FUNCTIONAL OUTCOME ANALYSIS OF PARALLEL PLATE TECHNIQUE FOR DISTAL HUMERUS FRACTURES

Dissertation submitted in

Partial fulfilment of the requirement for

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ORTHOPAEDIC SURGERY

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RAJIV GANDHI GOVT. GENERAL HOSPITAL

THE TAMILNADU DR.M.G.R.MEDICAL UNIVERSITY

CHENNAI-TAMILNADU

APRIL 2013

CERTIFICATE

This is to certify that this dissertation titled **“Functional Outcome Analysis of Parallel-Plate technique for distal humerus fractures”** is a bonafide record of work done by **DR.DINESH.L,** during the period of his Post graduate study from May 2010 to April 2013 under guidance and supervision in the Institute of ORTHOPAEDICS AND TRAUMATOLOGY, Madras Medical College and Rajiv Gandhi Government General Hospital, Chennai-600003, in partial fulfilment of the requirement for **M.S.ORTHOPAEDIC SURGERY** degree Examination of The Tamilnadu Dr. M.G.R. Medical University to be held in April 2013.

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DECLARATION

I declare that the dissertation entitled **"FUNCTIONAL OUTCOME ANALYSIS OF PARALLEL PLATE TECHNIQUE FOR DISTAL HUMERUS FRACTURES"** *submitted by me for the degree of M.S is the record work carried out by me during the period of* ***May 2010 to November 2012*** *under the guidance of Professor* ***Dr*****.M.R.RAJASEKAR M.S.ORTHO., D.Ortho.,** *Professor & Head of the Department of Orthopaedics, Institute of Orthopaedics and traumatology, Madras Medical College, Chennai. This dissertation is submitted to the Tamilnadu Dr.M.G.R. Medical University, Chennai, in partial fulfilment of the University regulations for the award of degree of M.S.ORTHOPAEDICS (BRANCH-II)) examination to be held in April 2013.*

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Functional Outcome Analysis of Parallel Plate Technique for Distal Humerus

BY DINESH LOGANATHAN

INTRODUCTION

14 Fractures of the distal humerus accounts for 2-6% of all fractures and 1/3 of all humeral fractures. Intraarticular distal humerus fractures are very rare accounting 0.5% of all fractures.(1) In this modern 1 society with a growing elderly population and a extremely active young population the incidence of distal humeral fractures is increasing having a bimodal distribution .1 In young adults, most distal humerus fractures occur from high-energy trauma like sideswipe injuries, motor vehicle accidents .1 In elderly persons with more osteoporotic bone, these injuries occur from simple falls.(2) In this era of modern orthopaedics, despite various advances ,distal humeral fractures remain 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 pose

CONTENTS

CASE PROFORMA

Functional Outcome Analysis of parallel plating in distal humeral fractures

Case no:……………………… Unit:………………………

Name:…….…………………………………………………Age/Sex:….…. /………

I.P No: ….………………………Occupation:………………………………………..

Address:………………………………………………………………………………………

………………………………………….Phone:…………………………………

Date of injury : ……………/…………./………………………….

Date of admission : ……………/…………./………………………….

Date of definitive surgery : ……………/…………./………………………….

Date of discharge : ……………/…………./………………………….

Mechanism of injury:

- ☐ **Road traffic accident**
- ☐ **Accidental fall**
- ☐ **Fall from height**
- ☐ **Assault with weapon Others……………………………………**

General condition:

- ☐ **Conscious**
- ☐ **Drowsy**
- ☐ **Unconscious**

Haemodynamic status:

- ☐ **Stable (Systolic BP>110 mmHg, PR<90/min)**

- ☐ **Moderately stable** **(Systolic BP 70 to 90 mmHg, PR 90 to 110/min)**
- ☐ **Unstable** **(Systolic BP<70 mmHg, PR>110/min)**

Side involved: (Right/Left)

<u>Type of injury</u>:

(a) Closed

(b) Open

- ☐ **Grade I**
- ☐ **Grade II**
- ☐ **Grade III A**
- ☐ **Grade III B**
- ☐ **Grade III C**

<u>Type of the fracture</u>:(Xray findings)

Type A: Extra-articular

- ☐ **A1: simple # of metaphysic**
- ☐ **A2: metaphyseal wedge #**
- ☐ **A3: complex metaphyseal#**

Type B: Partial-articular

- ☐ **B1: lateral condyle sagittal**
- ☐ **B2: medial condyle sagittal**
- ☐ **B3: frontal # of the capitellum or trochlea**

Type C: Complete articular

- ☐ **C1: simple # of both the articular surface and the metaphysic**
- ☐ **C2: simple # of articular surface, multifragmentery at metaphysic**
- ☐ **C3: multifragmentary # of articular surface**

Associated other long bone injuries: (Yes/No)

Associated head injury: (Yes/No)

Treatment history:

Date of surgery:

Duration of Surgery:

Implants used :

Blood transfusion: (yes/no)

Other fracture fixation:

Intra operative complication:

Immediate post operative complication:

Late post operative complication:

1 st Follow up	Date :	**Complaints**	
		Wound	
		x-ray	
		MEPS score	
		ROM	
		Advice	
		Asst. Sign	

2st Follow up	Date :	**Complaints**	
		Wound	
		x-ray	
		MEPS score	
		ROM	
		Advice	
		Asst. Sign	

3 rd Follow up	Date :	**Complaints**	
		Wound	
		x-ray	
		MEPS score	

		ROM	
		Advice	
		Asst. Sign	

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

INTRODUCTION

Fractures of the distal humerus accounts for 2-6% of all fractures and 1/3 of all humeral fractures. Intraarticular distal humerus fractures are very rare accounting for 0.5% of all fractures[1]. In this modern society with a growing elderly population and a extremely active young population, the incidence of distal humeral fractures is increasing and having a bimodal distribution .In young adults, most distal humerus fractures occur from high-energy trauma like sideswipe injuries, motor vehicle accidents(MVA) .In elderly persons with more osteoporotic bone, these injuries occur from simple falls[2].

In this era of modern orthopaedics, despite various advances ,distal humeral fractures remain 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 forementioned issues along with the complex three dimensional geometry pose great difficulties in internal fixation. Poor outcomes like contracture, secondary to prolonged immobilization thought to be necessary to protect the fixation, nonunion, high failure rate are noted with old internal fixation techniques. Attempt to achieve painless, stable yet mobile elbow requires a systematic approach in for open reduction and internal fixation[6,7,8,9,10,11] .

The treatment of these fractures 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 fractures 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 fractures include open reduction and internal fixation (ORIF) with plates and screws. ORIF of the fracture allows the surgeon to restore anatomical alignment of the fracture fragments and permit early range of motion (ROM) exercises which may aid in the return of a functional ROM of the elbow postoperatively. Various forms of internal fixation have been evolved over time in an attempt to best restore anatomical alignment of the distal humerus. The anatomical location to place the plates on the distal humerus has recently been debated throughout the literature with the majority of authors currently recommending at least two plates be utilized to provide adequate stability and allow for adequate restoration of anatomy.

The guidelines proposed by the AO/ASIF group for fixation of distal humeral fractures has been a gold standard till now with 2 plates placed at a 90° angle to one another (orthogonal/perpendicular/90°/90° plating).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 parallel plating (180°), 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 parallel 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] .

AIM AND OBJECTIVE

To analyse the functional outcome of patients treated with parallel plate technique in distal humeral fractures in Institute of Orthopaedics and Traumatology, Rajiv Gandhi Government General Hospital, Madras Medical College, Chennai from May 2010 to November 2012.

HISTORY AND REVIEW OF LITERATURE

Distal humeral fractures 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 fractures 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 fractures are the most difficult of all fractures, 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 fractures, 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 fractures, 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 fractures 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 intra-articular fractures. There is fair evidence to suggest that, the use of a triceps-splitting 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 fractures 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 fractures 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 fractures 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 fractures 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[13] 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.

In 2006, Doornberg et al [47] concluded from a long term follow-up study of 19 years, results of open reduction and internal fixation of 19 Type C fractures 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.

In 2001, O'Driscoll et al[12] defined the principles of fixation of these fractures using 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:

Eight Technical Principles in Distal Humerus Fixation

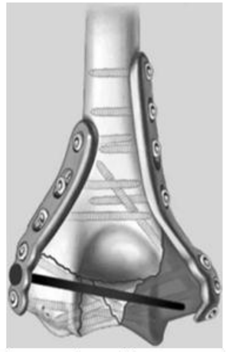
Principles concerning screws in the distal fragments (articular segment)

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.**

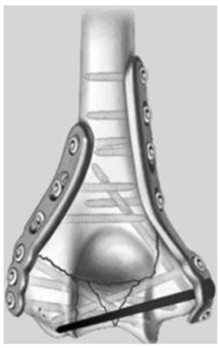
Principles concerning the plates used for fixation

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.**

8 TECHNICAL PRINCIPLES OF PARALLEL PLATING

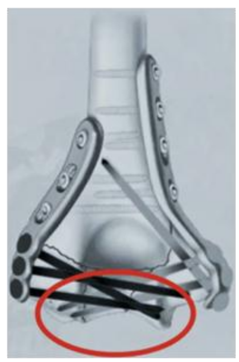


Every screw should engage a opposite column fragment fixed by a plate of that side

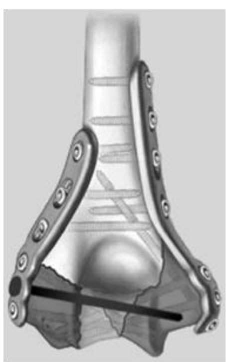


Each screw should pass through the plate

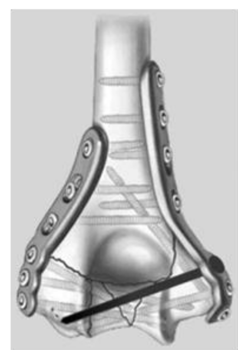
As many screws as possible should be placed in the distal fragment



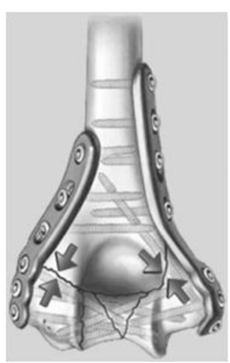
The screws in the distal fragment should lock together by inter-digitation



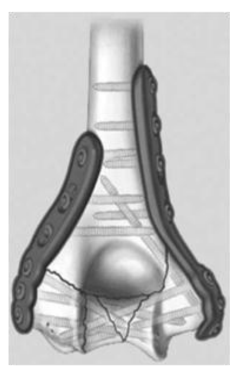
Each screw should engage as many articular fragments as possible



Each screw should be as long as possible



Plates should be applied with adequate supracondylar compression



Plates should be strong and stiff enough to resist all the forces

All these principles can be achieved by using parallel 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 fractures .

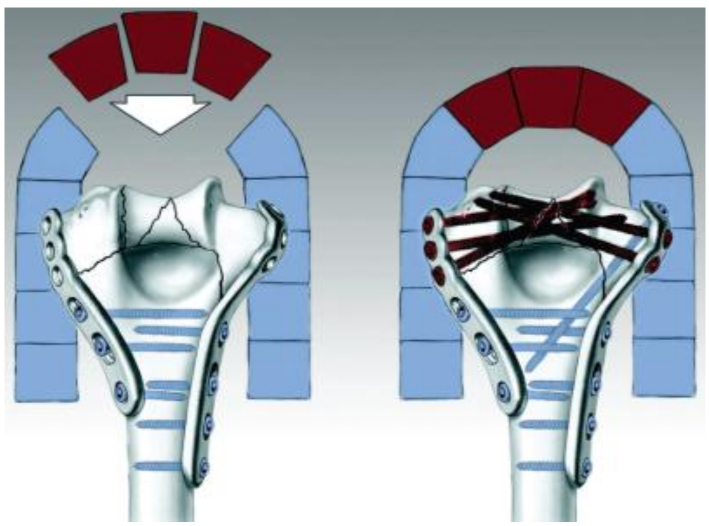


Figure showing the Interdigitating screws restoring keystone integrity of the arch

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.

After parallel 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]. 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.

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 fractures in his series by Letsch et al.[8], 3 of 57 reported on by Holdsworth and Mossad[19], 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] .There were no failures of fixation in series of O Driscoll's parallel plating[12,22]. 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 biomechanically stable than perpendicular as per cadaveric bone studies, clinical comparison of these two plates in large groups is not available till date.

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). 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 fractures [44].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.

ANATOMY OF DISTAL HUMERUS

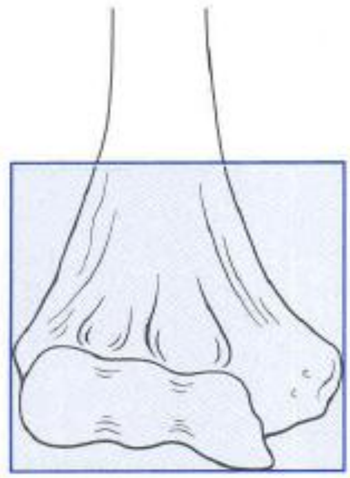


Figure shows the Epicenter described by Mueller

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. Proximal to the trochlea, the **prominent medial epicondyle** serves as a source of attachment of the ulnar collateral ligament and the flexor-pronator group of muscles. Laterally, **the lateral epicondyle** is located just above the capitellum and is much less prominent than the medial epicondyle. The lateral collateral ligament and the supinator-extensor muscle group originate from the flat, irregular surface of the lateral epicondyle. The posteroinferior aspect serves as a partial origin of the anconeus muscle.

