# INTRODUCTION

About 190 years have passed since A. Colle's described a fracture of distal end radius which remains even now of the most common fracture encountered by the orthopsedic surgeons.

Fracture distal end radius usually is classified as either intraarticular or extra-articular.

There is considerable disability, pain, deformity associated with this lesion. Although this is a minor ailment but to a housewife, a mechanic, a washer man, a carpenter, a black smith or a gardner, it can be a threat to his/her way of life.

Numerous studies have been conducted to uncover the importance of radiological aspect of this fracture and its relevance to functional and radiological parameters remains unsolved.

Distal radio-ulnar joint disruption occurs in approximately 40-70% of distal radius fracture due to injury to triangular fibrocartilage.

The stability of the DRUJ is provided by its soft tissue restraints and osseous architecture of sigmoid notch.

DRUJ disruption may occur with or without fracture of ulnar styloid.

In our study, an attempt is made to assess clinicoradiologically the prevalence of residual distal radio ulnar joint disruption in fracture distal end radius after various treatment modalities. But all this requires a firm knowledge of the anatomy of the distal radius.

This fracture was common in older age people, with osteoporosis in late 20$^{th}$ century, but with the advent of high speed transportation, mechanized farming and industrialization, this fracture has shifted its target from old to younger socially productive age group with increased propensity for intra-articular extension with consequent compromised outcome.

Cole and Obeletz comment that the goal of treatment of this fracture is good anatomical reduction and maintenance of reduction until the fracture heals has been confirmed by numerous workers. So we have, our present study endeavoured to achieve the goal of anatomical results by using conservative and operative modalities for a better functional outcome of fracture distal end radius.

The most common cause of residual disability after fracture of the distal radius continues to be the DRUJ. Therefore this joint deserves as thorough an evaluation in the acute stage as the injuries at an early stage and achieves anatomical restoration.

To assess the involvement of the DRUJ in acute distal radial fractures, the following issues should be analyzed:

Intra-articular incongruity (sigmoid notch, ulnar head), subluxation caused by inadequate reduction of the radius, TFCC tears, capsular soft tissue injuries and ulnar styloid avulsion with DRUJ subluxation inspite of adequate restoration of the anatomy of distal radius. Same element of DRUJ instability is present in every displaced radius fracture. The key to a successful result depends on exact restoration of the anatomic relationship of the joint (bone, articular surface, ligaments) which must be maintained during first 6 weeks after injury.

## AIMS AND OBJECTIVES

1. Clinicoradiological assessment of distal radioulnar joint disruption (DRUJD) after distal end radius fractures.
2. Prevalence of Residual DRUJD following different treatment modalities.
3. Functional Outcome after different treatment modalities.

## RELEVANT ANATOMY

### TOPOGRAPHICAL ANATOMY

Clinical examination of wrist begins with appreciation of topographical anatomy of wrist. As everywhere else in the body, topographical anatomy of wrist is important for diagnosis and management of wrist injuries. When wrist is flexed against resistance tendons which stand out prominently from radial to ulnar side are flexor carpi radialis, palmaris longus, flexor digitorum superficialis and flexor carpi ulnaris.

The ulnar nerve and vessels are present between FCU and FDS. The radial styloid is 1/2 inch distal to ulnar styloid. On the dorsum of lower end of radius, is **Lister's** tubercle, medial to which is the tendon of extensor pollicis longus. Various movements of wrist increase the accessibility of certain bony prominence. The ulnar styloid is present at ulnar palmar position in full pronation and dorsoradial position in full supination.

Dorsal tubercle (of Lister) is situated near the middle of the posterior aspect of the lower end of the radius in line with cleft between index and middle finger. Ulnar head forms a round elevation on medial side of posterior aspect of wrist in pronated hand. Ulnar styloid process can be determined by following the posterior border of ulna downwards. It is found projecting downwards from the ulnar head.

## OSTEOLOGY:

### Lower End Radius:

This is the widest part is four sided on transverse section. Its lateral surface is slightly rough and projects down as styloid process. It lies at about 1cm below the styloid process of ulna. The inferior surface of the lower end is smooth and takes part in formation of wrist joint. The anterior surface is a thick prominent ridge. The medial surface is the ulnar notch, a smooth strip concave from before backwards for articulation with the head of the ulna in inferior radioulnar joint. The posterior surface is marked by the dorsal tubercle, which is limited medially by a narrow oblique groove. A wide shallow groove lies lateral to the tubercle and is divided in two parts by a very faint vertical ridge. A similar but undivided groove marks the medial part of the posterior surface.

The tendon of the abductor pollicis longus and extensor pollicis brevis conceals the tip of styloid process of radius. It gives attachment· by its tip to the lateral collateral ligament of the wrist. The lateral surface of the lower end of radius, a little above the styloid process receives the insertion of the brachioradialis and is crossed obliquely from above downwards and forwards by the tendons of the abductor pollicis longus and extensor pollicis brevis.

The ulnar notch is limited below by a smooth ridge to which the base of the articular disc of inferior radioulnar joint is attached.

The dorsal tubercle gives attachment to a strip from the extensor retinaculum and is grooved on the medial side by the extensor pollicis longus tendons. The wide shallow groove to the lateral side of tubercle contains the tendon of ECRL laterally and ECRB medially together with their synovial sheaths. The medial part of the posterior surface in grooved by the tendon of the extensor digitorum but the extensor indicis and the posterior interosseous nerve intervene between them and bone. To the lower margin of the posterior surface is attached dorsal radiocarpal ligament.

**Lower End of Ulna:**

It comprises of a rounded head and the .styloid process. The head presents a convex articular surface on its lateral side for articulation with the ulnar notch of the radius. Its inferior surface is smooth and is separated from the carpus by the articular disc of the wrist joint, which is attached by its apex to the small rough area at the base of styloid process of ulnar on its radial side. The styloid process is a short rounded projection, which springs from the posteromedial aspect of the wrist. Ulnar col1ateralligament is attached to the tip of styloid process. On the dorsal surface is a shallow groove between the head and the styloid process, which occupies the tendon of ECU.

**ARTICULAR ANATOMY:**

The .wrist joint is a biaxial joint, grouped under ellipsoid variety. The bones taking part here are distal end of radius and articular' disc proximally and Scaphoid, Lunate and Triquetral distally hence termed mid carpal joint Articular surface of radius and lower surface of the triangular fibrocartilage form a concave surface which is elliptical in shape. The plane of thus surface faces distally and slightly volarly. Inferior surface of radius has a ridge, which forms two concavities in the radius i.e. scaphoid and lunate fossa respectively. The proximal articular surface of scaphoid, lunate and Triquetral hones form a smooth convex surface, which articulates with concave surface of lower end of radius and articular disc. The capsule covers all the three bones and is reinforced by dorsal, volar, lateral and medial ligaments. The capsule is lined by synovial membrane. The joint line corresponds to a line joining the styloid process of radius and ulna and is convex upwards.

**Distal Radio Ulnar Joint:**

Uni-axial pivot joint between convex lower end of ulna and concave ulnar notch of radius. They are enclosed together and held by articular disc. The capsule is lax superiorly through which there are out pouching called Recesses Sacciformis in front of lower part of interosseous membrane. The pronator quadratus has stabilizing effect on this joint. Supination and pronation occurs at this joint. The arterial supply is from anterior interosseous artery and carpal branches of radial and ulnar arteries. The nerves are derived from anterior and posterior interosseous nerve.

**LIGAMENTS:**

Simple capsular ligaments surround the joint. It is strengthened by two major groups of wrist ligaments.

- Extrinsic
- Intrinsic

**Extrinsic:**

These are those that link carpal bone to the radius, ulna and metacarpals and playa major role during ligamentotaxis.

1. Palmar Wrist Ligaments: Originate laterally from radial palmar facet of radial styloid and are directed in a distal ulnar direction where they meet ligaments originating medially from triangular fibrocartilage and distal ulna. It consists of 2 'V' shaped ligamentous bands. One is proximal and connects the forearm to distal carpal row while the other (the distal limb) consists of radioscaphocapitate ligament laterally and ulnocapitate ligament medially.

   The proximal limb consist of radioulnotriquetral and radio scaphoid ligament laterally and ulnotriquetral medially.
2. Dorsal Wrist Ligaments: These are radiotriquetral and scaphotriquetral ligaments which describe a V shape from the dorsal aspect of radius near Lister's tubercle to triquetral and then back to the dorsal scaphoid rim.

The dorsal ligaments are attached to proximal carpal row and volar ligaments are attached to proximal and distal carpal rows.

**<u>Intrinsic Ligaments</u>**:

These are intraarticular intrinsic ligaments connecting adjacent carpal bones. They are collections of relatively short fibres that bind to bones of either proximal or distal carpal rows to each other.

**Ulnar Collateral Ligament:**

It is attached to the ulnar styloid and divides into 2 slips, one slip is attached to medial side of triquetral and other to the pisiform.

**Radial Collateral Ligament:**

Extends from tip of styloid process of radial side to scaphoid and trapezium.

**RADIOLOGICAL ANATOMY**

Various radiographic measurements are used to evaluate anatomically the distal end of radius. The measurements are done on two standard views.

1. Posteroanterior (PA)
2. Lateral (Lat.)

The measurements are recorded in reference to the longitudinal axis of the radius. In posteroanterior and lateral views the longitudinal line/ axis is defined as the line through two points located in middle or diaphysis of radius at a distance of 3 cm and 6 cm proximal to radiocarpal joint.

Usually three radiographic measurements are recorded In anatomical evaluation of distal end of radius.

1. **Radial Angle:**

- It is measured on PA view.
- It is angle between a line joining the tip of radial styloid and ulnar comer of distal radial surface with a line perpendicular to longitudinal axis of radius.
- Also called as ulnar inclination
- **Sven Friberg** and **Bo-Liindstrom** in 1976 in their study described the range of ulnar inclination as 20° to 30°, the mean value being 25.4° and the standard deviation (S.D.) - 2.2°. There was no difference between sexes.

2. **Volar Angle:**

- It is measured on lateral view.
- It is defined as the angle between a line joining the volar and dorsal margins of distal articular surface of radius and a line perpendicular to longitudinal axis of radius.
- Mean value is 14.5° with a range of 4° to 22° and S.D. of 4.3°, There is no difference in sexes.

3. **Radial Length:**

- It is measured on PA view
- It is the distance between two perpendiculars to the longitudinal axis of radius, one drawn through the tip of radial styloid process and the other tangential to the distal articular surface of the ulna.
- Mean value is 12.8 mm range being 8-18 mm,

- It is lower for women (11.6 nun) than men (13.6 mm),

If we consider the bilateral measurements, average difference was seen in two wrists of the same individual. Most authors indicate a mean of 9.5° to 12° for the volar inclination of the articular surface (Nissen Lio; Gartland and Werley, 1951; Lidstrom; Golden, 1963; Frylnllan, Rochlin and Zeitler, 1968),

Based on measurements in 50 adults Keats et al stated a volar inclination of 6° as the normal value for males and 3° for females, They also indicated a range of variation from 11° volar to 4° dorsal inclination,

Wiklund and Miiller Aspcgrecn (1956) reported that the normal volar inclination varied between 5° to 15° and Gartland and Werley (1951) reported that the normal range is their series was 1° to 21°.

So if we look at the literature regarding the normal values of anatomical details of lower end of radius we find different values and a long range. So for an accurate assessment a comparison of the parameters measured in both wrists of the same individual shows that there are only small difference between the right and left wrists. Thus necessary values from one joint may be used as normal for assessing the other joint of the same individual.

Other measurements done are-

- The average distance between radius and ulna at the tip of inferior radioulnar joint is 0.3 mm.
- Subluxation of inferior radio ulnar joint - if on lateral X-ray triquetral shadow no longer lies in line with ulna.

**Ulnar Variance:**

It is measured on PA view. It is .the distance between 2 perpendicular to the longitudinal axis of radius, one tangential to the distal articular surface of ulna and other to the medial articular comer of distal end of radius. When the distal articular surface of ulna is distal to medial comer of distal end radius, it is called as positive ulnar variance while when distal articular surface of ulna is proximal to medial comer of radius it is called as negative ulnar variance. (When Colles' fracture settles with 2.5 mm of positive ulnar variance one can expect an increasing ulnar axial load of approximately 40%.) Development of these abnormal load patterns greatly increases the risk of secondary degenerative arthrosis at the contact stress points.

Newer studies are measuring the step and gap displacements of the articular surface described in mm from the normal circumference, of curvature of the radial articular surface. A step off of> 2 mm causes an increase in the incidence of osteoarthritis of the radiolunate and radioscaphoid joint thus adversely affecting the final functional outcome. (J. Knirk and J. Jupiter, 1986).

Articular Congmity grade by J. Knirk and J. Jupiter

| Step Off | Grade |
|---|---|
| U-1 llUll | 0 |
| 1-2 mm | I |
| 2-3 mm | II |
| >3mm | III |

The pattern of bone healing is also being recorded as documented by **Ulhtoff and Rahn.**

**I.** Trabecular internal healing from

Ia - Contact healing

Ib - Gap healing

II. Cortical Sealing Walls

IIa. With External callus

IIb. No bridging callus

## CLASSIFICATION SYSTEM

The description of a fracture of distal radius would be much incomplete without an initial recognition of the different types of fractures around distal end of radius.

Beginning with the classic description of an extraarticular distal radius fracture by Abraham Colles in 1814, many authors have reinvented fractures about the distal radius by their own classification depending on

- Location of fracture site.
- Direction of displacement
- Degree of comminution
- Joint involvement
- Associated ulnar styloid fracture

1. "This fracture takes place about qn inch and a half above the carpal extremity of the radius ... The carpus and the base of the metacarpus appear to be thrown backward so much as on first view to write a suspicion that the carpus is dislocated." (Abraham Co lies, 1814)
2. Barton's Fracture: "Subluxation of the wrist, consequent to a fracture through the articular surface of carpal extremity of the wrist" (John Rhea Barton, 1838).

It is actually a fracture dislocation in which the distal radius is displaced dorsally or volarly with the hand and carpus. The dislocation is most clinically and radiographically obvious anomaly.

- Type I - Dorsal Barton's
- Type II - Volar Barton's

3. Smith's Fracture: "A fracture of the lower end of radius 0 to 1 inch from the articular surface, in which the lower fragment and the carpus were forwards in relationship to the fracture" (Robert 1Villiam Smith, 1847)

   Also called, a reverse Colles' fracture, is a volarly angulated distal radius fracture with a "Garden Spade" deformity. This fracture may be extraarticular, intraarticular or part of a fracture dislocation of wrist.

Thomas[163] modified it in 1957 as

(a) Type I - Extraarti cuI ar

(b) Type II - Anterior marginal fracture with anterior subluxation of carpus

(c) Type III - Oblique fracture, displaced anteriorly and not comminuted.

4. Chauffeur's or Backfire Fracture:

   Occurred most commonly due to backfire of car handle (Starting Jack)

   "The Chauffeur's fracture is an oblique fracture of the lower end of radius by which a triangular piece of bone including the styloid process is separated from the main bone". (Harold C. Edwards, 1910)

(5) Lunate Load or Die Punch Fracture:

An articular fracture with displacement of the medial articular surface of rac1ius as described by **Rutherford** (1891) and **F.J. Cotton in** 1900. Selleck

(1962) coined the term "die punch" fracture, which usually represents a depression of the dorsal aspect of the Lunate fossa of the radius that allows proximal migration of the Lunate and or proximal carpal row.

Although these classification systems were in vogue, it was in 1951 that Gartland and Werley gave the first comprehensive system of classificaion, which subsequently showed new direction for never and sophisticated ones.

(6) Gartland and Werley (1951)

They were first to give the concept of intraarticular extension of the fracture. They noted that 88% fracture involved the articular surface.

(a) Type IA - Extraarticular

(b) Type IB - Extraarticular displaced.

(c) Type 1I - Intraarticular non-displaced (radio carpal joint)

(d) Type III - Intraarticular displaced (radio carpal joint)

(Type IB later added by Solgaard, 1965)

(7) Lidstrom's Classification (1959)

He based his classification on

- Articular involvement
- Amount of displacement
- Amount of comminution

Type I - Non displaced

Type II - (a) Extraarticular fractures with dorsal angulation

(b) Intraarticular fractures with dorsal angulation

(c) ExtTaarticular fractures with severe displacement

(d) Intraarticular fractures with severe displacement

(e) Intraarticular fracture with comminution with severe displacement

(8) Frykman's Classification (1967)

**Frylmlan's** classification has drawn the much-needed attention to the importance of distal ulna and distal radioulnar joint in the evaluation of treatment of distal radius fractures.

