"A STUDYOF MANAGEMENT FRACTURES OF BOTH BONES FOREARM USING LOCKING COMPRESSION PLATES"

By

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DISSERTATION SUBMITTED TO SRI DEVARAJ URS ACADEMY OF HIGHER EDUCATION AND RESEARCH CENTER, KOLAR, KARNATAKA

In partial fulfillment of the requirements for the degree of

MASTER OF SURGERY

IN

ORTHOPAEDICS

Under the Guidance of

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ABSTRACT

BACKGROUND AND OBJECTIVE:

The fractures of both bones forearm are one of the commonest fractures found and can be treated by different methods. The accepted management for fractures of both bones forearm is open reduction and internal fixation using dynamic compression plating. The present study is undertaken to evaluate the advantages and disadvantages over conventional Dynamic conventional plate(DCP)

OBJECTIVES:

- To study the functional outcome of treating diaphyseal fractures of both bones forearm with locking compression plates.

MATERIALS AND METHODS:

This study is a hospital based prospective study conducted in Department of Orthopaedics at R.L J hospital and research Centre, Kolar, from November2014 to February 2016 in which 30 patients with fracture both bones of forearm were treated by open reduction and internal fixation using Locking Compression Plate.

RESULTS:

In our series, majority of the patients were males, middle aged, with road traffic accidents being the commonest mode of injury, involving middle third and distal third. Transverse or short oblique fractures were most common. The fractures united in all 30 patients. Excellent or full range of mobility of elbow and wrist joints were present in 25 patients (83.3%), 5 (16.7%) patients having good range of movements.

INTERPRETATION /CONCLUSION

The LCP of forearm fractures produce excellent results, the advantage being early mobilization, stable fixation, surgical technique, duration of surgery and complications remains unchanged.

Mesh Key Words: shaft of both bones of forearm fractures, LCP, Open reduction and internal fixation.

LIST OF ABBREVATIONS

AO	-	Arbeitsgemeinschaft fur Osteosynthesefragen
ASIF	-	Association for the study of internal fixation
BP	-	Blood Pressure
BT/CT	-	Bleeding Time / Clotting Time
DCP	-	Dynamic Compression Plate
Deg	-	Degree
K wire	-	Kirschner wire
ECG	-	Electrocardiography
FBS/PPBS	-	Fasting Blood Sugar / Postprandial Blood Sugar
Hb	-	Haemoglobin
HbsAg	-	Hepatitis B Virus Surface Antigen
HIV	-	Human Immunodeficiency Virus
SFS	-	Small Fragment Set
DCP	-	Dynamic Compression Plate
LC-DCP	-	Limited Contact Dynamic Compression Plate
Lat	-	Lateral
PC-FIX	-	Point contact fixator
AP	-	Anterior posterior
ORIF	-	Open Reduction and Internal Fixation

OTA	-	Orthopedic Trauma Association
RR	-	Respiratory Rate
RTA	-	Road Traffic Accident
Wks	-	Weeks
#	-	Fracture
LCP	-	Locking compression plate

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INTRODUCTION

Forearm bone fractures are commonly encountered in today's industrial era. Various treatment modalities were introduced from time to time and each of them had some edge over the previous one. Continuing this process of revolution and based on many years of experience with compression plating and promising results obtained with so called internal fixation, an implants system has been developed which combines the two treatment modalities .The forearm, being a component of upper limb serves important movements that are important in activities of daily living. The forearm, in combination with the proximal and distal radio ulnar joints, allows pronation and supination which in turn helps hand, to perform multi axial movements.

The incidence of forearm fractures are increasing faster than the predicted rate due to increase in population, increasing number of vehicles, rapid industrialization, increased incidence of violence and various sports activities.

Fracture of the forearm both bones may result in severe loss of function unless adequately treated. Hence good anatomical reduction and internal fixation of these fractures is necessary to restore function.

Closed reduction which was employed in earlier days yielded unsatisfactory results from either non-union or loss of motion. Also there are complex forces acting on the forearm bone that makes reduction and its maintenance of displaced fracture fragments difficult.

Union may be achieved with any of the methods available however severe loss of function may be the end result unless adequately treated with proper technique and implants.

With the development of compression plate osteosynthesis which provides a good treatment option and predictable outcome, there is an important change in the treatment of forearm fractures. This method helps in perfect reduction of fracture fragments in anatomical position and by rigid fixation and early mobilization, the normal functions of the hand can be reachieved at the earliest

Despite the combination of these different treatment techniques no compromises were made with regard to application as a compression plate or as a bridging device in the form of an internal fixation. LCP

(Locking compression plate) is a product of these combinations and is in line with the latest plating techniques, the aim of which is to achieve the smallest surgical incision and to preserve blood supply to the bone and adjacent soft tissues and stability at the fracture site.

LCP has got features of both LC-DCP and a PC-Fix as it uses screw heads that are conically threaded on the undersurface and create an angular stable plate screw device.

This type of plate fixation relies on the threaded plate-screw interface to lock the bone fragments in position and do not require friction between the plate and bone as in conventional plating. The present study was undertaken to evaluate the use of LCPs in fractures of forearm bones.

The functional outcome was assessed using "Anderson et al, scoring system". The variables taken into consideration were:

a. Union of the fractures.
b. Range of elbow and wrist movements

OBJECTIVES

OBJECTIVES OF STUDY:

- To study the functional outcome of treating diaphyseal fractures of both bones forearm with locking compression plates.

REVIEW OF LITERATURE

Fractures have been recognized and treated as long as recorded in history. History of fracture and its knowledge dates back to Egyptian Mummies of 2700 B. C.[3]

In olden days, surgeons merely used to align and immobilize fracture fragments, which resulted in mechanical failure. In today's scenario evolution of the plates has taken place, with developments in engineering and material science has helped in better alignment and fracture fixation.[4]

For thousands of years the only option for the management of fractures was some form of external splintage. 5000 years ago the Egyptians used palm bark and linen bandages for management of fractures. Clay and lime mixed with egg white were used, but the material most commonly used has been, the wood[5].

In 1770, the first attempt at internal fixation took place in Toulouse, France. It was Lapejode and Sicre, two surgeons who used brass wire for cerclage of long bone fractures[5].

The term "Osteosynthesis" was coined by AlbinLambotte in 1894,Belgian surgeon regarded universally as father of modern internal and external fixation. He devised an external fixator and different plates and screws, together with surgical instruments[5].

In 1912, Beckman advocated plate fixation of diaphyseal fractures. A year later Nicholaysen described intramedullary nailing[6].

In 1913, Schone described the principles of intramedullary nailing in forearm fractures. Gilfillen devised metallic plate for fixation of fractures of Radius and Ulna[6].

Robert Danis, a surgeon in Brussels, published two books on Osteosynthesis in 1932 and 1949. The books contained fascinating observations on the use of rigid fixation devices.

In 1945, Mervyn Evans described the method to determine rotational alignment in forearm fractures by the so called Tuberosity View[7].

In 1949, Danis of Belgium was the first surgeons to report the use of inter fragmentary compression by applying plates under tension along the longitudinal axis of the bone[5].

In 1958, Maurice E. Muller, a Swiss Surgeon, was inspired by Robert Danis books and formed the AO group (Arbeitsgemeinschaft fur osteosynthesefragen), later on to be known in English speaking countries as the Association for the study of internal fixation (ASIF). This group dedicated itself to research into osteosynthesis, the design of appropriate instrumentation for fracture surgery and the documentation[5].

In 1959, Sage used the medullary forearm nail system. He had a exhaustive review of 555 fractures repaired with medullary devices for both radius and ulna.

A reported success using the compression plate in the treatment of forearm fractures[8].

In 1963, the removable compression device was developed by the AO group. The maintenance of compression of the bone relied on the friction between the plate undersurface and the surface of the plated bone[9].

The first attempt at biological plating were at Biotzy and Weberpers in1964[9], they treated forearm fractures in adults using plates. They believed that plate fixation as the most satisfactory treatment for forearm fractures and can achieve good functional results with avoidablecomplications[10].

In 1969, a study which was consisted of 1903 radial shaft fractures, 666 ulnar shaft fractures, for 97% cases narrow DCP was used. They noted that there were 3.2% non-union and rest of them had good functional outcome. They recommended the 3.5mm DCP for fixation of forearm fractures[15].

In 1975, they published a wonderful series of cast bracing. They avoided below and above joint immobilization and still documented excellent functional results[12].

In 1975, noted that, 244 patients with 330 diaphyseal fracturesof radius and ulna which were treated with ASIF compression plates. The overall union rate was 97.9% for the radius and 96.3% for the ulna showed excellent functional results in acute diaphyseal fractures of forearm and advised minimal stripping of periosteum before plate application[2].

In 1979, DCP was developed by Perren and used successfully in humans by Allgower et al in the same year. Its spherical geometry not only allowed self-compression but also enabled the maintenance of a congruent fit between the screw and the plate hole at different angles of inclination. Thus, the plate was more adaptable to different situations of internal fixation and could fulfill all the different plate functions[11].

In a study conducted on the animals to know the effect of compression on bone with the help of measuring device that measured compression as bone healing progressed ,they noted that there was loss of compression as the fracture heals ,some amount of compression persisted even after bony union. The fall in compression was due to the Haversian remodeling. They concluded that compression and absolute rigidity of fracture ends that results from the force applied is highly favorable for fracture healing[13].

In 1980, a study conducted in 64 patients with fracture of radius and ulna fixed with AO compression plates. The purpose of their study was to determine the effect of early postoperative mobilization after rigid fixation[14].

In 1983, authors outlined the complication of forearm fractures in 87diaphyseal radius/ulna fractures. Major complications occurred in 28% of cases. Non-union occurred in 93% of cases, noted in fractures treated with only4 screws[16].

They concluded that (i) plating with 4 screws may be inadequate fixation for forearm fractures and at least 5 screws must be used to affix the plate to either radius / ulna, (ii) The ulna remains the most difficult bone to achieve primary healing. This may be due to torsional stresses that increase during pronation and supination, (iii) Synostosis appears to be more common in patients who sustain concomitant head injury and hence heterotrophicossification[16].

In 1986, a study regarding immediate fixation of open fractures of the diaphysis of the forearm. They demonstrated immediate stable plate fixation is a beneficial method of treatment of open fractures of forearm and achieved excellent or good functional results in 85% of the series[18].

In 1989, a retrospective study of 129 diaphyseal fractures of radius and ulna, they used the 3.5mm and 4.5mm AO DCP. They noted 98% union and excellent results in 92% of patients. They noted, immediate internal fixation resulted in a low rate of complications. They concluded internal fixation with3.5mm AO DCP provides excellent results for diaphyseal fractures of radius and ulna[19].

In 1990, a study, author developed the limited contact dynamic compression plate (LC-DCP) to release the new concept of biological internal fixation.

The LC-DCP is technically a further development of DCP. The symmetrical self-compressing plate hole and deletion of the elongated distance between the innermost screw holes makes the LC-DCP more versatile for use in any fracture type. Grooves on the under surface of the LC-DCP serve three purposes.

i. Improved blood circulation by decreased contact between plates and bone.
ii. Allows for a small bone bridge beneath the plate at the most critical area, which is otherwise weak due to a stress concentration effect.
iii. More even distribution of the holes than in conventional plates[20].In 1991, the authors designed the dynamic compression unit(DCU),precursor of LC-DCP. They modified the plate holes, the lower side of the plate and the distribution of the plate holes[9].

In 1991, a study, they proposed the use of biodegradable polymeric materials, so that the implant dissolves after a certain time in the body avoiding a second operation for removal of implant. No such material has yet made available for use with conventional techniques of internal fixation, which combines adequate strength, ductility, maintenance of compression and degradability without marked tissue reaction. Tissue tolerance and local effects on infection are still unsolved problems[17]

In 1992,Schemitsch,Emil.H,Richards.R. studied the effect of mal-union after plate fixation of fractures of both bones of forearm in adults and concluded that restoration of normal radial bow was necessary and related to the functionaloutcome[21].

In 1995, a study conducted to check mechanical compression of DCP, LC-DCP and Point contact fixator (PC-fix) in cadaveric sheep tibia showed that the DCP has torsion and bending properties comparable with LC-DCP and PC-Fix in fixation of simple transverse diaphyseal fractures[22].

In a study, authors were carried a trial comparing the LC-DCP with PC-Fix for forearm fractures. Their study concluded plating as the best method of fixation for diaphyseal fractures of the forearm. Despite the differences in the concept of fracture fixation, these two implants appear to be equally effective for the treatment of diaphyseal forearm fractures.

In a study, authors concluded that the limited contact dynamic compression plate is used to treat the displaced fractures of radius and ulna, until other fixator device proven to be superior, the 3.5 limited contact dynamic compression plate remains the gold standard for internal fixation of forearmfractures[23].

In 2006, a study conducted by the use of LCP in 32 patients. Follow up was done for 20 months. Two patients had delayed union but none had non-union, 33% anatomical reduction, 56% fractures healed with minimal callus, 44% with moderate callus formation. Mean healing time was 16 months. Hence, LCP is an effective bridging device in treating comminuted diaphyseal fractures[24].

In 2008, a prospective study of 30 adult patients of forearm fractures. Follow up was done at 3,6, and 12months. All the fractures united with mean union time of 12.6 weeks. LCP is a stronger construct and by preventing primary and secondary loss of reduction it does not alter the natural course of healing of fracture, which is not possible with the use of DCP andLC-DCP[25.]

In 2008, a retrospective comparative study between LCP and DCP. 9 fractures were treated with LCP and 10 fractures with DCP. They observed that, as axial compression seems to be important in these fractures, the LCP would seem to offer little, technical advantage over the standard DCP[26].

In a study conducted on stability of locking compression plates in 18 pairs of fresh frozen human osteoporotic cadaver radii. Specimens had an average of 79 years and an average bone mineral density of 0.393 g/cm2 as measured by DEXA scanning. They observed that, use of an LCP leads to a more stable construct as compared with the standard LC-DCP[27].

Primary stability achieved with locking screw in a plate prevents secondary displacement irrespective of bone quality enabling good results in osteoporotic bone and young patients.

Internal fixation with plates allows excellent control of fracture fragment and therefore permits accurate restoration of anatomy which remains the key principle in treating forearm fracture as it preserves maximal forearm function.[33]

In 2009, a prospective study involved 31 patients with non unions of forearm diaphyseal fractures. Surgical revision was performed by restoring anatomic forearm length by autologous bone grafting of the resected nonunion from the iliac crest and compression plating. Radiographic showed bone union in 30 of 31 patients with mean time of 3.5 months[50].

In 2011, a comparative study in 36(18 in each group) patients with fracture both bone treated with LCP or LC-DCP in mean age group of 31.5years with follow-up of 2.1 years after accessing the functional out come with DASH SCORING SYSTEM showed that LCP is better as it had prevented refracture after plate removal[51].

In 2013, a prospective study[3] conducted in 40 patients to show the over all functional outcome after treating with LCP(20 patients) and DCP(20 patients) showed increased rate of callus formation and mean time for bone union in LCP series [52].

In 2013, a retrospective study done to evaluate the LCP fixation in 10 difficult non unions of long bone fractures. Mean follow up of 6 months and average time of union 3.4 months in these cases with bone grafting and LCP showed stability, acceptable reduction and good fixation[53].

In 2014, a retrospective study of LCP in diaphyseal fractures of forearm out of 47 patients, 91% patients showed good union rates,78.7% patients had excellent results,12.7% patients with satisfactory results and 8.5% patients with poor outcome[54].

In 2014,arandomised control study conducted to know the efficacy of LCP over DCP in 40(20 in each group) patients with a follow up at 1,3 and 6 months showed excellent results with LCP than that of DCP in terms of early mobilization, early union rates and helped in preventing fracture disease of affected limb[55]

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In 2015,a study conducted in 24 cases of diaphyseal both bones forearm fractures were treated with LCP and DCP, 12 in each group in the age group of more than 50 years. The mean age group of patients was 64.9 years for LCP and 64.25 years for DCP group. Road traffic accidents were the main cause of fractures. Fractures occurred predominantly in the male population. Surgery was performed within 2 to 10 days after injury.

Radiological union was seen at an average of 13.83 weeks in LCP group and 15.33 weeks in DCP group. Overall functional results were almost same in both the groups. Excellent in 17 cases (9 in LCP, 8 in DCP), Good in 5 cases (2 in LCP, 3 in DCP), Fair in 2 cases (1 in each group).[47]

In 2016, a study conducted in 20 middle aged male patients with road traffic accidents being most common mode of injury with transverse/ short oblique fractures showed excellent/full range of mobility in 17 patients(88%) and 3 patients (15%) with good range of motion after fixation with LCP.[48]

In 2106,a retrospectively reviewed 21 patients with non-union was managed surgically to achieve complete union of fractures and restore the functional anatomy by using compression of the fracture site and stimulation of bone formation by bone grafting and bone marrow injection showed satisfactory results.[49]

ANATOMY

ANATOMY OF FOREARM

The forearm fulfills an important role in the integrated function of the upper extremity. It maintains a stable link between elbow and wrist, provides an origin for many of muscles that insert on the hand, and allows rotation of the wrist to position the hand more effectively in space.

Acute injuries can involve different components of the forearm unit simultaneously, thus necessitating the understanding of forearm anatomy for planned reduction and surgical management.

EMBRYOLOGY[29]

Development of the limb buds.

- The forelimb bud appears about the 26th day (end of 4th week) and Hindlimb bud about the 28th day. The limbs become paddle-shaped after about 4 days (5th week).
- Grooves between the future digits (digital rays) can be seen by the 36th day(6th week).
- By the 50th day or so (8th week) the elbows and shoulder are established, and the fingers are free.
- Rotation of limbs occurs during the 7th week.

- Cartilaginous models of bones start forming in the 6th week, and primary centers of ossification are seen in many bones in the 8th week. They are present in all long bones by the 12th week.
- Each limb bud is covered by the surface ectoderm and contains a mesodermal core which is derived from the somatopleuric layer of the plate under the inductive influence of the adjacent somites The core mesoderm of the lateral plate differentiates to form the bones, ligaments, joints and vasculature of the limbs, whereas the limb musculature is derived from the mesodermal somites that migrate into the developing limb bud.
- The limb muscles are innervated by the branches from the ventral primary rami of spinal nerves; C5 to T1 for the upper limb.

SKELETAL ANATOMY:

Normal function of the forearm requires intact skeletal structures formed by radius and ulna, interosseous membrane, radio ulnar joints and normal soft tissue structures.

OSTEOLOGY OF THE FOREARM:

Ulna:

The ulna is the medial bone of the forearm and in homologous with fibula of the lower limb. It has a upper end, a shaft and lower end (head). It's size diminishes from upper to lower end. Upper end is strong, expanded and has hook like projection called trochlear notch which articulates with trochlea of humerus. It has two processes olecranon and coronoid processes and two articular notches, trochlear and radial notches. Lower end is smaller and has small rounded head. Styloid process projects downwards from the posteromedial aspect of the head and gives attachment to ulnar collateral ligament of the wrist.

The shaft of the ulna has interosseous, anterior and posterior borders. The interosseous border continues above with the supinator crest, which gives attachment to interosseous membrane. Posterior border begins at the posterior aspect of olecranon and is subcutaneous throughout its length. Anterior border is thick and rounded. Begins above and at the medial side of the tuberosity of ulna and runs down to the base of styloid process. Ulna has three surfaces, anterior, medial and posterior which serve for muscle attachments[30].

Radius:

Radius is the lateral bone of forearm and in homologous with the tibia of lower limb. It has upper end, a shaft and lower end. Radius has a characteristic bow which has demonstrated to be important for forearm rotation and must be accurately restored when this bone is fractured. It has double curvature in both anteroposterior and lateral planes. It has three borders, interosseous, anterior and posterior. Three surfaces, anterior, posterior and lateral. The lower half is practically subcutaneous on its lateral and dorsal aspect. It is cylindrical in upper half. The interosseous border in its lower three fourth gives attachment to interosseous membrane[30].

Lower end of the radius is the widest part of the radius is roughly quadrilateral in shape, with articular surfaces for the ulna, scaphoid and lunate bones. The distal end of the radius forms two palpable points, radially the styloid process and lister's tubercle on the ulna side. Along with the proximal and distal radio ulnar articulations, an interosseous membrane originates medially along the length of body of the radius to attach the radius to the ulna [30].

The maximum radial bow can be measured by standard lateral radiographs with forearm in neutral rotation. A reference line is drawn from the tip of the bicipital tuberosity to the ulnar most aspect of the distal radius. The maximum radial bow is measured as the number of millimeters along a perpendicular line to the reference line drawn plamarly.It is measured as the percentage distance from the tip of the bicepital tuberosity to the point of the apex of maximum radial bow along the length of reference line[21](i.e. x/y x100).failure to restore the parameters within approximately 4% of the opposite was associated with a loss of 20% or more of forearm rotation[33]

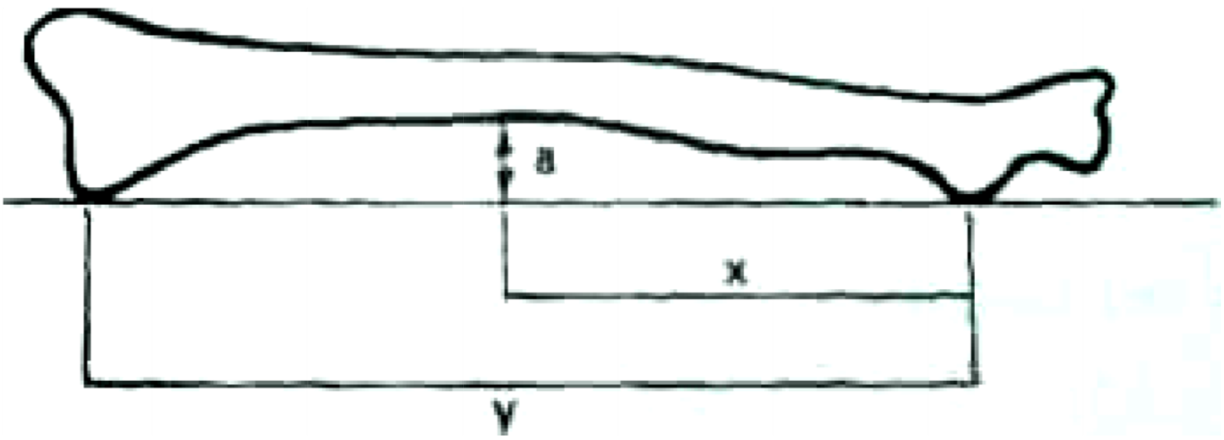


Fig:1 Measurement Of Radial Bow

Upper end of the radius has head, neck and bicipital tuberosity. head articulates with radial notch of the ulna. The upper surface of the head is hollowed out to form a shallow cup for the articulation with the capitellum. Below the head is neck and tuberosity. The rough posterior part of the tuberosity gives insertion to biceps brachii while its smooth anterior part is separated from the tendon by a bursa[30].

OSSIFICATION:

Ulna:

It ossifies in cartilage from one primary center for the shaft and secondary centers, one for distal end and two for olecranon. Primary center for the shaft appears in 8th week of intrauterine life. Secondary center for upper end (growing end) appears at 7-9 years in females and 8-10 years in males and unites with the shaft at 14th year in females and 17th year in males. Secondary center for lower end appears in 5th year in female and 6 years in males, fuses with shaft at 17th year in female and 18th year in male[30].

