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Functional outcome and radiological union in operated cases of AO type 12-B1 fractures of distal shaft humerus with interfragmentary screws and lateral anatomical plate

[1]Gopal Tukaram Pundkare, [2]Anish Nandkumar Tawde

[1]Associate Professor, Department of Orthopaedics, Bharati Vidyapeeth Deemed University Medical College and Hospital, Katraj, Pune, Maharashtra, India
[2]Assistant Professor, Department of Orthopaedics, Bharati Vidyapeeth Deemed University Medical College and Hospital, Katraj, Pune, Maharashtra, India

Corresponding Author:
Dr. Anish Nandkumar Tawde (anishtawde@gmail.com)

Abstract

Background: Extra-articular distal shaft humerus fractures at the junction of cylindrical and triangular portion are seen as torsion wedge fractures. Historically most shaft fractures were treated conservatively. Today's trend is towards surgical management due to high patient demand and availability of anatomical plates. This study aims to evaluate the functional results of plating in extra-articular distal humerus fractures with duration of clinical and radiological union.
Methods: A prospective study of 20 patients with torsion wedge fractures of AO Type 12-B1 was done over a period of 3 years. Demographic data was collected and all patients underwent fixation with posterior triceps splitting approach using an extra-articular distal humerus plate (EADHP) and inter-fragmentary screws. Results were evaluated by clinical and radiographic parameters. Functional results were monitored by modified Quick DASH score.
Results: There were 12 males and 8 females with a mean age of 34.45 years. Mean time to clinical and radiographic union was 10.5 weeks and 33.9 weeks respectively. The mean modified Quick DASH score at clinical and radiographic union was 24.8% and 13.76% respectively. Two patients developed radial nerve neuropraxia recovering spontaneously. One patient having inadequate reduction went on to unite both clinically and radiographically with good functional out come without any secondary intervention.
Conclusion: AO Type 12-B1 humerus fractures treated surgically with anatomical locking plates and inter-fragmentary screws give excellent anatomical and functional results. Though time to radiographic union is prolonged, no secondary intervention in the form of bone grafting or other modalities was required in any patient.

Keywords: Extra-articular, distal humerus fracture, anatomical plate, inter-fragmentary, functional outcome, radiological union

Introduction

Humerus is a classical bone of upper limb with cylindrical shape in upper 2/3RD and triangular in lower 1/3rd region. Humerus is well covered with a thick envelope of muscles with

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abundant blood supply by nutrient arteries and from muscles. The main nutrient artery enters in mid-distal humerus anteromedially. There is also an accessory nutrient artery which enters posteriorly and is a branch of profunda brachii artery. They can be damaged because of type 12-B fractures or posterior surgical exposure respectively [1]. Incidence of humerus shaft fractures is about 1-3% of all fractures [2, 3].

It has a bimodal presentation, in both young adults and elderly population. Mechanisms of injury are direct or indirect trauma with violent muscle contraction. Injury at the junction of middle and distal third humerus is very commonly seen and is typical in violent muscle contraction injuries in sports like baseball, arm wrestling, etc. Torsional forces affect this junction leading to spiral wedge fractures-combination of bending and torsional forces produces oblique fracture with a butterfly fragment. In this study, specifically AO type 12-B1 fractures specifically have been included. Type 12-B1 fractures include spiral wedge fractures of the distal third shaft of the humerus. Following is a diagrammatic representation of AO classification of humerus shaft fractures in Fig. 1.

History reveals conservative management of these fractures because of high union rates. It consists of hanging cast and coaptation splint (U slab) [4]. Conservative management has its own complications like malunion, malalignment of $\leq 20^0$ anterior angulation or $\leq 30^0$ varus/valgus angulation and <3cm shortening (bayonet position) is well accepted due to concealed deformity and shoulder movements. But varus deformity secondary to malunion is not always a benign condition as it may cause tardy posterolateral rotator instability of elbow joint as shown by O`Driscoll *et al.* [5] Today's trend for surgical option is increasing due to higher life expectancy and activity level as well as cosmetic demand in both young and elderly groups. Early mobilization is the basic consideration for surgical intervention. Conservative management still remains treatment of choice in low demand patients and in those not willing for risk of operative procedure. Absolute indications for surgery are open fractures, intraarticular extension, neurovascular injury, associated fractures (polytrauma), floating elbow, pathological fractures, failed conservative treatment and soft tissue injury around fracture. Pros and cons of nonoperative versus operative management are detailed in Table-1.

