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FUNCTIONAL OUTCOME OF ANTE-GRADE INTRAMEDULLARY INTER-LOCKING NAILING IN FRACTURE SHAFT OF HUMERUS

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ABSTRACT

Fractures of the humeral shaft are relatively common injuries. The uniqueness in the anatomy, the fracture configuration and the functional significance of the region influences the treatment options. The rules of managing certain clinical variants of humeral diaphyseal fractures need to be addressed surgically, this is the present consensus. Since ours is not a comparative study, no statement regarding superiority or otherwise can be made with regard to plate Osteo-synthesis. Indeed in one of our own non-union case we have had to resort to LCP with bone grafting. Thoraco-brachial immobilization involved use of the body as a splint. This was achieved by using body strapping or by shoulder arm spica application. This method of treatment was not reliable for maintaining the alignment of the bone and promotion of bone healing .

Keywords:diaphyseal fractures, Osteo-synthesis, humerus, bone grafting, deltoid, medullary cavity

Introduction

The treatment concept for these fractures has been evolving over the time period. Historically closed methods of treatment for humeral diaphyseal fractures have centred around one of the two principles

1. Thoraco-brachial immobilization
2. Dependency traction

Humeral shaft fractures account for approximately 3% of all fractures [1,2,3]. Treatment modalities have greatly evolved since it was first described in ancient Egypt (Circa 1600 BC); however the fundamental principles have broadly remained consistent throughout time [4]. For decades non-operative management had remained the mainstay, with acceptable healing in more than 90% of cases [5]. Surgical management was generally reserved for open fractures, poly-trauma patients, ipsi-lateral humeral shaft fractures and forearm fractures, vascular injury, associated nerve injury, floating elbow injury, fractures that have gone for non-union following conservative management and cases in which there is a failure to tolerate or maintain alignment in a functional brace[6,7,8]. With the orthopaedic fraternity`s never quenching desire to improve upon the functional and clinical outcome and with the advances in the internal fixation modalities, the outlook towards managing the shaft of humerus fractures conservatively, has undergone a sea change[9,10,11,12]. Operative treatment options are an external fixator, intra-medullary nails or various plating and screwing constructs, with each method claiming improved union rates and a near normal functional outcome[12,13]. For the last 3 decades, plate osteo-synthesis has remained the gold standard for humeral dia-physeal fractures.

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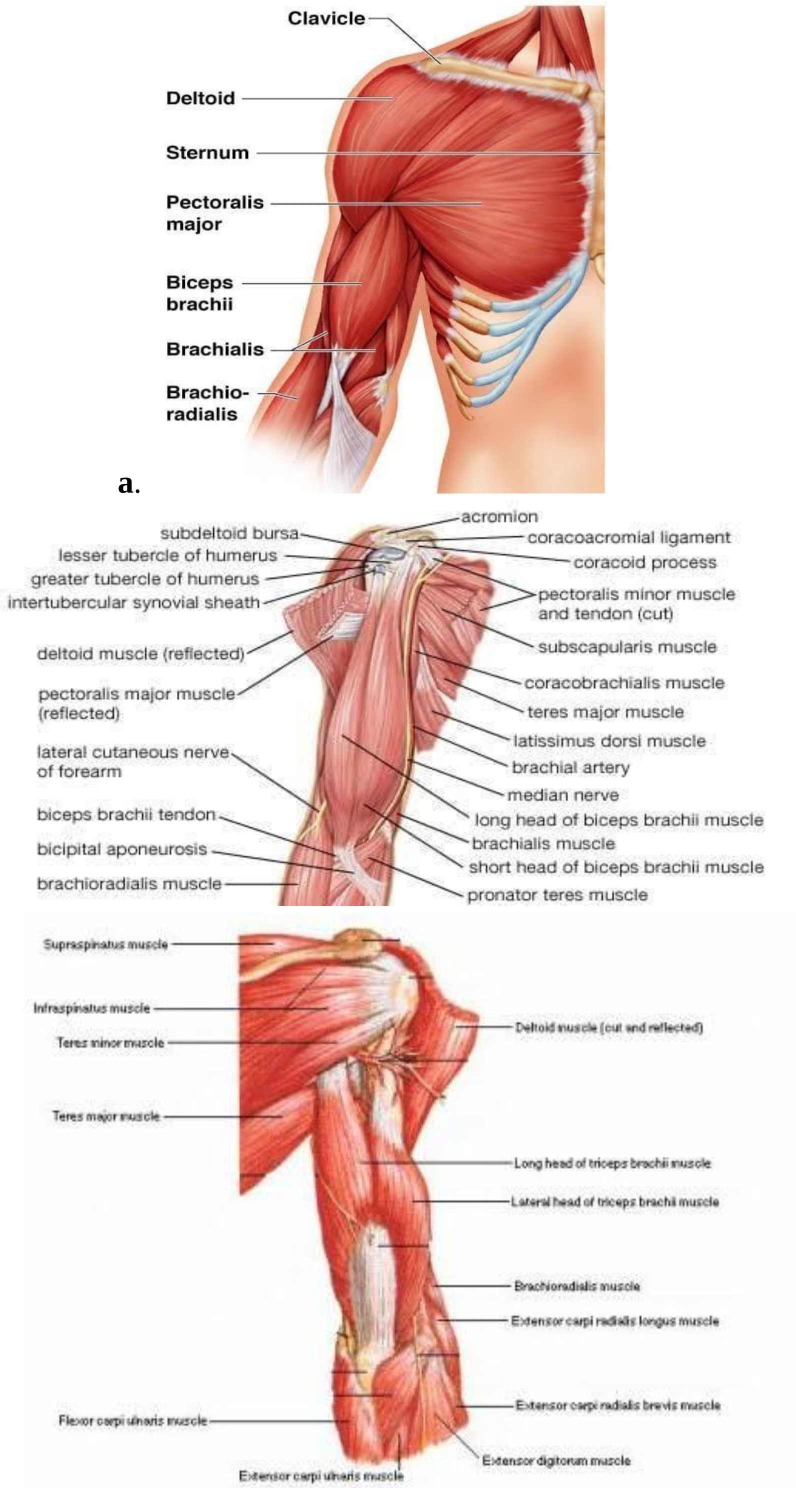

c.