Radius:

Ossifies in cartilage from one primary center and two secondary centers. Primary center appears at 8th week for the shaft. Secondary center for upper end appears at 3-4 years in females and 4-5 years in males, unites with the shaft at 14thyear in females and 17th year in males.

Secondary center of lower end appears at 1-2 years and unites with shaft at 17th year in females and 19th year in males. It is the growing end[30].

The radio ulnar articulations:

The radius and ulna are joined to each other at the superior and inferior radio-ulnar joints. The two bones are also connected by the interosseous membrane; which is sometimes said to constitute a middle radio-ulnar joint.

a) **Superior radio ulnar joint:**

The essential structure is the annular ligament which holds the head of radius in place. The annular ligament is attached to the anterior and posterior margins of radial notch of ulna and has no attachment to radius. Superiorly it blends with the capsule at the lower margin of the cylindrical articular surface. It is a pivot type of synovial joint.

Movement-pronation and supination of forearm.

b) **Inferior radio ulnar joint:**

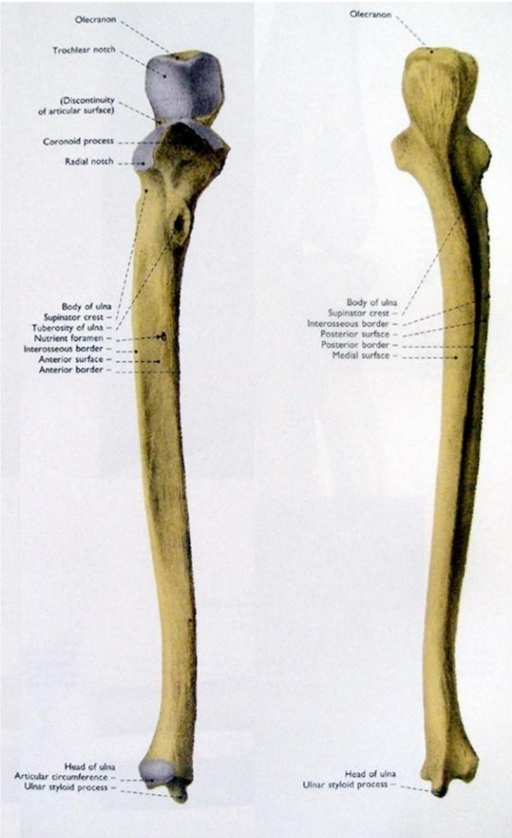
It is closed distally by a triangular fibrocartilage which is attached to its base to the ulnar notch of radius and by its apex to a fossa at the base of ulnar styloid.

Movement: pronation and supination of forearm.

c) **Interosseous membrane:**

This connects the borders of two bones. Its fibers run from radius down to the ulna at an oblique angle and are supposed to have an effect in transmitting thrust from the wrist to the elbow via lower end of radius to upper end of ulna and to the humerus. It provides attachment to many muscles of forearm. Interosseous membrane is relaxed in complete pronation and supination, becomes taut while hand is midway between pronation and in supination[30].

RADIUS: ANTERIOR AND POSTERIOR VIEW



ULNA: ANTERIOR AND POSTERIOR VIEW

Fig no. 2 Anatomy of forearm bones

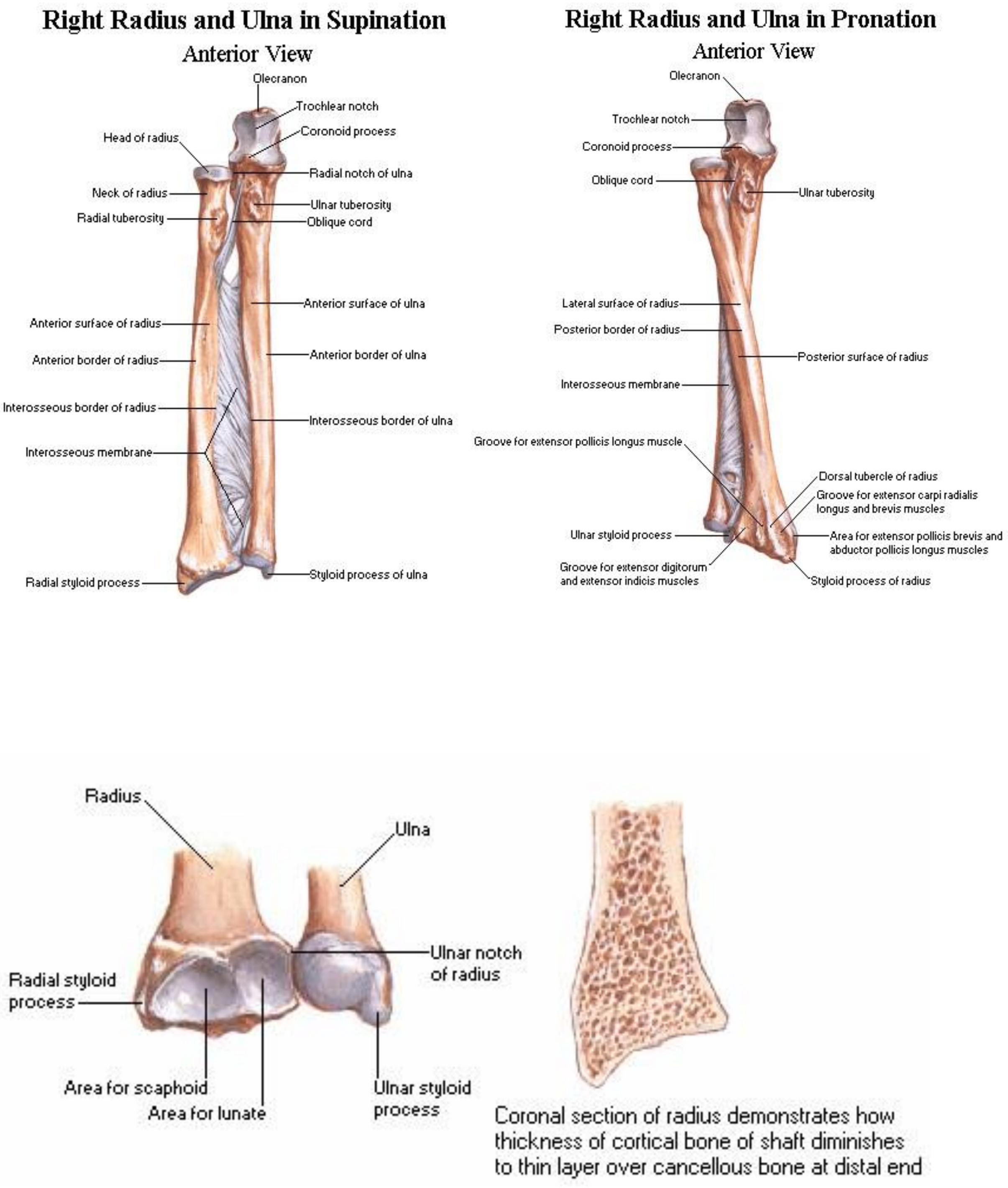


Fig no:3 Osteology Of Forearm

Table 1: ARTERIES OF FOREARM

Artery [31]	Origin	Course
Radial	Smaller terminal division of brachial artery in cubital fossa	Runs inferolaterally under cover of brachioradialis and distally lateral to flexor carpi radialis tendon; winds around lateral aspect of radius and crosses floor of anatomical snuff box to pierce fascia; ends by forming deep palmar arch with deep branch of ulnar artery
Ulnar	Larger terminal branch of brachial artery in cubital fossa	Passes infero medially and then directly, deep to pronator teres, palmaris longus, and flexor digitorum superficialis to reach medial side of forearm, passes superficial to flexor retinaculum at wrist and gives a deep palmar branch to deep arch and continues as superficial palmar arch.
Radial recurrent	Lateral side of radial, just distal to its origin	Ascends on supinator and then passes between brachioradialis and brachialis.
Anterior and posterior ulnar recurrent	Ulnar, just distal to elbow joint	Anterior ulnar recurrent artery passes superiorly and posteriorly, ulnar collateral artery passes posteriorly to anastomoses with ulnar collateral and interosseous recurrent arteries.
Common interosseous	Ulnar, just distal to bifurcation of brachial artery	After a short course, terminates by dividing into anterior and posterior intersosseous arteries.
Anterior and posterior interosseous	Common interosseous artery	Pass to anterior and posterior sides of interosseous membrane

NERVES OF FLEXOR COMPARTMENT:

- The lateral cutaneous nerve of the forearm, the cutaneous continuation of the musculocutaneous nerve, pierces the deep fascia above the elbow lateral to the tendon of biceps and supplies the anterolateral surface of the forearm. The medial cutaneous nerve of the forearm supplies front and back of the medial part of the forearm[32].

- The superficial terminal branch of the radial nerve, the cutaneous continuation of the main nerve, runs from the cubital fossa on the surface of supinator, pronator teres tendon and flexor digitorum superficialis, on the lateral side of forearm under cover of brachioradialis. In the middle third of the forearm it lies beside and lateral to radial artery. It then leaves the flexor compartment of the forearm by passing backwards deep to the tendon of brachioradialis and breaks into two or three branches.

- The median nerve leaves the cubital fossa between the two heads of pronator teres. It passes deep to the fibrous arch of flexor digitorum superficialis. Just above the wrist the nerve comes closer to the surface between the tendons of flexor carpi radialis and flexor digitorum superficialis, lying behind the tendon of palmaris longus. It supplies muscular branches to pronator teres, flexor carpi radialis, palmaris longus and flexor digitorum superficialis (lateral half), the nerve also supplies the elbow and proximal radioulnar joints. Deep to flexor digitorum superficialis, the median nerve gives off an anterior interosseous branch which runs down the artery of the same name and supplies flexor digitorumprofundus, flexor pollicis longus, pronator quadratus, the inferior radio ulnar, wrist and carpal joints. The ulnar nerve enters the forearm from the extensor compartment of arm by passing between the two heads of flexor carpi ulnaris. The nerve lies undercover of the flattened aponeurosis of flexor carpi ulnaris with the ulnar artery to its radial side. It supplies flexor carpi ulnaris and ulnar half of flexor digitorum profundus.

NERVE OF EXTENSOR COMPARTMENT:

Posterior interosseous nerve:

The nerve appears in the extensor compartment after passing through the supinator muscle. It passes downwards over the abductor pollicis longus origin and dips down to reach the interosseous membrane were it passes between the muscles as far as the wrist joint. Here it ends in a small nodule from which branches supply the wrist joint. The nerve supplies the muscles which arise from the common extensor origin and deep muscles of the extensorcompartment[32].

Table 2:muscles of anterior compartment of forearm[31]

SUPERFICIAL COMPARTMENT

Name of Muscle	**Origin**	**Insertion**	**Nerve Supply**	**Nerve Root**	**Action**
Pronator teres a) Humeral head b) Ulnar head	Medial epicondyle of humerus. Medial border of coronoid process of ulna.	Lateral aspect of shaft of radius	Median nerve	C6, C7	Pronation and flexion of forearm
Flexor carpi radialis	Medial epicondyle of humerus.	Base of second and third metacarpal bones	Median nerve	C6, C7	Flexes and abducts hand at wrist joint.
Palmaris longus	Medial epicondyle of humerus	Flexor retinaculam and palmar aponeuosis	Median nerve	C7, C8	Flexes hand

Flexor carpi Ulnaris a) Humeral head. b) Ulnar head	Medial epicondyle of humerus. Medial aspect of olecranon process and posterior border of ulna.	Pisiform bone, hook of the hammate, Base of fifth metacarpal bone	Ulnar nerve	C8, T1	Flexes and abducts hand at wrist joint.
Flexor digitorium superficials Humeroulnar head. Radial head	Medial epicondyle of humerus Medial border of coronoid process of ulna. Oblique line on anterior surface of shaft of radius.	Bases of Middle phalanx of medial four fingers	Median nerve	C7, C8, T1	Flexes middle phalanx of fingers and assists in flexing proximal phalanx and hand.

DEEP COMPARTMENT

Name of Muscle	Origin	Insertion	Nerve Supply	Nerve Root	Action
Flexor-Digitorium profundus	Anteromedial surface of shaft of ulna.	Bases of distal phalanx of medial four fingers	Ulnar (medial half) and median (lateral half) nerves	C8, T1	Flexes middle phalanx of fingers and assists in flexing proximal phalanx and hand.
Pronator quadratus	Anterior surface of shaft of ulna.	Anterior surface of shaft of radius.	Anterior interosseous branch of median nerve	C8, T1	Pronates forearm
Flexor pollicis longus	Anterior surface of shaft of radius.	Base of distal phalanx of thumb	Anterior interosseous branch of median nerve	C8, T1	Flexes distal phalanx of thumb.

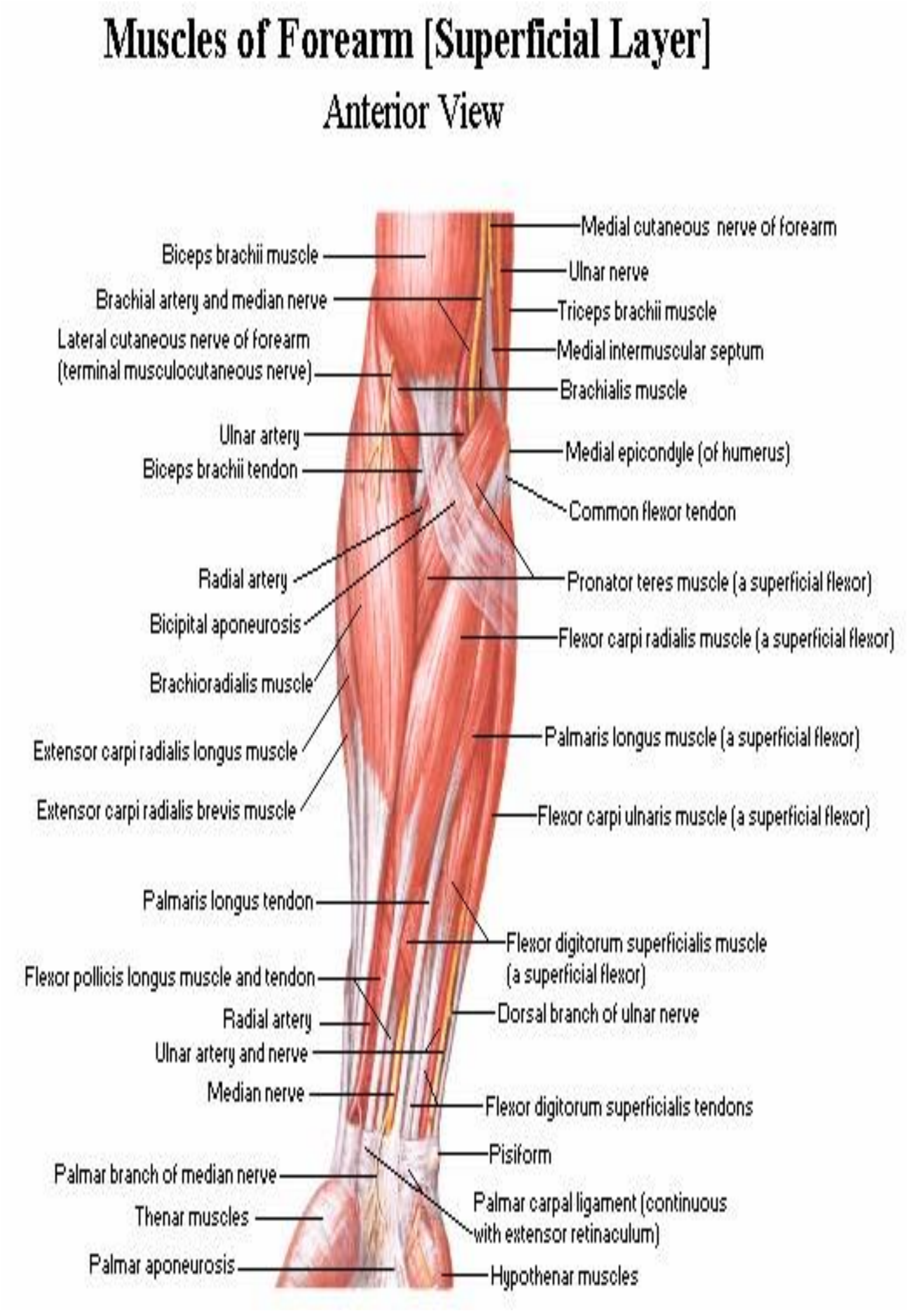


Fig:4 Superficial Muscles Of Forearm

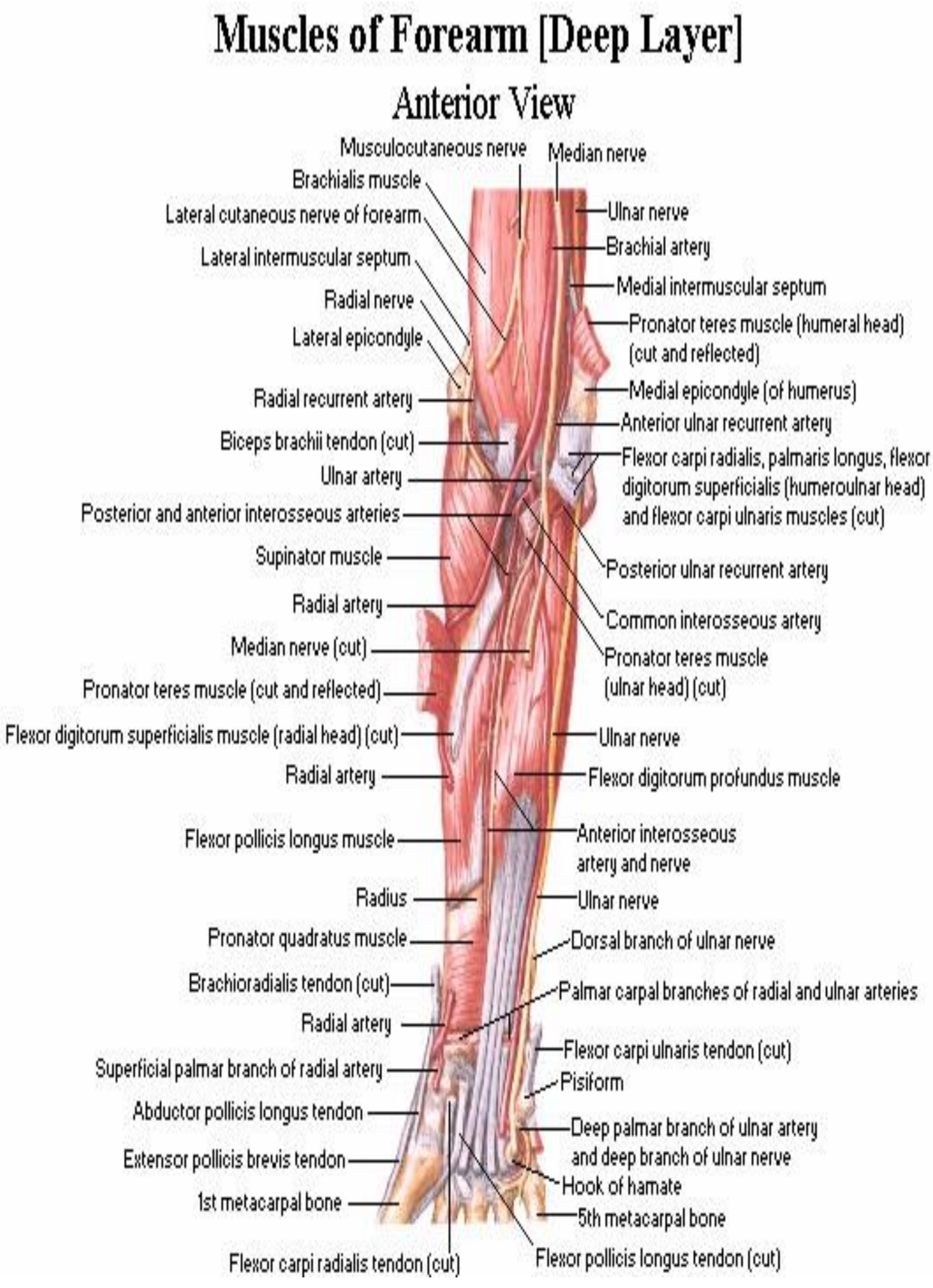


Fig :5 Deep Muscles Of Forearm

Table:3 muscles of posterior compartment of forearm[31]

Name of Muscle	Origin	Insertion	Nerve Supply	Nerve Root	Action
Brachioradialis	Lateral supracondylar ridge of humerus.	Base of styloid process of radius.	Radial nerve	C5, C6, C7	Flexes the forearm at the elbow joint; rotates forearm to the midprone position
Extensor carpi radialis longus	Lateral supracondylar ridge of humerus.	Posterior surface of base of second metacarpal bone.	Radial nerve	C6, C7	
Extensor carpi radialis brevis	Lateral epicondyle of humerus.	Posterior surface of base of third metacarpal bone	Deep branch of radial nerve	C7, C8	Extends and abducts hand at wrist joint
Extensor Digitorium superficialis	Lateral epicondyle of humerus.	Extensor expansion of middle and distal phalanges of medial four fingers	Deep branch of radial nerve	C7, C8	Extend fingers and hands
Extensor digiti minimi	Lateral epicondyle of humerus.	Extensor expansion little finger	Deep branch of radial nerve	C7, C8	Extends meta carpo phalangeal joint of little finger
Extensor carpi ulnaris	Lateral epicondyle of	Base of fifth metacarpal	Deep branch of radial	C7, C8	Extends and abducts hand at

	humerus.	bone	nerve		wrist joint
Anconeus	Lateral epicondyle of humerus.	Lateral surface of olecranon	Radial nerve	C7, C8, T1	Extends elbow joint
Supinator	Lateral epicondyle of humerus, annular ligament of proximal radioulnar joint, and ulna	Neck and shaft of radius	Deep branch of radial nerve	C5, C6	Supination of forearm
Abductor pollicis longus	Posterior surface of shafts of radius and ulna.	Base of 1st metacarpal bone	Deep branch of radial nerve	C7, C8,	Abducts and extends thumb
Extensor pollicis brevis	Posterior surface of shafts of radius.	Base of proximal phalanx of thumb	Deep branch of radial nerve	C7, C8	Extend meta carpo phalangeal joints of thumb.
Extensor pollicis longus	Posterior surface of shafts of ulna.	Base of distal phalanx of thumb	Deep branch of radial nerve	C7, C8	Extends distal phalanx of thumb
Extensor indicis	Posterior surface of shafts of ulna.	Extensor expansion of index finger.	Deep branch of radial nerve	C7, C8	Extends meta carpo phalangeal joint index finger.

