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CLINICAL RESULTS AND FUNCTIONAL OUTCOME OF HUMERAL SHAFT FRACTURES TREATED WITH MINIMALLY INVASIVE PLATE OSTEOSYNTHESIS TECHNIQUE

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Abstract

The pursuit of anatomical reduction in fracture fixation has been replaced by anatomic alignment and biologic fixation. Minimally invasive plate osteosynthesis (MIPO) is one such biological method.

The aim of this study was to evaluate the clinical results and functional outcome of humeral shaft fractures treated with MIPO technique.

A hospital based prospective serial follow-up study was conducted. We enrolled 30 patients with displaced humeral shaft fractures, which were fixed by the technique of closed reduction and MIPO. Patients were followed-up for a period of 6 months. Anatomic alignment was evaluated at visits. Functional evaluation was done by University of California & Los Angeles (UCLA) scoring for shoulder and Mayo Elbow Performance Score (MEPS) for elbow.

Mostly, 83.33% patients had anatomical alignment at 6 months. About 6.67% had less than 5° varus angulation, 10% had less than 5° valgus angulation. Five patients (16.67%) had radial nerve injury. Frequently, 63.33% patients had excellent UCLA scores at 6 months. Majority of the patients (93.33%) had excellent MEPS scores.

In conclusion, this study supports that MIPO is a decent method of treating humeral shaft fractures but it requires adequate imaging and surgical experience. Optimum arm function is achieved at an early date with better cosmoses. Suitable healing and low infection rates are obtained with MIPO. Risks of iatrogenic nerve injuries are low if appropriate surgical technique is used.

Key words: Humerus fracture, MIPO, Minimally invasive, Biological method.

Introduction

The timing and technique of intermediation are crucial in respecting the important role of soft tissue in bone healing; this saying is the basis on which minimally invasive surgery (MIS)”[1] has evolved as an alternative to the conventional approaches in orthopedic surgery and has gathered a great deal of attention. Damage to the tissue in the injury zone is the major factor for the occurrence of complications such as bone devitalization, infection, delayed union and nonunion.

For minimally invasive surgery in fracture care, the terms “minimally invasive osteosynthesis” (MIO) or “minimally invasive plate osteosynthesis” (MIPO) or “minimally invasive percutaneous plate osteosynthesis” (MIPPO)[2] are used. Access to the bone is through soft tissue windows (not only small skin incisions but also careful gentle handling of deep layers of soft tissues) with minimal trauma to the injured soft tissue and the bone.

The advantages of MIPO include faster bone healing, reduced infection rate, no need for bone graft, less post-operative pain and faster rehabilitation and last but not the least, more aesthetic result. These have superseded the disadvantages of MIPO like difficulties in indirect bone reduction and increased C-arm exposure. Minimally invasive plate osteosynthesis

(MIPO) has been widely applied to treat long bone shaft fractures in recent years because of its biological advantages and satisfactory clinical outcomes.

Various methods of treating humeral shaft fractures have continued to evolve, ranging from conservative methods[3-6], external fixation[7], antegrade & retrograde intramedullary nailing and plating[8-10] to minimally invasive osteosynthesis[2].

Wagner[2] in 2006, popularized MIPO in treating humeral shaft fractures. This method though technically demanding, causes less soft tissue disruption and preserves the fracture hematoma and blood supply to the bone fragments.

Locking compression plate has been the implant of choice for MIPO. In the last few decades, there have been shift of AO principles of fractures treatment from rigid internal fixation to biological fixation. The future of fracture treatment is biological fixation. It is an elastic fixation system that stimulates natural callus formation.

The aim of this study was to evaluate the clinical results and functional outcome of humeral shaft fractures treated with MIPO technique.

Patients and Methods

This study was conducted at our workplace during a period of 3 years. It was a hospital based prospective serial follow-up study. We enrolled 30 patients for our study with displaced humeral shaft fractures, which were fixed by the technique of closed reduction and minimally invasive plate osteosynthesis (MIPO). Adult patients of either gender with displaced/segmental/comminuted humeral shaft fractures determined by clinical examination and diagnostic imaging (X-rays) were included. Open fractures, Intra-articular extension into shoulder/elbow joint, associated vascular injury, associated nerve injury, another ipsilateral fracture of the upper limb were excluded. Patients were followed-up for a period of 6 months. University of California & Los Angeles (UCLA) scoring for shoulder and Mayo Elbow Performance Score (MEPS) for elbow were produced to them at every follow-up and evaluated at the end of 6 months.