Fig (1): (a, b): Anterior muscular anatomy of the arm
(c) Posterior muscular anatomy of the arm

The sleeve of muscles surrounding the bone and the rich vascularity provided by them helps in fracture healing. The mobility of the shoulder and the elbow joint accommodates for a minimal

degree of angulation and shortening. Since the upper limb does not take part in weight bearing or ambulation; it accommodates some shortening without compromising on function.
Because of all these inherent advantages of the region, conservative treatment results have been giving gratifying outcomes[14] . Treatment of humeral dia-physeal fractures has centered on non-operative techniques, which have been providing excellent functional results. The main disadvantage of shoulder stiffness has been overcome by the functional bracing techniques popularized by Sarmiento [8].

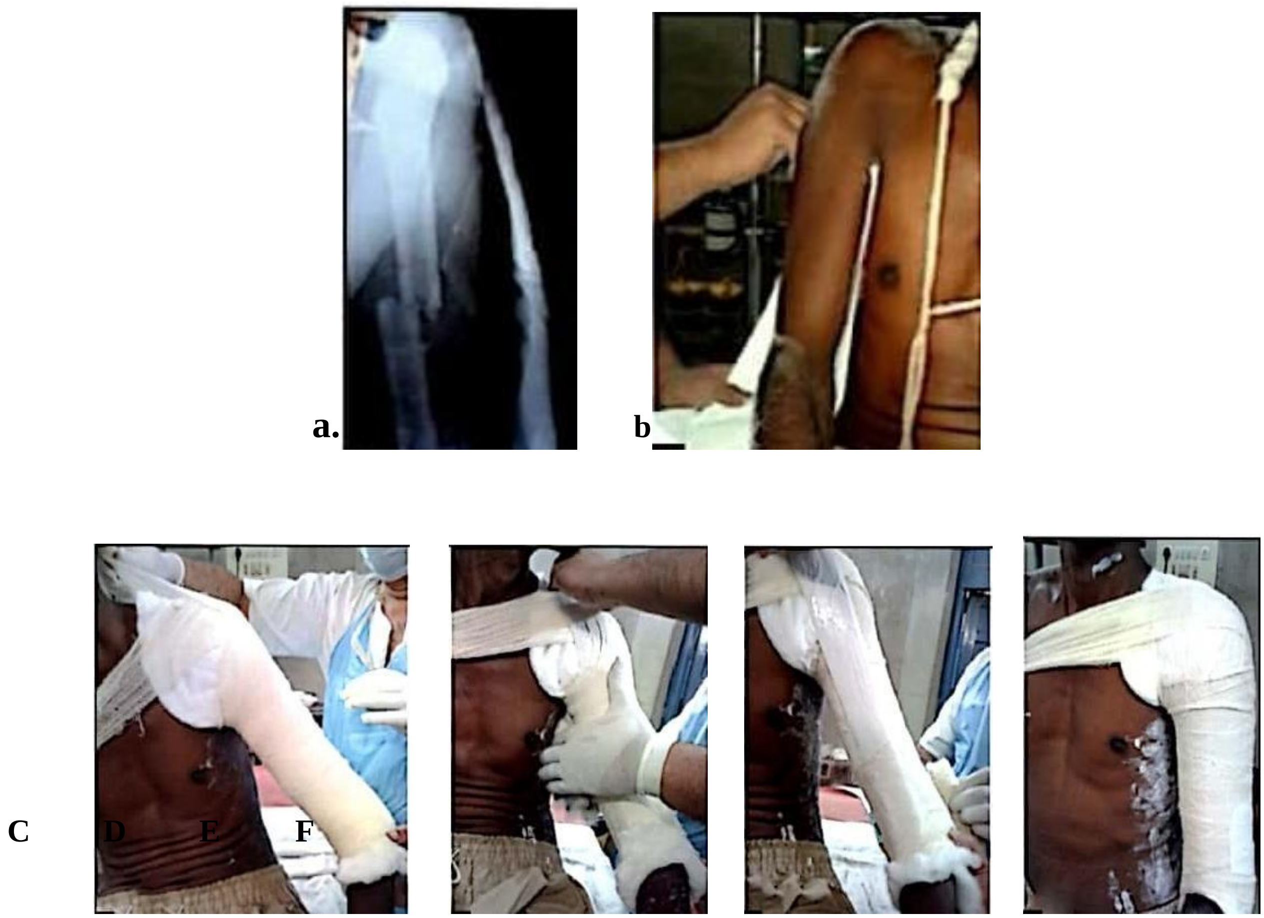

Fig (3): (a) X-ray of left arm with shoulder joint showing fracture of humeral shaft (b) Clinical photograph showing measurements of plaster of paris cast strip (medial) on the sound side. Clinical photographs showing (c) lateral and medial strips are applied (d) molding to correct residual deformities (e) anterior and posterior strips are applied (f) final picture

Shaft or diaphyseal fracture of the humerus is defined as extra articular fractures of the humerus excluding 5 cm in each ends. First reference on this issue is by Edwin Smith papyrus at about 3000 BC is contained in Breasted article published in 1932. Conservative treatment was only treatment continued for about 5000 years. In last 100 years, various operative techniques developed and been successfully used to manage difficult humeral

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diaphysealfractures. Initial classifications described are based mainly on the location and to some extent on morphology of the fractures. Subsequently AO classification combined them adequately but, while treating them, biological environments were paid less importance. The causes of diaphyseal fractures are simple fall, fall from height, sports injuries, road traffic accidents (RTAs) and direct blow.

AIM OF THE STUDY

The aim of this prospectively study is to establish the **"Functional Outcome of Ante-grade Intramedullary Inter-locking Nailing in Fracture Shaft of Humerus"** at the **Department of Orthopaedics**in **SreeBalaji Medical College and Hospital** , Chrompet, Chennai. The recruitment period of this study shall be from March 2017 to February 2018 (12 months). The follow-up period shall be for a minimum period of 8 months (range: 8 to 20 months).