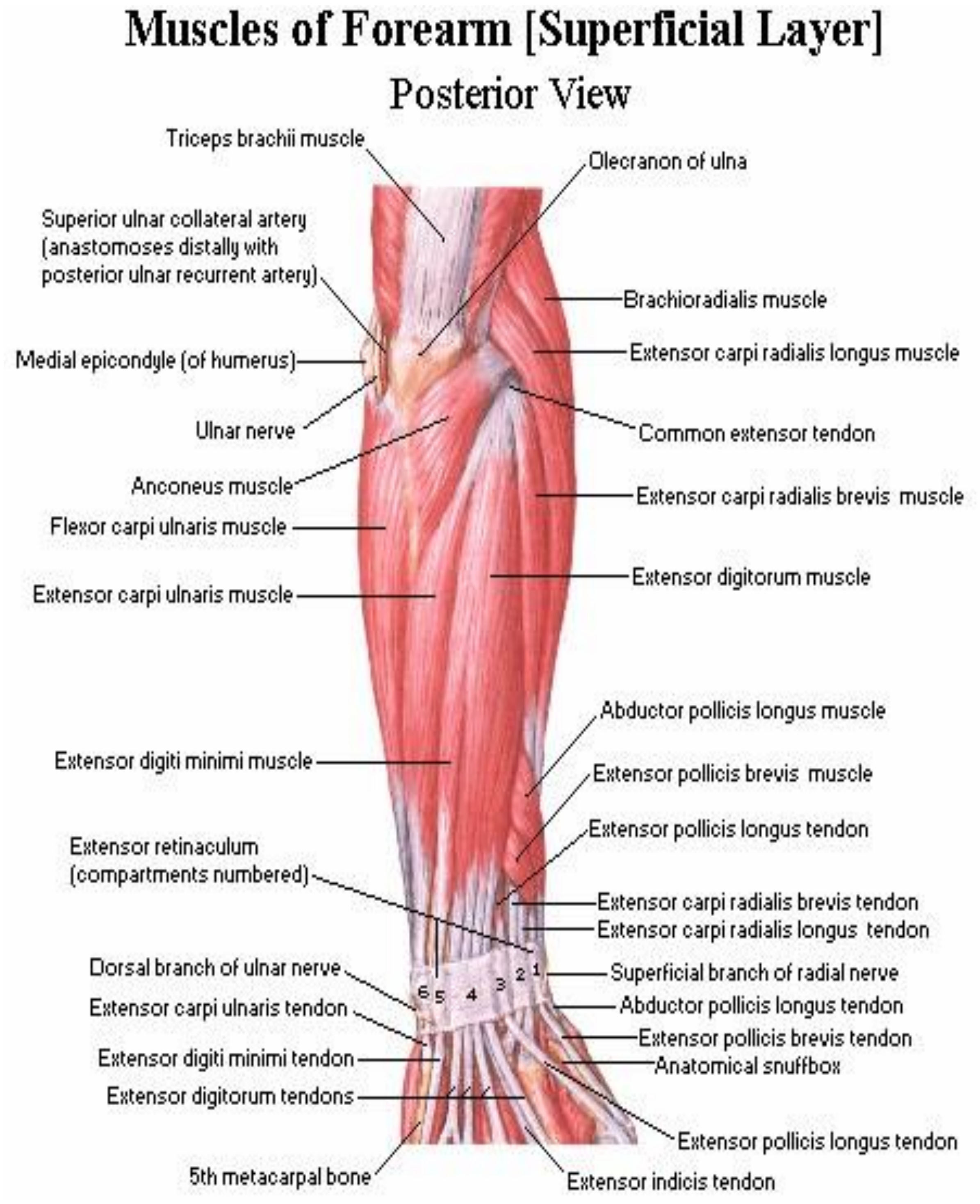


Fig:6 Muscles Of Forearm Superficial Layer (Posterior)

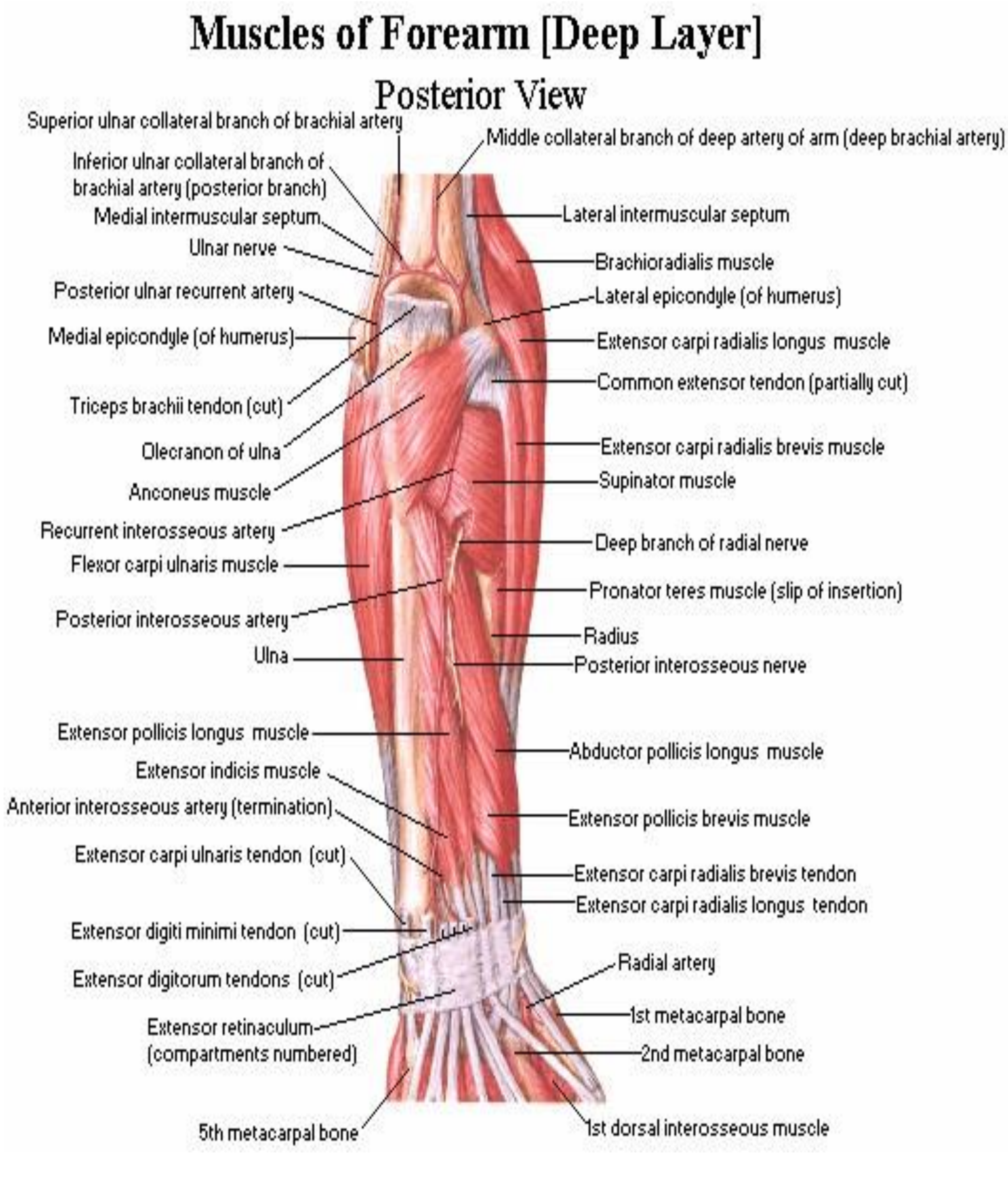


Fig :7 Muscles Of Forearm Deep Layer (Posterior)

BIOMECHANICS OF FOREARM:

Ulna is relatively straight bone, but the radius is much more complex. The ulna is a fixed strut around which the radius rotates in pronation and supination. The complexity of the angles and curves in the radius has to be maintained, especially the lateral bow of the radius, for restoration of full supination and pronation[33]

MECHANISM OF INJURY[33]

The mechanism of injury that cause fractures of radius and ulna are myriad. By far the most common is high speed vehicular trauma.

1. Direct violence:

Automobile and motorcycle accidents result in some type of direct blow to the forearm; other causes include fights in which one of the is striking on the forearm with a stick. Gun shot wounds can also cause fracture of both bones of forearm.

2. Indirect violence:

Fall on an outstretched hand results in most of these fractures. Most Forearm shaft fracture resulting from fall occurs in athletes and in fall from heights.

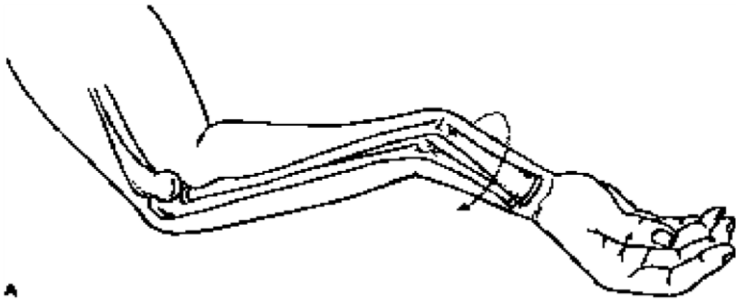


Fig:8 Deformity In Forced Supination

Forced supination of the forearm produces a fracture pattern with apex volar angulation in addition to dorsal displacement with supination of the distal fragment.

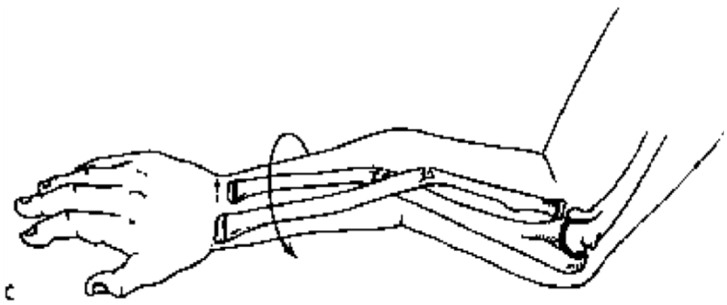


Fig:9 Deformity In Forced Pronation

Forced pronation of the forearm can result in a fracture pattern with apex dorsal angulation, in addition to pronation and volar displacement of the distal fragment.[25]

DISPLACEMENTS[34]:

Myriad displacements occur in fracture of both bones of forearm. The muscle groups acting across the forearm cause complex deforming forces when fractures are present. The radius and the ulna are connected to each other by three muscles viz. ,the supinator ,pronator quardratus and pronator teres. In addition to their name functions, when there is fracture, these muscles tend to approximate the radius and ulna by decreasing the interosseous space.

In fracture of the upper radius, below the insertion of supinator and above the insertion of pronator teres, two strong muscles (biceps and supinator exert an unopposed force that supinates the proximal radial fragment and the distal fragment gets pronated because of pronator teres and quadratus[34].

In the fracture of the radius located distal to the pronator teres, the combined forces of biceps and supinator is somewhat neutralized on proximal fragment by the pronator teres and the proximal fragment assumes mid prone position[35].

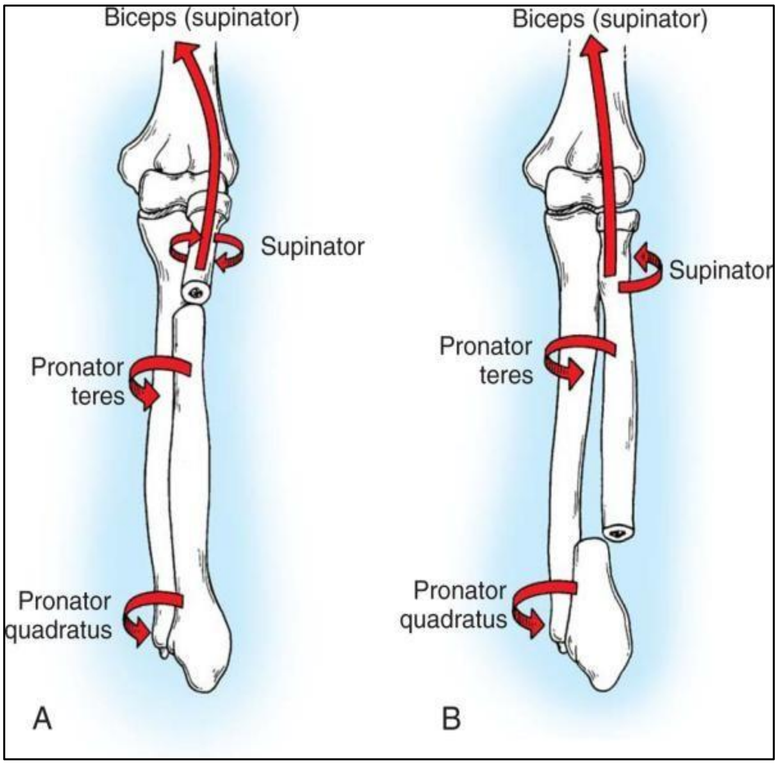


Fig :10 DISPLACEMENT

In fracture of distal third radius, the distal fragment is pronated because of pronator quadratus. Hence in closed treatment of fracture both bones forearm, immobilization in desired position is mandatory. For upper third fractures of radius, the forearm is to be immobilized in supination. For middle third and for distal third forearm in mid pronation. These immobilization positions help in satisfactory union and good functionalresults[35].The anatomical restoration of the double bow of the radius must be maintained to achieve normal pronation and supination. Bone healing of both radius and ulna is slow because of small contact surfaces at the fracture site and is the reason why stable fixation of fragments is very important.

Intramedullary nailing straightens the radius with loss of curvatures leading to cross union. Hence plating is considered to be the treatment of choice in forearm fractures[36].

The rotational alignment of the forearm is difficult to determine in the ordinary antero-posterior and lateral X-ray. The " Bicipital tuberosity view “recommended by Evans is helpful[21] ,because the surgeon has no hold on the proximal fragment, the distal radial fragment has to be brought into correct relationship with the proximal fragment. Ascertaining the rotation of the proximal fragment from the Evans tuberosity view before reduction, gives some idea of how much pronation or supination has to be done. The tuberosity view is made with the X-ray tube tilted 20 deg towards the olecranon, with the subcutaneous border of ulna flat on the cassette. The X-ray can be compared with serial diagrams showing the prominence in supination. As an alternative, a film of the opposite elbow can be taken at a given degree of rotation for comparison. In this method full supination is referred to as 180 deg and mid position 90 deg and full pronation as 0 deg

Since the normal range of pronation is by the radius crossing over the ulna and compressing the deep flexor muscles between the two bones, anything encroaching upon this space such as fibrous tissue, callus, edema or haemorrhage will alter the compressibility of the flexor muscles and limit pronation. It is therefore expected that in all the fractures of mid third radius/ulna some loss of pronation will occur and will last for a considerable time after union has occurred. Assessment of other factor limiting rotation is therefore based on measurements of supination rather than pronation[38].

The usual deformities encountered are rotation, angulation and overriding. Associated comminution may also be seen. Care must be taken to include the elbow and wrist joint radiographs to ascertain any associated dislocation or articular fractures.

However, because closed reduction is considered somewhat demanding and unpredictable, most orthopaedic surgeons prefer open reduction and internal fixation for fractures of both bones of forearm.

CLASSIFICATION OF THE DIAPHYSEAL FRACTURES OF BOTH BONE FOREARM

The AO classification has broadly classified into 3 types:

Type A- the simple fractures.

Type B-wedge fractures

Type C-Complex fractures.

The subtypes of these fractures are shown in the figure below.

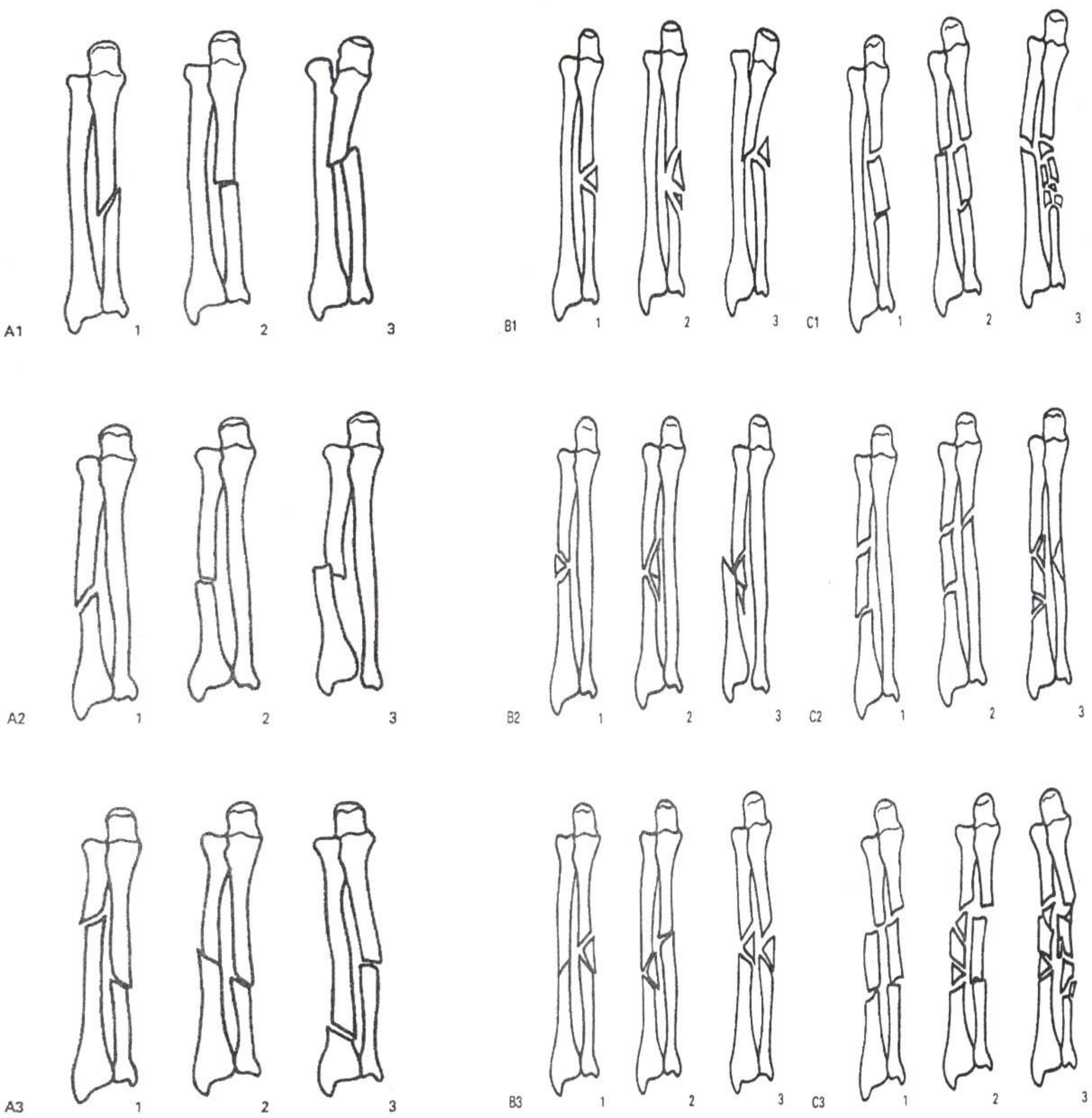


Fig:11 AO/OTA classification of the fracture of the diaphysis of the radius and ulna

Group A1: **Simple fracture of the ulna, radius intact**

A1.1 oblique

A1.2 transverse

A1.3 with dislocation of the radial head (Monteggia)

Group A2: **Simple fracture of the radius, ulna intact**

A2.1 oblique

A2.2 transverse

A2.3 with dislocation of distal radio ulnar joint (Galeazzi)

Group A3: **Simple fracture of both bones**

A3.1 radius proximal zone

A3.2 radius middle zone

A3.3 radius distal zone

Group B1: **Wedge fracture of the ulna, radius intact**

B1.1 intact wedge

B1.2 fragmented wedge

B1.3 with dislocation of distal radio ulnar joint (Galeazzi)

Group B2: **Wedge fracture of the radius, ulna intact**

B2.1 intact wedge

B2.2 fragmented wedge

B2.3 with dislocation of distal radio ulnar joint

Group B3: **Wedge fracture of one bone, simple or wedge fracture of other**

B3.1 ulnar wedge, simple fracture of the radius

B3.2 radial wedge, simple fracture of the ulna

B3.3 radial and ulnar wedges

Group C1: **Complex fracture of the ulna**

C1 ulna complex, radius simple

Group C2: **Complex fracture of the radius**

C2 radius complex ,ulna simple

Group C3: **Complex fracture of both bones**

C3.1 bifocal

C3.2 bifocal of one , irregular of other

C3.3 irregular

Orthopaedic trauma association (OTA) system for the fracture configuration

Type 1) Linear fractures:

Transverse

Oblique

Spiral

2) Comminuted fractures:

Comminuted – less than 50%

Comminuted – more than 50%

Butterfly – less than50%

Butterfly – more than50%

3) Segmental fractures:

Two levels

Three levels or more

Longitudinal split

Segmental comminuted fracture

4) Fracture with bone loss:

Bone loss less than 50%

Bone loss more than 50%

Complete bone loss.

TREATMENT

The orthopaedician has a variety of options for treating the patient with fracture of both bones of the forearm. They are cast immobilization, intramedullary nailing, external fixation and plate fixation. Conservative treatment of fracture both bones of forearm have met with poor functional outcome. The role of intramedullary nailing of forearm Fractures is very limited in adults. It is fair to say that the vast majority of Fractures of both bones of forearm can be most effectively treated by accurate anatomic reduction, rigid plate fixation and early mobilization of the softtissues[33].

Indications for open reduction of fractures of the shafts of the radius and Ulna[33].

1. All displaced fractures of radius and ulna in adults.
2. All isolated displaced fractures of the radius.
3. Isolated fractures of the ulna with angulation greater than 10°.
4. All monteggia fractures
5. All Galeazzi fractures
6. Fractures associated with compartment syndrome, regardless of the degree of displacement.
7. Multiple fractures in the same extremity.
8. Pathologic fractures.

APPROACHES TO THE RADIUS[39] :

ANTERIOR APPROACH: (Volar Henry’s approach)

It offers an excellent, safe exposure of the radius, uncovering the entirelength of the bone. The approach was first described by Henry, and his nameusually is associated with it.

Position of the patient:

Patient in supine position on the operating table, with the arm on thearm board. Place a tourniquet on the arm and finally supinate the forearm.

Land marks:

Biceps tendon, brachioradialis muscle and styloid process of the radius.

Incision:

Make a straight incision from the anterior flexor crease of the elbow justlateral to the biceps tendon down to the styloid process of the radius. Thelength of incision depends on the amount of bone that needs to be exposed.

