“STUDY OF MORPHOLOGICAL DISTRIBUTION OF INTRA-ARTICULAR FRACTURES OF DISTAL-END RADIUS BASED ON NOVEL THREE COLUMN CLASSIFICATION SYSTEM”

By

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LIST OF ABBREVIATIONS

GLOSSARY	ABBREVIATIONS
AO/OTA	Arbeitgemeinschaft für Osteosynthesefragen/Orthopedic Trauma Association
DRUJ	Distal Radio-ulnar Joint
RCL	Radial Collateral Ligament
TFCC	Triangular Fibro-Cartilaginous Complex
UCL	Ulnar Collateral Ligament
FCR	Flexor Carpi Radialis
PTOA	Post-Traumatic Osteoarthritis
DASH	Disabilities of the Arm, Shoulder and Hand
FOOSH	Fall On Outstretched Hand
NC	Not Classified
NPV	Negative Predictive Value
PPV	Positive Predictive Value

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ABSTRACT

Introduction: Distal End Radius fractures are common across all age groups, with complex intra-articular fracture patterns challenging classification and treatment. Existing systems focus on aspects like metaphyseal comminution or biomechanical forces, but often overlook key anatomical columns involved in wrist load transmission. A novel three-column classification system can improve communication among surgeons and enhance treatment planning and outcomes.

Objectives: To examine the morphological characteristics of distal radius fractures and assessing its consistency in clinical setting along-with comparing classification outcomes to existing standard systems

Materials and methods: 46 patients diagnosed with Intra-articular Distal End Radius Fractures admitted in KLE Hospital were classified according to novel system and morphological outcomes were compared.

Results: The 41-50 age group has the highest frequency at 26.5%, with males making up 69.4% and females 30.6%. Road traffic accidents (RTAs) account for 73.5% of cases, while FOOSH and trivial trauma make up 10.2% and 16.3%, respectively. The "Radial, Intermediate" column is most common, representing 44.9% of cases, with a peak in the 51-60 age group, indicating higher injury susceptibility.

Conclusion: This study emphasizes the importance of a precise classification for distal radius fractures, particularly with multiple-column involvement. Combining the three-column system with traditional methods helps tailor treatment, while advocating for detailed imaging and advanced techniques to minimize complications like displacement, osteoarthritis, and functional impairment in all patients.

INTRODUCTION

Distal End Radius fractures are one of the most common orthopedic injuries and occur in almost all age groups.[1] Etiologies for this injury are often road traffic accidents, or falls on an outstretched hand with excessive axial load being passed down the wrist.[2] Because the distal radius articulates with the scaphoid, lunate, and distal radioulnar joint, obtaining accurate articular congruity is essential to prevent chronic pain, stiffness, loss of motion, and arthritic changes.[3] Despite extensive research on these injuries, the complex morphology of intra-articular fracture patterns continues to pose challenges in classification and treatment.[4] Fragmentation may occur in isolation or in combination within the scaphoid fossa, lunate fossa, and distal radioulnar joint.[5] Die-punch fractures, which often involve the lunate fossa through an impaction mechanism, highlight how a single area of the distal radius can suffer localized articular depression.[6] These high-energy fractures have historically been difficult to manage because of the technical demands in restoring the joint surface and maintaining stable fixation.[7]

Over the years, multiple classification systems have attempted to categorize Distal End Radius Fractures based on features such as displacement, joint involvement, and mechanism of injury.[8] Well-known approaches include the AO/OTA, Frykman, Melone, and Fernandez classifications.[9] While each system contributes valuable perspectives—such as focusing on metaphyseal comminution, articular fragments, or biomechanical forces—they sometimes offer limited insight into the specific anatomical columns integral to load transmission at the wrist.[10] The distal radius effectively comprises three functional regions: the radial column (encompassing the scaphoid fossa), the intermediate column (centered on the lunate fossa), and the ulnar column (around the distal radioulnar joint and ulnar styloid).[11]

Understanding exactly which columns are affected by intra-articular extensions can provide more precise guidance for surgical approaches and fixation strategies.[12] Thanks to the advent of high-resolution computed tomography (CT) and three-dimensional reconstruction, surgeons can now identify subtle articular damage, including depressed or impacted fragments, far more reliably than with plain radiographs alone.[13]

In this context, a novel three column classification system was introduced to address limitations of the existing schemes and to underscore the importance of identifying which of the radial, intermediate, or ulnar columns are disrupted.[14] This classification highlights the load-bearing anatomy: the scaphoid fossa and lunate fossa each carry different loads through the wrist, while the ulnar column provides distal radioulnar joint stability.[15] Notably, die-punch fragments—often found in the intermediate column—reflect lunate fossa impaction and can be accompanied by additional fracture lines into the radial or ulnar columns.[16] By examining these distinct fracture pathways, surgeons can determine the best approach (volar, dorsal, or combined) and select fixation methods tailored to the injured columns.[17] For instance, a volar plate might stabilize the intermediate column effectively, while supplementary fixation, such as radial column plating or K-wires, may be necessary if comminution extends radially.[18] Early clinical studies indicate that a three-column approach can also enhance interobserver reliability, aid in the prediction of potential complications such as mal-reduction of depressed fragments, and align more meaningfully with surgical outcomes.[19] This system allows for more subtle mapping of fracture patterns, better biomechanical correlation, and a common language for comparing surgical interventions across different patient populations.[20]

Still, the implementation of this new classification to be widely adopted has several challenges.[21] Most surgeons still rely on the older systems, and the three-column concept requires regular CT-based assessments to differentiate between intricate morphological details.[22] Furthermore, fracture patterns differ significantly depending on patient demographics: younger patients usually experience high-energy trauma with greater comminution, whereas elderly patients—who may present with osteoporotic bone—need to take into account fragment stability and fixation strategies.[23] Future studies should associate three-column subtypes with clinical parameters like operative time and complications and with radiographic measurements (volar tilt, radial inclination, ulnar variance), as well as with functional measures like grip strength and range of motion.[24] Another pertinent variable may be wrist position at impact such that force is delivered more distally via either the scaphoid or lunate facet, or less distally, toward the ulnar column.[25] Identifying these subtle differences could refine the timing and extent of surgical intervention and guide the use of bone grafts or specialized implants to manage subchondral impaction.[26]

A clearer epidemiological understanding of which columns tend to be affected in intra-articular fractures will help validate the three-column classification's clinical utility.[27]

Although some retrospective series have begun applying this approach, more prospective and multi-center studies are needed to confirm reliability, consistency, and applicability across different healthcare settings.[28] If large datasets demonstrate that specific patterns—such as combined radial and intermediate column involvement—correspond with higher rates of malunion or functional impairment, then clinicians can anticipate more elaborate reconstructive requirements.[29]

Conversely, isolated column fractures might respond well to minimal fixation techniques, leading to simpler treatment algorithms.[30]

ANATOMY OF THE DISTAL RADIUS IN THE CONTEXT OF A NOVEL THREE-COLUMN CLASSIFICATION

INTRODUCTION

The distal end of the radius is of paramount significance in wrist function, stability, and load transmission. It articulates with the carpal bones and the distal ulna, forming the radiocarpal (wrist) and distal radioulnar joints (DRUJ). Intra-articular fractures involving this region can be challenging to treat due to the complex interplay of osseous, ligamentous, vascular, and muscular structures. A thorough understanding of the distal radius anatomy is vital for accurately describing fracture patterns, planning surgical interventions, and predicting clinical outcomes.