ANATOMY

The shoulder girdle includes three bones (the scapula, clavicle, and humerus) and three joints (the gleno -humeral, acromio-clavicular [AC], and sterno-clavicular [SC] joints).

The scapula-thoracic articulation is also considered part of the shoulder girdle. For every 2° of gleno-humeral motion, approximately 1° of scapulo-thoracic motion occurs. The AC and SC joints also participate in this scapulo-humeral rhythm. As a result of this coordinated movement, the shoulder has a greater range of motion than any other joint in the body.

The **humerus**is the longest and largest bone of the upper extremity; it is divisible into a **long tubular diaphysis, a globular proximal metaphysis and a flattened distal metaphysis.** The humerusconsists of a large rounded head joined to the body by a constricted portion called the **neck,** and two eminences, the **greater** and **lesser tubercles.**

The Head (caput humeri) — the head, nearly hemispherical inform, is directed upward, medial ward, and a little backward, and articulates with the glenoid cavity of the scapula. The circumference of its articular surface is slightly constricted and is termed the **anatomical neck,** in contradistinction to a constriction below the tubercles

called the **surgical neck** which is frequently the seat of fracture. Fracture of the anatomical neck rarely occurs.

The Body or Shaft (corpus humeri) — the body is almost cylindrical in the upper half of its extent, prismatic and flattened below, and has three borders and three surfaces.

Borders — the **anterior border** runs from the front of the greater tubercle above to the coronoid fossa below, separating the antero-medial from the antero-lateral surface. Its upper part is a prominent ridge, the crest of the greater tubercle; it serves for the insertion of the tendon of the Pectoralis major. About its centre it forms the anterior boundary of the deltoid tuberosity; below, it is smooth and rounded, affording attachment to the Brachialis.

The **lateral border** runs from the back part of the greater tubercle to the lateral epicondyle, and separates the antero-lateral from the posterior surface. Its upper half is rounded and indistinctly

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marked, serving for the attachment of the lower part of the insertion of the Teres minor, and below this giving origin to the lateral head of the Triceps brachii; its centre is traversed by a broad but shallow oblique

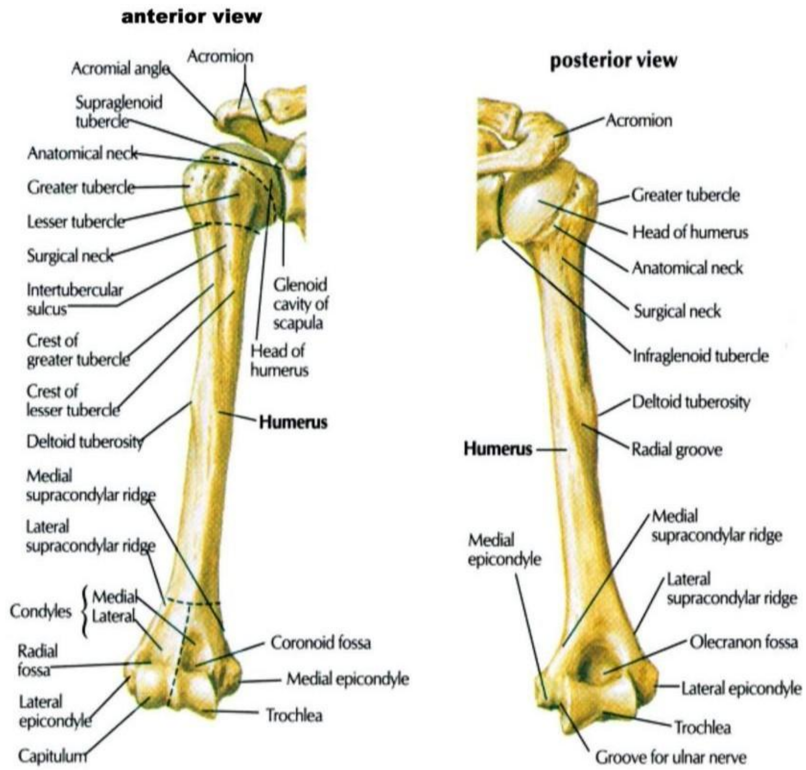

Fig. (5): Osteology of Humerus.

Depression, the **radial sulcus** (musculo-spiral groove). Its lower part forms a prominent, rough margin, a little curved from behind forward, the **lateral supracondylar ridge,** which presents an anterior lip for the origin of the Brachio-radialis above, and Extensor carpi radialislongus below, a posterior lip for the Triceps brachii, and an intermediate ridge for the attachment of the lateral inter-muscular septum.

The **medial border** extends from the lesser tubercle to the medial epicondyle. Its upper third consists of a prominent ridge, the **crest of the lesser tubercle,** which gives insertion to the tendon of the Teres major.

BIOMECHANICS

THE FRACTURE PER-SE:

Analysis of Fractures of the humeral diaphysis reveals the effect of muscular forces acting on the shaft at varying levels. In fractures occurring above the insertion of the pectoralis major, the proximal fragment is displaced into abduction and external rotation as a result of the action of the rotator cuff musculature. Fractures occurring in the interval between the insertion of the pectoralismajo r proximally and the deltoid insertion distally result in adduction of the proximal fragment and proximal and lateral displacement of the distal fragment. Fractures distal to the

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insertion of the deltoid muscle result in abduction of the upper fragment and proximal displacement of the distal fragment by unopposed musclecontraction. [17]

The energy absorbed by the humerus during a fracture is an important determinant of the amount of displacement. Low-energy fractures may be held in position by the internal splinting effect of the inter-muscular septa. The weight of the arm aids in preserving alignment and length in these low-velocity injuries. High-energy fractures result in comminution of the bone and disruption of the soft tissues, with loss of this internal splinting effect.