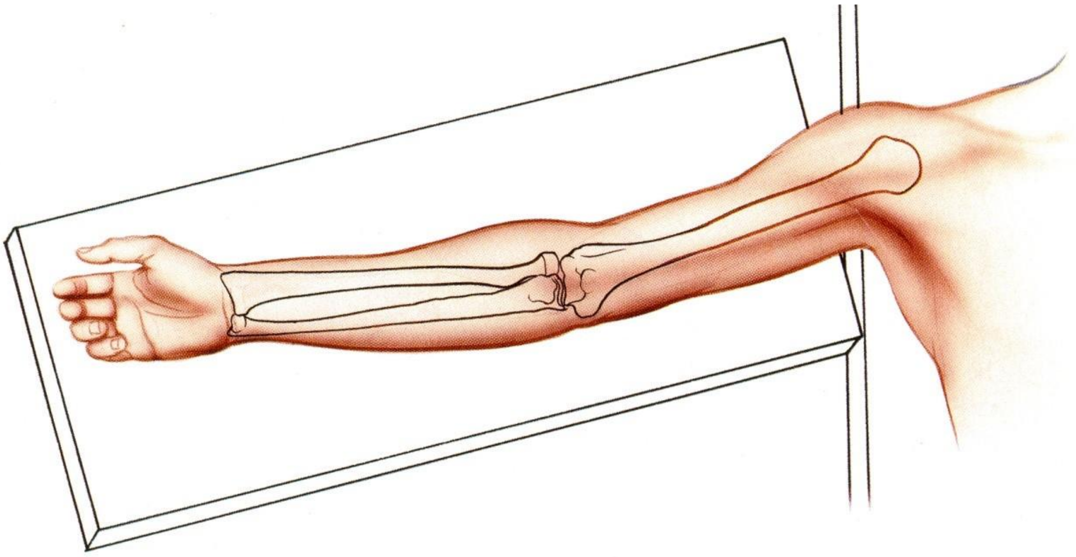


Fig:12 Position of the patient in supine position of the patient on table

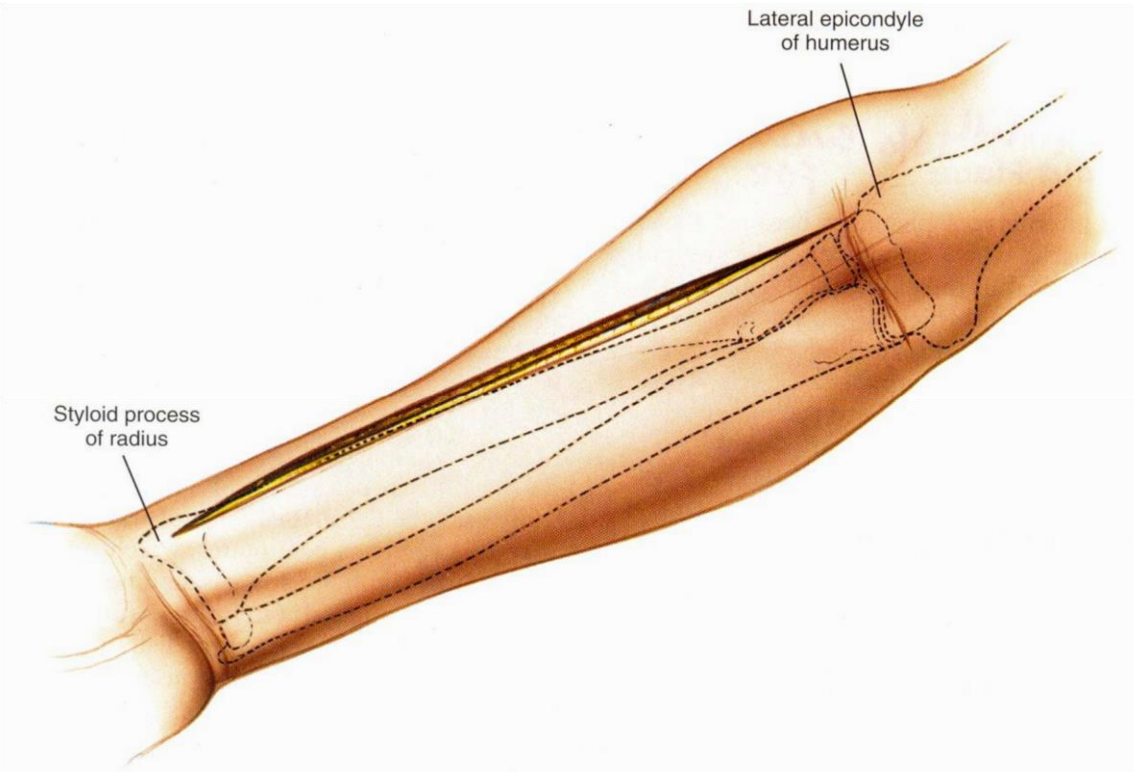


Fig:12 Straight incision on the anterior part of the forearm, from the flexor crease on the lateral side of the biceps down to the styloid process of the radius.

Internervous plane:

Proximally: Brachioradialis muscle (radial nerve) and pronator teres (median nerve)

Distally: Brachioradialis muscle (radial nerve) and Flexor carpi radialis muscle (median nerve)

Superficial surgical dissection:

After developing the plane, identify the superficial radial nerve running on the undersurface of the brachioradialis and moving with it. The radial artery lies beneath the brachioradialis in the middle part of forearm, the artery may have to be mobilized and retracted medially to achieve adequate exposure. Preserve the superficial radial nerve, which is a sensory nerve, also runs undercover of the brachioradialis.

Deep surgical dissection:

Proximal third: The proximal third of the radius is covered by the supinator muscle, through which the posterior interosseous nerve passes on its way to the posterior compartment of the forearm. The posterior interosseous nerve is vulnerable by this approach, hence fully pronate the forearm and perform subperiosteal dissection.

Middle third: To reach anterior surface of the bone, covered by pronator teresand flexor digitorum superficialis, pronate the arm so that the insertion of pronator teres onto the lateral aspect of the radius is exposed. Detach this insertion and strip the muscle off.

Distal third: To reach the bone, partially supinate the forearm and incise the periosteum of the lateral aspect of the radius lateral to the pronator quadratus and flexor pollicis longus. Continue the dissection sub-periosteal lifting them off the radius.

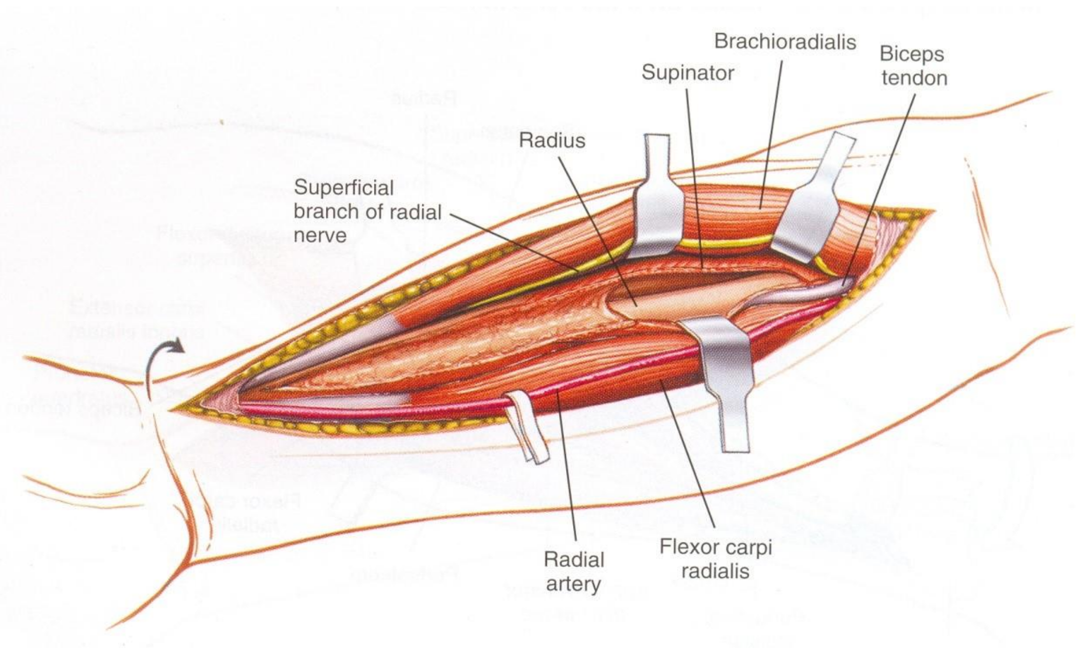


Fig:13 Exposure of the radius from proximal to distal end

Dangers:

Nerves:

- The posterior interosseous nerve
- The superficial radial nerve.

Vessels:

- The radial artery.
- The recurrent radial arteries - leash of vessels that arise from radial Artery just below the elbow joint.

POSTERIOR APPROACH TO THE RADIUS[39]: (Thompson approach)

It provides good access to the entire dorsal aspect of the radial shaft. It is named after "Thompson" hence dorsal Thompson approach to radius.

Position: Patient supine on operating table with arm on the arm board. Pronatethe patient's forearm to expose the extensor compartment.

Landmarks: Lateral epicondyle of the humerus, Lister's tubercle.

Incision: Make either straight or gently curved incision, extending from a point anterior to lateral epicondyle of the humerus to a point just distal to ulnar side of the Lister's tubercle at the wrist.

Internervous plane:

Proximally: Extensor carpi radialis brevis (Radial nerve) and Extensor digitorum communis (Posterior interosseous nerve)

Distally:

Extensor carpi radialis brevis (Radial nerve) and

Extensor pollicis longus muscle (Posterior interosseous nerve)

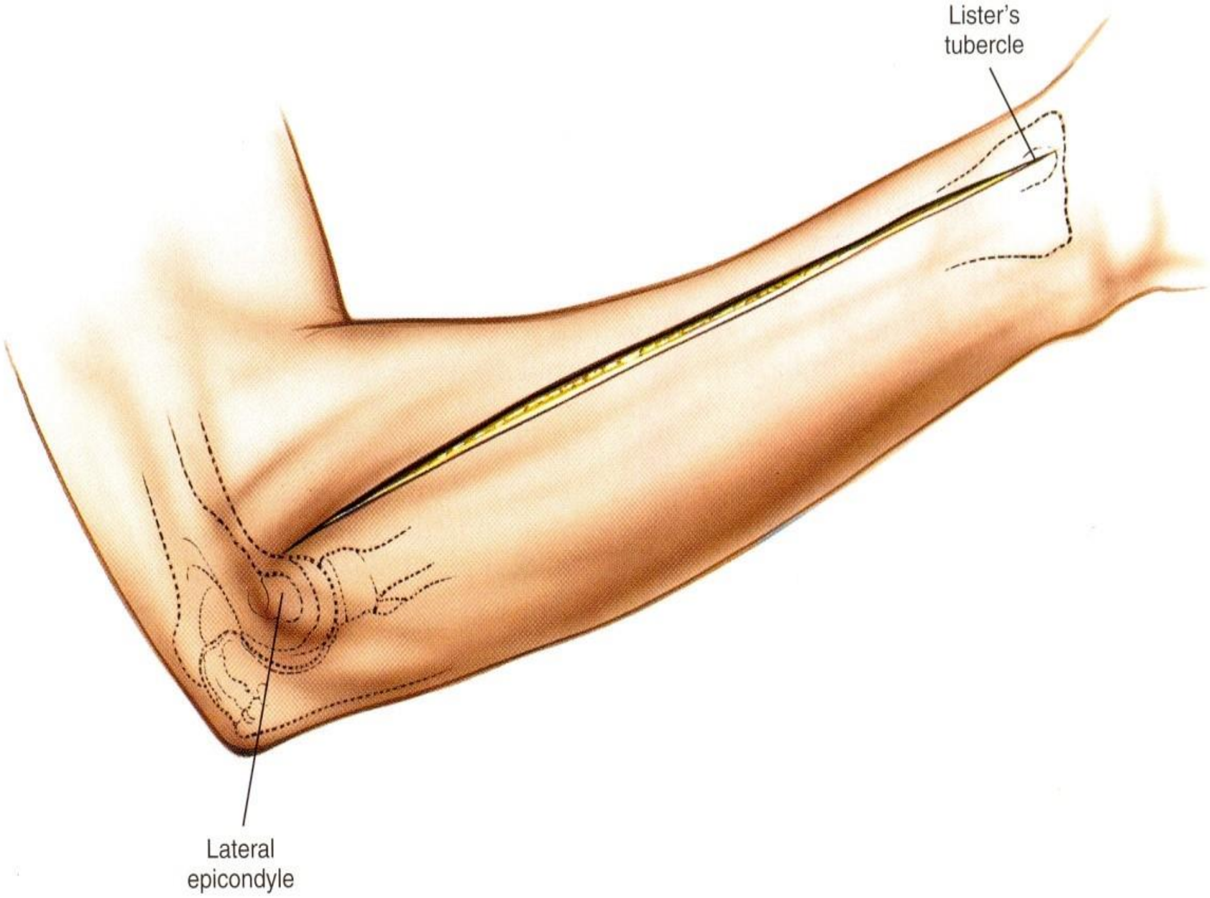


Fig:14 Posterior Thompson's approach to the radius

Superficial surgical dissection: Incise the deep fascia of the forearm in line with the skin incision. Identify the medial border of the brachioradialis, develop a plane between it and the flexor carpi radialis distally. The brachioradialis mobilized and retracted laterally. The radial artery and flexor carpi radialis medially.

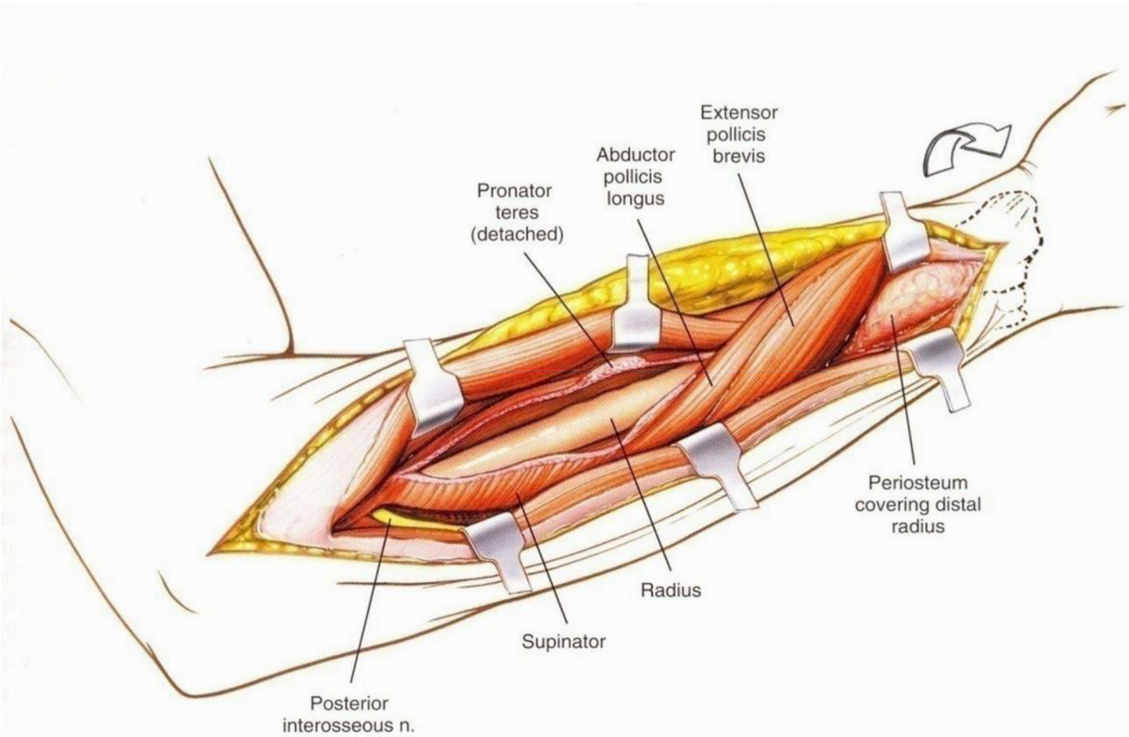


Fig:15 Exposure of the radius from posterior approach

Deep surgical dissection:

Proximal third: The supinator muscle cloaks the dorsal aspect of the upper third of the radius; the posterior interosseous nerve runs within its substance between the superficial and deep heads. Care should be taken not to injure the posterior interosseous nerve. Identify the nerve and fully supinate the arm to bring the anterior surface of radius into view. Detach the insertion of the supinator muscle from anterior aspect of the radius. Strip the supinator off the bone subperiosteally to expose the proximal third of the shaft of the radius.

Middle third: Two muscles, the abductor pollicis longus and the extensor pollicis brevis, blanket this approach as they cross the dorsal aspect of the radius before heading distally and radially across the middle third of the radius. Make an incision along their superior and inferior borders, and then retract them off the bone.

Distal third: Separating the extensor carpi radialis brevis from extensor Pollicis longus has already led directly onto the lateral border of the radius, subperiosteal dissection leads to dorsal aspect of the bone.

Dangers:

Posterior interosseous nerve identifying and preserving the nerve in the supinator muscle is the only means of ensuring that it will not be trapped beneath the plate.

APPROACH TO ULNA[39]:

Exposing the shaft of ulna is the simplest of all forearm approaches, uncovering the entire length of the bone.

Position: Place the patient in supine position on the operating table with the arm placed across the chest to expose the subcutaneous border of the ulna.

Landmarks: Subcutaneous border of ulna. Incision: Linear, longitudinal incision over the subcutaneous border of the ulna.

Inter-nervous plane: Extensor carpi ulnaris (posterior interosseous nerve) and Flexor carpi ulnaris (ulnar nerve).

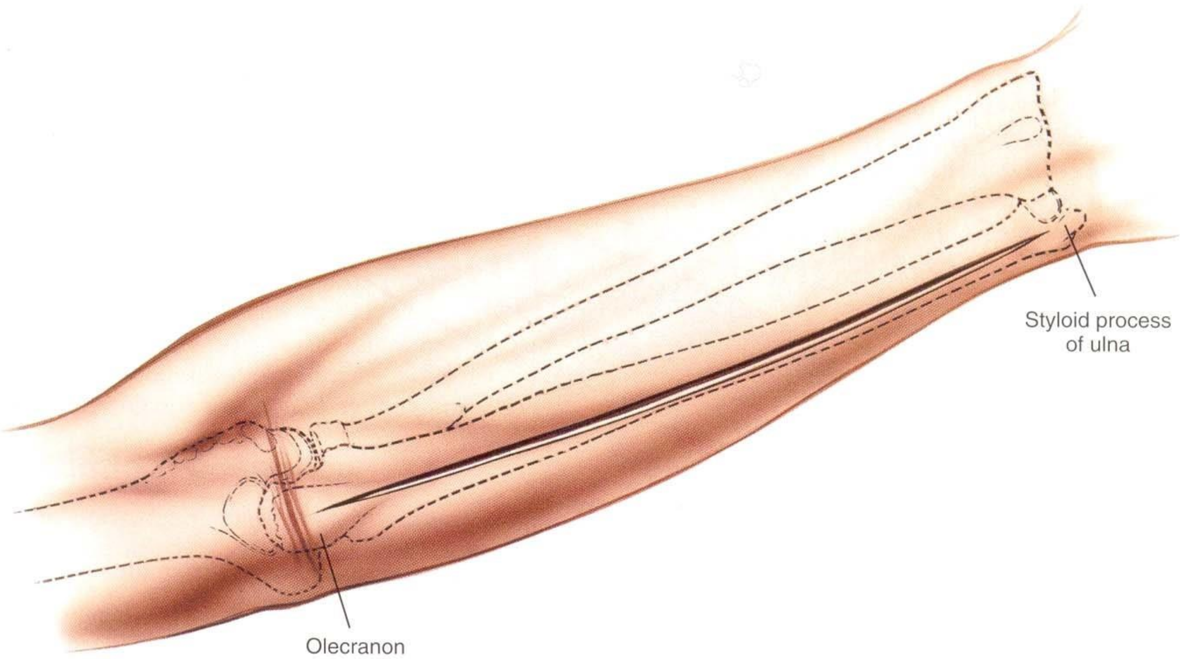


Fig:16 Incision for ulnar exposure over the subcutaneous border of the ulna

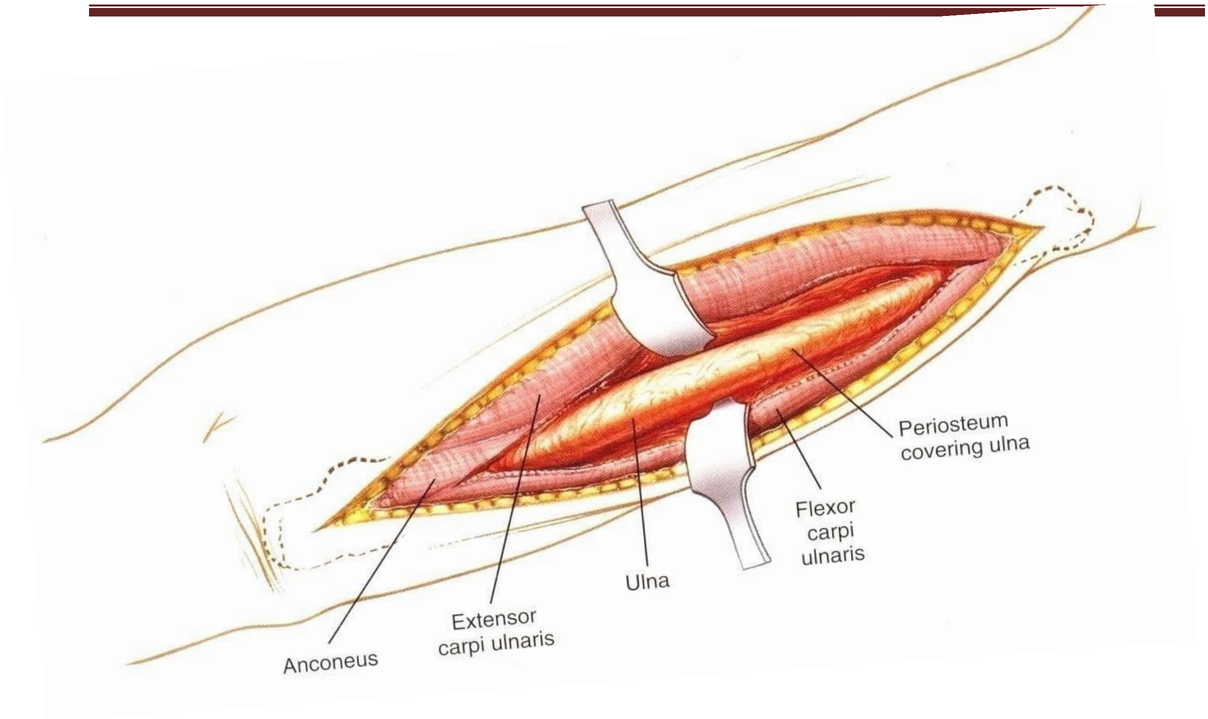


Fig:17 Exposure of the entire posterior length of the ulna

Surgical dissection:

Incise down the subcutaneous border of ulna. Even though the bone feels subcutaneous in its middle third, the fibers of Extensor carpi ulnaris muscle nearly always have to be divided to reach the bone.

Incise the periosteum over the ulna longitudinally and dissect around the bone in a subperiostal plane to reveal either the flexor or the extensor aspects of the bone as needed.

Dangers: Ulnar nerve, which travels down the forearm under the flexor carpi ulnaris, lies on the flexor digitorum profundus. The nerve is safe as long as the flexor carpi ulnaris is stripped off the ulna subperiosteally. Nerve is most vulnerable in its proximal dissections.

Vessels: The ulnar artery travels down the forearm with the ulnar nerve, lying on its radial side. Hence, it is vulnerable while dissecting the flexor carpi ulnaris.

COMPICATIONS

Infection:

Despite all attempts to prevent infection, some open fractures and closed fractures treated by open reduction inevitably become infected. If infected, care should be taken to combat infection by either appropriate antibiotics or debridement. The principle of the treatment is that union of the fracture must be obtained even in presence of the infection[33].