Surgical Technique:

All cases were done under general anesthesia, preceded by preoperative medical optimization. After induction, patient's arm was placed on a radiolucent board and arm abducted to 90°. Surgeon position was towards the lateral side of the arm and C arm was from the opposite side. A 5-cm incision was made at the anteromedial border of the deltoid muscle. The incision was about 5-cm distal to the acromion. The dissection was stopped when the sub-muscular plane was reached. Sub-muscular plane was also developed laterally underneath the deltoid muscle. Another 5-cm incision was made over the lateral side of the distal shaft of the humerus. The brachialis muscle was split with blunt dissection. The distal end of the incision is limited by the anatomical course of the radial nerve. We used 8-cm from the lateral epicondyle as the landmark for the radial nerve where it pierces the lateral intermuscular septum and winds along the lateral border of the humerus[11]. The nerve was usually not explored, and retraction was done gently. The muscle is split by blunt dissection until the periosteum was reached to avoid trapping the nerve between the plate and the bone.

The proximal fragment is usually positioned in an abducted and internally rotated position. Therefore, the assistant should align the fracture by abduction and internal rotation of the distal fragment to obtain a reasonable alignment. One of the major difficulties of MIPO is obtaining adequate fracture reduction. During conventional ORIF, fracture reduction is achieved by direct visualization of the fracture and temporary stabilization with bone clamps. MIPO on the other hand requires indirect reduction techniques and closed fracture manipulation while plate fixation is obtained. In order to obtain adequate alignment, special attention was paid to three aspects: (1) intraoperatively obtaining adequate abduction of the upper extremity in order to avoid varus malalignment, (2) maintaining 30 degrees of elbow flexion with longitudinal traction of the arm in order to avoid flexion–extension malalignment, and (3) assuring adequate intraoperative images in AP, lateral and oblique views.

A sub-muscular tunnel was developed by the plate itself with the locking sleeve as the handle. Through this tunnel a locking compression plate was inserted from the proximal incision passing over the fracture site and down to the distal incision. The anatomical alignment was considered as restored when the skin crease of the arm was normal in appearance and the longitudinal axes of the main fragments and the plate were parallel to each other, when visualized with C-arm and this was confirmed by different C arm views. Both the proximal and distal fragments were temporarily fixed with K wires inserted through locking drill sleeves. After final confirmation under C arm; locking screws were inserted proximally and distally giving an elastic construct of fixation. Slight malalignment was accepted as it can be compensated by shoulder range of motion, as in the closed treatment of these fractures. After obtaining initial fixation with the distal and proximal most screws, absolute certainty about alignment must exist before introducing the middle screws. Correction of angulation is not possible thereafter. Radial nerve injury is a potential complication which should always be kept in mind especially when encountering the middle-lower third shaft fractures. The forearm must always be kept fully supinated in order to move the nerve laterally along with splitting the brachialis muscle along its middle to protect the nerve from injury. Only gentle traction and judicious use of retractors has to be advocated.

Fig. 1: Sliding the plate

Fig. 2: Temporarily fixing plate with K wires

Postoperatively the arm was immobilized in an arm sling for 4-6 weeks and active shoulder and elbow exercises were encouraged early, usually within 2-3 days of surgery. All patients were followed post-operatively with clinical and radiographic examination at 4 weekly intervals, and more active exercises were started when callus appeared. The following parameters were noted and evaluated: age and sex of the patient, site of fracture, AO classification of the fracture, mode of injury, time period between injury and surgery, duration of surgery, total C arm duration, surgical complication, duration of hospital stay, time for union, fracture alignment at 6 months, UCLA scoring for shoulder at 6 months and MEPS for elbow at 6 months.

Illustrative case

Fig.3: Preoperative AP radiograph of upper third shaft humerus fracture

Fig.4: Fracture union at 6 months

Statistical analysis:
Quantitative variables were described via mean and standard deviation, and qualitative variables via absolute frequency and percentages. Due to the sample size, we opted for the use of nonparametric tests.
To test differences between groups in relation to the quantitative variables, we used the Mann-Whitney U test. To test differences between proportions, Fisher's exact test was used. All analyses were done with IBM SPSS statistical software. The value of $p < 0.05$ was adopted for statistical significance.