He divided fractures into 8 subtypes depending upon involvement of radioulnar joint, radiocarpal joint and fracture ulnar styloid.

| Type | Radicarpal Joint Involvement | Radioulnar Joint Involvement | Fractures ulnar styloid |
|---|---|---|---|
| I (Extraarticular) | - | - | - |
| II | - | - | + |
| III | + | - | - |
| IV | + | - | + |
| V | - | + | - |
| VI | - | + | + |
| VII | + | + | - |
| VIII | + | + | + |

This classification has its pros and cons:

Pros:

(a) Simple and effective

(b) Recognises the fracture of ulnar styloid process, which has an unfavourable outcome.

(c) Recognises the intraarticular component and this detennines the treatment protocol.

Cons:

(a) Does not differentiate between displaced and non-displaced intraarti cular fragment.

(b) Does not recognise comminution

(c) Does not recognise radial shortening.

Despite these, it is still most widely used classification and we have used it in our study as well.

(9) Melone's Classification (1987)

Melone recognised that many intraarticular fractures not only had instability but specific pattern of displacement. He identified that most intraarti cuI ar fractures had 4 components.

- Shaft
- Radial styloid
- Dorsal medial
- Palmar medial

} Medial complex' (Radial styloid, Dorsal medial)

He proposed four subclassifications

Type I - Undisplaced fracture with minimal comminution

Type II - Lunate fossa - die punch fractures

- Anterior displacement
- Posterior displacement

Type III - Dorsal displacement with radial spike (radial shaft fragment)

Type IV - Transverse split fracture (with fragment rotation)

He advocated closed treatment for type I and open reduction for 2/3/4.

(10) Universal classification (by **Cooney** et al, 1990)

In 1990 at a symposium conference on fracture of distal radius a new treatment related (universal classification) of distal radius fracture was proposed. This system was modelled after **Gartland and Werley's** system based on articular involvement, amount of displacement and stability of fracture.

| | |
|---|---|
| Type I | Extraarticular undisplaced |
| Type II | Extraarticular displaced |
| Type III | Intraarticular undisplaced |
| Type IV | Intraarticular displaced |

- Reducible and stable
- Reducible but unstable
- Irreducible and unstable
- Complex fracture

(12) Mayo Clinic Classification (1992):

This system tries to separate each articulation of the articular surface and thus recognize the Scaphoid, Lunate and sigmoid notch of radius as separate articulations.

| | |
|---|---|
| Type I | - Intraarticular undisplaced |
| Type II | - Involvement of radioscaphoid |
| Type III | joint |
| Type IV | - Involvement of radiolunate |
| | joint |
| | - Involves the radio scaphoid, radiolunate and |
| | sigmoid notch of radius. |

(12) Fernandez classification (1992):

He suggested a classification based on mechanism of injury with treatment recommendation for each subcategory based on the mechanism and displacement pattern.

| | |
|---|---|
| Type I | Bending |

| | |
|---|---|
| Type II | Shearing |
| Type III | Compression |
| Type IV | Avulsion |
| Type V | High velocity |

(13) AO/ASIF: (Arbeitsgemeinschaftfur Osteosynthesfragen/
Association of Surgeons for Internal Fixation)

This classification system is the most comprehensive and extensive system developed. In includes all the possible types of fracture of distal raelius. It has the advantage that fracture types determine the treatment protocol and have a prognostic value in the final outcome. It is organized in order of increasing severity of osseous and articular lesions.

There are 3 major groups each divided into 3 subgroups in which each subgroup have 3 subtypes. Thus overall there are 27 fractures patterns.

**A. Extraarticular fractures**

-AI Extraarticular fracture of the ulna, radius intact

1 Styloid process

2 Metaphyseal simple

3 11etaphyseal multifragmentary

-A2 Extraarticu1ar fracture of the radius, simple and impacted

1 Without any tilt

2 With dorsal tilt (Pouteau-Colles)

3 With volar tilt (Goyrand-Smith)

-A3 Extraarticular fracture of the radius, multifragmentary

1 Impacted with axial shortening

2 With a wedge

3 Complex

**B. Partial Articular fracture**

-B1 Partial articular fracture, of the radius, sagittal

1 Lateral simple

2 Lateral multifragmentary

3 Medial

-B2 Partial articular fracture, of the radius, dorsal rim (Darton)

1 Simple

2 With lateral sagittal fracture

3 With dorsal dislocation of the carpus

-B3 Partial articular fracture, of the, radius, volar rim (reverse Barton, Goyrand-Smith II)

1 Simple, with a small fragment

2 Simple, with a large fragment

3 Multi fragmentary

**C. Complete Articular fracture**

-C1 Complete articular fracture, of the radius, articular simple, metaphyseal simple

1 Postero-medial articular fragment

2 Sagittal articular fracture line

3 Frontal articular fracture line

-C2 Complete articular fracture, of the radius, articular simple, mctaphysealmul tifragmelltary

1 Sagittal articular fracture line

2 Frontal articular fracture line

3 Extending into the diaphysis

-C3 Complete articular fracture, of the radius, multifragmentary

1 Metaphyseal simple
2 Metaphyseal mul tifragmentary
3 Extending into the diaphysis

There are other classification systems, Older (1965), Sarmiento et al (1980), Solgaard (1985), Jenkins (1989), McMurthy and Jupiter.

## MECHANISM OF INJURY

For a long time in the late 17ili and early 18th centuries experiments on cadavers failed to produce any remarkable findings regarding the mechanism of injury. In late 18th century the work of **Lilicnfeldts** had to some extent shaped the conception of fracture mechanism at the wrist joint. He demonstrated that manipulating two factors viz. the position of hand and angle between the forearm and the surface of impact could vary the type of injury. Thus it was concluded that the direction of the traumatic force determines the type of wrist injury.

There are following three theories in literature concerning mechanism of injury in the fracture of distal radius.

(a) ***Blow/Counterblow Theory*** - Advance by **Dupuytren (1843)** Suggests that body weight generates a counter blow from the surface of impact which is transmitted to the carpal bone which is then transmitted to the distal radius as the head of the radius is impacted fiml1y against the humerus. This causes the distal radius to fracture at its cortico- metaphyseal junction where the bone is thinnest.

(b) *The Avulsion Theory* - It was pointed out that the design of the olecranon gives the ulna a much more intimate contact with the humerus, than the radius, and that consequently the ulna is probably alone absorbing the impact of the fall on the hand. The force is transmitted to the radius via the interosseous membrane and the strong volar carpal ligaments. The resultant fracture is then produced by avulsion due to traction in the strong volar radiocarpal ligament. This theory, suggested by **Linhart (1852)** and analyzed byLecomate (1861) was subsequently criticized that if avulsion is the primary mechanism one would expect the fracture line to run a volar proximal - dorsal distal course, whereas in fact it generally does just the opposite. It was later concluded that both mechanism probably act in combination.

(c) ***The Bending Fracture Theory* -** This was first suggested by Meyer (1928) who definitely rejected the avulsion theory. He argued that the course of the fracture in the individual case is determined by three factors, the position of the hand, the surface of impact, and the magnitude of the force. If tension simultaneously arose in the ulnar collateral ligament, there would be an accompanying fracture of the ulnar styloid process.

Lewis (1950) envisaged the bending fracture mechanism as follows: The absence of other abrasions on the palm suggests that at moment of fracture, the hand stays put on the surface of impact, the kinetic energy causes the forward movement of the body to continue, the wrist becomes hyper extended and the patient falls over the hand. Thus loads the volar articular surface, the force being stopped by the Scaphoid and Lunate bones. It is then transmitted to the radius, which, factures at its weakest point in the same manner as a beam that is loaded beyond the limit of its elasticity. Lewis so considered this fracture as 'Bending Fracture"

In considering comminuted intraarticular fractures, however, all three mechanisms appear to come into play.

***Pathomechanics of Fracture:***

Biomechanical experiments show that ·fractures of distal radius were obtained when the wrist was loaded in 40°-90° of dorsiflexion and 0-35° of ulnar and radial deviation. Considerable force appears to be required to produce this fracture with the mean of 195 kg for women and 282 kg for men.

When a person falls on the outstretched hand, the radius through rigidity bonded carpus, bears the force transmitted through the thenar eminence. A great strain is thrown upon the palmar carpal ligaments and the line of force drives the carpus upon the radius. The radius first fractures on the volar surface in tension. Then the fracture propagates dorsally where the bending movement forces induce compression stresses resulting *in* dorsal cortex comminution or the fracture line producing the 45° sheer stress lines. The cancellous bone is compacted further reducing dorsal stability. **Charnley** has shown that the dorsal comminution is a cause of late collapse of the radius during the period of immobilization.

The Colles' fracture occurs while the triangular fibrocartilagenous disc of inferior radioulnar joint is still intact. Therefore, distal fragment rotates on thus lunge with the centre of rotation at the ulnar styloid in the direction of supination. If the force is excessive and continues to act, the strain thrown upon the disc may bring about the fracture of ulnar styloid.

Hyperextension is commonly considered the major force causing these fractures. But the intraarticular fractures are prevalent among physically active persons whose wrists are exposed to violent multi component force comprising of compression, shearing, tension and direct crush. The prominent among these forces is axial compression where by proximal carpus (Lunate) acting like die-punch impacts and disrupts the distal radius articular facets. So the resultant articular fracture comprises of four components: 1. Metaphyseal or Shaft, 2. Radial styloid, 3. Dorsal medial and 4. Palmar medial. The dorsal medial fragment is referred to as die-punch fragment as coined by Scheck (1968).

**Motion in Wrist Joint:**

Indeed no other animal can so effectively transmit torque into the hand from the forearm for the accomplishment of specific tasks. It is this function which in part makes the wrist so complex a functional wrist.

The mechanical equivalent of radiocarpal and medial part of midcarpal joint is a link joints such as exists in the simplest form between the units of chain of a bicycle.

In each of these chains the proximal carpus functions as an intercalated bone. The specific shape of these intercalated bones establishes a simultaneous movement in radiocarpal and midcarpal joint, which makes; flexion, extension, deviations or combination possible.

Typical of the confusion that currently exists is the controversy concerning the location of the normal centre of rotation for radial and ulnar deviation of the hand relative to forearm. Kapandji states that this centre lies between the Lunate and the Capitate, whereas MacConaill, Volz and Von Bouin contend that it remains in the head of the Capitate. 'Vriglle believes that the centre is the head of the Capitate for radial deviation. Linscheid and Dobyns state that the centre remains in the neck of the Capitate, whereas Landsmeer locates it in the body of the Capitate.

The situation for normal flexion and extension motion of the hand relative to the forearm is also confusing. Fick and Kapandji believe that there are 2 parallel and closely spaced axes of rotation located in the radiocarpal and midcarpal joints. MacConaill and Volz state that there is a single axis of rotation that remains in the head of the Capitate. Wrighe also believes that the centre of rotation is located in the head of the Capitate during flexion, but states that for extension the centre lies at the intercarpal joint.

Robert J. Schultz in his book *"The Language of Fracture"* in 1972 described that abduction (radial deviation) occurs mainly at the mid carpal joint (60-65%) and adduction (ulnar deviation) primarily at radiocarpal joint (approximately 55-60%). Flexion occurs predominantly at radiocarpal (65-75%) and extension mostly at mid carpal joint (7585%). Circumduction occurs as a combination of the motion of adduction, abduction, flexion and extension.

The mean values of maximal excursion of motion of wrist joint is follows:

| | | |
|---|---|---|
| Dorsi flexion | - | $90^0$ |
| Palmar flexion | - | $90^0$ |
| Ulnar deviation | - | $50^0$ |
| Radial deviation | - | $40^0$ |

In the forearm, pronation and supination take place involving the proximal and. distal radioulnar joints. The mean values of maximal excursion of pronation and supination are:

| | | |
|---|---|---|
| Pronation | - | $90^0$ |
| Supination | - | $90^0$ |

The ulnar head forms a pivotal point, in relation to which normal position of the other bony landmarks are determined and about which all motions of the wrist are believed to occur.

The motion of wrist occurs in three planes. Each one plane for flexion/extension, radial deviation/ulnar deviation and supination/ pronation. During radial deviation the motion occurs at intercarpal joint (i.e. between proximal and distal carpal row). Motion of proximal carpal row (scaphoid, lunate, and triquetral) relative to the radius and each other is negligible.

During ulnar deviation motion occurs at both intercarpal and radiocarpal joints. During flexion extension, motion of the wrist occurs with synchronous rotation of proximal and distal carpal rows.

According to Sarrafian *et al* (1977) the average in degree and percentage of total wrist motion in flexion extension as an average of 100 wrists is:

| | | | |
|---|---|---|---|
| Flexion | R-C | : | 26.2° (40%) |
| | I-C | : | 40.1 ° (60%) |
| Extension | R-C | : | 3r (66.5%) |
| | I-C | : | 18° (33.51%) |

**Functional Wrist Motion:**

The function of various joints of the upper extremity IS to position the hand in space so that it can perform activities of daily living. The wrist seems to be the key to hand function.

It is an established fact that an arc of 45° of wrist motion (10° flexion to 35° extension) is sufficient to perform most of the activities of personal Care.

The activity of eating and drinking needs a range of approximately 3° of flexion to 35° of extension. The other daily activities like raising from a chair, reading a newspaper, using a telephone also requires wrist extension of zero to 63°. Rising from chair employs the greater arc of motion of nearly $63^0$.

***FORCES AROUND WRIST:***

For practical purposes the intrinsic forces supplied by the musculo-tendinous units crossing the wrist are most important in that they act continuously on carpal elements. External forces become important when they exceed the constraint forces of the carpal ligaments or the strength of the bones. The muscles of the wrist e.g. the flexor carpi radialis and extensor carpi ulnaris are arranged around the perimeter of carpus in a fashion that provides optimal force arm for wrist control.

**Stability of the Wrist:**

The proximal carpal row, as the intercalated segment of two-link system that in a simplified version is considered the radius, lunate and capitate is inherently unstable. Since the capitate-lunate column is highly unstable, the radial ulnar column supplies the stability. Moreover, the intrinsic interosseous membrane between the proximal carpal rows contributes to the stability.

Dissociation of lunate and triquetral leads to a palmar flexed deformity of volar intercalated segment instability (VISI).

When interosseous membranes are intact, the carpal row retains relative stability.

Dissociation of the scapholunate area results in a dorsiflexion of lunate or a dorsal intercalated segment instability (DISI) pattern.

**Contact Areas and Load Bearing of the Wrist:**

As with the other joints, there appears to be a combination of rolling and sliding motion, which protects anyone area of the joints from prolonged or excessive loading and the cartilage from shear stress.

On inspection of the articular surface of radius and TFCC from the carpal aspect, a total surface of 320-370 $mm^2$ (avg. 342 $mm^2$) is noted. The lunate fossa accounts for 43% and TFCC for 11 % of this area.

Using the technique of arthography, the contact area appears to be the greatest in the dorsiflexion and ulnar deviation, and least in the palmar flexion and radial deviation. This accords well with the position of power grip, which occurs in the dorsiflexion and ulnar deviation position and should require the largest contact area. On careful reading of sections of tomography it appears that under light loading conditions the moment of force created is distributed to both palmar and dorsal aspects of radial curvature. These findings may help in understanding the position in which distal radius fractures are casted and or immobilized e.g. dorsal displacement in a Colles' fracture is treated in palmar flexion to oppose the moment of force acting to displace the distal fragment dorsally.

**Ulnar Variance and Load Distribution:**

Ulnar lengthening or radial shortening and ulnar shortening or radial lengthening has important effects on load borne by ulna. Ulnar shortening of 2.5 mm results in drop of force borne by distal ulna from an average of 18% of the force to 4% of the total forearm forces. Ulnar lengthening of 2.5% nun results in increased forces over the distal ulna to 42% of the total forearm forces.

**Distal Ulnar Stability:**

The extensor retinaculum, pronator quadratus and geometry of sigmoid notch are important stabilizers of the distal radioulnar joint. The role of dorsal and volar radio-ulnar collateral ligaments is yet to be proved.

## BIOMECHANICS OF WRIST

In English the word "Wrist" persists from the old Teutonic (wraestan) which means to twist and also accounts for wrest and wrestle.

Numerous studies were carried out to evolve our knowledge of kinematics of wrist. The study of Wrist motion began in the true sense after the discovery of x-rays in 1895 by Roentgen. Efforts subsequently were made to analyze the motion of wrist using various techniques such as stereoscopic and plane radiographs, plaster moulds and dissection, cineradiography and simple dissections.

**MECHANISM OF CARPAL JOINT:**

It is known that the wrist joint allows the hand to combine dorsopalmar flexion and radio ulnar deviation and that this unique combination of function is made possible by highly complex system of joints that involves simultaneous movements at the radio-carpal and midcarpal levels as well as between the individual proximal carpal bones which are bound together by ligaments. The mechanism underlying the movements of the hand to forearm have been evaluated throughout the use of mechanical models that have been based all number of different principles. Two such theories are:

**(1) Fixed** Row **Concept:**

It was generally recognized that movements of wrist joint involve mutual displacement of proximal bones. The mechanism of wrist joint was approached from the assumption that both the distal and proximal carpal rows were rigid bodies that moved to relation in the radius and ulnar articular disc but without any movement amongst the individual bones of each row. According to Henke's model, the movements of the hand to forearm i.e. flexions and deviations are brought about by different combination of movements that may occur in the same direction or in the opposite direction at both the radiocarpal and midcarpal joints. This theory yields only a description of the movements of hand to the forearm offering no insight into the mechanism of the wrist joint.