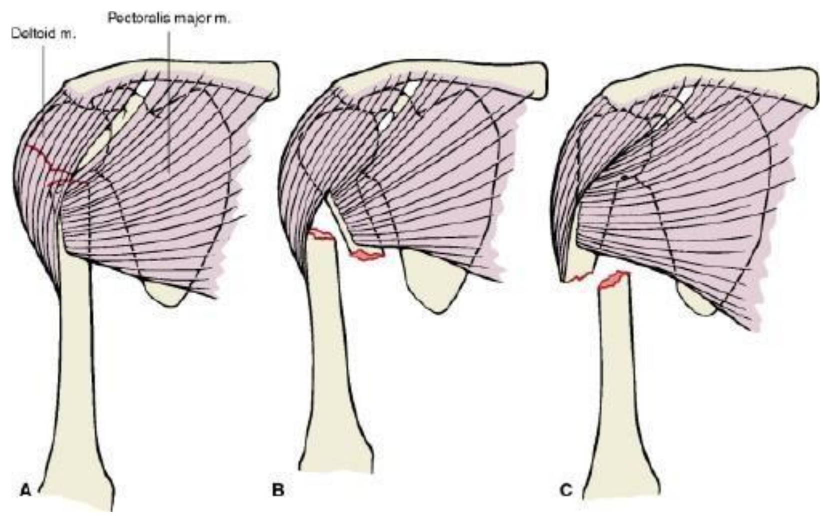

Fig (7): Displacing force vectors, depending on the level of fracture.

A consideration other than location of the fracture and the amount of energy absorbed or dissipated in the injury is the mobility of the shoulder and the elbow joints, which tends to minimize the effect of post-traumatic angulation and rotational deformities. It has been shown experimentally that the musculature around the humerus will accommodate 20 ° of anterior angulation and 30 ° of varus angulation without compromising function or appearance. The normal mobility in the shoulder and elbow joints will compensate for this degree of deformity. The humerus can easily accept 15 ° of mal-rotation and still function fully. The amount of shortening that can be accepted in fractures of the humerus without loss of significant function is approximately 3 cm.

IMPLANT

Kuntscher introduced the concept of elastic intra- medullary nailing based on the principle of elastic impingement (i.e. radial compliance). The nail, which has a slot, could be compressed while insertion. The nail will expand and occupy the entire medullary canal, once the insertion is complete. This was used in fixation of the femur and tibia. Even though his concept was successful in treatment of the fractures of lower limb, it was found to be not effective in treating the humeral diaphyseal fractures. Further mechanical testing had shown that these nails are stable on the basis of three-point fixation rather than radial compliance.

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Significant deforming mechanical stress is exerted on the bone by the muscles getting attached on to it. These stresses may be bending stress, compression stress, rotational stress and distraction stress.

An intra-medullary nail being located in the centre of the bone provides rigid temporary stiffness to the bone. It acts as an internal splint and works as a load-sharing device. Permitting load transmission across the fracture site and thus promoting fracture healing. These nails are best suited to control the bending and translational stresses. Since it shares the center of rotation of the bone it is not effective in controlling the rotational stress of the bone.

This can be achieved by additional fixation like de-rotation plates, interlocking screws or pins.

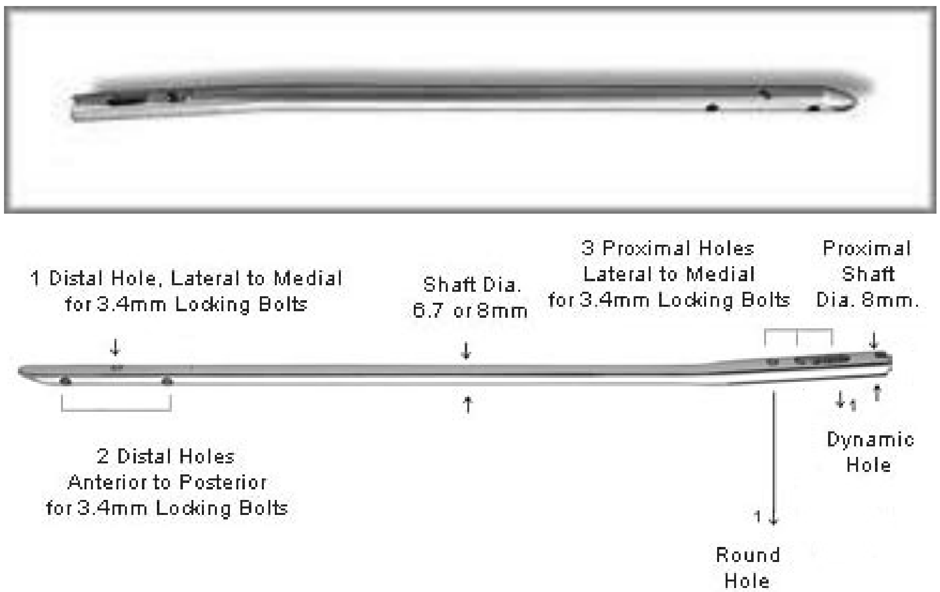

Fig.(8): Implant design.

The introduction of inter-locking nail has made the use of unlocked nails obsolete. Screw insertion at the two ends of the humeral nail provides for the rotational stability by inter-locking the nail with the proximal and the distal fragment. Inter-locking essentially maintains the bone length and more importantly controls the rotational stability at the fracture site[1]. This is very significant in the Humerus, as the stresses are more of a rotational type, rather than a compression distraction type. Static locking achieves a stable bridging fixation.

In bridging fixation the implant extends across the fracture site and is fixed to the major proximal and distal bone fragments by locking screws away from the fracture site.

NAIL DESIGN1[19]:

The shape and diameter of the nail determines its bending and torsional strength. The diamond shape nail has greatest bending resistance. A clover leaf nail resists bending most effectively. The presence of slot does not reduce the bending stiffness of nail, but if reduce torsional stiffness. The hollow core, of the nail admits thick and strong guide wise that fills the space completely. So

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that nail remains centered in the canal and passes smoothly into the distal fragment across the fracture site.