The novel three-column classification system divides the distal radius into the **radial (lateral) column**, **intermediate (central) column**, and **ulnar (medial) column**. This anatomical conceptualization aids in correlating specific fracture fragments with their respective biomechanical roles. This chapter provides an in-depth exploration of the distal radius's osteology, associated ligaments, muscular attachments, neurovascular supply, and embryology, emphasizing how these structural details underpin the three-column classification framework.

Embryological Overview

Understanding the embryological development of the distal radius can elucidate its adult morphology and certain congenital variations:

1. **Formation of the Forearm Skeleton**
    - The radius and ulna develop from the lateral plate mesoderm during embryonic weeks 4–7. Chondrification centers appear first, followed by endochondral ossification.
    - The distal radius growth plate (physis) begins to form around week 8 of gestation and remains open until skeletal maturity.
2. **Physeal Arrangement and Growth Contribution**
    - The distal radial physis is responsible for a significant portion of the radius's longitudinal growth—approximately 75–80%.
    - Abnormal embryological development or injury to the physis can lead to angular deformities and altered distal radial anatomy, sometimes predisposing to certain fracture patterns.
3. **Implications for Adult Morphology**
    - The broad metaphysis in the distal radius and the distinct architecture of the radial styloid, lunate fossa, and sigmoid notch are a culmination of sequential ossification events.
    - Variations in the alignment or shape of the distal radius can result from genetic factors or early cartilage modeling anomalies, potentially impacting wrist biomechanics and fracture susceptibility.

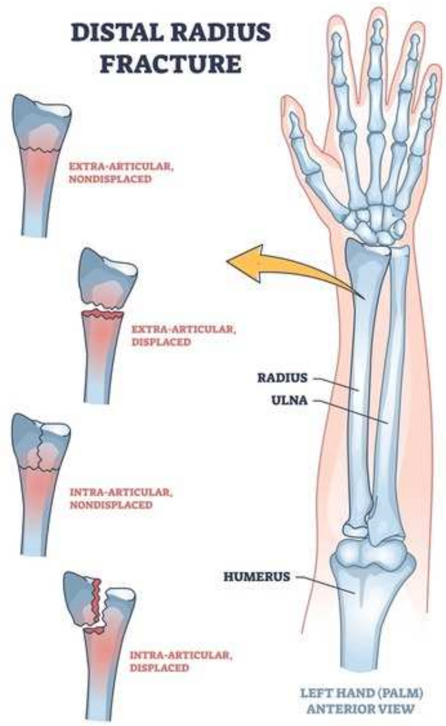
Macroscopic Osteology of the Distal Radius

3.1 Overall Shape and Orientation

The distal radius flares into a wide, somewhat rectangular or trapezoidal shape when viewed on the anteroposterior (AP) projection. It is compressed dorsoventrally, creating distinct palmar (volar) and dorsal surfaces. Key parameters that describe its orientation include:

- **Radial Height (or Radial Length)**: The distance between two parallel lines drawn perpendicular to the long axis of the radius—one across the tip of the radial styloid and the other across the ulnar corner of the distal radius. Normal values range around 11–13 mm.
- **Radial Inclination**: Measured on the AP radiograph, it reflects the oblique angle of the distal radial articular surface relative to a horizontal line. Typically, this is about 21–25°.
- **Volar Tilt (or Palmar Tilt)**: Assessed on the lateral radiograph, it describes the tilt of the distal radial articular surface relative to the perpendicular axis of the forearm's shaft. A normal volar tilt often measures 10–15°. These angular and linear measurements are clinically relevant; alterations can significantly affect wrist function and load distribution through the radiocarpal joint.

Figure 1: Distal Radius—Anterior (Volar) View



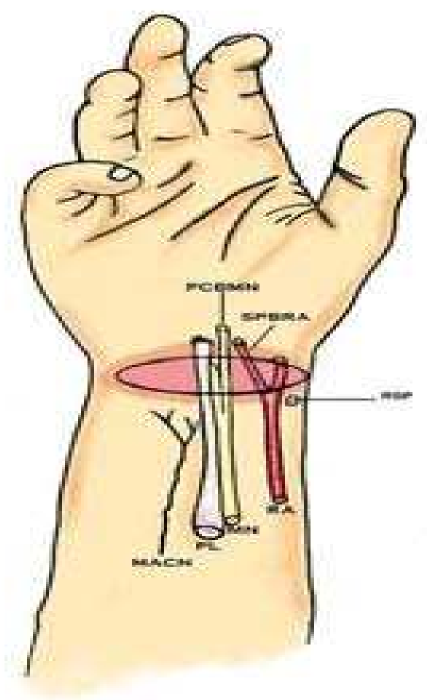
3.2 Radial Styloid Process

A prominent lateral projection, the **radial styloid** is easily palpable on the wrist's lateral aspect. It provides attachments for:

- The **brachioradialis tendon**, which inserts onto its base.
- Important ligamentous structures, including the **radial collateral ligament (RCL)**, connecting the styloid to the scaphoid and trapezium.

The radial styloid, being the lateral boundary of the wrist joint, plays a significant role in limiting ulnar deviation and stabilizing the scaphoid.