**(2) Carpal Link Concept:**

Put forward by Gilford (1943), the wrist joint function as a link joint, consisting of three longitudinal articulation chains of which the capitate lunate radius chain forms the central part. This system has as an advantage in that each joint in the chain has to move only half the range of the total excursion of the hand. The chain can move mediocarpally and radiocarpally, but these movements are independent of each ether. Therefore the scaphoid, acting as a bar connected to all members of the central chain or acting as a slider crank, cannot prevent a zigzag deformity of the lunate chain.

It has been suggested that the mechanical equivalent of the radiocarpal and the medial part of the mid carpal joint is a 'Link' joint such as exists in its simplest form between the units of the chain of a bicycle. This type of joint is stable only when it is under tension and 'on centre' i.e. when the links are in line, and unless it is strengthened by the addition of a 'stop', mechanism, it buckles when subjected to a compression force acting in its long axis, especially when it is 'off centre'.

The mechanical equivalent of the radiolunate and the lunatocapitate join is a simple pivot located at the centre of rotation of each joint. The displacement of control chain depends to a large extent on the shape of intercalated lunate. The four end positions of intercalated lunate with respect to capitate and" radius are:

**Dorsal Flexion:** Lunate shifts to radius palmarly and to capitate, dorsally.

**Volar Flexion:** Lunate shifts to radius dorsally and to capitate palmarly.

**Ulnar Deviation:** Lunate shifts to radius and capitate palmarly.

**Radial Deviation:** Lunate shifts to radius and capitate dorsally.

Thus the position of carpal bones and the relationship between these changes and the joint functions by means of intercalated bones, as they move simultaneously at the radiocarpal and mid carpal level.

**KINEMATIC CONSIDERATION OF WRIST:**

The wrist functions both kinetically by transmitting forces from the hand to the forearm and vice versa and kinematically by allowing for changes in the location and orientation of the hand relative to the forearm.

The intrinsic forces acting on the wrist are well distributed around the perimeter. While the extrinsic forces for the fingers are centralised of affect wrist position minimally. The stability of the wrist in which the proximal carpal row presents an inherently unstable intercalate segment is provided by complex osseo-ligamentous arrangement. The scaphoid performs a unique function as a mechanical link between the carpal rows, interacting with arcs of oblique ligamentous support for radiocarpal areas. This allows synchronous angulation (: f the proximal and distal carpal rows and by virtue of correct angulation, adaptive geometric change to encourage radial-ulnar deviation. Tile distal radio-ulnar joint functions both as support of the carpus on ulnar aspect of the joint and as a primary pivot for forearm rotation through a unique anatomic arrangement.

The movements at the wrist occur in three planes as flexion extension motion (FEM), radio-ulnar deviation (RUD), and pronation supination movements (PSM). In normal wrist this amounts to approximately 2.5 radians (140), one radian (60) and 2.6-radian (150) respectively.

In mechanical terms, this represents three degree of freedom, one for each axis. A single joint with three degrees of freedom, such as hip or shoulder is however, difficult to stabilize without massive circumferential muscles, a condition clearly impossible to achieve without displacing the mass moment of inertia well down the arm. The design of wrist solves this problem uniquely; it has a compound joint consisting of radio-carpal (Re), inter-carpal for the former two functions and the distal radio-ulnar joint (DRUJ) for the latter.

Anatomically, the wrist consists of eight bones; of these seven are conventionally assigned together the proximal or distal carpal rows.

As such the wrist consists of two rows or three colunms:

**Two Rows Are:**

**(a)** Proximal Carpal Row

**(b)** Distal Carpal Row

Scaphoid acts as connecting link between the two on radial aspect.

**Three Columns Concept:**

In 1919, Navarro (quoted by Scaramuzza) introduced his concept of the columnar or vertical carpus. He proposed that the carpal bones be grouped into three vertical columns; central, or flexion extension column, formed by the lunate, the capitate and the lunate; lateral or mobile column composed of the scaphoid, trapezium and trapezoid: medial or rotation colunm consisting of the triquetral and pisiform. A modification of Nayarro's theory was advanced in 1976, whereby the central column was expanded to include the lunate and all four of the distal carpal bones, reducing the lateral column to the scaphoid and the medial column to the triquetral.

In 1941, M.A. Macconaill: made an analysis of carpal movements using cadaver specimen and roentgenograms, which contrasts sharply with the foregoing account. It is pointed out that in most positilll1S of the hand, the carpal bones are loosely packed and relatively mobile and those they becomes a rigid block in full extension which is the close packed position for both radio carpal and most carpal joints. Further close packing is achieved in two distinct stages. The carpus IS regarded as divisible into four functional parts: (1) Trapezium, (2) Scaphoid (3) Hamate, capitate and Trapezoid (4) Triquetral and Lunate. When passing from full flexion to full extension the follow-; .g stages are considered to occur.

Initially the distal row (i.e. 3) moves on the proximal row (i.e. 2 and 4) until the hand is approximately in line with the forearm, at which point the hamate, capitate trapezoid and scaphoid come into mutual close pack and form a rigid mass (i.e. 2 and 3). During the second stage the rigid mass moves as a whole upon the triquetral and lunate which themselves move at the radio-carpal joint until full extension is reached, with close-packing of the radiocarpal joint and most of the carpal joints (i.e. except the articulation of pisiform and trapezium). In such a position, which is adopted only when a special effort is to be made, exceptionally large forces may be generated across the articular structures. A similar position is often, assumed during a fall on the out stretched hand and commonly results in traumatic damage e.g. a 'supination (Colles') fracture, a fracture of scaphoid or a dislocation of lunate.

**Lichtman (1981)** proposed a ring concept of wrist kinematics. According to this concept, the interosseous ligaments stabilize the semirigid proximal and distal carpal rows. Limited mobility occurs between the scaphotrapezial joints and the triquetrohamate joints. Bone or ligament disruption of the ring creates instability deformities, with the Lunate titling either dorsally (dorsal intercalated segmental instability [DISI] or toward the volar aspect (volar intercalated segmental instability [VISI]

**Biomechanics of Treatment (John M Agee, 1987)**

As the dorsal cortex fails in compression the dorsal soft tissue periosteal hinge remains intact. **DePalma (1952)** demonstrated in cadaver models that ligaments of the wrist joint i.e. the extrinsic and intrinsic remain intact even in severely comminuted fracture. This cadaver study has a very important role in the biomechanics of the treatment of this fracture.

As shown in the figure when a longitudinal traction 'T' is applied to the hand it causes generation of traction force in the carpus which is transmitted via the intact wrist ligaments (mainly in the extrinsic groups connecting the distal radius to the proximal and distal carpal row) to the distal radius. This causes a correction of the radial length. For impacted fragments ligamentotaxis on a distractor assembly puts the ligaments in tension thus causing disimpaction of the fragments. Normal radial length maintenance occurs along with a near anatomical reconstruction of the distal radial articular surface due to the realignment forces acting in presence of normal soft tissue structure around the fracture.

Once the normal radial length has been maintained a translating force 'F' acting at the mid carpal level causes palmar translation of the carpus. This force 'F' is generated by the routine palmar deviation used during cast application. When an external fixator is applied a dorsolateral positioning of the distal Schanz screws causes palmar displacement of the carpus during ligamentotaxis. This palmar translational force 'F' leads to generation of a 'moment of rotatory force'· '$M_{DFT}$' with it·; centre at the head of the capitate. Around this axis the Lunate rotates which in the presence of a normal dorsal periosteal soft tissue acts like a hinge thus bringing along with it the distal radial articular surface to face in a volar direction but excessive force is generated to correct the radial length it causes an exaggerated dorsal tilting of the articular surface because the dorsal periosteum acts like a hinge and there occurs dorsal movements of the distal radius as its is the short lever arm.

Once these two deformities are corrected a ulnar deviation of the carpus causes correction of radial inclination. In a cast this is obtained by ulnar deviation of the wrist while in an external fixator a slight lateral over distraction cause's ulnar translation of the carpus thus causing correction of the radial tilt.

So we see that application of a Cast or External Fixation in the correct biomechanical principles causes correction of all the three factors responsible for an Anatomical and Stable reduction. So in our series, we have used these 2 methods in the treatment of intraarticular fracture of the distal radius.

## REVIEW OF LITERATURE

The anatomical nature of many of the more troublesome fractures and dislocations about the wrist joint was clearly identified prior to discovery of X-rays. Among the 1st to distinguish the impacted radius fracture from wrist dislocation was **Pouteau** of Lyon in 1780. In France and other parts of world this fracture was called "Pouteau's Fracture ".

In **1814, Abraham** Colles (1773-1843). Professor of Anatomy and Surgery at Trinity College in Dublin clearly identified the fracture. In the same paper (published in Edinburgh Medical and Surgical Journal) he outlined the treatment of his choice.

"This fracture takes place about an inch and a half above the carpal extremity of radius. If surgeon holds his hand in that of patients and make extension even with moderate force the restores the limb in its natural form but distortion of limb instantly returns an extension being removed".

In **1836, Goyrand** substantiated his clinical observation with post-mortem examination of distal radius fractures of two types (some with dorsal displacement while other with volar one).

Although the method of reduction by manipulation is widely accepted, the technique of immobilization is widely debated. A variety of methods have been evolved to devise a method of fixation which would prevent effectively re-displacement of the distal fragment during immobilization and also would permit functional exercises at the earliest possible.

Abraham Colles (1814) used anterior and posterior splints to maintain reductions. In first quarter of present century the treatment had altered little from original immobilisation of Colles by Wooden "Carr splints" where immobilisation with different types of bandages become popular and has been recommended by Lexer (1909), Trocell (1913), Huelsmann (1923).

Bohler (1919) used only dorsal splint for immobilisation. Many authors consider this fixation inadequate. White (1940), Wire (1948); Humphries (1949), Cozen (1951), Me Nutt (1956) Glock, Mackel and Brown (1957) immobilised the fracture of distal radius in a circular plaster cast extending above the elbow. Cassebaum (1950) stated that permitting elbow motion is a frequent cause of motion at the fracture site with subsequent loss of reduction. So they immobilised the elbow.

Taylor and Parsons (1938) and Mayor (1940) considered this type of fixation necessary only in fractures associated with instability in the radio-ulnar joint. Others adopting a middle path, used circular plaster casts around the forearm only (Klapp, 1921; Gurd, 1937; Hozensgard, 1945; Chandler, 1950; Osmond, Clark, 1951) or both a volar or dorsal plaster splint (Hitzrot and Murray, 1921;

Charnley and Mroz, 1932; Gartland and Werley, 1951)

The frequency of comminution in this fracture is witnessed by bite (1940), who reported an incidence of 74 percent comminution in 66 patients. The amount of comminution varied from gross shattering of distal radial fragment with displacement of extra and intra-articular fragment in various directions to less extensive crushing limited to the iorsal and lateral cortices.

In 1929, Bohler published his method of reduction of comminuted fracture by longitudinal traction and its maintenance by ske1etal pins incorporated in plaster cast.

In 1944, Roger Anderson and Gordon O'Neil described new method of immobilisation by use of 2 slender rods instead of POP cast and reduction through skeletal traction and counter traction.

DePalma (1952) described ulnar pinning temporarily fixing the reduced distal radial fragment to ulna by means of a threaded wire.

Bacorn and Kurtzke (1953) reported a series of 2000 cases recorded by New York States Workmen Compensation Board in Which only 2% had no permanent disability and the average disability regardless of age and adequacy of treatment of severity of fracture was 24 % permanent loss of function of the hand.

According to Green and Gay (1956) average disability was 19% and permanent loss of function of hand varied from 25% to 50%. So they concluded that accurate reduction and maintenance, frequent radiological studies, mild over correction, preyention of oedema and early exercises of joints of the upper limb are desirable.

F. Brian Thomas (1957) gave classification of ventrally displaced fracture and pointed out that a ventrally displaced Barton fracture is a pronation injury best immobilised in supination.

John J Dowling and Blackwell Sawyer (1961) used internal fixation by using Steinmann pin through an' intact ulna as a fixation point obliquely across upon the radial styloid.

In 1962, Sheck reporting on 24 patients treated with Kirschner wire transfixation and cast immobilization acknowledged 21 percent unsatisfactory results.

In 1966, James M. Cole and Benjamin E. Obletz treated 54 patients of comminuted fractures of the distal end of the radius by skeletal transfixation in plaster cast. One Steinmann pin was inserted into bases of fifth and fourth metacarpal and second Steinmann pin was inserted into the mid shaft of the radius, penetrating both cortices. Plaster cast applied incorporating the pins from the metacarpal heads to the proximal end of forearm.

Jerry Knirk and Jesse Jupiter (1986) in a classic treatise on the intra-articular fracture treated by various methods demonstrated that after 6.7 years articular surface reconstruction was the most critical factor in achieving a successful result. An articular step off of > 2 mm invariably leads to an occurrence of osteoarthritis of the radiocarpal joint.

In 1969, Spira E. and Weigl K with 84 cases of comminuted fractures of distal end of radius with articular involvement reported 51.4% unsatisfactory results with reduction and use of cast.

In 1972, Henry Marsh and Stephan Teal advocated effectively Bohler's method of skeletal traction.

In 1973, Thomas Laughin introduced a new concept in which K-wire was introduced in second and third metacarpal bone and another in proximal radius and both incorporated in below elbow cast.

In 1973, Christopher pool in his prospective study of treatment of Colles' fracture mentioned the most common site 9f residual pain was over the ulnar collateral ligament whether or not the ulnar styloid fracture united. Compression of median nerve was $2^{nd}$ most common complication. Sudeck's atrophy was found in only one case. Last but not least was that many patients had some residual deformity. He concluded that above elbow plaster cast was not advantageous, rather many have some disadvantages.

In 1975, David P. Green reported complications in 20 cases out of 45, disconcerned whether the complications were major or minor. Failure of maintenance of reduction achieved was the most common complications.

In 1975, Augusto Sarmiento from Maine advocated functional cast bracing in supination to overcome deforming force of the muscle - brachioradialis. He reported redisplacement in 39%. Few cases had restriction of finger movement.

This method also did not entirely prevent collapse of the fracture; small amount of collapse in most cases 1 S encouraging.

Charnley advocated his theory of "controlled collapse" of cancellous bone for fracture union. The cosmetic appearance of the wrist was acceptable and grip returned rapidly according to him.

Position of hand during immobilization has also been given importance with the idea that by adopting a certain position of hand, re-displacement of distal fragment might be prevented and integrity of radio-ulnar joint might be restored. Cotton (1910) advised immobilization in position of extreme flexion and ulnar deviation at wrist. Good results were reported with this method by Breatz (1887), Trocell (1913), Walking (1938), Chandler (1950), Milch (1950), Gartland and Verley (1951) and McNutt (1956), Parson (1938) and Mayor (1940) stated that triangular cartilage heals better by adopting this method.

Lambrinudi (1938) opined that Colles' fracture is supination injury and hence advised immobilisation in pronation after reduction.

Carothers and Berning (1949), Platt (1952) used a position of moderate palmar flexion. Bohler (1919) described a fixation with extended wrist midway between pronation and supination combined with moderate ulnar deviation. It still seems to be the one most generally accepted (Hansa, 1962; Kudelka, 1963; Mandell, 1965; Rehn, 1965).

Several authors, however, prefer a completely neutral position for the wrist i.e. midway between flexion and extension, ulnar and radial deviation, pronation and supination (Saren, 1985).

Guttman (1959) and Mack (1959) also recommended neutral position between flexion and extension for wrist but in combination with ulnar deviation. This position of immobilization was most common in Lidstrom's (1959) series.

Re-displacement is one of the fundamental problems in the treatment of fractures of the distal radius due to the fact that it is a characteristic compression fracture. Cornell (1935) among others observed that the force of injury produces a triangular zone of compression on the dorsal angulation. A similar zone radially results from radial displacement. It soon became obvious that the usual methods of immobilization could often not prevent the reduced fragments from slipping back to more or less the original position of fracture. Muscle pull (Brachioradialis) has been considered an important factor in causing redisplacement (Klapp, 1921; Bohler, 1923; and Sarmiento, 1975.

Frequency of redisplacement varied with authors. Nissenlie (1939) reported 42% redisplacement in 143 cases. Madsen (1946) reported frequency of 59% redisplacement, Hotlland (1957) 46% redisplacement. Gartland and Werley (1951) observed a frequency of 60% redisplacement. Lidstrom (1959) recorded 23% redisplacement, lark and Magor (1953), 26% and Leung F (Dec. 2000), 28%

Incidence of malunion is also a common finding in Colles' fractures. Boyd and Stone in 1944 studied the results of resecting the distal ulna. There were 22 resections in 20 patients. In every instance appearance of wrist was improved.

