Functional Outcome Of Treatment Of Intra Articular Distal Humerus Fracture With Open Reduction And Internal Fixation By Bicolumnar Locking Plate

by

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Dissertation submitted to

In partial fulfillment for the degree of

MASTER OF SURGERY

IN

ORTHOPEDICS

Under the Guidance of

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2019

ABBREVIATIONS

M	:	Male
F	:	Female
R	:	Right
L	:	Left
RTA	:	Road Traffic Accident
MVA	:	Motor Vehicle Accident
OTA	:	Orthopaedic Trauma Association
LCP	:	Locking Compression Plate
MCL	:	Medial Collateral Ligament
LCL	:	Lateral Collateral Ligament
3D	:	Three Dimensional
CT	:	Computed Tomogram
MEPS	:	Mayo Elbow Performance Score

ABSTRACT

AIMS AND OBJECTIVES

1. To assess the functional outcome and to study the results, complications of the surgery after surgical management of intra-articular fracture of distal humerus.
2. To assess the range of movements, pain and union.

MATERIAL AND METHODS

A prospective study was done to evaluate the functional outcome of bicolumnar locking plating technique in treatment of distal humeral fracture and to analyse the results.

The study group consists of 23 Patients with distal humeral fracture, who underwent osteosynthesis with bicolumnar locking plating technique between 1st November 2017 - 31st May 2019 at ______________________ Medical College, ____________, _____________.

RESULTS

In our study of 23 cases, there were 15 male and 8 female patients with mean age of 38.5 years. 65.2% of the cases admitted were due to motor vehicle accident, 21.7% due to accidental fall and 13% due to fall from height with right side (73.9%) being more commonly affected side. Mayo Elbow Performance Score was 83.3% in our study and the mean arc of motion was 107°. Satisfactory rate of 82% was achieved with this study.

CONCLUSION

Our study concludes that bicolumnar locking plating in patients with intra-articular distal humerus fracture resulted in good to excellent functional outcome in avbout 82% cases in our study with 107 of mean arc of motion and stability. Absence of implant failure and non-union may be attributed to the highly stable construct system achieved by bicolumnar locking plating. Hence bicolumnar locking plating can be used as a successful technique for internal fixation of these complicated fracture.

KEY WORDS: Distal humerus intra-articular fracture, bicolumnar locking plating, olecranon osteotomy

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INTRODUCTION

Fracture of the distal humerus accounts for 2-6% of all fracture and 1/3 of all humeral fracture. “Intraarticular distal humerus fracture is rare accounting 0.5% of all fracture”.[1] In this growing elderly population and an extremely active young population, the incidence of distal humeral fracture is increasing and is seen to have a bimodal distribution .

“In young adults, most distal humerus fracture occur from high-energy trauma like side-swipe injuries, motor vehicle accidents(MVA) etc .In elderly persons with more osteoporotic bone, these injuries occur from simple falls”[2]

Intra-articular bicondylar fracture of distal humerus (Type C, AO classification) are difficult to manage. Malunion, stiffness and osteoarthrosis are common. Many methods like close reduction, hanging arm cast, traction, limited internal fixation, open reduction with rigid fixation and elbow replacement have been described. In the last few decades, the popularity of internal fixation of this fracture is growing fast. Being intra-articular fracture the importance of anatomical reduction is vital. Surgical treatment gives a chance for accurate anatomical reduction of the joint surface. Most of the recent reports emphasize that accurate restoration of the articular surface anatomy, stable fixation and early mobilization gives the best result. We are reporting the result of internal fixation of these fracture in young adults.

In this era of modern orthopaedics, despite various advances, distal humeral fracture remains one of the most challenging injuries to treat. Composite problems in distal humerus fracture management include frequent articular involvement, metaphyseal communition, bone loss and osteopenia. The fore mentioned issues along with the complex three dimensional geometry, poses a great difficulty in internal fixation. Poor outcomes like contracture, non-union, high failure rate are noted with old internal fixation techniques. Attempt to achieve painless, stable yet mobile elbow requires a systematic approach for open reduction and internal fixation[6 7 8 9 10 11].

The treatment of these fracture is still debated, and an ongoing quest for the ideal solution still remains. The chances of functional impairment and deformity are very high following conservative treatment of distal fracture of the humerus[3,4,5]. In the elbow, the principles of good anatomical alignment, absolute stabilization and early mobilization is of prime importance than in any other joint. Majority of current recommendations in the management of distal humeral fracture include open reduction and internal fixation (ORIF) with plates and screws. ORIF of the fracture restores anatomical alignment of the fracture fragments and permits early range of motion (ROM) exercises which helps in the return of a functional ROM of the elbow postoperatively. To restore anatomical alignment of the distal humerus, over a time various forms of internal fixation have evolved. Two-plate fixation recommended by majority of authors provide adequate stability and allow for adequate restoration of anatomy.

The guidelines proposed by the AO/ASIF group for fixation of distal humeral fracture are the gold standard till now. Using these fixation techniques, different authors have reported unsatisfactory results in 20% to 25% of patients due to implant failure occurring, if mobilized early[6,7,8,18,19,20].

As a result of ongoing search for a more secure technique, later evolved the concept of bicolumnar locking plating, which involves placing one plate along the medial column of the distal humerus and the other plate along the lateral column, with the screws in the distal fragment interdigitating with each other, restoring the *'tie-beam arch'* of the distal humerus. Several biomechanical studies have proven the superiority of bicolumnar locking plating over traditional plating methods, yet there are only fewer clinical studies to analyse the functional outcome of parallel plating in distal humerus fracture fixation[21,24] .

AIMS AND OBJECTIVE

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2. To assess the range of movements, pain and union.

HISTORY

"Distal humeral fracture represents a constellation of complex articular fracture, resulting from severe trauma to elbow, which are difficult to treat. The complex three dimensional structure of distal humerus poses a challenging task for reconstruction if fractured. The diversity of views on the subject is an indication of poor quality of results. Among patients, who sustain a fracture in the distal humerus, there is a bimodal distribution, with respect to age and gender, with peaks of incidence in

males aged 12 to 19 years and females aged 80 years and over. The proportion of elderly patients who sustain these injuries is increasing, and this trend will continue. With this change in population, come fresh challenges for reconstruction, including poor bone quality, fracture comminution, and reduced capacity for rehabilitation. Injury to distal humerus occurs from a spectrum of low velocity to high velocity injuries. Low velocity injuries, are simple domestic falls in middle-aged and elderly females, in which the elbow is either struck directly or axially loaded, in a fall onto the outstretched hand"[25,26]. "Road-traffic accidents (RTA), and sport injuries, are more common cause of high velocity injury, in younger males. These patients, often have open fracture and other injuries, (17% other orthopaedic injuries and 5%multisystem injuries)"[25] . These, young population when injured, adds to the socio-economical burden of the community.

In 1811, Desault was the first one to come to a conclusion that, these fracture are the most difficult of all fracture, with treatment options, ranging from essentially no treatment to replacement of joint. In early 20th century, many authors like Hitzrot (1932), Eastwood (1937), Evans (1953) Watson jones (1956), Deplama (1959) and Brown & Morgan(1971) were in favour of conservative approach. But, as the results of conservative approach were, incongruous joint, non-union, malunion, and stiff elbow, most condemned conservative management in all type of fracture, and advised surgical management. The goals of treatment are a stable, painless and functionally useful elbow, and this can be achieved by proper anatomical restoration of articulating surface by open reduction, and stable internal fixation followed by early rehabilitation.

It was Van Gordner (1940) and Cassebaum (1952), who first approached these fracture, by posterior means. They emphasized the advantages of posterior approach over others as-

1. It affords a more adequate exposure of fractured fragments
2. It allows more freedom in the use of implants
3. It involves dissection of soft parts that contain no major neurovascular structures, the ulnar nerve have been identified and retracted previously
4. It is the only approach that can give clear view of the joint surface
5. With this, not only the posterior surface, but also the borders of distal humerus can be utilized for fixation purposes
6. Less number of cutaneous nerves, when compared to medial and lateral approaches[48].

The trans-olecranon osteotomy approach, which is considered to be the gold standard, for management of distal humeral fracture was, first employed by "Cassebaum in 1952 and achieved good results. Other approaches which are proved useful, include the paratricipital (Alonso-Llames)" [27 28], triceps-reflecting (Bryan- Morrey)[29], triceps-reflecting anconeus pedicle (TRAP)[30],triceps- splitting[31,32]. "On the basis of the available evidence, a Grade-C recommendation can be made for the use of the paratricipital approach for extra-articular or simple intraarticular fracture. There is fair evidence to suggest that, the use of a tricepssplitting approach leads to functional outcomes, equivalent to those provided by an olecranon osteotomy, while potentially avoiding the complications associated with the olecranon osteotomy, rendering this as a Grade-B recommendation"[33].

"Chen G in 2011 came to a conclusion after analysis of 67 patients, that ORIF via the triceps-sparing approach confers inferior functional outcomes for intercondylar distal humerus fracture in patients over the age of 60 years, for whom the olecranon osteotomy approach may be a better choice. However, for patients less than 60 years of age, especially those less than 40 years of age, either approach confers satisfactory outcomes"[34]. In 1953, Mervin Evans treated distal humeral fracture by reduction and fixation of the articular surfaces, followed by attaching it to the humeral shaft. Restoration of articular surface is of prime importance, and any residual displacement between the fixed articular fragments and the shaft, will not have great deleterious effects on the ultimate function. Rehabilitation of the injured elbow, following surgery is equally important,

as elbow is prone for stiffness when immobilized for long time[35]. For early rehabilitation, the fracture should be fixed with a stable construct. "The stable fixation is achieved by internally fixing the reconstructed articular block, with the shaft by plating on both pillars"[12]. "Without this dual plate arrangement, stability of fixation can be inadequate, and this has been proven by many studies"[7 13 14 15 16 18 36]. These plates can be placed either, posteriorly on lateral side and over ridge, on medial side (perpendicular plating) or over ridges on both sides (parallel plating). In the last quarters of the century, improved outcomes of surgery for distal humeral fracture were reported, AO-ASIF group set out their principles of anatomical articular reduction and rigid internal fixation, through their perpendicular plating techniques.

“In 1990, Helfet, Hotchkiss did biomechanical analysis of the perpendicular plating technique and added creditability to this technique. A number of subsequent clinical studies, revealed nearly 75–85% good to excellent results with 90–90 plating”[13]. “In 2006, Doornberg et al concluded from a long term follow-up study of 19 years, results of open reduction and internal fixation of 19 Type C fracture of the distal part of the humerus are similar to those reported in the short term. This suggests that the results of surgical fixation are durable over time”[47].

“In 2001, O’Driscoll et al defined the principles of fixation of these fracture using bicolumnar plating by parallel plating technique and defined two goals that should be met: First, fixation within the distal fragment must be maximized, and second, all fixation in distal fragments should contribute to stability between the distal fragments and the shaft. In addition, he defined eight technical principles by which these goals are met”[12]

Eight Technical Principles in Distal Humerus Fixation

Principles concerning screws in the distal fragments (articular segment)

1. Every screw in the distal fragments should pass through a plate.
2. Every screw should engage a fragment on the opposite side that is also fixed to a plate.
3. As many screws as possible should be placed in the distal fragments.
4. Each screw should be as long as possible.
5. Each screw should engage as many articular fragments as possible
6. The screws in the distal fragments should lock together by inter-digitation, creating a fixed-angle structure.

Principles concerning the plates used for fixation

7. Plates should be applied, such that compression is achieved at the supracondylar level for both columns.
8. The plates must be strong enough and stiff enough to resist breaking or bending before union occurs at the supracondylar level.

Figure 1- 8 technical principles of bicolumnar plating

All these principles can be achieved by using bicolumnar plate orientation [12], while the principle of locking of screws by interdigitation in the distal fragment is limited in orthogonal plate orientation. Linking the plates together through the bone with screws, thereby creating the architectural equivalent of an arch, offers the greatest biomechanical stability for comminuted distal humeral fracture

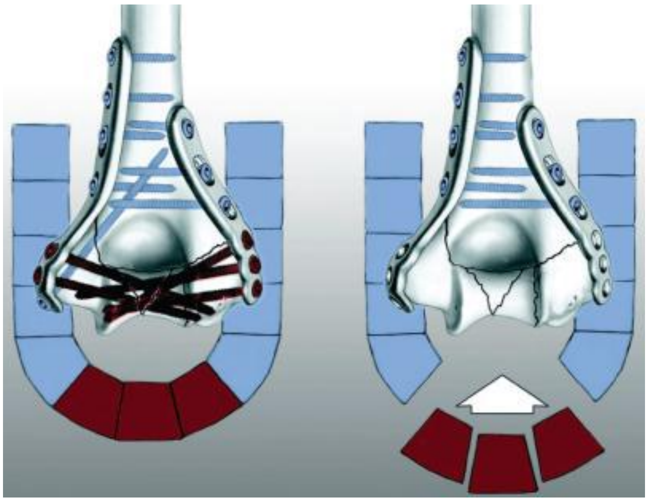


Figure2- Interdigitating screws restoring keystone integrity of the arc

The arch is formed by inter-digitation of locking screws passing through the distal fragments from both plates in the sagittal plane. Small osteochondral fragments can be fixed with countersunk screws, headless screws or absorbable screws. Before the invent of principle based parallel plating, perpendicular plating proposed by AO-ASIF was followed universally.

REVIEW OF LITERATURE

1. “After bicolumnar plating concept was introduced, numerous biomechanical studies were conducted between parallel and perpendicular plating for validation of the superior one”[39, 40]. Of these mechanical studies, two studies by Schemitsch et al (1994) and Self et al (1995) , Arnader (2008) showed parallel plate fixation to be substantially more stable than 90-90 plate fixation[21,39], and two demonstrated no difference[23,40].

2. Zalavras et al[37] (2011) concluded that higher degree of stiffness and higher degree of resistance in torque, cyclical varus loading axial and sagittal loading to failure was exhibited by parallel plating compared to orthogonal plate constructs.

3. “Many studies have documented 20% to 25% of unsatisfactory outcomes after the usual orthogonal plating”[6,7,8,18,19,20]. Henley et al[6] reported failure in 5 of 33 patients in his series, 5 of 88 fracture in his series by Letsch et al.[8], 3 of 57 reported on by Holdsworth and Mossad1[9], 9 failures in 72 cases “in the series of Wildburger et al.[38], and 16 of 96 reported on by Sodergard et al”.[35]. “The cause of failure being, less number of screws in distal lateral column, leading to loss of screw purchase, with resultant instability at both columns, causing non union at supra-condylar level”[6,13,17,20,21] .

4. “There were no failures of fixation in series of O Driscoll’s parallel plating.The perpendicular technique requires less soft tissue dissection, technically easy and the reports of non-union, in this technique are stastically insignificant. Though, parallel plating is more biom echanically stable than

perpendicular as per cadaveric bone studies, clinical comparison of these two plates in large groups is not available till date”[12,22].

5. “The Various plates that are available for fixation are Locking compression plates(LCP), 3.5 mm reconstruction plates (simple and locking), one third tubular plates, lambda plates and precontoured distal humeral plates (parallel and perpendicular)”[43]. Deshmukh and Deivendran et al[43] in 2010 showed less implant failure with distal humeral locking plates .“The pre-contoured geometry allows easier reduction and saves operating time in fixation of these complex fracture”[44].

6. A study by Corradi A et al[42] in the same year compared the effectiveness between distal humeral locking compression plates and conventional reconstruction plates showed no significant differences between the two fixation methods based on clinical outcome, complications and function of the affected limb . “The principle of each long screw engaging a fragment on the opposite column fixed by a plate of the ipsilateral column creates a locked arch even without a non-locking screw alleviating the need of a locking plate”[42]

7. I Ibomcha Singh *et al*[45]., in their study of “twenty two cases of type C intra articular fracture of distal humerus showed that all fracture united at 13 weeks,mean loss of extension was 28^0,mean range of movements achieved was 106^0.They concluded that internal fixation with precontoured Locking Plates is a good method of treatment to get restoration of articular surface anatomy,stable fixation and early mobilization”[45].

8. Imatani *et al*[46]., in 2005, conducted study on 17 patients aged older than 70 years with displaced intercondylar fracture treated with customized AO-Small T-Plate and transcondylar screw showed excellent results in 3 cases, good in 11 and failed in 3 by modified, Cassebahum's, rating scale. They concluded new surgical technique with AO-Small plate and transcondylar screw provided good stability even in case with small osteoporotic fragment[7].

9. Joaquin Sanchez-Sotelo *et al*[47].,in 2007, in their study of internal fixation of distal humerus fracture with a Principle-based parallel plate technique concluded "that stable fixation and a high rate of union of complex distal humeral fracture can be achieved when a Principle-based surgical technique that maximizes fixation in the distal segments and stability at the supracondylar level,is employed. In this study the mean MEPI score was 85 points"[5].

10. Job N.Doornberg *et al*[48]., in 2007, evaluated the functional outcome of thirty patients at an average of 19 years. Average American Shoulder and Elbow Surgeons score(ASES) was 96 points,Disability of Arm Shoulder and Hand (DASH) score was 7 points,and Mayo Elbow Performance Index (MEPI) score was 91points. It was concluded "that the long term results of open redeuction and internal fixation of AO-Type C fracture of the distal humerus with locking plates are similar to those reported in short term suggesting that results are durable"[6].

11. Sudhir Babhulkar *et al*[49]., in 2011, in his study concluded “that the high rate of union can be achieved in complex intra-articular fracture of distal humerus if the proper principles of stable fracture fixation are followed ie.,a posterior trans-olecranon approach and dual fixation of both the columns and restoration of continuity of articular surfaces. The stability achieved by this technique permits instituition of early intensive physiotherapy to restore elbow function”[7].