Figure 2: Prominent Radial Styloid (Surface Anatomy)



3.3 Articular Facets: Scaphoid and Lunate Fossae

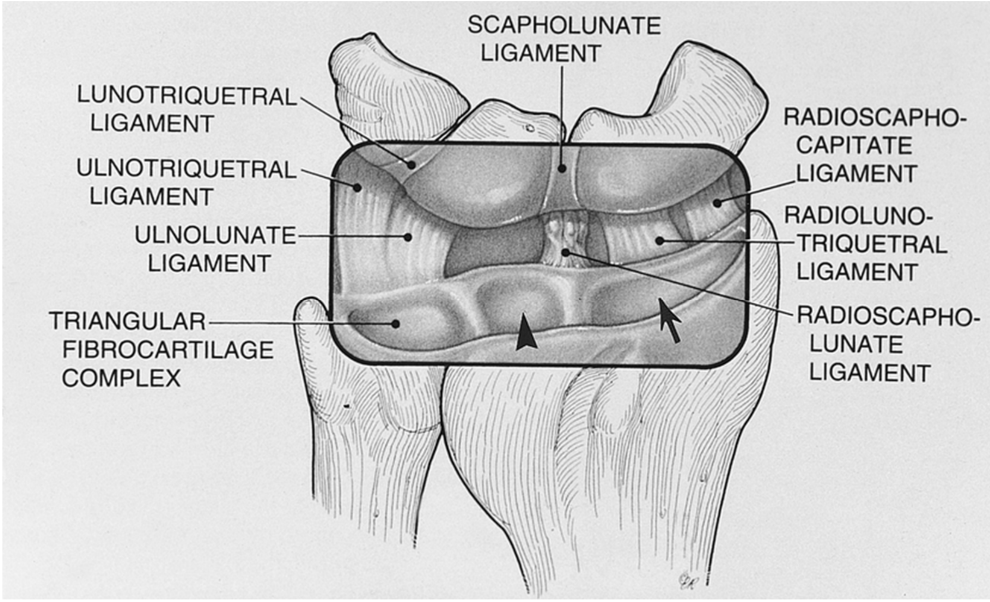
The distal radius's articular surface is concave in both the AP and lateral planes, subdivided into two major facets:

1. **Scaphoid Fossa**: Lateral portion of the distal radius articulating with the scaphoid bone. It often appears narrower but can bear substantial load, particularly during radial deviation.

2. **Lunate Fossa**: Medial and slightly broader compared to the scaphoid fossa, articulating with the lunate bone.

These fossae are delineated by a subtle ridge; however, in many healthy individuals, the surface appears nearly continuous. The relative sizes of these fossae can vary among individuals, influencing how force is transmitted across the wrist.

Figure 3: Distal Radius Articular Surface—Scaphoid and Lunate Fossae



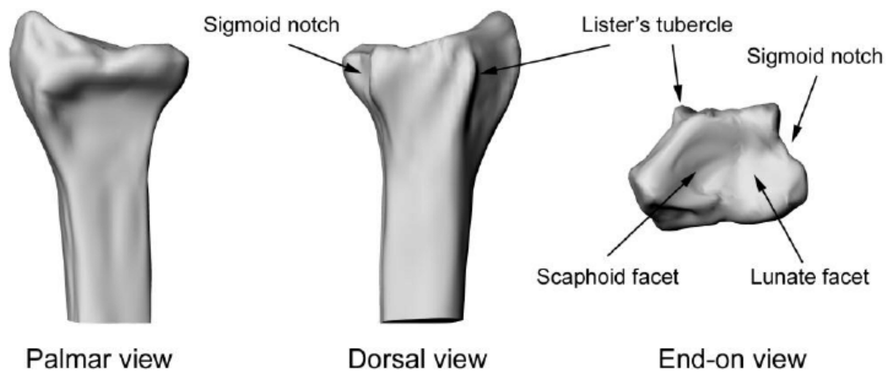
3.4 Sigmoid Notch (Ulnar Notch)

On the medial margin of the distal radius is the **sigmoid notch**, a concavity articulating with the head of the ulna to form the **distal radioulnar joint (DRUJ)**. Its shape and depth are crucial for stable rotation of the forearm. Key points include:

- The **curvature** of the notch must closely match that of the ulnar head to maintain DRUJ congruence.
- The volar and dorsal rims of the sigmoid notch provide attachment for the **triangular fibrocartilage complex (TFCC)**, which further stabilizes the DRUJ.

Even slight changes in the geometry of the sigmoid notch can lead to altered kinematics, forearm instability, and susceptibility to degenerative changes.

Figure 4: Sigmoid Notch (Medial View of Distal Radius)



3.5 Volar and Dorsal Surfaces

- **Volar (Anterior) Surface**: Generally smooth and concave. The distal aspect near the joint often contains ridges for ligament attachments. This surface is the site of approach for many surgical procedures (volar plating).
- **Dorsal (Posterior) Surface**: Marked by various grooves and tubercles for extensor tendon passage. Six compartments for the extensor tendons cross the distal radius dorsally.

Figure 5: Dorsal Grooves for Extensor Tendons

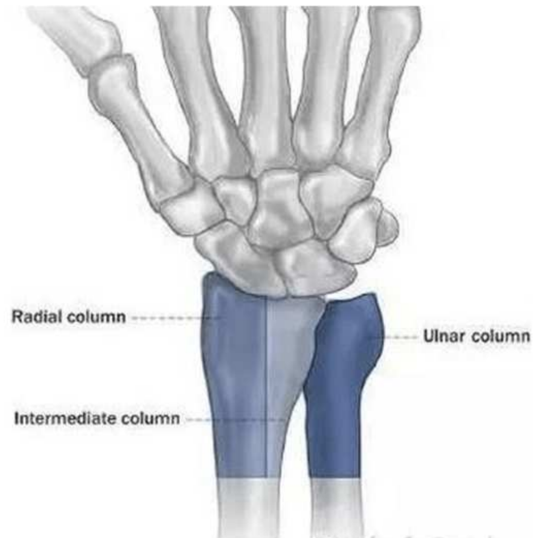
4. The Three-Column Concept

4.1 Overview of Three Columns

Reflecting advancements in fracture fixation strategies and morphologic understanding, the distal radius is frequently divided into:

1. **Radial (Lateral) Column**
    - Incorporates the **radial styloid** and the **scaphoid fossa**.
    - Stabilizes the scaphoid and resists varus forces (i.e., radial deviation).
    - Fracture lines isolated to this column often present as **radial styloid** or **shear-type** fractures.
2. **Intermediate (Central) Column**
    - Formed predominantly by the **lunate fossa**.
    - Represents the principal load-bearing axis of the wrist.
    - “Die-punch” or impaction fractures frequently affect this column, compromising the radiocarpal joint surface.
3. **Ulnar (Medial) Column**
    - Encompasses the **sigmoid notch** region and distal radioulnar joint.
    - Ensures forearm rotational stability (pronation-supination).
    - Fractures in this column may involve the “ulnar corner” or the **DRUJ** interface, leading to instability if not adequately reduced and stabilized.