Nerve injury:

They are uncommon in closed fracture of forearm bones. They are more common in major compound wounds with extensive soft tissue loss. Posterior interosseous nerve is at danger during dorsal (Thompson) approach to proximal radius[33].

Vascular injury:

The viability of the forearm and hand is not in jeopardy, if either the radial or the ulnar artery is functioning. Radial artery poses a threat when radius is approached anteriorly. It is rare to have both radial and ulnar artery getting lacerated except in open fractures[33].

Compartment syndrome:

This can occur either after trauma or after surgery on the forearm bones. They are usually due to faulty hemostasis or closure of the deep fascia. They can usually be avoided by releasing the tourniquet before wound closure to make sure hemostasis is adequate, by closing only the subcutaneous tissue and skin, and by using suction drains[33].

Radio ulnar synostosis:

Seen frequently in patients with either a crushing injury of forearm or ahead injury. The highest risk for synostosis is in proximal fractures treated through single incision.

Excision of the synostosis, obliteration of the dead space with muscle, prevention of hematoma formation and early mobilization are the goals in the treatment of synostosis[33].

Muscle and tendon entrapment and adherence:

Muscle tendon units get trapped between or adherent to the forearm bones following fracture. They can restrict the motion of fingers, thumb, or wrist. Release of entrapped muscle belly can result in return of full active finger motion[33].

Mal union:

Fracture both bones forearm results in mal union if neglected and can be corrected by corrective osteotomy.

Non union:

They appear to have been caused by infection or errors in technique. Accurate open reduction and rigid internal fixation will prevent these complications.

Soft tissue contracture:

Contracture of the interosseous membrane, proximal radio ulnar joint, or Distal radio ulnar joint either in isolation or combination will result in significant loss of forearm rotation. Prevention of contracture is achieved by rigid fixation and early motion[33].

PLATES

Plates are devices fastened to bone for the purpose of providing fixation. They provide anatomical fracture reduction and stable fixation. Regardless of their length, thickness, geometry, configuration/type of holes, all plates are classified into four groups[4].

1. **Neutralization plate:** It acts as a bridge, transmitting various forces from one end of the bone to the other, bypassing the area of fracture. A plate used in combination with a lag screw is also a neutralization plate.

2. **Compression plate:** The plate produces a locking force across a fracture site to which it is applied. The effect occurs according to Newton's third law. The bone under compression will have superior stability, improved milieu for bone healing and early mobilization. Compression will result in

a) Compaction of the fracture to force together the inter digitation spicules of bone and increase the stability of the construct.

b) Reduction of the space between the bone fragments to decrease the gap to be bridged by the new bone.

c) Protection of the blood supply through enhanced fracture stability

d) resists the tendency of the fragments to slide under torsion or shear.

3. **Buttress plate:** As the name suggests, is to strengthen (buttress) a weakened area of cortex. The plate prevents the bone from collapsing during the healing process. It has a large surface area which facilitates wider distribution of load.

4. **Condylar plate**: It has been used in the treatment of intra articular distal femoral fractures. It maintains the reduction of the major intra articular fragments, hence restoring the anatomy of the joint surface. It also rigidly fixes the metaphyseal components to the diaphyseal shaft, permitting early movement of the extremity. This plate functions as both neutralization and buttressing.

Short coming of the DCP[17]

1. Flat under surface:

The extensive contact of the undersurface of the plate with bone leads to major interference with periosteal blood supply and plate induced osteoporosis. Following plate removal from the bone, there is a notch in the bones, which behaves as a stress riser and induces or facilitate a refracture.

2. Inclination of screw hole:

The geometry of DCP hole allows the screw to be tilted about 25 deg in longitudinal axis. This has led in difficulties to lag oblique fractures through the plate.

3. Distribution of plate holes:

The conventional round hole plates has an extended middle segment without holes. This middle segment has led to difficulties when a fracture with a zone of fragmentation has to be stabilized. Once the position of the plate is chosen and the first hole drilled, because of the middle segment it becomes impossible to shift the plate in the long axis of the bone. When plate bridges a defect in the bone diaphysis, a fatigue fracture can occur because stress, due to cyclic weight bearing and torsion loads, becomes concentrated at the exposed plate holes.

4. Asymmetry of plates holes:

Symmetric plate holes allow compression in both directions. The plate hole of DCP is asymmetric: the self compressing part of the plate hole is located at end of the plate hole away from fracture.

5. Fragile lining:

Plates with rectangular cross section provoke the formation of a comparatively thin bony wall along the length of the plate. If the ridges so formed are thin they are easily nicked at the time of the plate removal. This not only renders the bone less strong but may also act as a stress riser and contributes to failure.

Solution to the problem of DCP[17]:

The LC-DCP is further development of DCP having improved design offering the following advantages.

Structured under surface:

A groove in the undersurface of plates significantly improves the blood supply of the plated bony segment. As a corollary to the improvement in the periosteal blood supply and cortical blood supply the osteoporosis which was said to have been result of the so called "stress shielding" has disappeared. Grooves under surface of the plate allow for the formation of a small amount of callus in the most critical area. A small bridge of callus in this "critical zone “greatly adds to the strength of the bone.

UNDERCUT SCREW HOLES

Undercut at each end of the plate hole allows 40deg tilting of the screws both ways along the long axis of the plate. Lag screw fixation of short oblique fractures is thereby possible. Screws can be tilted +\- 7deg in the transverse plane. Furthermore, the undercuts reduce the contact area between plate and bone even more.

The LC-DCP screw hole is made of two inclined and one horizontal Cylinder meeting at the same angle and permits compression at the both ends.

UNIFORM SPACING OF HOLES

The uniform spacing of the screw holes and the elimination of the middle segment allow for the easy shifting of the plates in the long axis as well as easy changes in the plate length. The enlarged cross section at the plate holes and reduced cross section between holes offer a constant degree of stiffness along the long axis of the plate. No stress concentration occurs at the holes when the plate is exposed to a bending load or during the contouring. The constant distribution of the stiffness along the plate offers advantages with respect to avoiding failure.

TRAPEZOID CROSS SECTION

The trapezoid cross section of the plate with the smaller surface in contact with the bone has resulted in the formation of the lower and broader ridges of bone along the length of the plates. Such ridges are less likely to be injured at the time of plate removal.

ADDITONAL NEW COMPRESSING PRINCIPAL

A basic spherical gliding principal of the screw within the screw hole of the DCP has been preserved, but the screw hole has been redesigned so that this feature is present at both ends of the hole. This improves the versatility of the plate when complex fractures are being fixed. The holes allow 1.0 mm displacement of the fragment if a load screw is inserted.

THE AVOIDANCE OF BONE DAMAGE AND IMPROVEMENTS IN COMPRESSION

Whenever a lag screw is passed through a DCP screw hole to lag Fracture , it is subjected to a transitional force, which tends to shift the screw head towards the buttress position as the screw is tightened. This may give risk to one of the complication:

i. Either the screw head or thread may abut against the inner wall of the plate hole.

ii. Thread of the screw may bite on one side into the wall of the sliding hole which may reduce the large defect by as much as 37%. The use of an elongated and undercut screw hole avoids these complications.

TITANIUM

This is known to be biological exceptionally inert and therefore it is well tolerated as an implant material. Before the application of the LC-DCP, the plate has to be contoured / prebent and the fracture is anatomically reduced. The LC-DCP 3.5mm is fixed to the bone with 3.5mm cortical screws. The screw can be inserted into different positions; neutral, load, and buttress. For this purpose special drill guides have to be used the LC-DCP drill guide 3.5 mm or the universal drill guide, 3.5mm.

THE LC-DCP DRILL GUIDES

The 3.5 mm LC-DCP drill guides will be similar to the DCP drill guide; it has neutral (green) and a load (yellow) guide combined on a handle. The inserts will only fit this special handle, which has been designed with the same undercut plate to distinguish it from the DCP guide handle. The neutral guide places the screw in a neutral position if the arrow points towards the fracture. Turned 180 deg, the arrow pointing away from the fracture, the buttress position is obtained. The (yellow) load guide places the screw in an eccentric position for the compression. When the arrow points towards the fracture, the displacements is 1.0 mm.

Because of the spherical end of the guides, they have a congruent fit in the plate hole; also can be tilted 40deg in the longitudinal end +/- 7deg in the transverse plane.

The LC-DCP universal drill guide 3.5mm has two different sleeves combined on a handle. The two sleeves are pre loaded by a spring in such away that the inner sleeve protrudes at the tip, by applying pressure the inner sleeve pushed back into the outer sleeve. When the sleeve is placed in the plate hole and pressure is applied the rounded ends of the outer sleeve follows the inclined "cylinder" of the plate hole to neutral position. The load position is obtained by placing, protruding inner sleeve in the far end (away from the fracture) of the plate hole. Similarity, the buttress position is obtained when this sleeve is placed in the end of the plate hole nearer the fractures.

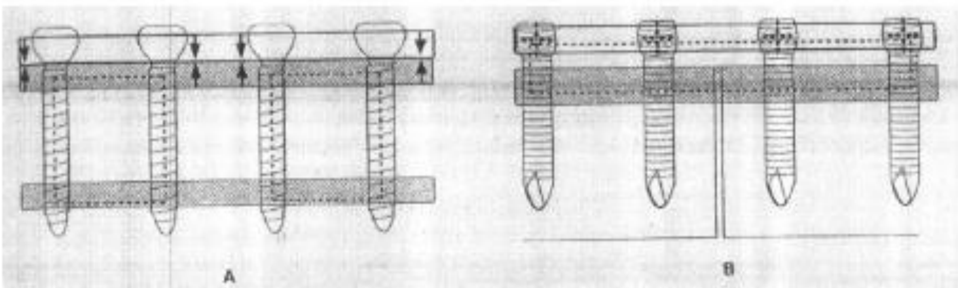
2.1nternal fixator [LCP]

The concept of internal fixators was devised by a group of Polish surgeons. Principles they used to design the implants were

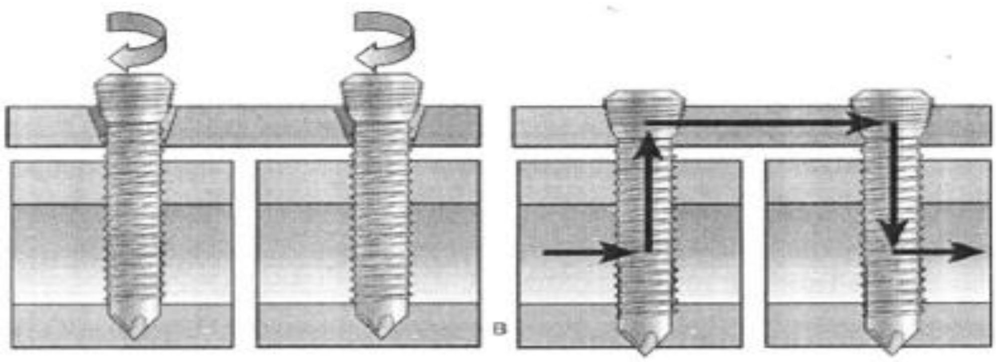
- The screws should be fixed to the plate
- Compression b/w the plate & bone should be eliminated.
- The number of screws necessary for stable fixation should be reduced.
- Plate stability &inter fragmentary compression should be preserved.

The new technology is more closely related to concept of pure splinting. The function of screws in internal fixator is more akin to that of external fixator pins.

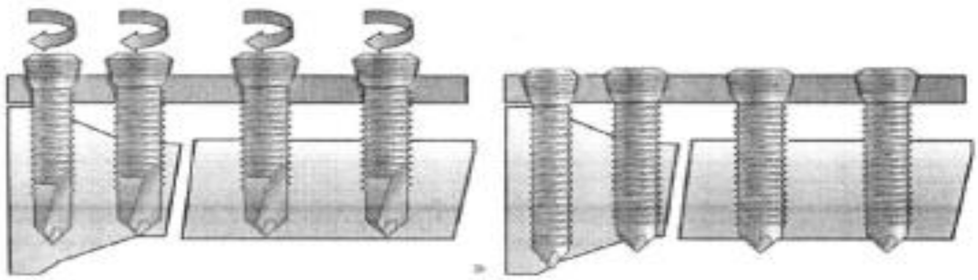
1. The basic principle of the internal fixator is its angular stability, whereas stability of conventional plate osteosynthesis relies on friction caused by compression between the bone & the plate. In contrast the principle of fixation of angular stable devices is screw locking. Compression between bone and plate is a voided, thereby biological integrity of periosteum is maintained.



2. Friction transfers load tangentially between the implant surface and bone in DCP, while in LCP the screws with threaded head acts as a peg connecting the splint to bone.



3. Precise contouring of the fixator is not necessary, where as screw tightening in poorly contoured conventional plates causes fracture mal-alignment the internal fixator holds the fragments in position. This feature makes the internal fixator ideal for MIPO.



4. Locking of the screws in the locked internal fixator plate (LIFP) and the very close proximity of the plate to the bone allows for the use of mono cortical screws. Damage to the intramedullary blood vessels by the application of conventional bi-cortical screws is eliminated by the use of mono cortical screws.

Locking Compression Plates- features

The Locking Compression Plates (LCP) have these LC-DCP features:

• 50 deg of longitudinal screw angulation

• 14 deg of transverse screw angulation

• Uniform hole spacing

• Load (compression) & neutral screw positions

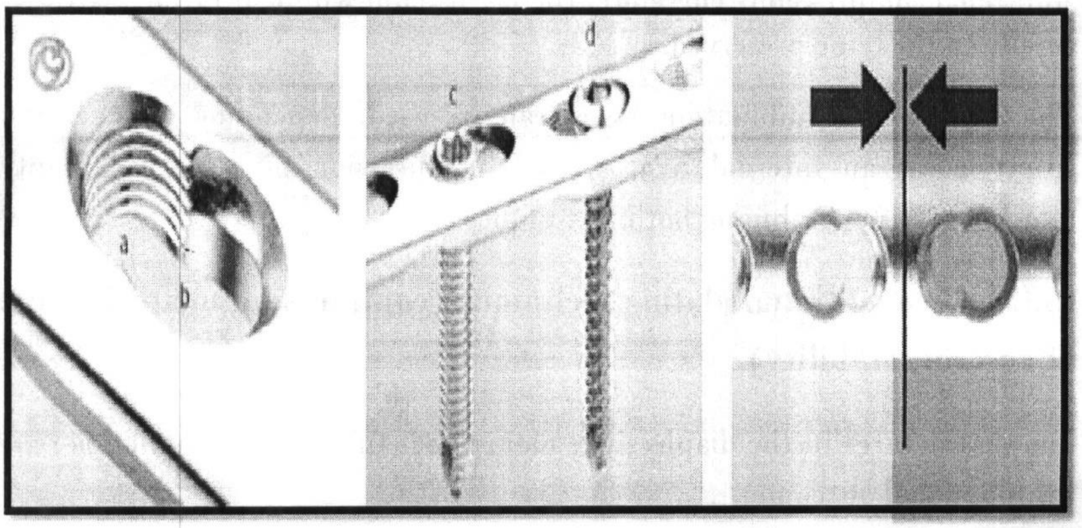
The most promising idea to compensate was to merge a DCU (dynamic compression unit) hole geometry of the DCP & LC-DCP with the conical threaded hole of the PC-fix II & less invasive stabilization system(LISS), the result being the so called combi hole.

The locking & compression holes allow placement of conventional cortex &cancellous bone screws on one side or threaded conical locking screws on the opposite side of each hole.

A. Threaded hole section for locking screws

B. DCU hole section for conventional screws

The locking head screw is captured in the threaded part of the Combi hole& provides angular & axial stability.



FIXATION PRINCIPLES

Bridge/Locked Plating Using Locking Screws

• Screws lock to the plate, forming a fixed-angle construct.

• Bone healing is achieved indirectly by callus formation when using locking screws exclusively.

Maintenance of primary reduction

Once the locking screws engage the plate, no further tightening is possible. Therefore, the implant locks the bone segments in their relative positions regardless of degree of reduction.Precontouring the plate minimizes the gap between the plate & the bone, but an exact fit is not necessary for implant stability. This feature is especially advantageous in minimally or less invasive plating techniques because these techniques do not allow exact contouring of the plate to the bone surface.

Stability under load

By locking the screws to the plate, the axial force is transmitted over the length of the plate. The risk of a secondary loss of the intraoperative reduction is reduced.

Blood supply to the bone-Locking the screw into the plate does not generate additional compression. Therefore, the periosteum will be protected & the blood supply to the bone preserved.

The LCP with combination holes can be used, depending on the fracture situation, as an internal fixator, as a compression plate or as an internal fixation system combining both techniques.

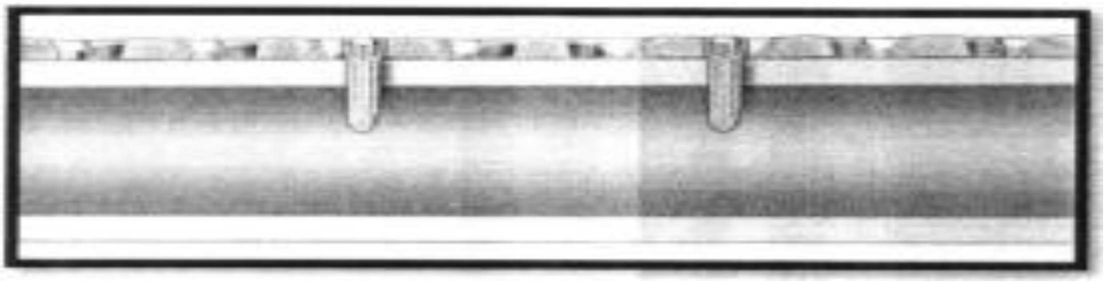
I) LCP a conventional plating technique (compression method, principle of absolute stability).

- Simple fractures in the diaphysis & metaphysis (if precise reduction is required for functional outcome).
- Articular fractures
- Delayed or non-union.
- Closed wedge osteotomies.

The operative technique is much same as conventional plating. In case of good bone quality, additional screws can be regular cortical screws, giving stability by increasing fixation between plate & the bone. Three bi-cortical conventional screws on each side of fracture are effective. In osteoporotic bone stability is increased by using locking head screws.

II. LCP in a MIPO technique (internal fixator method, principle of relative stability)

- Multi fragmentary fractures in diaphysis & metaphysis
- Simple fractures in metaphysis & diaphysis
- Open-wedge osteotomies
- Periprosthetic fractures
- Secondary fractures after intramedullary nailing.



In bones of good quality, the use of unicortical locking head screws is sufficient. However atleast 3 screws must be inserted on either side of fracture in each main fragment.

In osteoporotic fractures, use of locking screws in strongly recommended with atleast 3 screws in each manifestation, on either side of fracture, of which at least one must be inserted bio-cortically.

III. LCP in a combination of both methods (compression method & internal fixator method)

Articular fracture with a multifragmentary fracture extension into the diaphysis: anatomical reduction &interfragmentary compression of the articular component, bridging of the reconstructed joint block to the diaphysis. Segmental fracture with two different fracture patterns (one simple & one multifragmentary) conventional method & compression at simple fracture &bridging technique, internal fixator principle for multifragmentary fracture.

The term 'combination' describes the combination of two biomechanical principles i.e. use of combination of interfragmentary compression & the internal fixator method (bridging).

BIOMECHANICAL & CLINICAL BENEFITS OF LCP:

• The plate & screws form one stable system & the stability of the fracture depends on the stiffness of the construct. Locking the screw into the plate to ensure angular as well as axial stability eliminates the possibility for the screw to toggle, slide or be dislodged & thus strongly reduces the risk of postoperative loss of reduction.

- Multiple angle stable screw fixation in the epiphyseal and metaphyseal region, allows for fixation of many fractures that are not treatable with standard devices.
- Improved stability in multifragmentary, complex fractures, which have loss of medial/lateral buttress or have bone loss - double plating avoided.
- The fixed angle stability avoids subsidence of fixation in metaphyseal areas. This allows for less precise contouring of the plate, as fixation depends on plate-screw construct rather than friction between plate bone interface.
- Improved biology for healing. Fixation provided by the plate does not depend on the compression between the plate & bone but on the fixation of the screw to the plate & anchorage of the screw in the bone, the plate no longer needs to make any contact with the underlying bone. The immediate advantage of this is that there is

absolutely no interference with periosteal blood supply. Maintained bone perfusion decreases infection rate, bone resorption, delayed union, non-union & secondary loss of reduction.

- Better fixation in osteoporotic bone.
- No or less need for primary bone graft as more fractures fixed with bridging technique with elastic fixation & also because of angle stable constructs avoiding post operative collapse.

These benefits of LCP are seen especially in the following situation:

- Epiphyseal / metaphyseal fractures (short articular block, little bone mass for purchase, angular stability).
- In situations where the MIPO technique is indicated or possible, because accurate contouring of the plate is not mandatory.
- Fractures with severe soft tissue injuries.
- Fractures in osteoporotic bone.

DISADVANTAGES OF LCP

1. The surgeon has no tactile feedback as to the quality of screw purchase into the bone as he tightens the screw. As the screw lock in the plate, all screws abruptly stop advancing when the threads are completely seated in the plate regardless of bone quality.
2. Current locking plate designs can be used to maintain fracture reduction but not to obtain it. The fracture must be reduced & limb

alignment, length &rotation must be set properly before placement off any locked screws. Inability of the surgeon to alter the angle of the screw within the hole &still achieve a locked screw.

3. Any attempt to contour locked plates could potentially distort the screw holes & adversely affect screw purchase.

METHODOLOGY

The present study includes treatment of 30 cases of fracture both bones of forearm by open reduction and internal fixation with 3.5 mm LCP between November 2014 to February 2016 at R.L Jalappa Hospital attached to Sri Deva Urs medical college,Tamaka,kolar-563-101

Inclusion and Exclusion criteria:

INCLUSION CRITERIA:

- Patient above the age of 18 years.
- Patients with diaphyseal fractures of both bones forearm.
- Both open and closed type fractures

EXCLUSION CRITERIA:

- Patients with diaphyseal fractures of type-III B and IIIC.
- Patients medically unfit for surgery.

On admission of the patient, a careful history was elicited from the patient and/or attendants to reveal the mechanism of injury and the severity of trauma. The patients were then assessed clinically to evaluate their general condition and the local injury.

The patient vital signs were recorded. Methodical examination was done to rule out fractures at other sites. Local examination of injured forearm revealed swelling, deformity and loss of function. Any nerve injury was looked for and noted

Palpation revealed abnormal mobility, crepitus and shortening of the forearm. Distal vascularity was assessed by radial artery pulsations, capillary filling, pallor and paraesthesia at finger tips.

Radiographs of the radius and ulna i.e., antero posterior and lateral views, were obtained. The elbow and wrist joints were included in each view.The limb was then immobilized in above elbow Plaster of Paris slab with sling. The patient was taken for surgery after routine investigations and after obtaining fitness towards surgery. The investigations are as follows: Hb%,Urine for sugar, FBS, Blood urea, Serum creatinine, HIV, HBSAg and ECG.

Proximal radius was approached by dorsal Thompson incision and volar Henry approach was used for middle and distal radius. A narrow 3.5mm LCPwas used and a minimum of 6 cortices were engaged with screw fixation in each fragment.