12. Jason M. Erpelding *et al*[50]., in 2012, showed that extensor mechanism-on approach of open treatment of distal humerus fracture with parallel plating resulted in “excellent healing,a mean elbow flexion-extension arc exceeding 100^0, and maintainance of 90% of elbow extension strength compared with that of the contralateral,normal elbow”[8].

13. Githens *et al*[51].,in 2014 in his study with mean age less than 60 yrs, revealed that “total elbow arthroplasty and ORIF with Plating for the treatment of geriatric dist.al humerus fracture produced similar functional outcome scores and range of motion”[9].

14. Abhilekh mishra *et al*[52]., in 2015 in study on 20 patient showed excellent result in 18 patient and poor in 2 patient ,concluded that the locking plates is a useful implant for the treatment of complete articular (type c) distal humeral fracture.

15. Singh v *et al*[53]., in 2016 in his study on 27 patient with age more than 18 years showed 17 patient with excellent and 1 with implant failure and concluded

that intercondylar humerus fracture classified by riseborough and radin system and treated by ORIF by pre contoured AO locking plates is useful in providing stable fixation for complex distal articular fracture and facilitating early postoperative rehabilitation.

16. Gujinder Singh *et al*[54]., in 2017 in study on 31 patient showed 90% excellent and 10% poor score of MEPS concluded that anatomical preshaped distal humerus locking plate system is useful in providing stable fixation of distal humerus fracture, thereby facilitating early postoperative rehabilitation.

17. Riaz B. Shaik *et al*[55]., in 2017 in his study on 20 cases showed 14 cases excellent and 6 cases poor score on MEPS concluded that distal humerus fracture are known for their complex nature and technical difficult in surgical management. Proper anatomical reconstruction and stable fixation helps in restoring painless and functional elbow.

18. Patel *et al*[56]., in 2017 in his study on 31 cases showed 90% excellent and 10% poor score on MEPS concluded that open reduction and internal fixation with precountoured distal humerus locking plate system is a good method of treatment for complex supra intercondylar fracture of distal humerus with good functional outcome and low complication.

ANATOMY AND BIOMECHANICS-

ANATOMY OF DISTAL HUMERUS

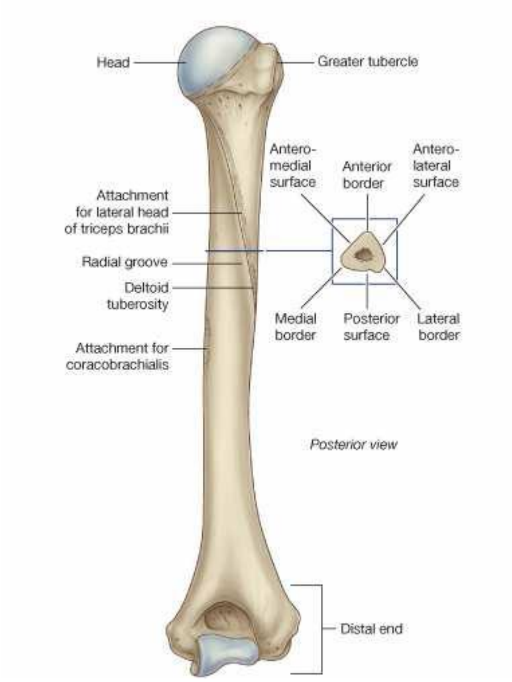


Figure 3- Anatomy of Humerus

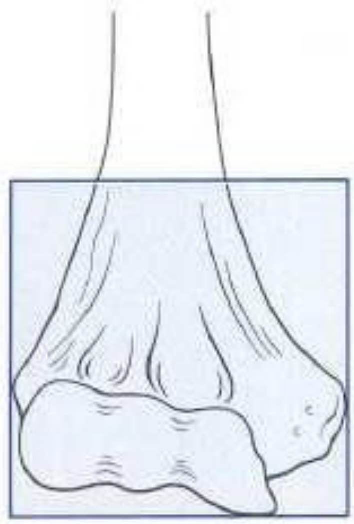


Figure 4- Epicenter described by Muller

Figure 5- Anatomy of Distal End of Humerus

The distal humerus is defined as the square of the epicentre between the epicondyles as described by Mueller.

The distal humerus consists of two condyles, forming the articular surface of the trochlea and capitellum. The flexor-pronator group of muscles and the ulnar collateral ligament are attached to the prominent medial epicondyle, proximal to the trochlea. The medial epicondyle is more prominent than the lateral epicondyle which is situated just above the capitellum.

The irregular and flat surface of the lateral epicondyle gives rise to the lateral collateral ligament and the supinator-extensor group of muscles. The postero-inferior aspect serves as a partial origin of the anconeus muscle.

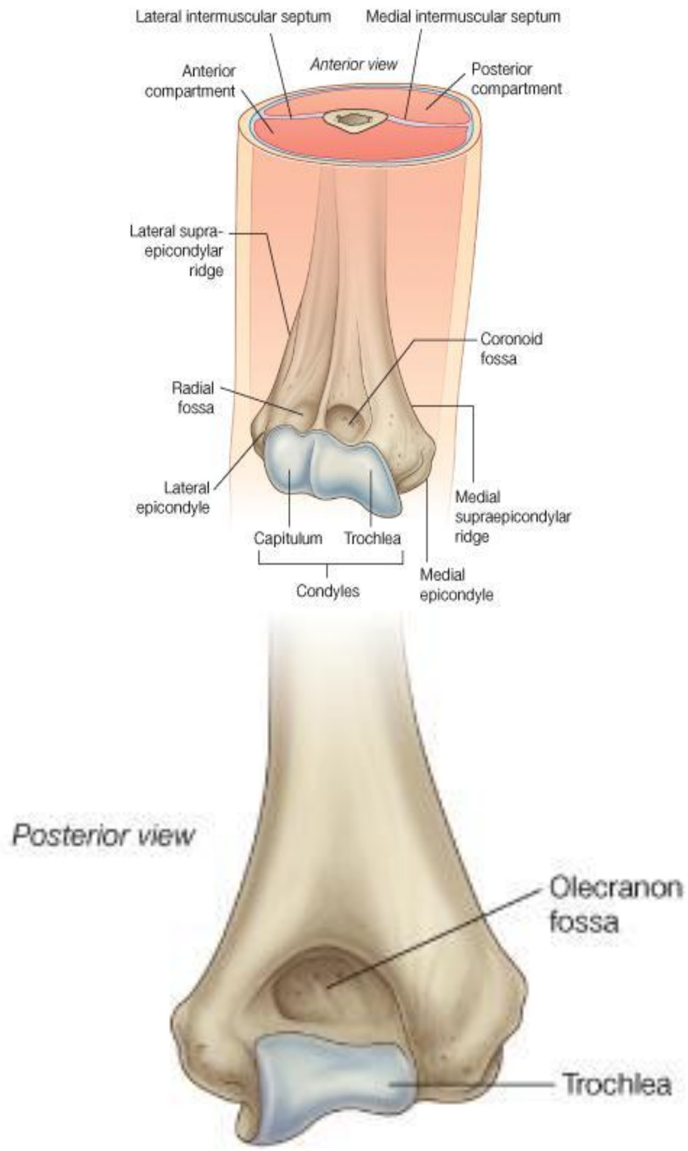


Figure 6- Anterior and posterior view of distal humerus

Just above the articular surface of the capitellum, the radial fossa accommodates the radial head during flexion. The coronoid inserts into a large coronoid fossa superior to the trochlea. Posteriorly, the olecranon fossa serves a similar purpose, receiving the tip of the olecranon during extension. In about 90 percent of individuals , the olecranon and coronoid fossae are separated by a thin membrane of bone, although there is some race and sex variation with this anatomical feature. The coronoid and olecranon fossae are bordered by the strong lateral supracondylar column and a smaller medial supracondylar column. The difference in size of these two structures is important because the smaller medial column may be vulnerable to fracture during insertion of some designs of humeral components at the time of elbow prosthetic replacement surgery. The lateral supracondylar column is flat from the posterior aspect, whereas the anterior surface is slightly curved. This allows ease of application of contoured plates to the posterior aspect of the lateral column and forms the basis of routine orthogonal plating. Safe interval is the space between extensor carpi radialis longus and brachioradialis anteriorly and the triceps posteriorly, which is separated into two by prominent lateral supracondylar ridge. Many lateral surgical approaches are performed through this important landmark. The radiologic appearance of the various bony landmarks is shown in the pictures below.

Figure 7- Radiologic landmarks of elbow

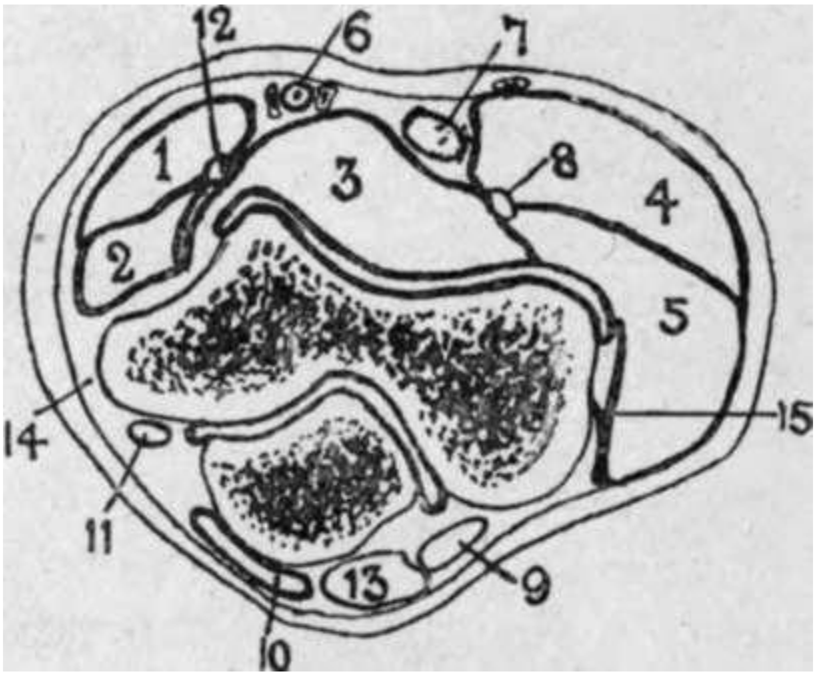


Figure 8- Outline Diagram of Transverse Section of Elbow

1. Pronator teres.

2. Flex, carpi rad.

3 Brach. ant.

4 Supinator longus.

5 Ext. carpi rad. long.

6. Brachial vessels.

7 Biceps tendon.

8. Radial nerve.

9 Anconeus.

10. Bursa.

11. Ulnar nerve.

12. Median nerve.

13 Triceps tendon.

14. Int. lat. ligt

15 Ext. lat. ligt.

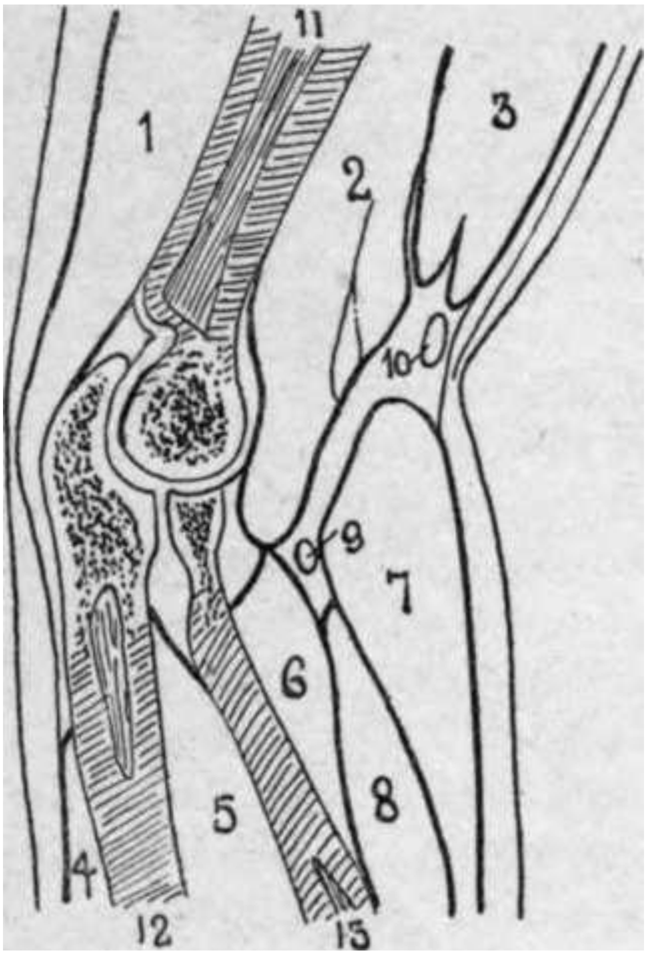


Figure 9- Longitudinal Section of Elbow

1. Triceps.
2. Bradi, ant.
3. Biceps.
4. Ext. carp. uln.
5. Flex, profund. dig.
6. Sup. brev.
7. Sup. longus.
8. Ext. carp. rad. long.
9. Radial nerve.
10. Median cephalic vein
11. Humerus.
12. Ulna.
13. Radius.

In 1 to 3 percent of individuals, a supracondylar process is observed, proximal to the medial epicondyle, about 5 to 7 cm along the medial intermuscular septum. Ligament of Struthers, a fibrous band, originates from supracondylar process and attaches to the medial epicondyle. This spur, when present, serves as an origin point for pronator teres and serves as a site for anomalous insertion of the coracobrachialis muscle. Numerous pathologic processes like fracture and median and ulnar nerve entrapment have been associated with the supracondylar process.

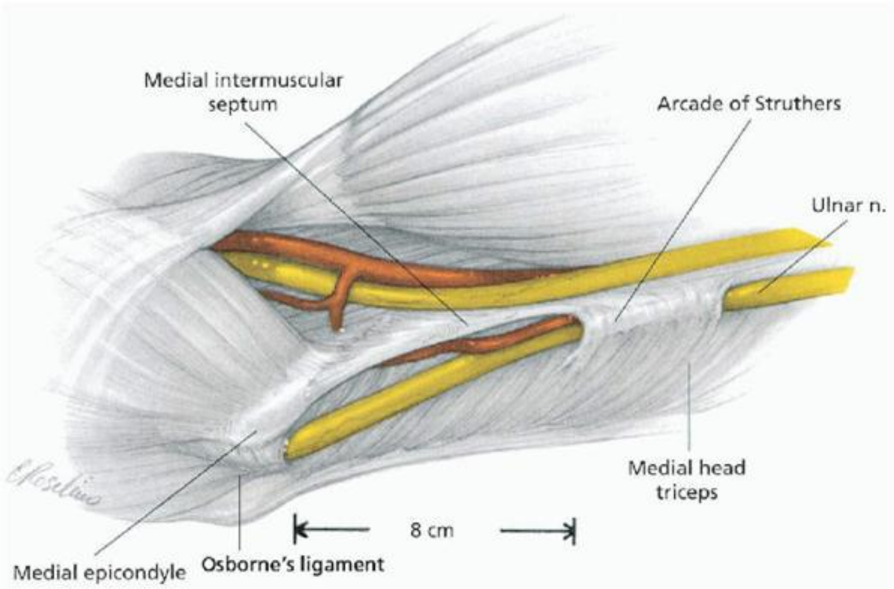
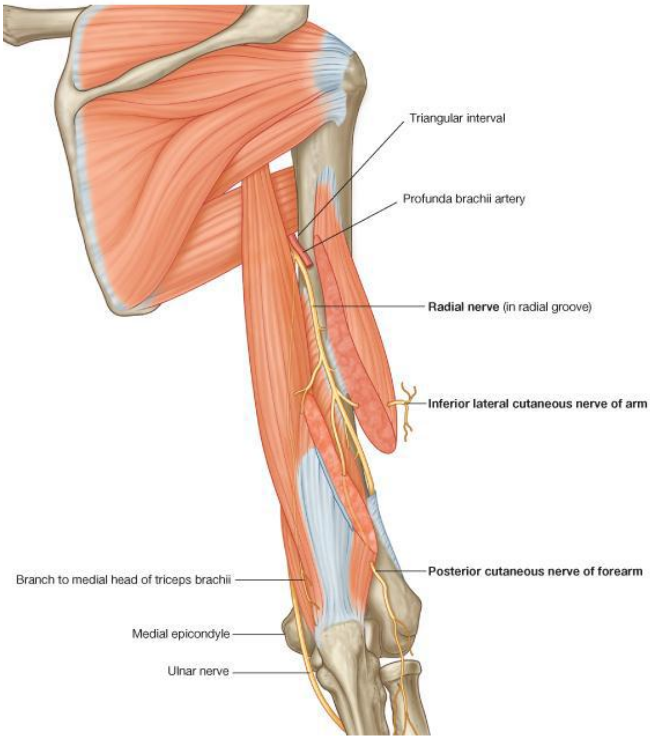


Figure 10- Nerves in relation to distal humerus

Surgical Anatomy of the Ulnar nerve-

In the midportion of the arm the ulnar nerve lies anterior to the medial head of the triceps and posterior to the medial intermuscular septum. In 70% of extremities a medial musculofascial arcade of Struthers, covers the nerve. This arcade is located approximately 8 cm proximal to the medial epicondyle and is composed of the deep fascia of the arm, superficial fibers of the triceps, and the internal brachial ligament arising from the coracobrachialis tendon. The nerve then passes into a fibroosseous groove that is bordered anteriorly by the medial epicondyle, posterior and laterally by the olecranon and ulnar humeral ligament, and medially by a fibroaponeurotic band. Here, the nerve is accompanied by numerous branches of the superior and inferior collateral and posterior ulnar recurrent arteries and several veins. Also at this level, a small articular branch leaves the ulnar nerve to innervate the joint capsule. After exiting the fibroosseous groove, the ulnar nerve travels between the humeral and ulnar heads of the flexor carpi ulnaris covered by a fibrous called Osborne's ligament or arcuate ligament. It is often very thick and is a common cause of ulnar nerve compression. The ulnar nerve gives off motor branches to this wrist flexo, lying within the flexor carpi ulnaris muscle. Travelling distally, the nerve pierces the flexor pronator fascia and then lies between the flexor digitorum superficialis (FDS) and the flexor digitorum profundus (FDP).