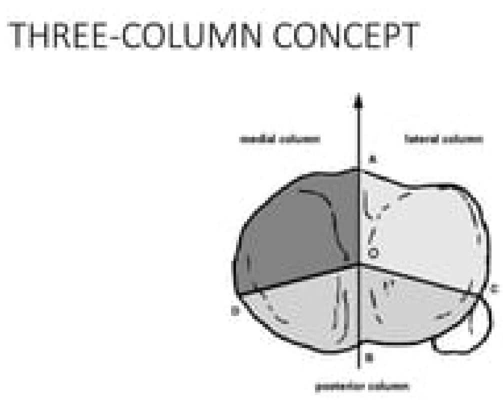
Figure 6: Schematic Representation of the Three Columns of the Distal Radius



4.2 Rationale for Columnar Division

Traditional two-column models (radial and intermediate) offer limited insight into ulnar corner fractures that compromise the DRUJ. By **designating the ulnar column** as its own entity, surgeons can recognize and specifically address fracture fragments around the sigmoid notch and the ulnar corner—structures vital for rotational mechanics. This **three-column approach** aligns closely with modern fragment-specific fixation techniques, wherein each fracture fragment is handled based on its column.

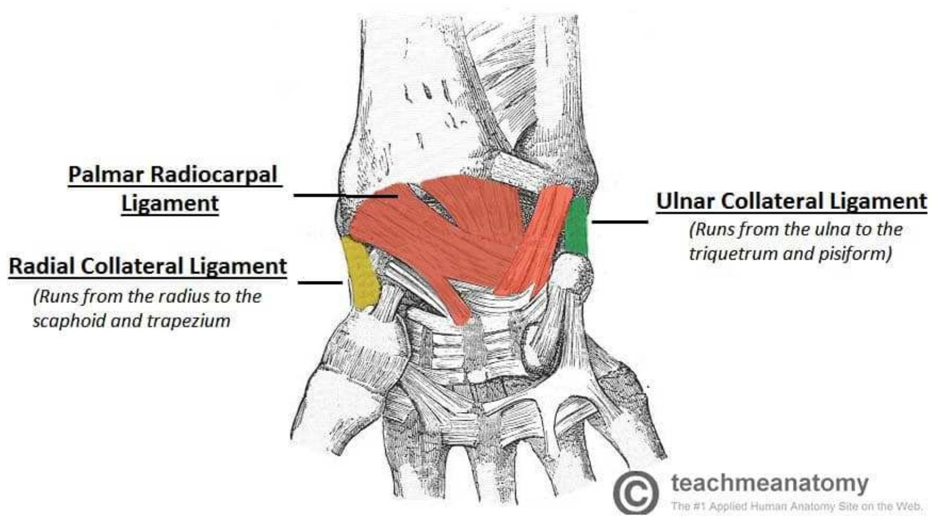
Figure 7: Column-Specific Fixation Concept



5.4 Radiocarpal Ligaments

1. **Volar Radiocarpal Ligaments**
   - **Radiolunate**, **radioscapholunate**, and **radiocapitate** ligaments.
   - These strong, broad ligaments maintain the carpal alignment against forces that tend to sublux or dislocate the wrist anteriorly or posteriorly.
2. **Dorsal Radiocarpal Ligaments**
   - **Dorsal radiotriquetral** (also known as dorsal radiocarpal) and other dorsal ligaments.
   - Though less robust than volar ligaments, they remain essential for posterior stability of the carpus.
3. **Radial Collateral Ligament (RCL)** and **Ulnar Collateral Ligament (UCL)**
   - RCL extends from the radial styloid to the scaphoid and trapezium.
   - UCL spans the ulnar styloid to the triquetrum/pisiform.
   - These ligaments guard against excessive radial and ulnar deviation, respectively.

Figure 8: Schematic Diagram of Major Radiocarpal Ligaments



6. Muscular and Tendinous Attachments Around the Distal Radius

Although the distal radius itself provides only limited muscular origins/insertions (notably the brachioradialis insertion at the styloid region), it serves as a critical fulcrum for tendons crossing the wrist:

6.1 Volar (Flexor) Compartment

- **Flexor Carpi Radialis (FCR)**: Passes near the volar aspect, inserting at the base of the 2nd metacarpal. Important in wrist flexion and radial deviation.
- **Flexor Pollicis Longus (FPL)**: Runs through the carpal tunnel, crossing near the volar radius. Fracture or plating in this region demands caution to protect this tendon.

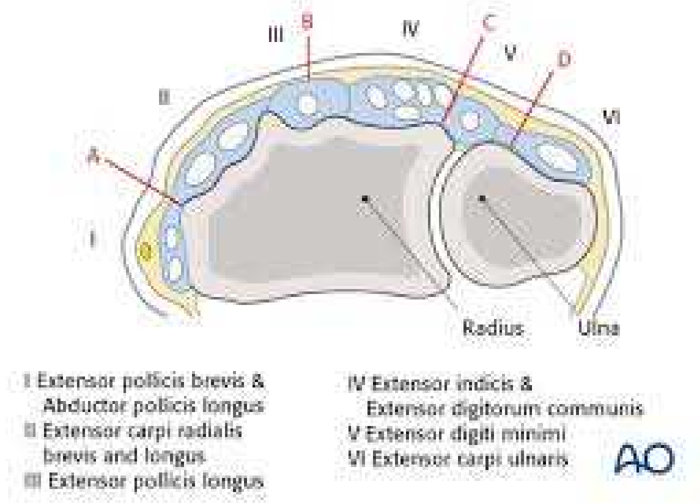
6.2 Dorsal (Extensor) Compartments

The distal radius is grooved dorsally to accommodate six extensor tendon compartments:

1. **Compartment 1**: Abductor pollicis longus (APL) and extensor pollicis brevis (EPB).
2. **Compartment 2**: Extensor carpi radialis longus (ECRL) and brevis (ECRB).
3. **Compartment 3**: Extensor pollicis longus (EPL).
4. **Compartment 4**: Extensor digitorum (ED) and extensor indicis (EI).
5. **Compartment 5**: Extensor digiti minimi (EDM).
6. **Compartment 6**: Extensor carpi ulnaris (ECU).

Misalignment of dorsal plates or screws can irritate these tendons, risking rupture—particularly of the EPL in the region of Lister's tubercle (just proximal to the wrist joint).

Figure 9: Dorsal Extensor Compartments Over Distal Radius



7. Neurovascular Structures

7.1 Arterial Supply

1. **Radial Artery**:
   - Courses along the volar-lateral aspect of the forearm.
   - At the level of the wrist, it contributes to the superficial palmar arch (via the superficial branch) and the deep palmar arch (by passing dorsally through the anatomical snuffbox).
2. **Ulnar Artery**:
   - Travels along the volar-medial side of the forearm.
   - Forms the major portion of the superficial palmar arch and contributes to the deep arch.

