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Original Article

Results of Open Reduction and Internal Fixation of Humeral Shaft Fractures using Locking Compression Plate

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Abstract

Introduction: Fractures shaft of the humerus is common in an orthopedic practice. Open reduction and plating of these fractures allow anatomical reduction without affecting elbow and shoulder function but involve extensive soft tissue stripping. We treat 22 cases of humeral shaft fractures using locking compression plate (LCP).

Objective: The objective of this study was to measure the clinical outcome which includes fracture healing, radial nerve recovery, infection, and functional range of motion in the shoulder and elbow. Radiographic measurements included fracture alignment, time to healing, delayed union, and non-union.

Materials and Methods: Twenty-two skeletally mature patients with acute humeral shaft fractures requiring surgical stabilization as indicated by the fracture pattern, failure to maintain reduction by conservative method, and associated injuries were treated by open reduction and internal fixation (ORIF) using LCP. Follow-up was possible only on 20 patients.

Results: Nineteen Humeral shaft fractures united completely, one fails to unite necessitating subsequent procedure which was united afterwards within 1½ years. Two superficial wound infections in patients with an open fracture and one transient post-operative radial nerve palsy were the only complications. A functional range of motion in the elbow and shoulder was regained in all except in one patient who had severe bone and soft tissue injuries in the same extremity.

Conclusion: ORIF with locking compression plating becomes the treatment of choice with increased popularity for humeral shaft fracture as it can give good results by providing both biologic and mechanical advantages.

Key words: Humeral shaft, Internal fixation, Locking compression plate, Treatment outcome

INTRODUCTION

Humeral shaft fractures account for 3–5% of all fractures.[1] Although most closed fractures of the humeral shaft can be treated successfully with closed method, open reduction and internal fixation (ORIF) with direct fracture exposure often yields near anatomic alignment without affecting elbow and shoulder function.[2,3] It is advocated that compression plating offers the best treatment for humeral shaft fractures that require surgical intervention.[4] The rates of non-union and hardware failure necessitating revision range from only 0% to 7%.[5] Locking the screws to the plate allows the plate to sit at a distance offset from the underlying bone surface providing a biologic advantage for bone fracture healing by preserving the periosteal blood supply underlying the plate.[6-8] The functional range of motion of the elbow and shoulder predictably returns after plate fixation when complete motion is not obtained; it is often the case that other associated skeletal or neurologic injuries exist.[9] The two approaches that we used for fracture exposure and plate fixation are the anterolateral and posterior approach. Fractures in the proximal third often require the anterolateral approach.[10]

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Evidence also suggests that immediate weight-bearing on an upper extremity that has been treated with ORIF has little or no deleterious effect.[11] The most common complications associated with plating procedures are infection and iatrogenic nerve palsy (2–5%), with most cases being a transient problem that requires no further intervention (0–6%).[12,13] Some surgeons prefer not to plate humeral shaft fractures due to the difficulties of dealing with fracture exposure, the technical aspects of plating and complex fracture patterns, as well as due to concerns about radial nerve injury.[14] This paper presents the results obtained after internal fixation of fractures of the humeral shaft using locking compression plate (LCP).

MATERIALS AND METHODS

Over the 3-year period from February 2011 to January 2014, 22 patients with acute fractures of the humeral shaft treated by ORIF using LCP were included in the study. Informed written consent of all the patients was obtained before clinical and radiographic assessment. There were 15 male patients and seven female patients, and the average age was 37 years (range, 16–71 years) [Table 1]. The left humerus was fractured in 16 patients and the right in six. The fractures were located in the proximal third of the shaft in six patients, in the middle third in 12, and distal third in four [Table 2].

Ten of the fractures were comminuted and the remainder was either transverse or short oblique. The cause of injury was road traffic accident in 14 patients, a fall in five, direct assault in two, and following arm wrestling in one [Table 3].

Five patients had a neural injury in the extremity when they were first seen. These included an injury of the radial nerve in four patients, an injury of the posterior interosseous nerve with an associated Monteggia fracture in one. In still another patient, a radial nerve palsy developed after attempted closed manipulation of the fracture.

