Minimally Invasive Plate Osteosynthesis in Humeral Shaft Fractures via Anterior Approach

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ABSTRACT

BACKGROUND

This case series was conducted to evaluate the intraoperative and post-operative outcomes of fracture shaft of humerus managed by indirect reduction and minimally invasive plate osteosynthesis (MIPO) via anterior approach.

METHODS

In this case series 26 diaphyseal fractures of the humerus treated with MIPO, between June 2017 and February 2020 at a tertiary care hospital were included. All the patients were followed up for a minimum period of 2 years postoperatively. The objective was to evaluate these cases clinically for shoulder and elbow range of motion and document any complications. Other parameters such as duration of surgery and radiological time for fracture union were also documented.

RESULTS

The mean duration for surgery was 86.5 minutes. The University of California Los Angeles (UCLA) shoulder scoring system rated 18 patients (69.2 %) as excellent outcome, 07 patients (26.9 %) as good outcome, and 1 patient (3.8 %) as fair outcome. The MAYO Elbow Performance Scoring system rated 20 patients (76.9 %) as excellent outcome and 06 patients (23.1 %) as good outcome. About 96 % of patients achieved fracture union by the end of 16 weeks post-operatively (mean 13.4 weeks). No complications related to infection, iatrogenic radial nerve injury or implant failure were noted in the study. 4 cases had varus angulation deformity but did not affect shoulder or elbow function.

CONCLUSIONS

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

KEYWORDS

Fracture Fixation, Fracture Healing, Humeral Fractures, Radial Nerve, Shoulder

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BACKGROUND

Diaphyseal fractures of the humerus are commonly encountered in orthopaedic emergencies accounting for 1 - 3 % of all fractures, 5 - 10 % of all long bone fractures and 20 % of all humeral fractures.[1]

Conservative treatment is still indicated in most of these fractures, but it has its own limitations.[2] While the indications of operative intervention include failure of closed reduction, neurovascular compromises, intra-articular extension, floating elbow, open fractures, bilateral humeral shaft fractures, patients with polytrauma and pathological fractures.

Open reduction and compression plate fixation are currently a widely accepted operative method, with a high union rate and early active mobilisation.[3,4] However, compression plate fixation requires extensive surgical dissection, is technically demanding and has a risk of neurovascular damage.

Intramedullary nailing is a good option with percutaneous incision, thus, having less soft tissue damage and biomechanically more stable.[5] Nevertheless, depending on the entry site of the nail, shoulder and elbow function may be affected.

The conflict between the need for soft tissue preservation and at the same time the desire for absolute anatomical reduction has been going on for a long time. Along with soft tissue healing, one of the leading goals is also the early recovery of the function of the limb. This disadvantage of rigid fixation by plating led to a shift towards the concept of 'biological plate osteosynthesis', where secondary fracture healing occurs.[6,7]

Minimally invasive plate osteosynthesis, is a technique based on relative stability, where the plate is inserted through a percutaneous approach, by two separate incisions, offering the advantages of less soft tissue disruption and blood loss, also while preserving the fracture haematoma and blood supply to the bony fragments.[8] MIPO can be done by both lateral and anterior approaches to the surface of the humerus, however, anterior approach is recommended as it carries the least risk of injury to the nearby neurovascular structures.[9]

This study aimed to evaluate the duration of surgery, time of union, and functional outcomes in the shoulder and elbow joints after application of minimally invasive bridging plates for the management of diaphyseal humeral fractures via an anterior approach.

METHODS

This is a case series conducted in our hospital from June 2017 to February 2020. A total number of 26 patients with diaphyseal fractures of the humerus were included in this study, aged between 20 years to 65 years, closed and first-degree open fractures and who consented to the study. Criteria of exclusion were patients with second-degree or third-degree open fractures, those with high-velocity gunshot injuries, or with pathological fractures, vascular insufficiency of the upper limb, nerve injury of the injured limb, coexisting medical disorders, polytrauma patients with an injury severity score of > 16 points and patients with known alcohol or drug dependency. Fractures were classified according to the AO classification of humerus shaft fractures. Routine preoperative clinical and radiological evaluation was done, which included radiographs in anteroposterior (AP) and lateral (LAT) views of the humerus. All the patients were operated on by the same surgeon within 7 days of the injury. The implant used to fix these fractures was a 4.5 mm narrow locking compression plate.

Surgery was performed on a radiolucent operating table with the patient in a 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 - 5 cms proximal to the elbow crease [Figure 1].

Biceps is retracted medially to expose the brachialis with the musculocutaneous nerve lying on the muscle. By blunt dissection, the brachialis muscle is split and retracted with the medial part cushioning the musculocutaneous nerve and the lateral part cushioning the radial nerve. A long eight to twelve-hole narrow locking compression plate (LCP) was then inserted below the brachialis extraperiosteally using a tunnelling instrument 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, correct the varus and valgus angulation and rotation. The rotational deformity was minimised using the 'cortical step sign' and the 'diameter difference sign' described by Krettek.[10] Three to four screws were inserted in each fracture fragment.