Table 1: Pros and cons of non-operative versus operative management

Non-Operative	Operative
Risk of immobilization	Risk [nerve palsy, non/delayed union]
Strict follow up [more visits, readujustment]	Prescribed follow-up
Mobilization delayed	Early mobilization
Discomfort to patient [>2months till union]	No discomfort
Better in low demand patients	High demand and young patients
Mal-union	Sound, anatomical union

So operative management is more advantageous, because of patient's factor for early motion, rapid return to work and pain control [6]. Healing of fracture in plating group is by endosteal or internal callus. Cells in marrow are determined osteogenic precursor cells (DOPC) for osteogenesis. These cells have little to no ability to divide and hence healing process is slow. Clinical union is said to occur when there is gradually increasing stiffness and strength provided by the mineralization process which makes the site of fracture mechanically stable and pain free. Radiographic union is present when plain radiographs show bone trabeculae or cortical bone crossing the fracture site [7].

Radial nerve palsy is not common in these types of fractures. It is seen in lower 1/3rd oblique fractures classically described by Holstein-Lewis.

Operative procedure is not without risk. Risks and benefits of surgery should be discussed with the patients. Proper written consent is taken before surgery. Iatrogenic radial nerve palsy

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is major concern [8].
Early mobilization stimulates osteogenesis by muscle contractions as stated by Wolff`s law. Compression at fracture site with inter-fragmentary screws and plating induces bone formation [9]. Distraction at fracture site reduces rate of bone formation, so bone gap has to be avoided in plating.
In our study, inter-fragmentary screws for compression and a protection plate were used to stabilize the fracture. This method of fixation in type 12-B1 fractures is more effective and mechanically stable [10]. Locking plate construct is biomechanically strong and provides stiffness against bending and torsional forces. Similarly, other peri-articular long bone fractures treated with single locking plates have shown good results without any mechanical failure e.g. distal tibia [11].

Subjects and Methods

We conducted a prospective observational study on 20 patients diagnosed with AO/OTA Type 12-B1 (wedge spiral) type of humeral shaft fractures between February 2016 and October 2019 at our tertiary care hospital. Our study group consisted of 12 men and 8 women. Patient's ≥18 years and AO/OTA Type 12-B1 (wedge spiral) type of humeral shaft fractures were included (Fig. 2 and 10). Exclusion criteria were age <18 years, fractures through a pathologic lesion, subjects with an incomplete or unavailable radiographic record, and subjects with follow up ≤48 weeks.
These fractures were treated with open reduction and fixation of fragmented wedge with inter-fragmentary screws. Depending on length of wedge two or three inter-fragmentary screws applied. Protection plate is used to counteract the disruptive forces like bending, torsion and shear. This allows early mobilization of the extremity which helps in osteogenesis. In our study, a 3.5 mm pre-contoured posterolateral extra-articular distal humerus anatomic plate, is used as protection plate (Fig. 3 and 11). In only one case DCP is used as protection plate.