Motion in wrist was improved especially pronation and supination and ulnar deviation and in some instances dorsiflexion.

Albert et al (1963) studied 21 patients after resection of distal ulna for old Colles' fracture. Nineteen had full pronation and supination or less than 10° restriction and other 2 had 30° or less restriction. All had noticed improvement in grip and function of the hand.

As one of the prime problems in the management of these fractures was that of radial shortening, Roger Anderson and O'Neil were the first to give the use of an external fixation device in the treatment of comminuted intraarticular fracture of distal radius. The corrected position was maintained throughout the duration of treatment and thus resulted in good anatomical and functional outcomes.

Though Malgaigne first used external fixator in 1853 for fractures patella by a claw like device, Parkhill (1897) described use of two half pins above and two below the fracture in long bones externally joined by ingenious clamp.

Pikin and Blackfield (1931) were first to advocate pin inserted through both cortices.

In 1974, Gyorgy Fenyo and Ozoflsacansson[77] described that in a prospective investigation of 100 fracture of the distal radius, secondary displacement exceeding a dorso volar angulation of 10° occurred in 20 percent of the cases. They further emphasized that correct treatment of a distal fracture of the radius was still a subject of divergent views in literature. Correct anatomical healing, however is generally regarded desirable. This presupposes good reduction, fixation and effective control of possible redislocation in order to be able to correct it when necessary.

Willam Grana and Joseph Kopta (1979) have used the Roger Anderson devise in 21 patients having intraarticular fractures of radius with the aim of preventing the integrity of the radiocarpal joint and giving a good range of motion. 71 % of their patients were 45 years or younger who may be expected to place heavy demands on their wrists. They reported 16 satisfactory and 5 unsatisfactory results with 3 complications. They concluded that this device provides satisfactory immobilization and functional results in-co-operative young and active patients

W.P. Cooney (1979) reported that the early loss of reduction and late collapse after Colles' fractures are 2 complication that are not readily accepted. This is due to the excessive comminution and inadequate reduction and adequate reduction requires the radial length to be restored. This requires stable volar buttress plus dorsal tension by tissue or appropriate apparatus that prevents dorsal collapse (external fixator).

William P. Cooney (1979) used a quadrilateral frame (double pin Roger Anderson device) in 130 patients with unstable Colles' fractures. 88% were intraarticular. Mter following up for 2 years and evaluating with McBride system 90% satisfactory and 10% satisfactory results were obtained with 16% patients having pin loosening as a non sequelae complication. They opined that a strong, painless wrist with excellent motion and good strength is finally assured in all but a small percent of patients.

In June 1980, P. Connel et al studied the complications of Colles fracture at Mayo clinic and found complications in 31 % i.e. in 177 out of 565 cases, out of that neuropathy in 45 cases, radio-carpal and radio-ulnar arthritis in 37 cases, malunion 30 cases, tendon rupture 7 cases. Volkmann's ischaemia 4 cases, shoulder hand syndrome in 20 cases and finger stiffness in 9 cases. Methods of treatment adopted were; 86 patients by closed reduction and plaster, 17 cases primary external pin fixation and in twenty cases secondary external pin fixation. Complication were more found in unstable i.e. Frykman IV to. VIII fractures.

In 1980, W.P. Cooney, J.H. Dobyns and R.L. Linscheid pointed out that the soft tissue injury was partly responsible for the resulting stiffness. After early mobilisation of an injury, the blood supply to bone and soft tissues returns rapidly to normal and joint stiffness is reduced (Miiller, et aI, 1979; Salter, et aI, 1980).

In 1981, W. Vander Linden and R. Ericson used five different types of below elbow plaster cast immobilisation in 250 cases of Cplles fracture. Whatever type used the anatomical and functional results were surprisingly similar.

George Lucas and K. Sachjten (1981)65 have used rush rods (designed by Leslie Rush, 1949) in fixation of comminuted distal radius fractures. They reported 32 satisfactory and 1 unsatisfactory results out of 33 patients and stated that hand function is the main goal of treatment of wrist fractures and rush rod immobilization for Colles' fracture in an easy method with minimal postoperative immobilization which encourages joint and finger movement, thus avoiding osteodystrophy and finger movements.

G.K Frykman and G.S. Tooma (JHS 1989) have compared 11 fixators for treatment of wrist fractures on the basis of rigidity, weight, cost, design structure and provision for wrist motion. The fixators studied were Roger Anderson frame, Hanson Baylor Mini Hoffman, rectangular mini Hoffman, Ace-Colles, Unilateral C series Hoffman, Bilateral C-series Hoffman, small AG., Methyl methacrylate, Regular Hoffman, Clyburn and Orthofix. Based on the above they have prepared a fornlat that will guide the surgeon in the selection of an appropriate fixator for his patient.

W.P. Cooney (CORR 1983) has analyzed the results of treatment of comminuted intraarticular dista1 radius fracture by 4 different externa1 fixator frames. 60 patients were treated by the Roger Anderson devise using K-wires, 15 patients with Ace-Colles fixator using threaded 3 mm half pins, 15 with mini Hoffman fixator using 3 mm threaded pins inserted into distal radius (not in 2$^{nd}$ metacarpal) and 10 patients with Hoffman C series with (3 mm Hoffman pins). The reduction technique used was similar in a11 100 patients. The results were as follows:

| | |
|---|---|
| R.A. Frame (N=60) | 90% Satisfactory (Excellent + Good) |
| | 10% Unsatisfactory |
| | 30% Complications rate with maximum incidence of pins loosening. |
| Ace-Colles Unit (N=15) | 93% Satisfactory |

| | |
|---|---|
| | 7% Unsatisfactory |
| | 26% complications rate with minimal pm loosening. |
| Mini-Hoffman (N=15) | 80% Satisfactory |
| | 33% complication rate |
| Hoffman Series (N=10) | 60% Satisfaction results |
| | 30% complication rate |

Charles P. Melone (1984) gave the need for differentiation between extra and intraarticular fracture of distal radius. Based on his experience of 330 articular fractures he proposed his classification system with a guide for best treatment in each group. He divided the fractures into having four basic components (Please See Classification).

Stewart (1984) et al using an orthoplast brace 10 days after injury was unable to demonstrate any advantage in early mobilization over conservative treatment since months after the fracture.

In treatment of comminuted Colles' fractures K-wire fixation has been used alone, in combination with external fixator or with plaster (Green 1975; Clancey 1984; Wanger and Jakob 1985; Puna and William 1986).

Marti and Polowaski (1984) advocated internal fixation and cancellous bone grafting for comminuted fracture.

Paul Vaughan and Spencer Lui (JBJS 1985) also used the R.A. frame in 52 patients with 80% cases being intraarticular. Using Lucas modification and

Sarmiento demerit point system they had 89% good + excellent results with 84% complication rate. Contrary to the observations made by Grana and Kopta (1978) they had good results eyen in elderly patients.

Martyn, Porter and Ian Stockley (1985) published the intermediate and end result in relation to radiological parameters in comminuted fractures distal and radius.

S.C. Weber and R.M. Szabo (JHS 1986) critically analyzed the complications associated with external fixators versus pins and plaster in severely comminuted distal radius fractures. 13 patients were treated by external fixation in their series and they noted a very high rate (61 %) of complications in these patients. They recommended a careful patient selection for external fixators in severe comminuted fractures but still consider them as an unsolved problem.

Jerry Knirk and Jesse Jupiter (1986) emphasized the importance of reduction of Scheck's dorsomedial "dies punch" fragment. They stressed on the use of external fixator with distracter to pins and plaster treatment. They also advocated use of additional percutaneous Kwire fixation for comminuted fragments.

In 1986, Melone treated severely comminuted fracture of lower end of radius by open reduction and internal fixation usually with multiple Kirschner wires followed by early mobilisation. He failed to achieve adequate anatomical reduction reporting an average loss of radial length of 3.2 mm and an average loss of volar tilt of $8.5^0$, 93% of these patients had some joint irregularity or degenerative change.

J. Kongsholm and C. Olerud (AOTS, 1987) treated comminuted Colles' fracture with external fixation and compared the results with cast treatment. They used Lidstrom's criteria for result evaluation and stated that external fixation has the following advantages.

- Better radiographic position.
- Lower frequency of pseudoarthrosis of ulnar styloid.
- Better range of motion with better grip strength in comparison to conservative treatment.

In February 1987, T.A. Clyburn[31] from Texas published paper on dynamic external fixator (whose design was based on work of Y OUID et al) for comminuted distal radius fracture only. Out of 32 patient 29 were followed. He claimed that external fixator maintained reduction and allowed early functional range of motion of wrist.

In March 1987, N.H. Jenkins and others treated 58 patients aged less than 60 years with Colles' fracture, either by a forearm plaster or by the application of an external fixation. The external fixator proved more effective at holding the manipulated position, and the radiological loss of position during fracture union was minimal compared with that seen in patients treated in plaster.

In August 1987, R.N. Villar from Cambridge published 3 years prospective study of 90 Colles' fracture in which 55% were mtraarticular. The most significant parameter to correlate with diminished grip score even at the end of 3 years was radial shortening. Involvement of inferior radio ulnar joint was associated with reduced grip strength and not ranges of motion.

Heather Prince and P. Worlock (1987) advocated use of small AO external fixator.

In 1988, Szabo and Weber stated that comminuted intra articular fractures of the distal radius are increasingly common after high energy injuries.

K.S. Leung and W.Y. Shen (JBJS, 1989) have used ligamentotaxis and bone grafting in 75 distal radius fractures, with 93% being intraarticular. After obtaining reduction the fixator (C-Hoffman) was applied and the site packed with cancellous bone chips. The fixator was removed after 3 weeks 80% of their patient gave full range of movements with minimal complication.

Soren Solgaard (1989-Acta. Ortho. Scand.) used mini Hoffman external fixator for unstable fractures and compared the results with below elbow POP cast application. He stated that external fixation was associated with better results but reported a high incidence of complication in his series. The most common complication noted was sensory disturbances in thumb, which they thought could be eliminated by modifying the surgical technique.

In 1989, Atkins, Duckworth and Kanis showed that many features of algodystrophy were common following a Colles' fracture, but probably transient.

In 1989, Hassan found that radial shortening had greater prognostic power for prediction of unstability of Colles' fractures. Patient's age and Lidstrom's criteria added prognostic information. Initial shortening of radius of 5 mm or more generally indicated an unfavourable anatomic end result.

In November 1989, Futami et al studied the Chinese external fixator treated for distal radial fractures and got good results in elderly. They believe that it serves as a kind of functional brace.

In 1990, Leung and Shen used ligamentotaxis on external fixator for 3 weeks along with cancellous bone graft to enhance early healing and reduce the time of fixator applied for comminuted distal radius fracture and reported a low complication rate with excellent results.

Haim Stein and Goshen Volpin (1990) carried out a prospective study in 126 cases comparing external fixator and plaster cast for fractures of distal radius. Out of 40 patient treated with AO external fixator 36 had excellent and good results.

Geissler W.B., Freeland, A.E. et al (1991) managed sixty patient who had a displaced intraarticular fractures of distal end of radius with manipulative reduction and internal fixation, under both fluoroscopic and arthroscopic guidance according to AO classification and concluded that occurrence of tears of carpal interosseous ligaments and triangular fibrocartilage complex is common in displaced lntraarticular fractures of distal end of radius that are not detectable on standard radiographs. So possibility of a soft tissue injury in association with the fracture of the distal end of the radius should always be considered.

In .March 1991, I. Jakim, H.S. Pieterse and M.B.E. Sweet treated 132 patients of an average age of 35 years, with unstable intraarticular fractures of the distal radius by external fixator. 83% had good or excellent results. There was a statistically significant correlation between the severity of the fracture and the clinical outcome, irrespective of radiological restoration.

In March 1991, R.M.H. Roumen and others reported the results of a prospective randomized controlled trial of the management of 101 Colles' fracture in patients over the age of 55 years. Within two weeks of initial reduction 43 fractures had displaced with either more than 10° dorsal angulation or more than 5 mill radial shortening. These patients were randomly divided into two groups; 21 were re-manipulated and held by an external fixator, in the control group of 22 patients the re-displacement was accepted and conservative treatment was continued. Patients treated with external fixation had a good anatomical result, but their function was no better than that of the control group. They found no correlation between final anatomical and functional outcome, and concluded that the severity of the original soft tissue injury is the major determinant of functional end result.

In March 1991, Ajay Gupta studied 204 consecutive patients with displaced Colles' fractures had closed reduction then plaster immobilization. Positions of wrist in plaster were randomly allocated into palmar flexion neutral and dorsi flexion. The results in the three groups were compared. Fractures immobilized with the wrist in. dorsiflexion showed the lowest incidence of re-displacement, especially of dorsal tilt, and had the best early functional results.

Gert Robbek, Anderson, Hensbo Ras Mussen and Benny Dahl and Seren Selgaard (1991) assessed the reliability of Older's classification of Colles' fracture by determining the intraobserver and interobserver variation. The system of Older et at (1965) focuses primarily on· axial compression and proved superior to other classification regarding the radiological and functional prognosis.

Diego Fernandez and W.B. Geissler (1991 JHS May) used open reduction with plate/screws or K wires for restoration of normal articular congruity. They observed that external fixators with ligamentotaxis could not always restore the die punching of the Lunate and thus required open reduction and internal fixation.

John M. Agee (OCNA, 1993) found that though ligamentotaxis achieved radial length correction it didn't obtain correction of palmar tilt and hence put forward the concept of multiplanar ligamentotaxis using his self designing Wrist Jack.

William H. Seitz Jr. (OCNA-1993) published an article in which he reviewed the literature available on external fixator for intraarticular fractures of distal radius and has given the basic technical principles of application of external fixator, in which he has used the open technique of pin insertion in the $2^{nd}$ metacarpal and distal radius so as not to injure the superficial cutaneous branches of the radial nerve and also the tendons.

R.S. Kulkarni (1993) studied 652 cases of fracture Colles' treated with above elbow cast in supination and pronation and below elbow cast in pronation found that the position of supination significantly improves the clinical result of displaced intraarticular and extraarticular fractures.

Tommo, T Sukazaki and Katsuso Iwasak (1993) treated 109 patients with unilateral Colles' fracture with closed reduction and cast immobilization and re-examined after 4 years. At follow up 40 patients had ulnar wrist pain. The most important factor for predicting ulnar pain was final dorsal angulation of the radius. They suggested that ulnar wrist pain following Colles' fracture is caused by incongruity of distal radio ulnar joint.

Peter M, Waters, George J. Kolettis and Richard Schwend 11994) suggested that displaced distal physeal fracture of radius is at risk for development of median neuropathy. If patient has associated median neuropathy, early percutaneous pinning rather than constrictive cast may lessen the risk of acute compartment syndrome.

Leiv M. Hove and Anders O. Molester (1994) treated 13 patients with malunited fractures of distal radius with pain and impaired function with opening wedge lengthening osteotomy with or without re-attachment of triangular fibro cartilage complex. At re-examination after a median of 4 years all patient but 2 were improved by the procedure.

M. Altissoni, G.B. Manicini, A. Azzora and E. Ciattoloni (1994) showed a grater incidence of secondary shortening of Older's type II and IV fracture and gave importance to severity of initial radial shortening as a reliable indicator of instability.

O.M. Christensen, T.G. Christensen M. Krashenim, Koff and f.F. Hansen (1995) carried out clinical controlled trial with the purpose of evaluating whether it was safe to reduce the time of immobilization in a plaster splint from 5 to 3 weeks in patient of Older type I and IV. They did not find any difference in radiological healing at 3 months or in the functional scores after 3 and 9 months.

Howard Lipton and Ronit Wollstein (CaRR, 1996) have tried to reconstruct the articular surface of distal radius with the aim of good range of motion normal strength, minimal pain and minimal complication rate. They have given the various algorithms for a logical approach to the treatment of these fractures. External fixation in their 3eries has only a limited role in the way of temporary stabilisation during application of other means of internal fixation. They have primarily used plate and screws or K wires in their series. The plates used were placed either dorsally or volarly.

Schuind F. et al (Jan. 1996) compared in normal subjects the variability of wrist x-ray film measurements between right and left sides. They concluded that in unilateral wrist disease, the normal wrist should be used to provide the reference value of the carpal height and of the carpal angles on profile x-ray films. However for the radial inclination and palmar tilt of the distal radius and for the ulnar variance the normal side does not provide a better reference than normal values obtained from databases.

Louis Catalano and J. Cole (JBJS, 1997) carried out a 7 year retrospective study in 21 displaced intraarticular distal radius fractures treated by open reduction and internal fixation (plate and screws and K wires), After 7.1 years osteoarthritis of the radiocarpal joint was evident will those patients in whom a step off of > 2 mm was present at the time of union. Although they noticed a strong association between the presence of residual articular displacement and development of osteoarthritis, the functional outcome at the time of the latest follow up did not correlate with the magnitude of residual step/gap displacements at the time of fracture healing.