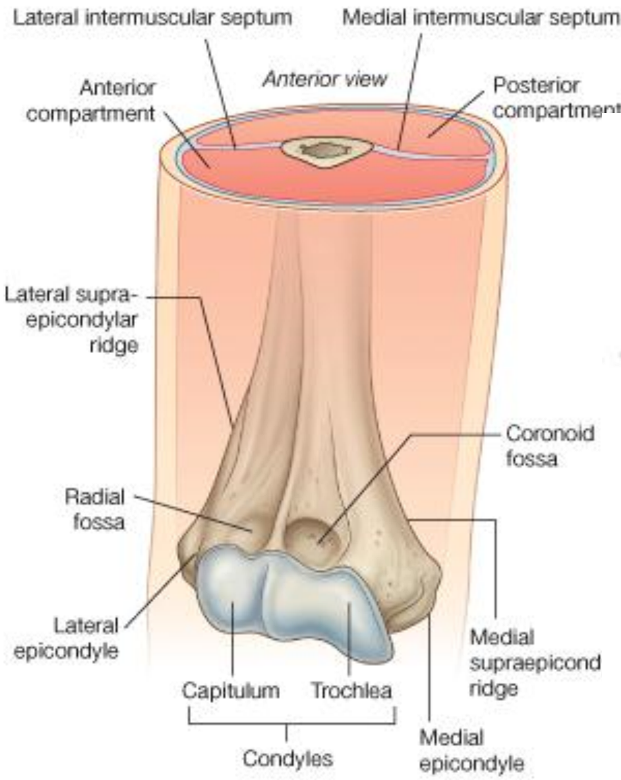
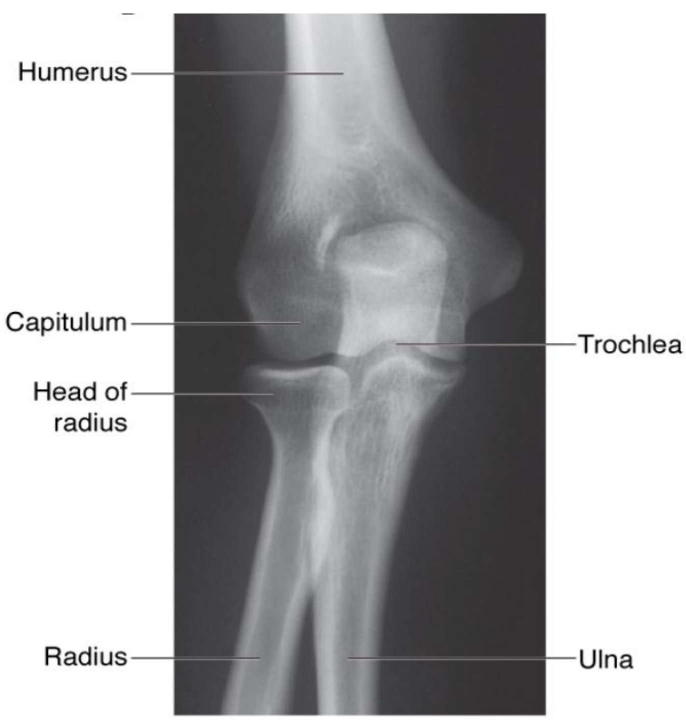


Figure shows anterior view of the distal humerus

Figure shows aposterior view of the 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.A thin membrane of bone separates the olecranon and coronoid fossae in about 90 percent of individuals, 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 posterior aspect of the **lateral supracondylar column** is flat, 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. The **prominent lateral supracondylar ridge** separates the two surfaces into the so-called safe interval between the brachioradialis and extensor carpi radialis longus anteriorly and the triceps posteriorly. This serves as an important landmark for many lateral surgical approaches. The radiologic appearance of the various bony landmarks is shown in the pictures below.

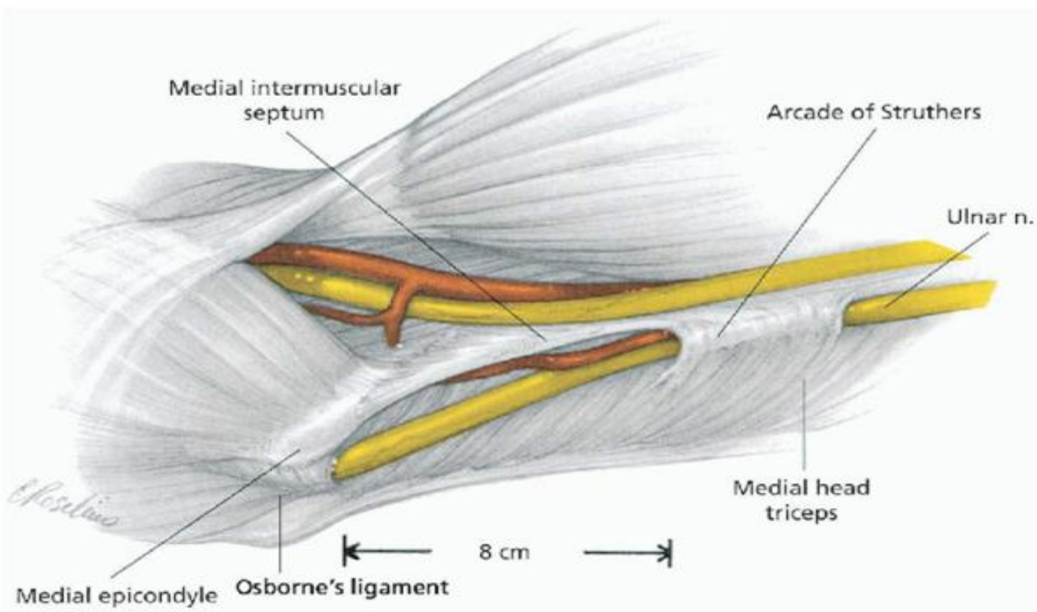


Figures showing the Anteroposterior and Lateral Radiographs of elbow

Proximal to the medial epicondyle, about 5 to 7 cm along the medial intermuscular septum, **a supracondylar process** is observed in 1 to 3 percent of individuals. A fibrous band termed the ligament of Struthers may originate from this process and attach to the medial epicondyle. When present, this spur serves as an anomalous insertion of the coracobrachialis muscle and an origin of the pronator teres muscle. Various pathologic processes have been associated with the supracondylar process, including fracture and median and ulnar nerve entrapment.

NERVES IN RELATION TO DISTAL HUMERUS:

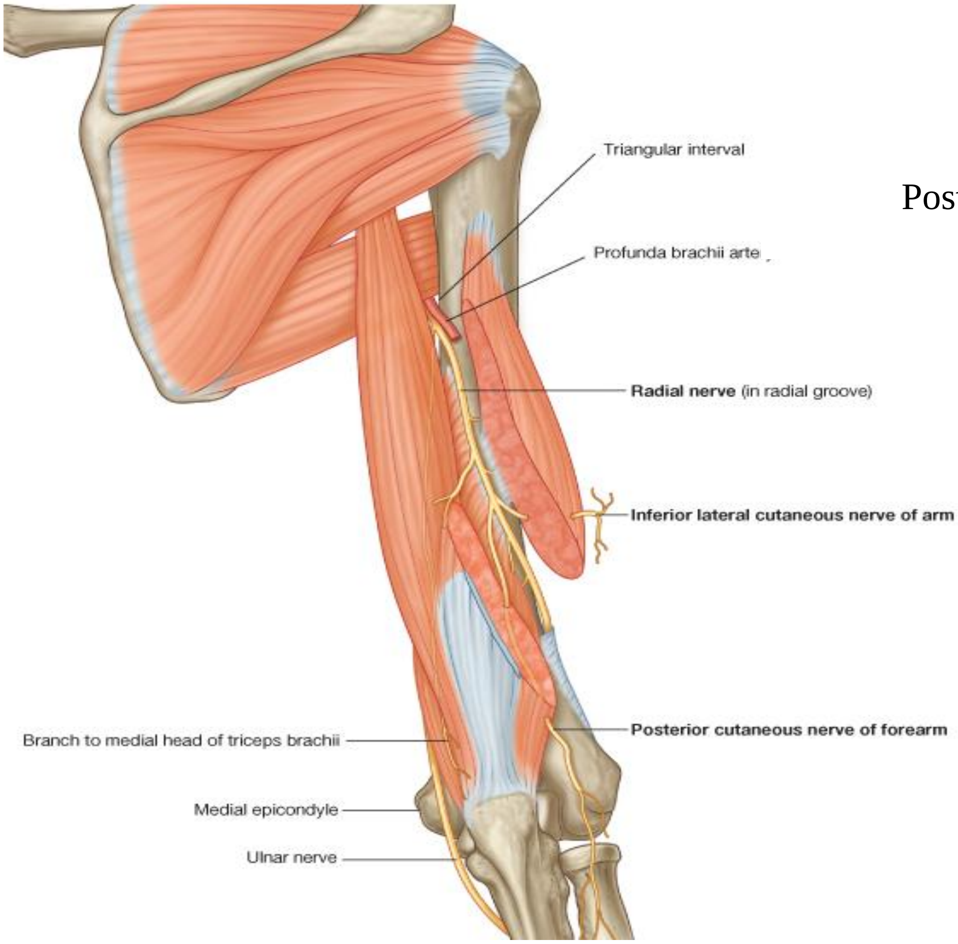
Surgical Anatomy of the Ulnar nerve:



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. In this region, numerous branches of the superior and inferior collateral and posterior ulnar recurrent arteries, as well as several veins, accompany the nerve. Also at this level, a small articular branch leaves the ulnar nerve to innervate the joint capsule.

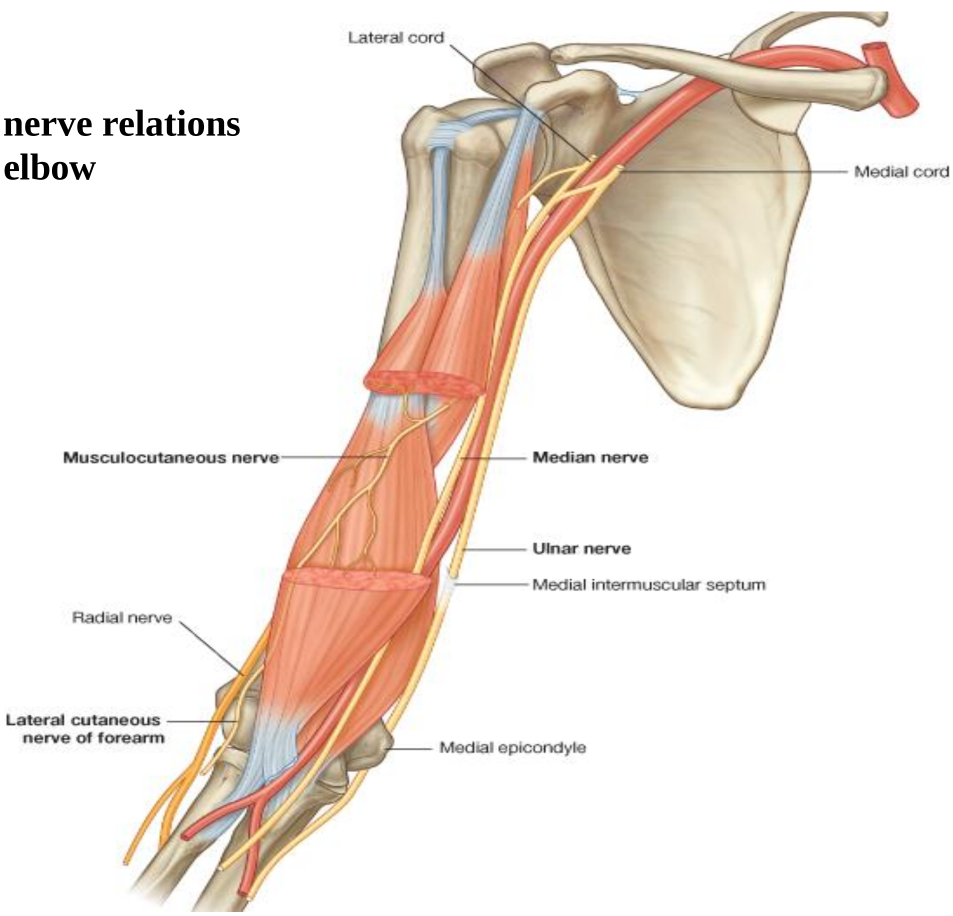
After exiting the fibroosseous groove, the ulnar nerve travels between the humeral and ulnar heads of the flexor carpi ulnaris covered by a fibrous called Osborne’s ligament or arcuate ligament. It is often very thick and is a common cause of ulnar nerve compression. While lying within the muscle of the flexor carpi ulnaris, the ulnar nerve gives off motor branches to this wrist flexor. Traveling distally, the nerve pierces the flexor pronator fascia and then lies between the flexor digitorum superficialis (FDS) and the flexor digitorum profundus (FDP).

Posterior View



Figures showing the nerve relations around the elbow

Anterior View



The radial nerve winds around from the medial to the lateral side of the humerus in a groove with the profunda brachii artery, between the medial and lateral heads of the Triceps brachii. It pierces the lateral intermuscular septum approximately 10 cm proximal to the lateral epicondyle and enters the anterior compartment. It later passes between the Brachialis and Brachioradialis to the front of the lateral epicondyle, where it divides into a superficial and a deep branch.