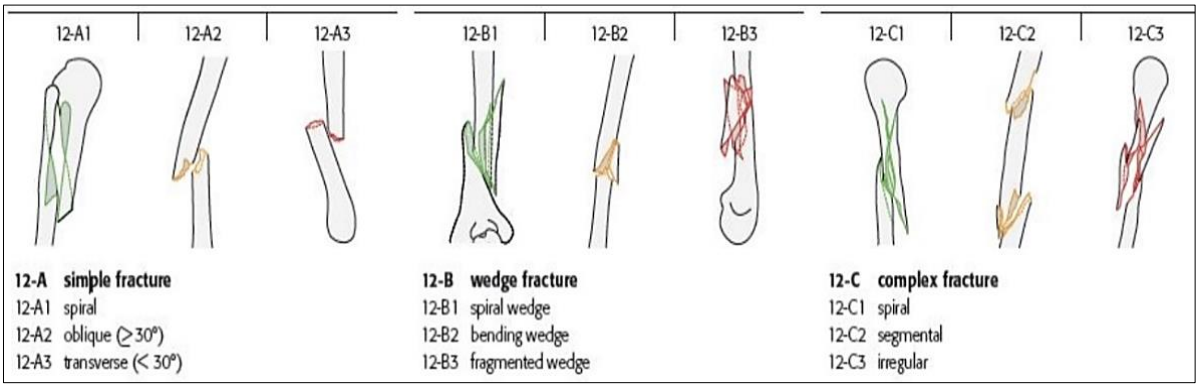

Fig 1: B1-spriral wedge, B2-bending wedge and B3-fragmented wedge

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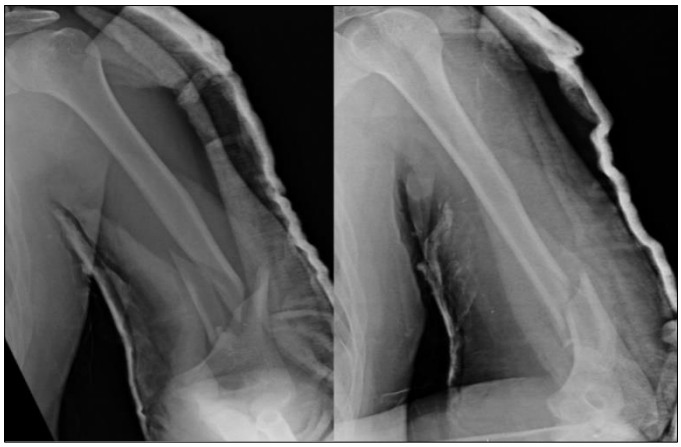

Fig. 2: Preoperative radiograph of arm anteroposterior and lateral view showing fracture shaft of humerus (AO Type 12-B1)

Fig 3: Immediate post-operative anteroposterior and lateral radiographs with extra articular distal humerus locking plate and inter-fragmentary screws showing good reduction and excellent cortical contact between fragments

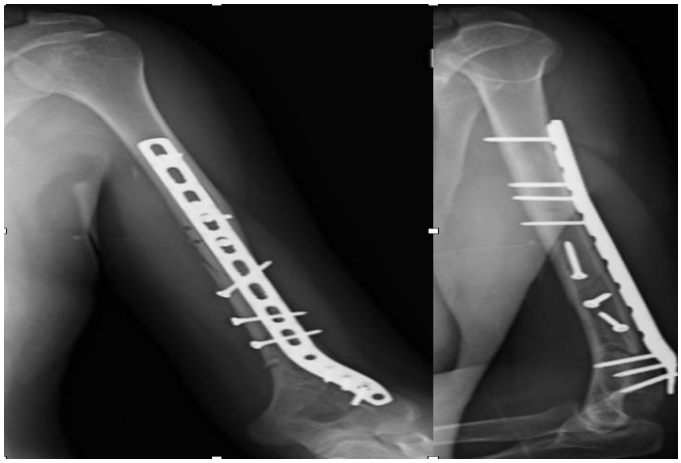

Fig 4: Postoperative radiograph at 4 weeks of follow up

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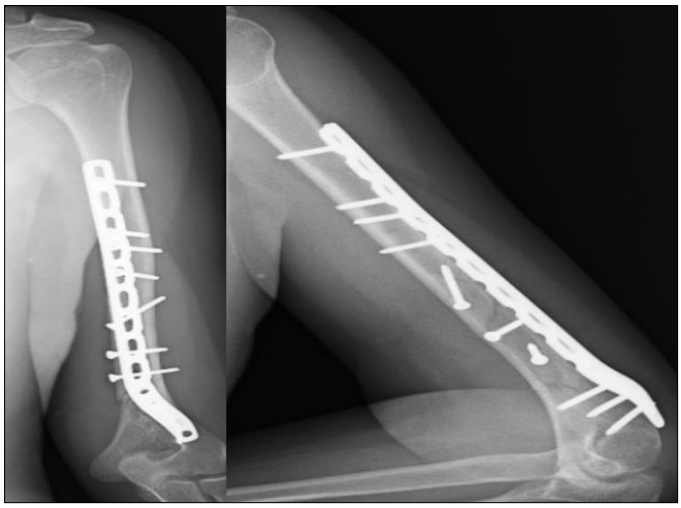