DIAMETER:
The most important factor in determining nail strength is the nail diameter. Strength is directly proportional to diameter. Bending rigidity is proportional to a third power of nail diameter. Torsional rigidity is propositional to a forth power of diameter.

CURVES:
The long bone have a curved medullary cavity. If a straight nail is inserted into such a cavity, they will bend, produce stress and fracture of bone. So nails are contoured to accommodate these natural curves.

HOOP STRESS:
Circumferential expansion of bone is called Hoop stress. The greater the insertion force the larger the hoop stress. Excess hoop stress can split the bone converting a simple, transverse fracture into comminuted fracture.

MATERIALS AND METHODS

This prospective study was conducted on 35 patients who came to Orthopaedics OPD and casualty at SreeBalaji Medical College and Hospital, Chrompet from March 2017 to February 2018. Hence the recruitment period for patients was 12 months. The study concluded in October 2018, so that the minimum follow up period shall be 8 months (range 8 to 20 months).

INCLUSION CRITERIA:
Our patients (skeletally mature male and female) were selected based upon following criteria:

1. In the age group 31 to 55 alone were included.
2. Closed fracture shaft of humerus
3. An angulation of more than 15 degrees after closed reduction
4. Poly-trauma
5. Patients with fracture pattern falling in Type 12A & Type 12B of AO/OTA classification of Shaft of Humerus fractures.

EXCLUSION CRITERIA:

1. Age less than 31 and age more than 55 years
2. Associated neuro-vascular compromise
3. Patients with fracture pattern falling in Type 12C of AO/OTA classification of Shaft of Humerus fractures.

HISTORY TAKING:
Humeral shaft fractures typically result from falls, twisting injuries, penetrating injuries, and pedestrian or motor vehicle crashes. In a poly-trauma patient, the history is infrequently available from the patient because of the patient's medical condition and associated injuries. In such situations, delineating the mechanism of injury provides important clues to the nature of the patient's injuries[32].

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In addition to the mechanism of injury, information pertaining to co-morbidities such as previous neurologic injury, metabolic bone disease, malignancy, or lower extremity injuries (requiring use of the upper extremities for ambulation) should be obtained from either the patient or family members [37].

PHYSICAL EXAMINATION:
In general, the treatment of a humeral fracture is a relatively a low priority in the resuscitation of a severely injured patient, which should proceed according to the guidelines of the Advanced Trauma Life Support (ATLS) protocol[35]. Following stabilization of the patient, attention is turned to the affected arm.

The neuro-vascular status of the entire limb should be evaluated at multiple levels. Careful motor and sensory examination of the radial, ulnar, and median nerves is essential. A careful clinical examination is the most useful way to follow a radial nerve injury. Attention should be directed to motor function in the brachio-radialis and extensor carpi radialislongus muscles. Electro-myography and nerve conduction studies may also be used to follow-up the recovery of injured radial nerves [36]. However, these studies reveal nerve recovery only, at most, 1 month before it is detectable by clinical examination. In addition, they cannot identify severed nerves.

The soft tissue compartments of the arm and forearm should be examined, and the possibility of a compartment syndrome should be considered.

The shoulder and elbow joints should be carefully evaluated. Abrasions, lacerations, or puncture wounds on the arm should raise suspicion of an open injury necessitating emergency management.

INVESTIGATIONS:
Routine investigations like haemogram, Blood Sugar, Urea, Creatinine, Serum electrolytes, X-Ray Chest, ECG, BT/CT was done. In addition, HIV and HBsAgwas done. In warranted cases, Cardiology and Nephrology opinion was sought. In the presence of skin lesion, Dermatology opinion also was sought. All the patients were medically fit for Anesthesia and Surgery.

RESULTS

In the 12 months of recruitment period and confirming to our inclusion criteria, we were able to recruit 35 patients, who qualified for ante-grade humeral nailing for humeral diaphyseal fractures.

Table (2): Age and Sex Distribution.

AGE IN YEARS	**MALE**		**FEMALE**		**TOTAL 'n' (% age)**
	NO. OF PATIENTS 'n'	**% age**	**NO. OF PATIENTS 'n'**	**% age**	
31- 35	6	17.16	1	2.86	7 (20. 00)
36- 40	7	20.00	1	2.86	8 (22. 86)

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41- 45	5	14.28	1	2.86	6 (17. 14)
46- 50	4	11.43	3	8.56	7 (20. 00)
51- 55	3	8.56	4	11.43	7 (20. 00)
TOTAL	25	71.43	10	28.57	35 (100)

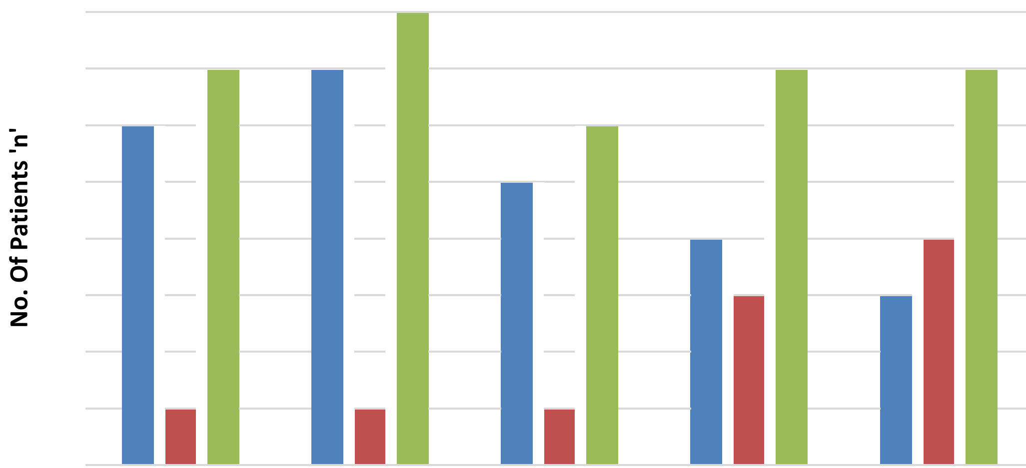

Fig. (16): Age and Sex Distribution.