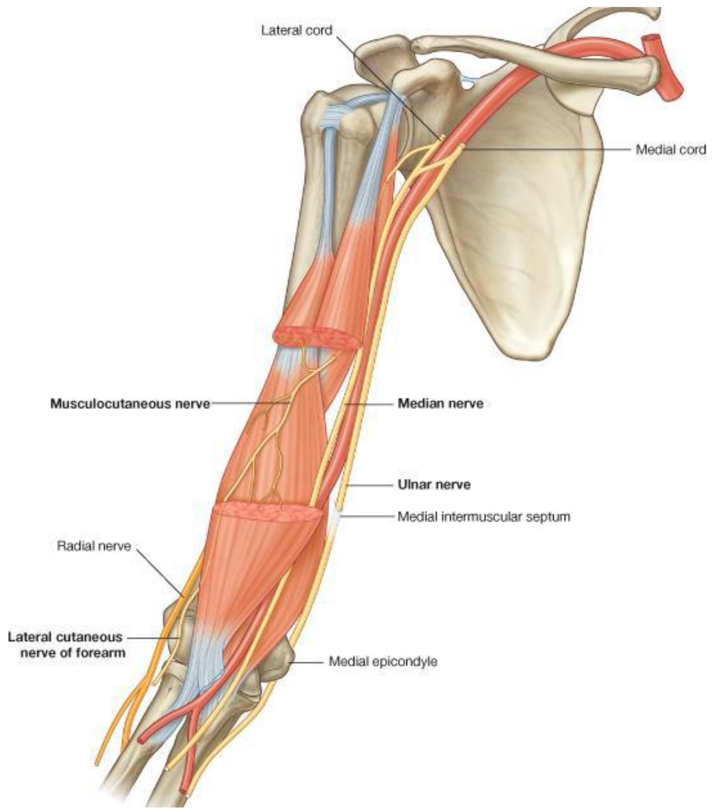


Figure 11- Course of Ulnar Nerve

In a groove between the medial and lateral heads of triceps brachii muscle, the radial nerve alongwith the profunda brachii artery, turns around to the lateral from the medial side of the humerus, and pierces the lateral intermuscular septum approximately 10 cm proximal to the lateral epicondyle and enters the anterior compartment. Then the nerve passes to the front of the lateral epicondyle, dividing into a superficial and a deep branch between the brachialis and brachioradialis.

As the median nerve runs down the arm, it lies lateral to the brachial artery. At the level of insertion of the coracobrachialis, it crosses the artery and lies on its medial side at the bend of the elbow. Bicipital fascia (lacertus fibrosus) runs above the nerve and is separated from the elbow-joint by the brachialis.

LIGAMENTS AROUND THE ELBOW

The lateral collateral ligament (LCL) complex is made up of the lateral ulnar collateral ligament, radial collateral ligament, and the annular ligament. The annular ligament attaches to lesser sigmoid notch at the anterior and posterior margins. In contrast, the radial collateral ligament arises from an isometric point on the lateral epicondyle and fans out to attach to the annular ligament. The crista supinatoris of the upper part of ulna gives attachment to lateral ulnar collateral ligament. This ligament in turn arises from the isometric point on the lateral epicondyle, it functions as an important restraint to posterolateral rotatory instability and varus and is vulnerable to injury during application of a direct lateral plate; therefore, exposure of the lateral aspect of the distal lateral column should not extend past the equator of the capitellum. The medial collateral ligament (MCL) consists of an anterior bundle, posterior bundle and transverse ligament. The anterior bundle is of prime importance in elbow stability. It originates from the anteroinferior aspect of the medial epicondyle, inferior to the axis of rotation, and inserts on the sublime tubercle of the coronoid. The MCL functions as an important restraint to valgus and posteromedial rotatory instability.It is susceptible to injury at its origin during placement of a medial plate that curves around the medial epicondyle to lie on the ulnar aspect of the trochlea.

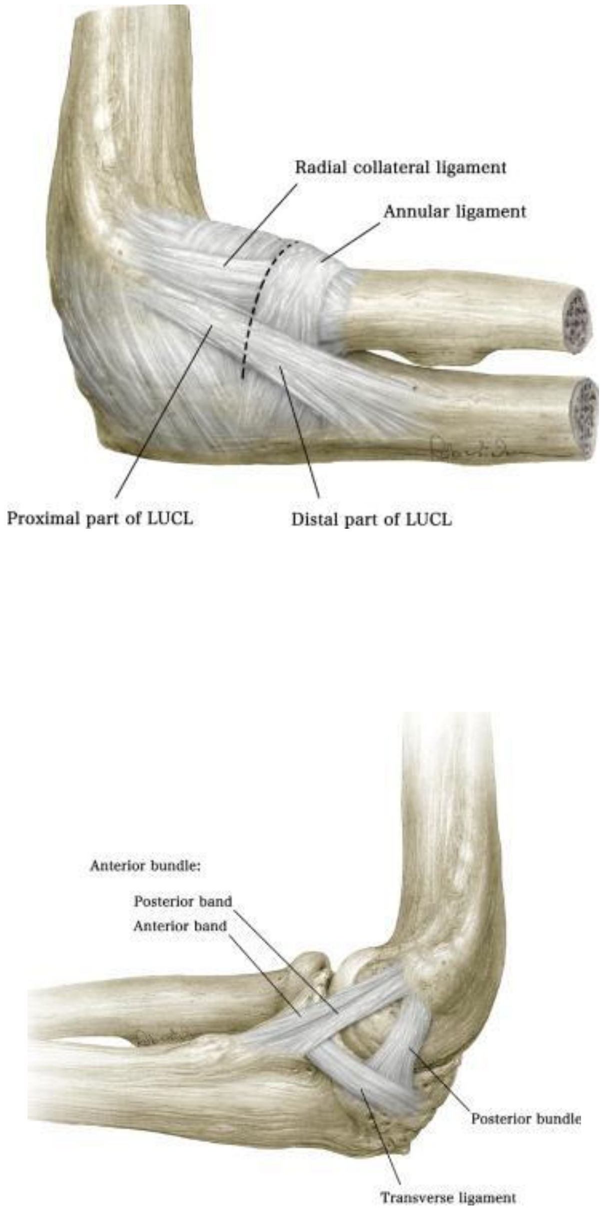


Figure 12- Ligaments around the elbow

VESSELS IN RELATION TO ELBOW JOINT

The major **blood supply** of distal humerus comes from brachial artery and its anastomosis around elbow. Brachial artery and its anastomosis provides **blood supply** to distal humerus. The branches anastomosing *in front* of medial epicondyle are:

- Anterior branch of inferior ulnar collateral
- Anterior ulnar recurrent
- Anterior branch of the superior ulnar collateral

Those behind medial epicondyle are:

- Inferior ulnar collateral,
- Posterior ulnar recurrent
- Posterior branch of superior ulnar collateral.

The branches anastomosing in front of lateral epicondyle are:

- Radial recurrent
- Terminal part of profundabrachii.

Those *behind* lateral epicondyle (perhaps more properly described as being situated between lateral epicondyle and olecranon) are:

- Inferior ulnar collateral
- Interosseous recurrent
- Radial collateral branch of profundabrachii.
- There is also an arch of anastomosis above the olecranon, formed by the interosseous recurrent joining with the inferior ulnar collateral and posterior ulnar recurrent artery.

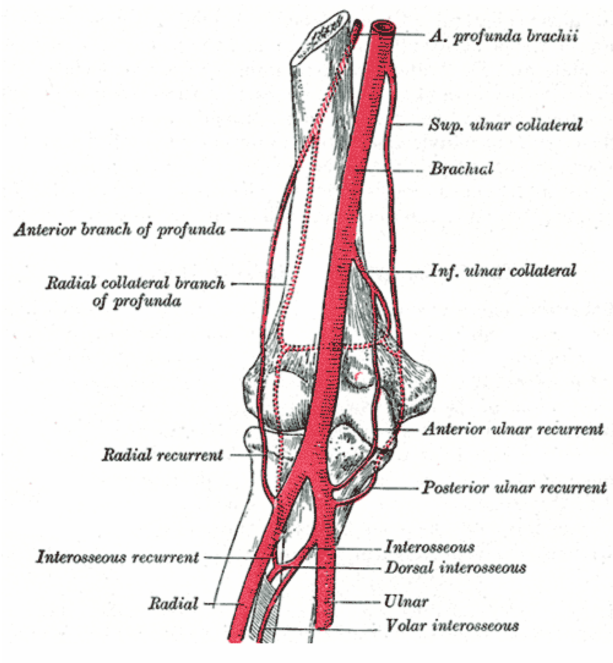


Figure 13- Vessels in relation to elbow joint

SURGICAL ANATOMY

The elbow is anatomically a trocho-ginglymoid joint, meaning that it has trochoid (rotatory) motion through the radiocapitellar and proximal radioulnar joints and ginglymoid (hinge-like) motion through the ulnohumeral joint. The olecranon of the ulna articulates around the trochlea of humerus. The trochlea normally is tilted in 5 degree of valgus in males and 8 degrees of valgus in females, thus creating the carrying angle of the elbow[65]. The line drawn tangential to the articular surface on the AP view of the distal humerus makes an angle of 4 and 8 degrees of valgus to the shaft axis. In the male, the mean carrying angle is 11 to14 degrees, and in the female, it is 13 to 16 degrees.

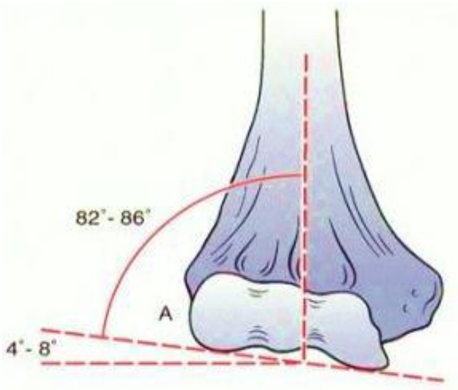


Figure 14- Valgus angulation of the articular surface of the distal humerus

The trochlea is externally rotated 3-8 degrees from a line connecting the medial and lateral epicondyles, resulting in external rotation of the arm when the elbow is flexed 90 degrees.

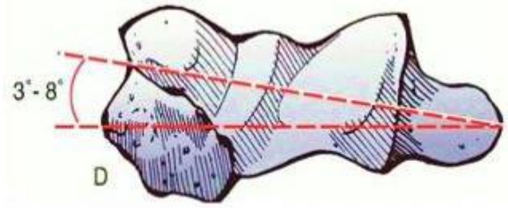


Figure 15- Externally rotated trochlea

The articular segment just forward from the line of the shaft at 40 degrees and functions architecturally at the arch at the point of maximum column divergence distally. It is to noted that the medial epicondyle is on the projected axis of the shaft, whereas the lateral epicondyle is projected slightly forward from the axis .

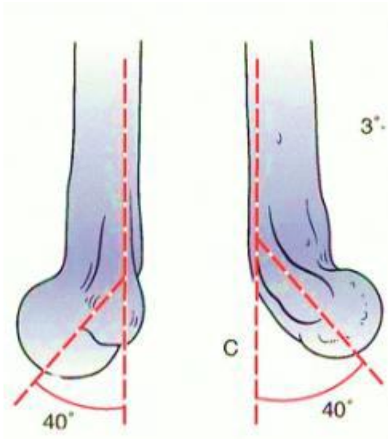


Figure 16- Anterior angulation of the distal humerus with the shaft

The trochlea must be restored to its normal position, acting as a tie beam between medial and lateral columns of the distal humerus and thus acts as a keystone of the arch.This forms the triangle of the distal humerus, which is crucial for stable elbow motion. Both columns must be securely attached to the trochlea. So every attempts to restore the proper valgus and external rotation of the trochlea to allow for stability, full motion and a normal carrying angle.

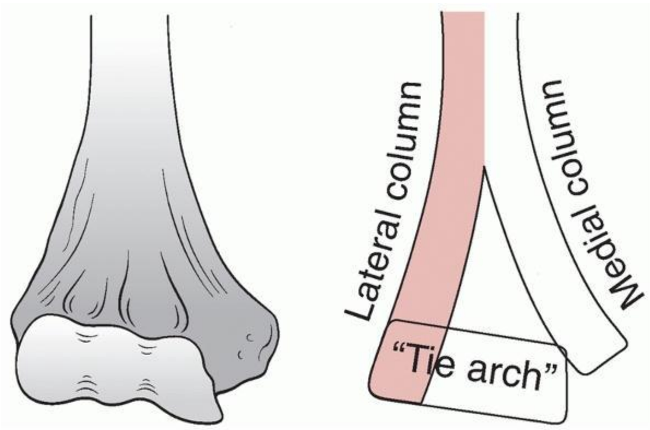


Figure 17- Tie-beam arch in the distal humerus

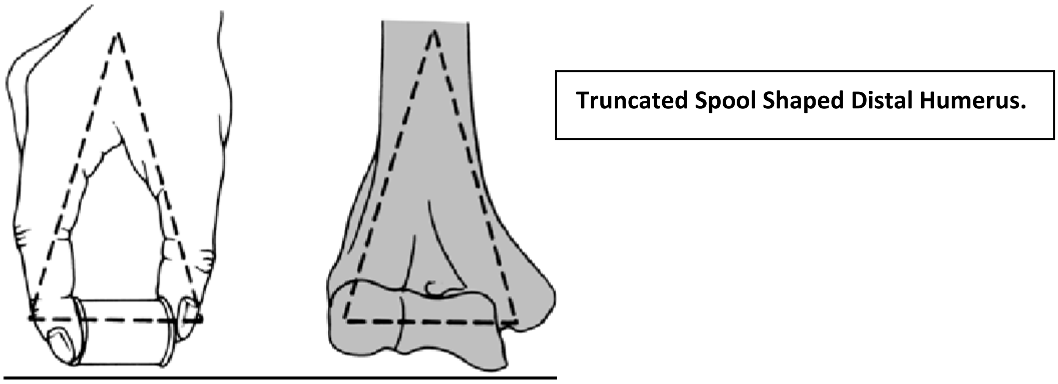


Figure 18- Trucated Spool shaped distal humerus

The medial column diverges from the humeral shaft at approximately 45 degrees, continues and ends in the medial epicondyle. As nothing articulates with the anteriomedial epicondyle, the entire surface is available for internal fixation hardware. Care should be taken to protect and transfer the ulnar nerve anteriorly. The lateral column diverges from the humeral shaft at approximately 20 degrees and is largely cortical bone with a broad flat posterior surface, making it ideal for plate placement. The coronoid is important to elbow stability and should be reduced and fixated if displaced. The recessed and thinned bone just cephalad to the waist of the trochlea anteriorly is the coronoid fossa and its counterpart posteriorly is the Olecranon fossa. The thin wafer of bone that separates the depth of these fossae may be partially deficient in a small percentage of the population. These fossae are designed for the receipt of the radial head and the coronoid and olecranon processes with full flexion and extension respectively (These are important points to bear in mind in the seating of screws on the distal lateral or medial columns for the address of distal humeral fracture). Safe screw placement assures no violation of these fossae. Impingement by a misdirected implant blocks terminal joint motion. If the medial and lateral columns can be securely fixated to the trochlea, early motion should be tolerated.[66] At the posterior capitellum, cancellous screws must be used to avoid interrupting the anterior capitellar cartilage.

A second range of motion occurs with the elbow joint in supination and the forearm in pronation; this ROM is allowed by the radial head articulation with the capitellum and ulnar notch[65].

BIOMECHANICS

The ulnohumeral articulation is the cornerstone of osseous Stability and mobility in the flexion - extension plane – especially the coronoid process. The coronoid process resists posterior subluxation in extension beyond 30o or greater, depending on the other injuries[67]. The medial facet of the coronoid is especially crucial to stability in varus stress. At the extremes of ulno-humeral motion, the coronoid or olecranon processes may ‘lock’ into their corresponding fossae, adding additional stability from muscular contraction and with little input from the ligaments. However, most activities in most patients rely on a combination of ligamentous integrity and bony integrity of the articulation. The anterior band of the medial collateral ligament secures the medial side of the joint, running from an area just medial and distal to the medial epicondyle and to the sublime tubercle, slightly distal and medial to the coronoid itself. The brachialis muscle inserts more distally on the anterior surface of the proximal ulna. Fracture near the base of the coronoid may compromise these important.

Attachments-

The radial head also contributes to elbow stability by widening the base of support of the forearm, tensioning the posterolateral ligament and acting as an anterior buttress. Fracture of the coronoid process, radial head, medial epicondyle, os olecranon may be associated with elbow dislocation, making treatment more complex. Soft tissue structures about the elbow are responsible for as much as 40% of the resistance to valgus stress and 50% of that to varus stress in the extended position. The anterior bundle of the medial collateral ligament may provide one-third to one half of the elbow's resistance to valgus stress depending on the amount of elbow flexion. A large fracture of the coronoid process, a fracture of the medial epicondyle, and rupture of the medial collateral ligament may completely disrupt the medial components of the elbow. The lateral collateral ligament complex inserts onto the annular ligament. Injury to this ligament is responsible for posterolateral rotatory instability that may lead to recurrent dislocation if not properly protected during the rehabilitation[29] The muscles surround the elbow, besides the biceps / brachialis and triceps, theoretically stabilize the elbow as well. However, it is difficult to quantify the importance of the supinator tendon, ECU and the extensor origin. Except for anecdotal recommendations, repair of these muscles after acute injury has never been documented to be crucial in preventing redislocation, despite certain injury and disruption[67].