Incisions were then sutured in layers using interrupted sutures. No patients required the use of bone grafting or bone substitute in the primary surgery. Radial nerve was not explored in any of the cases. Postoperatively immobilisation was achieved with a humeral brace, which was worn full time by the patient and discontinued after 6 weeks post-surgery. Active non weight bearing exercises of the elbow and pendular exercises of the shoulder were allowed since, first post-operative day. Assisted shoulder exercises were started after 3 weeks and gradual weight bearing exercises for the shoulder were added after 6 weeks post operatively. Stitch removal was done after two weeks. Post-operative follow-up visits for clinical assessments were performed at six weeks, three months, six months, 1 year and yearly thereafter for two years.

At 1-year post-operative follow up, the patients' shoulder and elbow function were assessed using the UCLA shoulder score[11] and the Mayo Elbow Performance Score (MEPS).[12] The UCLA shoulder score was graded into excellent (34 – 35 points), good (29 – 33 points), fair (21 – 28 points), and poor (0 – 20 points). Function of the elbow was graded based on MEPS into excellent (≥ 90 points), good (75 – 89 points), fair (60 – 74 points), or poor (< 60 points).

Radiologically, anteroposterior and lateral radiographs were assessed for signs of union by the presence of bridging

callus in three out of the four cortices, and any potential loss of fracture reduction. Union was defined as the presence of bridging callus along with the absence of pain [Figure 2].

Relevant statistical methods were applied to data recorded in this case series, and the various data subsets were compared to external comparison groups wherever necessary.

RESULTS

Out of 26 patients, twenty (76.9 %) were males and six (23.1 %) were females. In our study, the age group ranged from 20 to 65 years, with the mean age of 39.5 years. The fracture was more common between the age group 30 - 50 years, which accounted for more than 50 % of the cases. 18 patients were affected on the right side. Road traffic accident (RTA) was the most common mode of injury (17 patients, 65.3 %), followed by fall (either at surface level or from a height) and direct trauma. According to the AO classification six cases were A1, four cases were A2, five cases were A3, two cases were B1, four cases were B2, zero cases were B3, three cases were C1, two cases were C2, and zero cases were C3 type.

The duration of surgery depended upon the type of fracture, with a mean surgical time of 80.5 minutes overall. [Table 1].

The operative time was longer in more comminuted fractures. [Table 2].

Fracture union was achieved in all the patients by the end of 20 weeks (mean 13.42 weeks). About 96 % of patients achieved union till the end of 16 weeks and 60 % of cases achieved union within 14 weeks postoperatively. Fracture union was particularly delayed in C1 and C2 fractures in our study.

The UCLA shoulder assessment score at 1-year post-operative follow up classified 18 patients as excellent (34 – 35 points), 7 patients as good (29 – 33 points), 1 patient as fair (21 – 28 points), and none had poor (0 – 20 points) outcome.

According to the Mayo Elbow Performance Scoring system at 1-year post-operative follow up 20 patients (76.9 %) had an excellent result, 6 patients (23.1 %) had a good result and none had a fair or poor result.

Shoulder and elbow movements showed no limitation when compared to the normal side. No infection was reported in any of the cases. No complications such as implant failure, screw loosening or screw breakage were noted. None of the patients had iatrogenic radial nerve palsy. Varus angulation was seen in 3 cases, present across different fracture patterns. While 1 case with C1 pattern of fracture had a valgus angulation of 3^0. However, all malalignments were less than 10^0 and did not affect the function at the shoulder or elbow joint.

Parameter	Range	Mean
Age (in years)	20 - 62	39.5
Surgery time (in minutes)	66 - 118	80.5
Union (in weeks)	11 - 20	13.4
UCLA score (points)	27 - 35	33.5
MEPS (points)	80 - 100	94

Table 1. Statistics for the Study

Type of Fracture	No. of Patients	Mean Surgery Time (minutes)	Mean Time to Union (in weeks)	Mean UCLA Score	Mean MEPS
A1	6	72.6	12.3	34.2	95
A2	4	74.5	12.5	34.8	100
A3	5	83	13.4	34.4	94
B1	2	75	11.5	33	97.5
B2	4	79.2	14	32.7	91.2
C1	3	85.3	14.3	32.3	91.7
C2	2	111	18	31	85

Table 2. Fracture Distribution

Figure 1. Incision and Plate Insertion

Figure 2a. Preoperative X-Ray

Figure 2b. Immediate Post-Operative X-Ray

Figure 2c.
Post-Operative X-Ray after a Month

Figure 2d.
Post-Operative X-Ray after a Year

DISCUSSION

The main treatment for fracture humerus is still non-surgical (5 - 30) but it often leads to non-union, unsatisfactory clinical outcomes and limited range of motion.[13]