Of the 35 patients, 71.43 % (n = 25) were male and the remaining 28.57 % (n=10) were female patients. Thus establishing a male to female preponderance ratio of 5:2. The patient distribution in the 5 age groups, when considered as a sample, total was almost equal at 20% $\pm$ 2%. But the striking feature was that while the male patients showed a sequential decrease from age group 31 to 55 years, in striking contrast, the female recruits jumped 3 to 4 times in the age 46 to 55 years.

Table (3): Sidedness of the Injury Distribution.

SIDEDNESS OF FRACTURE	MALE		FEMALE		TOTAL 'n' (%age)
	'n'	%age	'n'	%age	
RIGHT	20	57.14	7	20.00	27 (77.14)
LEFT	5	14.29	3	8.57	8 (22.86)
TOTAL	25	71.43	10	28.57	35 (100)

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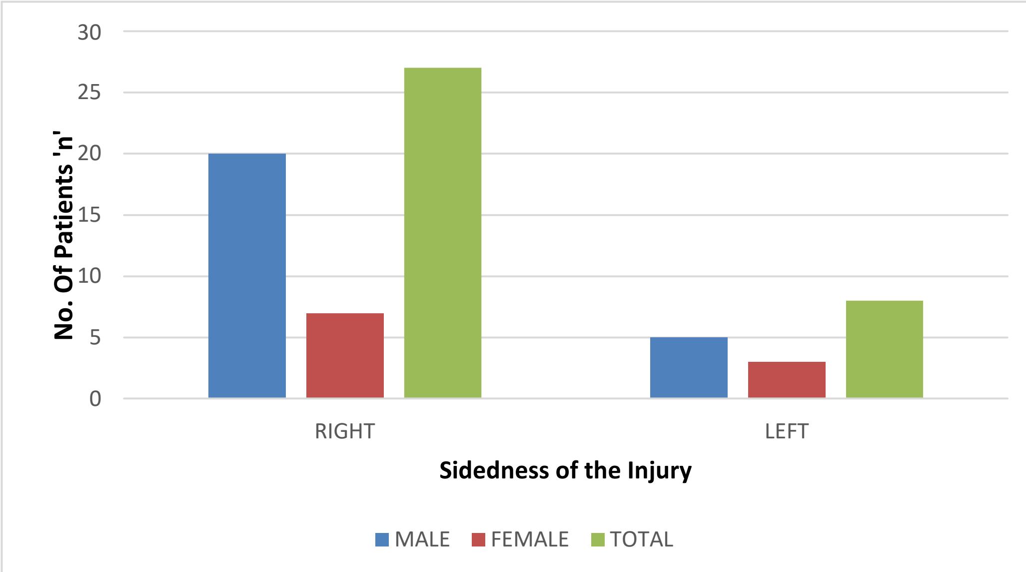

Fig. (17): Sidedness of the Injury.

With regard to the sidedness of the injury, 77.14 % (n=27) cases had the diaphyseal humeral fractures on the right side and the remaining 22.86% (n=8) on the left side.

CASE ILLUSTRATION

NAME	:	S1
AGE/SEX	:	5O/MALE
MODE OF INJURY	:	RTA
EXTREMITY	:	LEFT
ASSOCIATED INJURY	:	NIL
AO CLASSIFICATION	:	A2
TIME INTERVAL BETWEEN INJURY AND SURGERY	:	9 DAYS
TIME OF UNION	:	16 WEEKS
RANGE OF MOVEMENTS	:	FULL
COMPLICATIONS	:	NIL
ASES CRITERIA	:	EXCELLENT
RODRIGUEZ-MERCHAN CRITERIA	:	EXCELLENT

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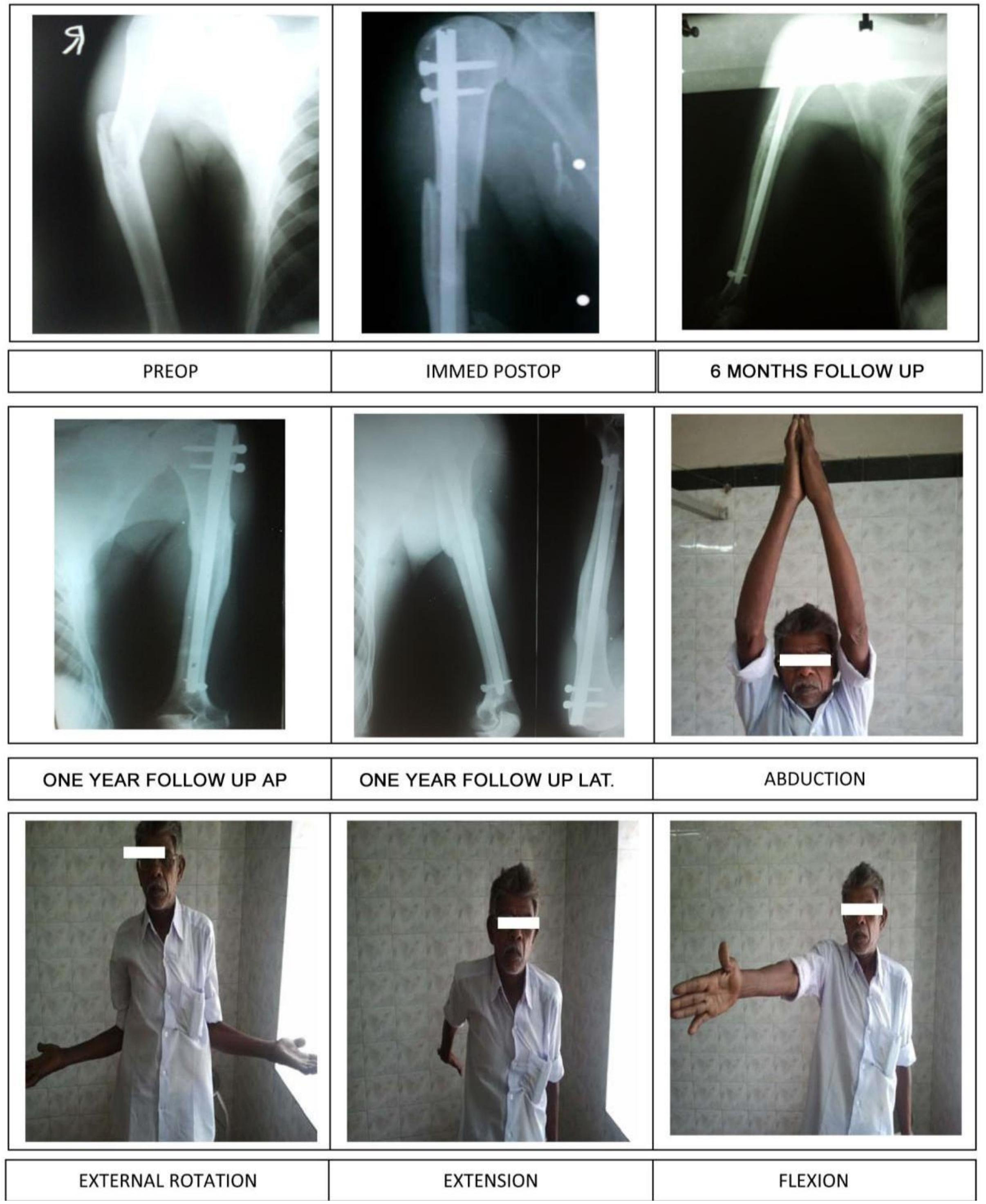