The indication for ORIF in this series was as follows:

- Fracture in proximal third of the humerus that remains displaced and angulated despite manipulation and immobilization by functional cast brace in six patients
- Comminuted fracture in the mid and distal third of the humeral shaft that remains completely displaced in 10 patients, of which four patients had initial radial nerve palsy
- Loss of radial nerve function after closed manipulative reduction in one patient
- In the remaining five patients, either an open fracture or associated injury or both were the indications for internal fixation.

The associated injury group included one patient who also had an injury of the head, an abdominal injury with splenic rupture in another patient and an additional injury in the same or opposite upper extremity in the remaining. The additional injury in the same upper extremity included an ipsilateral fracture of the forearm or elbow or neurovascular compromise or a soft tissue injury for which skeletal stability was needed to allow soft tissue reconstruction.

The ORIF was performed between 4 h and 21 days after the injury. We used either anterolateral approach or posterior approach depending on the site of fracture and condition of the soft tissues. In upper one-third of the humeral shaft fracture, we used anterolateral approach, and in middle and lower third fracture, we used posterior approach if the condition of soft tissue allowed. Utmost care was taken intraoperatively not to injure the radial nerve by careful exposure and inspection of the nerve. Interfragmentary compression by means of lag screws was used if possible. In general, an LCP that permitted screw fixation to at least six cortices, that is, three in the proximal and another three in the distal fragment was used [Figure 1]. A 4.5 mm

Table 1: Age and sex variation in the study group (*n*=22)

Age	Male (*n*)	Female (*n*)	Total (*n*)
<40	9	4	13
40–60	6	2	8
>60	0	1	1
Total	15	7	22

Table 2: Site of humeral fracture (*n*=22)

Humeral site	*n* (%)
Proximal one-third	6 (27.3)
Middle one-third	12 (54.5)
Distal one-third	4 (18.2)

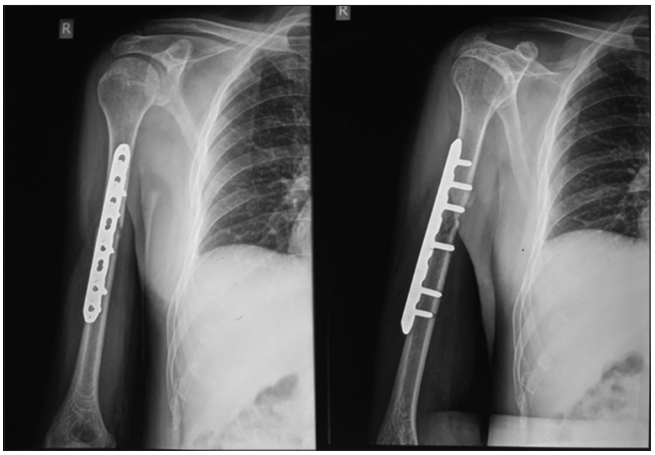

Figure 1: X-ray of fracture shaft right humerus (AP and lateral view) fixed with LCP in a 36-year-old male