In 1996, Minimally Invasive Percutaneous Osteosynthesis (MIPO) was demonstrated for the first time by Krettek and Tscherne in supracondylar femur fractures.[10]

The treatment of choice, when operative intervention is needed in humeral diaphyseal fractures is Open Reduction and Plate Osteosynthesis (ORPO).[3,4,14] ORPO leads to compression and 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 stripping.[15] With plating, local vascularisation is hampered leading to osteonecrosis underneath the implant, which could cause delayed or non-union.[16] Primary bone healing seen in plating is weaker and it presents a real risk of re-fracture after implant removal.[17] The posterior approach with a longer incision also has an increased risk of iatrogenic radial nerve injury and infection.[18,19]

MIPO is a relatively flexible fixation as compression and full reduction of fracture fragments is usually not accomplished. So, secondary healing occurs by the formation of callus which is more effective and faster than primary healing.[20] Secondary bone healing is considered a more biological form of fracture fixation, having another advantage that the potential of remodelling is much higher in contrast to primary bone healing.[21] In MIPO, a long plate is used to distribute the bending stresses over a long segment of the plate and reducing the stress per unit area, correspondingly reducing the rate of plate failure.[22,23]

Our mean duration of surgery was 80.5 minutes (range 65 - 120 minutes) which is in our experience a little less than that for open reduction and internal fixation (ORIF) of fracture humerus shaft and in concurrence with previous literature.[9,13,22]

The mean time for fracture union, assessed radiologically was 13.4 weeks which is comparable to other similar studies described further. Union time was particularly longer (16 weeks and 20 weeks) in 2 patients with C2 fractures which could be attributed to difficult or less than adequate reduction of all fracture fragments by indirect reduction methods or to the initial soft tissue injury compromising the vascularity of the fracture site.

Apivatthakakul et al. pointed out when the plate is placed on the anterior side of the humeral shaft, the distance from the radial nerve to the closest part of the plate is 3.2 mm. During pronation, it was noted that the radial nerve moved closer to the distal part of the plate. So, to prevent the risk of iatrogenic radial nerve injury, the forearm is to be kept in full supination during the surgery. He also described the danger zone for the radial nerve, which lies 36. 35 % - 59.2 % of humeral length above the lateral condyle i.e., primarily in the middle third of the shaft of humerus.[19] The brachialis muscle also acts as a protection to the radial nerve when the plate is placed on the anterior surface beneath it. In our study, no cases were reported with iatrogenic radial nerve injury.

Intramedullary although being a minimally invasive procedure has its own limitations such as shoulder and elbow dysfunction and iatrogenic humeral shaft fractures.[14,9] MIPO leads to less functional impairment of the shoulder and risk of iatrogenic radial nerve injury in comparison to intramedullary nailing.[24] MIPO is to be preferred over intramedullary nailing in patients with smaller humeral canal diameter.[19]

Indirect reduction in MIPO may lead to malalignment, as seen in our study however, all the malalignments were less than 10^0, therefore shoulder and elbow functions seem to be preserved, due to the wide range of motion in these joints (9), which was in concurrence with other studies.[25,26]

UCLA shoulder score, assessing the functional outcome showed 18 patients (69.2 %) with excellent outcomes and 7 patients (26.9 %) with good outcomes, while the Mayo elbow score rated 20 patients (76.9 %) to have excellent outcomes, which is consistent with the existing literature.[16]

Esmailiejah et al. in a comparative group of 65 patients found better results in MIPO (32 patients) as compared to ORIF (33 patients) with regards to the rate of infection (0 and 6 % respectively), iatrogenic radial nerve palsy (3 % and 12 % respectively), while having a shorter time for union in the MIPO group.[9] An et al. also found a higher incidence of iatrogenic radial nerve injury in the ORIF group and a faster time for union in the MIPO group.[27] Oh et al. in a comparative study of 59 patients had similar functional

outcomes in two comparative groups but higher primary union rate in the MIPO group.[24,28] Kim et al. reported good functional outcomes without any iatrogenic radial nerve injury in the patients treated with MIPO.[29] None of the cases in our study reported iatrogenic radial nerve palsy while achieved a faster radiological time to fracture union.

It could be said that MIPO is preferred due to the advantage of having a limited skin incision thereby offers a better cosmetic appearance along with less risk of infection and iatrogenic radial nerve injury therefore, leading to better patient satisfaction.[30]

CONCLUSIONS

MIPO is a safe and effective method for the management of diaphyseal humerus fractures with reproducible results. MIPO technique has satisfactory functional outcomes, with early fracture healing, less risk of complications such as infection and iatrogenic radial nerve injury, along with a cosmetically acceptable scar. However, the limitations of this study are that it has no control group and a large multicentric study with a controlled group will be required to arrive at a definitive conclusion.

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