Results

Males outnumbered females in our study (60:40 ratio).

Table I: Gender Distribution

Gender	Frequency	Percentage
Female	12	40
Male	18	60
Total	30	100

Mean age was 40.23 years with 60% less than 40 years of age.

Table II: Age Group

Age Group	Frequency	Percentage
<=30	9	30.0
31-40	9	30.0
41-50	6	20.0
51-60	3	10.0
> 60	3	10.0
Total	30	100.0

Table III: Site of Fracture

Site	Frequency	Percentage
Lower 1/3	10	33.3
Middle 1/3	11	36.7
Upper 1/3	9	30.0
Total	30	100.0

About 73% of the fractures were 'A type' (AO classification).

Table IV: Fracture types- AO classification

Type	Subtype	Frequency	Percentage
A	A1	5	6.7
	A2	10	33.3
	A3	7	23.3
B	B1	1	3.3
	B2	1	3.3
	B3	1	3.3
C	C1	2	6.7
	C2	1	3.3
	C3	2	6.7
Total	30		100

Road traffic accident being the commonest mode of injury (60%), fall being 33.3% and direct hit in 6.7% of cases.

Table V: Mode of Injury

Mode of Injury	Frequency	Percentage
Direct hit	2	6.7
Fall	10	33.3
Road Traffic Accident	18	60
Total	20	100

The Mean interval between injury & plating was 3.27 days with 80% operated within 3 days of injury.

Table VI: Interval between Injury and MIPO

Days	Number of patients	Percentage
1	2	6.67
2-3	22	73.33
4-5	4	13.33
>5	2	6.67
Total	30	100

Mean operating time was 112 minutes with 86.67% operated within 130 minutes.

Table VII: Duration of Surgery

Operating Time	Number of patients	Percentage
<=90 minutes	5	16.67
91-110 minutes	11	36.67
111-130 minutes	10	33.33
131-150 minutes	3	10
>=151 minutes	1	03.33
Total	30	100

Radiation exposure was 180 seconds or less for majority (65%) of patients with a mean radiation exposure of 165.67 seconds (range: 90-240 sec). Our initial 15 cases had a mean operating time of 118 minutes with a mean radiation exposure of 183.33 seconds; while the last 15 cases had a mean operating time of 107.33 minutes with a mean radiation exposure of 148 seconds. We also found out that the complex humeral shaft fractures (type C) and wedge fractures (type B) took a lesser operative time with lesser radiation exposure in comparison to the 'type A' fractures. Type B fractures had a mean operating time of 90 minutes with a mean radiation exposure of 133.33 sec, type C fractures had a mean operating time of 74 min & mean radiation exposure of 104 sec; while type A fractures had a mean operating time of 124.55 min with mean radiation exposure of 184.10 sec.

Table VIII: Mean Radiation Exposure (in Seconds)

Radiation exposure (in seconds)	Number of patients	Percentage
<=120 seconds	6	20
121-150 seconds	5	16.67
151-180 seconds	8	26.67
>=181 seconds	11	36.67
Total	30	100

Majority of the fractures (83.33%) united within 5 months of date of surgery, with remaining 16.67% fractures united between 5-6 months since surgery. No fracture showed evidence of nonunion.

Table IX: Time for Union

Time for radiological union	Number of patients	Percentage
3 months	6	20
4 months	10	33.33
5 months	9	30
6 months	5	16.67
Total	30	100

Mean duration to union was 4.43 months. 83.33% patients had anatomical alignment at 6 months. 6.67% had varus angulation which was less than 5 degrees, 10% had valgus angulation which was less than 5 degrees of valgus.

Table X: Fracture reduction on X-ray at 6 months

Fracture reduction	Number of patients	Percentage
Anatomical alignment	25	83.33
Varus less than 5°	2	6.67
Valgus less than 5°	3	10
Total	30	100

Out of all the complications, 5 patients (16.67%) had radial nerve injury, 3 patients had superficial infection (10%).