Table 3: Characteristics of fracture included in the study

Clinical details of fracture							
Sex/age	**Occupation**	**Sides**	**Presentation (days)**	**Mechanism**	**Classification**	**Associated injury**	**Radial N Palsy**
Male/58	MW	L	2	RTA	Prox/spiral/close	Nil	Nil
Female/42	HW	R	1	RTA	Prox/trans/close	Nil	Nil
Male/16	Student	L	3	*Fall in sports	Prox/obl/close	Nil	Nil
Male/30	MW	L	4	Direct blow	Prox/trans/close	Nil	Nil
Male/40	MW	L	16	RTA	Prox/obl/close	Nil	Nil
Female/23	Student	L	3	RTA	Prox/trans/close	Nil	Nil
Male/24	Student	R	1	*Arm wrestling	Mid/spiral/close	Nil	Nil
Male/38	MW	L	1	RTA	Mid/obl/open	Head injury	Nil
Female/52	HW	R	4	RTA	Mid/trans/close	Nil	Nil
Male/45	MW	L	3	RTA	Mid/com/close	Nil	P
Male/53	MW	L	1	RTA	Mid/com/open	Nil	Nil
Male/51	MW	L	1	RTA	Mid/trans/close	Abdominal injury (splenic rupture)	Nil
Female/26	HW	L	5	RTA	Mid/com/close	Nil	P
Male/21	Student	L	1	RTA	Mid/spiral/open	Elbow injury (opp)	Nil
Female/71	HW	L	6	Fall	Mid/com/close	Nil	Nil
Male/34	MW	L	2	*Direct blow	Mid/obl/close	Nil	P
Female/29	MW	R	2	RTA	Mid/com/close	Nil	Nil
Male/46	MW	L	3	Fall	Mid/spiral/close	Nil	Nil
Male/39	MW	L	1	RTA	Dis/trans/close	Monteggia #(ips)	Nil
Female/28	HW	R	2	Fall	Dis/com/close	Nil	P
Male/31	MW	R	1	RTA	Dis/obl/open	Elbow injury (Ips)	Nil
Male/18	Student	L	1	*Fall from height	Dis/com/close	Nil	Nil

N=Nerve, MW=Manual worker, HW=House worker, RTA=Road traffic accident, Prox=Proximal, Mid=Middle, Dis=Distal, Trans=Transverse, Obl=Oblique, Com=Comminuted, L=Left, R=Right, P=Palsy

narrow LCP was used in these fractures as the size of the humerus was not large enough to use large fragment broad plate construct [Figure 2]. In three patients, cancellous bone grafts were placed about the fracture site at the time of fixation. Bone grafts were used when the continuity of the cortex of the humeral shaft could not be completely restored due to bone loss or comminution, especially if a defect was present in the cortex opposite the plate. The limb was put on an arm pouch and no post-operative immobilization given and physiotherapy instituted as soon as the pain subsided, usually within 72 h. Active hand, wrist mobilization along with assisted shoulder and elbow exercises was commenced from the 3rd day itself. Patients were follow-up at monthly interval till radiographic union was seen. Functional assessment was done as per system of the American Shoulder and Elbow Surgeons (ASES) score as adopted by KcCormack *et al.*[15] and visual analog pain score was recorded.

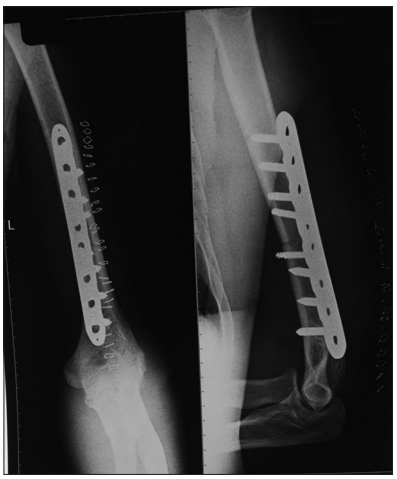

Figure 2: X-ray of fracture shaft left humerus (AP and lateral view) fixed with LCP in a 50-year-old male

RESULTS

Of the 22 patients, only 20 patients were followed until the fracture had healed. The time to the union was determined as the time when the fracture line was no longer visible radiographically, but in two patients, the fracture line remained visible long after consolidation of the bone grafts. Thirteen fractures healed within 4 months; four within 6 months; and two delayed but unite within 1 year. One required subsequent operation for hypertrophic non-union with implant failure due to immediate weight-bearing activity done by the patient; replating and autogenous bone grafting were performed and the fracture united within 6 months from the second operation [Table 4].