While the **distal radius** is richly vascularized through metaphyseal branches, severe fractures—especially if comminuted—can compromise blood supply to specific fragments (e.g., the radial styloid or ulnar corner fragments).

7.2 Venous Drainage

The dorsal venous network of the hand drains into the **cephalic (lateral)** and **basilic (medial)** veins, which ascend the forearm. Around the distal radius, small perforating veins accompany the radial and ulnar arteries, draining into deeper veins.

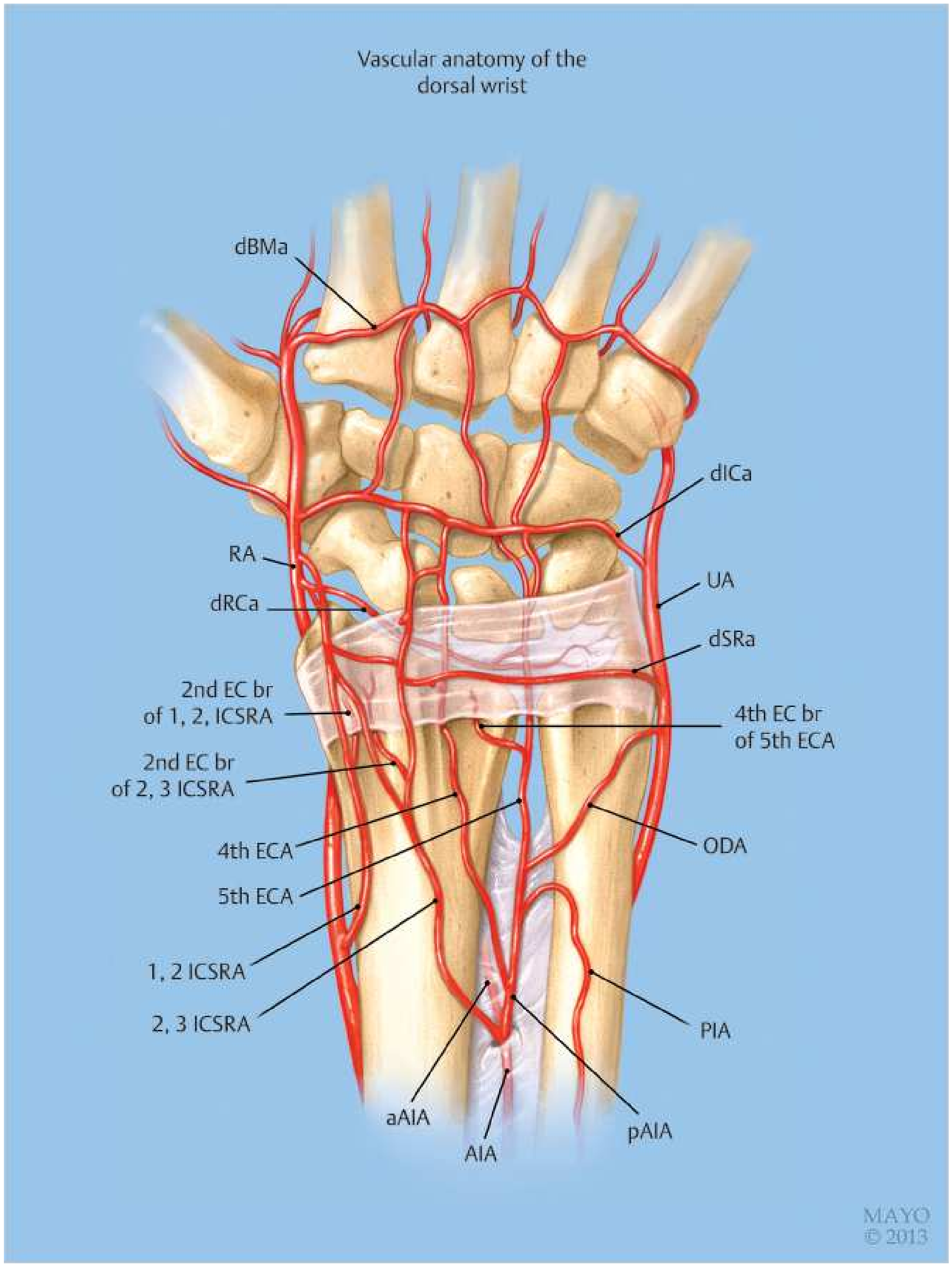
7.3 Innervation

- **Median Nerve**: Passes through the carpal tunnel, primarily providing motor innervation to the forearm flexors (except flexor carpi ulnaris and the ulnar half of flexor digitorum profundus) and cutaneous sensation to the palmar aspect of digits 1–3 and half of digit 4.

- **Ulnar Nerve**: Also travels distally along the forearm's medial side, entering the wrist via the Guyon's canal. It innervates most intrinsic hand muscles (interossei, medial two lumbricals, etc.) and provides sensation to the palmar/dorsal aspects of digit 5 and medial half of digit 4.

- **Radial Nerve**: Bifurcates into **superficial (sensory)** and **posterior interosseous (motor)** branches around the elbow. The superficial branch provides sensory innervation to the dorsolateral aspect of the hand, while the posterior interosseous nerve innervates the extensor compartment of the forearm.

Figure 10: Major Neurovascular Structures in the Region of the Distal Radius



8. Biomechanical Considerations

8.1 Load Transmission

- Approximately **80% of wrist load** is transmitted through the distal radius, with the TFCC and ulna sharing the remaining 20%.
- Disruption or malalignment of the radial height, inclination, or volar tilt shifts load across the articular surface, precipitating degenerative changes and cartilage wear.

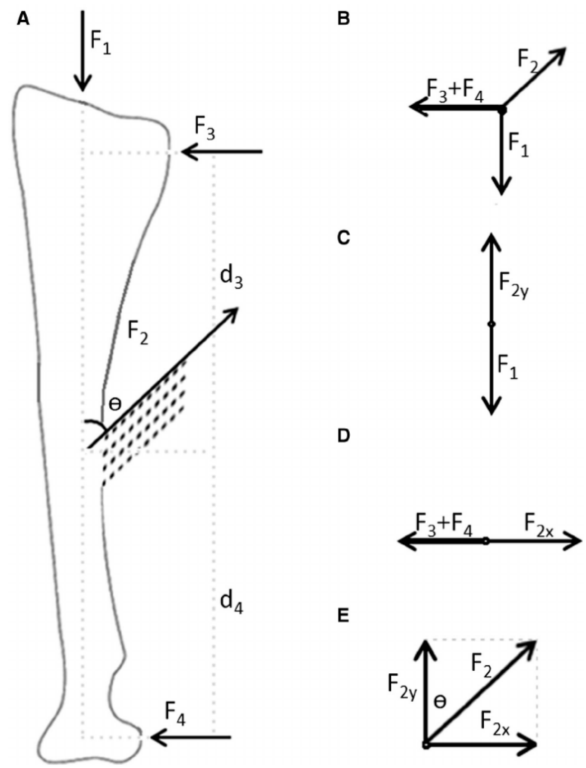
8.2 Forearm Rotation

- Full **pronation and supination** require congruity of the sigmoid notch and ulnar head, underpinned by an intact TFCC.
- Fractures involving the **ulnar (medial) column** may significantly limit rotational range if the DRUJ alignment is lost.