INSTRUMENTS AND IMPLANTS USED IN LOCKING COMPRESSION PLATING FOR FOREARM BONES:

1. Narrow 3. 5mm stainless steel LCP of varying length
2. 3. 5mm Drill sleeve for locking screws
3. 3. 5mm Drill sleeve system
4. Drill bits of 2. 7mm and 3. 5mm
5. Hand drill/Power drill
6. 3. 5mm counter sink
7. Tap for 3. 5mm cortical screw
8. Depth gauge
9. 3.5 mm locking screws
10. 3. 5mm cortical screws of varying sizes.
11. Hexagonal screw driver
12. Bending templates
13. Bending press/pliers
14. Sharp hook
15. General instruments like retractors, periosteal elevators, reduction clamps, bone levers etc.
16. Pneumatic tourniquet.

Preoperative planning:

- If evidence of compartment syndrome, surgery has to be done as soon as possible. Consent of the patient or relative was taken prior to the surgery.
- Appropriate length of the plate to be used was assessed with the help of radiographs.
- A dose of tetanus toxoid and antibiotic were given preoperatively.
- Preparation of the part was done before a day of surgery.
- The injured forearm was immobilized in above elbow POP slab during preoperative period.
- Instruments to be used were checked beforehand and sterilized.

Position:

- Pneumatic tourniquet is recommended.
- Patient supine on the operating table.
- Henry's approach-the arm is placed on an arm board with elbow straight and forearm in supination.
- Thompson approach-the arm is on the arm board, Elbow flexed and forearm in mid pronation.

Incision:

- Ulnar shaft: Parallel and slightly volar to the subcutaneous crest of the ulna.
- Radial shaft: Dorsal Thompson approach and Volar Henry's approach.

OPERATIVE PROCEDURE:

- Type of anaesthesia: General anaesthesia and brachial block
- Pneumatic tourniquet was applied: Time noted.
- Painting and draping of the part done.
- The Radius was approached using either dorsal Thompson/Volar
- Henrys approach. For proximal radius, dorsal Thompson approach was preferred and for distal radius fracture Volar Henry's approach was preferred. Ulna was approached directly over the subcutaneous border.
- The bone which was less comminuted and more stable was fixed first and later the other bone was fixed. After identifying the fracture ends, periosteum was not elevated and fracture ends were cleaned.
- With the help of reduction clamps fracture was reduced and held in position. The plate was then applied after contouring if required.

- A plate of at least 6 holes was chosen and longer plates were used in spiral, segmental and comminuted fractures.
- For upper third radial fractures, the plate was fixed dorsally. For middle third, the plate was fixed dorsolateral and for distal radial fractures the plate was fixed on the volar aspect. In ulnar fractures, plate was applied over the posterior surface of ulna.
- A drill sleeve for locking screw is fixed in the hole, near the fracture site, and 2.7 mm drill bit is use to drill both the cortex of the bone, the sleeve is removed and the screw length is measured with depth gauge.
- A 3.5 mm locking screws are then inserted, as the locking screws are of self tapping, tapping of the screw hole is not done.
- After adaptation of the fragments, a screw hole for axial compression is drilled in the fragment which forms an acute angle near the plate. Here the load guide is used with the arrow pointing towards the fracture line to be compressed. At this position, a lag screw will be inserted for axial compression.
- The lag screw is applied by subsequently over drilling (3.5mm) the near cortex to create a gliding hole. The lag screw and remaining screws are inserted.

- Once stable fixation is achieved hemostasis secured after release of tourniquet, the wound is closed with suction drain and sterile dressing is applied.

After treatment:

Postoperatively a crepe bandage was applied over the affected forearm and arm pouch was given. The patient was instructed to keep the limb elevated and move their fingers and elbow join. Wound was inspected after 3-4 days postoperatively. Antibiotics and analgesics were given to the patient till the time of suture removal. Suture/staples removed on 10th postoperative day and check X-ray in anteroposterior and lateral views were obtained.

Later patient were discharged after suture/staple removal with the forearm in arm pouch and advised to perform shoulder, elbow, wrist and finger movements. Patients were advised not to lift heavy weight or exert the affected forearm.

Follow-up:

All the patients were followed up at monthly intervals for first 6 months and evaluation was done based on "Anderson et al” scoring system. Elbow movements and wrist movements were noted and the union was assessed radiologically.

The fracture was designated as united when there was presence of periosteal callus bridging the fracture site and trabeculation extending across the fracture line.

INSTRUMENTS AND IMPLANTS:

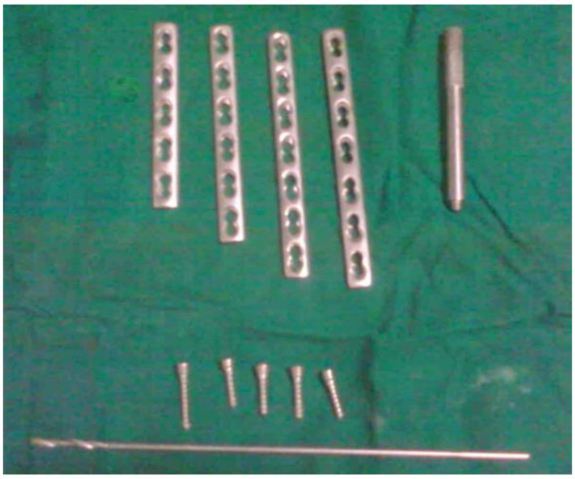


Fig:18 Instruments and plates for both bone forearm

SURGICAL PROCEDURE

Position of forearm

Reduction of fracture radius

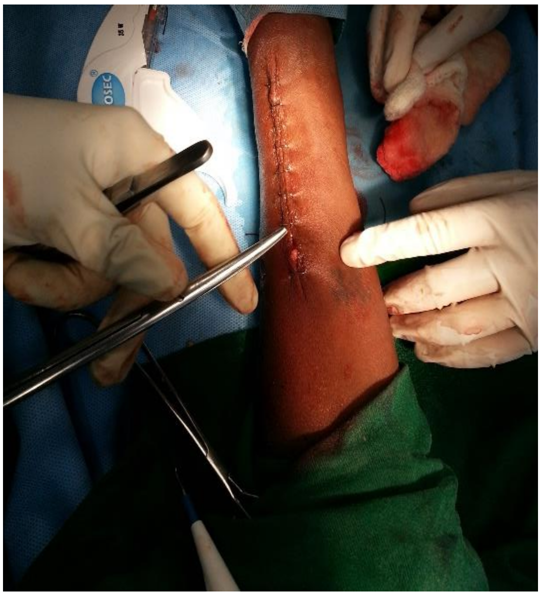
Plate Fixation of radius

Wound closure

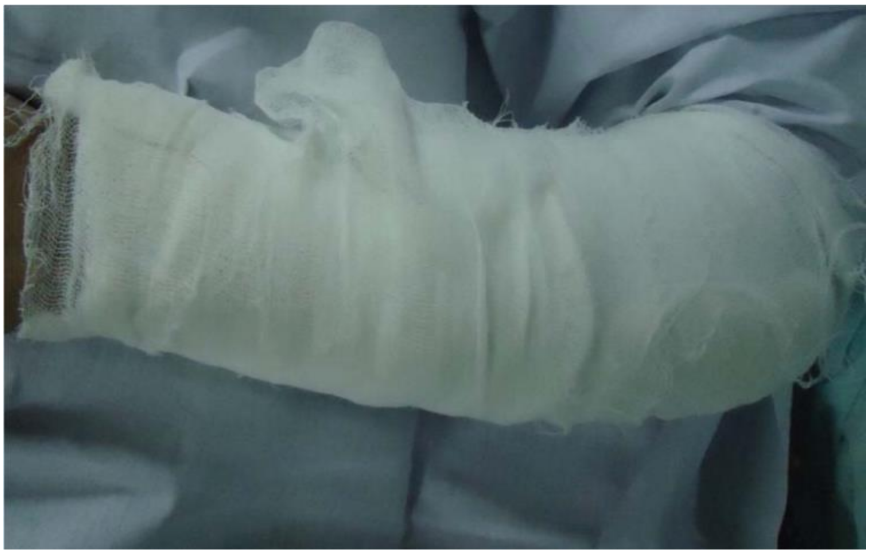
<u>Exposure of ulna</u>

Reduction of fracture of ulna

Plate fixation of ulna



Ulna wound closure



Sterile Dressing With Slab Application

Statistical analysis:

Data was entered into Microsoft excel data sheet and was analyzed using SPSS 22 version software. Categorical data was represented in the form of frequencies and proportions.

Continuous data was represented as mean and standard deviation.

Graphical representation of data: MS Excel and MS word was used to obtain various types of graphs such as bar diagram and Pie diagram.

Statistical software: MS Excel**,** SPSS version 22 **(**IBM SPSS Statistics, Somers NY, USA) was used to analyze data. EPI Info (CDC Atlanta), Open Epi, Med calc and Medley's desktop were used to estimate sample size, odds ratio and reference management in the study.

Results:

Table 4: Age distribution of subjects

		Number	%
Age	< 25 years	11	36.7%
	26 to 35 years	8	26.7%
	36 to 45 years	5	16.7%
	> 45 years	6	20.0%
	Total	30	100.0%

In our study 36.7% were below 25 years, 26.7% were between 26 to 35 years, 16.7% were between 36 to 45 years and 20% were >45 years. The youngest patient was 19 years old and oldest was 65 years.

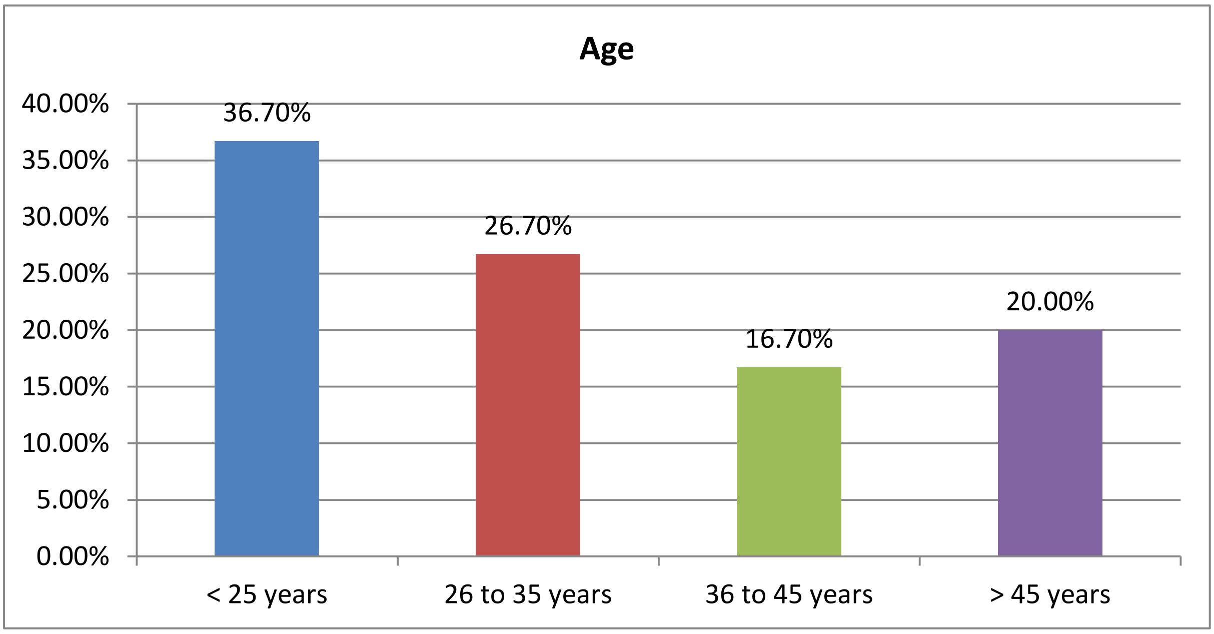


Figure 19: Bar diagram showing Age distribution

Table 5: Sex distribution of subjects

		Number	%
Sex	Female	2	6.7%
	Male	28	93.3%
	Total	30	100.0%

In the study majority of subjects were males (93.3%) and 6.7% were females.

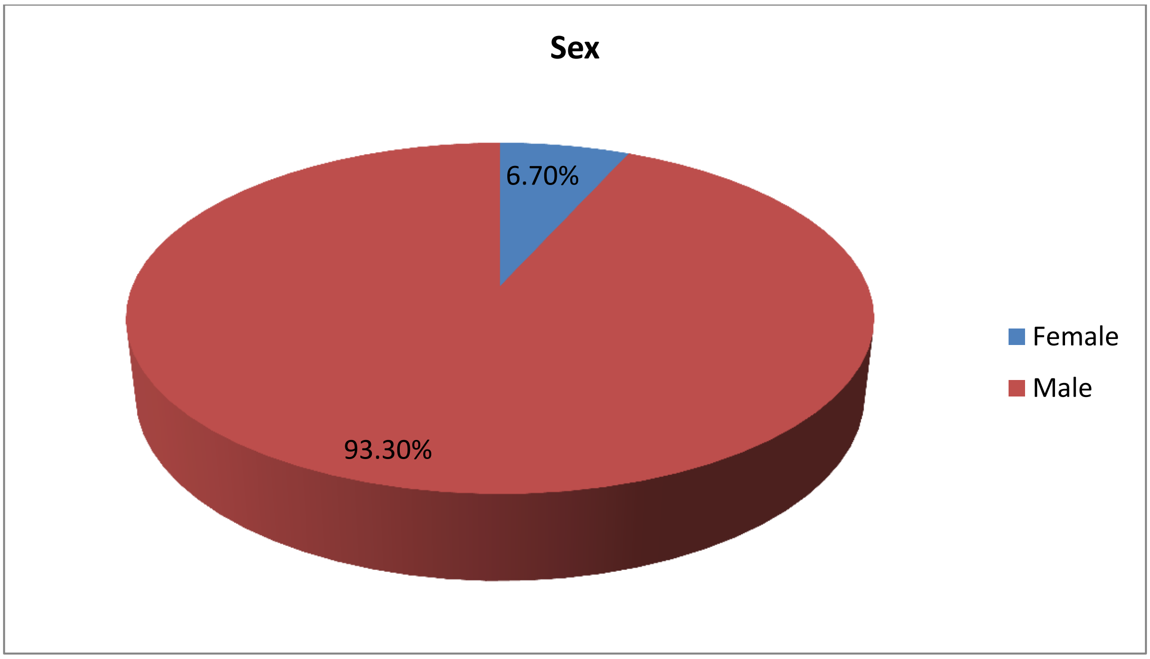


Figure 20: Pie diagram showing Sex distribution

Table 6: Side of Fracture

		Number	%
Side of Fracture	Left	12	40.0%
	Right	18	60.0%
	Total	30	100.0%

40% of subjects had fracture on left side and 60% of them had fracture on right side.

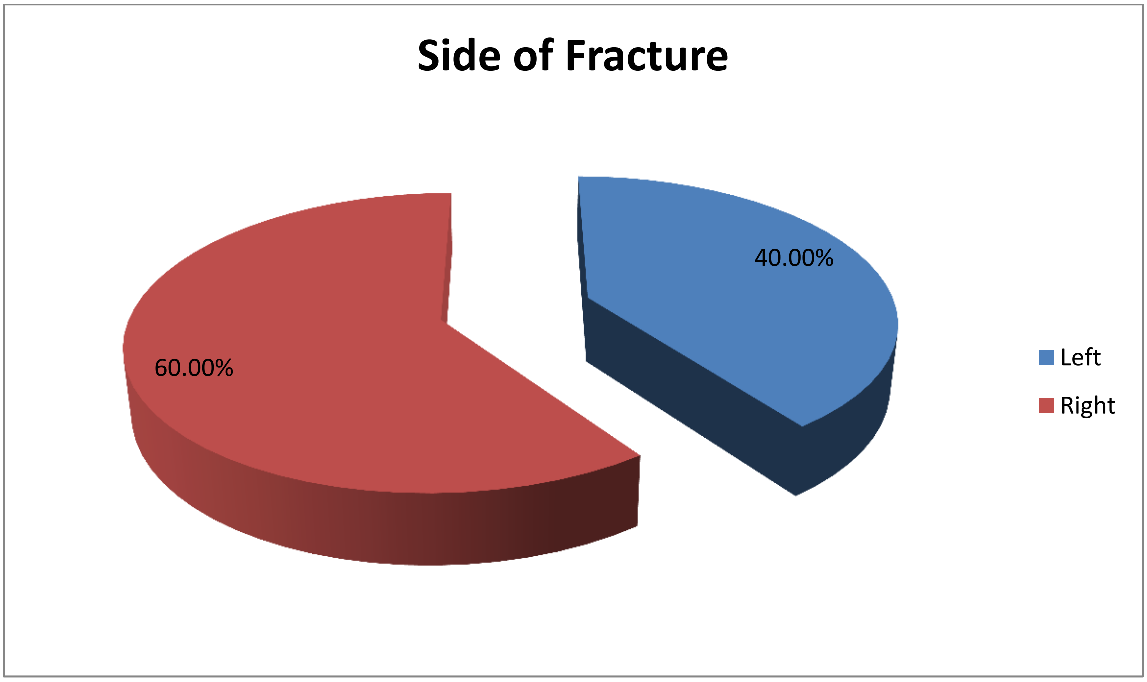


Figure 21: Pie diagram showing Side of Fracture

Table 7: Mode of Injury

		Number	%
Mode of Injury	RTA	23	76.7%
	Self Fall	7	23.3%
	Total	30	100.0%

76.7% had injury due to Road traffic accident and 23.3% had injury due to self-fall.

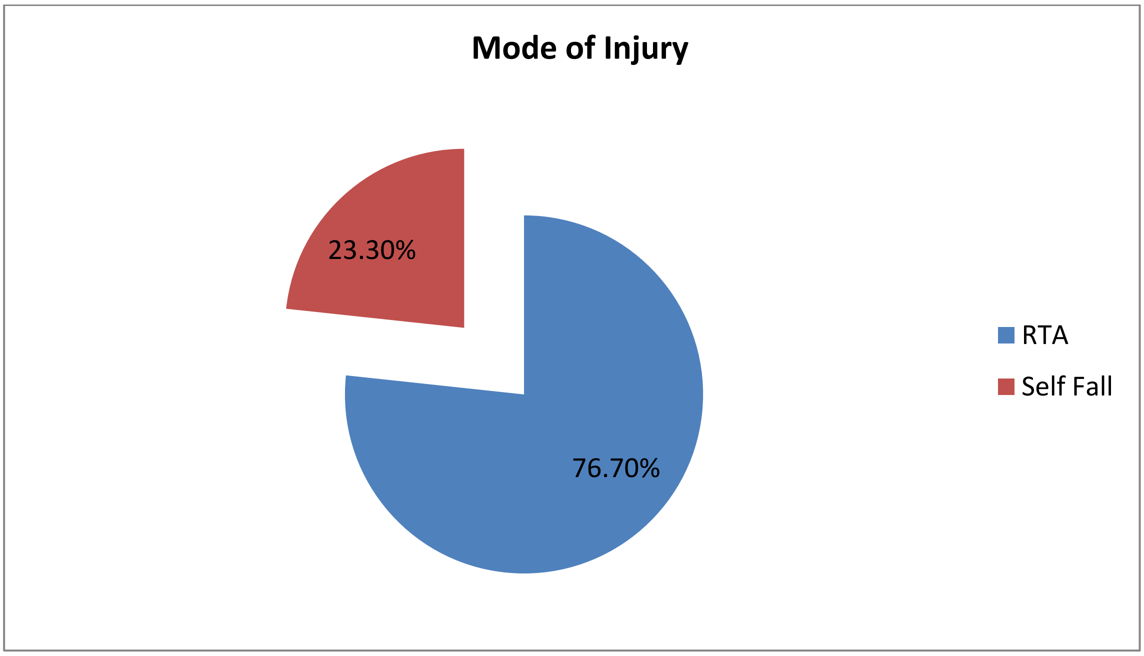


Figure 22: Pie diagram showing Mode of Injury

Table 8: Site of Fracture site in Radius and Ulna bone

		Radius		Ulna	
		Number	%	Number	%
Site of Fracture	Distal 3rd	11	36.6	11	36.6
	Middle 3rd	14	46.6	15	50
	Proximal 3rd	5	16.8	4	13.4
	Total	30	100.0	30	100.0

In this study Distal 3rd of Fracture was seen in 36.6% of radius and ulna, Middle 3rd of fracture was seen in 46.6% of radius # and 50%of ulna, Proximal 3rd fractures were seen in 16.8% of radius and 13.4% of ulna fractures.

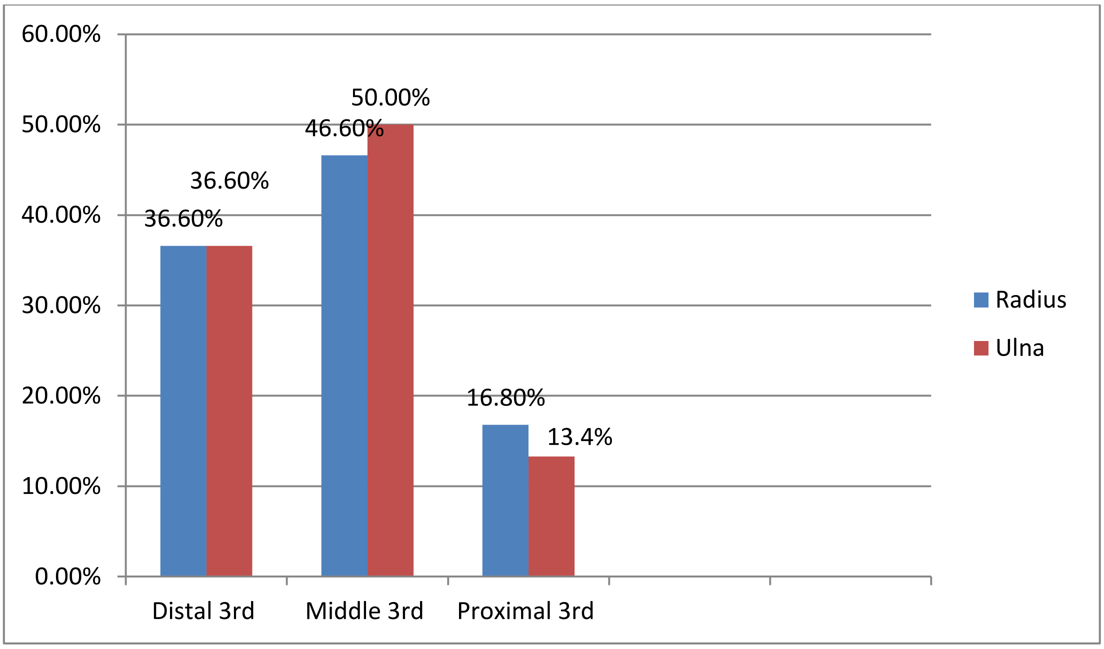


Figure 23: Bar diagram showing Site of Fracture site in Radius and Ulna bone

Table 9: Type of Fracture in Radius and Ulna bone

		Radius		Ulna	
		Number	%	Number	%
Type of Fracture	Transverse	19	63.3	12	40.0
	Comminuted	6	20.0	13	43.3
	Oblique	2	6.7	3	10.0
	Spiral	3	10.0	2	6.7
	Total	30	100.0	30	100.0

In this study 63.3% of fractures radius and 40% of ulna fractures were transverse, 20% of radius and 43.3% of ulna fractures were comminuted, 6.7% of radius and 10% of ulna fractures were oblique , 10% of radius and 6.7% of ulna fractures were spiral. All the fractures were closed type.