The median nerve descends through the arm, it lies at first lateral to the brachial artery; about the level of the insertion of the Coracobrachialis it crosses the artery, usually in front of, but occasionally behind it, and lies on its medial side at the bend of the elbow, where it is situated behind the lacertus fibrosus (bicipital fascia), and is separated from the elbow-joint by the Brachialis

LIGAMENTS AROUND THE ELBOW

The lateral collateral ligament (LCL) complex

It consists of the radial collateral ligament, the lateral ulnar collateral ligament and the annular ligament. The annular ligament attaches to the anterior and posterior margins of the lesser sigmoid notch, whereas the radial collateral ligament originates from an isometric point on the lateral epicondyle and fans out to attach to the annular ligament. The lateral ulnar collateral ligament also arises from the isometric point on the lateral epicondyle and attaches to the crista supinatoris of the proximal ulna. The LCL complex functions as an important restraint to varus and posterolateral rotatory instability. The LCL complex 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 showing
Lateral Collateral Ligament Complex

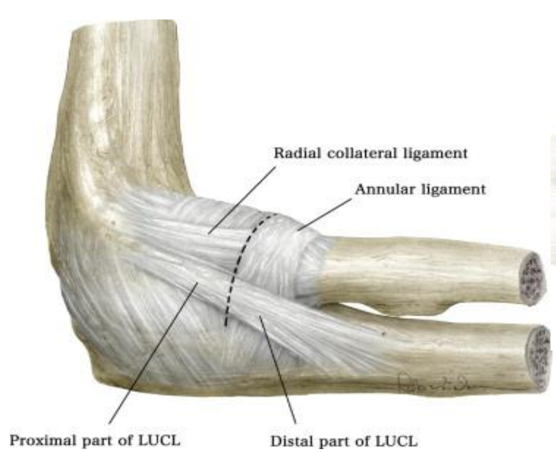


Figure showing
Medial Collateral Ligament Complex

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[53]. The line drawn tangential to the articular surface on the **AP view** of the distal humerus makes an angle of between 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.

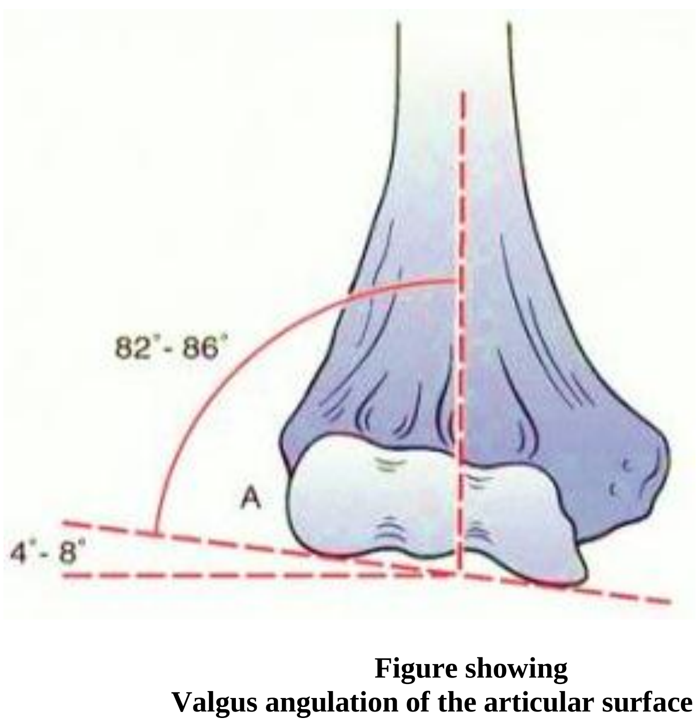


Figure showing
Valgus angulation of the articular surface of the distal humerus

- 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.

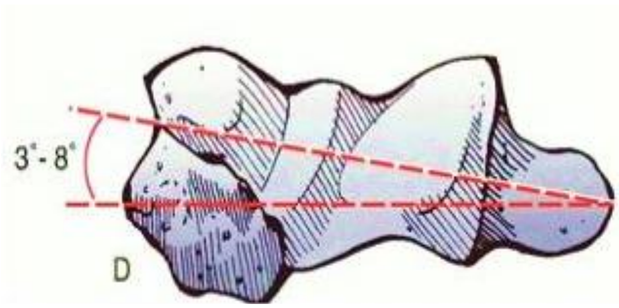


Figure showing Externally rotated trochlea

- The articular segment **juts 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 .

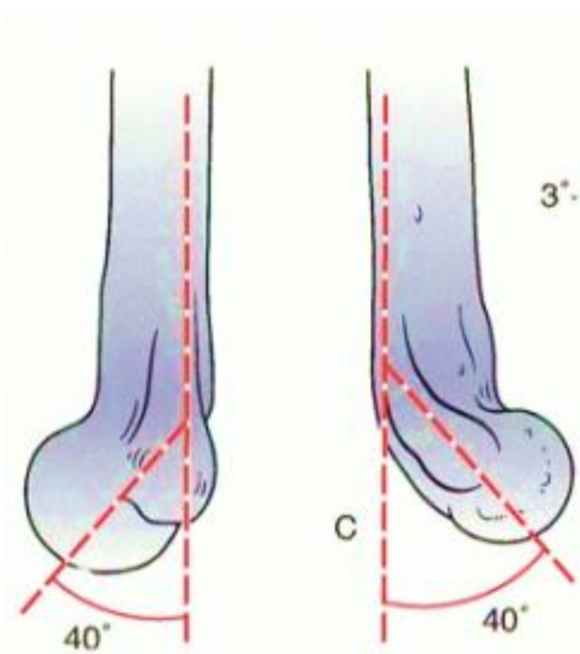


Figure showing the anterior angulation of the distal humerus with the shaft

- 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.

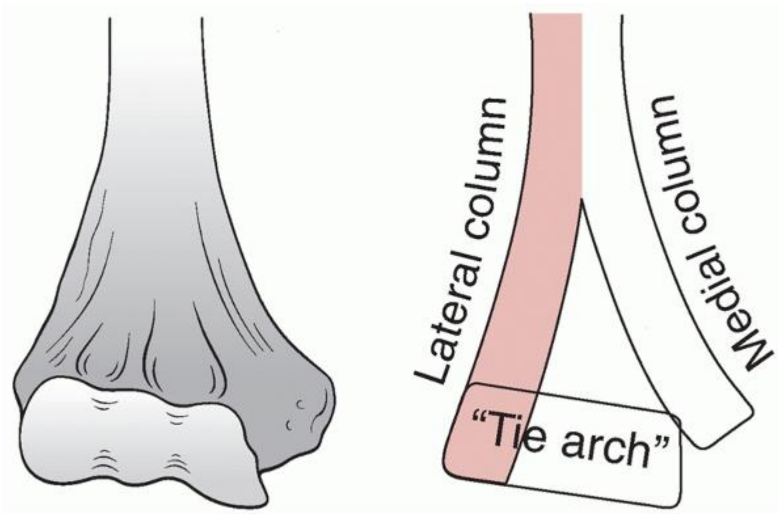


Figure showing *Tie-beam* arch in the distal humerus

- 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 fractures). 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.[54]

- 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[53].

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 30^{o} or greater, depending on the other injuries[55]. 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.

- 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[55] .

CLASSIFICATION OF DISTAL HUMERUS FRACTURES

ANATOMICAL CLASSIFICATION:

Supracondylar fractures, transcondylar fractures, intercondylar fractures, fractures of the condyles (lateral and medial), fractures of the articular surfaces(capitellum and trochlea), and fractures of the epicondyles.

THE COMPREHENSIVE AO – OTA CLASSIFICATION [45]:

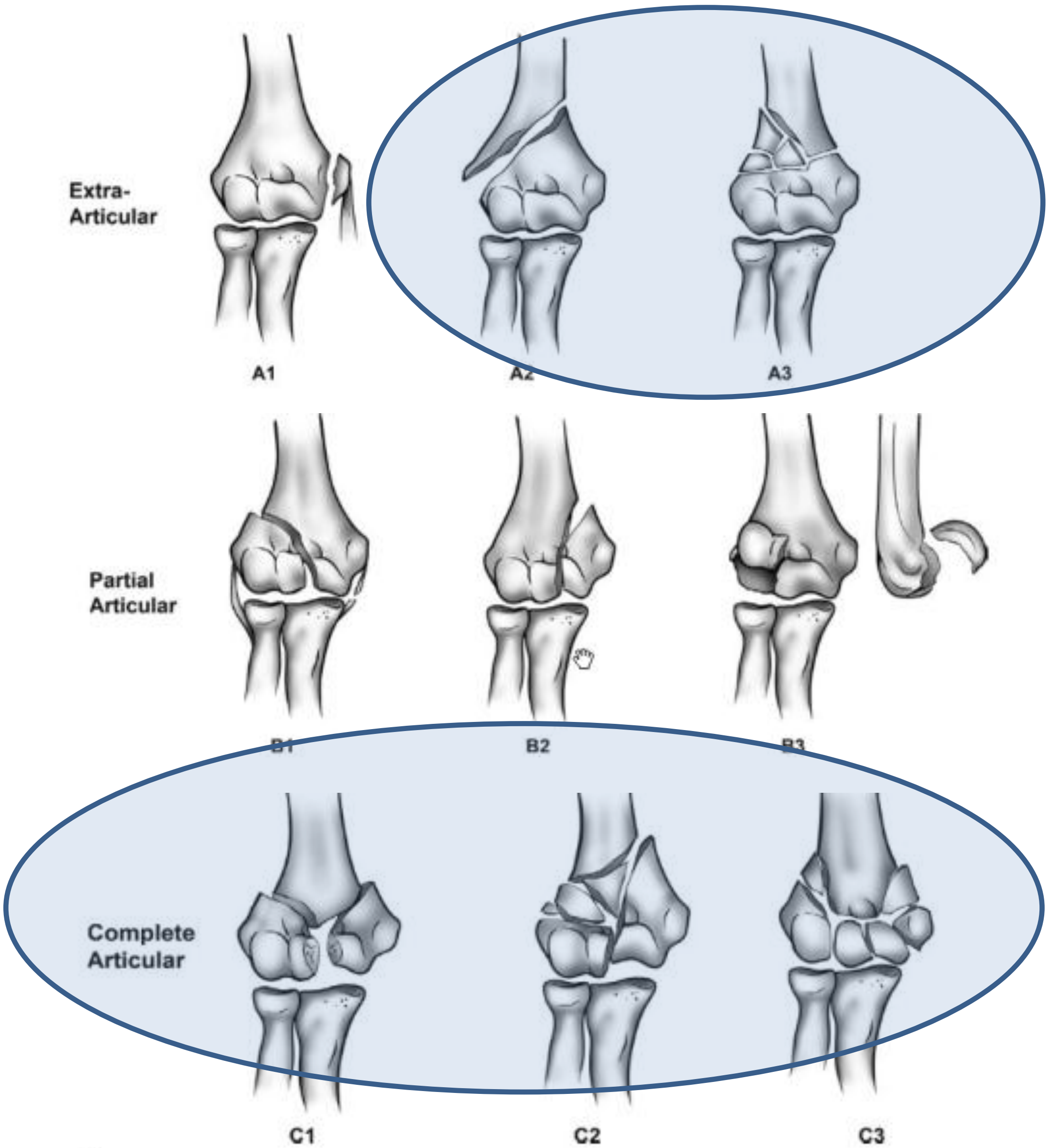
Distal humeral fractures -13

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

We adopted the AO Classification scheme for our study(Types A2,A3 and Type C)



THE MEHNE AND MATTA CLASSIFICATION [46]

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 divergent single column fracture

b. Bicolumn: high T, low T, Y, H, medial lambda, lateral lambda fractures

c. Articular surface: capitellum, trochlea or both

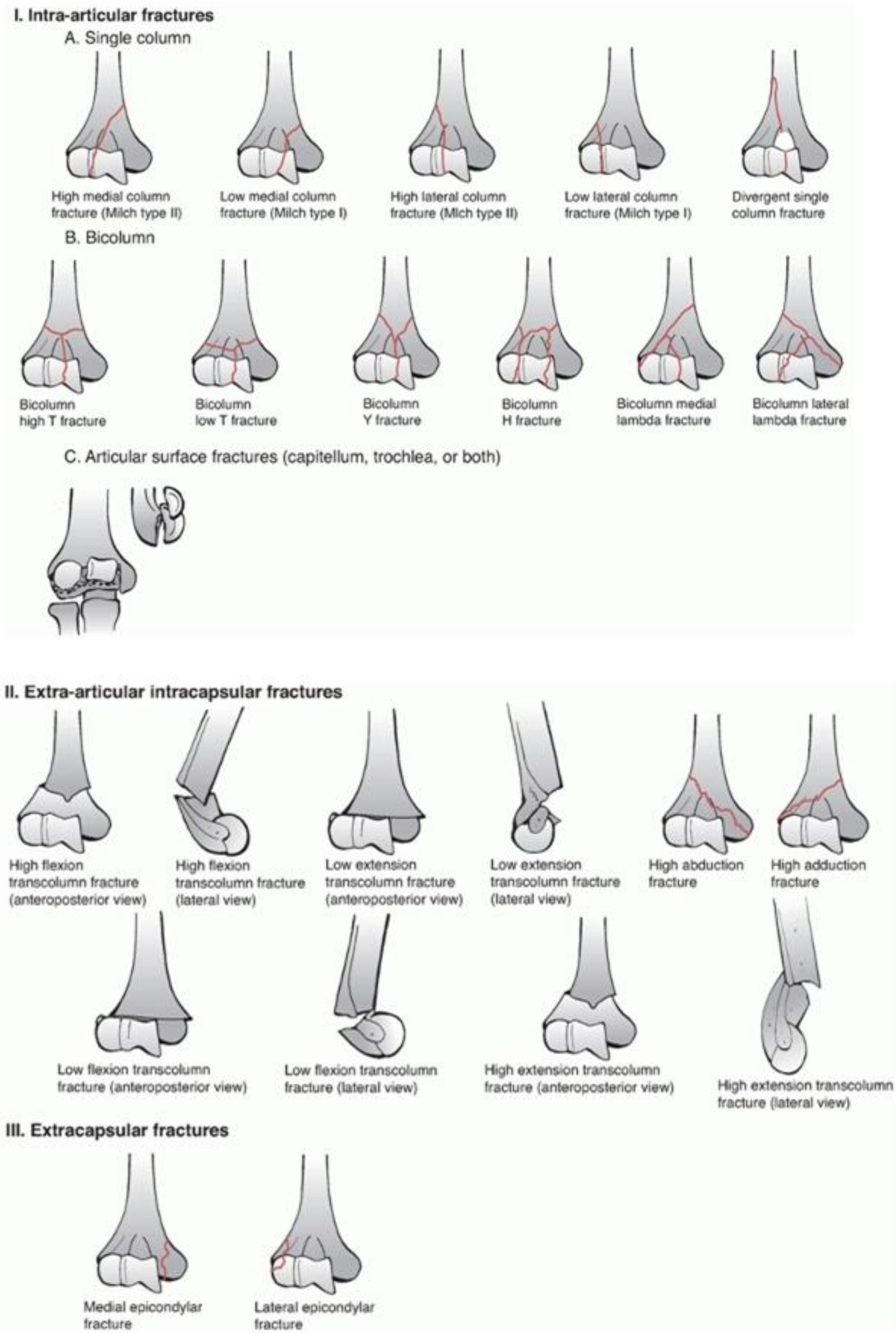
2. Extra-articular intra capsular fractures

high flexion, low flexion, high extension and low extension, trans column fractures, high abduction and high adduction fractures.