CLASSIFICATION OF DISTAL HUMERUS FRACTURE

ANATOMICAL CLASSIFICATION:

- Supracondylar fracture,
- Transcondylar fracture,
- Intercondylar fracture,
- Fracture of the condyles (lateral and medial),
- Fracture of the articular surfaces(capitellum and trochlea), and
- Fracture of the epicondyles.

THE COMPREHENSIVE AO – OTA CLASSIFICATION [45]

Distal humeral fractures -13

A – Extra-Articular fracture
A1: Apophyseal avulsion
A2: Metaphyseal simple
A3: Metaphyseal Multifragmentary

B – Partial-Articular fracture
B1: Lateral sagittal
B2: Medial sagittal
B3: Frontal

C – Complete articular fracture
C1: Articular simple;Metaphyseal simple
C2: Articular simple;Metaphyseal multifragmentary
C3: Articular; Metaphyseal multifragmentary

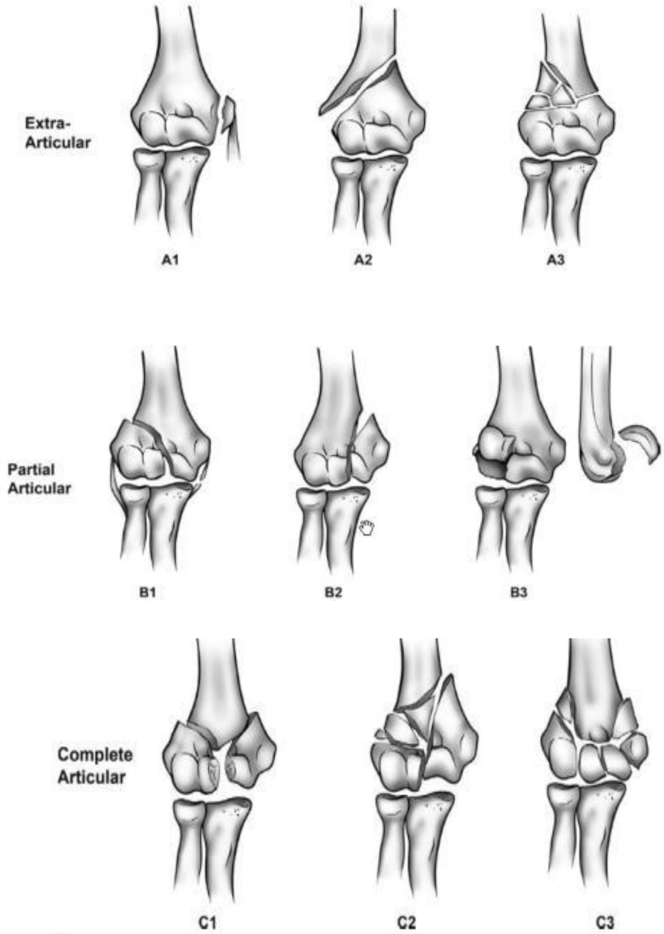


Figure 19- AO-OTA Classification

THE MEHNE AND MATTA CLASSIFICATION [58]

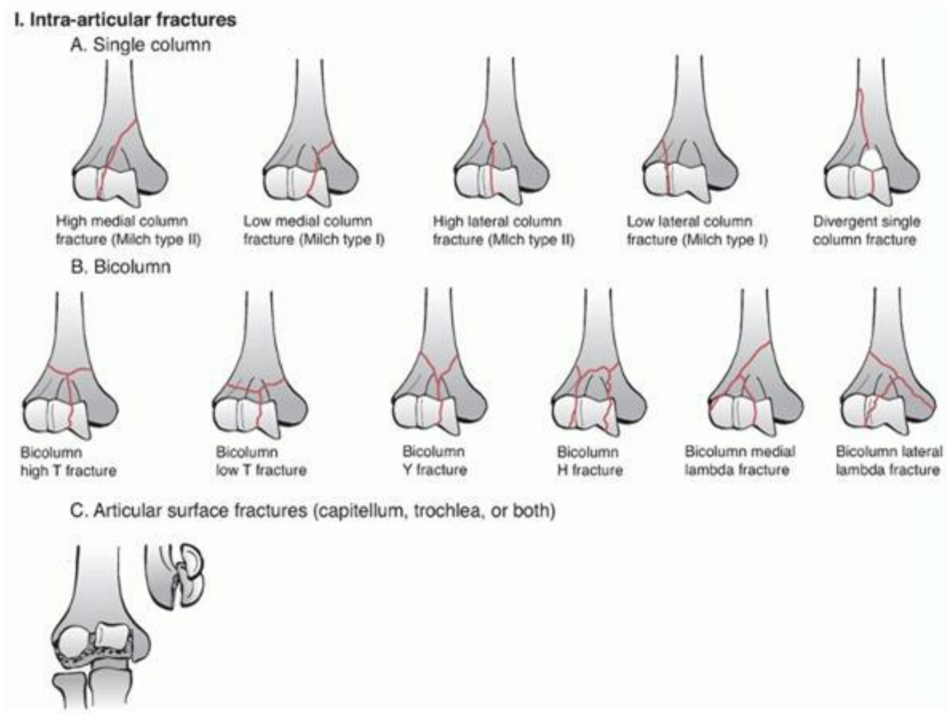
It is based on, Jupiter's model of distal humerus, which is composed of two divergent columns, that support an intercalary articular segment.

1. Intra articular

   a. Single column: high medial, high lateral, low medial, low lateral and
   b. divergent single column fracture
   c. Bicolumn: high T, low T, Y, H, medial lambda, lateral lambda fracture
   d. Articular surface: capitellum, trochlea or both

2. Extra-articular intra capsular fracture high flexion, low flexion, high extension and low extension, trans column fracture, high abduction and high adduction fracture.

3. Extra- capsular fracture medial epicondylar and lateral epicondyle fracture



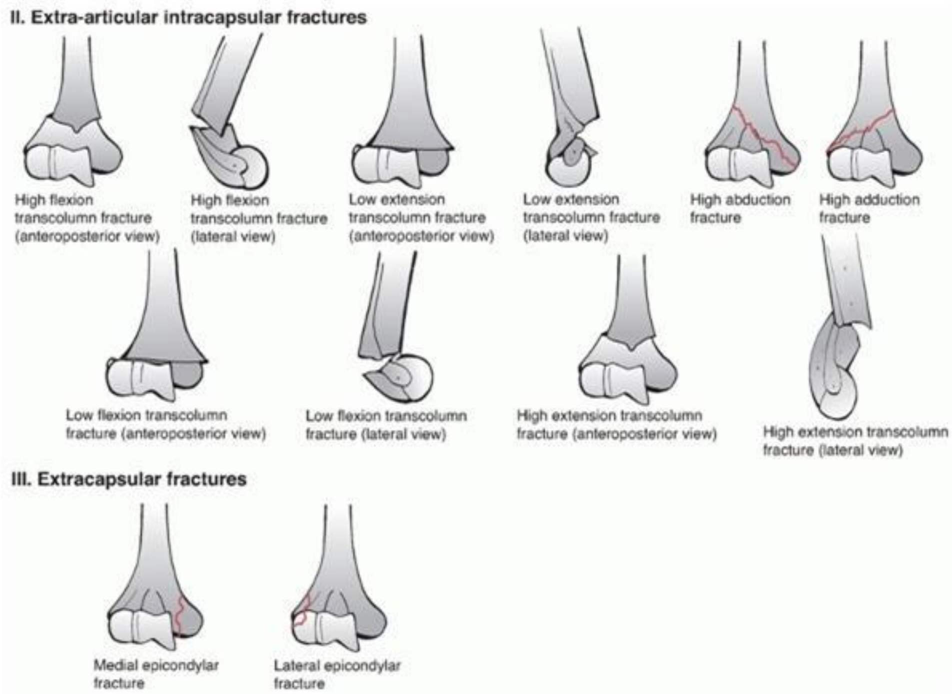


Figure 20- The Mehne and Matta Classification

RISEBOROUGH AND RADIN CLASSIFICATION

Table 1- Riseborough and Radin Classification

Type I	Nondisplaced
Type II	Slight displacement with no rotation between condylar fragments
Type III	Displacement with rotation
Type IV	Severe comminution of articular surface

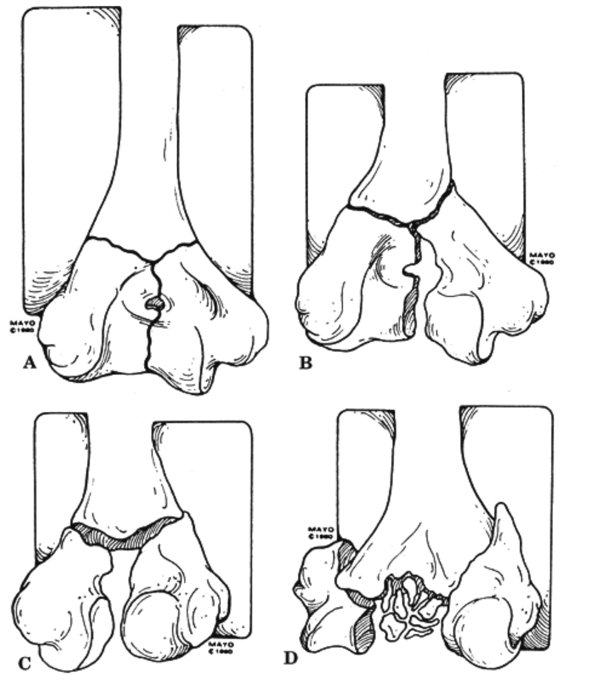


Figure 21- Riseborough and Radin Classification

SURGICAL APPROACHES

1. **TRICEPS- SPLITTING APPROACH (CAMPBELL)** [31.32]:

- Distal part of the triceps is split through the aponeurosis
- Distally extend the split on to the olecranon
- Proximally extend till the radial nerve is identified
- The approach provides only a limited exposure to the articular surface

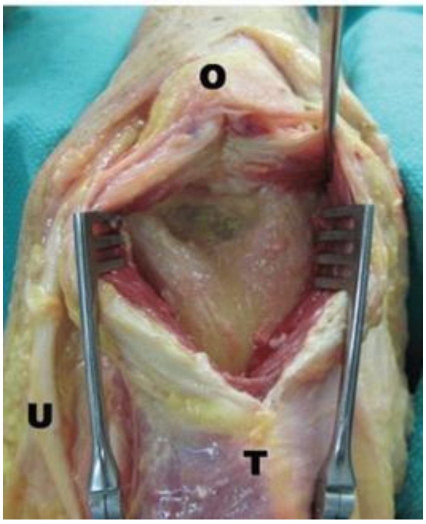


Figure 22- Triceps splitting approach

2**. TRICEPS-REFLECTING APPROACH (BRYAN- MOOREY)**

- The entire triceps muscle is elevated subperiosteally from the posterior distal humerus
- The triceps can be removed with some part of ulna to facilitate bone to bone attachment
- Entire triceps is reflected upwards and laterally to expose the joint

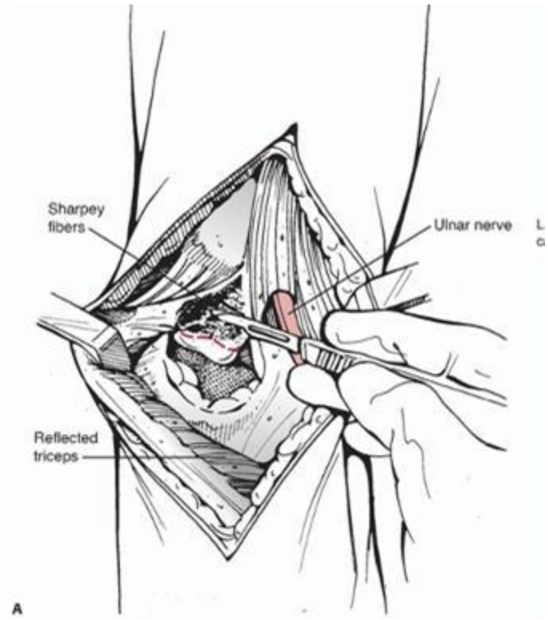


Figure 23- Triceps reflecting approach

3. **TRAP APPROACH (0'DRISCOLL) [30] :**

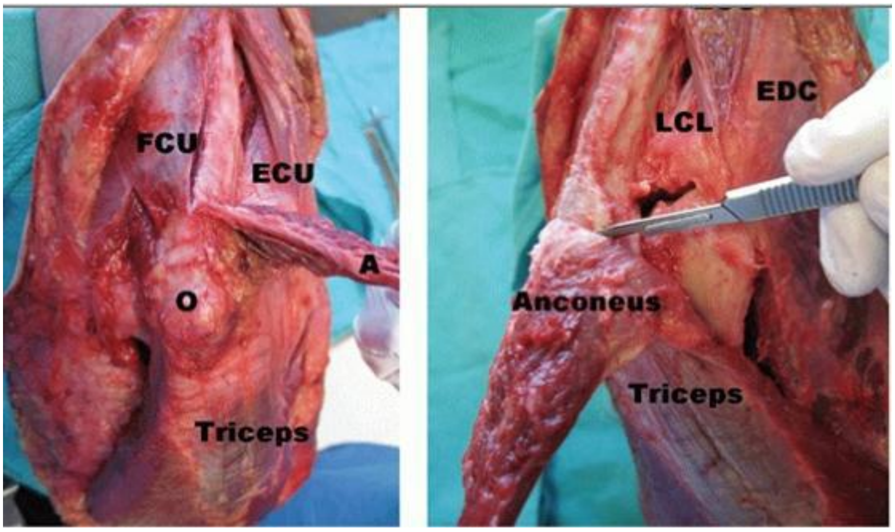


Figure 24- TRAP approach

4. PARA- TRICIPITAL APPROACH (ALONSO- LLAMES) [27]

- Triceps muscle is elevated subperiosteally from posterior distal humerus.
- Two separate windows are created on either of the triceps muscle.
- This approach is can be used for type A and type C1 fracture with expertise.
- Can produce excellent outcomes as extensor mechanism is not disturbed

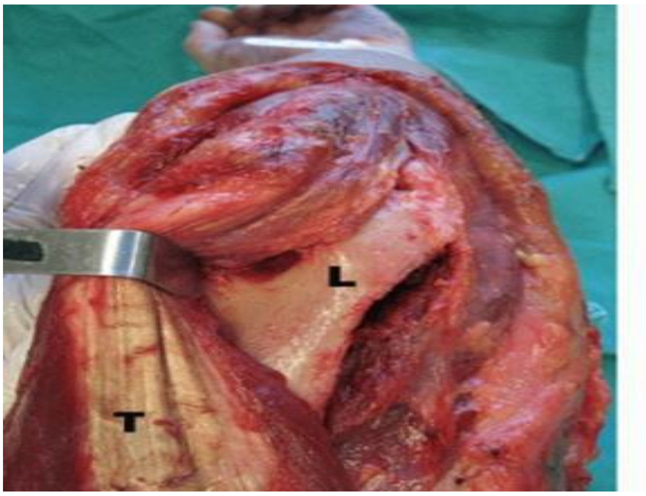


Figure 25- Para tricipital approach

5. **OLECRANON- OSTEOTOMY APPROACH**

- This approach can give an excellent exposure of the articular surface
- Ideal for type C fracture
- **'V' shaped Chevron osteotomy** is preferred for good union and stable fixation[12].
- It has an inherent rotational stability as well as translational stability when compared to the transverse osteotomy.

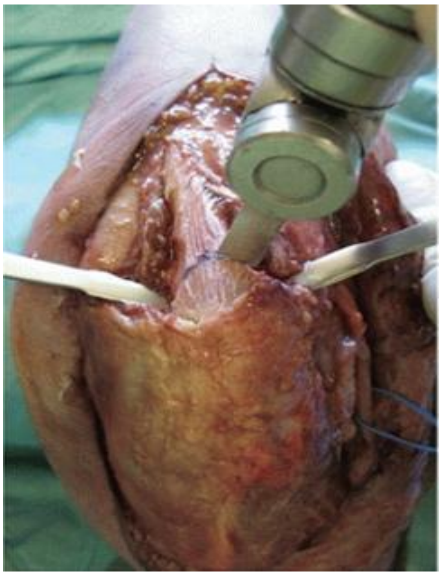


Figure 26- Olecranon osteotomy

TREATMENT PROTOCOL

CLINICAL HISTORY AND EXAMINATION:

A detailed history regarding name, age, sex, date of injury, mechanism of injury, residential address, occupational status and associated injuries were recorded. Patients' general condition and vitals were noted. Patients' affected limb were x-rayed in both true antero-posterior and true lateral views in slight traction after removing slab if applied previously.

LABORATORY WORK UP:

The patients were submitted to a battery of routine investigations required for pre-anesthetic checkup. Associated medical comorbidities were dealt with, if present. 3D reconstruction CT of elbow joint were taken for evaluating the number of fragments, degree of comminution and displacement in Intraarticular fracture[41], which aided in planning of surgery, type of implant needed and placement of screws.

SURGICAL TECHNIQUE:

The patient, were given a general anesthesia or regional anesthesia and were positioned in the lateral position, with the involved limb supported over bolsters in OT table as depicted in the picture below.