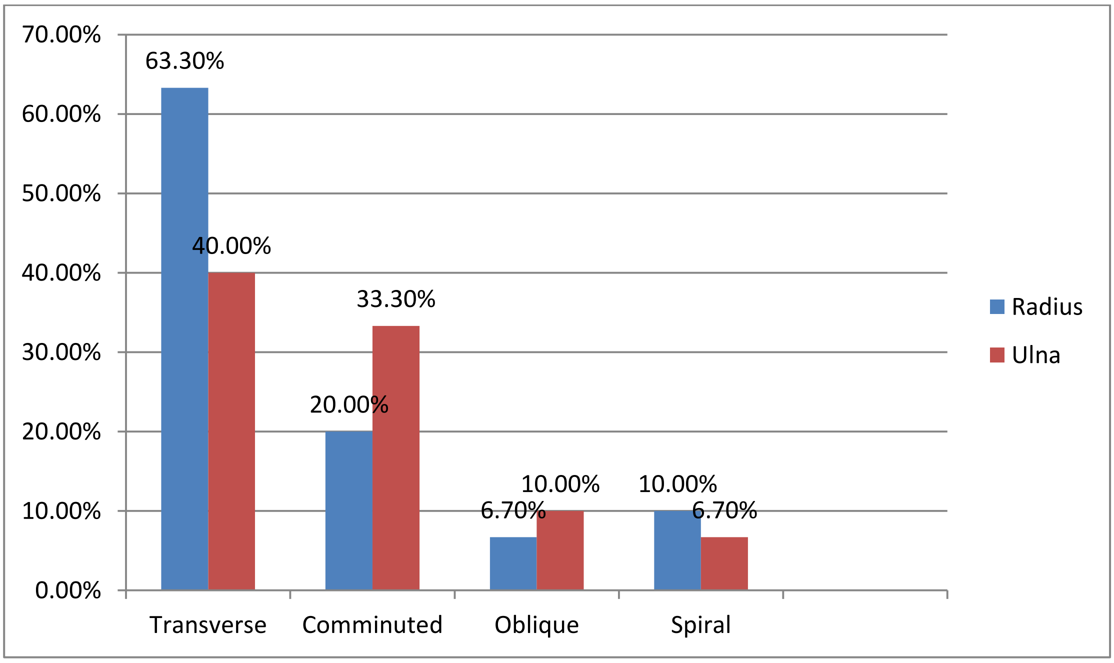


Figure 24: Bar diagram showing Type of Fracture in Radius and Ulna bone

Table 10: Associated Injuries

		Number	%
Associated Injuries	Nil	22	73.3%
	Left Proximal tibia & clavicle #	1	3.3%
	Right Distal femur & tibia shaft #	1	3.3%
	Right Radio-ulnar disruption	1	3.3%
	Right Side Clavicle, Ribs, Hip	1	3.3%
	Right Side Elbow dislocation	1	3.3%
	Right side Tibia and Shaft #	1	3.3%
	Right side humerus #	1	3.3%
	Right Side Proximal Tibia #	1	3.3%
	Total	30	100.0%

73.3% of subjects had no associated injuries and 3.3% of subjects had other associated injuries as shown in above table.

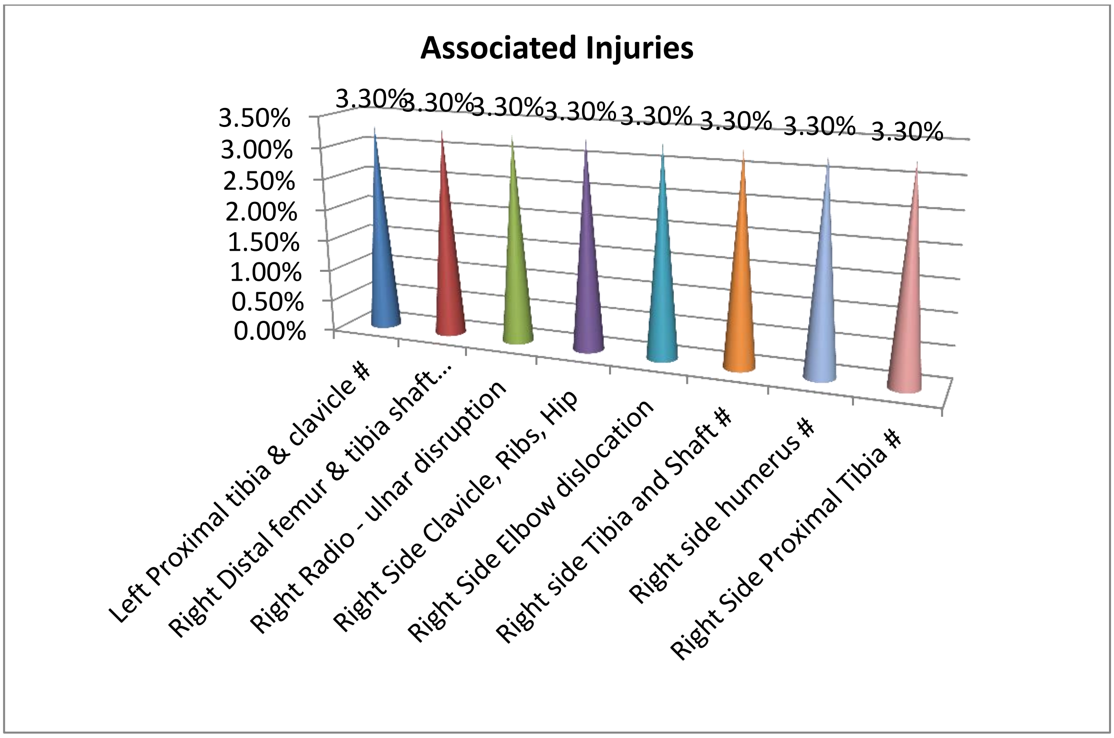


Figure 25: Bar diagram showing Associated Injuries

Table 11: Time of Union in weeks

		Number	%
Time of Union in weeks	12	3	10.0%
	13	6	20.0%
	14	10	33.3%
	15	9	30.0%
	16	1	3.3%
	18	1	3.3%
	Total	30	100.0%

Mean Time of Union in subjects was 14.1 ± 1.3 weeks. 10% of fractures united in 12 weeks, 20% were united in 13 weeks, majority 33.3% were united in 14 weeks, 30% by 15 weeks, 3.3% by 16 weeks and 18 weeks respectively.

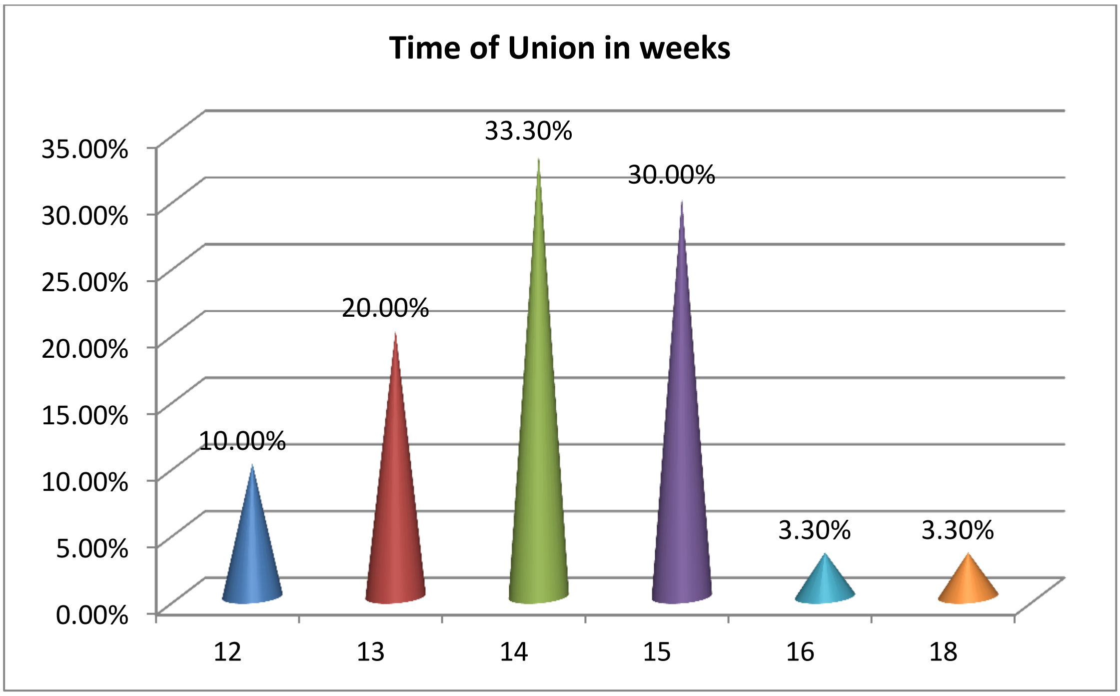


Figure 26: Bar diagram showing Time of Union in weeks

Table 12: Range of Movements in elbow and wrist joint

		Number	%
Range of Movements	Full	26	86.7%
	Good	3	10.0%
	Loss of 10 Deg Pronation	1	3.3%
	Total	30	100.0%

Range of movements after surgery was full among 86.7% of subjects, good among 10% and loss of 10 degree pronation was seen in 3.3% of subjects.

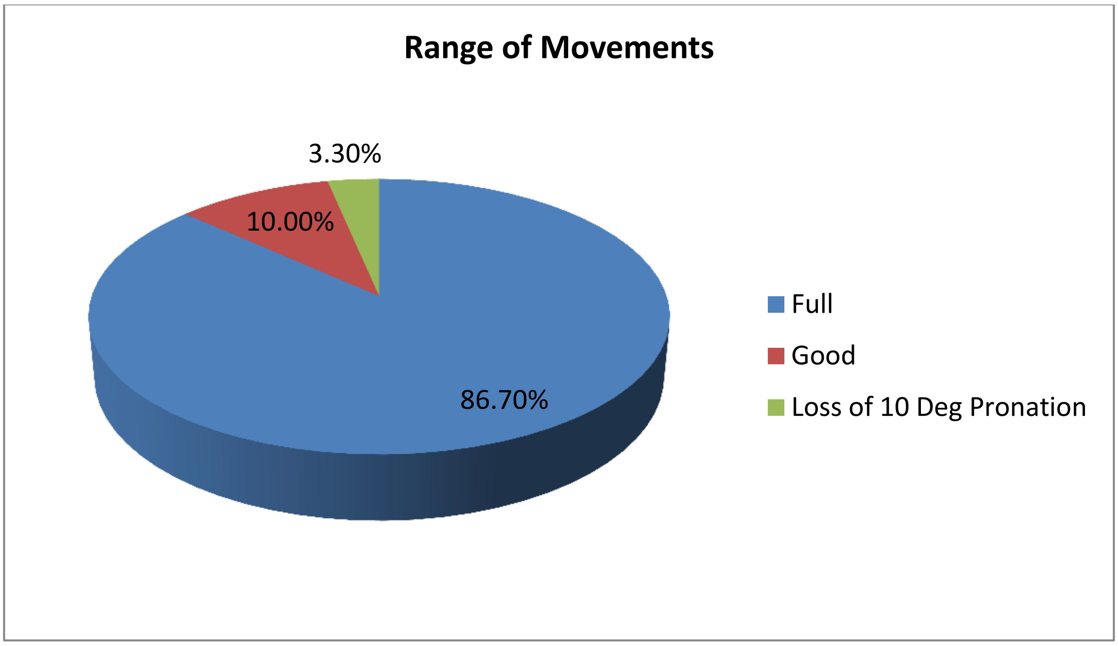


Figure 27: Pie diagram showing Range of Movements after surgery

Table 13: Complications following surgery

		Number	%
Complications	NIL	27	90.0%
	PIN palsy	2	6.7%
	Infection	1	3.3%
	Total	30	100.0%

PIN palsy was seen in 6.7% of subjects and infection was seen in 3.3% of subjects.

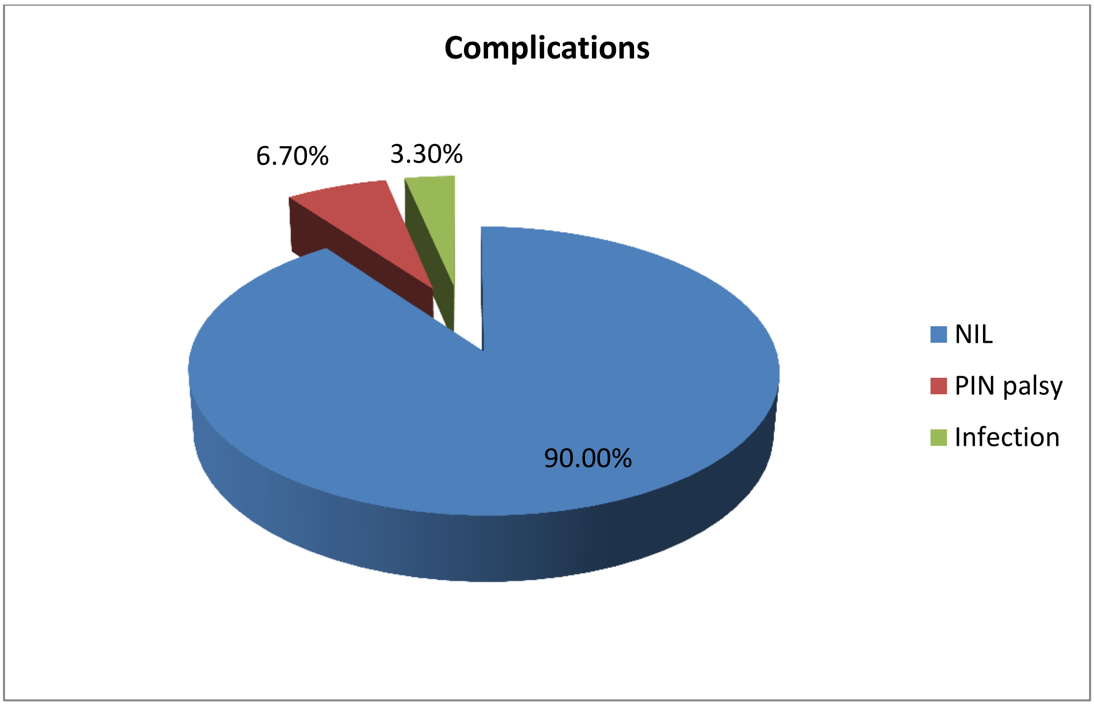


Figure 28: Pie diagram showing complications following surgery

Table 14: Outcome after surgery

		Number	%
Results	Excellent	25	83.3%
	Satisfactory	5	16.7%
	Total	30	100.0%

83.3% of subjects had excellent result and 16.7% had satisfactory resuls.

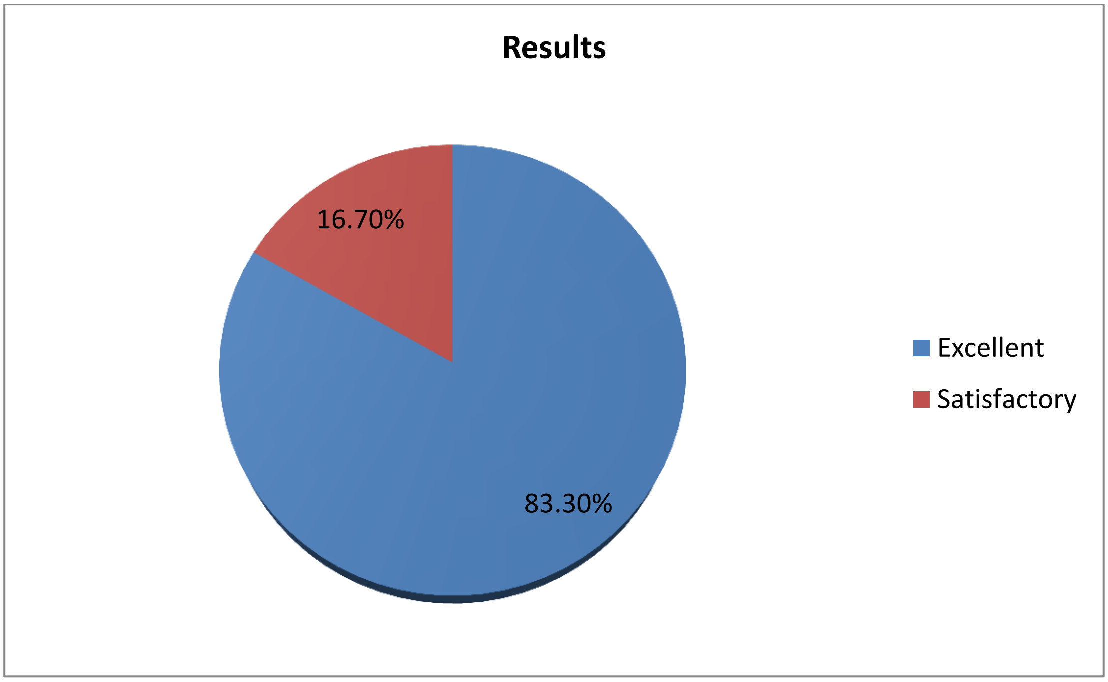


Figure 29: Pie diagram showing Results after surgery

Table 15: Duration of Surgery

		Number	%
Duration of Surgery in minutes	60	2	6.7%
	70	8	26.7%
	75	4	13.3%
	80	11	36.7%
	85	2	6.7%
	90	3	10.0%
	Total	30	100.0%

Mean duration of surgery in study was 76.67 ± 7.69 min. Majority of subjects were operated for 80 min and lowest time taken was 60 min in 6.7% and highest time taken was 90 min among 10%.

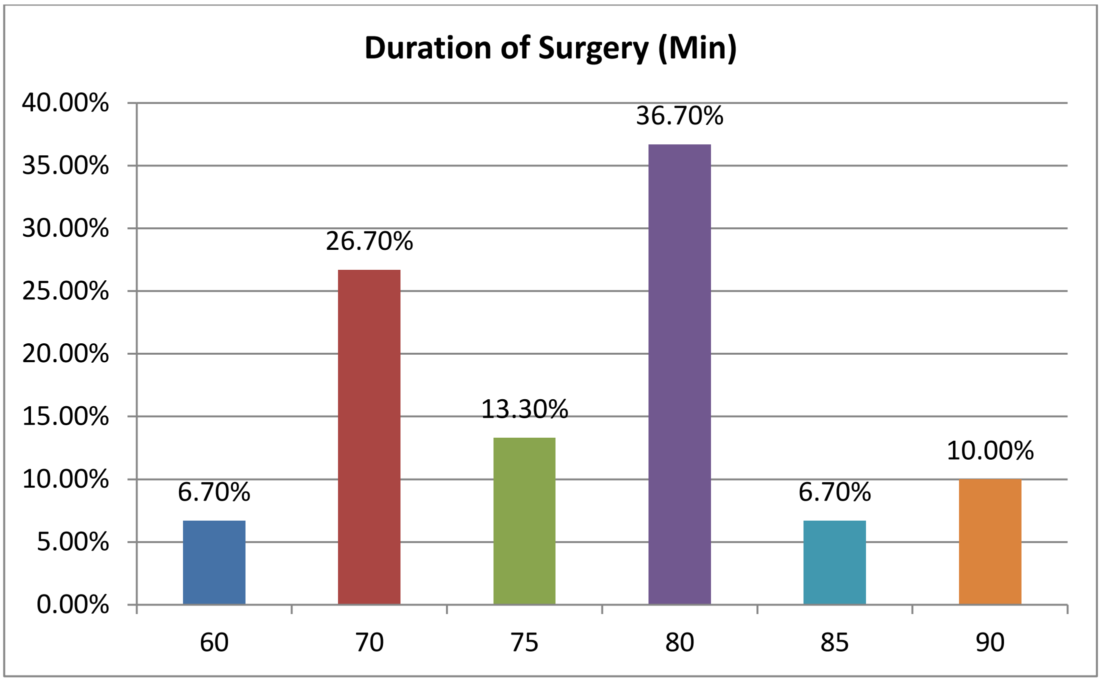


Figure 30: Bar diagram showing Duration of Surgery

Table 16: Tourniquet Time

		Number	%
Tourniquet Time	60	2	6.7%
	70	8	26.7%
	75	4	13.3%
	80	10	33.3%
	85	2	6.7%
	90	4	13.3%
	Total	30	100.0%

Mean duration of surgery in study was 77.00± 8.05min. In Majority of subjects tourniquet time was for 80 min and lowest tourniquet time was 60 min in 6.7% and highest tourniquet time was 90 min among 13.3%.