Table XI: Surgical Complications

Complications	Number of patients	Percentage
Nerve injury (axillary/radial/musculocutaneous nerve)	5	16.67
Infection (superficial)	3	10
Total out of 30 cases	8	26.67

On calculating UCLA scores at 6 months, 63.33% patients had excellent scores with the remaining 36.67% patients having good scores. No patient had either fair or poor score. Mean UCLA score at 6 months was 33.70 in our study.

Table XII: University of California & Los Angeles scoring for shoulder at 6 months

UCLA score (points)	Number of patients	Percentage
Excellent (34-35)	19	63.33
Good (29-33)	11	36.67
Total	30	100

On calculating MEPS scores at 6 months, majority of the patients (93.33%) had excellent scores while remaining 6.67% had good scores. Our mean MEPS score at 6 months was 96.33. No patient had either fair or poor scores.

Table XIII: Mayo Elbow Performance Score for elbow at 6 months

MEPS Score (points)	Number of patients	Percentage
Excellent (90-100)	28	93.33
Good (75-89)	2	6.67
Total	30	100

Discussion

Humerus fractures have been treated in a variety of different ways. Conservative methods require a long period of immobilization and rehabilitation, thereby decreasing the patient compliance. These patients typically require longer abstinence from their work. Maintaining reduction by conservative means is difficult especially in obese arms and in proximal third fractures of shaft of humerus where the proximal fragment has a tendency to go into abduction due to the action of deltoid muscle. Discomfort of cast is compounded by hot and humid weather conditions[12].

Intramedullary nailing is another option for humeral shaft fractures, but it carries a higher risk of failed fixation, especially in comminuted fracture patterns.

Complications like shoulder pain, delayed union and nonunion are also not so uncommon after intramedullary nailing of humerus[13].

Open reduction and plate fixation is considered as the standard of operative treatment for humeral shaft fractures. However this method involves violating the periosteal circulation of the fracture fragments resulting in a relatively high rate of nonunion[14]. Also increased soft tissue dissection leads to increased rates of infection. Additionally a lengthy scar is cosmetically unacceptable to majority of the patients' especially young females. These issues are addressed by minimally invasive plate osteosynthesis (MIPO).

Understanding of the importance of the vascular network in fracture repair is one of the cornerstones of minimally invasive fracture surgery[15]. With increasing level of comfort with locking compression plate system (LCP), humeral shaft fractures could be stably fixed using MIPO[12]. With LCP, it's not necessary to contour the plate to the bone. Further, with a locking head screw, the plate does not press directly against the bone, but instead leave some space between the bone and the plate with the absence of contact with periosteum beneficial to bony union[16].

Keeping these facts in mind, 30 patients with humeral shaft fractures were treated with MIPO technique in our department.

Most of the patients underwent surgery within 5 days of injury. This early intervention enabled easy reduction of fracture fragments. Our initial cases took a longer duration as we were early in our learning curve.

As our experience grew further, we found out that the complex humeral shaft fractures (type C) and wedge fractures (type B) took a lesser operative time with lesser radiation exposure where a relatively good reduction was adequate and attained easily in comparison to the 'type A' fractures where absolute reduction was required and required a longer duration. Type B fractures had a mean operating time of 90 minutes with a mean radiation exposure of 133.33 sec, type C fractures had a mean operating time of 74 min & mean radiation exposure of 104 sec; while type A fractures had a mean operating time of 124.55 min with mean radiation exposure of 184.10 sec. Zhiquan et al.[14] (mean operative time=113.8 min) & Oh et al.[17] (mean operating time=110 min) have values similar to our study. Our values are higher than Shetty et al.[15] (mean operative time = 91.5 min; mean radiation exposure=160.3 sec) probably due to greater proportion of A type fractures in our study.

The duration of radiation documented with intramedullary nailing 18 was 140 seconds, which is close to our values. An added advantage of MIPO is that it is devoid of the entry point problems of intramedullary nailing such as rotator cuff impingement/ trauma. The operating time is less compared to open methods as documented by Oh et al.[17] who compared MIPO with open methods (MIPO: 110 minutes; open: 169 minutes).

In our study, majority of the fractures (83.33%; n=25) united within 5 months of date of surgery, with remaining 16.67% (n=5) fractures uniting between 5-6 months since surgery. Mean union time for fractures in our study was 4.43 months with a range of 3-6 months.