3. Extra- capsular fractures

medial epicondylar and lateral epicondyle fractures

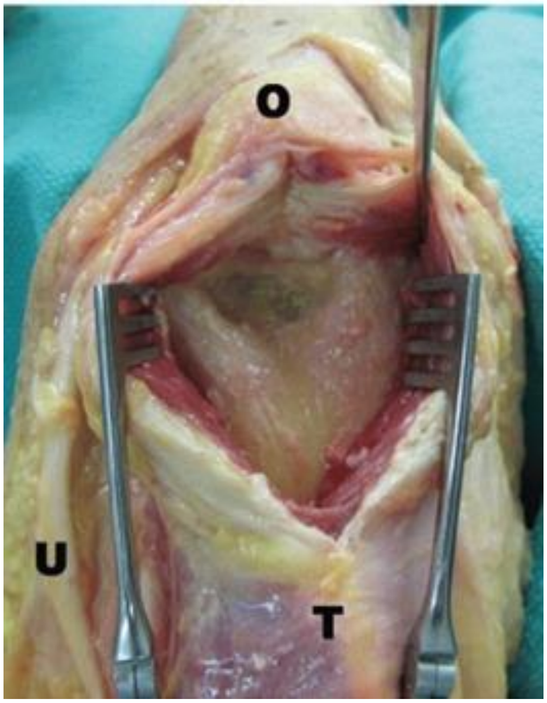
THE MEHNE AND MATTA CLASSIFICATION



SURGICAL APPROACHES

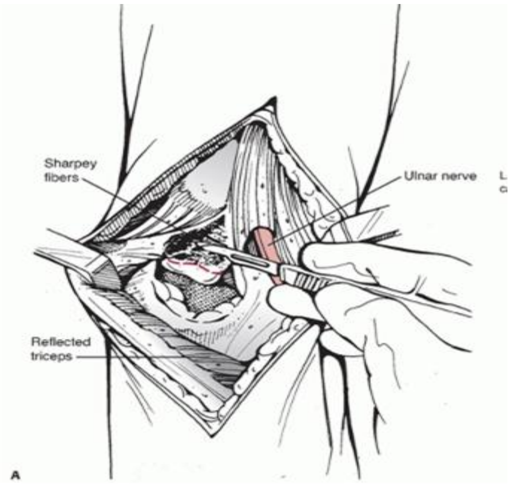
1. TRICEPS- SPLITTING APPROACH (CAMPBELL) [31.32]:

- 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

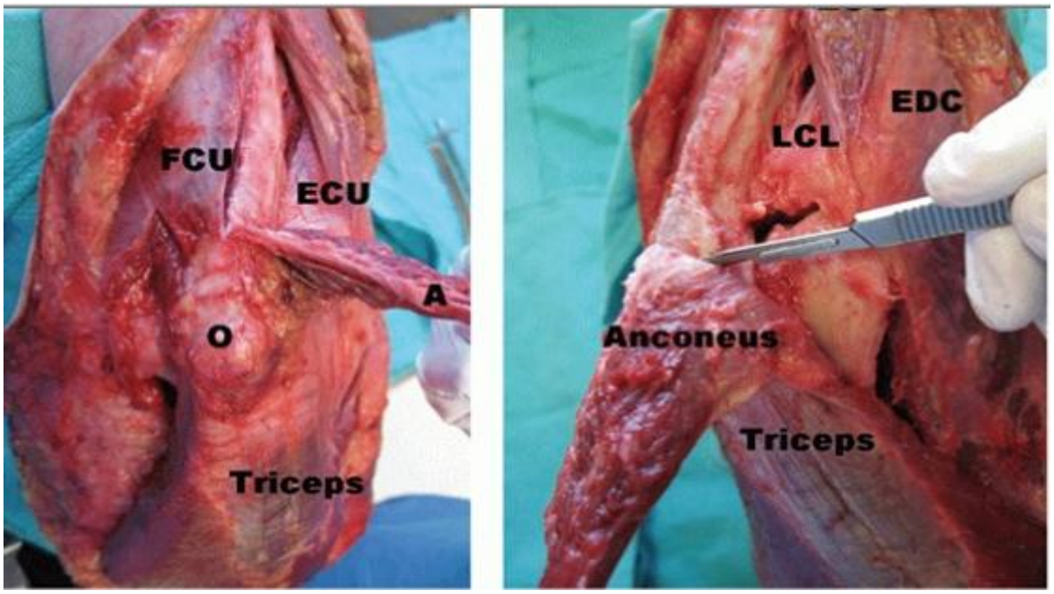


2. TRICEPS-REFLECTING APPROACH (BRYAN- MOOREY) [29] :

- 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

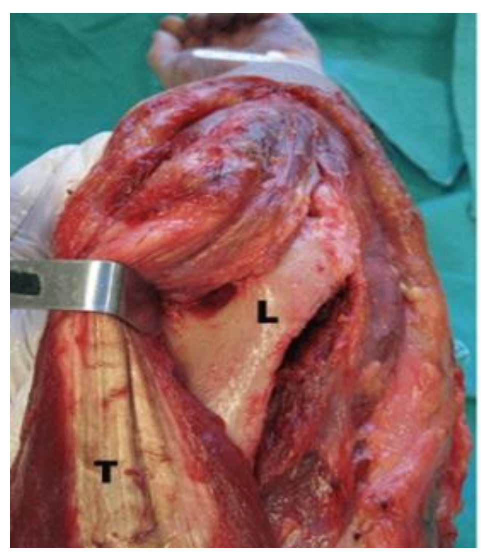


3. TRAP APPROACH (0'DRISCOLL) [30] :



- It combines the reflection of triceps along with the laterally placed anconeus muscle as a single unit.
- The anconeus is first exposed distally and later reflected as a whole proximally
- The medial exposure is similar to the triceps reflecting approach

4. PARA- TRICIPITAL APPROACH (ALONSO- LLAMES) [27, 28]:



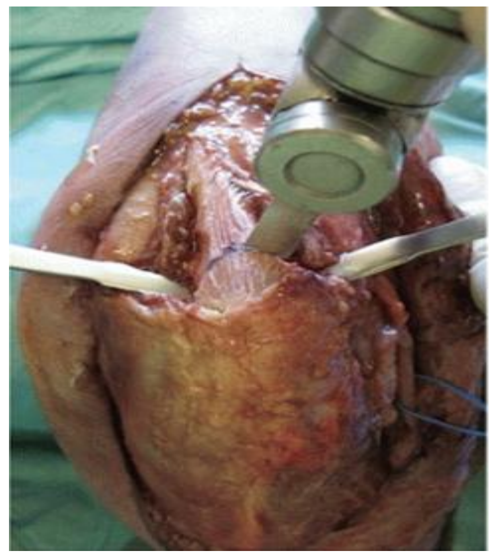
- triceps muscle is elevated subperiosteally from posterior distal humerus.
- Two separate windows are created on either of the

triceps muscle.

- This approach is can be used for type A and type C1 fractures with expertise.
- Can produce excellent outcomes as extensor mechanism is not disturbed.

5. OLECRANON- OSTEOTOMY APPROACH [7, 12,49]:

- This approach can give a excellent exposure of the articular surface
- Ideal for type C fractures
- 'V' shaped chevron osteotomy is preferred for good union and stable fixation[12].
- It has inherent rotational stability as well as translational stability when compared to the transverse osteotomy[7.49,]



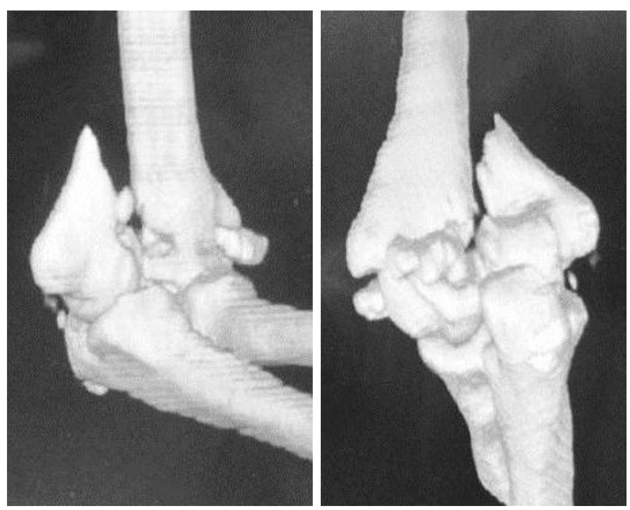
TREATMENT PROTOCOL

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, 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:

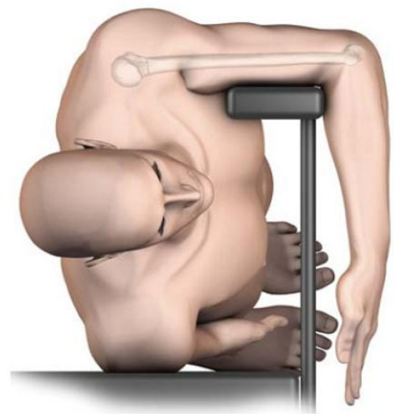
The patients were submitted to a battery of routine investigations required for pre-anesthetic checkup. Associated medical comorbidities were dealt with if present. 3D reconstruction CT of elbow joint were taken for evaluating the number



of fragments, degree of comminution and displacement in Intraarticular fractures [41], which aided in planning of surgery, type of implant 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.



A midline posterior skin incision made[48], deep fascia incised and before proceeding further, the ulnar nerve is 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 [7,12,49] incompletely with saw and completed with an osteotome in complex articular fractures. as it provides adequate exposure of the aricular 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 PARALLEL 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.

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 were placed in one of the proximal hole 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 provisionally fixation.

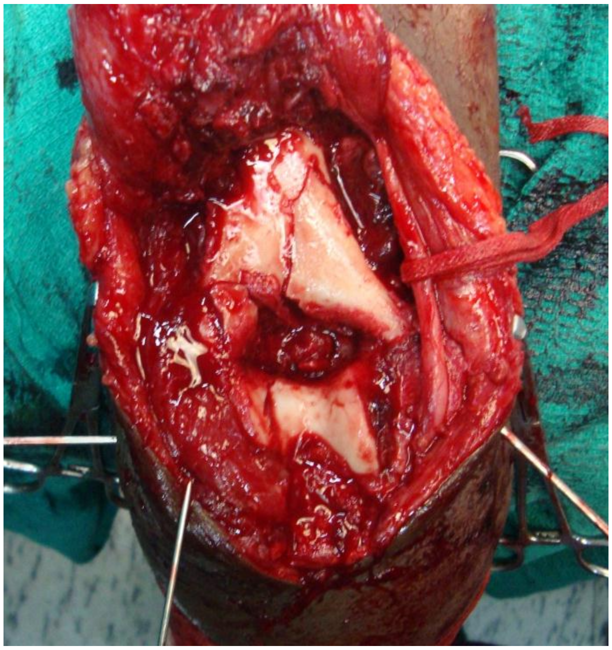


Figure showing ulnar Nerve Isolation, articular reduction and provisional fixation with K wires

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 to eccentrically load the supracondylar region. A second proximal screw was inserted through the plate in compression mode, and then the backed out screw is retightened.