Fig. (26): Case I

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CASE – II

NAME	:	S2
AGE/SEX	:	39/MALE
MODE OF INJURY	:	RTA
EXTREMITY	:	RIGHT
ASSOCIATED INJURY	:	IPSI-LATERAL CLOSED# BB FOREARM
AO CLASSIFICATION	:	B 2
TIME INTERVAL BETWEEN INJURY AND SURGERY	:	5DAYS
TIME OF UNION	:	17 WEEKS
RANGE OF MOVEMENTS	:	FULL
COMPLICATIONS	:	NIL
ASES CRITERIA	:	EXCELLENT
RODRIGUEZ-MERCHAN CRITERIA	:	EXCELLENT

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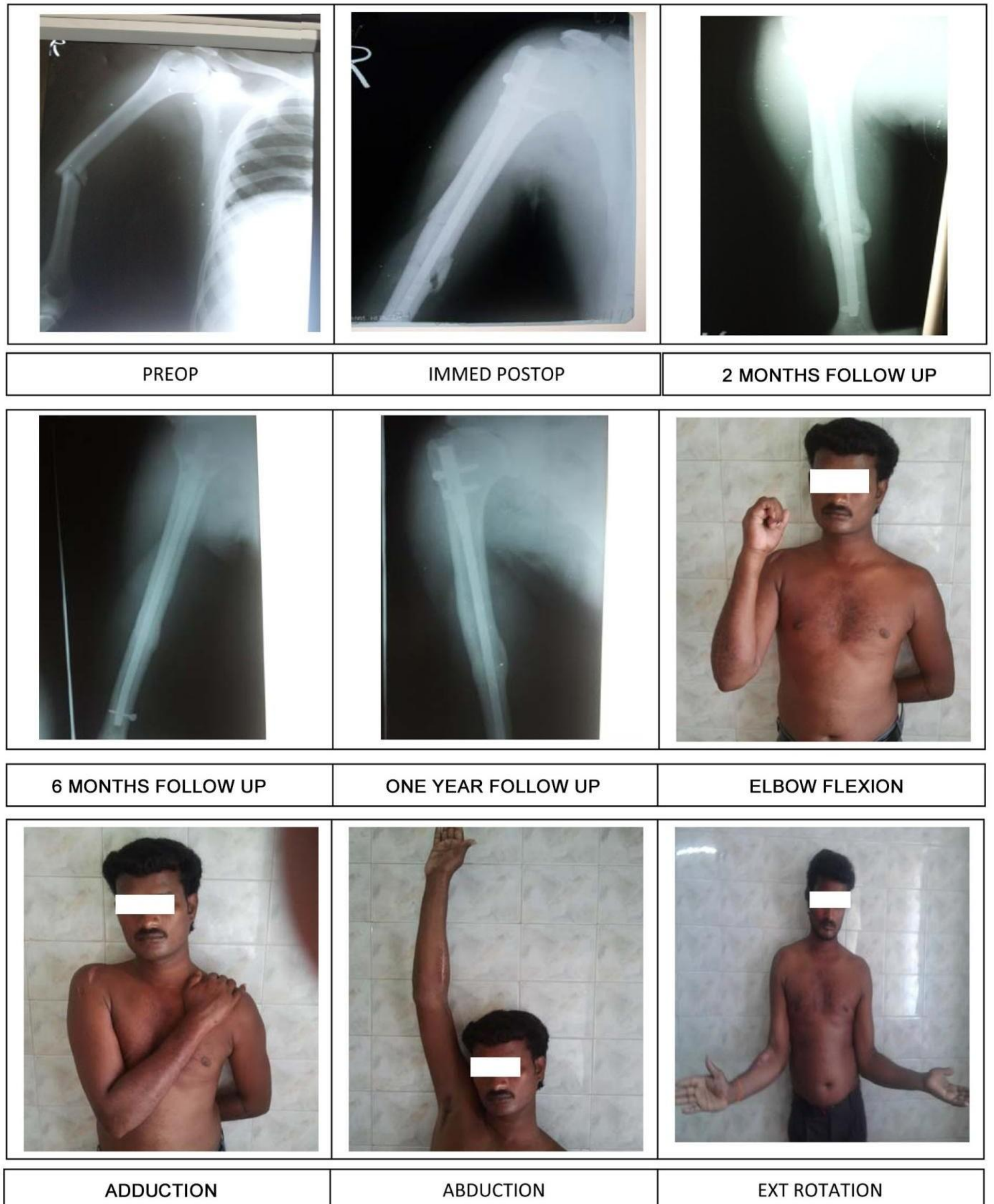

Fig. (27): Case II

Discussion

DISCUSSION

The incidence of humeral diaphyseal fractures is pretty high at 1.3 per 10,000 per year [14]. There is overall a bimodal distribution. For the males it peaks between age of 20 to 30 years and strikingly distinct peaks for females between age of 60 to 70 years [15].