Fitoussi and Chow (JBJS 1997) treated 34 intraarticular displaced radius fractures with dorsal and volar plate and screw and gave a high rate (26%) of complications but still reported a good final functional outcome.

Graham C.A. et al (1997) compared vanous methods of anaesthesia (general anaesthesia, Bier's block, IV sedation and haematoma blocks) used for distal radius fractures in UK and Scotland and concluded that Bier's block is the anaesthetic method of choice for management of distal radius fracture both in efficiency and economic.

M.M. McQueen et al (JBJS, 1998) carried out a prospective study in 60 patients comprising the results of bridging and non-bridging external fixation used in unstable distal radius fracture. They concluded that non-bridging external fixation with pins placed in the distal fragment of radius (whenever possible) gave significantly better results that bridging external fixation.

C.W. Flisch and Della-Santa-DR (1998) used flexible intramedullary nailing in intraarticular fractures of distal radius. They praised the simplicity of the system but at the same time reported high complications rate. They advised it for simple extraarticular fracture.

Board T, Kocialkowski A and Andrew G (1999) studied 46 patients aged 55-90 with intraarticular displaced fracture treated with Kapandji pinning. They concluded that mean dorsal angle was significantly better in wired group and that a strong correlation existed between functional outcome and both dorsal angle and radial length at union.

Mehta J.A. and Bain G.I. (1999) agreed with prevailing thinking of reducing the intraarticular fracture and maintenance of reduction by restoring the radial height, volar tilt and intraarticular step.

Rose S, Frank J, Marzi I (1999) in 30 patients with intra-articular fractures found associated tears of scapholunate ligament in 20% and tears of triangular fibrocartilage complex in 60% which were repaired by arthroscopic shaving, K -wire stabilisation of ulnar head or arthroscopic suture of distal radius fracture. They opined that arthroscopic reduction of distal radius fracture allows minimal invasive reconstruction of joint surface diagnoses relevant ligamentous tears and should applied with incongruencies of the joint surface greater than 2 mm and in widely dislocated fracture.

Chan B.K., Leong L.C. Low CO, and See H.F. (1999) used penning or AO external fixator in 30 patients with intraarticular fracture of distal radius. After 90.2 weeks of evaluation they found excellent to good result in 65% of cases, but also some complication mainly fingers stiffness, pin tract infection and even loss of reduction.

Morawiecki P, Soshin P and Dutka J (1999) studied carpal instability after fracture of distal and radius in 339 patients and concluded that DISI was more common in intra (44%) than in extra (20%) articular fractures and also increasing percentage of DISI was in older age group that to> 70 years.

Nien Stedf F (Feb. 1999)126B compared 21 intraarticular Smith fracture treated with external fixator and K-Wire, palmar T plate, K-wires and cast. They pronounced that treatment of choice is palmar T plates in intraarticular Smith's fracture and K-wire with cast should be used only in simple articular fracture with a large palmar fragment.

Geissler W.B., Trumble T.E. Culp R.W. and Berges R.A. (1999) in American Instructional Course lecture surfaced opinion that long term functional outcome in intraarticular fracture of radius is determined in part by severity of fracture as determined by amount of communition, the initial severity of displacement and number of fracture fragments. They advised use of CT scan for fracture classification and surgical planning. They emphasized once again that restoration of length of radius is of at most importance for enhancing recovery of motion and grip strength.

Goslings J.C. et al (Aug. 1999) carried out a prospective study involving 44 patients with intraarticular distal radius fracture treated with three-dimensional dynamic external fixator. During period of dynamization with a median flexion of 30°, extension 18°, radial deviation 0° and ulnar deviation 20° range of motion needed to perform activity of daily living was approached. They found excellent/ good results in 82% of patients and concluded that though despite early mobilization reduction was maintained, the devise needs further Improvement.

A.L. Ladd and Pliam N.B. (1999)100 looked for a bone substitute for intraarticular fracture of distal end radius. Bone substitute can be broadly classified into naturally occurring material (e.g. demeneralized human bone matrix, bovine collagen mineral composition and processed corraline hydroxyapatite) and synthetic material (e.g. calcium sulphate pellets, bioactive glass, and calcium phosphate cement). There are also new generation of substitutes, which incorporate growth factors.

Joosten U, Joist A (Nov. 1999)90 evaluated 174 patients with severely displaced intraarticular fracture treated with bridging external fixator (Grthofix). After evaluating with Gartland and Werley score, they obtained 29.3% excellent, 42.5% good, 10.3% fair and 2.9% poor results. Complication included pin tract infection, metacarpal pin cut out, fixator dislocation and algodystrophy. They emphasized importance of anatomical reduction and especially restoration of radial length in order to obtain good functional outcome,

D.W. Lundy (1999)106 evaluated intraarticular distal fracture of radius with tilted lateral radiogram, a radiograph taken 22° from true lateral (forearm held at 22° angle from the horizontal film cassette) depression of Lunate fossa fractures were analysed with normal lateral PA and 22° tilted lateral radius view. Measurement error from actual deepression average 1.1 mm when the evaluators evaluated the 22° lateral and PA films, 1.5 mm for the standard lateral and PA views, and 0.8 mm for the standard lateral, 22° lateral and P A radiographs (combined groups). Thus he suggested that the 22° tilted lateral, either in combination with the standard lateral radiograph or just with the PA view may help the hand surgeon better understand the intraarticular depression of Lunate facet fractures of the distal radius.

Kapoor **H,** A. Agrawal, Dhaon B.K (March 2ooo) compared displaced intraarticular fracture of lower end radius treated with either CMR and plaster or GRIP or external fixation alone. After assessing with Sarmiento system, they found 43% good and excellent, 50% fair and 7% poor in plaster group; 80% good and excellent, 20% fair and poor result in external fixator group and 63% good and excellent, 26% fair 11% poor in GRIF. They hence concluded that displaced severely comminuted1mllnuted intraarticular fracture of distal radius should be treated external fixator.

Haddad M. et at (2000) retrospectively analysed 36 patients with unstable intraarticular radius fracture treated with external fixator. One group for 3 weeks followed by cast for 2 weeks and other group for 5 weeks of external fixator alone. There was no significant difference between the functional outcomes of two groups. Radiologically, group I had less radial shortening than in group II but there was no difference in degree of dorsal angulation.

Beaule P.E. (May 2000) et al carried out a study in 55patients with distal radius fracture to record the spectrum of self-reported disability following distal radius fracture and to gauge for difference in hand dominance in the use of subjective outcome data. They concluded that because patients who sustain a dominant wrist injury are likely to report greater functional impairment across a wider range of activities, they also posses a greater potential for improvement. They urged to incorporate hand dominance into outcome studies for treatment of distal radius fracture.

Frank W.M., Dahler C. (Oct. 2000)53 in a study involving 40 patients with intraarticular distal radius fracture compared non bridging external fixation and K-wire fixation with plaster treatment and put forward following advantages of nonbridging fixator. (1)early functional therapy of wrist (2) simplified reduction of fracture and 3) considerable less restriction of wrist mobility in day to day situation. 3ut the final examination 6 months after treatment showed identical functional results for both groups.

Mittelmeier W. et af (2001) compared Kapandji K-wiring and established K-wiring technique of the distal radius fracture for primary stability in a biomechanical model. They found that application of the Kapandji procedure with K-wire at a smaller angle to the axis of the radius results in the highest primary stability of the procedures investigated in the essential range of initial deformation.

Abboudi J. (April 2001) inferred that, arthroscopy if properly modified assists in the evaluation and reduction of displaced intraarticular fracture of the distal radius in treating associated injuries within the carpus.

Although external fixator device may maintain radial length, individual fracture fragment may still heal in a displaced or angulated position.. Markiewitz A.D. and Gellman H (April 2001) carried out a study with five pin external fixator. The $5^{th}$ pin being a dorsal pin which corrects the dorsal tilt, He argued that the $5^{th}$ pin helped' with reduction of those fractures that would not improve with traction and with maintenance of reduction.

**Fuji et al** (2002) reviewed retrospectively the functional and anatomical results distal end radius with severe displacement and found that functional results did not correlate with radiographic evidence of minor deformities.

In a prospective study of conservative treatment of Colles type fracture of distal radius by **Smilovic** & **Bilie** (Dec, 2003) aimed to determine the anatomical and functional results of conservative treatment of extra-articular lower end radius fractures and ascertain the borderline value of each anatomical parameter for the best possible correlation with functional end results, statistically significant correlation was found between the anatomical and functional results. The acceptable borderline dorsal angle was less or equal to $9^0$, loss of radial inclination less or equal to $3^0$ and loss of radial length less equal to 2 mm.

**Chozo Uchikura, Jun Hirano et al** (2004) department of orthopaedic surgery Kyorin University Mitaka Japan. The purpose of study was to compare non-bridging external fixator (group NB) with bridging external fixator (group B) in the treatment for unstable distal radius fracture. The subject consisted of 84 patients 42 in each group. Patients of group B showed reflex sympathetic dystrophy (RSD). On Saito evaluation criteria the proportions of patient evaluated as good or better was 100% in group NB & 95.6% in group B. This finding can be taken as evidence that group NB patient showed better results.

**Maki Shin, Taniguchi Yoshi Yasu et al** (2005) they work on fracture distal radius using the HC-50 plate. In 6 cases of the distal end of radius fracture they used HC-50 plate between July to November 2004. They use this system for the distal end radius fracture which had a radial column, dorsal ulnar, split or a dorsal cortical wall fracture to fix each fragment and start early motion exercise post operatively. These cases were examined by XP & functional evaluation of the wrist joint post operatively there was no displacement at the fracture site and good functional recovery was obtained in each cases this system seems to be one of the choice when we treat the distal end of the radius fracture which has a radial column, dorsal ulnar split or dorsal cortical wall fracture.

**Sahin M, Tasbas BA et al** (2005) the effect of long or short arm casting on the stability of the reduction on bone mineral density in conservative treatment of Colles fracture. In this study patient randomly assigned in long and short arm casting after CMR then BMD measure after 1 week & after cast removal BMD of unaffected side also measure for reference. Results shows that BMD losses and deterioration in reduction following treatment of Colles fracture occurs irrespective of which type of casting is used.

**Andrew A. Willis et al** (2006) they study a biomechanical analysis of volar plate fracture stability the purpose of present study was to compare the relative stability of five distal plates (4 volar and 1 dorsal). Four different types of volar plate (AO T-plate, AO 3.5 mm small fragment plate, AO 3.5 mm small fragment locking plate and Hand innovation DVR locking plate) and a single dorsal plate (an AO Pi plate). Dorsal pi plate at the highest resistance to fracture gap motion. The locked volar plate showed significantly higher resistance to fracture gap motion than the unlocked plate did suggesting that either surgical approach (dorsal or volar) combined with rigid plate fixation allow for early assisted finger or wrist motion in the treatment of comminuted distal radial (Colles type) fracture.

**Boparai RPS, Boparai RS, Kapila Rajesh Pandher, Dilbans Singh** (2006) department of orthopaedic SGTB Hospital Government Medical College Amritsar, India. Study the role of ligamentotaxis in management of comminuted intra/juxtra articular fractures.

**Delpinal F, Gareia Bernal FT et al** (2006) study on correction of malunited intra-articular distal radius fracture with inside out osteotomy technique.

**Gruber Gerald et al** (2006) surgical treatment of distal radius fracture with an angle fixed bar. Palmer plating system a single center study of 102 patients over 2 years period. The purpose of this study was to evaluate functional & radiographic result of DRFs treated with palmer plating system regarding patient quality of life. This study shows in a representative number of cases that palmer plating of unstable fracture of distal radius is a safe and effective treatment modality. Early surgical treatment result in optional outcome regarding patient quality of life.

**JL Jaremko, RGW, BH Rowe, SR Majundar et al** (2006) study on radiographic indices of distal radius fracture reduction predict outcomes in older adults receiving conservative treatment his aim of study was to investigate whether radiographic deformities suggesting inadequate reduction would be associated with adverse clinical outcome. They had radiograph at cast removal and completed DASH (Disability of Arm, Shoulder, Hand), SF - 12 (Health related quality of life and satisfaction) surveys 6 months post fracture result of this study shows 6 months post reduction self reported disability was low (DASH = 24 ± 17), Health related quality of life was near normal and 72% were satisfied with their care no radiographic index of wrist deformity (alone or in combination) was significantly correlated to any of the patient reported outcome.

**Eli-Lilly and Company** (2007) effect of Teriparatide on distal radius fracture healing. This study started from 2004 December and completed on June 2007. This is a trial purpose (placebo control drug system) type of study.

## MATERIAL AND METHOD

This is prospective study for clinicoradiological assessment of prevalence of residual DRUJ disruption after various treatment modalities carrying out in department of Orthopaedics, S.S. Medical College & associated SGMH, Rewa from June 2007 to May. 2009. 69 cases were studied out of which 21 cases were treated surgically and 48 cases treated conservatively.

Conservatively treated 38 cases and operatively treated 21 cases completed their follow up of 6mths and 10 cases lost during follow up. These patients were selected as per inclusion and exclusion criteria.

**INCLUSION CRITERIA-**

DRUJ disruption associated with fracture distal end radius in more than 20 yrs age group.

**EXCLUSION CRITERIA-**

1. Pathological fracture.
2. Fractures in paediatrics age group.
3. Compound Fracture
4. Carpal fracture
5. Refracture
6. Isolated DRUJD (due to ligamentous injury)

These patients were treated as outdoors patients (mostly), only those having associated injuries or those with high-speed trauma were admitted

Broadly these patients were treated with either by close manual reduction and cast application under general anaesthesia or external fixation (JESS-Joshi's External Stabilisation System) with ligamentotaxis or k-wire fixation. No sooner the patient reported in OPD, than the clinical evaluation was done, immediate first aid was given to patient and objected to radiographic examination by taking routine AP and lateral · views of wrist with forearm (with elbow included, if possible))

They were thus divided into stable and unstable injuries based on Cooney’s criteria.

W.P. Cooney in 1989 in a Journal of Hand Surgery article led down following criteria for stable and unstable injuries.

- Marked dorsal comminution.
- Dorsal angulation> 20°
- Radial shortening> 10 mm
- Articular step> 3 mm
- If after closed reduction, there is loss of reduction with dorsal angulation> 10° and 5 mm or more of radial shortening.

We preferred the first 3 criteria and included our own - open fractures or severe displacement and based on these formulated two groups.

1. Conservative: Included stable fractures according to Cooney's criteria and underwent closed manipulative reduction with above elbow or below elbow

Plaster of Paris cast application.

2. Operative: Included unstable fractures according to Cooney's criteria and underwent closed manipulative reduction with external fixator distractor assembly application or Kirnscher wire fixation.

All cases above 20 years were undertaken for the study and followed up to about 3 months (average) to the maximum of 6 months. The fractures after radiological examination were classified using Frykman's system.

In some patients cast treatment was used even when they had VIII/ VII type fractures due to (1) Patient unwillingness (2) Economic reasons.

**Treatment Protocol for Conservative Group:**

The patients who underwent conservative treatment were old people with osteoporosis and or had low energy trauma with mild to moderate displacement. They were mostly type ill, IV Frykman or stable variety as per Cooney's criteria and treated on outdoor basis.

We obtained routine PA and lateral view of forearm with wrist (with elbow if possible). The volar tilt, radial length and radial angle were noted in prereduction X-ray as per Jupiter and Masem (1988) and the fractures were classified according to Frykman.

**Material:**

- 4" POP cast bandage
- 6" POP cast bandage
- Cotton roll

**Method of Reduction:**

As early as possible all the cases were reduced under general anaesthesia. Bohler's method was used for reduction.

After putting the patient supine on reduction table, traction was given in the limb holding thumb and middle three fingers (Charnley) with the elbow flexed and held by another assistant, thus giving countertraction. The forearm was pronated. The traction was given for 3-5 minutes till the radial length correction was obtained as assured by the level of the styloid process. Once the correction of radial length was obtained, dorsal displacement and tilts were corrected followed by lateral displacement and tilt. Then the hand was palmar flexed (10-15°) with slight ulnar deviation (Classical Cotton Loder position) and the cast was applied. In presence of dorsal cortical comminution, we used above elbow cast while in absence of it below elbow cast was given. Care was taken to keep metacarpophalangeal joints free, so that their free movement could be possible.

**After Care:**

Elevation of forearm was advised in every case to minimise swelling. The patient was asked to come next day to check for swelling and cast related complications.

**Physiotherapy:**

We gave due emphasis on physiotherapy. Finger movements were advised from day one. Patient was motivated to continue active movement of shoulder and elbow (in case of below elbow cast) and metacarpophalangeal joints.