b. This step 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

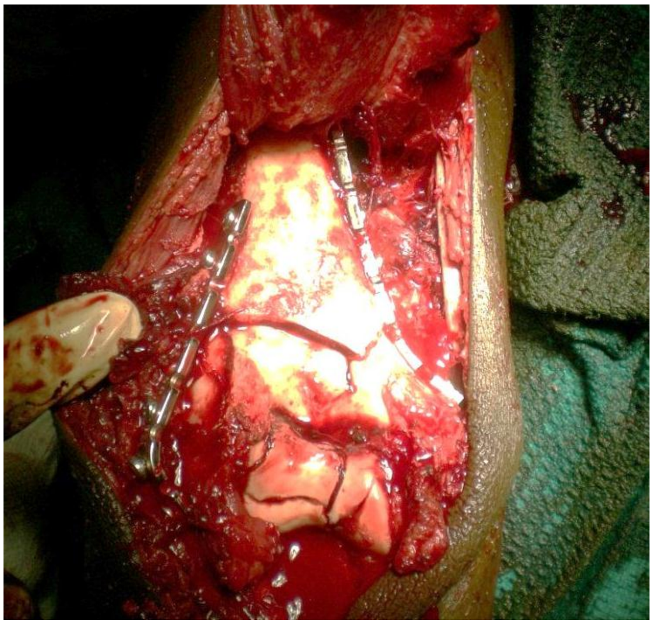
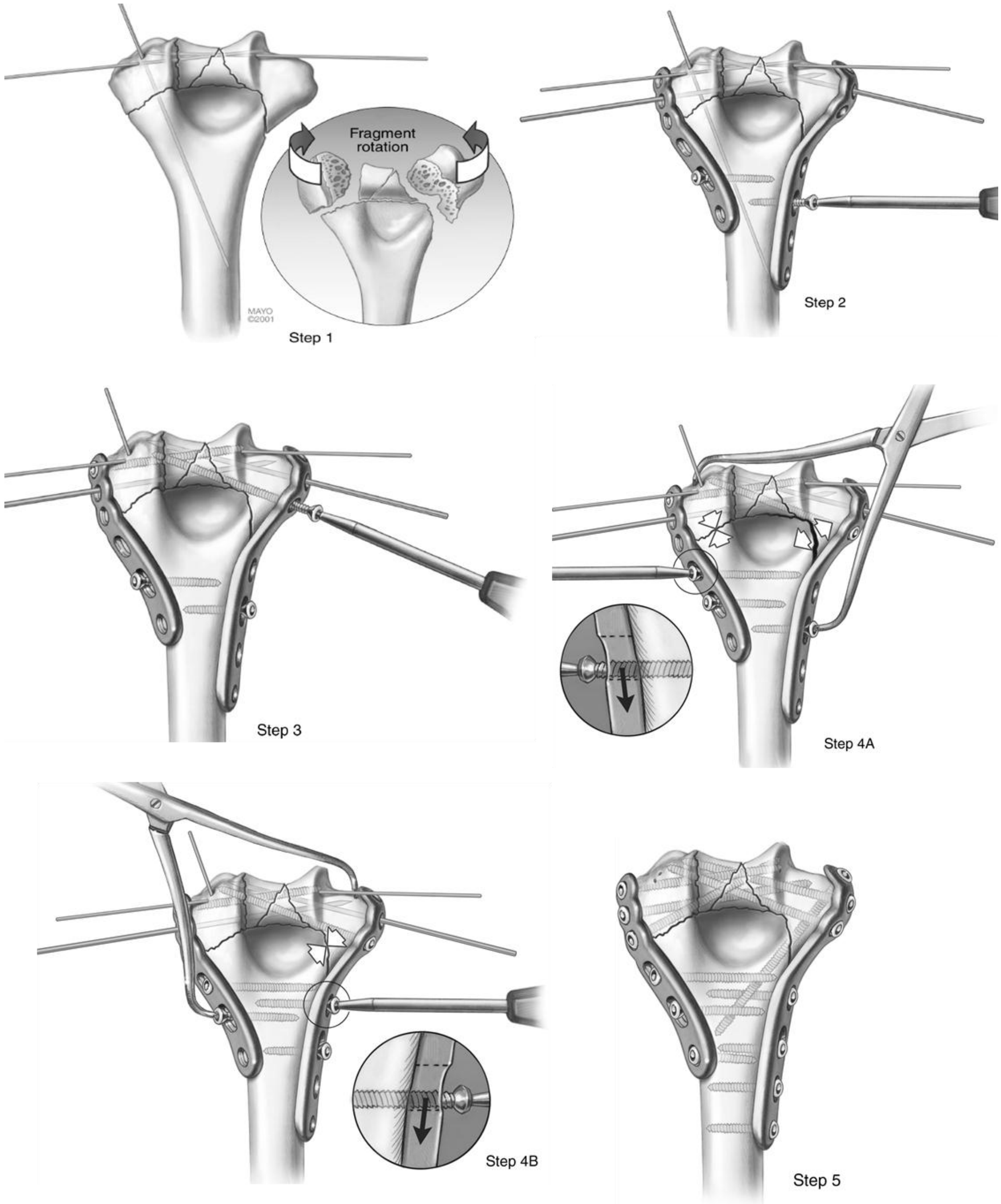


Figure showing Final Plate Placement with both plates ending at different levels

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.

ILLUSTRATIVE SURGICAL TECHNIQUE OF PARALLEL PLATING



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
- Indomethacin prophylaxis for heterotopic ossification was given for the first postoperative month (75 mg/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.
- at 6 months patients were allowed to their routine full activities
- Follow up at 2nd, 4th , 6th, 8th week . 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).

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 parallel plating technique in treatment of distal humeral fractures and to analyse the results.

STUDY GROUP:

The study group consists of 24 Patients with distal humeral fractures, who underwent osteosynthesis with parallel plating technique between May 2010 and Oct 2012 at the institute of orthopaedics and traumatology, Madras medical college and Rajiv Gandhi Government General Hospital, Chennai. 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.

a. INCLUSION CRITERIA:

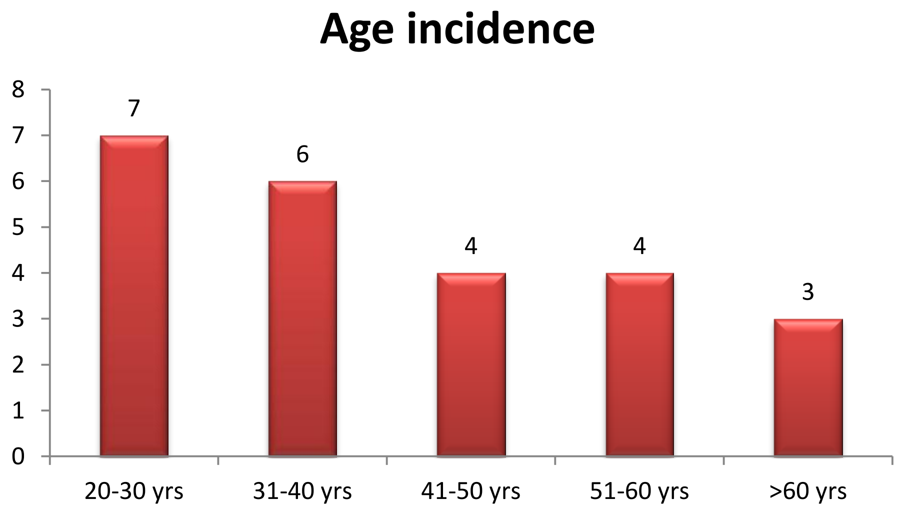
1. Intra articular fractures of distal humerus
2. Age >18 years
3. AO Types A2,A3 and C (supracondylar and bicondylar)
4. Closed ,Grade I and grade II compound injuries
5. Consenting to study

b. EXCLUSION CRITERIA:

1. With vascular injuries
2. Grade III compound Open fractures
3. severe unreconstructable intra-articular communited fractures in elderly
4. uncooperative patients for the rehabilitation and follow up
5. Patients who were not medically fit for surgery
6. not willing to participate

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.

AGE INCIDENCE AND DISTRIBUTION

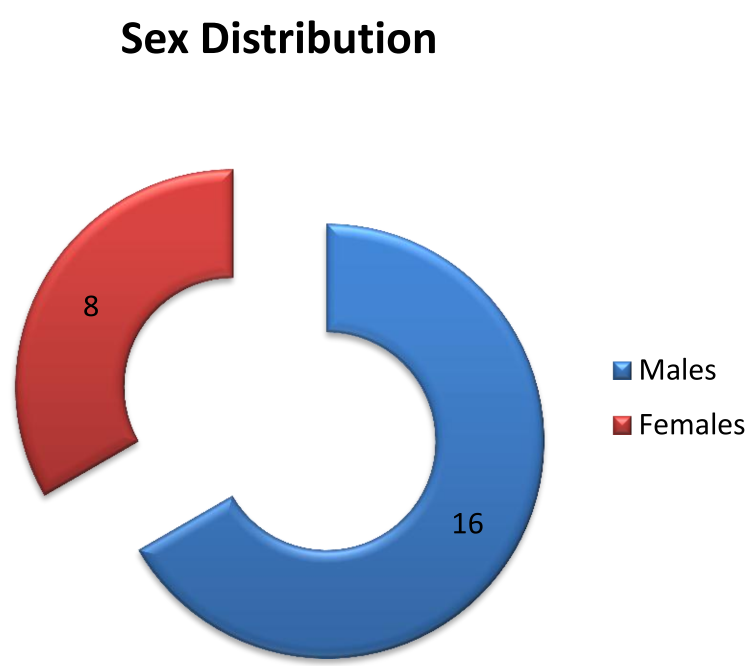


Age	No of Patients	Percentage
20 to 30 Years	7	29.2%
31 to 40 Years	6	25%
41 to 50 Years	4	16.7%
51to 60 years	4	16.7%
>60 years	3	12.5%

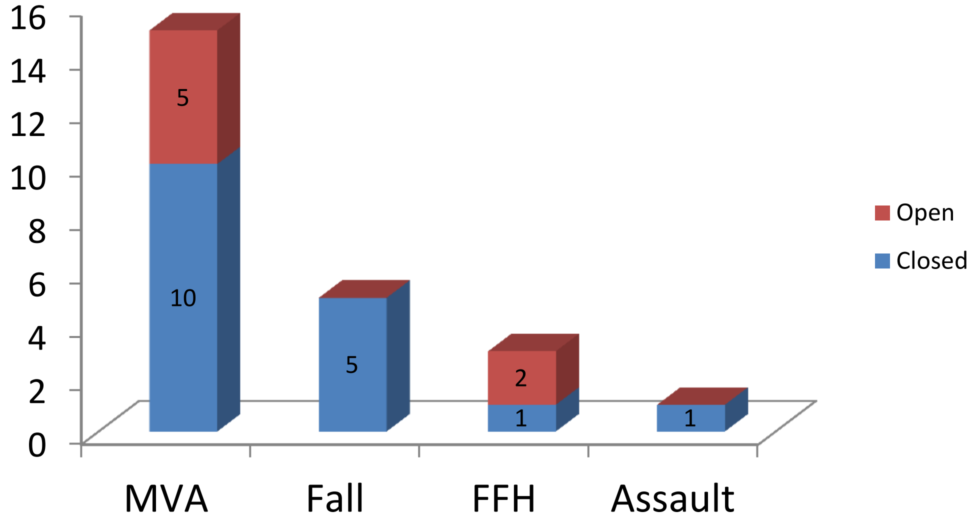
The Mean age of the patients was 39 years ranging from 20 to 65 years.

SEX DISTRIBUTION:

Males dominated our study .Male: Female ratio was 2:1 (16:8)



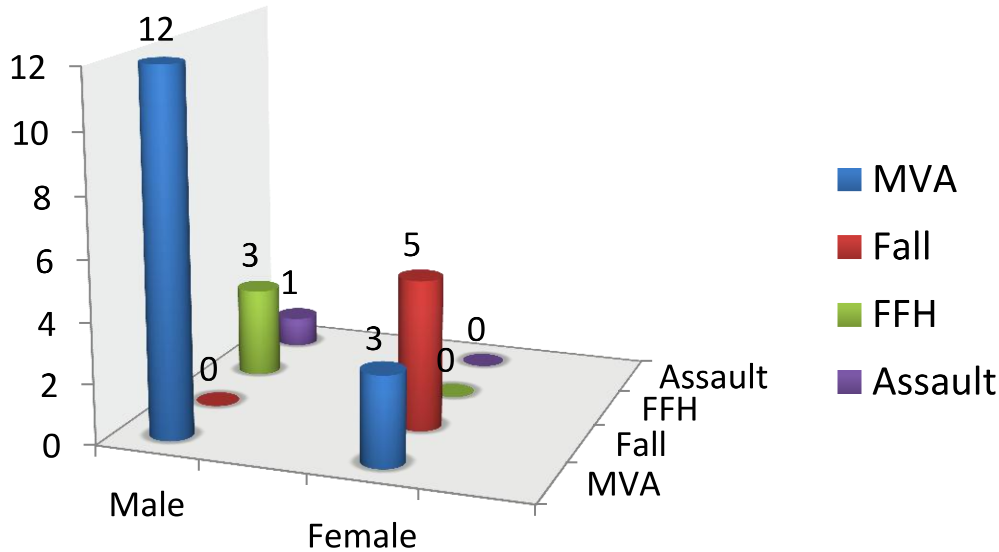
MODE OF INJURY:



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) , assault. 71% of the fractures were closed injuries while the Open fractures (Grade I and II Gustilo Anderson types) constituted remaining 29% of the cases.