Fig 5: Postoperative radiograph at 10 weeks of follow up

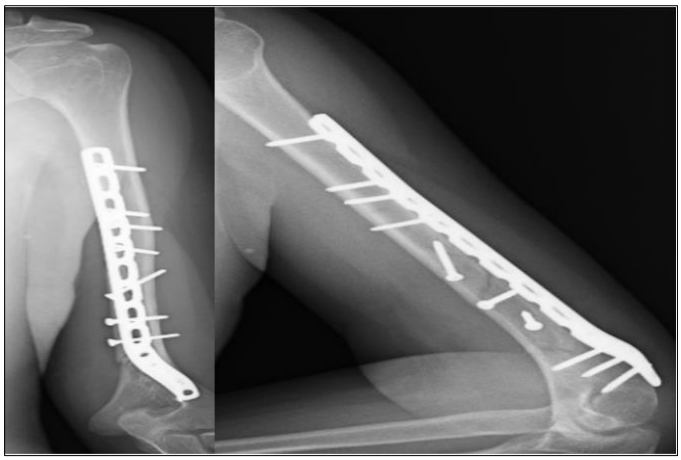

Fig. 6: Postoperative radiograph at 18 weeks of follow up

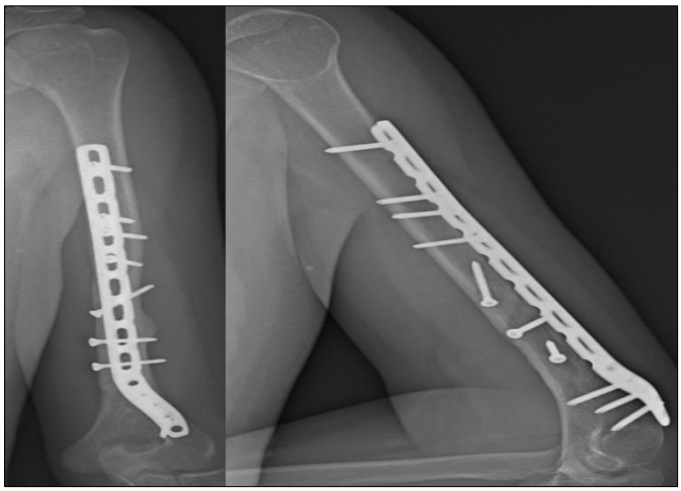

Fig 7: Postoperative radiograph at 27 weeks of follow up showing bridging callus

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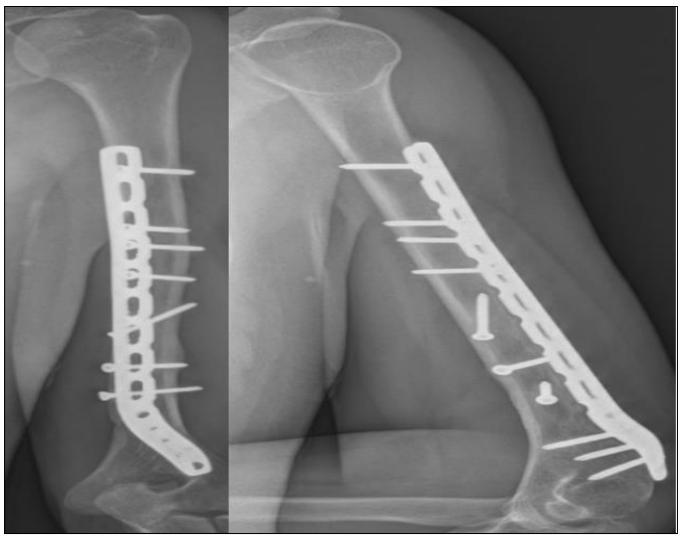

Fig 8: Postoperative radiograph at 40 weeks of follow up showing complete radiological union

Fig 9: Patient showing excellent elbow and shoulder functionality at final follow up

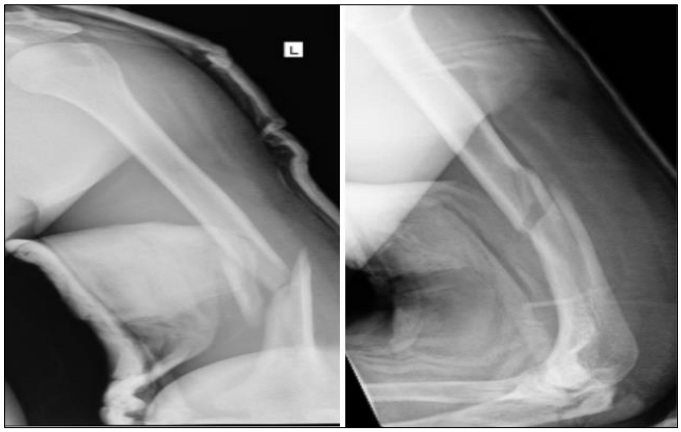

Fig 10: Preoperative radiograph of arm anteroposterior and lateral view showing fracture shaft of humerus (AO Type 12-B1)

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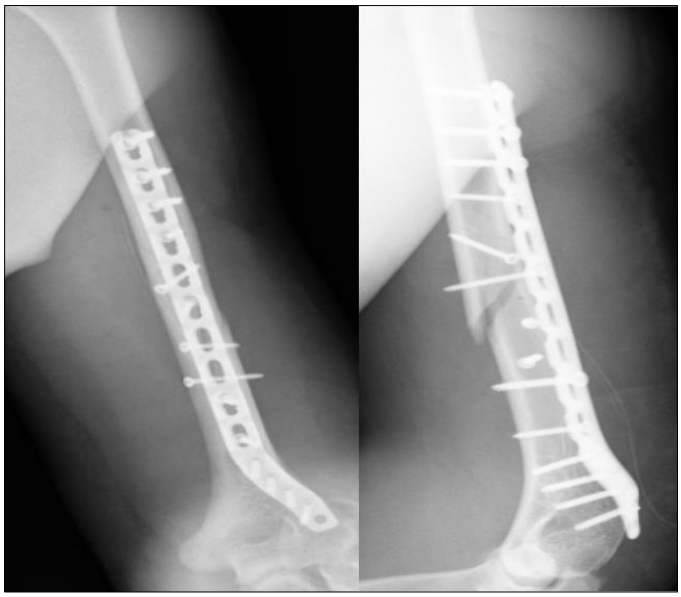