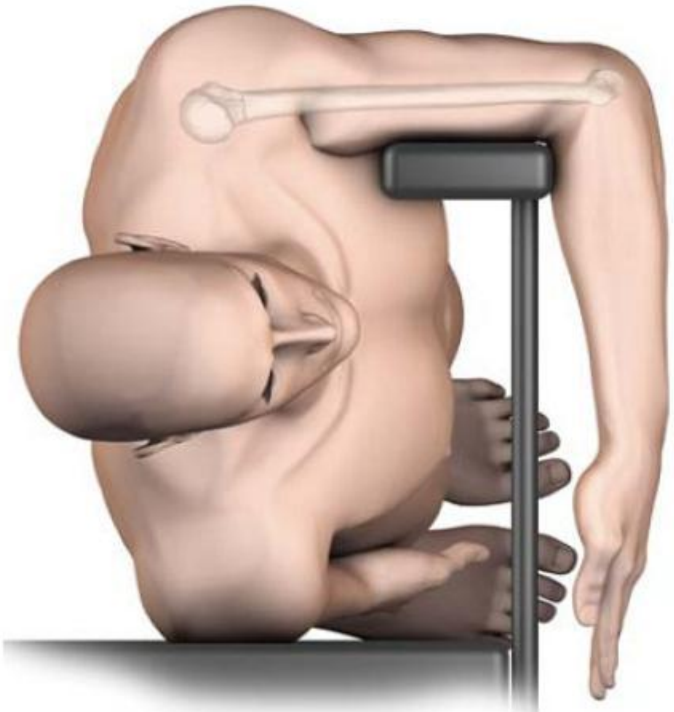


Figure 27- Position of patient

A midline posterior skin incision made[48], deep fascia incised and before proceding further, the ulnar nerve was identified, dissected out and retracted gently with an umbilical cotton tape. Triceps muscle identified and released on either side from the intermuscular septum. Fracture site exposed further with Chevron V shaped olecranon osteotomy[7 12 61] incompletely with a saw and completed with an osteotome in complex articular fracture, as it provides adequate exposure of the articular fragments[16].In other types, we utilized any of the described approaches like TRAP, paratricipital or Triceps splitting approach [27 28 30 31 32] .

TECHNIQUE OF BICOLUMNAR PLATING [12]:

We attempted to achieve the eight technical principles derived from the two major goals of:

(1) Maximizing fixation in the distal fragments and
(2) Ensuring that all fixation in the distal segment contributes to stability at the supracondylar level.

Once the fracture is exposed the following steps are carried out-

Step 1: Articular reduction

Articular fragments were aligned in anatomy and were fixed provisionally with K wires placed subchondrally in a way not interfering in plate placement.[40]

Step 2: **Plate placement and provisional fixation**

Slightly undercontoured 3.5mm plates were placed in medial and lateral ridges in a way that both end at different levels at the shaft region and atleast 3 screws were placed in shaft. A (first proximal) screw was placed in one of the proximal holes of each plate but not fully tightened, leaving some freedom for the plate to move proximally later during compression. K wires were used in distal fragments for provisional fixation.

Step 3: **Articular fixation**

Long medial and lateral distal screws fixing maximum fragments were applied

Step 4: **Supra condylar compression**

A. The proximal screw on one side was backed out and a large bone clamp was applied distally on that side and proximally on the opposite cortex. **Figure 29** shows ulnar Nerve isolation. Articular reduction and provisional fixation with K wires[41] load the supracondylar region. A second proximal screw was inserted through the plate in compression mode, and then the backed out screw was retightened.

B. This step was repeated for other column also.

C. Diaphyseal screws was to be applied to achieve residual compression through undercontoured plates.

Step 5: **Final fixation**

Provisional K wires in the distal fragment were removed and replaced with screws. After fixing the fracture segments, TBW of osteotomized olecranon was carried out either with two K wires or a 6.5mm cancellous screw. Meticulous repair of soft tissues was done in layers with a suction drain.

Figure 28- Midline posterior skin incision

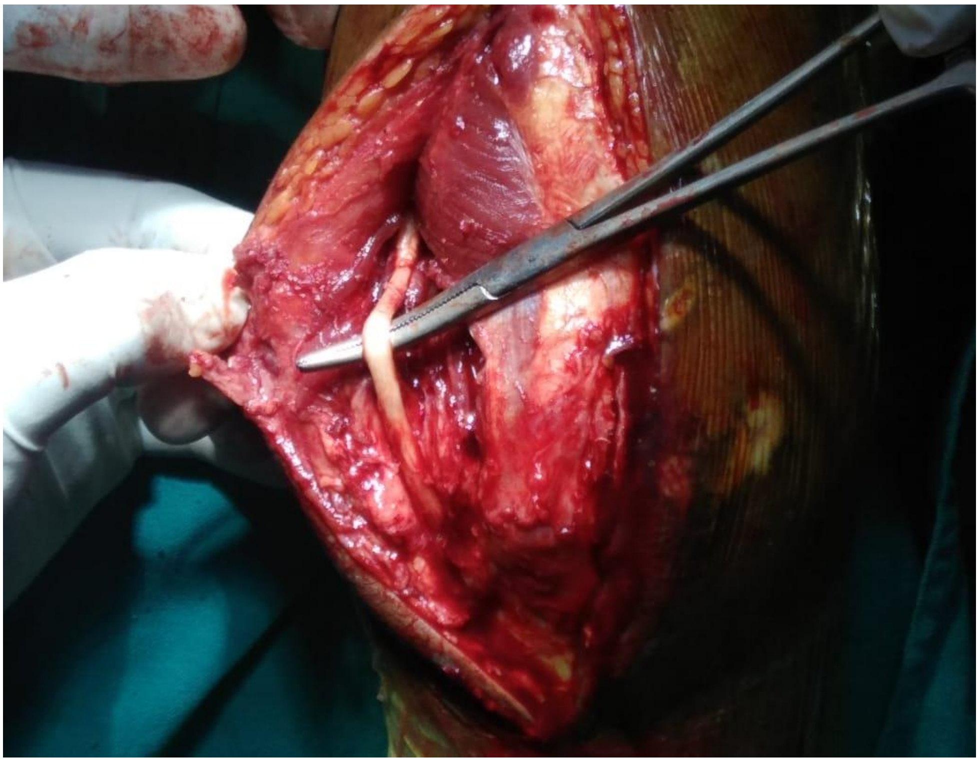


Figure 29- Isolation of ulnar nerve

Figure 30- V- shaped Chevron Osteotomy

Figure 31- Triceps reflected

Figure 32- Reduction of fragments

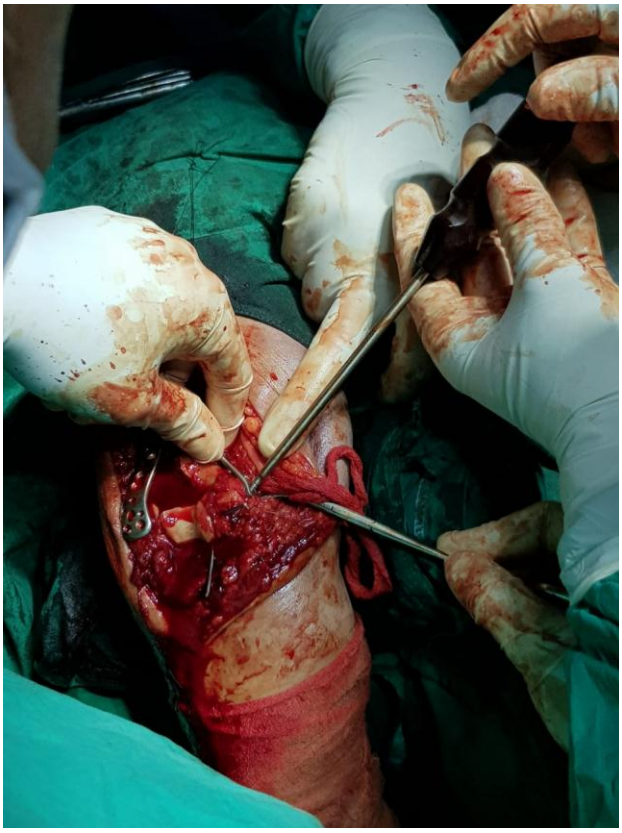


Figure 33- Plating

Figure 34- Olecranon tension band wiring

Figure 35- Skin closure

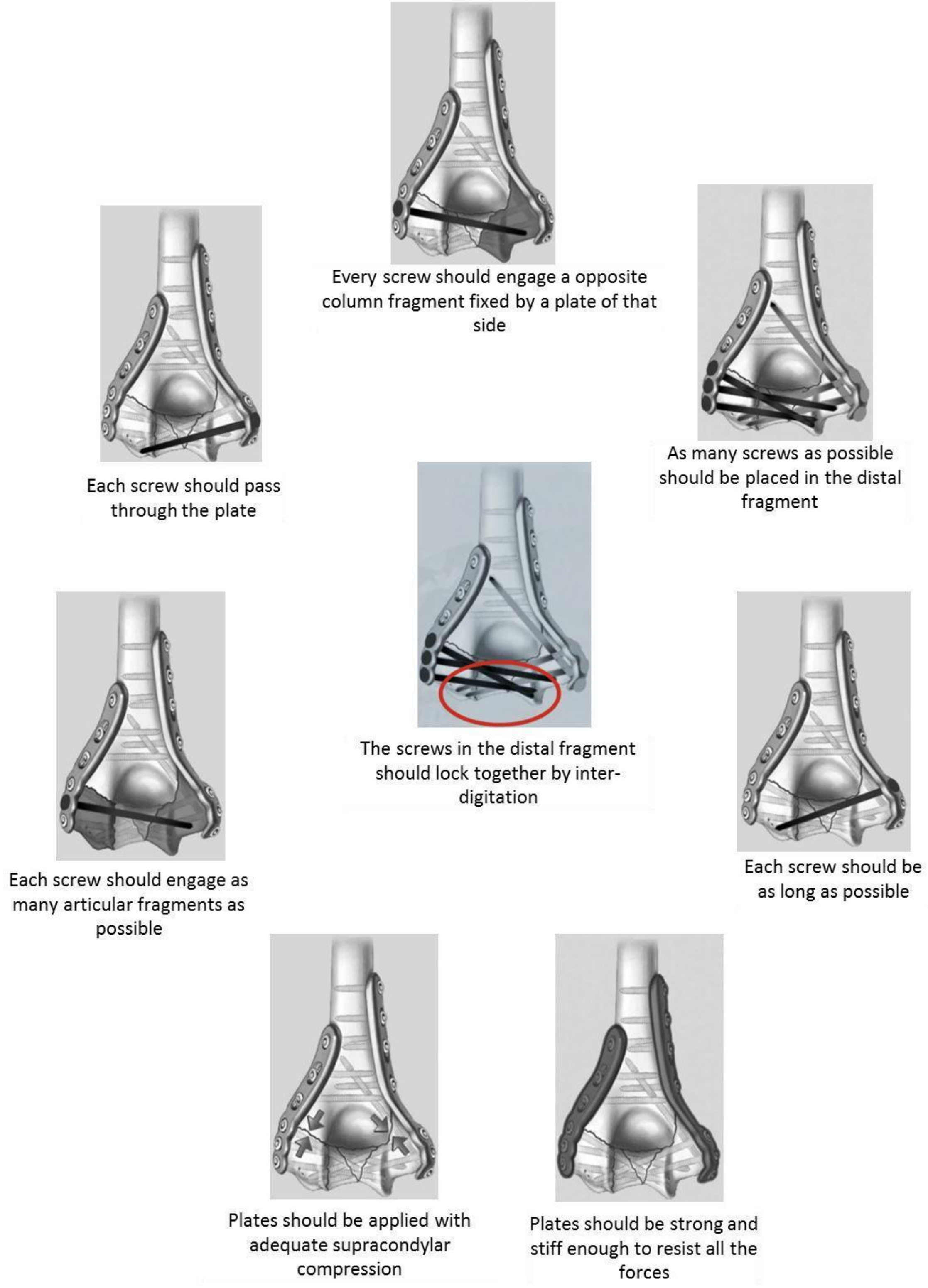


Figure 36- Illustration of bicolumnar plating technique

POST OP PROTOCOL:

- Patients were placed in a well-padded plaster extension splint applied anteriorly and the limb elevated for first 3 days.
- Active finger movements started from day 1.
- Intravenous antibiotics were given for 3 days; Oral antibiotics were given for 3 days.
- Drain removal at 48 hours ; Suture removal done on 12th day
- Elbow range of motion was started between days 3 and 7 postoperatively, as tolerated by the patient.
- Generally, active-assisted and active range of motion were encouraged (flexion, pronation, and supination) of elbow.
- Passive supported (gravity assisted) extension was reserved for patients that underwent an extensor mechanism disrupting approach.
- Follow up at 6 weeks, 3 month, 6 month. At each follow up, patients were evaluated clinically and radiologically for union, and the outcomes were measured in terms of Mayo elbow performance score (MEPS).
- At 6 months patients were allowed to resume their routine full activities

MAYO ELBOW PERFORMANCE SCORE (MEPS)

SECTION 1: PAIN INTENSITY
None 45
Mild 30
Moderate 15
Severe 0

SECTION 2: RANGE OF MOTION
Arc of motion greater than 100 20
Arc of motion between 50-100 15
Arc of motion less than 50 5

SECTION 3: STABILITY
Stable 10
Moderately Unstable 5
Grossly Unstable 0

SECTION 4:FUNCTION
Can comb hair 5
Can eat food 5
Can wear shoes 5
Can perform hygiene 5
Can wear shirt 5

OUTCOME RATING BASED ON MEPS:

- Greater than 90 **excellent**
- Score 75 to 89 **good**
- Score 60 to 74 **fair**
- Score less than 60 **poor**

MATERIALS AND METHODS

STUDY DESIGN:

A prospective study was done to evaluate the functional outcome of bicolumnar locking plating technique in treatment of distal humeral fracture and to analyse the results.

STUDY GROUP:

The study group consists of 23 Patients with distal humeral fracture, who underwent osteosynthesis with bicolumnar locking plating technique between 1st November 2017 - 31st May 2019 at ________________________________ Medical College, _________, __________.

Follow up period was 6 weeks, 3 months and 6 months.

The study was done with clearance from hospital ethical committee. Those who fulfilled the inclusion criteria given below were invited to participate in the study. Informed consent was obtained from all the patients willing to take part in the study.

INCLUSION CRITERIA

1. Patients with intra-articular fracture of the distal humerus .
2. Patient aged more than 18 years.
3. Patients who give consent for surgery.

EXCLUSION CRITERIA

1. Patient not fit for surgery.
2. Open fracture
3. Pathological fracture.

4. Immunocompromised status.
5. Non-union or malunion.
6. Associated neurovascular injury.

On admission, careful history was elicited from the patients or attendants to reveal the mechanism of injury and associated injuries.A detailed clinical examination and radiological assessment was done to assess the fracture pattern, deformity, neurovascular status associated injuries and for vital signs. Then the injured limb was immobilized in a above elbow plaster slab until surgery.

TABLE 2: DISTRIBUTION OF CASES ACCORDING TO AGE

AGE (YRS)	N	%
≤25	4	17.4
26-30	3	13
31-40	6	26.1
41-50	7	30.4
51-60	3	13
Total	23	100

	Range	Mean	SD
AGE (YRS)	19-60	38.5	11.4

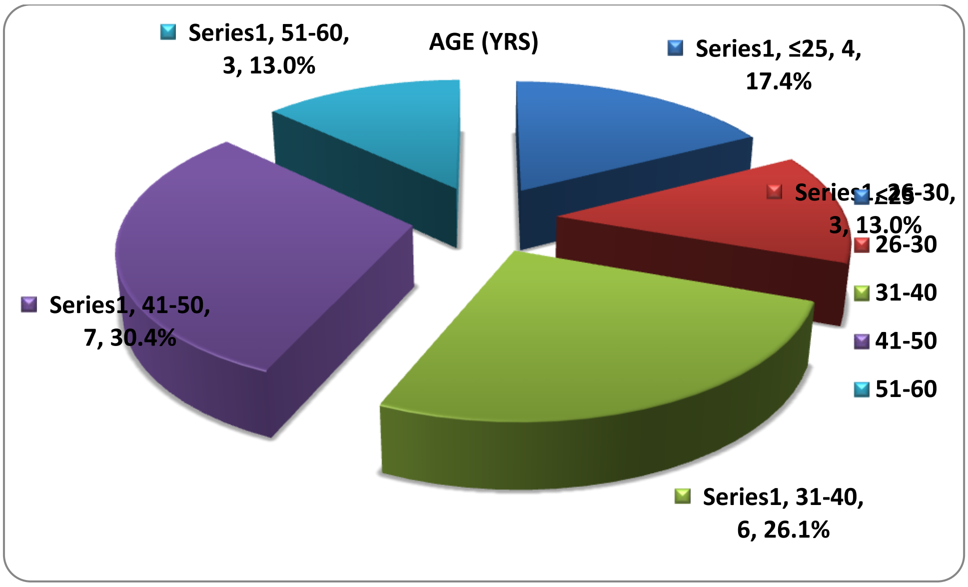


FIGURE 37: DISTRIBUTION OF CASES ACCORDING TO AGE

The Mean age of the patients was 38.5 years ranging from 19 to 65 years.