Mode of injury	**No. of Patients**			**Percentage**
	Closed	**Open**	**Total**	
MVA	10	5	15	62.5%
Simple Fall	5	-	5	20.8%
FFH	1	2	3	12.5%
Assault	1	-	1	4.2%

GENDER Vs MODE OF INJURY:



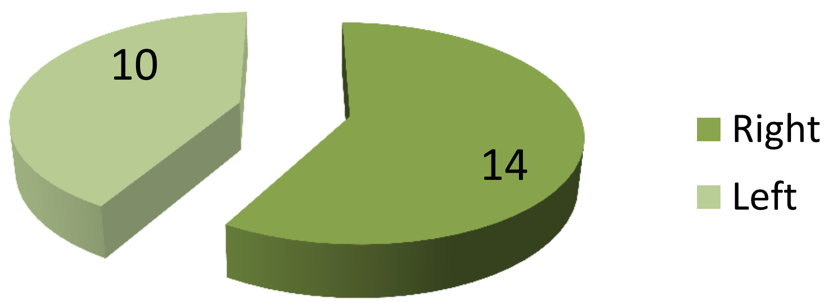
Males constituted two-thirds of our study.Young males predominantly sustained injury by Road traffic Accidents(RTA) whereas older females predominantly sustained accidental fall . Male:Female= 2:1

Mode of injury	Male	Female
MVA	12	3
Simple Fall	-	5
FFH	3	-
Assault	1	-
TOTAL	16	8

SIDE OF INJURY:

14 patients(58.3%) had fracture of right distal humerus and 10 (41.7%) patients had fracture of left side.

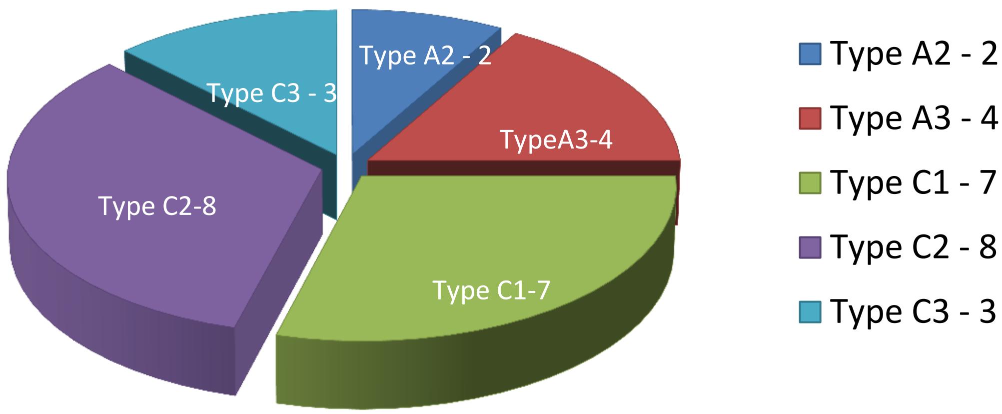
Side of Injury



FRACTURE DISTRIBUTION:

Fracture type (AO-OTA)	**No. of Patients**	**Percentage**	
C3	3	12.5%	Complete Articular 75%
C2	8	33.3%	
C1	7	29.2%	
A3	4	16.7%	Extraarticular 25%
A2	2	8.3%	

Intraarticular fractures constituted majority of our cases accounting for about 75%.Extraarticular Metaphyseal fractures constituted the remaining 25%.



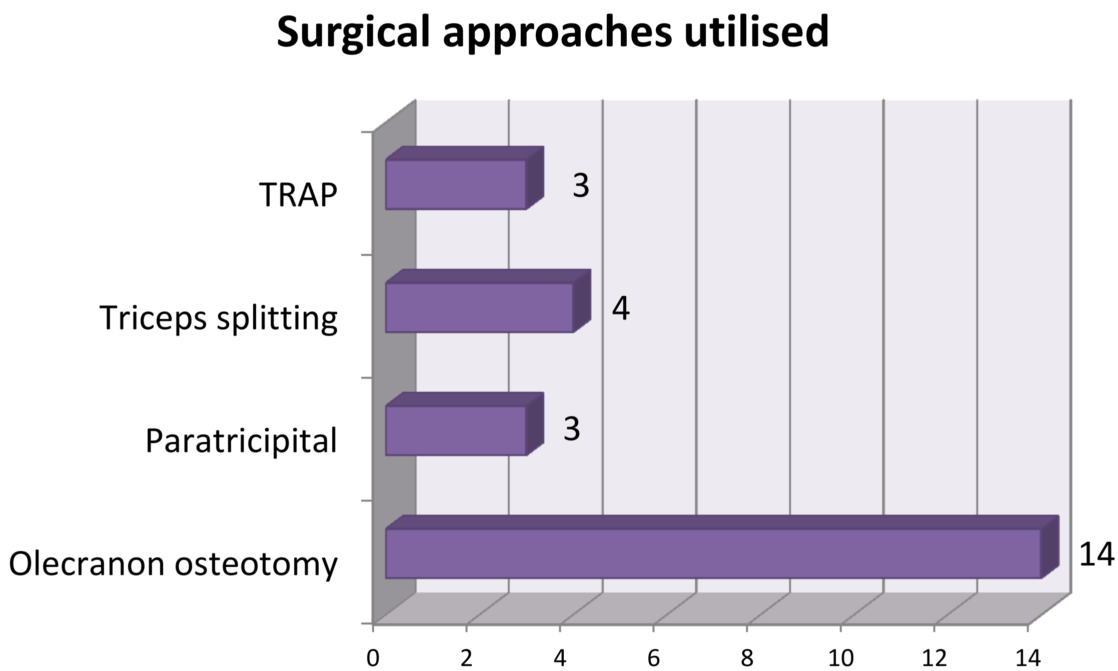
In our study we noted the following associated injuries.

Associated injuries	**No. of Patients**
Fracture of Distal radius	2
Fracture shaft of contralateral humerus	1
Fracture of pubic rami	2
Intertrochanteric Fracture of Femur	1
Fracture shaft of Femur	1
Fracture Metatarsals	1
Radial Nerve palsy	1
Ulnar Nerve palsy	1
Head injury	1

SURGICAL APPROACHES :

We used chevron osteotomy of the olecranon for fracture fixation in 14 of our cases(58.33%) as intraarticular fractures dominated our study.Other approaches used were paratricipital approach in 3 cases(12.5%),triceps splitting approach in 4 cases(16.66%) and TRAP approach in 3 cases(12.5%).

Procedure	**No. of Patients**
Olecranon osteotomy	14
Paratricipital	3
Triceps splitting	4
TRAP	3



OBSERVATION AND RESULTS

The following observations were made in our study.

1) The Mean age of the patients was 39 years ranging from 20 to 65 years . Nearly 30% patients belong to 3rd decade followed by 4th decade (25%). 71% of the patients belong to less than 50 years.

2) Males dominated our study group with a ratio of 2: 1

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 was a major form of injury in younger males whereas simple falls from standing height had been the most common mode of violence in elderly females.

6) Completely articular fractures constituted 75% while extraarticular transcondylar fractures constituted only 25% of our cases.

7) Of the complete articular types, the order of most common types were

   C2(44.4%) > C1(38.9%) > C3(16.6%)

8) Seven patients had associated skeletal injuries. One patient had radial nerve injury,one patient ulnar nerve injury, and one patient had a head injury.

9) Most of the patients were operated by Chevron osteotomy approach (14 Patients). Four patients were operated by Triceps splitting approach. TRAP approach and paratricipital approach were used each in three patients.

10) In our study, the average surgical time delay was 6 days ranging from 5 to 17 days.

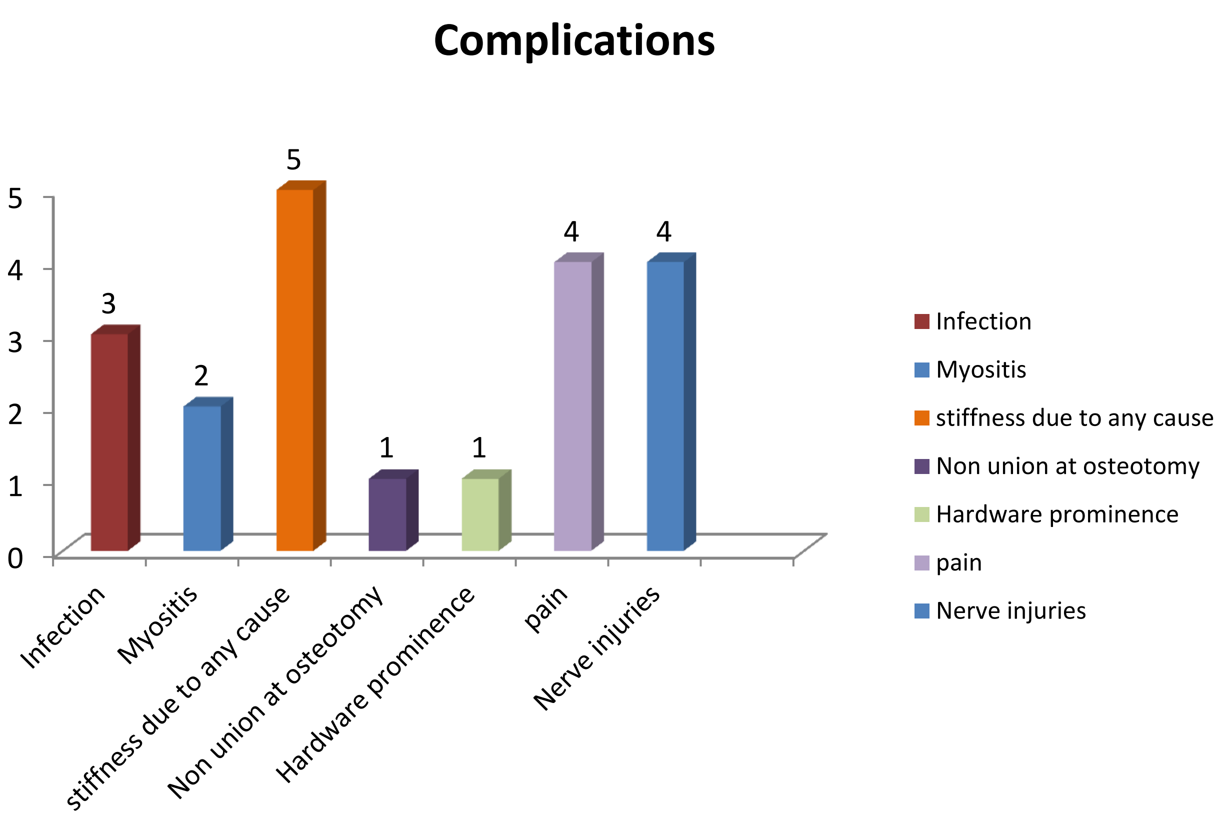
11) The average surgical time was 110 minutes ranging from 60 minutes to 3 hours.

12) Complications encountered in our study were paraesthesia along ulnar nerve distribution, ulnar nerve and radial nerve neuropraxia, infection, stiffness, delayed union, heterotopic ossification, non-union at osteotomy site and hard ware prominence.

13) Three patients had infection. One patient was treated conservatively with antibiotics. One patient who had a wound gapping on the 5 day over the olecranon healed by secondary intention and Split skin grafting. One patient who had a initial open injury developed a deep seated infected which warranted wound debridement and finally closed with a abdominal flap cover. He had a delayed union, stiffness and ultimate poor outcome.

14) 3 patients reported numbness and paraesthesia along ulnar border of little finger which was treated conservatively. One patient developed ulnar and radial nerve neuropraxia. Radial neuropraxia showed recovery but anterior transposition was done after 12 weeks for the ulnar nerve which recovered partially after 8 months.

15) Stiffness was noted in 5 patients. Heterotopic ossification with reduced elbow ROM was observed in 2 patients.One patient who developed deep seated infection required flap cover, also developed stiffness. Another patient stiffness occurred due to pain , post fixation and other had a soft tissue contracture.



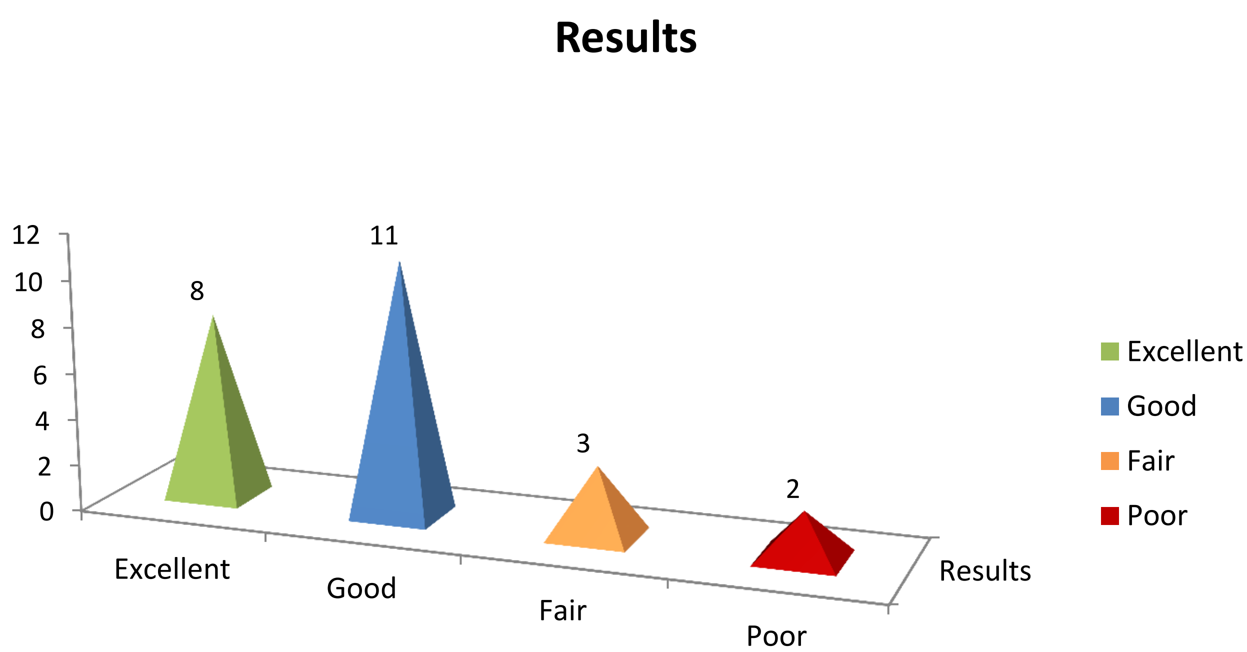
16) One patient who had a nonunion at the osteotomy site was done a revision osteosynthesis with tension band wiring.