Fig 11: Immediate post-operative of anteroposterior and lateral radiographs with extra articular distal humerus locking plate and inter-fragmentary screws showing inadequate reduction and end to end contact of fragments with gap in cortex opposite to the plate

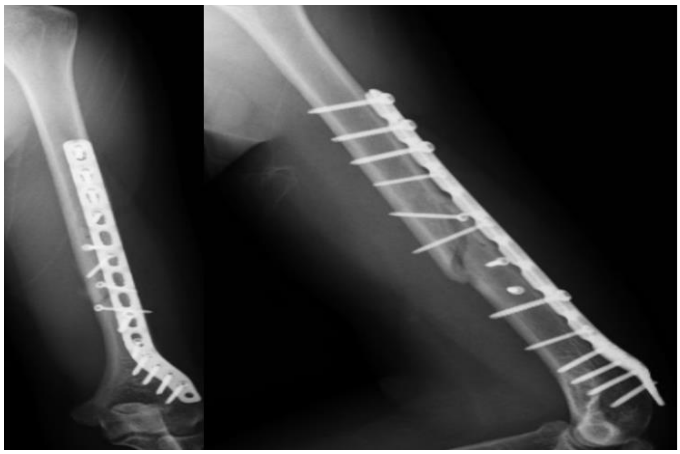

Fig 12: Postoperative radiograph at 6 weeks of follow up

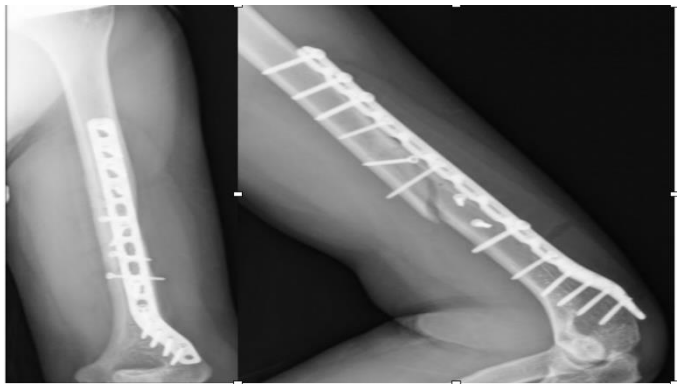

Fig 13: Postoperative radiograph at 12 weeks of follow up

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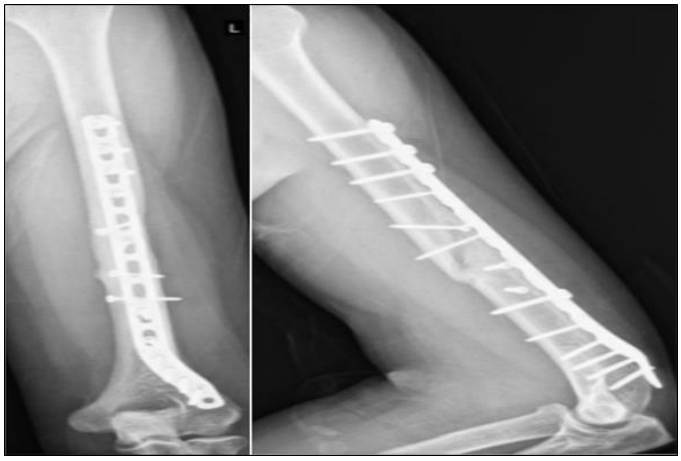

Fig 14: Postoperative radiograph at 24 weeks of follow up

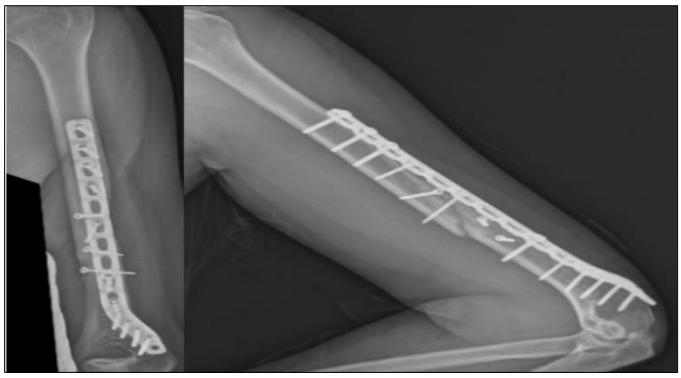

Fig 15: Postoperative radiograph at 36 weeks of follow up showing bridging callus