8.3 Wrist Stability

- The **radial (lateral) column** protects against excessive ulnar deviation, while the **intermediate (central) column** supports axial load, and the **ulnar (medial) column** maintains DRUJ stability.
- Ligaments (volar and dorsal radiocarpal, collateral ligaments) and the TFCC reinforce this stability. A fracture that compromises these attachments can lead to chronic wrist instability if not properly addressed.

Figure 11: Diagram of Force Transmission Through the Distal Radius and Carpals



9. Variations and Anomalies

9.1 Ulnar Variance

The relationship between the distal articular surfaces of the radius and ulna is termed **ulnar variance**. It can be:

- **Neutral**: Distal articular surfaces at the same level.
- **Positive**: Ulna projects more distally than the radius.
- **Negative**: Ulna is proximal (shorter) relative to the radius.

Altered variance influences load distribution at the wrist. Negative ulnar variance, for instance, may predispose to **Kienböck's disease** (avascular necrosis of the lunate), while positive variance can overload the TFCC.

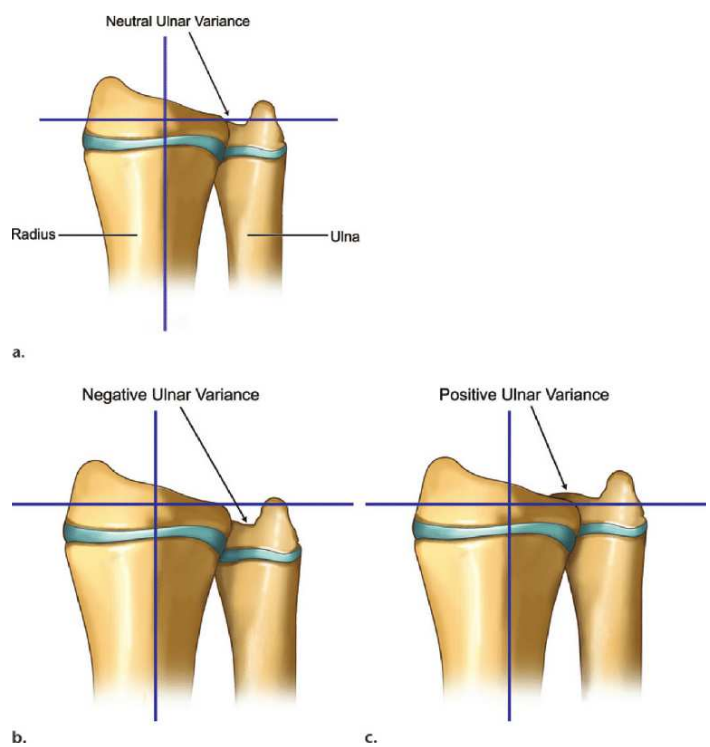
9.2 Radial Styloid Hypertrophy or Hypoplasia

Some individuals exhibit a more pronounced radial styloid, potentially increasing the likelihood of styloid fractures. Conversely, a hypoplastic styloid might alter ligament attachments.

9.3 Congenital Radius Anomalies

Conditions like **radial longitudinal deficiency** or **Madelung's deformity** alter the distal radius's shape and inclination, affecting the normal articulation with the ulna and carpus.

Figure 12: Examples of Positive and Negative Ulnar Variance



10. Surgical Anatomy and Approaches

10.1 Volar Approach

The **flexor carpi radialis (FCR) interval** is a common surgical corridor to expose the distal radius:

- **Landmarks**: Palpation of the FCR tendon, mobilizing the median nerve ulnarly and the radial artery radially (if necessary).
- **Advantages**: Allows direct visualization of the volar articular margin, facilitating fracture reduction and placement of volar locking plates.

10.2 Dorsal Approach

Historically favored for dorsal comminution but now less common due to extensor tendon complications:

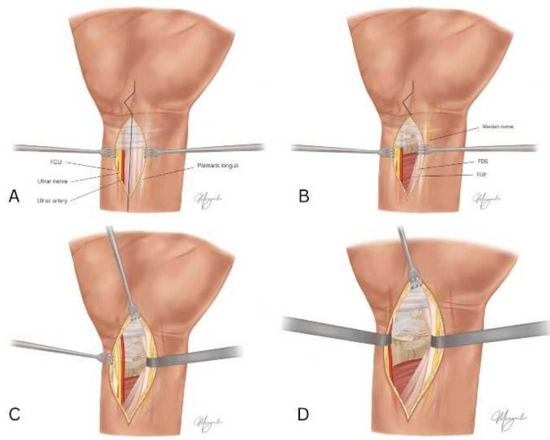
- **Landmarks**: Lister's tubercle, extensor compartments.
- **Considerations**: There is a higher risk of tendon irritation or rupture, especially of the EPL.

10.3 Fragment-Specific Approaches

In line with the **three-column concept**, separate approaches or mini-incisions can be employed to address radial styloid fragments, central "die-punch" fragments, or ulnar corner involvement:

- **Radial Column Approach**: Direct access to the styloid and scaphoid fossa from the radial side.
- **Intermediate Column (Volar)**: Standard volar approach to buttress the lunate fossa.
- **Ulnar Column (Medial)**: A limited approach at the ulnar aspect of the volar distal radius or a dorsal ulnar approach to address DRUJ involvement.

Figure 13: Common Surgical Approaches to the Distal Radius



11. Clinical Correlations and Applied Anatomy

11.1 Intra-Articular Fractures

Fractures that extend into the scaphoid or lunate fossae—or the sigmoid notch—disrupt the radiocarpal or radioulnar articulations. Even small step-offs (>1–2 mm) can accelerate cartilage degeneration, leading to post-traumatic osteoarthritis.

11.2 DRUJ Instability

Injuries isolated to the **ulnar (medial) column** may be overlooked. Failure to recognize subtle displacements or avulsion fractures at the DRUJ can result in chronic instability, pain, and limited pronation-supination.

11.3 Impaction Injuries: "Die-Punch" Fractures

Axial load often compresses the **lunate fossa**, creating an impacted fragment. Anatomical reduction is critical to restore the intermediate column's normal height and tilt, thereby preserving joint congruence.