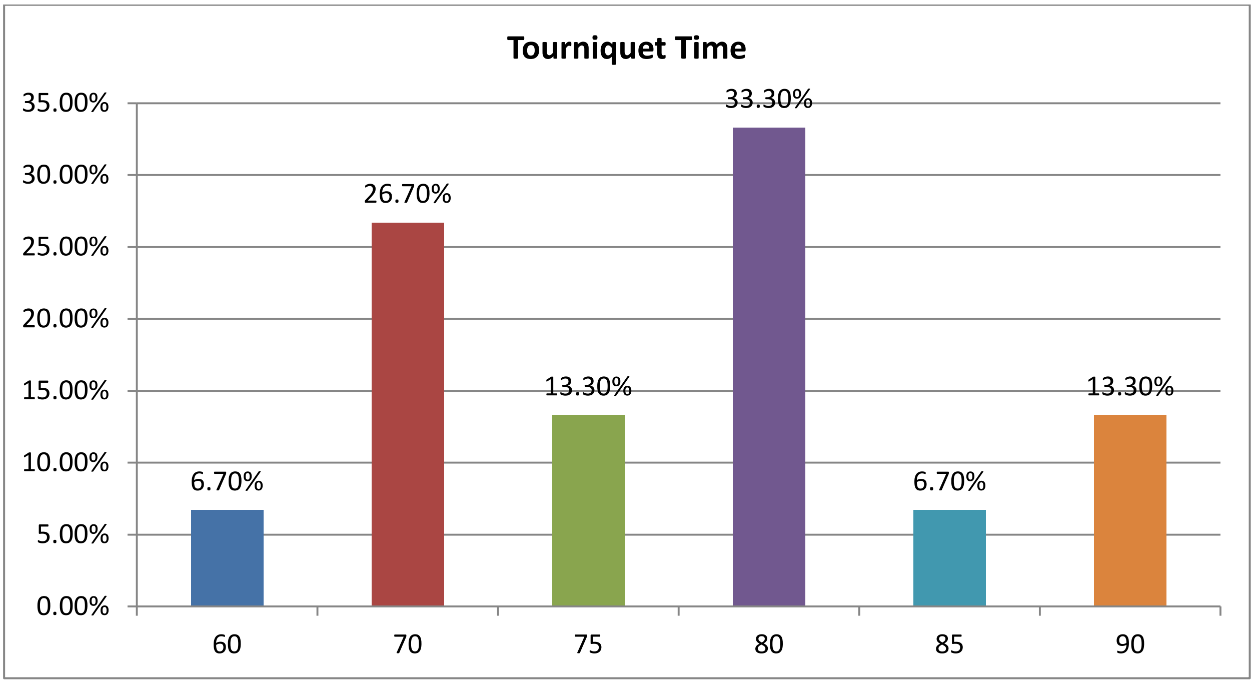


Figure 31: Bar diagram showing Tourniquet Time

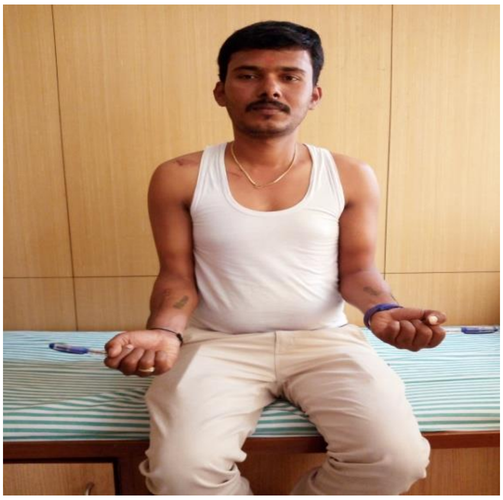
Preoperative

Post operative

At 1 month

After 3 month

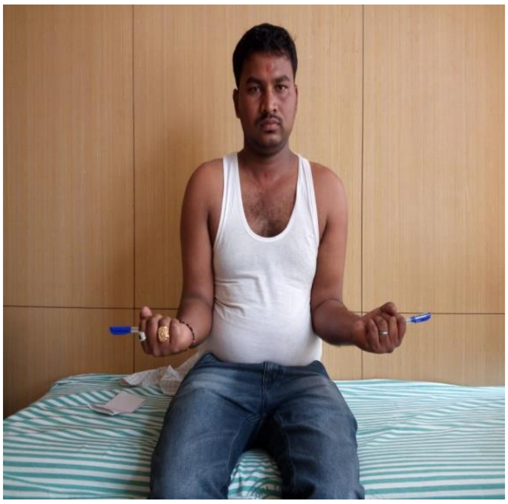
After 6months

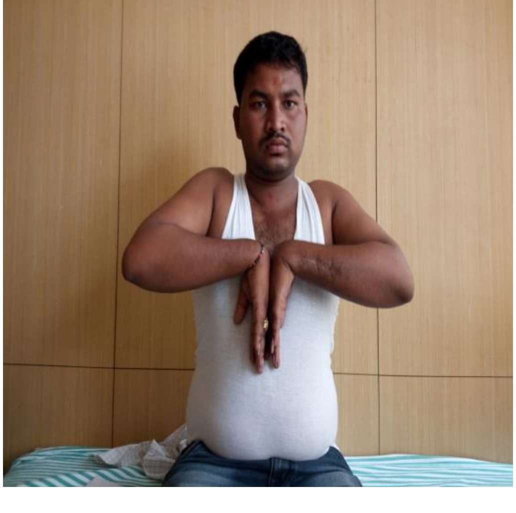


Preoperative Post operative

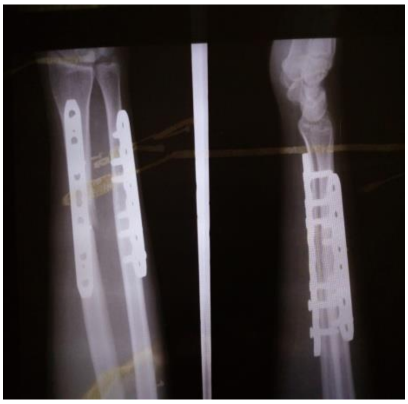
At 1 month After 3 months

After 6months



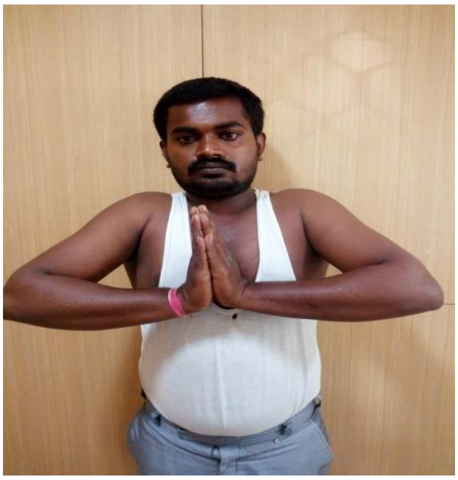


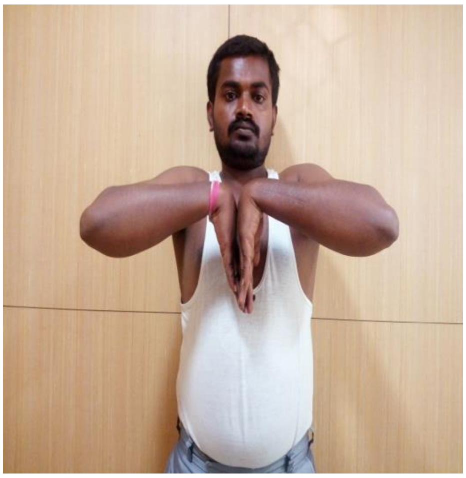

Preoperative Post operative

1 Month After 3 Months

After 6 months





DISCUSSION

Fracture both bones of forearm presents a formidable challenge to the orthopaedicians as the various muscle forces acting upon the fracture tend to displace it. Hence to provide a functional upper limb, anatomic reduction and rigid fixation is mandatory. This is achieved by open reduction and internal fixation with dynamic compression plate and screws[42]

The present study was undertaken to determine the efficacy of LCP in the treatment of fractures of both bones of the forearm. A total of 30 patients of fracture both bones of forearm were treated with open reduction and internal fixation using 3.5mm LCP.

We evaluated our results and compared them with those obtained by various other studies utilizing different modalities of treatment. Our analysis as follows.

1) **Age distribution:**

In our study, fracture was commoner in the second and third decade, with average age of 33.8 years (18-55 years).

TABLE 17: AGE DISTRIBUTION

Series	Years	Average age (years)
Michael W.Chapman et al	1989	33
Frankle Leung	2003	36
Boussakri H et al	2016	34.52
Goud etal	2016	33.5
Present study	2016	33.8

2) **Sex distribution**:

Majority of the patients in our study were male 93.3%.If correlated with other study quoted below

Series	Years	Males (%)	Females (%)
Michael Chapman	1989	78	22
Frankie Leung	2003	82.6	17.4
Gouda et al	2016	70	30
Present study	2016	93.3	6.7

3) **Mode of injury**:

In our series 76.7% of cases were due to road traffic accidents and 23.3% due tofall as compared to studies quoted below.

MODE OF INJURY

Series	**Year**	**Accident (%)**	**Fall (%)**	**Direct blow/Miscellaneous (%)**
Smith	1959	45	36	19
Grace	1980	45	22	33
moed	1986	70	14	16
Gouda etal	2016	50	40	10
Present study	2016	76.7	23.3	0

4) Extremity affected:

We had 60% incidence of fracture both bone on right extremity. If correlated with other studies as shown below

Series	**Years**	**Right (%)**	**Left (%)**
H.N.Burwell	1964	50	50
M.W.Chapman	1989	55	45
Babu et al	2015	50	50
Present study	2016	60	40

5) **Fracture anatomy**:

a) Type of fracture:

In our series and 64% of fractures were transverse/short oblique and 36 % were comminuted .The other series are as shown below

Series	Years	Transverse/Short Oblique	Comminuted
Chapman	1989	47%	53%
Gouda et al	2016	72.5%	27.5%
Present study	2016	64%	36%

b) **Level of fracture**:

In our series 48.4% of fractures were in middle third,36.6 %lower third and 15% in proximal third. The incidence fracture of middle third are more in our study compared to others as quoted below.

Series	Years	Proximal third	Middle third	Distal third
Dodge	1972	7%	71.5%	21.5%
Sarmiento	1975	-	84.6%	15.4%
Gouda et al	2016	15%	70%	15%
Present study	2016	15%	48.4%	36.6%

Time of union:

In the present study the average union time was 14 weeks with range of 12 to 20weeks. Which was similar to most of the study we had 100% union of both radius and ulna our results are compared with other studies as shown below.

Series	Union times (weeks)	Range (Weeks)	Union (%)
Anderson	7.4	5 – 10	97
Chapman	12	-6 – 14	98
Gouda et al	14	8-20	100
Present study	14	12-20	100

6) Functional results:

In our series we had 83.3% were excellent, 13.7% were satisfactory. Our results are comparable with majority of studies as quoted below.

Series	Excellent (%)	Satisfactory(%)	Unsatisfactory (%)	Failure (%)
Anderson	50.9	34.9	11.3	2.9
Frankie	98	2	-	-
Chapman	86	7	12	5
Goud et al	85	15	-	-
Present study	83.3	13.7	-	-

8. Complications

Complications	Anderson	Chapman	Present study
Superficial infection	2.9%	2.5%	3.3%
Non-union	2.9%	2.3%	-
Post-interosseous nerve injury	2%	1.5%	6.7%
Radio-ulnar synostosis	1.2%	2.3%	-

In our series we had a case of superficial infection which resolved with antibiotics. We had two case of posterior interosseous nerve injury immediately following surgery. Both cases recovered spontaneously probably were neuropraxia due to retraction .

CONCLUSION

The present study was conducted to assess the outcome of LCP plating in fractures of both bones forearm.

We conclude:

- Fractures of both bones of forearm in adults are more common in second and third decade of life. Predominant in males due to manual working and outdoor activities.

- Majority of the fractures were due to road traffic accidents transverse/short oblique in the middle shafts of both bones forearm and were due to vehicle accidents/fall.

- Use of tourniquet, separate incisions for radius and ulna and preservation of the natural curves of radius will lower the rate of complications.

- The 3.5mm LCP, properly applied, is an excellent method for internal fixation of fractures of the forearm bone.

- These fractures have to be fixed as early as possible and it is important to achieve anatomical reduction and stable internal fixation for excellent functional outcome.

- A minimum of 6 cortices has to be fixed on each fracture fragment.

- After LCP fixation, postoperative support, given in the form of arm pouch in most instances, can be discontinued after the soft tissues have healed and rapid return to full, painless motion can be anticipated.

- Most of the fracture united within 4 months. We conclude, with proper preoperative planning, adherence to AO principles. Post-operative rehabilitation locking compression plate gives excellent results.

SUMMARY

This study was undertaken to determine the functional outcome of diaphyseal fractures of both bones, forearm treated with LOCKING COMPRESSION PLATE at R L Jalappa Hospital attached to Sri Deveraj Urs Medical College, Tamaka, Kolar, from NOV 2014 to May 2016**.**

1. This is a time-bound prospective study.
2. Thirty cases of fractures of both bones forearm were treated by open reduction and internal fixation with 3.5 mm LCP.
3. The average age was 33.85years with fracture being most common in second and third decade.
4. Majority of patients were males
5. The mechanism of injury in most cases was road traffic accident .
6. Side effected is left forearm 12 and right forearm 18.
7. Most of the fractures of both bones forearm were located in the middle third and the fracture pattern transverse/short oblique was commonest.
8. Minimum duration of follow up was 6 months.
9. All patients has good union .
10. The average time for fracture healing was 14 weeks.

11. The results were based on Anderson et al scoring system and in our study, there were 25 (83.3 %) patients with excellent results and 5 (13.7 %) with satisfactory.

12. Hence, the study shows that LCP is an effective device for treatment for diaphyseal fractures of both bones forearm.

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ANNEXURE-I

PROFORMA

A STUDY OF FRACTURES OF BOTH BONE FOREARM TREATED LCP
PROFORMA

SL.No :

NAME : DOA:

AGE/SEX : DOS:

OCCUPATION: DOD:

ADDRESS : CONSULTANT:

RELIGION:

Presenting complaints **1.**

2.

3.

History of presenting complaints:

- Date of injury-
- Mode of injury- a) Vehicular accident

  b) Assault

  c) Fall on out streached hand

  d) Domestic

  e) Others
- Immediate first aid given:
- Time interval between injury and surgery:
- Complications :

- Associated injuries :

Significant past history :

Personal history – Occupation
Diet –veg/non-veg/mixed
Habits –smoking/alcohol/other
Sleep- Impaired /Not impaired
Bowel and bladder habits

Examination :

General physical examination

Built and nutrition

Pallor –present /absent

Pulse

BP

Temperature

Other significant findings

Systemic Examination:

CVS	P\ A
RS	CNS

Local Examination:
Inspection
Side –left / right
Attitude of the limb:
Swelling:
Deformity:
Wounds:
Others:

Palpation:
Local rise of temperature:

Tenderness :

Abnormal mobility:

Crepitus :

Peripheral pulses:

Movements :

Distal neuro-vascular status
Radial artery :
Ulnar artery :
Sensory disturbances:
Motor disturbances :

Associated injuries:

Investigations:

Blood routine:

Urine routine:

X-ray Forearm – AP
Lateral

Level of fracture
Radius:
Ulna :

Type of fracture
Radius: Transverse /Oblique / Spiral /Comminuted

Ulna : Transverse /Oblique / Spiral /Comminuted

Treatment :

1.Pre-operative:

Above elbow POP slab with sling

Antibiotics

Analgesics

2. Surgical procedure:

Type of anaesthesia - GA/brachial block

Duration of surgery:

Tourniquet time:

Approach – Thompson:
Henry:

Operative findings:

Operative Complications

Difficult reduction: Stable/Unstable

Plate's applied-

Radius:6 holed /7 holed / 8 holed /9 holed

Ulna : 6 holed /7 holed / 8 holed /9 holed

Intrafragmentary compression screw:

Other surgical procedure

3.Post operative:

Immobilisation for __________ days / weeks

Antibiotics:

Suture removal after _____ days(Wound healing / Gaping / Infected)

4.Duration of Hospital stay:

5.Follow up:

Follow up	**Radiograph (union)**	**Elbow/Wrist flexion/extension**	**Radio-ulnar Supination/pronation**	**Remarks**
1 month				
3 month				
6 month				

6. Assessment of results:

ANDERSON et al CRITERIA

□**Excellent -** Union + loss of < 10° Flexion/Extension + loss of < 25% pronation / supination.

□**Satisfactory -** Union + loss of < 20° Flexion/Extension + loss of <50% pronation / Supination.

□**Unsatisfactory -** Union + loss of > 30° Flexion / Extension + loss of 50% supination / pronation.

□**Failure -** Nonunion with / without loss of motion

7.Complications:

Infection- Superficial/Deep

Delayed union

Mal union

Loss of movements

Non union

Others

1)VIC (Volkmann's Ischemia)

2) Nerve injury

ANNEXURE-II

INFORMED CONSENT

I………………aged……unreservedly and in my full senses give my consent to take part in above mentioned study which include x ray of fore arm ,routine investigations and LCP for forearm.

These procedures and complications have been explained to me in my own understandable language. I am willing to pay for the investigations and the procedure. I don't hold any treating doctor, nursing staff and hospital management for any untoward consequences.

I here by give my consent for the same.

SIGNATURE OF THE SUBJECT

DATE :

ANNEXURE-III

PATIENT INFORMATION SHEET

I……. Patient have been explained about the procedure to be performed (LCP), also the alternate procedures that can be performed and complications(infection, stiffness, delayed union, mal union, nonunion, nerve injury) associated with the procedure. I am willing to get operated with locking compression plating.

.

Signature of the patient

Date

KEY TO MASTER CHART

Com	-	Comminuted
F	-	Female
IP No	-	In patient number
Lt	-	Left
D/3	-	Distal third
M	-	Male
M/3	-	Middle third
P/3	-	Proximal third
MOI	-	Mode of injury
R	-	Radius
Rt	-	Right
ROM	-	Range of motion
RTA	-	Road traffic accident
Sl . No	-	Serial number
Sub	-	Subcutaneous approach
Henry	-	Henry approach
U	-	Ulna
#	-	Fracture

SI.NO	NAME	AGE	SEX	IP.NO	MODE OF INJURY	SIDE	FRACTURE OF SITE	TYPE OF FRACTURE	ASSOCIATED INJURIES	SURGICAL APPROACH	TIME OF UNION	RANGE OF MOVEMENTS	COMPLICATIONS	DURATION OF SURGERY	TORNIQUATE TIME	RESULTS
1	Arun kumar	31	M	150898	RTA	RT	R-U -MID/3	R&U- Com	Elbow disloactaion rt side	R-henry ,U-SUB	14 weeks	FULL	NIL	75 mints	75 mints	EXCELLENT
2	Prakash B.c	28	M	26121	RTA	RT	R-U -MID/3	R&U- Trans	rt-clavicle,ribs and hip	R-henry ,U-SUB	14 weeks	FULL	NIL	70 mints	70 mints	EXCELLENT
3	Ganesh	27	M	164830	RTA	RT	R-U-DIST/3	R&U- Trans	NIL	R-henry ,U-SUB	13 weeks	FULL	NIL	80 mints	80 mints	EXCELLENT
4	Harish	21	M	125778	RTA	RT	R-U- DIST/3	R&U-Trans	NIL	R-henry ,U-SUB	14 weeks	GOOD	NIL	90 mints	90 mints	SATISFACTORY
5	Muzahid	29	M	226308	RTA	RT	R-U -MID/3	R&U- comm	NIL	R-henry ,U-SUB	15 Weeks	FULL	NIL	70 mints	70 mints	EXCELLENT
6	mahesh	21	M	107169	RTA	LT	R-U - DIST/3	R-Spirl & U-Obq	RT side proximal tibia #	R-henry ,U-SUB	16 weeks	FULL	NIL	70 mints	70 mints	EXCELLENT
7	Raghu	24	M	158756	RTA	LT	R-U -MID/3	R&U- trans	NIL	R-henry,U-SUB	13 weeks	FULL	NIL	80 mints	80 mints	EXCELLENT
8	krishnappa	60	M	286003	SELF-FALL	RT	R-U -PROX/3	R&U-Trans	NIL	R-henry,U-sub	15 weeks	FULL	SP INFECTION	70 mints	70 mints	EXCELLENT
9	Mithun	24	M	240490	RTA	LT	R-U -DIST/3	R&U-Trans	NIL	R-henry,U-sub	12 weeks	FULL	NIL	85 mints	85 mints	EXCELLENT
10	Munishamappa	55	M	142514	RTA	RT	R-U -PROX/3	R&U- Trans&Comm	RT humarus #	R-henry,U-SUB	15 weeks	FULL	PIN palsy	70 mints	70 mints	SATISFACTORY
11	Ramanna	30	M	244586	RTA	RT	R-U -DIST/3	R&U- SPIR&TRANS	NIL	R-henry,U-sub	14 weeks	FULL	NIL	80 mints	80 mints	EXCELLENT
12	Ramesh	26	M	249432	RTA	RT	R-U-DIST/3	R&U- Trans	Radio-ulnar disruption	R-henry,U-SUB	14 weeks	LOSS OF 10 DEG PRONATION	NIL	75 mints	75 mints	SATISFACTORY
13	Narayana swamy	45	M	87775	SELF-FALL	RT	R-U- DIST/3	R&U- Trans	NIL	R-henry,U-SUB	15 weeks	FULL	NIL	70 mints	70 mints	EXCELLENT
14	Prakash	22	M	197039	RTA	LT	R-U-MID/3	R-Trans & U-Obq	NIL	R-henry,U-SUB	13 weeks	FULL	NIL	80 mints	80 mints	EXCELLENT
15	Rajanna	24	M	111012	RTA	RT	R-U-DIST/3	R&U- Spiral	Distal femur & tibia shaft #	R-henry,U-SUB	15 weeks	GOOD	NIL	80 mints	80 mints	SATISFACTORY
16	SudhaKar	24	M	244481	SELF-FALL	LT	R-U-DIST/3	R-Obq & U - Trans	NIL	R-henry,U-SUB	14 weeks	FULL	NIL	90 mints	90 mints	EXCELLENT
17	Samuyal	26	M	277071	RTA	LT	R-U -MID/3	R&U- comm	NIL	R-henry,U-SUB	14 weeks	FULL	PIN palsy	70 mints	70 mints	EXCELLENT
18	Santosh	21	M	190518	SELF-FALL	RT	R-U-PROX /3	R-Trans & U-comm	NIL	R-henry,U-SUB	13 weeks	FULL	NIL	70 mints	70 mints	EXCELLENT
19	Shamanna	65	M	158027	RTA	LT	R-U-MID/3	R&U- Trans	proximal tibia & lt clavicle #R-THOM,U-SUB	R-henry,U-SUB	15 weeks	FULL	NIL	80 mints	80 mints	EXCELLENT
20	Shiva kumar	24	M	114575	SELF-FALL	LT	R-U -DIST/3	R&U-Spirl & TRANS	NIL	R-henry,U-SUB	14 weeks	FULL	NIL	60mints	60 mints	EXCELLENT
21	Vijay kumar	35	M	271916	SELF-FALL	RT	R-U -MID/3	R&U-Trans&spirl	NIL	R-henry,U-SUB	13 weeks	FULL	NIL	90 mints	90 mints	EXCELLENT
22	Asmath pasha	50	M	284125	RTA	RT	R-U-DIST/3	R&U-Spiral	NIL	R-henry,U-sub	14 weeks	FULL	NIL	8O mints	90 mints	EXCELLENT
23	Basamma	47	F	725397	RTA	LT	R-U-MID/3	R&U-Trans	NIL	R-henry,U-SUB	12 weeks	FULL	NIL	80 mints	80 mints	EXCELLENT
24	Subba raju	36	M	896075	RTA	RT	R-U-MID/3	R-Obq & U - Trans	NIL	R-henry,U-SUB	13 Weeks	FULL	NIL	75mints	75 mints	EXCELLENT
25	Narayana swamy	40	M	337669	RTA	RT	R-U-MID/3	R-Trans & U-OBQ	NIL	R-henry,U-SUB	15 weeks	FULL	NIL	75 mints	75 mints	EXCELLENT
26	Suresh	19	M	903659	RTA	LT	R-U-MID/3	R-Trans & U-comm	NIL	R-henry,U-SUB	18 weeks	FULL	NIL	80 mints	80 mints	EXCELLENT
27	Uday kumar	23	M	916645	RTA	LT	R-U-MID/3	R-Trans & U-comm	NIL	R-henry,U-SUB	12 weeks	FULL	NIL	80 mints	80 mints	EXCELLENT
28	Manjunath	43	M	932164	RTA	RT	R-U-MID/3	R-Trans & U-comm	RT TIBIA MID SHAFT #	R-henry,U-SUB	14 weeks	FULL	NIL	80 mints	80 mints	EXCELLENT
29	Muniswamy reddy	45	M	327519	SELF-FALL	LT	R-U-PROX /3	R-Trans & U-comm	NIL	R-henry,U-SUB	15 weeks	GOOD	NIL	85 mints	85 mints	SATISFACTORY
30	Muniakkayamma	51	F	288009	RTA	RT	R-U- PRO & MID /3	R-Trans & U-comm	NIL	R-henry,U-SUB	15 weeks	FULL	NIL	60 mints	60 mints	EXCELLENT