working space available at the distal humerus.

The functional outcomes assessed by UCLA shoulder score

and MEPS systems in the affected shoulders and elbows in the two groups were also consistent with the literature.[26,33,34] Excellent shoulder scores in 27 (84.3%) of the cases in this series could be because of the level of fracture (the shaft and lower one-third fractures). The remaining cases had good outcome. The elbow function gauged by the MEPS showed excellent outcome in 26 cases (81.2%), good outcome in five cases (15.6%), and a fair result in one case (3.1%) (who had an associated fracture in the olecranon). Most importantly, this function was achieved by 6 months postoperatively and the patients maintained their function up to their last follow-up. Thus, our case series shows that optimum arm function is achieved at an early date following MIPO of humerus shaft fractures. MIPO is also associated with less operative scars and better cosmesis. This contributes to the high patient satisfaction with this novel treatment.

The limitation of the study was that we did not have a control group for comparison or another group treated with some other technique of humeral diaphyseal fracture fixation. The evaluation of the standardized radiographs was done by a different surgeon in an attempt to minimize bias. A larger multicenter study with control groups will help us to arrive at a definitive conclusion.

To conclude, MIPO is a complex technique, requiring a relatively long learning curve. However, the results are good and reproducible and there are few risks. The plate placement and indirect reduction requires experience.

ACKNOWLEDGMENT

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