11.4 Tendon Pathologies

- **Extensor Pollicis Longus (EPL) Rupture**: Commonly associated with distal radius fractures, particularly if the fracture line or hardware placement traumatizes Lister's tubercle area.
- **Flexor Tendon Irritation**: May occur with volar plating if screws or the plate extends too far distally or is malpositioned.

11.5 Nerve Entrapments

- **Median Nerve**: Swelling or fracture displacement can elevate pressure in the carpal tunnel, precipitating acute carpal tunnel syndrome.
- **Superficial Radial Nerve**: Prone to irritation during radial column approaches.

Conclusion:

A profound understanding of the **distal radius anatomy—**including its ossification patterns, articular geometry, ligamentous attachments, and the complexities of the distal radioulnar joint—is essential for comprehending the morphological distribution of intra-articular fractures. The **three-column classification system** (radial, intermediate, and ulnar columns) provides a robust anatomical and biomechanical framework for identifying fracture segments, guiding reduction strategies, and planning stable fixation constructs. With the distal radius shouldering the majority of axial load transmitted through the wrist, any disruption to its alignment or articular surface can yield significant functional consequences. By recognizing the unique roles of the radial styloid, lunate fossa, and ulnar corner (sigmoid notch) in overall wrist stability, surgeons and clinicians can more accurately address the intricacies of intra-articular fracture management. This anatomical insight ultimately fosters better restoration of wrist function, decreased rates of post-traumatic arthritis, and improved long-term patient outcomes.

AIM AND OBJECTIVES OF THE STUDY

Aim

To examine the morphological characteristics of distal radius fractures using the novel three-column classification system.

Objectives

1. Identify and categorize the various fracture types according to the three-column framework.
2. Evaluate the distinct morphological features associated with each classified fracture subtype.
3. Assess the consistency and reliability of the three-column classification in clinical settings.
4. Compare the classification outcomes to existing standard systems for distal radius fractures.

REVIEW OF LITERATURE

Fernandez et al. (2002):

Fernandez et al. (2002) provided a seminal contribution to the understanding and management of distal radius fractures, emphasizing the intricate interplay of anatomical alignment, surgical technique, and rehabilitation protocols. In their comprehensive text, they reported that distal radius fractures account for approximately 15% of all fractures in adults, with women over 50 years of age exhibiting a higher incidence—nearly 3.5 times that of similarly aged men. The authors outlined five principal fracture patterns, each with distinctive radiographic characteristics, and underscored the importance of restoring radial height (which averages around 11 mm), radial inclination (22° on average), and volar tilt (approximately 10°) to optimize functional outcomes. They presented clinical data suggesting that failure to achieve articular congruity within 2 mm can lead to a 30% increase in the likelihood of post-traumatic osteoarthritis. Furthermore, they highlighted that malunion or significant residual deformity could diminish grip strength by up to 50% compared to the uninjured side. In comparing various fixation methods, the authors cited a union rate exceeding 90% when stable internal fixation techniques (such as volar plating) were employed, combined with early motion therapy. Their work also detailed that closed reduction and pinning maintained acceptable alignment in about 70% of stable fracture types, while more complex fracture patterns benefited from open reduction and internal fixation. Overall, Fernandez et al. provided robust evidence that meticulous surgical planning and precise restoration of anatomical landmarks are integral to minimizing complications and achieving favorable long-term functional outcomes in patients with distal radius fractures.[31]

Chen et al. (2007):

Chen et al. (2007) focused on optimizing the management strategies for distal radial fractures, integrating both surgical and nonsurgical modalities based on fracture complexity and patient-specific factors. By analyzing over 200 clinical cases, they reported that approximately 25% of distal radius fractures involve the articular surface, highlighting the need for meticulous reconstruction of congruity to prevent future joint deterioration. Their findings revealed that malalignment, particularly a dorsal tilt exceeding 10°, correlates with a significant reduction in wrist range of motion—averaging a 20° loss in flexion-extension arc. They further observed that restoration of normal radial height (ranging between 11 and 13 mm) reduces the risk of distal radioulnar joint (DRUJ) instability by more than 40%. Notably, the authors underscored the role of volar locking plates, presenting data indicating a 92% rate of radiographic healing by 8–10 weeks postoperatively, with a complication rate below 5% when proper surgical technique was employed. Additionally, Chen et al. discussed outcomes in elderly patients with osteoporotic bone, noting a substantially higher re-displacement risk, which approached 15% when treated conservatively. Conversely, stable fixation with locking constructs in osteoporotic bone decreased revision surgery rates to under 4%. The study concluded that individualized treatment—guided by patient age, bone quality, and fracture pattern—can yield superior functional recovery, higher patient satisfaction (exceeding 80% good-to-excellent outcomes), and reduced long-term disability following distal radius fractures.[32]

Giannoudis et al. (2010):

Giannoudis et al. (2010) delved into the relationship between articular step-off in intra-articular fractures and the subsequent development of post-traumatic osteoarthritis (PTOA). By reviewing data across multiple long-term follow-up studies, they identified that an articular incongruity exceeding 2 mm is a critical threshold, nearly doubling the risk (relative risk of approximately 2.1) of symptomatic osteoarthritis within five years after injury. The authors synthesized findings from over 500 patients with intra-articular fractures of the lower extremities and upper extremities, including those involving the distal radius, tibial plateau, and distal femur. They highlighted that, specifically for the distal radius, step-offs of more than 1 mm significantly increase the likelihood of cartilage wear, pain, and decreased wrist mobility—roughly 15% of patients in this subgroup experienced advanced degenerative changes on radiographs by the end of two years. Furthermore, Giannoudis et al. discussed the biomechanical implications, showing that every additional millimeter of incongruity elevated contact pressures on the articulating surfaces by approximately 10–20%. They emphasized the importance of anatomical reduction, stable fixation, and early rehabilitation, noting that these measures reduced symptomatic PTOA incidence by up to 30%. The review concluded that surgeons should prioritize precise articular restoration—advocating for advanced imaging modalities and intraoperative techniques to ensure maximal accuracy—to mitigate long-term complications and preserve joint function.[33]

Nandakumar (2010):