Prolonged time to healing did not seem to correlate with clinical symptoms, function, or severity of the initial injury. There was no case of non-union in our study. In the series, three of the patients with an open fracture both internal fixation and wound closure were delayed up to 3 weeks. Immediate internal fixation after debridement with delayed wound closure was used in the other two patients

with an open fracture. Both methods were successful in achieving union. Fifteen patients recovered full motion of the shoulder and elbow. Four patients had full motion of the shoulder, but motion of the elbow was from 15° to 125° of flexion. Two of these four patients had an associated skeletal or soft tissue injury in the extremity. The remaining one patient with associated injury of the elbow and forearm had >60° of flexion of the elbow. To assess function, we used the ASES shoulder score for 13 activities of daily living requiring full shoulder and elbow movement [Table 5]. The maximum possible score is 52 points. The average score was 48.5 (range, 40–52). Pain was quantified using visual analog scales, with zero being no pain and 10 as extreme pain.

There was one transient post-operative radial nerve palsy, which we attributed to excessive retraction during the procedure. Of the four patients who had a radial nerve palsy when they were first seen, one was found to have a partially lacerated nerve; two had contusion of the nerve at the level of the fracture; and in one, the nerve appeared normal. In the patient who lost radial nerve function after closed manipulation, the nerve was found within the fracture site.

Nerve function was restored in all five patients who had a radial nerve palsy initially as well as in the one patient whose palsy developed after manipulation. Posterior interosseous nerve palsy with an associated Monteggia fracture of ipsilateral forearm also recovered after stabilization of the fracture. The details of the results in this study are shown in Table 6.

Two patients with an open fracture; one treated with delayed and one with immediate internal fixation had a superficial infection that resolved after administration of the third-generation cephalosporin. There were no deep infections and no patients had osteomyelitis.

Table 4: Time of union of fracture

Number of patients	Time of union
13	Within 4 months
4	Within 6 months
2	Within 1 year
1	Within 1½ years
2	Loss follow-up

Table 5: Details of the American Shoulder and Elbow Surgeons score

Back pocket	Perineal care
Wash opposite axilla	Eat with utensil
Comb hair	Use arm at shoulder level
Carry 10 lb at side	Dress
Sleep on affected side	Pull
Use hand overhead	Throw
Lift	

4: Normal, 3: Mild compromise, 2: Difficulty, 1: With aid, 0: Unable, NA: Not available

Table 6: Details of the results in the study

Overall assessment	Outcome
ASES functional score (52 points)	48
Visual analog scale for pain (0–10)	1.0
Impingement symptoms	0
Primary bone graft	3
Secondary surgery with bone grafting	1
Radial N palsy	
Pre-operative – 4 no.	Recovered fully
Post-operative – 1 no.	
Deep infection	Nil

ASES: American Shoulder and Elbow Surgeons

DISCUSSION

At present, open reduction and compression plating remain the treatment of choice for humeral shaft fractures that require operative intervention. Locking the screws to the plate allows the plate to sit at a distance offset from the underlying bone surface providing a biologic advantage for bone fracture healing by preserving the periosteal blood supply underlying the plate.[6-8] Mechanically this provides stability without the need for the plate to match the curvature of the bone surface and without the need to compress and maintain friction between the plate and bone surface.[8] Nowadays, all of the locking plates modeled were offset 1 mm from the cortex avoiding undue stress shielding and contact below the plate. This advantage with locked plates has been suggested to prevent local bone necrosis.[16] It is, therefore, advocated that compression plating offers the best treatment for humeral shaft fractures that require surgical intervention.[4,17] However, the risks of any musculoskeletal procedure cannot be overlooked and in the case of compression plating include extensive dissection, iatrogenic radial nerve injury, an increased risk of infection, and non-union.[17]

Surgical stabilization is considered to be better treatment for bilateral fractures of the humerus and ipsilateral fractures of the humerus and forearm, as well as in cases of polytrauma, progressive neurological deficit, vascular injury, and failed conservative treatment.[18] The most frequent indication for operative treatment is the presence of associated multiple injuries.[19] In a comparative study of dynamic compression plating versus locked intramedullary nailing for humeral shaft fractures shows significant association with a higher risk of infection and post-operative nerve palsy in those fixed by plating, but there is no difference with respect to non-union and revision rate.[20]