Different union time has been reported by different authors; Livani et al.[19] (mean union: 10.4 weeks), Jiang et al.[16] (mean union=14.3 weeks), Zhiquan et al.[14] (mean union: 16.2 weeks), Lau et al.[12] (mean union: 24 weeks), Shetty et al.[15] (mean union: 12.9 weeks), Oh et al.[17] (mean union for MIPPO: 17.3 weeks; open: 16.7 weeks). Our duration is comparable to Oh et al. study[17], and is slightly more than reported by them for open methods. Mean union time for 'type A' fractures was 4 months, for B type was 4.14 months and for C type fractures was 6 months. With C type of fractures, union took a longer time probably because 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. There were no incidences of nonunion, which is not as uncommon after the open plating procedures as reported by Oh et al.[17].

At 6 months follow up, 83.33% patients (n=25) had anatomical alignment at 6 months with 6.67% (n=2) had varus angulation which was less than 5 degrees & 10% (n=3) had valgus angulation which was less than 5 degrees; however, this did not affect their functional outcome.

Postoperative radial nerve injury occurred in 5 patients (16.67 %) who had lower 1/3 shaft fractures. This can be attributed to excessive traction during reduction of fractures, use of retractors through small incisions, attempt to achieve sufficient cortical purchase in the relatively short distal fragment and the precarious relationship of the radial nerve in relation to the distal shaft of humerus, This probably could have been minimized by adopting utmost meticulousness and taking care of the above facts. All the nerve injuries recovered spontaneously after 4-5 months and no patient had any neurological deficit at final follow up. There were no cases of other nerve injuries in our study. Livani et al.[19], Jiang et al.[16], Zhiquan et al.[14], Concha et al.[20], Shetty et al.[15] reported no radial nerve injuries in their study. Lau et al.[12] reported 3 cases out of 17 (17.65%) and Oh et al.[17] reported 1 case out of 29(3.45%) of iatrogenic radial nerve injury in their study. Shetty et al.[15] also reported 2 cases of radial nerve neuropraxia in their study. Superficial infection was reported in 3 cases out of 30 (10%) which resolved after a course of oral antibiotics.

The functional outcome of the shoulder was assessed by UCLA scoring at 6 months. Mean UCLA score at 6 months was 33.70 in our study. 63.33 % (n=19) patients had excellent scores, remaining 36.67 % (n=11) patients had good scores. Mean UCLA score in Zhiquan et al.[14] study was 33.15 & in Shetty et al.[15] study was 34.03. Oh et al.[17] reported mean UCLA scores for open method as 33.8 & for MIPO as 34.3. Our results are comparable to Shetty et al.[15] & Oh et al.[17] study.

A MEPS scoring was used to assess the function of the elbow. Our mean MEPS score at 6 months was 96.33. Majority of the patients (93.33%; n=28) had excellent outcomes while 6.67% (n=2) had good outcome. Our results are comparable to Zhiquan et al.[14] study (mean MEPS: 98.46); Shetty et al.[15] study (mean MEPS: 93.9) & Oh et al.[17] study (mean MEPS: 97.6). In fact Oh et al. reported better MEPS for MIPPO (mean MEPS: 97.6) as compared to open methods (Mean MEPS: 97).

Conclusion;

Despite well-established concept of preserving soft tissues during open reduction of fractures, surgeons traditionally have sought to achieve maximal mechanical stability regardless of the impact it might have on the vascularity of fracture fragments. This traditional approach is responsible for many of the problems for which plating was condemned. Precise reduction and absolute stable fixation has its biological price. Not just solid healing, but immediate and continuous function of the limb is now a leading goal.

Minimally invasive plate osteosynthesis can achieve comparable radiological and functional results to open plate osteosynthesis method for humeral shaft fracture, while reducing the operative time and perioperative complications.

The MIPO has a better patient compliance with early rehabilitation and a better cosmetic outcome. Chances of nonunion, delayed union and deep infection are less.

The major limitations of our 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. Also the follow-up of our patients was for 6 months. The MIPO is an intricate technique for treatment of humeral shaft fractures requiring a relatively long learning curve. However, the results are good and reproducible .The risk of radial nerve injury is real and should not be undervalued, even when all the technical precautions are followed especially in mid-lower 1/3 shaft fractures.

The decision to choose this method should be taken individually and on a case-by-case basis, analyzing the type of fracture, staff training and its acceptance by the patient, after being duly informed of the potential risks involved.

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