SEX DISTRIBUTION:

TABLE 3: DISTRIBUTION OF CASES ACCORDING TO SEX

SEX	N	%
MALE	15	65.2
FEMALE	8	34.8
Total	23	100.0

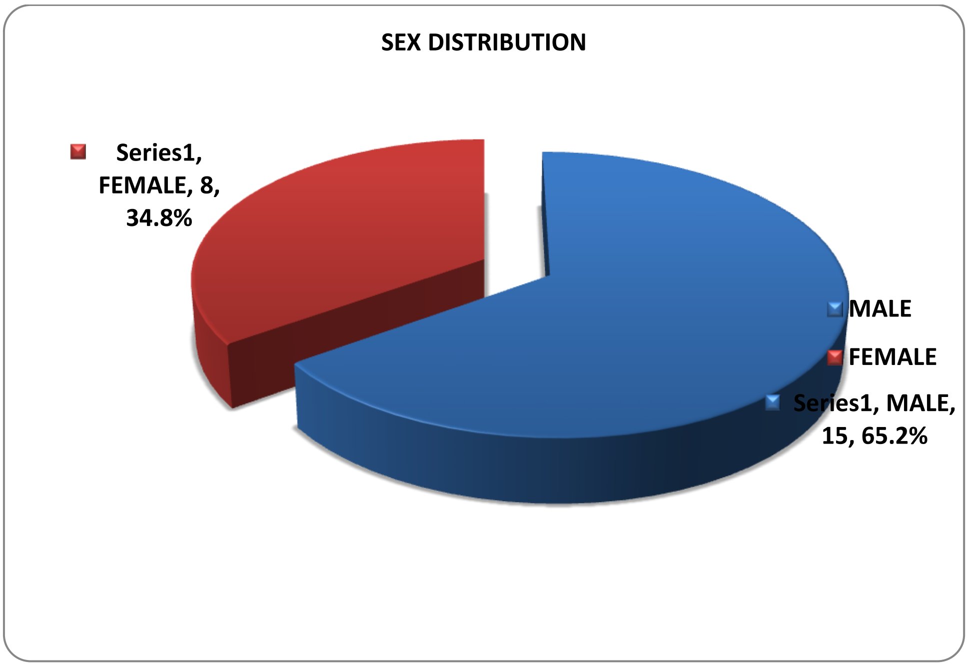


FIGURE 38: DISTRIBUTION OF CASES ACCORDING TO SEX

SEX DISTRIBUTION AS PER AGE-

TABLE 4: DISTRIBUTION OF AGE ACCORDING TO SEX

AGE (YRS)	MALE		FEMALE		p value
	N	%	N	%	
≤25	2	13.3%	2	18.2%	0.696
26-30	2	13.3%	1	9.1%	
31-40	4	26.7%	2	18.2%	
41-50	4	26.7%	3	27.3%	
51-60	3	20.0%	0	0.0%	
Total	15	100.0%	11	100.0%	

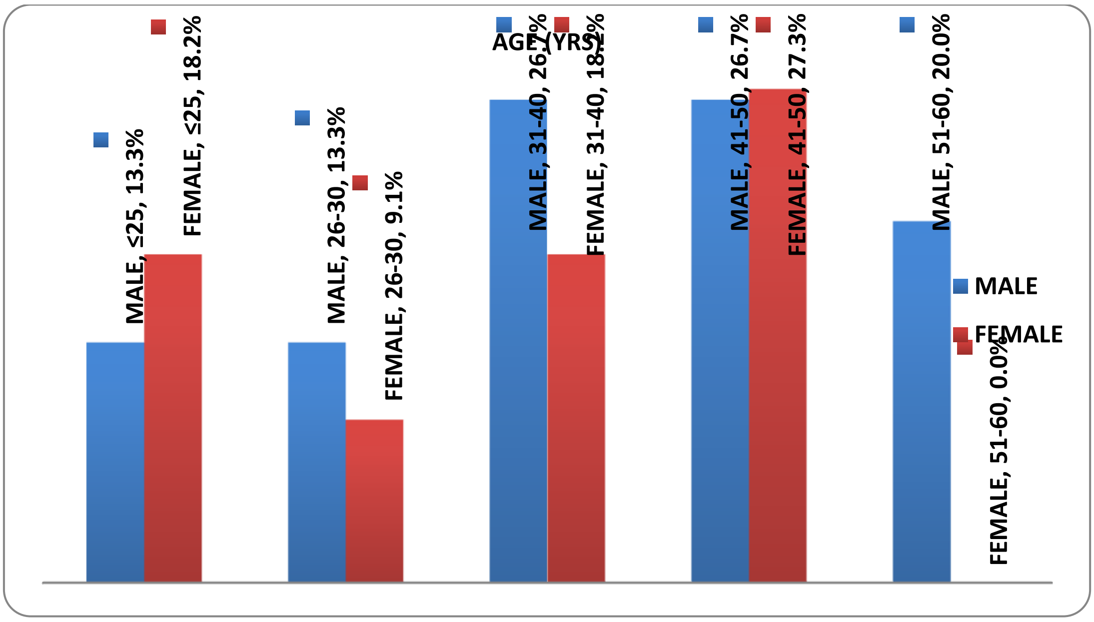


FIGURE 39: DISTRIBUTION OF AGE ACCORDING TO SEX

MODE OF INJURY-

TABLE 5: DISTRIBUTION OF CASES ACCORDING TO MODE OF INJURY

MODE OF INJURY	N	%
Fall	5	21.7
Fall from height	3	13
MVA	15	65.2
Total	23	100

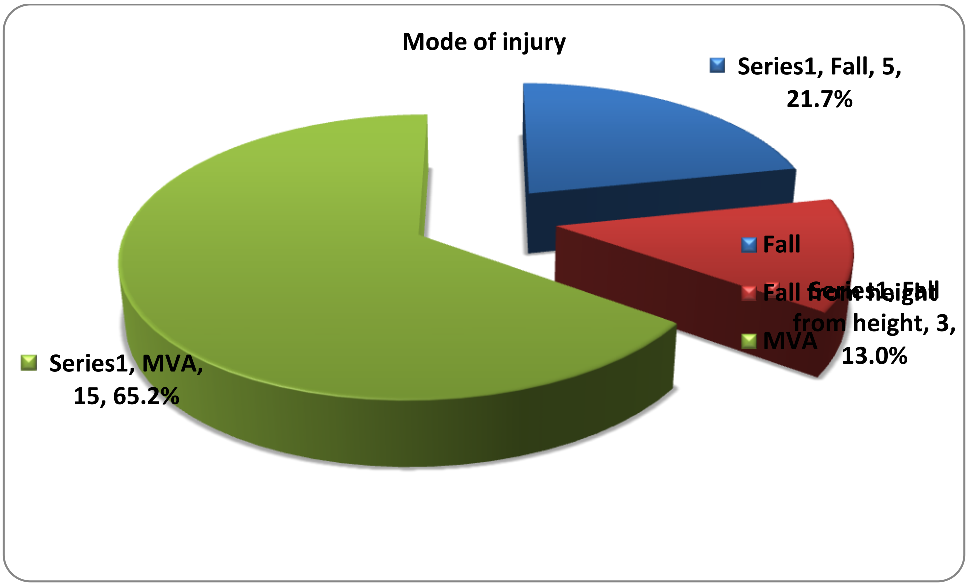


FIGURE 40: DISTRIBUTION OF CASES ACCORDING TO MODE OF INJURY

Majority of the patients suffered Motor vehicle accidents (MVA) . The second most common mode of injury was simple accidental falls. Other mode of injuries were fall from heights(FFH) and assault.

SIDE OF INJURY-

TABLE 6: DISTRIBUTION OF CASES ACCORDING TO SIDE

SIDE	N	%
LEFT	6	26.1
RIGHT	17	73.9
Total	23	100

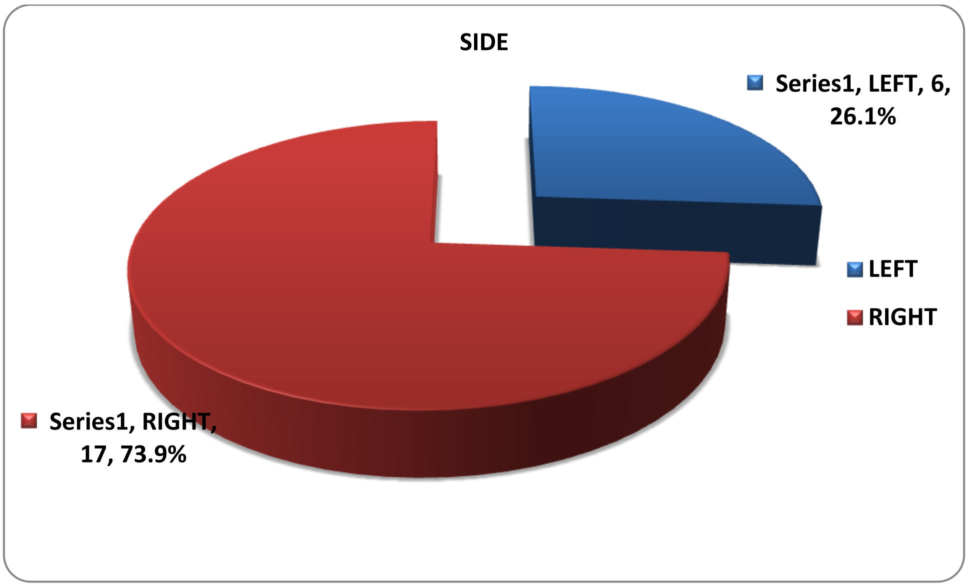


FIGURE 41: DISTRIBUTION OF CASES ACCORDING TO SIDE

17 patients (73.9%) had fracture of right distal humerus and 6 (26.1%) patients had left distal humerus fracture.

ACCORDING TO FRACTURE TYPE, GRADE AND APPROACH-

TABLE 7: DISTRIBUTION OF CASES ACCORDING TO AO TYPE

AO TYPE	N	%
C1	9	39.1%
C2	10	43.5%
C3	4	17.4%
Total	23	100

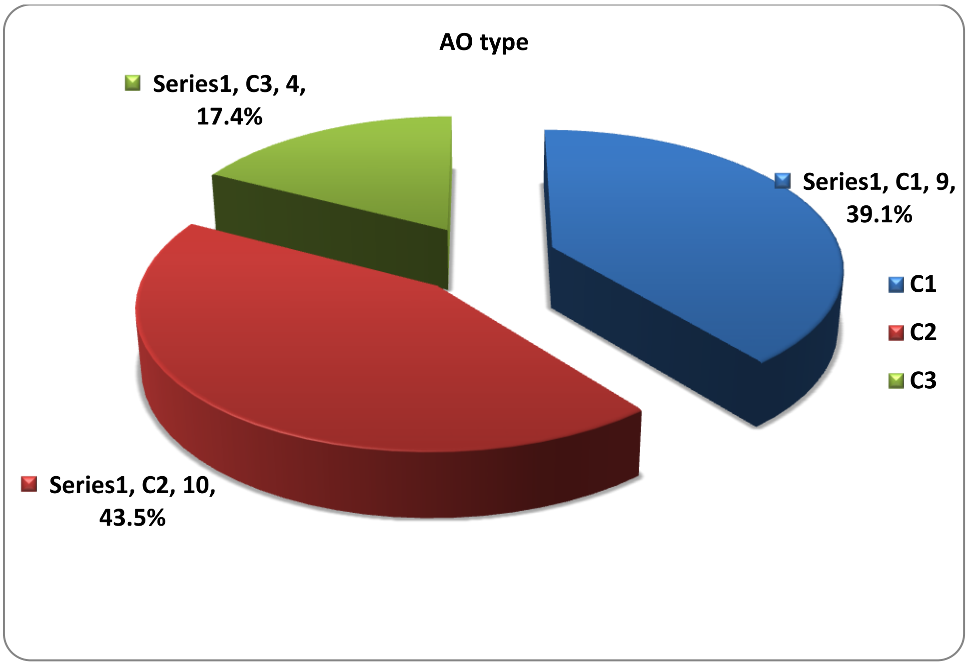


Figure 42- DISTRIBUTION OF CASES ACCORDING TO AO TYPE

TABLE 8: DISTRIBUTION OF CASES ACCORDING TO GRADE

GRADE	N	%
Closed	23	100
Total	23	100

TABLE 9: DISTRIBUTION OF CASES ACCORDING TO TREATMENT

TREATMENT	N	%
ORIF with bicollumnar plating	23	100
Total	23	100

TABLE 10: DISTRIBUTION OF CASES ACCORDING TO APPROACH

APPROACH	N	%
Olecranon osteotomy	23	100
Total	23	100

ACCORDING TO ROM-

TABLE 11: DISTRIBUTION OF CASES ACCORDING TO ROM

ROM	N	%
10-110	9	39.1
10-120	5	21.7
10-135	1	4.3
10-140	1	4.3
15-95	1	4.3
20-120	1	4.3
20-130	2	8.7
20-140	1	4.3
20-90	2	8.7
Total	23	100

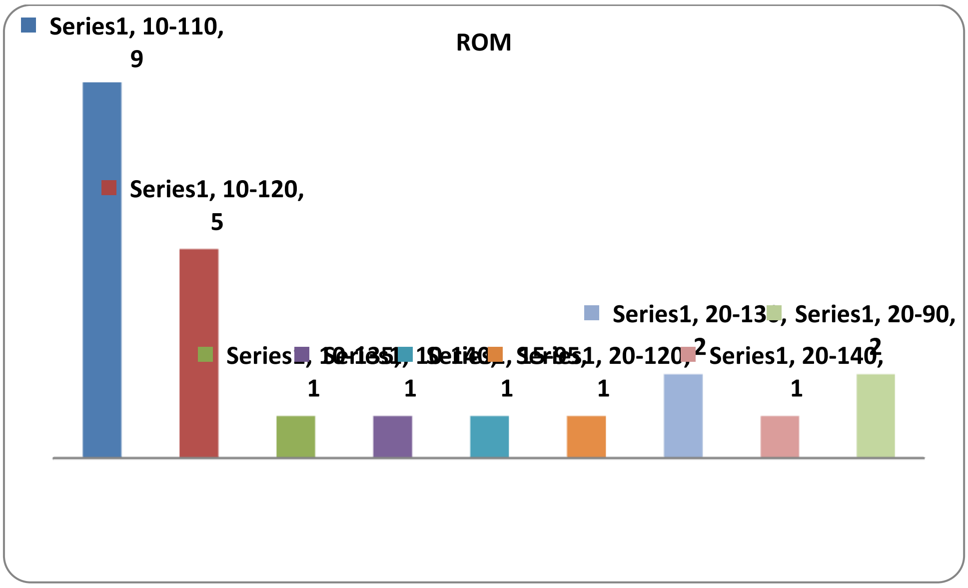


FIGURE 43: DISTRIBUTION OF CASES ACCORDING TO ROM

ACCORDING TO PAIN-

TABLE 12: DISTRIBUTION OF CASES ACCORDING TO PAIN

PAIN	N	%
MILD	1	4.3
MODERATE	2	8.7

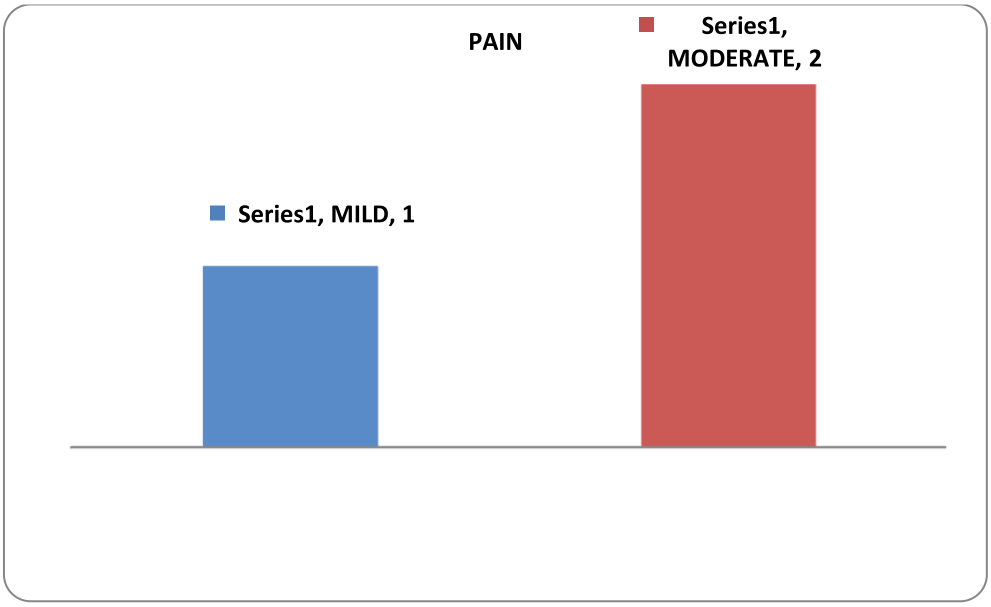


FIGURE 44: DISTRIBUTION OF CASES ACCORDING TO PAIN

ACCORDING TO MEPS SCORING-

TABLE 13: DISTRIBUTION OF CASES ACCORDING TO MEPS SCORE

MEPS SCORE	N	%
55	1	4.3
65	1	4.3
70	2	8.7
80	4	17.4
85	6	26.1
90	6	26.1
95	3	13
Total	23	100

	Range	Mean	SD
MEPS	55-95	83.3	10.1

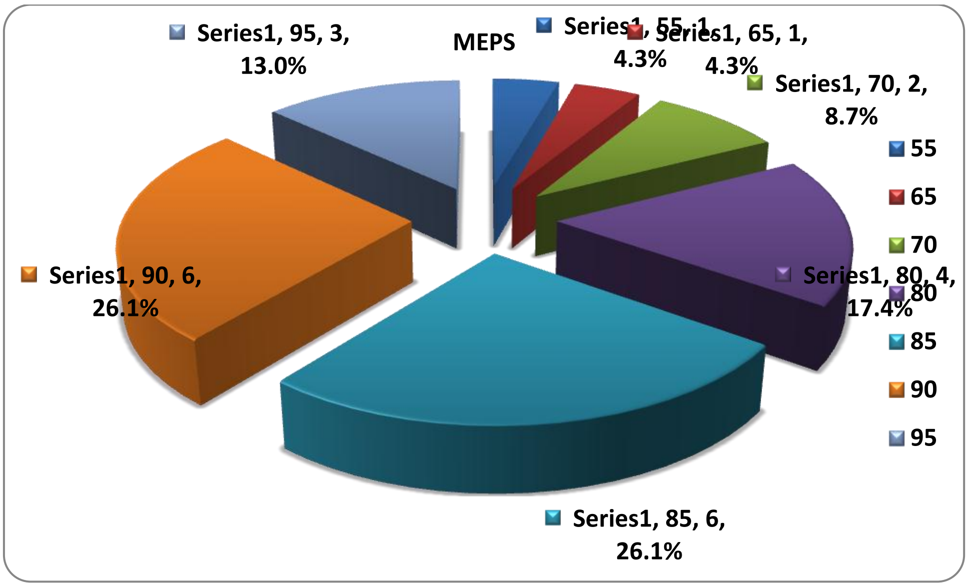


FIGURE 45: DISTRIBUTION OF CASES ACCORDING TO MEPS SCORE

ACCORDING TO COMPLICATIONS-

TABLE 14: DISTRIBUTION OF CASES ACCORDING TO COMPLICATIONS

COMPLICATIONS	N	%
Decreased elbow ROM due to heterotopic ossification	1	4.3
Hardware prominence	1	4.3
Non union at osteotomy site	1	4.3
Parasthesia in Ulnar N sensory area	2	8.7
Stiffness	2	8.7
Superficial infection	2	8.7