Fig 16: One year after follow up showing complete union and satisfactory alignment without any secondary intervention

Surgical technique

Patient is under brachial block or general anaesthesia in lateral position with arm supported on flat radiolucent post. A posterior midline skin incision is taken and deep dissection is done

by triceps splitting approach. Proximally, the radial nerve is isolated between the long and lateral head of triceps and is protected by a rubber infant feeding tube. Intra-operatively, we observed that the radial nerve crosses the lateral border and enters the anterior compartment roughly 15 cm proximal to the lateral epicondyle of humerus. Here it gives a branch called the lateral cutaneous nerve of the arm. Distally the bone is exposed through the triceps aponeurosis. The wedge fractured fragment is fixed with the main fragment using inter-fragmentary screws and without disturbing its soft tissue attachment. Depending on length of the wedge, 1 to 3 inter fragmentary screws are used. Then a protection plate of stainless steel is fixed passing under the radial nerve proximally. Lateral anatomic plate gives adequate screw fixation in distal part leading to strong mechanical construct. Skin is closed over drain. No slab or any form of immobilisation is given. Range of movement at shoulder, elbow and hand started immediately post-operatively as per the pain tolerance of the patient. Any complications arising post operatively to the patient and any secondary procedures done for the same were also noted.

All patients were subjected to regular clinical and radiological follow up in OPD. Patient's age, sex, mode of injury, associated injuries, time to clinical union and radiological union were noted (Table-2). At the latest follow up visit, patients were assessed for union clinically and radiographically; clinically by absence of pain and tenderness on palpation, range of motion at elbow and shoulder joint and ability to perform activities of daily living without pain (Fig 9). Anteroposterior and lateral radiographs were done, and the healing progress of the distal humerus fracture was assessed (Fig. 4, 5, 6 and Fig. 12, 13, 14). Union was defined by the absence of fracture line (Figs. 8 & 16) or bridging of the fracture site on at least 3 of the 4 cortices (Fig. 7 & 15) and the absence of implant loosening or failure.

Table 2: Showing the different variables which were observed

Sr. No	Age/ Sex	Occupation	Mode of Injury	Associated Injuries	Time to clinical union (weeks)	Quick DASH Score (Clinical union)	Time to radiographic union (weeks)	Quick DASH Score (Radiographic Union)	Complications and secondary procedures
1	29/M	Office clerk	Road Traffic Accident	Nil	6	27.5%	24	2.5%	None
2	36/M	Labourer	Fall from height	Nil	12	27.3%	30	4.5%	None
3	25/F	Student	Fall while walking	Nil	6	22.7%	30	11.4%	None
4	41/M	Office worker	Road Traffic Accident	Ipsilateral radius and ulna	12	27.3%	42	25%	None
5	37/M	Delivery person	Fall from two wheeler	Nil	12	22.7%	36	9.1%	None
6	19/M	Student	Fall over outstretched hand	Ipsilateral distal end radius	6	18.2%	24	4.5%	None
7	40/F	Housewife	Road Traffic Accident	Nil	12	36.4%	42	31.8%	None
8	30/M	Surgeon	Arm Wrestling	Nil	6	18.2%	48	6.8%	Radial nerve palsy, recovered
9	27/F	Housewife	Fall from staircase	Nil	6	22.7%	36	13.6%	None
10	30/F	Office clerk	Road Traffic Accident	Ipsilateral tibia fracture	12	22.7%	30	18.2%	None

11	42/M	Labourer	Fall from height	Nil	12	27.5%	36	20.5%	None
12	51/M	Engineer	Road Traffic Accident	Nil	18	27.3%	48	25%	None
13	33/M	Pharmacist	Fall from two wheeler	Nil	12	20.5%	30	6.8%	None
14	23/F	Labourer	Fall from height	Nil	6	25%	24	4.5%	None
15	34/M	Cricketer	Throwing ball	Nil	12	27.3%	30	6.8%	None
16	45/M	Bus conductor	Road Traffic Accident	Ipsilateral femur fracture	12	22.7%	42	15.9%	None
17	41/F	Housewife	Domestic Fall	Nil	12	25%	36	20.5%	Radial nerve palsy, recovered
18	38/F	Housewife	Fall over outstretched hand	Nil	12	31.8%	36	27.3%	None
19	22/M	Student	Road Traffic Accident	Nil	6	20.5%	24	2.3%	None
20	46/F	Office worker	Fall from two wheeler	Nil	12	22.7%	30	18.2%	None

Functional results were monitored by modified Quick DASH score at the final follow up which was taken to be at the time of radiographic union.