17) No patient died during treatment or follow up.

18) Twenty four patients of distal humeral fractures were treated surgically with parallel plating and analyzed with average follow up of 13months (6 months – 2 ½ years).

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

20) The mean flexion-extension arc was 107°. The mean MEPS score was 82 in our study. The results were excellent for 8 elbows, good for 11, fair for 3, and poor for 2 patients.



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 (62.5%) 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 high male:female ratio seen in our centre (2:1) 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.

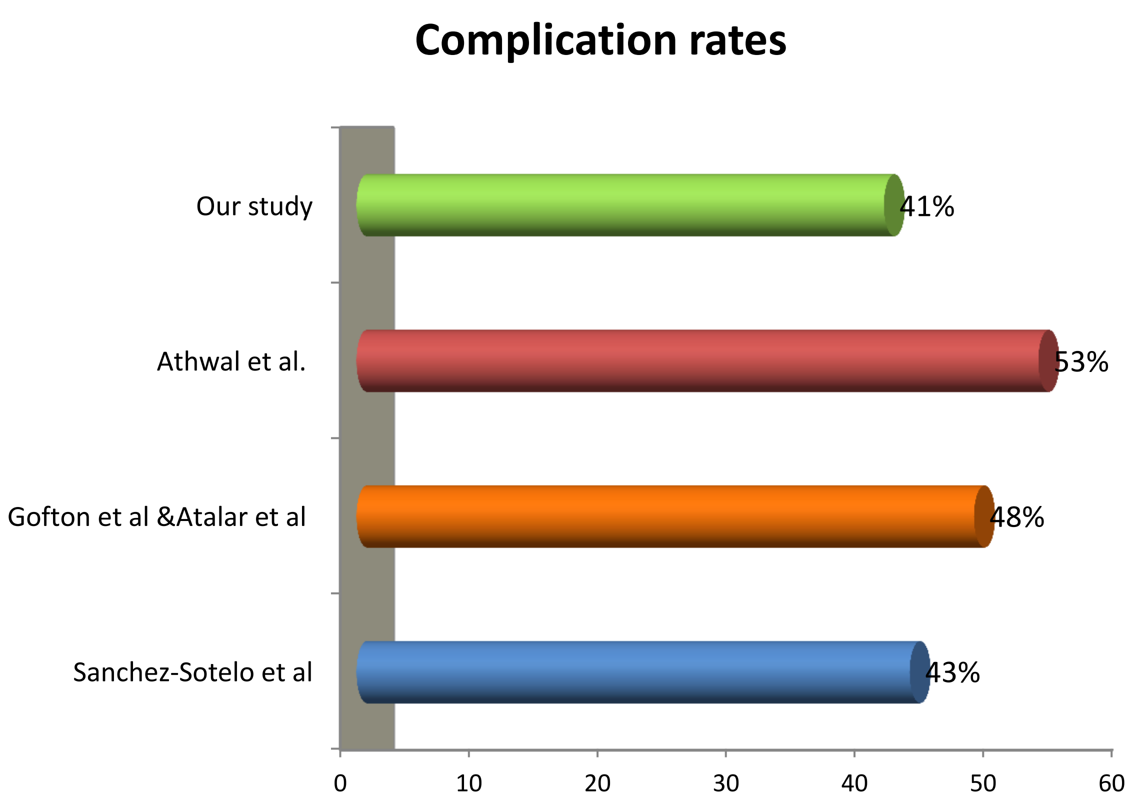
Olecranon osteotomy was done in 14 of our cases. Eight of them were fixed with modified TBW with K wires and three of our cases were fixed with cancellous screws with TBW. This allowed us complete examination of the articular surfaces of trochlea, capitellum, olecranon and radial head. It also gives 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 14 osteotomized elbows showed a non-union which united with revision osteosynthesis with modified TBW.

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

Complications :

Elbow stiffness (secondary to infection(1) ,heterotopic ossification(2) and moderate pain (1) and soft tissue contracture without pain(1)) was the commonest complication encountered in 5 patients. We had infection requiring further operative intervention in 2 patients. Both of them required surgical debridement once and repeated dressings before the wound was closed by skin grafting and flap cover one in each case. Another patient who developed a superficial infection was treated conservatively with antibiotics .Hardware prominence was a major complaint in one patient. All but four elbows were completely painless at the final follow up. All fractures 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] describes 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 41 % which is concurrent with the international literature which included infection (12.5%), heterotopic ossification (8.3%) ,Nonunion at osteotomy (4%),permanent ulnar neuropathy(4%),stiffness with pain excluding myositis and infection(8.3%),hard ware prominence(4%).



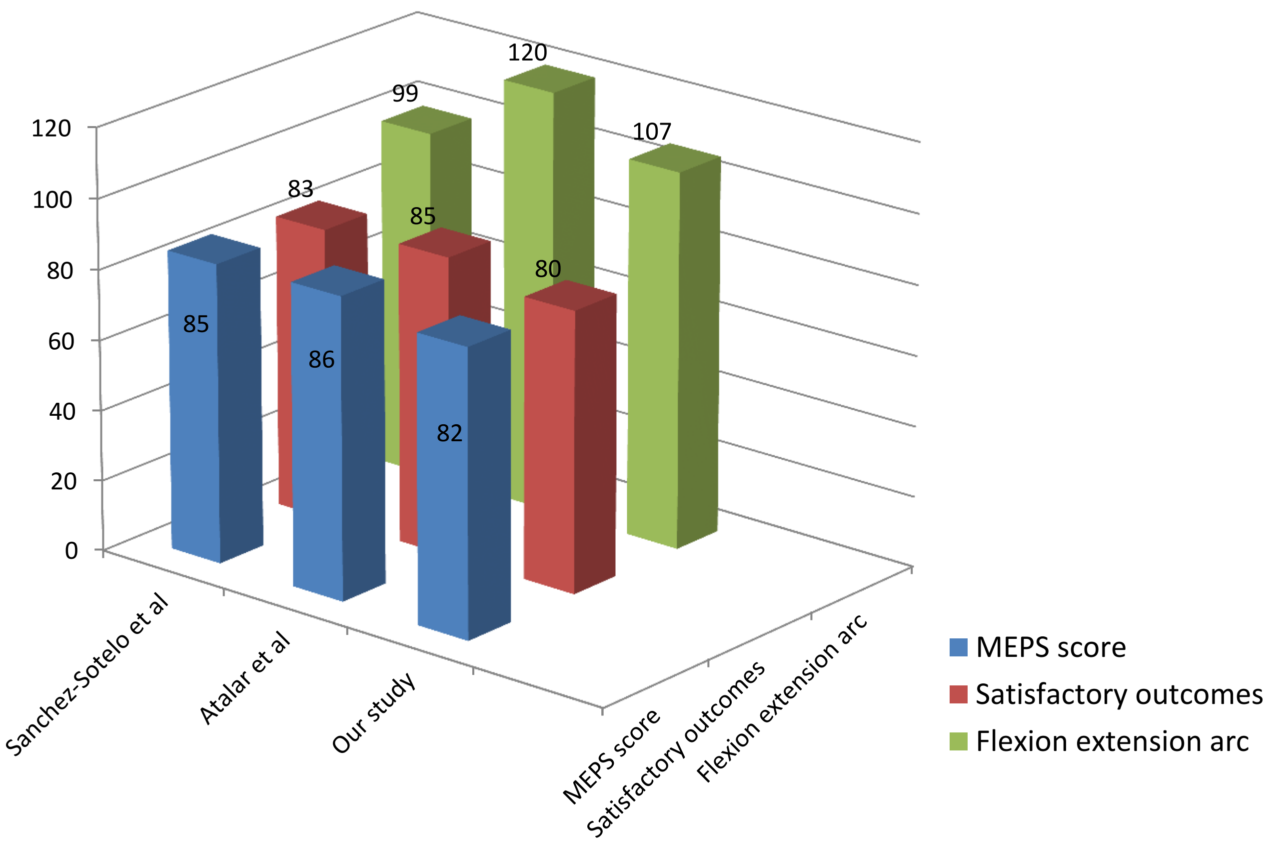
Elbow stiffness due to all causes was the commonest complication(21%) in our study group .Poor compliance to physiotherapy and mobilisation was a major determinant in elbow stiffness. Though the construct might favour early mobilisation ,the motivation and compliance for physiotherapy plays a major role in instituting earlier range of motion exercises after surgery and to get a better functional outcome.

Iatrogenic nerve complications were noted in 4 patients(16.6%) in our study. Post-operative ulnar nerve paraesthesia was observed in 3 patients. 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 both sensorimotor involvement of the ulnar nerve and radial nerve with neuropraxia postoperatively. Initially the patient was treated conservatively when he showed recovery of only the radial nerve symptoms. Anterior transposition of the ulnar nerve was done at the end of three months. 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 39 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. The incidence of open fractures in our study group was 29%.One of our patients who at the presentation had a grade II compound injury was treated with initial wound debridement and parallel plating with primary skin grafting .But he developed wound infection which after settled after serial debridement and ultimately ended in a flap cover. He had a delayed union and post traumatic stiffness and had a poor outcome.

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, except for the one patient with deep infection had a delayed union.

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 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 82(flexion extension arc of 107 deg) which was comparable to the previous studies and shows that parallel 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	24	32	21
Mean Age	39 yrs	58 yrs	47 yrs
M:F ratio	2:1	1.4:1	2:1
Mean Follow up	13 months	24 months	28 months
Fracture types AO	A2=2A3 = 4, C1=7,C2 = 8, C3 = 3	A3 = 3, C2 = 4, C3 = 25	C1 = 3, C2 = 6, C3 = 12
Open injuries	7(29%)	13(41%)	8(38%)
Major mode of violence	RTA	Fall	Not specified
Bony union	13.4 weeks	12 weeks	Not specified
Complication rate	41%	43%	48%
Resurgeries	Wound debridement /coverage(2), Revision osteosynthesis at Osteotomy(1),Anterior transposition of ulnar Nerve(1)	Wound débridement or coverage (4), bone-grafting (1), HO removal (4), distraction arthroplasty (1), triceps reconstruction (1)	Wound débridement (1), HO removal (2), Stiffness (2), Osteotomy site Implant removal (5)
Ulnar Neuropathy	4(16.6%)	6(18.75%)	Nil
Mean Arc of motion	107°	99°	90.2±31.1°
MEPS	82	85	86.1±12.6°
Satisfactory rate	80%	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 80% 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 parallel 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.

- Parallel plating can be a successful technique for internal fixation of these complicated fractures when its principles are strictly adhered to.

CASE ILLUSTRATIONS

CASE 1

NAME: Kamalakannan

IP NO: 127654

AGE: 32 yrs

OCCUPATION: tractor driver

Diagnosis: fracture of distal humerus right side

AO/ASIF: Type 13 C2

ASSOCIATED INJURIES: nil

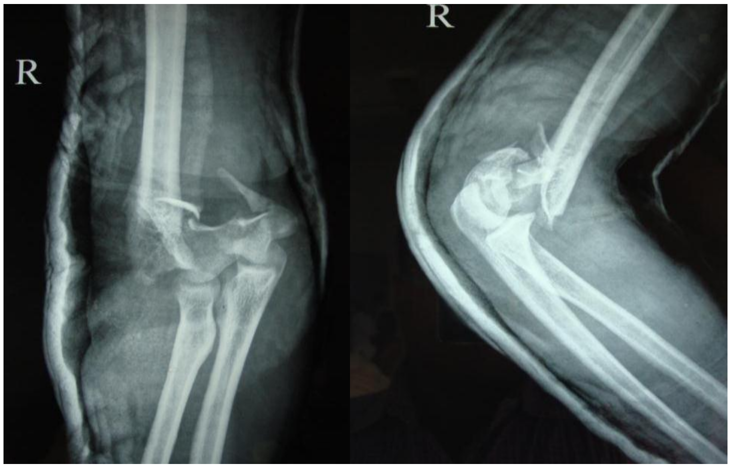
PROCEDURE DONE: parallel plating via olecranon osteotomy approach

COMPLICATIONS: nil

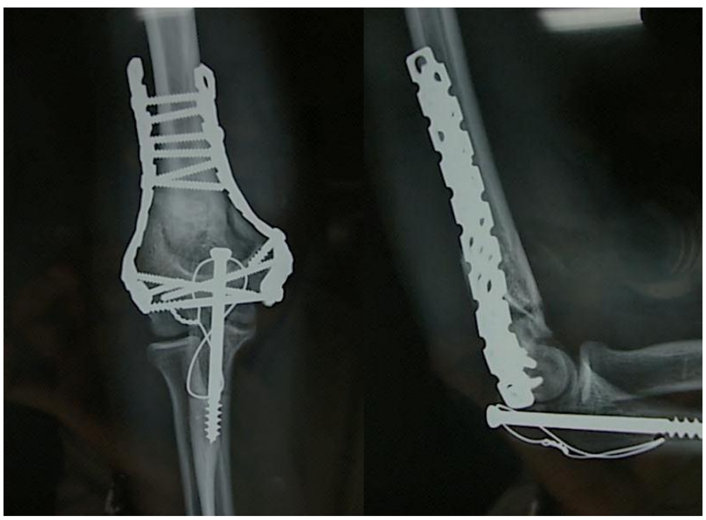
SECONDARY PROCEDURE: nil

TIME OF UNION	10 weeks
ELBOW ARC OF MOTION	10-135 deg
MAYO SCORE	95
FUNCTIONAL OUTCOME	Excellent