**Follow Up:**

The check X-rays were done on next day of reduction after checking cast complications. Radial length, radial angle and dorsal tilt were again measured and compared with pre reduction status. If satisfied, patient was asked for follow up every two weeks till his cast was removed. Otherwise re-reduction was performed as early as possible. At each visit the patient was examined for any complication or breakage of cast. In cases of latter, repair and correction was done on OPD basis.

The cast was kept for 4-6 weeks with removal done as early as possible after 4 weeks as the fracture anatomy permitted. After cast removal physiotherapy was regularly carried out and taught to the patient. The patient was advised to come biweekly check until a maximum of 12-16 weeks.

After removal of cast, crepe bandage was applied for further one week.

**Treatment Protocol for Operative Group**

Most of these injuries were due to high-speed trauma and many had associated injury. So they were treated as indoor patients. They were mostly types V, VI, VII and VIII Frykman type or unstable variants as per Cooney's criteria. We also applied external fixator in bilateral cases to facilitate ease of mobilisation with usage of both the hands.

We obtained routine P A and lateral view of forearm with wrist (with elbow if possible). The volar tilt, radial length and radial angle were noted in prereduction X-ray and the fracture was classified according to Frykman.

**Material:**

- 3.5/3.0 rom Schanz pin.
- 2. 0/2.5 rom Schanz pin.
- External fixator distractor frame in small, large and medium size.
- K-wires
- Hand Drill
- T Handle
- Allen / L Key

**Method:**

For most patient general anaesthesia was used. In three patients we used elbow block. Tourniquet was not used in any of our cases. After steri1e painting and draping, CMR under image intensifier by traction and countertraction method was carried out (as in conservative treatment). Once the radial length was corrected, two 2.0/2.5-mm Schanz screws were inserted in the $2^{nd}$ metacarpal by closed means. First one in the flare and other one 2 cms proximal to the head of second metacarpal. The pins were advanced so as to obtain purchase on the $3^{rd}$ metacarpal if possible.

These pins were inserted in a slight dorsolateral manner (45-60° angles to both coronal and sagittal plane). Metacarpal' Schanz screws are to be passed taking care to flex index finger so as to draw the first dorsal interossei muscle as volarly as possible so as to avoid impaling the tendon, which otherwise results in stiffness of index finger.

Two 3.0/3.5 mm Schanz pins were inserted into the distal radius about 5-8 mm proximal to the joint line so as to avoid injuries to the superficial branch of Radial Sensory nerve (Schuind and Burney, 1984). No predrilling was done. Skin stab incision was given. Hand drill was used.

Pins were inserted gaining purchase of both cortices for increased stability. A total number of four Schanz pins were thus placed to avoid pin loosening following tract infection and thus mechanical fai1~e of the frame. Schanz screws included were 3.0- 3.5 mm for radius and 2.0/2.5 mm for metacarpal because these screws confirmed to the principle of being less than $1/6^{th}$ the diameter of bone. 3.0/3.5 mm pins were not used for metacarpals as they cause severe weakening and occasional shattering of cortex on insertion.

After insertion of pins a JESS (Joshi's external stabilisation system) distractor (double holed) was applied and ligamentotaxis was carried out as dictated by prereduction x-rays. Distractor rod allows fine distraction and thus minor adjustments in length are provided for, O.4mm with each turn. The pin sites were covered with sterile gauge.

**After Care:**

Patient was advised to elevate limb and active finger physiotherapy once he was out of general anaesthesia. Active pronation and supination movement were started from day first. To our surprise most of the patient could hold glass/ cups as early as 72 hours after surgery and felt comfortable with frame.

**Follow Up:**

Check X-rays were done and again radial angle, radial length and volar tilt were measured. Any residual deformity was corrected by ligamentotaxis. Patient was discharged when their other injuries permitted and were given intravenous antibiotics if compound injuries were present. Early pin tract infections were managed with repeated dressings and oral antibiotics.

Patient was advised to come biweekly and during this period regular dressing of pin site was taught to patient. The fixator was kept on for 5 to 8 weeks. Removal was done as early as possible after 5 "weeks. During this patient was encouraged to actively move his fingers, elbow and shoulders. All the deformities were corrected by ligamentotaxis alone and no other supplementary method was used. In one case K-wire fixation was done. After fixator removal crepe bandage was applied for further 1 week. During follow up patient was analysed for stability of fixator and complication related to pins.

It is vital to psychologically encourage the people from rural areas who may develop phobia of external fixator.

Percutaneous K-Wire Fixation:

Percuta;neous K-wire fixation of radial styloid fragment is done under image intensifier from the lateral aspect of tip of styloid and is fixed to metaphysis of radius or its opposite cortex.

By pressing the head of ulna, inferior radioulnar joint is reduced. A K-wire is passed from base of bulb in direction of radial styloid process.

**METHOD OF ASSESSMENT:**

At each follow up, patient were assessed both objectively and radiologically and for any complication.

**(A) Objective:**

This included complete clinical and physical examination of the affected limb. The wrist was inspected for area of tenderness and deformity was noted and followed up for any exaggeration or relief.

The range of motion of the wrist was measured in all the six planes with the help of a Goniometer.

1. Flexion-Extension (2) Pronation-Supination (3) Abduction- Adduction (Measurement was done as passive joint motion under load)

Pronation and supination were recorded from day 1 in both the groups. The other movements were only recordable once the fixation method was removed. The movements were recorded at 2 weekly intervals.

Grips strength was measured only twice. Once after the cast/fixator removal and once at the final follow-up. We used a commercially· available dynamometer. The highest value of 3 or 4 consecutive trials was used and the value was multiplied by a factor of 0.85 if the dominant hand was involved and 1.17 if the non dominant hand was involved. **Bechtol** (1954) stated that the non-dominant hand can be as much as 30% weaker than the dominant, although most subjects have only 5 to 10% differences.

**Radiological Evaluation:**

This was carried out on P A and lateral Views, according to the criteria laid down by **Jupiter** and Masem (1988). In each fracture three variables were noted

1. Radial Length: In the AP radiograph the distance between the tip of the radial styloid process and the medial articular surface of the ulna was measured and expressed in rom (Normal value 11-12 mm)

2. Radial Angle : In the AP radiograph the angle the radial articular surface made with the perpendicular to long axis of the forearm (Normal 22-23°)

3. Volar Tilt: In the lateral radiograph the angle made by radial articular surface to the long axis of the forearm. (Normal 11-12°)

In each case a radiograph of the normal wrist was also done and the measurements in the final result evaluation were reported as difference from the normal (radial length). We neither measured step/gap displacements nor the carpal affections associated or as a consequence of the distal radius fracture, F in our present series.

The objective and radiological findings were quantified by system of Jakim's. The outcome of each fracture was graded as excellent, good, fair and poor.

**Jakim's scoring system: (for clinico-radiological correlation) 1991**

Clinical subjective (normal 30 points)

Pain/function

| | |
|---|---|
| None/Normal | 30 points |
| Mild Occ./slight limitation | 24 Points |
| Moderate, needs analgesia/slight limitation | 15 points |
| Severe/week with loss of function | 0 point |

Clinical Objective:

| | | |
|---|---|---|
| | Normal | 15 |
| Mobility | <30% loss of range | 12 |
| | Minimal function | 07 |
| | Less than minimal | 00 |
| | Normal | 12 |
| Grip | 15% loss | 10 |
| | 16-30% loss | 06 |
| | >30% loss | 00 |
| | None | 03 |
| Deformity | Slight | 01 |
| | Obvious | 00 |
| Radiological (Positive 40 Points) | | |
| | 23 to 18 | 15 |
| Radial angel (Degrees) | 17 to 13 | 12 |
| | 12 to 10 | 09 |
| | <10 | 00 |
| | 13 to 10 mm | 15 |
| | 9 to 7 mm | 12 |
| Radial Length | 6 to 5 mm | 09 |
| | <5 mm | 00 |
| | 11 to 7 | 10 |
| Volar Tilt ( Degrees) | 6 to 3 | 08 |
| | 2 to 3 | 06 |
| | Negative | 00 |
| Radiological Negative (Normal 0 points) | | |
| Incongrurncy | 1 to 2 mm | -5 |
| Radio-Ulnar Joint | Subluxation | -10 |

| | | |
|---|---|---|
| | Dislocation | -5 |
| Arthritis | Minimal | 5 |
| | Moderate | -10 |
| | Severe | -20 |
| Final Results: | | |
| | Excellent | 90-100 |
| | Good | 89-80 |
| | Fair | 79-70 |
| | Poor | <70 |

# OBSERVATIONS

We have followed prospectively 69 cases of DRUJD treated either by conservatively or operatively. This study was carried out in the Department of Orthopaedics, S.S. Medical College and associated S.G.M.H. Rewa from June 2007 to May. 2009. Following observations were made-

**Table No. 1**

**Age Distribution of Patients**

| S. No. | Age group (In yrs) | Conservative | | Operative | | Total |
|---|---|---|---|---|---|---|
| | | Male | Female | Male | Female | |
| 1 | 19-30 | 01 | 01 | 02 | 01 | 05 |
| 2 | 31-40 | 02 | 05 | 02 | 01 | 10 |
| 3 | 41-50 | 05 | 05 | 03 | 03 | 16 |
| 4 | >51 | 12 | 17 | 04 | 05 | 38 |
| | **Total** | **20** | **28** | **11** | **10** | **69** |

Majority of patients was female and they belonged to around 51yrs of age group. Which is socially productive group and hence need utmost attention for better functional outcome.

**Table No. 2**

**Mode of Trauma**

| S. No. | Mode of Trauma | Conservative | Operative | Total |
|---|---|---|---|---|
| 1 | Fall from Ht.<4ft | 05 | 02 | 07 |
| 2 | Fall from Ht.>4ft | 27 | 07 | 34 |
| 3 | High speed Trauma | 10 | 11 | 21 |
| 4 | Direct Injury. (Assault) | 06 | 01 | 07 |
| | **Total** | **48** | **21** | **69** |

We can see that the most common cause of injury is fall from heights, in these cases mostly trees. It was most common cause in conservative series while in operative cases RTA was the main culprit.

**Table No. 3**

**Study Group**

| S. No. | Sex | Number | Percentage |
|---|---|---|---|
| 1 | Male | 31 | 44.92% |
| 2 | Female | 38 | 55.08% |
| | **Total** | **69** | **100.0** |

Most patients were female but males also were in majority, mainly due to increased outdoor activities.

**Table No. 4**

**Side of Fracture**

| S. No. | Side | Number | Percentage |
|---|---|---|---|
| 1 | Right | 39 | 56.52% |
| 2 | Left | 29 | 42.02% |
| 3 | Bilateral | 01 | 1.46% |
| **Total** | | **69** | **100.0** |
| Dominant hand involved in 57% of cases | | | |

Fracture was more common on the right side and involved dominant hand in 58% of cases, thus stressing the need for anatomical reduction leading to excellent functional outcome.

**Table No. 5**

**Operative Procedure**

| S. No. | Procedure | Total |
|---|---|---|
| 1 | JESS | 7 |
| 2 | K-wire fixation | 11 |
| 3 | Volar Buttress Plate | 2 |

Most of the fracture were fixed with K-wire followed by JESS.

**Table No. 6**
**Type of Fracture**
**(FRYKMAN'S CLASSIFICATION)**

| S. No. | Type | Conservative | Operative | Total |
|---|---|---|---|---|
| 1 | III | 16 | 00 | 16 |
| 2 | IV | 09 | 04 | 13 |
| 3 | V | 11 | 00 | 11 |
| 4 | VI | 06 | 03 | 09 |
| 5 | VII | 03 | 05 | 08 |
| 6 | VIII | 03 | 09 | 12 |
| | **Total** | 48 | 21 | 69 |

We see pooling of fracture at the poles i.e. type III and type VIII form the largest group. Conservative group comprises mostly of type III fractures while operative group comprises mainly type VIII fractures. Type III, IV, V VI were mostly undisplaced with minimal metaphyseal comminution hence were subjected to conservative treatment where as type VII and type VIII found their place in operative group.

**Table No. 7**
**Associated Injuries**

| S. No. | Injuries | Conservative | Operative |
|---|---|---|---|
| 1 | # Calcaneum | 1 | 1 |
| 2 | # Tibial/Fibula | 0 | 1 |
| 3 | # Patella | 1 | 0 |
| 4 | # Shaft Femur | 0 | 1 |
| 5 | # Trochanter | 1 | 1 |
| 6 | # Neck Femur | 0 | 1 |
| 7 | # Pelvis | 1 | 0 |
| 8 | # Acetabulum | 0 | 1 |
| 9 | # Spine | 0 | 1 |
| 10 | # Ribs | 0 | 1 |
| 11 | # Head Injury | 0 | 1 |

| | | |
|---|---|---|
| **Total** | **04 (13.33%)** | **09 (75.0%)** |

We had 30.95% of associated injuries in operative group taking the lion's share (75.0%) while 13.33% in conservative group, there were two cases of multiple trauma > 2 injuries and all of them due to high speed trauma and most of them were managed operatively.

**Table No. 8**

**Initial (Pretreatment) Loss of Radial Length in mm**

**(Compared to the Unaffected Side)**

| S. No. | Type of Fracture | Conservative | Operative |
|---|---|---|---|
| 1 | Type III | 4.15mm | - |
| 2 | Type IV | 3.86mm | 8.8mm |
| 3 | Type V | 5.56mm | - |
| 4 | Type VI | 5.90mm | 9.77mm |
| 5 | Type VII | 6.53mm | 10.11mm |
| 6 | Type VIII | 7.88mm | 15.68mm |
| | **Mean** | **5.64mm** | **11.09mm** |

Table infers that initial loss of radial length increases as the type of frykman's increases and it was thus most in type VIII due to gross metaphyseal comminution. This streem radial length loss was competently corrected by external fixator (JESS) application. The overall mean initial loss of radial length in our series was 8.37mm.

**Table No. 9**

**Final (post treatment) Loss of Radial Length in mm**

**(Compared to the Unaffected Side)**

| S. No. | Type of Fracture | Conservative (in mm) | Operative (in mm) |
|---|---|---|---|
| 1 | Type III | 1.80 | - |
| 2 | Type IV | 2.90 | 1.25 |
| 3 | Type V | 3.20 | - |
| 4 | Type VI | 3.80 | 2.00 |
| 5 | Type VII | 4.10 | 1.00 |
| 6 | Type VIII | 4.90 | 4.00 |
| | **Mean** | **3.45** | **2.06** |

The correction of radial length in the conservative series was not statistically significant and the region will be discussed later on. It was significant in operative group and the final loss of radial length in our series was 2.76mm.

**Table No. 10**

**Initial (Pretreatment) Volar Angle (In Degrees)**

| S. No. | Type of Fracture | Conservative | Operative |
|---|---|---|---|
| 1 | Type III | 3.90 | - |
| 2 | Type IV | -6.00 | -7.50 |
| 3 | Type V | -7.60 | - |
| 4 | Type VI | -8.00 | -10.00 |
| 5 | Type VII | -11.11 | -15.40 |
| 6 | Type VIII | -13.5 | -22.00 |
| | **Mean** | **-7.05** | **-13.72** |

Table shows that as the comminution and articular involvement increases the dorsal tilt also increases. Hence it was more type VIII.

**Table No. 11**

**Final (Post treatment) Volar Angle (In Degrees)**

| S. No. | Type of Fracture | Conservative | Operative |
|---|---|---|---|
| 1 | Type III | 10.20 | - |
| 2 | Type IV | -2.0 | 0.5 |
| 3 | Type V | -3.0 | - |
| 4 | Type VI | -2.5 | - 0.5 |
| 5 | Type VII | -2.5 | -1.0 |
| 6 | Type VIII | -4.6 | -1.5 |
| | **Mean** | **-0.73** | **-0.63** |

The above table shows that the correction of volar angle obtained in the conservative group is statistically significant.

**Table No. 12**

**Initial (Pre treatment) Radial Angle (In Degrees)**

| S. No. | Type of Fracture | Conservative | Operative |
|---|---|---|---|
| 1 | Type III | 19.25 | - |
| 2 | Type IV | 14.20 | 13.25 |
| 3 | Type V | 12.10 | - |
| 4 | Type VI | 10.30 | 10.20 |
| 5 | Type VII | 9.80 | 9.5 |
| 6 | Type VIII | 9.5 | 9.0 |
| | **Mean** | **12.53** | **10.45** |

This also follows: suit with volar angle as comminution increases (or frykman's type) increases radial angle decreases. The radial angle is more pronounced in type VIII.

**Table No. 13**

**Initial (Post treatment) Radial Angle (In Degrees)**

| S. No. | Type of Fracture | Conservative | Operative |
|---|---|---|---|
| 1 | Type III | 22.50 | - |
| 2 | Type IV | 20.00 | 24.10 |
| 3 | Type V | 19.30 | - |
| 4 | Type VI | 15.40 | 20.80 |
| 5 | Type VII | 14.90 | 19.20 |
| 6 | Type VIII | 15.80 | 17.50 |
| | **Mean** | **17.98** | **20.4** |

The radial angle is one of the most easily corrected anatomical deformity by the fixator.