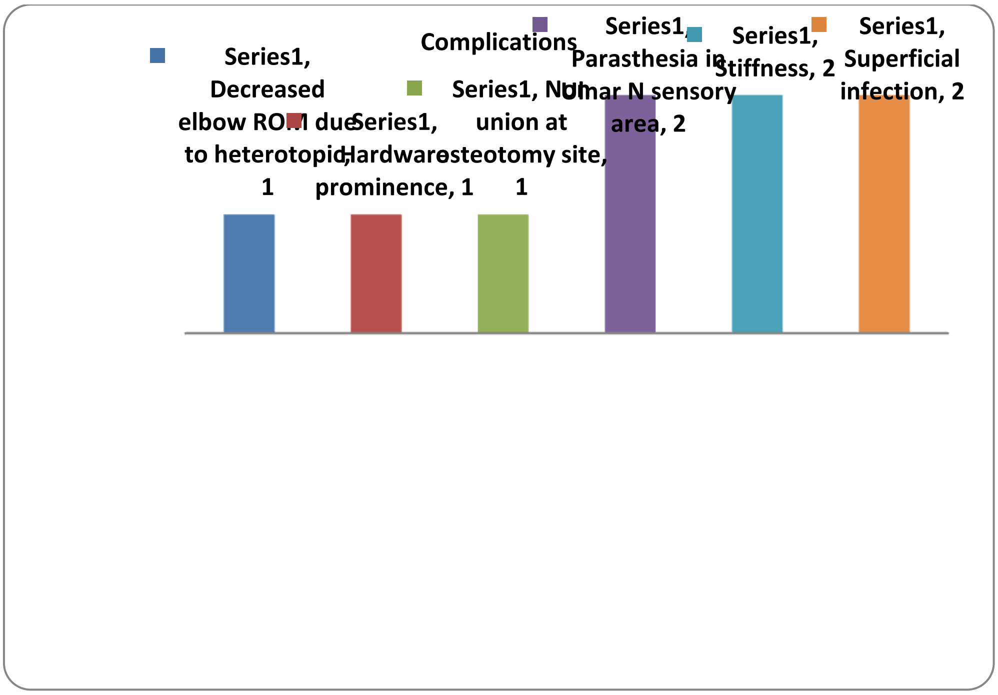


FIGURE 46: DISTRIBUTION OF CASES ACCORDING TO COMPLICATIONS

OBSERVATION AND RESULTS

The following observations were made in our study-

1) The Mean age of the patients was 38.5 years ranging from 19 to 65 years . Nearly 26.1% patients belong to 3rd decade followed by 4th decade (30.4%). 86.95% of the patients belonged to less than 50 years.
2) Males (2:1) predominated our study group.
3) Right limb injuries were more common.
4) Motor vehicle accidents and accidental simple falls were the common mechanisms of injury.
5) Motor vehicle accidents were major form of injury in younger males whereas simple fall from standing height had been the most common mode of violence in elderly females.
6) Intra-articular fracture constituted 100% of cases in our study.
7) Of the complete articular (intra-articular) types, the order of most common types were C2(43.5%) > C1(39.1%) > C3(17.4%)
8) All patients were operated by Chevron osteotomy approach (23 Patients).
9) In our study, the average surgical time delay was 4 days ranging from 2 to 7 days.
10) The average surgical time was 150 minutes ranging from 90 minutes to 3 hours.
11) Complications encountered in our study were paraesthesia along ulnar nerve distribution, superficial infection, stiffness, heterotopic ossification reducing ROM, non-union at osteotomy site and hard ware prominence.

12) Two patients had infection. One patient was treated conservatively with antibiotics. One patient who had a wound gapping on the 5th day over the olecranon, healed by secondary intention and split skin grafting was done.

13) Two patients reported numbness and paraesthesia along ulnar border of little finger which was treated conservatively.

14) Heterotopic ossification with reduced elbow ROM was observed in one patient. One patient who developed superficial infection was treated with antibiotics. Stiffness was noted in two patients. Stiffness in one patient occurred due to pain , post fixation.

15) One patient who had a nonunion at the osteotomy site was done a revision osteosynthesis with tension band wiring.

16) No patient died during treatment or follow up.

17) Twenty three patients of distal humerus fracture were treated surgically with bicolumnar locking plating and analyzed with average follow up of 6 months (6 weeks, 3 months, 6 months).

18) In our study, solid radiologic union was achieved primarily in all patients. The average time to union was about 14 weeks. Hardware failure or non-union did not occur in any patient.

19) The mean flexion-extension arc was 107°. The mean MEPS score was 83 in our study. The results were excellent for 9 elbows, good for 10, fair for 3, and poor for 1 patients.

CASE ILLUSTRATIONS

CASE 1

NAME: Umakant

IP NO: 35117

AGE/SEX: 35 yrs/Male

OCCUPATION: Tractor driver

Diagnosis: Fracture of distal humerus left side

AO/ASIF: Type 13 C3

ASSOCIATED INJURIES: nil

PROCEDURE DONE: Bicolumnar locking plating via olecranon osteotomy approach

COMPLICATIONS: nil

SECONDARY PROCEDURE: nil

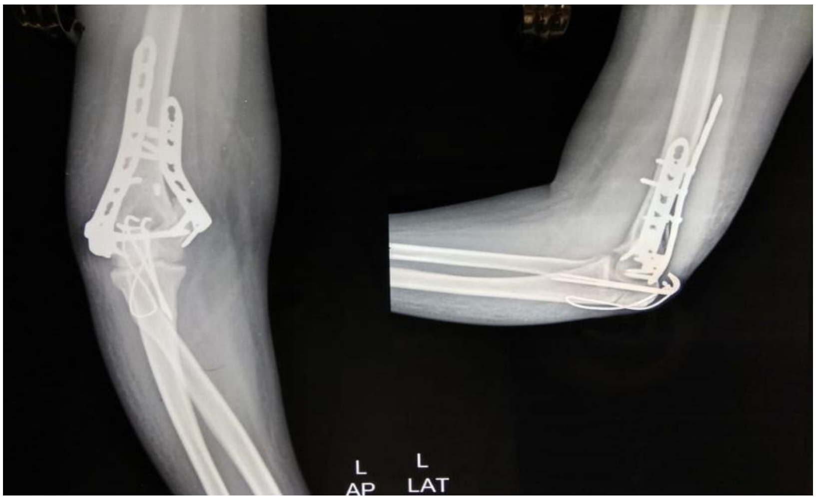
TIME OF UNION	10 weeks
ELBOW ARC OF MOTION	20-130 deg
MAYO SCORE	95
FUNCTIONAL OUTCOME	Excellent

PREOPERATIVE-

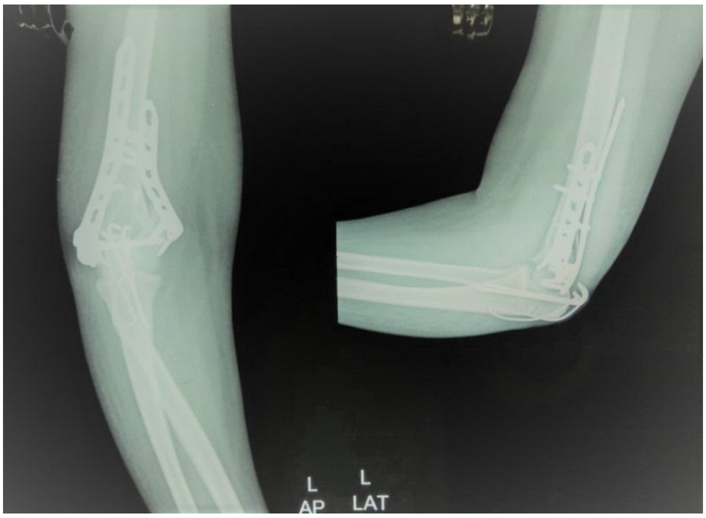
IMMEDIATE POSTOPERATIVE PERIOD-

AT 6 WEEKS-

AT 3 MONTHS-



AT 6 MONTHS-



ROM at 6 MONTHS-

CASE 2-

NAME: Kishore

IP NO: 36389

AGE/SEX: 50/M

OCCUPATION: Farmer

Diagnosis: Fracture of distal humerus right side

AO/ASIF: Type 13 C3

ASSOCIATED INJURIES: nil

PROCEDURE DONE: Bicolumnar locking plating via olecranon osteotomy approach

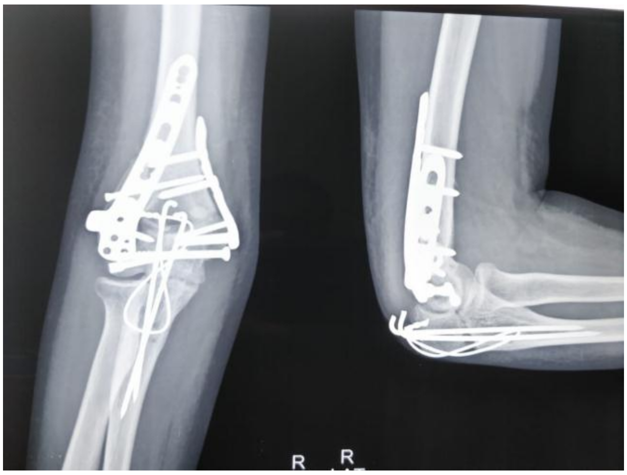
COMPLICATIONS: nil

SECONDARY PROCEDURE: nil

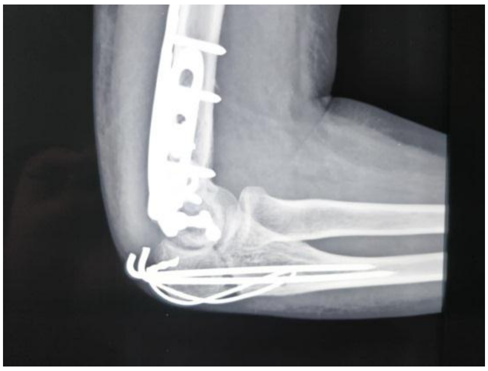
TIME OF UNION	11 weeks
ELBOW ARC OF MOTION	20-130 deg
MAYO SCORE	95
FUNCTIONAL OUTCOME	Excellent

PREOPERATIVE-

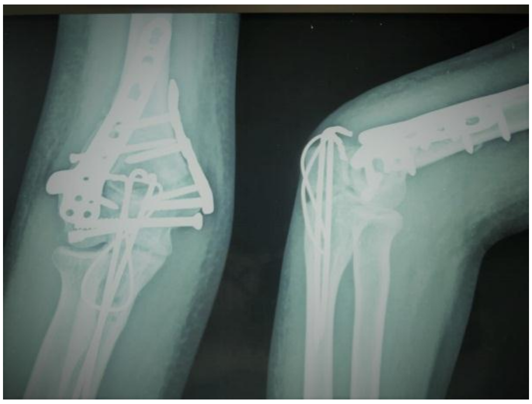
6 WEEKS-



3 MONTHS-



6 MONTHS-



ROM-

CASE 3-

NAME: Deepa

IP NO: 17153

AGE/SEX: 25/F

OCCUPATION: Homemaker

Diagnosis: Fracture of distal humerus left side

AO/ASIF: Type 13 C1

ASSOCIATED INJURIES: nil

PROCEDURE DONE: Bicolumnar locking plating via olecranon osteotomy approach

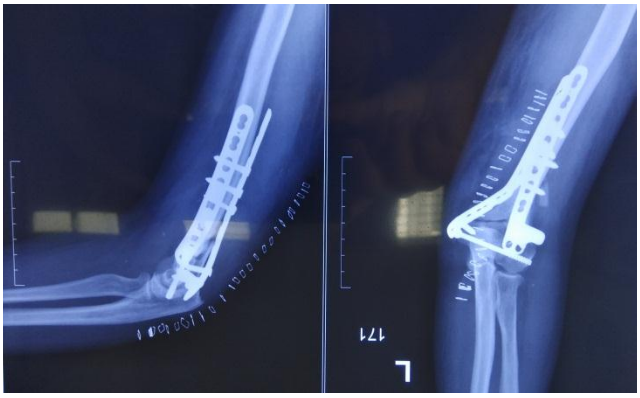
COMPLICATIONS: nil

SECONDARY PROCEDURE: nil

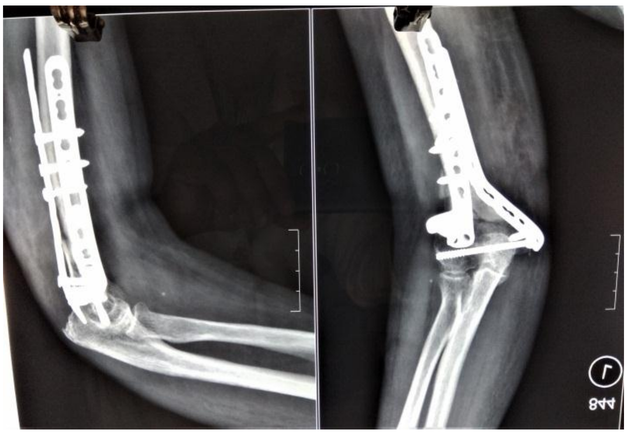
TIME OF UNION	10.5 weeks
ELBOW ARC OF MOTION	10-140 deg
MAYO SCORE	90
FUNCTIONAL OUTCOME	Excellent

PREOPERATIVE-

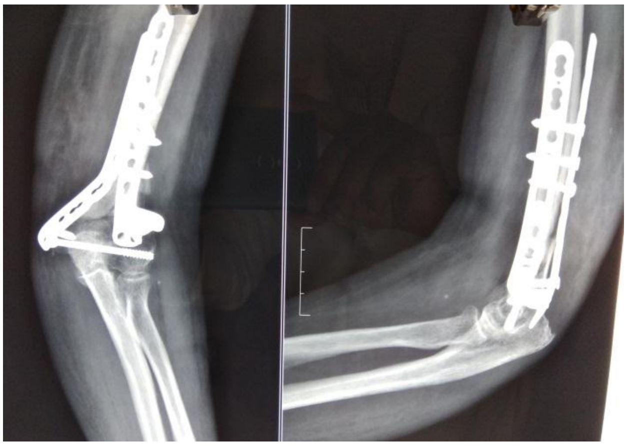
IMMEDIATE POSTOPERATIVE-



6 WEEKS-



3 MONTHS-



6 MONTHS-

ROM-

CASE 4-

NAME: Shiva

IP NO: 38503

AGE/SEX: 49/M

OCCUPATION: Farmer

Diagnosis: Fracture of distal humerus left side

AO/ASIF: Type 13 C2

ASSOCIATED INJURIES: nil

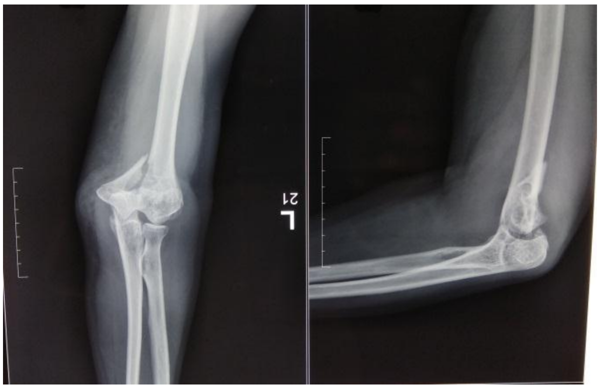
PROCEDURE DONE: Bicolumnar locking plating via olecranon osteotomy approach

COMPLICATIONS: nil

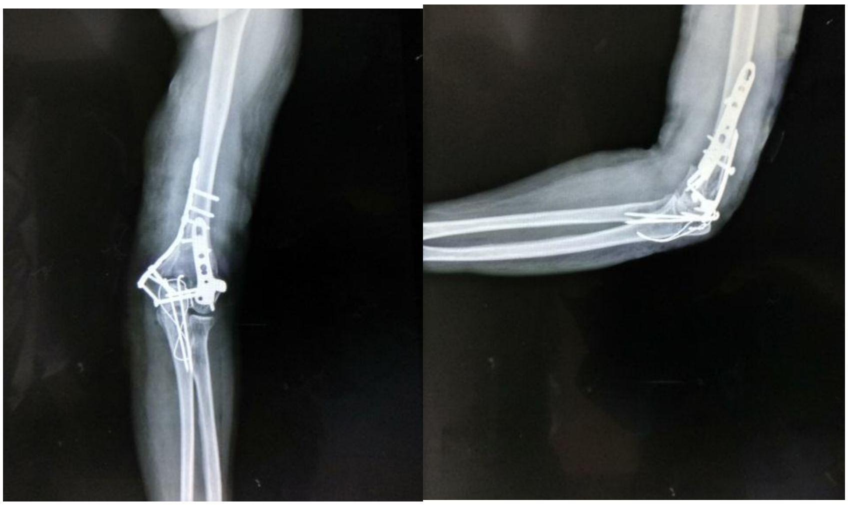
SECONDARY PROCEDURE: nil

TIME OF UNION	12 weeks
ELBOW ARC OF MOTION	10-120 deg
MAYO SCORE	90
FUNCTIONAL OUTCOME	Excellent

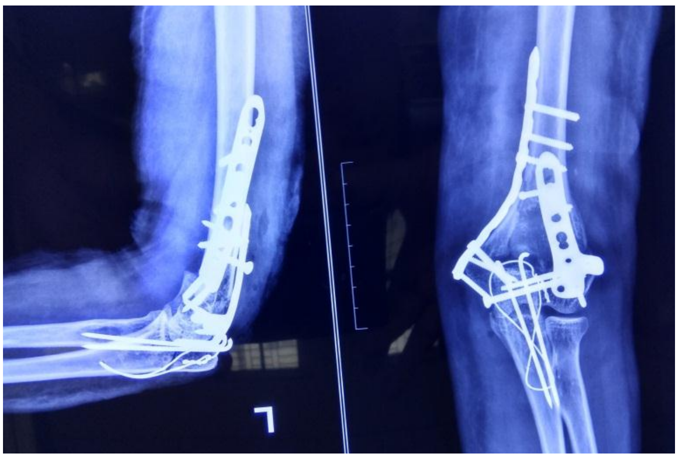
PREOPERATIVE-



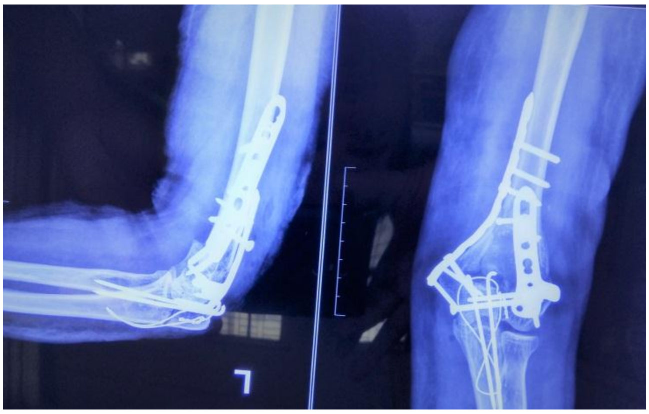
IMMEDIATE POSTOPERATIVE-



6 WEEKS-



3 MONTH



6 MONTH

ROM-

DISCUSSION

Functional elbow is very essential for an individual for social and economic thriving. Fractures of the distal humerus may directly affect the functional movement of elbow especially intercondylar (intra-articular) fracture. The relationship of the radiohumeral joint and ulnohumeral joints must be perfect for a good functional outcome.