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The incidence has significantly increased in the last 2 decades with a growing elderly population [16].

Non-operative management of humeral shaft fractures using functional cast bracing was until a decade ago accepted as a gold standard of treatment [17]. Splints and casts which generally included the shoulder and elbow shall eventually result in stiffness, once the treatment regimen were completed at 4 to 5 months. Sarmiento et al;[8] recognized this potential morbidity, and popularized his "Functional Cast Brace" system. This he suggested that if it be applied between day 7 to day 14, once the acute pain and swelling subsided.

The FCB for the humerus is usually a prefabricated polypropylene sleeve, which encompasses the injured arm, allowing for compression of the arm soft tissue by way of adjustable straps of Velcro, but significantly does not inhibit shoulder or elbow movement.

Fig. (32): Functional cast brace

Sarmiento et al; [8] had concluded whilst achieving union of above 90% of cases, preserve ROM at elbow and shoulder. Ali E et al; [18](2015) and Derand A J et al;[19] started questioning the role of FCB for humeral shaft fractures of all types. Derand A J et al; [19] concluded that "in certain clinical scenarios, these fractures may well be served with compression plating".

Huttunen T T et al; [20] (2012) carried out a study in finland between 1987 and 2009, had suggested humeral shaft fractures being treated surgically in the last two decades.

Open reduction and plate fixation and intra-medullary nailing are the most commonly opted for surgical fixations of humeral diaphyseal fractures.

Vennettilli et al; [21] (2011) had concluded that there are distinct advantages and disadvantages in both the most often sought for operative regimens.

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Fig. (33): Plate fixation and IMIL nailing of diaphyseal fracture of humerus.

Heinman et al; [22](2010) did meta-analytical study of 5 trials which included 237 patients and demonstrated that fewer complications were encountered in the open reduction and plate fixation group.

The systemic review of Nicholas Clement et al;[23](2015) failed to identify any properly randomized control trials. They observed that there is a void in the literature currently.

The study by Denard et al; [28] was an eye opener. They published that in operated group the non-union rates were at 9% which when compared to the operated group was at a high of 21%. This was pretty significant! Their mal-union rate for operative vs non-operative was 1% vs 13%. There was however no demonstrable significantly identifiable difference with regard to rate of infection, radial nerve palsy, time to union or the range of movement achieved between either group. Ding et al; [24](2014) had cited smoking as an important cause for non-union. This was by far the

best comparative study till date and significantly supports operative intervention of humeral diaphyseal fractures in specific clinical scenerios.to concretise the concepts postulated by Ding et al; the study by Mahavier K C et al;[25] (2013) affirmed that there are equal complication rates between the operative and non-operative group.

The rate of non-union for humeral diaphyseal fractures treated either conservatively or operatively ranges from 0-23%[8,26]. Surprisingly however there is one consensus in the literature that non-unions when operated give good to excellent outcomes in over 90% of cases [27,28].

Findings of our study (2017 -2018) can be summarized as follows:

a) Our male to female ratio, in the sampled age group of 31 to 55 years, was 5:2. Hence there was a clear male dominance in the sampled total of n=35 patients. On critical analysis of this, while the male preponderance dropped when we move up the age scale, many female recruits had joined the study beyond age 46 to 55 years. Thus this bimodal model is as distinctly reflected in our study too.
b) Right sided injuries predominated at 77.14% (n=27) in our study.

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c) In the younger age group of 31 to 45 RTA was the predominant mode of injury. As we move up the age scale from 46 to 55 years, trivial fall constituted the majority of recruits, who also happened to be females.

d) As per the 2018 AO-OTA adult diaphyseal classification system adopted in our study, type 12 B
3 constituted 40% (n=14) cases, followed closely by type 12 B 2 at 31.42 % (n=11).

e) Our average injury to surgery time lapse was at 5.9 days (range : 0 to 11 days). From surgery to discharge our time of hospitalization was at 14.7 days (range : 8 to 19 days)

f) 34.29 % (n=12) cases in our series of 35 cases, had an associated skeletal injury.

g) Our average time for bone union in 97.14% (n=34) cases was 16.8 weeks (range : 12 to 21 weeks). We encountered 2.86% (n = 1) cases of non-union in a 55 year old female, who had hysterectomy done at age of 38 years for DUB at 6 months and was appropriately subjected to LCP with bone grafting which united in 5.3 months. This particular case type 12 B 3 AO-OTA grade at index fixation.

h) Of the total complications that we encountered, 8.58
% (n=3) were minor complications like; superficial wound infection, shoulder impingement and radial nerve palsy. All resolved without affecting the final clinical or functional outcome. We did encounter a 2.86% (n = 1) of major complications of non-union, as described earlier and resolved with resurgery.

i) Our functional and clinical outcomes by the rodriguez-merchan criteria was at 88.56 % (n=31) good to excellent, 8.56% (n = 3) of fair and 2.86 % (n=1) of poor result.

CONCLUSION

The deficiency in the currently available literature comparing the outcomer of non-operative and operated cases of diaphyseal humeral fractures. This is concluded that equal complication rates can occur with operative and non - operative management of these fractures. The Study established equal union rates with plate-osteosynthesis and IMIL nailing. Our short term experience with stringent inclusion criteria for indicative diaphyseal humeral fractures have yielded appreciable results, and it is recommended to be held as a worthy alternative to plate osteo-synthesis. Our study would want to emphasize that in the young non-porotic bone without much displacement and angulation functional cast bracing`s role stands its own deserved consideration.

Funding: No funding sources

Ethical approval: The study was approved by the Institutional Ethics Committee

CONFLICT OF INTEREST

The authors declare no conflict of interest

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