**Table No. 14**
**Final range of movement assessed at the latest follow-up**
**(In Degrees and as Percentage Loss)**

| S. No. | Type of Fracture | Conservative (% Loss) | Operative (% Loss) |
|---|---|---|---|
| 1 | Extension | 57/72 (20.83%) | 65/73 (10.96%) |
| 2 | Flexion | 50/68 (24.47%) | 56/70 (20.0%) |
| 3 | Pronation | 65/82 (20.73%) | 66/86 (23.30%) |
| 4 | Supination | 62/81 (23.46%) | 64/85 (24.71%) |
| | **Mean** | **58.5/75.75** | **62.75/78.5** |

The movements were compared with the normal unaffected limb. N o limb could secure pre-injury level movement. Average loss of 10-25 degrees occurred in all range of movement, mostly in supination and flexion but the regained movement was sufficient per activities of daily living. The final range of movement achieved in complete series was 60.63 degree as compared to 77.13 degree in uninjured extremity.

**Table No. 15**
**Grip Strength**

| S. No. | Grip Strength | Conservative (%) | Operative (%) |
|---|---|---|---|
| 1 | Excellent (99-100%) | 30.0 | 41.0 |
| 2 | Good (70-90%) | 52.0 | 55.0 |
| 3 | Poor (<70%) | 18.0 | 4.0 |

Grip strength when measured for consecutive three times with the mean being taken as a reading gives the percentage of strength of injured hand with respect to normal hand, with correction made for physiological difference between dominant and non-dominant hand. We found excellent and good grip strength in 82.0% of cases.

**Table No. 16**

**Complications**

| S. No. | Complications | Conservative | Operative | Total |
|---|---|---|---|---|
| 1 | Finger Stifness | 11 | 4 | 15 |
| 2 | Wrist pain | 7 | 2 | 9 |
| 3 | Pin Site Infection | NA | 3 | 3 |
| 4 | Prominence of ulnar head | 5 | 1 | 6 |
| 5 | Compression neuropathy (Median Nerve) | 1 | NA | 1 |
| 6 | Pin Breakage | NA | NA | 0 |
| 7 | Pin Loosening | 1 | 1 | 2 |
| 8 | Metacarpal Pain | NA | 2 | 2 |
| 9 | Sudeck’s osteodystrophy | 2 | NA | 2 |

| | | | | |
|---|---|---|---|---|
| 10 | Frame Breakage | NA | NA | 0 |
| 11 | Superficial Radial Nerve Palsy | NA | NA | 0 |
| 12 | Iatrogenic Fractures | NA | NA | 0 |
| **Total** | | **27** | **13** | **40** |

The most common complication in conservative series was finger stiffness, while prime position in operative series was taken by pin site infection. The other clinical significant complication in conservative series was compressive neuropathy and iatrogenic patients fractures in one patient each, while no such complication in operative group. The most common complication in whole series was clinically inconsiderable wrist pain.

# BIBLIOGRAPHY


1. Abboudi J, Cui P RW : Treating fractures of the distal radius with arthroscopic assistance. Orthop Clin North Am. 2001 Apr. 32(2): 307-15.
2. Agee M. John: Extemal fixation - Technical advances based upon multi planar ligamentotaxis: OCNA-VoI.24, NO.2, April 1993,265-274.
3. Altissimi M., Mancini G.B, Azzora A., Ciaffoloni E. : Early and late displacement of fractures of the distal radius.- the predictor of instability: Intr.Orth -(18)2,ApriI1994,61-65.
4. Anderson Roger and O'Neil Gordon: Comminuted fractures of the distal end radius:
   Surg., Gynec. And Obstet.-78, 1944,434-440.
5. Ark Jon and Jupiter B. Jesse: The rational for precise management of distal radius fractures: OCNA-VoI.24, NO.2, April' 1993,205-210.
6. Atkins, RM. Duck\-\()rth T, and Kanis J.A.: Algodystrophy following Colles' Fractures. JHS14-B: 161-164, 1989.
7. Augusto Sarmiento, G.W.Pratt, N.C. Berryand W.F.Sinciair: Colles'

fracture-Functional bracing in supination: JBJS 57 A, April 1975,311-317.

8. Bacorn RW. and Kurtzke J.F.: Colles' fracture. A study of tVvQ thousand cases from the New York State Workmen Compensation Board: JBJS-35A,July 1953,643658.
9. Barton J. R: Views and treatment of an important injury to the wrist: Med. Examiner-1, 1838, 365.
10. Bartosh RA. and Saldana M.J.: Intraarticular fractures of the distal radius -A cadaveric study to determine if ligamentotaxis restores radiopalmar tilt: JHS-15(A), 1990,1821.
11. Baskin B. Raskin and Melone P. Charles, Jr. Unstable articular fractures of the distal radius Comparative techniques of Iigamentotaxis: OCNA-VoI.24, NO.2, April 1993,273-286.
12. Beaule P.E. and Dervin G. F.: Self reported disability following distal radius fractures - the influence of hand dominance: JHS-25 (3) Am., May2000, 476-482.
13. Belsole J. Robert and Hess V. Alfred.: Concomitant skeletal and soft tissue injuries:
OCNA-VoI.24, NO.2, April 1993,327-332.
14. Board T; Kocialkowski A; Andrew G: Does Kapandji wiring help in older patient? A retrospective comparative review of displaced intraarticular distal radius fractures in patients over 55 years. Injury 1999 Dec. 30(10): 663-9.
15. Bohler Lorenz: The treatment of fractures: New York, Grune and Stratton, 1929.
16. Bohler Lorenz: Die funktionelle bewegungs behandlung der "typischen" radiusbruche: Munchen med. Wochenschr. -70,1923,387-390.
17. Boyd HB, Stone MM: Resection of the distal end of the ulna. J. bone

Joint Surg. 26: 313, 1944.

18. William Seitz et al: Biomechanical analysis of pin placement and pin size for external fixator of distal radius fracture. CORR -251,207-212, 1990.

19. Carother, RG., and Berney: Thumb traction technique for reduction of Calles' Fractures. Arch. Surg. 848, 1949.

20. Cassebaum W.H.: Calles' fracture-A study of end results: J.Am.Med.Assn-143, 1950,963-965.

21. Castaing J: Recent fractures of the inferior extremity of the radius in the adult (French). Rev. Chir. Orthop 50: 582-696, 1964.

22. Catalano.W. Louis, Cole Jeffrey et al : Displaced intraarticular fractures of the distal aspect of the radius: JBJS 79A,Sept. 1997,1290-1302.

23. Chapman, DR.; Bennett J.B., Brayan, W.J. and Tullos H.S.: Complications of distal radius fractures: Pins and Plaster Treatment J. Hand Surg. 7: 509512, 1982.

24. Charnley John: The closed treatment of common fractures. Edinburgh Churchill Livingstone, 1961.

25. Christensen O.M. Christensen T.G.,: Length of immobilisation after fractures of distal radius: IntI. Orthopaedics-1 ,26-29,1995.

26. Christensen OM, Christensen TC: Plaster cast compared with bridging e~ernal fixation for distal radius fractures of the Colle's type: Int. Orthop. 2001: 24(6); 358-60.

27. Christensen OM, Christensen TC: Occupational therapy and Calles' fractures. (In Process Citation) Int. Orthop. 2001: 25(1); 43-5.

28. Christopher Pool: Calles' fracture prospective study of treatment: JBJS-55B, 1973, 540-544.

29. Clancey G.J.: Percutaneous Kirschner Wire Fixation of Calles' Fractures. A prospective study of 30 cases. J. Bone and Joint Surg., 66-A: 1008-1014, Sept. 1984.

30. C.O. Bechtol: Grip Test: the use of a dynamometer with adjustable handle spacings. JBJS, 36A, 820-4, 1954.
31. Clyburn TA: Dynamic external fixaton for comminuted intraarticular fractures of the distal end of the radius: JBJS 69A, Feb.1987, 248-254.
32. Cole .J.M. andObletz B.E.: Comminuted fractures of the distal end of the radius treated by transfixation in plaster cast. An end result study of thirty-three cases: JBJS48A, July1966, 931-945.
33. Calles A.: On the fractures of the carpal extremity of the radius: Edinburgh Med. And Surg. J.10,1814,182-186.
34. Collins Cifaldi Diane: Management and rehabilitation of distal radius fractures: OCNA-VoI.24, NO.2, April 1993, 365378.
35. Cooney P. Williams: Fractures of the distal radius-A modern treatment based· classification: OCNA-VoI.24, NO.2, April 1993,211-216.
36. Cooney P.Wiliiam et al: Complications Of Colles' Fractures: JBJS, June 1980,613-619.
37. Cotton F.J.: Adequate reduction and care in Calles' fractureNew methods: Boston med. And Surg. J.181,1919,651-656.
38. Cotton F.J.: The pathology of fractures of the lower extremity of the radius: Ann. Surg.-32, 1900,194.
39. Cozen Lewis: Colles' fractures. A method of maintaining reduction. California Med.75: 362-365, 1951.
40. Dee W., Klein W., Rieger H.: Reduction techniques in distal radius fractures: Injury-31, Suppl-1, 2000,48-55.
41. DePalma A.F.: Comminuted fractures of the distal end of the radius treated by ulnar pinning: JBJS-34A, July 1952,651-662.
42. Dias J.J, Wray C.C, et al: The value of early mobilisation in the treatment of Calles' fractures: JBJS-S9B, May 198, 463467.
43. Dobyns. H. James and Linscheid L. Ronald: Carpal bone injuries-

Editorial comment: CORR NO.149, June1980, 2-3.

44. Dowling. J. John and Sawyer Blackwell: Comminuted Calles' fractures: JBJS-43A, July 1961, 657-668.

45. Dunning C.E. and Lindsay C.S.: llizarov hybrid external fixator for fractures of the distal radius: Part I !.I nternal fixation versus lIizarov hybrid external fixation: Stability as assessed by cadaveric simulated motion testing: JHS-26 (2) Am, Mar-2001, 218-227.

46. Edwards G.S.: Intraarticular fractures of the distal part of the radius treatment Vvith small AO external fixator : JBJS-73A, Sept.1991, 1241-1250.

47. Ewans M, Kanis J.D., Ken~ghtJ,Tanner K.E.: The Oxford external fixateur. The Sixth Annual Report of the Nuffield Orthopaedic Centre. Headington, Oxford, 1979.

48. Eelma J. and McElfresh E. C.: Colles' fractures in young adults: Minn. Med.66,1983,487-490.

49. Fernandez D.L. and Jupiter J.B., Ring D.: Surgical management of delayed union and nonunion of distal radius fractures: JHS-26 (2) Am, Mar.2001, 201-209.

50. Fernandez L. Diego: Reconstructive procedures for malunion and traumatic arthritis: OCNA-VoI.24, NO.2, April 1993,341-363.

51. Ferris B.D., Stanton J, Zamora J : Kinematics of the ~st, Evidence for tv..u types of movements. J. Bone Joint Surg. Br. 2000; 82(2): 242-5.

52. Flisch C.W., Della Santa D.R.: Osteosynthesis of distal radius fractures by flexible intramedullary nailing. Chir Main, 1998; 17(3): 245-44.

53. Frank W. M. et al : Distal radius fractures is non bridging articular external fixator' a therapeutic altemative. Unflachirurg, 103 (10): 826-33, Oct 2000.

54. Freeland A.E., Sud V : Early wrist arthrodesis for irreparable

intraarticular distal radius fractures. Hand Surg. 5(2): 113-8, Dec. 2000.
55. Friberg Sven and Lundstrom Bo: Radiographic measurements of the radio-carpal joint in normal adults: Acta. Radiol. Diag.17,1976,249-256.
56. Frykman G: Arthritis of distal radio-ulnar joint after injury. JBJS Vol. 64B, 1964,350.
57. Frykman GK, Tooma GS, Boyko K: Comparison of eleven extemal fixators for treatment of unstable vvrist fractures. J. Hand. Surg. 14(A): 247-254, 1989.
58. Frykman Gosta: Fracture of the distal radius including sequelaeshoulder-hand-finger syndrome, disturbance in the distal radioulnar joint and impairment of nerve function-A clinical and ex)erimental study: Acta Orthopaedic Scand Supplementum108,1967,1.
59. Perren S. M.: Biomechanical aspects of prevention of pin loosening in the fixators exteme. AO/ASIF Dia. 1:4; 11-13, March 1988.
60. Futami et al: Chinese external fixation: JHS-(A), Nov.89.
61. Gartland J.J.,Jr. and Werley C.W.: Evaluation of healed Colles' fractures:JBJS33A, Oct. 1951 ,895-907.
62. Brinker W.O.: Stiffness studies on various configurations and types of external fixators: J.Am Animal Hosp. Assn-21 ,801-808, 1985.
63. Gausepohl T, Pennig D, Mader K: Principles of external fixation and supplementary techniques in distal radius fractures: Injury 31, Suppl 1: 56-70, 2000.
64. Chao E.Y.S. and Pope M.H.: The mechanical basis of external fixation. In concepts in external fixation,13-39,edited by David Selingson and Malcolm Pope, New York Grune and Stratton, 1982.
65. Geissler W.B. and Femandez D.L.: Percutaneous and open reduction of intraarticular distal radius fractures: JHS-5 (2) Am, Dec.2000, 85-92.
66. Geissler W.B. and Freeland: Intercarpal soft tissue lesions associated

with intraarticuiar fractures of distal end of radius: JBJS-73B,Mar.1991,312-315.

67. George L.Lucas and Kenneth M Sachtjen: An analysis of hand function in patients with Colles' fracture treated by Rush rod fixation: CaRR No. 155,1981,172.

68. Gilford W.W., Boltan R.H., Lambrinudi C.: The mechanism of the vvrist joint with special reference to fractures of the scaphoid: Guy's Hosp. Rep-92,1943,52.

69. Gliatis J.D., Plessas S.J. and Davis T.R.: Outcome of distal radius fractures in young adults: JHS-25 (6) AM, Dec.2000, 535-543.

70. Glock W.R, Brown F.W. and Mackel F.O.: Colles' Fractures. J. Indiana Med. 50:4349,1957.

71. Golden G.N.: Treatment and prognosis of Colles' fracture: Lancet-i,1963,511-515.

72. Goslings JC et al: Three dimensional dynamic extemal fixatiOfl of distal radius fractures. A prospective Study. Injury 30(6)L 421-30, Aug. 1999.

73. Graham CA, Gibson AJ.: Anaesthesia for the management of distal radius fractures in adults in Scottish hospitals. Eur. J. Emerg Med. 4(4); 210-2, Dec. 1997.

74. Grana A William and Kopta A Joseph: The Roger Anderson device in the treatment of fractures of the distal end of the radius :JBJS 61A,Dec.1979,1234-1238.

75. Green J.T. and Gay F.H.: Calles' Fractures. Residual Disability. Am. J. Surg. 91: 636-42, 1956.

76. Green P.David: Pins and plaster treatment of comminuted fractures of the distal end of the radius :J8JS 57A,April 1975,304-310.

77. Gupta Ajay: The treatment of Calles' fracturesimmmobilisation with wrist dorsiflexed:JBJS738,Mar.1991 , 312-315.

78. Gurd F.B.: The Colles' Pouteau fractures of the lower end of the radius. Am. J. Surg. 38: 526-538, 1937.
79. Gyorgy Fenyo and Ozof Isacansson: Acta Orthop. Scand.-45,No.1, 1974
80. Haddad M, Jacoby S, Snerum L, Overgaard S: Extemal fixation of distal radius fractures: 3 or 5 weeks of extemal fixation. Int. Orthop 2000; 24(4): 224-6.
81. Hammond G.: Comminuted Colles' fractures: Am. J. Surg.78,1949,617-624.
82. Haren K, Backman C: Effect of manual lymph drainage as described by Vodder on oedema of the hand after fracture of the distal radius: A prospective clinical study. Scan J. Plast Reconstr Surg Hand Surg 34(4): 367-72, Dec. 2000.
83. Heppenstall RB.: Fracture treatment and healing: W.B. Saunders Company, Philadelphia,1980,120-136.
84. Hitzrot J.M. and Murray C.R: The factors that influenced the prognosis in fractures at the base of the radius. Am. J. Surg. 35: 17-29, 1921.
85. Horesh Z, Volpin G, Hoerer D: The surgical treatment of severe comminuted intraarticular fractures of distal radius with the small AO external fixation device: A prospective three and half year follow up study. Clin. Orthop. 263: 147-153, 1991.
86. Home J.G.: A prospective randomized trial of external fixation and plaster cast immobilisation in treatment of distal radius fractures; Trauma 4, 1990; 30-34.
87. Howard A. Lipton, Ronit Wollenstein: Operative treatment of intra-articular distal radial fracture. CORR, 1996: No. 327, p. 110124.
88. Hutchinson DT, Bachus KN External fixation of the distal radius: to predrill or not to predrill. J. Hand. Surg. (Am.) 2000Nov. 25(6): 1064-8.
89. Jakim L., Pieterse H.S., Sweet M.B.: External fixator for intraarticular

fractures of distal radius: JBJS-73B, Mar.1991, 302-306.