The majority of distal humerus fractures presenting to our centre were resulting from road traffic accidents (65.2%) compared to study by Sanchez-*Sotelo et al* [50] where the major mechanism of injury was accidental fall from standing height(56%). This is probably reflective of the fact that several trauma cases are being referred to our centre which is the tertiary referral centre for trauma care of this region.

The male predominance (2:1) was seen in our centre as compared to 1:1 recorded by *Sanchez-Sotelo et al* [50] is the resultant of the high number of trauma cases treated in our centre and the fact that males are more prone for road traffic accidents compared to females because in our society females travel less.

Fracture configuration according to the OTA type had a significant bearing on the outcome in distal humerus patients treated surgically. Group C had a poorer outcome than group A patients. This has again stressed the importance and prognostic significance of the OTA classification. Study by *Sanchez-Sotelo et al* [50] revealed that the commonest fracture type was OTA class A and C which our study concurs It is also important to stress on the fact that incidence of type C fractures is more than the type A fractures suggesting that the incidence of high velocity injuries is on the rise.

The restoration of elbow function is dependent on three salient features: exposure, fixation and the post-operative rehabilitation, with later two are of primary consideration. Adequate exposure is necessary for visualization fixation of the fracture fragments. The optimal exposure is provided by the posterior approach with osteotomy of the olecranon.

Olecranon osteotomy was done all our cases. All of them were fixed with modified TBW with K wires. This allowed us complete examination of the articular surfaces of trochlea, capitellum, olecranon and radial head. It also gives access to the medial and lateral supracondylar ridges. Full evaluation of the fragments of the fracture and reduction can then be performed.

Although non-union of the osteotomy may be regarded as a potential complication of this exposure, TBW of the osteotomy has provided sufficient stability of the olecranon for immediate use of the elbow through a secure range of motion. Only one case in our 23 osteotomized elbows showed a non-union which was reunited with revision osteosynthesis with modified TBW.

23 cases in our study were operated with bicolumnar locking plating which provided absolute stability for early mobilisation. The lateral plate placement directly on the lateral column allows for lengthy screw placement which is limited in traditional orthogonal plating due the fear of anterior capitellar breach in the same. Since we use the 3.5mm reconstruction plates, it allows for easy contourability for both column fixation. The previous concept of using the more malleable 1/3 tubular plate for the medial column which requires heavy contouring is now in question and several authors recommend at least a stronger 3.5mm plates or precontoured plates for both columns to achieve a more stable and rigid construction to allow for early

mobilization. In our study we have not met any implant failures or non-union at the fracture site which is in par with the fact that bicolumnar locking plating offers an inherently stable construct in a given clinical situation and in concurrence with studies done on bicolumnar locking parallel plating by *Sanchez-Sotelo et al* [50] and *Atalar et al* [51].

COMPLICATIONS :

Elbow stiffness (secondary to heterotopic ossification(1) and moderate pain (1)), superficial infection and paresthesia in ulnar nerve sensory area were commonly seen in 6 patients. We had two patients who had infection, both were managed conservatively with antibiotics. Hardware prominence was a complaint in one of the patient. All but three elbows were completely painless at the final follow up. All fracture united within the study period .There were no cases of non-union at the fracture site except for a non-union at the osteotomy site due to distraction which united with revision osteosynthesis with modified tension band wiring.

Sanchez-Sotelo et al [50] describe complication rates of 43% which included wound-healing complications (6%), deep infection (3%), nonunion (3%), heterotopic ossification (16%),Osteonecrosis 1 (3%),Posttraumatic arthritis 2 (6%) Permanent ulnar neuropathy(6%). Gofton et al reported a complication rate of 48%, which included heterotopic ossification(17%), olecranon nonunion(9%), and infection (9%). *Atalar et al* [51] showed a complication rate of 48% in their study group of 21 patients. The other previously referenced studies reported complication rates of 11% to 29% [21,24]. In the recently published retrospective series of *Athwal et al.*[52] assessing the Mayo Elbow parallel plate technique, they noted a complication rate of 53 percent, with complications arising in 17 of 32 patients. The most common complication noted was postoperative nerve injuries (16%), wound complications(12%) including two wound dehiscences requiring surgical debridement. One olecranon nonunion was noted which was treated non-operatively. Our study showed a similar complication rate of 39 % which is concurrent with the international literature which included infection (8.7%), heterotopic ossification (4.3%), Nonunion at osteotomy (4.3%), stiffness with pain excluding myositis and infection(8.7%),hard ware prominence(4.3%).

Elbow stiffness due to all causes was one of the complications (8.3%) in our study group .Poor compliance to physiotherapy and mobilisation was a major determinant in elbow stiffness. Though the construct might favour early mobilisation, the motivation and compliance for physiotherapy plays a major role in instituting earlier range of motion exercises after surgery and to get a better functional outcome.

There was no iatrogenic nerve complication in our study. Post-operative ulnar nerve paraesthesia was observed in 2 patients (8.7%). These paraesthesia were transient and all of them recovered without any particular treatment within 2 months post op. Medial plates or ulnar nerve handling may be a reason for this. One patient had sensory involvement of the ulnar nerve. He showed a partial recovery of the ulnar nerve function at the last follow up. Ulnar neuropathy can occur during the initial injury or iatrogenically during surgical fixation. The rate of ulnar neuropathy following ORIF of distal humerus fractures has been reported as being between zero and 12% in the previously described studies[20-23]. McKee et al reported on 20 patients with ulnar neuropathy following failed elbow reconstruction; they found mostly good to excellent recovery from ulnar neuropathy when they performed neurolysis and transposition of the nerve.

The mean age of our study group was 38.5 years as compared to 58 years in the study by *Sanchez-Sotelo et al* [50] and 47 years in study by *Atalar et al* [51].This shows a rising incidence of these injuries among younger population due to the higher incidence of road traffic accidents in developing countries like India. Younger patients, often males had these high velocity injuries like motor vehicle accidents and fall from height in working place associated with soft tissue injury.

Bony union took an average of 13.4 weeks in our study which is comparable to 12 weeks obtained by Sanchez-*Sotelo et al*[50]. All patients had bony union at end of the study period.

Atalar et al [51] had a mayo elbow score of 86 with 85% good to excellent results in his series (flexion –extension 120°). *Sanchez-Sotelo et al* [50] showed an average MEPI score of 85 (flexion –extension 99 deg) with 83% good to excellent results in his series. *Athwal et al* [52]in his recently published retrospective review of AO/OTA type C fractures treated with the precontoured bicolumnar parallel plates. In their series of 32 patients, the mean elbow arc of motion was 97 degrees. The mean Mayo Elbow Performance score was 82 points. Our study group had an average Mayo elbow score of 83(flexion extension arc of 107 deg) which was comparable to the previous studies and shows that bicolumnar locking plating can produce consistently good to excellent functional outcomes in management of these complex injuries.

Comparison with similar studies in the literature

	Our study	*Sanchez-Sotelo et al*[50]	*Atalar et al*[51]
Number of elbows	23	32	21
Mean Age	38.5 yrs	58 yrs	47 yrs
M:F ratio	2:1	1.4:1	2:1
Mean Follow up	6 months	24 months	28 months
Fracture types AO	C1=9,C2 = 10, C3=4	A3 = 3, C2 = 4, C3 = 25	C1 = 3, C2 = 6, C3 = 12
Resurgeries	Revision osteosynthesis at Osteotomy(1)	HO removal (4), distraction arthroplasty (1), triceps reconstruction (1)	(2), Stiffness (2), Osteotomy site Implant removal (5)
Ulnar Neuropathy	-	6(18.75%)	Nil
Mean Arc of motion	107°	99°	90.2±31.1°
MEPS	83.3	85	86.1±12.6°
Satisfactory rate	82%	83%	85%

CONCLUSION

- Incidence of complex distal humerus fractures among younger population is on the rise due to increasing motor vehicle accidents.
- Absolute stability of the system allows early post-operative rehabilitation and thence a better functional outcome.
- Good to excellent functional outcome was achieved in about 82% of the study group in terms of arc of motion and stability
- Absence of implant failure and non-union may be attributed to the highly stable construct system achieved by biolumnar locking plating.
- Though it appears to be a variant of traditional plate placement, it is completely a different concept providing a greater stability in osteoporotic and communited bones.
- Biolumnar locking plating can be a successful technique for internal fixation of these complicated fracture, when its principles are strictly adhered to.

SUMMARY

- In our study, bicolumnar locking plating was done for 23 intra articular distal humerus fracture, among age group more than 18 years. Mean age of incidence was 38.5 years.
- Male : Female ratio of 2:1 was noted.
- Major mode of injury was seen to be motor vehicle accident with most cases presenting as C2 intra articular fracture according to AO Classification.
- Mean duration of bony union was seen to be 13.4 weeks.
- 39% patients were seen to have complications namely stiffness in 2 patients, decreased elbow ROM due to heterotopic ossification in 1 patient, hardware prominence in 1 patient etc.
- Mean arc of motion in the end of study was seen to be 107°.
- MEPS Score of 83.3 and 82% satisfactory rate was achieved with our study.
- Patients were discharged from hospital with mean hospital stay period of 11 days.
- Patient follow up was done at 6 weeks, 3 months and 6 months.
- Majority of our patients were pain free with near full range of motion.

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ANNEXURES

ETHICAL CLEARANCE CERTIFICATE

PROFORMA

___________________ MEDICAL COLLEGE, HOSPITAL AND RESEARCH CENTRE, _________________

CASE NO. :

NAME :

AGE/SEX :

I P NO :

DATE OF ADMISSION :

DATE OF SURGERY :

DATE OF DISCHARGE :

OCCUPATION :

RESIDENCE :

Presenting complaints with duration :

History of presenting complaints :

Family History :

Personal History :

Past History :

General Physical Examination

Pallor:	present/absent
Icterus:	present/absent
Clubbing:	present/absent
Generalized lymphadenopathy:	present/absent
Built:	poor/moderate/well
Nourishment:	poor/moderate/well

Vitals

PR: RR:

BP: TEMP:

Other Systemic Examination:

Local examination:

Right/ Left elbow

Gait:

Inspection:

a) Attitude/ deformity

b) Abnormal swelling

- Site

- Size

- Shape

- Extent

c) Skin

d) Compound injury if any

Palpation:

a) Local tenderness

b) Bony irregularity

c) Abnormal movement

d) Crepitus

e) Swelling

Movements:		Active	Passive
ELBOW	FLEXION		
	EXTENSION		
	SUPINATION		
	PRONATION		

INFORMED CONSENT FOR PARTICIPATION IN DISSERTATION/RESEARCH

________________________ MEDICAL COLLEGE HOSPITAL AND RESEARCH CENTER, ________________

I, the undersigned,_______________ , S/O D/O W/O ________________, aged ____years, ordinarily resident of ____________ do hereby state/declare that Dr. __________________ of _____________ Medical College Hospital and Research Centre has examined me thoroughly on ______________ at ______________ (place) and it has been explained to me in my own language that I am suffering from ________________ disease (condition) and this disease/condition mimic following diseases. Further Dr. _________________ informed me that he/she is conducting dissertation/research titled functional outcome of treatment of inter articular distal humerus fracture treated with open reduction and internal fixation by Bicolumnar locking plate.

" Under the guidance of ________________ requesting my participation in the study. Apart from routine treatment procedure, the pre-operative, operative, post-operative and follow-up observations will be utilized for the study as reference data.

Doctor has also informed me that during conduct of this procedure like adverse results may be encountered. Among the above complications most of them are treatable but are not anticipated hence there is chance of aggravation of my condition and in rare circumstances it may prove fatal in spite of anticipated diagnosis and best treatment made available. Further Doctor has informed me that my participation in this study help in evaluation of the results of the study which is useful reference to treatment of other similar cases in near future, and also I may be benefited in getting relieved of suffering or cure of the disease I am suffering.

The Doctor has also informed me that information given by me, observations made/ photographs/ video graphs taken upon me by the investigator will be kept secret and not assessed by the person other than me or my legal hirer except for academic purposes.

The Doctor did inform me that though my participation is purely voluntary, based on information given by me, I can ask any clarification during the course of treatment / study related to diagnosis, procedure of treatment, result of treatment or prognosis. At the same time I have been informed that I can withdraw from my participation in this study at any time if I want or the investigator can terminate me from the study at any time from the study but not the procedure of treatment and follow-up unless I request to be discharged.

After understanding the nature of dissertation or research, diagnosis made, mode of treatment, I the undersigned Shri/Smt ______________________________ under my full conscious state of mind agree to participate in the said research/dissertation.

Signature of patient:

Signature of doctor:

Witness: 1.

2.

Date:

Place

KEY TO MASTERCHART

S.No	**Serial number**
R	**Right**
L	**Left**
MOI	**Mode of injury**
ROM	**Range of motion**
MEPI	**Mayo Elbow Performance Index**
MEPS	**Mayo Elbow Performance Score**
M	**Male**
F	**Female**
ORIF	**Open reduction and internal fixation**

MASTER CHART

S. NO	Name	IP NO.	Age/ Sex	R/L	MOI	AO	Grade	Treatment	Approach	A/I	ROM	Pain	MEPI	MEPS	Complications
1	Umakant	35117	40/M	R	MVA	C3	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	-	20-130		Excel lent	95	
2	Nagappa	35917	60/M	R	MVA	C1	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	-	10-110		Good	85	Superficial infection
3	Pavitra	35910	26/F	R	MVA	C1	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	0	20-130		Excel lent	90	
4	Basapa	37244	44/M	R	MVA	C1	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	0	15-90		Poor	55	Decreased elbow ROM due heterotopic ossification
5	Kishor	36389	50/M	R	Fall	C3	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	0	20-130		Excel lent	95	
6	Neeta	39241	34/F	R	MVA	C2	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	0	10-110		Good	85	

7	Prakash	37614	25/M	L	MVA	C2	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	0	15-95		Fair	70	Decreased elbow ROM due heterotopic ossification
8	Sadashiv	39738	49/M	L	Fall	C2	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	0	10- 110		Good	80	Non union at osteotomy site
ep9	Kallappa	38471	30/M	R	MVA	C2	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	0	20- 130		Excel lent	95	
10	Suresh	30330	56/M	L	Fall from height	C 2	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	0	10- 135		Excel lent	90	
11	Rajesh	30179	32/M	R	MVA	C 2	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	0	20- 120		Good	85	
12	Manjula	31612	25/F	R	MVA	C 1	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	0	10- 120		Excel lent	90	Paresthesia in ulnar nerve sensory area
13	Shiva	38503	49/M	L	MVA	C 2	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	0	10- 120		Excel lent	90	

14	Ravi	33444	29/M	R	Fall	C 1	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	0	10-110		Good	80	Superficial infection
15	Poornima	34335	36/F	L	Fall	C1	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	0	20-90	Moderate	Fair	70	Stiffness due to pain
16	Girish	34747	50/M	R	MVA	C3	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	0	10-120		Good	80	
17	Umesh	25939	36/M	R	MVA	C3	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	0	10-120		Good	85	Hardware prominence
18	Kumar	26755	32/M	R	MVA	C1	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	0	20-90		Fair	65	Stiffness
19	Deepa	17153	25/F	L	Fall from height	C1	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	0	10-140		Excellent	90	
20	Shivanand	27602	51/M	R	MVA	C1	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	0	20-130	Mild	Good	85	

21	Renuka	28060	41/F	R	MVA	C2	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	0	10-120		Good	85	
22	Sumitra	28575	47/F	R	MVA	C2	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	0	10-110		Good	80	
23	Janabi	28510	19/F	R	Fall	C2	Closed	ORIF with bicolumnar locking plating	Olecranon osteotomy	0	20-140		Excellent	90	Paresthesia in ulnar nerve sensory area