The posterior approach allows for direct observation of the fracture and posterior and lateral plate placement but requires the nerve to be dissected out because it is in the middle of the operative field. In contrast, the anterolateral approach avoids direct observation of the nerve and allows for anterior and lateral plate placement.[21]

Fractures of the middle and middle-distal parts of the shaft had a significantly higher association with radial nerve palsy than those in other parts. Transverse and spiral fractures were more likely to be associated with radial nerve palsy than oblique and comminuted patterns of fracture.[22] The surgical approach and plate fixation technique are of immense importance to avoid radial nerve injuries and achieve a high degree of absolute stability.[23]

Pal *et al.* described modified functional cast brace as one of the options in treatment for humeral shaft fractures as it can be applied on the 1st day of the presentation in most of the situations also mentioned about the usefulness of simple objective scoring system, particularly in uneducated patients.[24]

One of the disadvantages of conservative treatment being a constant contraction of the surrounding muscles and the pull of gravity which tends to distract the fracture fragments. Other disadvantages of conservative treatment include joint stiffness, edema, muscle atrophy, and osteoporosis. Inadequate immobilization may lead to delayed union and non-union, whereas prolonged immobilization may lead to stiffness of elbow and shoulder joint. Therefore, transverse fractures should be treated with a compression plate, as it aids achieving bone-to-bone contact, and dynamic compression screws can pull opposite fracture fragments together when tightened.[25]

The attractive theoretical advantages of locking humeral nails have not been borne out in clinical studies by Bhandari *et al.*, but complications such as shoulder pain, delayed union or non-union, fracture about the implant, iatrogenic fracture comminution, and the difficulty in the reconstruction of failures have diminished their usefulness. The precise role of locking nails in the treatment of humeral shaft fractures has yet to be defined. Furthermore, when surgical treatment is contemplated, it is still generally believed that intramedullary nailing may not be the best choice.[26] The suitability of antegrade interlocking humeral nailing by flexible nailing technique has been described by some authors due to their non-requirement of extensive soft tissue dissection, bone grafting, and external immobilization in case of comminuted and segmental fracture patterns.[27]

Demirel *et al.* in their studies shown additional advantage of retrograde locked nailing by sparing the rotator cuff and subacromial bursa, thus preserving the shoulder functions.[28] Although nailing and plating are effective treatments for fractures of shaft of humerus, antegrade nailing may not be suitable in elderly patients, as it can cause significant shoulder dysfunction.[29,30] The patients operated with interlock nailing underwent more number of secondary bone grafting procedures.[30]

Various methods of the treatment of humeral shaft have been described, some author mentioned about minimally invasive plate osteosynthesis (MIPO) giving a good and reproducible results with few risks, but MIPO is a complex technique, requiring a relatively long learning curve. The plate placement and indirect reduction require experience.[31] Ilizarov method is another treatment option, the main disadvantages of Ilizarov fixation include the presence of a bulky implant on the arm, pin-tract infection, painful impingement of the frame on the chest wall, and the possibility of neurovascular injury due to the wires.[32,33]

Thus, LCP is a reliable option to achieve union of humeral shaft fractures even in younger patients with higher physiological demands and elderly group with poor bone quality. LCP seems to be the implant of choice even in the presence of significant bone loss requiring strut grafts. Along with LCP, corticocancellous iliac crest grafts are adequate in the treatment of segmental bone defects. Thus, plating is still the gold standard for fracture shaft humerus.

CONCLUSION

The locking compression plating is the preferred method in the majority of fractures of the shaft of the humerus with better preservation of joint function. When indicated, ORIF of the diaphysis of the humerus using LCP followed by early physiotherapy of shoulder and elbow joint is a safe and efficacious procedure.

LCP is reliable in achieving union even in patients belonging to the younger age group with higher activity levels as well as elderly group with poor bone quality as it offers both biologic and mechanical advantages. The second episode of bone grafting may be necessary to accelerate union in some patients. The LCP should probably be the implant of choice and it has been associated with excellent outcomes.

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