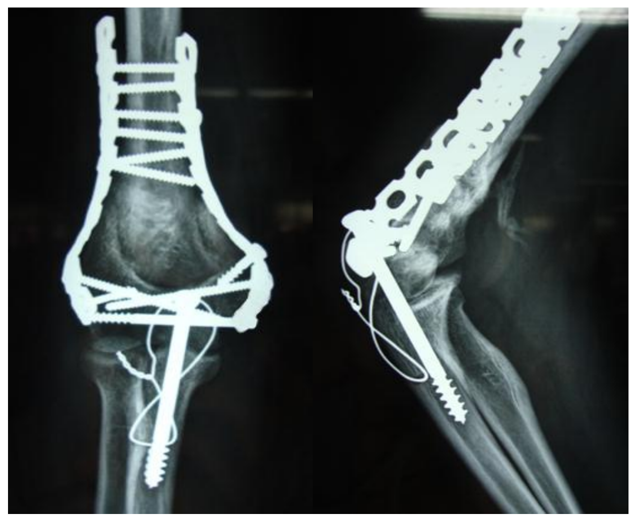
PREOP



IMMEDIATE POSTOP



AT 8 MONTHS FOLLOW UP



RANGE OF MOVEMENTS AT 8 MONTHS

CASE 2

NAME: Saraswathy

IP NO: 157363

AGE: 65/F yrs

OCCUPATION: House wife

DIAGNOSIS: Osteoporotic communited fracture of distal humerus Left

AO/ASIF: Type 13 C3

ASSOCIATED INJURIES: nil

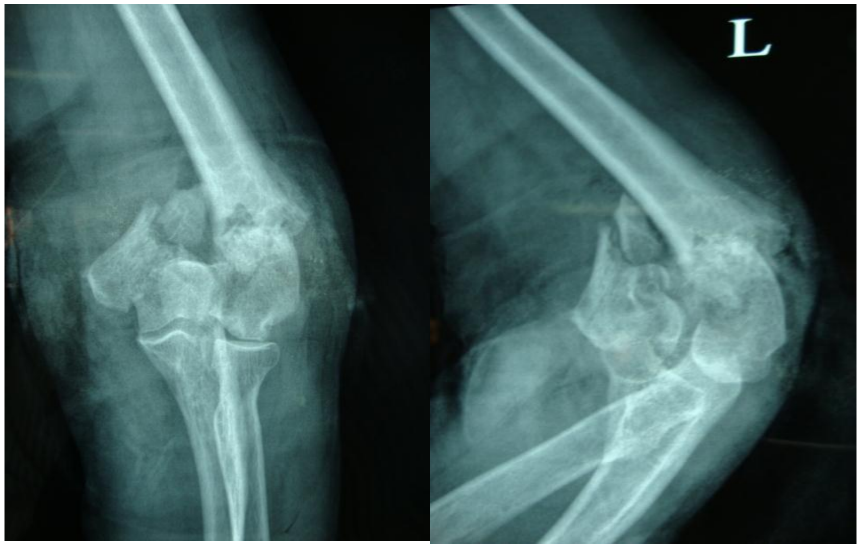
PROCEDURE DONE: ORIF with parallel palting

COMPLICATIONS: nil

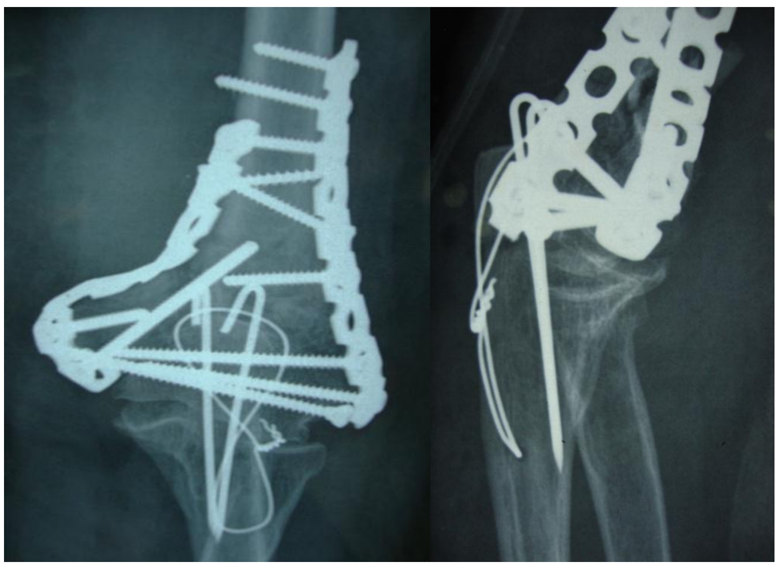
SECONDARY PROCEDURE: nil

TIME OF UNION	11 WEEKS
ELBOW ARC OF MOTION	10-110 Deg
MAYO SCORE	85
OUTCOME	Good

PREOP



IMMEDIATE POST OP



AT 6 MONTHS FOLLOW UP

CASE 3

NAME: Rajendran

IP NO: 20928

AGE: 54/M yrs

OCCUPATION: cook

DIAGNOSIS: fracture of distal humerus Right

AO/ASIF: Type 13 C2

PROCEDURE DONE: ORIF with Parallel plating

APPROACH: Olecranon osteotomy

COMPLICATIONS: paraesthesia in ulnar sensory area

TIME OF UNION	14 weeks
ELBOW ARC OF MOTION	10-120 Deg
MAYO SCORE	90
OUTCOME	Excellent

PREOP

IMMEDIATE POST OP

ROM AT 12 MONTHS FOLLOW UP

CASE 4

NAME: Ganesh

IP NO: 146715

AGE: 22/M

OCCUPATION: college student

Diagnosis: fracture of distal humerus left

AO/ASIF: Type 13 A3 .3

ASSOCIATED INJURIES: nil

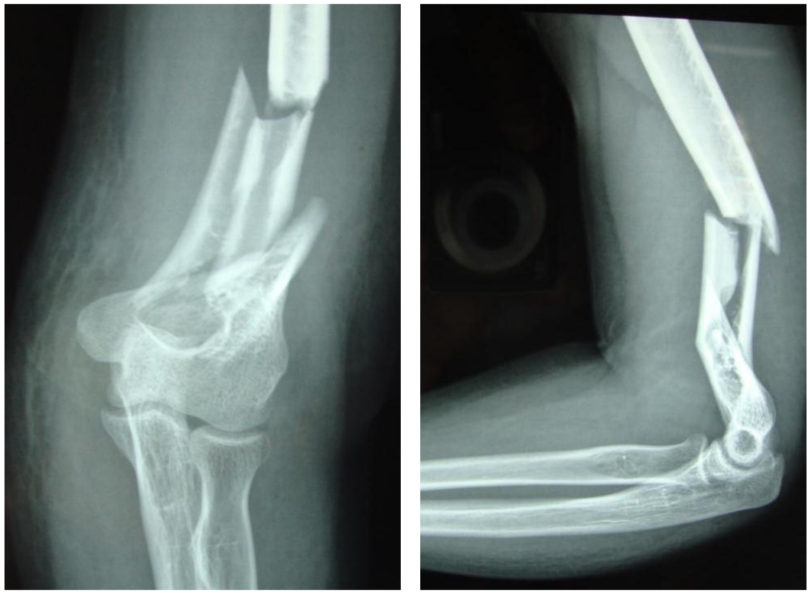
PROCEDURE DONE: ORIF with parallel plating

COMPLICATIONS: nil

SECONDARY PROCEDURE: nil

TIME OF UNION	13
ELBOW ARC OF MOTION	10-135
MAYO SCORE	90
FUNCTIONAL OUTCOME	Excellent

PREOP



IMMEDIATE POST OP

AT 12 MONTHS FOLLOW OP

ROM AT 12 MONTHS FOLLOW OP

COMPLICATIONS :

1 .Grade II compound fracture developed infection with ultimate requirement of flap cover. He had a delayed union with elbow stiffness

AT 6 MONTHS AFTER FLAP COVER



PREOP **IMMEDIATE POSTOP** **AT 6 MONTHS**



2. Pain and Restricted ROM due to heterotopic ossification

XRAY SHOWING
HETEROTOPIC OSSIFICATION

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S.No	Name	IP No.	Age/ Sex	R/ L	Mode of injury	AO type	Grade	Treatment	Approach	Associated injuries	ROM	Pain	MEPI rating	MEPS	Complications
1	Sathish	95345	20/M	R	MVA	A2	closed	ORIF with parallel plating	paratricipital	-	10-135	-	Excellent	95	-
2	Asok	96223	31/M	L	MVA	A3.3	Closed	ORIF with parallel plating with neurolysis	Triceps splitting	Radial N. palsy	0-125	mild	good	85	Superficial infection settled with antibiotics for 3 weeks
3	Saral	106531	60/F	L	Fall	A3.3	closed	ORIF with parallel plating	Triceps splitting	-	10-130	-	Excellent	90	-
4	Sivaraj	98456	26/M	R	MVA	C1	Grade II	ORIF with parallel plating & Bone grafting	Olecranon osteotomy	-	30-90	-	poor	55	Decreased elbow ROM due to heterotopic ossification
5	Kamala kannan	127654	32/M	R	MVA	C2	Grade I	ORIF with parallel plating	Olecranon osteotomy	-	10-135	-	Excellent	95	
6	Saraswathy	157363	65/F	L	Fall	C3	closed	ORIF with parallel plating	Olecranon osteotomy	-	10-110	-	Good	85	-
7	Vanda	149573	45/F	R	MVA	C1	Closed	ORIF with parallel plating+ Anterior transposition done	Olecranon osteotomy	Preoperative ulnar N palsy, Head injury, Contralateral shaft of humerus #	30-95	mild	Fair	70	1.Decreased elbow ROM due to Heterotopic ossification with head injury 2.only partial recovery of ulnar nerve after 1 year
8	Dinesh	152154	35/M	R	Fall from height	C2	Grade II	ORIF with parallel plating	Olecranon osteotomy	Right superior and inferior pubic rami #	10-110	-	Good	80	Non union at osteotomy site revision of osteosynthesis done
9	Sohail	113096	20/M	L	MVA	C2	Closed	ORIF with parallel plating	Olecranon osteotomy	-	20-130	-	Excellent	95	-
10	Ganesh	146715	22/M	L	Fall from height	A3.3	Grade II compound	ORIF with parallel plating & Bone grafting	TRAP	-	10-135	-	Excellent	90	-
11	Ramesh	126421	41/M	L	MVA	C1	Grade I compound	ORIF with parallel plating	paratricipital	-	20-120	-	Good	85	-
12	Rajendran	20928	54/M	R	Assault	C2	closed	ORIF with parallel plating	Olecranon osteotomy	Right superior Pubic rami #	10-120	-	Excellent	90	Parasthesia in Ulnar N sensory area

13	Shanmugam	27457	36/M	R	MVA	C2	Grade II Compound	Primary ORIF with parallel plating + SSG for soft tissue defect after debridement	Triceps splitting	-	30-90	-	poor	55	compound injury with laceration over anteriorlateral distal arm: Wound necrosis for which abdominal flap cover done.Delayed union and elbow stiffnes
14	Saroja	20933	65/F	R	fall	A2.3(t rans Cond ylar)	closed	ORIF with parallel plating	Triceps splitting	Left intertrochanteri c # femur	10-110	-	Good	80	Superficial infection settled after debridement and SSG for raw area
15	Sulochana	30132	55/F	L	Fall	C1	closed	ORIF with parallel plating	TRAP	-	20-90	moder ate	fair	70	stiffness due to pain
16	Balaji		53/ M	L	MVA	C3	closed	ORIF with parallel plating	Olecranon osteotomy	-	10-120	-	good	80	Iatrogenic Ulnar N neuropraxia - anterior transposition done 6 weeks later Iatrogenic Radial N neuropraxia which recovered in 3 months
17	Shankar	63426	45M	R	MVA	C2	Closed	ORIF with parallel plating	Olecranon osteotomy	-	10-120	-	good	85	Hardware prominence
18	Shamu	94519	23/M	R	MVA	C2	closed	ORIF with parallel plating	Olecranon osteotomy	-	10-90	-	fair	65	Stiffness
19	Meeto	105408	29/M	L	Fall from height	C3	closed	ORIF with parallel plating	Olecranon osteotomy	-	10-140	-	excellent	90	-
20	vijaya	81213	38/F	R	MVA	C2	closed	ORIF with parallel plating	Olecranon osteotomy	Distal radius # R	20-130	mild	good	85	-
21	harish	92561	24/M	R	MVA	C1	closed	ORIF with parallel plating	paratricipital	-	10-120	-	good	85	-
22	kamal	84642	32/M	L	MVA	A3	Grade I compound	ORIF with parallel plating	Olecranon osteotomy	Metatarsal # R foot	10-110	-	good	80	-
23	kasthuri	76343	46/F	R	Fall	C1	closed	ORIF with parallel plating	TRAP	-	20-140	-	excellent	90	Parasthesia in Ulnar N sensory area
24	Rajeshwari	66478	52/F	R	MVA	C1	closed	ORIF with parallel plating	Olecranon osteotomy	Shaft of femur R	10-130	-	good	85	Parasthesia in Ulnar N sensory area