Results

A total of 20 patients were included in our study. Our study group comprised of 12 men and 8 women. The average age of the patients in the study was 34.45 years (range 19- 51 years) with 12 males and 8 females. The most common mode of injury was by road traffic accidents (10 patients) followed by fall from height (8 patients). Two patients sustained injury during sports events which included arm wrestling and throwing a cricket ball. Four patients sustained additional injuries; two had an ipsilateral radius fracture, while the other two had an ipsilateral tibia and ipsilateral femur shaft fracture respectively. All 20 patients were operated within 3 days of injury. All fracture patterns included in the study were of AO type 12-B1 (wedge spiral). Lag screws (ranging from 2 to 4) were used in all the cases. Plates of eight whole length were used in the majority of the cases.

The mean time to clinical fracture union was 10.5 weeks (range 6-24 weeks) (Fig. 9) and the mean time to radiographic fracture union was 33.9 weeks (range 24-48 weeks) (Fig. 8 and 16). The Quick DASH scores, which were taken at the time of both clinical and radiological union, are presented in Table-2. The mean Quick DASH score at clinical union was 24.8% (range 18.2% - 36.4%) and the mean Quick DASH score at radiographic union was 13.76% (range 2.3% - 31.8%). There were no patients with secondary loss of reduction at the fracture site, non-union, ulnar nerve problems, superficial or deep infections. Two patients developed radial nerve neuropraxia post-operatively all of which recovered spontaneously in three weeks. One patient had inadequate reduction in the cortex opposite to the plate (Fig. 11) and radiographic union was seen at 48^{th} week of follow up without any intervention (Fig. 16). All surgical wounds healed by primary intention. All patients had full elbow flexion and extension at 12 weeks of follow-up.

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Discussion

Non operative treatment of distal humerus fractures gives good results. Caldwell introduced hanging cast treatment for these fractures in 1933. At this level of fractures, displacement and overriding is due to muscle contraction. This observation is considered as principle of hanging cast. Union rate is high with less complications. It has its own disadvantages like frequent radiological check for reduction, adjustment of sling for correction of displacement, maintenance of erect or semi-erect position for gravity to act, distraction at fracture site especially in transverse fractures, patient compliance for regular follow up and discomfort. Late complications like malunion, delayed or non-union are present due to fracture pattern and loss of reduction even though literature reports 93 to 96% excellent results [12, 13].

Coaptation splint or Sugar-tong splint (U-slab) is another method of treatment for these fractures. It is especially useful where distraction is possible even with light hanging cast. Advantage of this splint is movement of adjacent joints is permitted from day one [14].

Functional bracing advocated by Sarmiento is also used as modality of treatment in distal humeral fractures [15]. Mechanism of this bracing is compression of surrounding soft tissues at fracture thus maintaining reduction. It is used after initial treatment by hanging cast or U slab. It is contraindicated in soft tissue injury, unreliable patient and gross deformity or shortening [16].

All these conservative measures are contradicted in soft tissue injuries and non-compliant patients in whom there is difficulty in maintenance of reduction and those with excessive shortening and angulations. Manipulations of fracture fragments sin these cases may sometime cause radial nerve entrapment injury. Hence open reduction and internal fixation is the treatment of choice. Schenk and Willenegger described two stages of primary bone healing; gap healing and haversian remodeling [17]. When there is good contact at fracture direct lamellar bone is formed, parallel to long axis of bone. If small gaps are present, gap healing takes longer time at slower rate and necrotic cortical bones remain non-remodelled for a prolonged time. Rigid fixation and early mobilization prevents ‘fracture disease’.

Blood supply to distal shaft is mainly by anteromedial nutrient artery and some contribution by posterior nutrient artery. In most of these type 12-B1 fractures, this supply gets disrupted. In addition to this, by using the posterior approach, posterior nutrient artery also gets damaged, following which the distal shaft depends on blood supply from surrounding soft tissue. Preservation of soft tissue is paramount in plating for union of fracture and hence, triceps sparing or paratricipital approaches are being used in recent studies. Meloy *et al.* reported no radial nerve palsy after using triceps sparing approach [18]. Voigt *et al.*, in his cadaveric study showed low strain over radial nerve by paratricipital approach [19]. In our study, with triceps splitting approach where we isolated the radial nerve, we encountered radial nerve palsy in only 2 patients (10%) post operatively. The patients recovered spontaneously within a span of 3 weeks without any intervention being done for the same.