90. Jakob Roland and Fernandez Diego: The treatment of wrist fractures with the small AO external fixation device. In Current Concepts of External Fixation of Fractures, pp. 307-314, Edited by H.K. Uhthoff.

91. Jenkins N.H, Jones D.G, et al : External fixaton of Colles' fractures .An anatomical study: JBJS 69B,March 1987,207211.

92. Jerry L.Knirk and Jesse B. Jupiter: Intra articular fractures of the distal end of the radius in young adults :JBJS-68A,June 1986,647-659.

93. Jesse B. Jupiter: Current concepts review, fractures of distal end of the radius :JBJS 73A,March 1991,461-469.

94. Joosten U and Joist A: The treatment of unstable fractures of the distal radius using a bridging external fixator. Results from a long term evaluation. Chirurg 70(11): 1315-22; Nov. 1999

95. Jupiter J.B. and Masem M.: Reconstruction of post traumatic defoll11ity of the distal radius and ulna: Hand ClinicsNO.3,1988,377.

96. Kaempffe FA and WalkerK.M.: External fixator for distal radius fractures Effects of distraction on outcome: CORR-380, Nov.2000, 220-225.

97. Kapoor H, Agrawal A, Dhaon B.K.: Displaced Intraarticular Fractures of distal radius: A comparative evaluation of results following closed reduction, external fixation and open reduction with internal fixation: Injury 2000 Mar 31(2): 75-9.

98. Kauer M.G.John: Functional anatomy of the wrist: CORR NO.149, June1980, 9-11.

99. Kauer M.G.John: Mechanism of carpal joint: CORR-202, 1986, 16-26.

100. Keats T.E.,Diamond A.E.,and Williams J.M.: Normal axial relationship of the major joints:
Radiology-87,1966,904.

101. Kongsholm Jorgen and Olerud Claus: Plaster cast versus external fixation

for unstable intraarticular Colles' fracture: CORR-241,April 1989,57-64.

102. Kopylov P., Aspenberg P., Yuan X, Ryd L.: Radiostereometric analysis of distal radius fractures displacement during treatment -A randomised study comparing Norian SRS and external fixation in 23 patients: Acta. Ortho. Scand.-72(1), Feb.2001, 57-61.

103. Kulkarni R.S.: Colles' fracture-A review of 652 cases: Indian Journal of orthopaedics-voI.27.No.2,July 1993,179-183.

104. Ladd A. L. and Pliam N.B.: Use of bone graft substitute in distal radius fractures: JAm. Acad Orthop. Surg7(5),Sept.1999,279-290.

105. Lambrinudi, Lovel C.S.: A new aid in the management of Colles' fracture: Am. J. Surg.-84,1952,375-377.

106. Landsmeer J.M.F.: Studies in the anatomy of articulation: Acta. Morph. Neert. Scand.-3, 1961,287.

107. Leroy Young, Paul Pin: Fluctuation in grip and pinch strength among normal subjects. J.H.S. 1989; 14A; 125-9.

108. Leung F, Ozkan M: Conservative treatment of intraarticular fractures of the distal radius - factors affecting functional outcome. Hand Surg. 2000 Dec. 5(2): 145-53.

109. Leung K.S. and Shen W.Y., et al.: An effective treatment of comminuted fractures of the distal radius: JHS-15(A), 1990, 11-17.

110. Lidstrom Anders: Fractures of the distal end of the radius. A clinical and statistical study of end results: Acta Orthop. Scand., supplementum-41, 1959.

111. Lundy OW; Quisling SG: Tilted lateral radiographs in the evaluation of intraarticular distal radius fractures. J. Hand Surg. (Am.) 1999 Mar. 24(2): 249-56.

112. MacConaill M.A: The mechanical anatomy of the carpus and its bearing on some surgical problems: J. Anatomy-75, 1941, 166.

113. MacDermaid J.C., Richards R.S., Donner A., Bellamy N., Roth J.C.: Responsiveness of Short Form-36, disability of the arm, shoulder and hand questionnaire. patient related 'Mist evaluation. and physical impairment measurements in evaluating recovery after a distal radius fracture: JHS-25 (2) Am. Mar.2000. 330-340.

114. Mannur A, Shah RR: Gulbarga Fixator in management of distal radius fractures. Indian Joumal of Orthopaedics. 2001 October 34(4).

115. Mark Andrew Katz: CT scanning of intraarticular distal radius fractures: Does it influence treatment? Paper No. 094, Orange County Convention Center, 15 March 2000.

116. MarkieVvitz AD, Gellman H: Five pin extemal fixation and early range of motion for distal radius fractures. Ortho. Clin. North Am. 2001 Apr. 32(2): 329-35.

117. Marsh H.O. and Teal S.W.: Treatment of comminuted fractures of the distal radius Vvith selfcontained skeletal traction: Am. J. Surg.-124, 1972,715-719.

118. Masse A, Bruno A, Basetti M : Prevention of pin track infection in extemal fixation Vvith silver coated pins: Clinical and Microbiological results. J. Biomed Mater Res. 2000 Sep; 53(5): 600-4.

119. Mayer J.H. Colles' Fracture. Sr. J. Surg. 27: 629, 1940.

120. McAuliffe T.B, Hillar K.M, et al: Early mobilisation of Colles' fractures - A prospective trial: JBJS-69B, Nov.1987. 727-730.

121. McMurthy R. Y. and Jupiter J.B.: Fractures of the distal radius .In skeletal trauma, edited by B.Bro'M1er, J.Jupiter, A Levine and P. Trafton. Philadelphia, W.B. Saunders. Unpublished Data.

122. Mcnutt, J.C. Pitfalls in the management of Colles' Fractures. Illinois Med. J. 109: 133-134, 1956.

123. Mcqueen Margaret and Caspers Jeanette: Colles' Fracture-Does the

anatomical result affect the final function?: JBJS-70B, Aug.1988, 649-652.

124. McQueen, MM, MacLaren, A and Chalmers John: The value of Remanipulating Colles' Fractures. J. Bone and Joint Srug., 68-B(2):232-233, 1986.

125. Mehta JA, Bain GI: An overview of distal radius fractures. Aust. J. Rural Health, 1999, May 7(2): 121-6.

126. Mehta JA, Bciin GI, Heptinstall RJ: Anatomical reduction of intraarticular fractures' of the distal radius. An arthroscopically assisted approach. J. Bone Joint Surg. Br. 2000 Jan. 82(1): 79-86.

127. Halim A: Surface and radiological anatomy. 2nd edition, 1993, 13-20.

128. Melone C.P. Jr.: Articular Fractures of the Distal Radius. Orthop. Clin. North America, 15: 217-236, 1984.

129. Melone C.P. Jr.: Open treatment for displaced articular fractures of the distal radius. Clin. Orthop, 202:103-111, 1986.

130. Melone P. Charles, Jr.: Distal radius fractures - Patterns of articular fragmentation: OCNA-VoI.24, NO.2, April 1993, 239-253.

131. Metz M. Victor and Gilula A Louis: Imaging techniques for distal radius fractures and related injuries: OC NA-Vol. 24, NO.2, April 1993, 217-228.

132. MitlelmeierW, Braun C, Schafer R: The Kapandji technique for fixation of distal radius fractures a biomechanical comparison of primary stability. Arch Orthop Trauma Surg. 2001: 121(3): 135-8.

133. Morawicki P; Sosin P Dutka J: Carpal instability and fractures of the distal end of the radius. Chir Narzadow Ruchu Orthop. Pol. 1999; 64(2): 127-31.

134. Nienstedt F: The operative treatment of intraarticular Smith fractures. J. Hand. Surg. Br. 1999 Feb. 24(1): 99-103.

135. Older T.M., Stabler E.V. and Cassebaum W.H.: Colles' fracture- Evaluation and selection of therapy: J.Trauma-5,1965, 469-476.

136. Overgaard S0ren and Solgaard Soren: Osteoarthritis after Colles' fracture: Orthopaedics- 12, 1989,413-416.

137. Palmer AK, et al: Functional Vv'list motion-A biomechanical study: JHS-NO.1, 1985,39.

138. Palmer AK. and WernerF.W.: Biomechanics of the distal radioulnar joint: CORR-No.187, 1984,26.

139. Platt H: Colles' Fractures. British Medical Journal, ii, 288.

140. Pogue D.J, ef al : Effects of distal' radius fracture malunion on Vvtistjoint mechanics: JHS 15 (A), 1990,721.

141. Porter, Martyn and Stockley Ian: Fractures of the distal radius. Intennediate and End Results in Relation to Radiologic Parameters. Clin. Orthop. 220: 241-251, 1987.

142. Prince Heather: The small AO external fixatorin the treatment of unstable distal foreann fractures: JHS-13(B), Aug.1988,294-297.

143. Rayhack M. John: The history and evolution of percutaneous pinning of displaced distal radius fractures: OCNA-VoI.24, NO.2, April 1993,287-300.

144. Rockwood and Green's: Textbook of Orthopaedics. Fractures in Adults. Vol. 1, 1996, 4th Ed. p. 769-790.

145. Rogachefsky R.A., Lipson S.R., McAuliffe J.A.: Treatment of severe comminuted intraarticular fractures of the distal end of the radius by open reduction and combined internal and external fixation: JBJS-83A, ApriI2001,509-519.

146. Ronald Linscheid: Kinematic considerations of the Vvtist: CORR, nO.202, Jan 1986,27-39.

147. Rose S, Frank J, Marzi I: Diagnostic and therapeutic significance of

arthroscopy in distal radius fracture. Zentralbl Chir 1999; 124(11): 984-92.

148. Roumen R.M.H., Heps W.L.E.M.: Unstable Colles' fractures in elderly patients: JBJS-73B, Mar.1991,307-311.

149. Ryu J, ef al : Functional ranges of motion of the Vvtist joint: JHS-16 (A), 1991,409.

150. Sanders A.R, ef al: External fixation of distal radius fractures Results and complications: JHS-16 (A), 1991,385.

151. Sarmiento, Augusto; Zagorski, J.B. and SindairW.F.: Functional bracing of Colles' Fractures: A prospective study of immobilisation in supination vs. pronation. CORR 146: 175-83,80.

152. Sarrafian S., Melamed J.L., Goshgarian G.M.: Study of Vvtist motion in flexion and extension: CORR-126,1977,153.

153. Scheck Max : Long term follow up of treatment of comminuted fractures of the distal end of the radius by transfixation with Kirschner wres and cast :JBJS44A, Mar 1962,337-51.

154. Schuind F., Burny F., Alemzad.eh S., Stallenberg B. : Does the normal contralateral Vvtist provide the best reference for X ray film measurements of pathologic Vvtist?: JHS-21(1),Jan.1996,24-30.

155. Schuind F.,Donkerwolcke M. And Burny F. External fixation of Vvtist fractures: Orthopaedics-7, 1984,841-844.

156. Scultz J. Roberts: The Language of fractures, 1972.

157. Seitz H. William: External fixation of distal radius fractures Indications and technical principles: OCNAVol. 24, NO.2, April 1993, 255- 264.

158. Shin AY; Bishop AT: Vascular Anatomy of the distal radius: Implications for vascularized bone grafts. Clin Orthop 2001 Feb; ,383: 60-73.

159. Smaill G.B.: Long-term follow-up of Colles' fracture: JBJS47B, Feb.1965, 80-85.

160. Solgaard Soren: Classification of distal radius fractures: Acta Orthop. Scand.-56,1985, 249-252.

161. Solgaard, S; Bunger, C; and Solund K: Displaced distal radius fractures. A comparative study of early results following external fixation, Functional Bracing in supination or dorsal Plaster Immobilisation. Arch. Orthop. and Traumat. Surg.109: 34-38,1989.

162. Spira E. and Weigl K.: The comminuted fractures of the distal end of the radius: Reconstr. Surg. Traumato!. 11,1969, 128-138.

163. Stader Otto: Treating fractures of long bones with the. reduction splint. North American Veter. 20: 5559,1939.

164. Stein Harm, Volpin Gershan: Cast or external fixation for fractures of distal radius: Acta Ortho. Scand.voI.61,No.5,Oct.1990,453-456.

165. Stephen C. Weber and R. M. Szabo: Severely comminuted distal radial fracture as an unsolved problem. J.H.S., Mar. 1986; 11A : 157-165.

166. Stewart H.D., Innes A.R., Burke F.D: Functional cast bracing for Calles' fractur~s- A comparison betvveen cast bracing and conventional plaster casts: JBJS-66B, 1984, 749-753.

167. Szabo M. Robert: Extraarticular fractures of the distal radius: OCNA-VoI.24, NO.2, April 1993,229-237.

168. Szabo Robert M. and Weber Stephen C.: Comminuted intraarticular fractures of the distal radius: CORR No. 230, May 1988,39-48.

169. T.G.Sommerkamp et al : Dynamic extemal fixation of unstable fractures of the distal part of the radius. A prospective randomised comparison with static extemal fixaton :JBJS 76A,Aug 1994,1149-1161.

170. Taleisnik Julio: The ligaments of the Vvfist: JHS-1, 1976,110118.

171. Taylor G.W. and Parsons C.L.: The role of discus articularis in Calles'

fracture: JBJS-20, 1938, 149-152.

172. Thomas F.B.: Reduction of Smith's fracture:JBJS-39B, Aug.1957 463-470.

173. Trumble TE, Culp RW, GeisslerWB: Intraarticular fractures of the distal aspect of the radius. Instr. Course Lect. 1999; 48: 465-80.

174. Van Der Linden W. and Ericson R.: Calles' fracture-How should its displacement be measured and how it should it be immobilised? JBJS-63A, esoteric Oct. 1981 , 1285-1288.

175. Vaughan, P.A.; Lui S.M., Harrington I.J. and Maistrelli, G. L.: Treatment of unstable fractures of the distal radius by extemal fixator. J. Bone and Joint Surg., 67-8(3); 385-389, 1985.

176. Vesely D.G: The distal radio-ulnar joint: CORR-No.51, 1967,75.

177. Villar RN, Marsh O, et al: Three years after Colles' fracture-A prospective review JBJS-69B, Aug. 1987, 635-638.

178. Volpin G., Katznelson G. Lin E.: Tension band wiring for fixation of comminuted fractures of the distal radius : Injury-12, 1980,240

179. Volz R.G.: The development of a total wrist arthroplasty: CO.RR-116, 1976,209.

180. Von Bonin G: External pin fixation for unstable Colles' fracture :JBJS-61A,Sept. 1979,

181. W.P.Cooney, R Lindscheid and James Dobyns: The role of physiotherapy and clinical predictors of outcome after fractures of the distal radius. JBJS- Br. 82(7): 972-6, Sept. 2000.

182. Wakefield A.E., McQuen M.M. : Colles' fracture of the radius. A method of treatment. Lancet 2: 354-355, 1952.

183. Walker Dennis: Colles' fractures: with notes on poor results. SCNA- 18: 1965-1703, 1938.

184. Walkling AA: Acute median neuropathy following physeal fract. of the

distal radius:JPO.-14,173-7,94.

185. Waters, Peter M., Schwend Richard : Osseous integration of Bovine hydroxypatite ceramic in metaphyseal bone defects of the distal radius.Am.JHS25(5):833-41 Sep.200l).

186. Werber K. D. et al : Colles' Fractures. Canadian Med. Assn. J. 43: 148-151, 1940.

187. White A.W.: A review of Smith's fractures: JBJS-51 B, May 1969,324-329.

188. Woodyard J.E.: A detailed study of movement of the wrist joint: J. Anatomy-70, 1935, 137.

189. Wright RD. Kinamatics of the wrist: CORR-No.149, June 1980,21-32.

190. Youm Yougnil and Flatt E.: Outcome following unoperative treatment of displaced distal radius fractures in low demand patients older than 60 years. JHS- Am. 2000 Jan; 25(1): 19-28.

191. Young BT, Rayan GM: Pin reduction and fixation of volar fracture fragments of distal radius fractures via the flexor carpi radialis tendon. J. Trauma 2000 Sep. 49(3): 433-9.

192. Ziran BH, Scheel M, Keith MW: Radisplaced unstable fractures of distal radius. JBJS-1998; Vol. 80B, NO.4, July 685-9.

193. M.M. Mc Queen: Ligamentotaxis and bone grafting in comminuted fractures of distal radius. JBJS71(B), 1989,838-842.

194. W.P. Cooney: External fixation of distal radius fractures. CORR, 1983, No. 180. p. 44-48.

195. Campbell's: Operative orthopaedics, $9^{th}$ Ed. VoI.IV,34453500, 1998.