There are different modalities of fixation available from nailing to plating for distal extra-articular shaft humerus fractures. But nailing is less stable with a difficult fixation due to the short distal fragment and narrow or practically absent medullary canal [20]. Various types of plates are used for fixation of extra-articular distal humeral shaft fractures both in number and configuration. Single conventional DCP is inadequate in distal short fragment fixation with chances of encroachment on the olecranon fossa [21]. To add more biomechanical strength both column plating can also be used. However, it requires more soft tissue dissection which may lead to infection or non-union due to compromised blood supply. Hence, stability at expense of biology is not valid [22]. To counter this problem, in some studies a single oblique plate is used, having more screws in the distal fragment. Recently, a retrospective study by Trikha *et al.* [23] evaluating elbow functionality via the Mayo Elbow Performance Score (MEPS) and fracture union in thirty six patients of extra-articular distal humerus fractures

operated using a single extra articular distal locking plate, yielded satisfactory results with minimum complications. However, some studies have shown complications of medial off shooting of plate and inadequate proximal fixation in long spiral oblique fractures like type 12-B1 [24, 25].

In our study, we have used traditional posterior triceps splitting approach. We have used 1 to 3 IFS depending on length of wedge to fix it to main fragment. Lateral anatomic plate of 4.5 mm screw placement facility in proximal fragment with 3.5 mm locking screws were used. This hybrid construct is mechanically stronger [26]. In our study, no mechanical failure was observed even though the patients were using the operated limb for routine day to day activities. Though triceps splitting approach is thought to be inferior to other approaches, we did not encounter any such issue in view of infection or union.

In a systematic review of contemporary published clinical outcomes studies pertaining to long bone fracture healing in order to document current definitions being used for fracture union of long bones and radiographic assessment of fracture healing, conducted by Corrales and Bhandari [27], the most common clinical criteria were absence of pain or tenderness during weight bearing (49%), followed by absence of pain and tenderness on palpation or physical examination (39%) and ability to perform activities of daily living with no pain (14%). The radiographic definitions of fracture healing in the studies involving use of plain radiographs were bridging of the fracture site by callus, trabeculae, or bone(53%) followed by bridging of the fracture site at three cortices (27%). In our study, we defined clinical union by the absence of pain and tenderness on palpation and ability to perform activities of daily living without pain. Radiographic union in our study was defined by the absence of fracture line or bridging of the fracture site on at least 3 of the 4 cortices and the absence of implant loosening or failure.

The average time of union with EADHP has been reported as 15.7 weeks (range 9-34 weeks) and 7.3 months (range 3-13 months) by Fawi *et al.* [28] and Capo *et al.* [29] respectively. In our study clinical union was achieved on an average period of 10.5 weeks (range 6-18 weeks) and radiographic union was seen on an average period of 33.9 weeks (8.5 months, range 24 – 48 weeks) after the index surgery. This variation is explained by the mechanism of bone healing in these fractures. Most of these show union by direct primary bone healing with minimum bridging callus at the fracture sites. In one case, complete radiological union was only seen at 48 weeks after the index surgery, most likely due to inadequate reduction achieved in the cortex opposite to the plate intraoperatively. A significant gap was seen in one cortex in the immediate post-operative radiograph (Fig. 11). The fracture united without any secondary procedure being done for the patient (Fig. 16).

In a study conducted in Norway, the normal Quick DASH score in the general population has been reported to be around 15% with a standard deviation of 17.01% [30]. In our study, the mean Quick DASH score at final follow up (taken as the time of complete radiological union), was 13.76% ranging from 2.3% to 31.8%. This shows excellent functional outcome of the patients treated with our surgical modality of anatomical lateral plate and inter-fragmentary screws with normal and uneventful return to their daily and professional activities.

Conclusion

In our study, we found that AO Type 12-B1 fractures of the humerus treated with single anatomical plate and inter-fragmentary screw gives excellent anatomical and functional results. Our observation is that although time to radiological union is prolonged in this approach, clinical union is achieved much earlier with all the patients having satisfactory function by 11 weeks post-surgery. Despite this prolonged radiographic union time seen in most patients of our study, there was no requirement of any intervention for healing of the

fractures. This should be borne in mind by the operating surgeon who may consider going for a secondary procedure much earlier than is required in view of the slow progress to union seen radio-graphically. Patience on the part of both the surgeon and the patient plays a key role post operatively. The operating surgeon must also alleviate any queries and ease any concerns regarding the same by the patient.

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