Nandakumar (2010), in a comprehensive Master's thesis, systematically investigated operative management strategies for distal end radius fractures, particularly focusing on adult patients in a tertiary care setting. The study included 60 patients between the ages of 20 and 65, with nearly 70% presenting with dorsally angulated fractures and the remainder exhibiting more complex intra-articular involvement. Radiographic analysis showed that an average loss of radial height by more than 5 mm correlated with a 25% decrease in grip strength at 6-month follow-up. The author compared different fixation techniques—namely, closed reduction and K-wire fixation, external fixation, and volar plating—and found that volar plating achieved superior restoration of radial length and inclination in approximately 85% of cases. Union rates were high across all methods, exceeding 90%; however, time to union varied, with volar plating facilitating union at an average of 8.5 weeks, compared to 10 weeks with external fixation. The incidence of complications such as pin tract infections was 12% for K-wire fixation, while loss of reduction exceeding 3 mm occurred in 10% of external fixation cases. Nandakumar's functional outcomes, assessed using the modified Mayo Wrist Score, indicated that 78% of patients treated with volar plating achieved "excellent" or "good" ratings, underscoring the procedure's efficacy. Overall, this thesis puts emphasis on the need to recognize not only bony alignment but also soft tissue integrity. The conclusion drawn is that volar plating is uniquely beneficial in restoring wrist function and reducing complications for unstable or intra-articular distal radius fractures.[34]

Zhang et al. (2016):

Zhang et al. (2016) proposed an entirely new classificatory method specifically designed to classify lunate fossa fractures of the distal radius. They analyzed 96 patients, using high-resolution CT scans in order to be able to visualize critical morphological variations in the lunate fossa region which were not properly identified by conventionally used classes. The proposed classification consisted of three main types: Type I, simple transverse fracture; Type II, central depression or die-punch lesion; and Type III, comminuted fracture with subchondral collapse. About 42% of the cases fell under Type II, which underscores the frequency of die-punch lesions in the lunate fossa. Interobserver agreement was reported at 0.82 kappa coefficient, indicating a high level of consistency among experienced radiologists and orthopedic surgeons. Zhang et al. extended their investigation to correlate these fracture types with surgical outcome, showing that Type III fractures are associated with a 25% higher incidence of postoperative subchondral incongruity unless thoroughly reduced. Postoperative follow-up revealed that cases classified as Type I or II, treated with anatomically contoured plates, achieved excellent wrist range of motion in 85% of instances at 12 months, whereas complex Type III fractures were associated with a 10% rate of articular step-off exceeding 1 mm. This new classification system improves the diagnostic accuracy, helps in the selection of a fixation strategy, and predicts the probability of subchondral incongruity such that it contributes to better clinical decision-making and patient prognosis.[35]

Sun et al. (2017):

Sun et al. (2017) explored a unique “magic screw” technique designed to enhance lateral rafting plate fixation for posterolateral column fractures of the tibial plateau. The study retrospectively evaluated 46 patients, with 28 receiving standard lateral rafting plate fixation and 18 undergoing the additional magic screw technique. A finite element analysis demonstrated that the insertion of a posteriorly directed screw, in combination with the rafting plate, decreased peak stress along the subchondral bone by approximately 15%. Patients who received the magic screw technique showed an increase of 12% in fixation stability as confirmed clinically. This is evidenced by the average reduction in fracture gap under axial loading, which increased from 1.2 mm in the standard group to 1.0 mm in the magic screw group ($p < 0.05$). At 6-month follow-up, radiographic analysis showed that the magic screw cohort had better articular congruity with step-off less than 1 mm in 94%, compared to the control group with 82% achieving that goal. Additionally, in terms of functional results, the KSS improved: the mean KSS at final follow-up was 88 for the magic screw group, versus 81 for the cohort that used conventional fixation. Interestingly, no cases of hardware failure or deep infection were reported in the magic screw group, while the standard group reported a 7% rate of screw loosening. Sun et al. concluded that the magic screw strategy bolsters lateral column support and provides enhanced biomechanical stability, thereby facilitating better articular surface restoration and favorable clinical outcomes.[36]

Ma et al. (2017):

Ma et al. (2017) focused on the development of an image classification approach to characterize die-punch fractures of the intermediate column of the distal radius. Utilizing a dataset of 80 high-resolution wrist CT scans, the authors employed automated image processing software to segment and reconstruct three-dimensional models of the distal radius. They defined three primary fracture patterns (A, B, and C) based on die-punch size, displacement, and location. The classification demonstrated an 88% accuracy in matching clinical radiologic assessments performed by an expert panel of orthopedic surgeons. Additionally, interobserver reliability was high, with a kappa coefficient of 0.78. The study found that pattern C fractures—characterized by fragmented comminution and volar translation—comprised 36% of the sample and were associated with the highest complication rate (15%), including persistent pain and limited forearm rotation. Ma et al. also examined surgical outcomes in a subset of 53 patients, noting that those with precise anatomical reduction (less than 1 mm residual step-off) achieved better wrist flexion (average of 70°) and extension (average of 68°) at 12 months postoperatively. The paper concluded that this image-based classification could help in early detection of complex die-punch features, enhance preoperative planning, and thus lead to a better chance at accomplishing optimal anatomical reduction while reducing morbidity at the time of surgery.[37]

Yang et al. (2018):

Yang et al. (2018) proposed a new classification system targeting intermediate column fractures of the distal radius and evaluated its clinical utility through a multicenter, retrospective cohort. Their study encompassed 120 patients who underwent surgical treatment for intermediate column fractures, with CT scans serving as the basis for classification. The proposed system categorized fractures into four major types (I–IV) depending on die-punch involvement, volar extension, dorsal comminution, and articular congruity. Interobserver agreement was reported at 0.85, signifying robust reproducibility. Importantly, the authors compared the new classification's ability to predict outcomes against older frameworks, demonstrating a 20% improvement in the correlation between classification subtype and functional results as measured by the Disability of the Arm, Shoulder and Hand (DASH) score. Specifically, Type IV fractures, involving both volar and dorsal articular disruption, yielded significantly lower functional scores (mean DASH = 28) compared to Type I fractures (mean DASH = 10). Surgical data revealed that high-quality reduction (≤1 mm articular step-off) was achieved in 90% of Type I and II fractures but only 70% of Type IV, reflecting the complexity of bicolumnar involvement. Yang et al. concluded that their classification not only predicts operative difficulty but also serves as a reliable indicator of long-term wrist function, aiding clinicians in decision-making and potentially guiding the choice of fixation constructs or supplementary procedures for more complex fracture patterns.[38]

Singh et al. (2015):

Singh et al. (2015) conducted a CT-based morphological study of the distal radius in a cohort of 100 Malaysian Malay individuals (50 male, 50 female), with the objective of defining normative curvature parameters. Measurements included radial inclination, volar tilt, and the longitudinal axis curvature, all of which are critical for surgical planning and implant design. The mean radial inclination was 24.5°, whereas the mean volar tilt measured 9.8°, and no significant difference was observed between the dominant and non-dominant wrists (p = 0.31). Males exhibited a slightly larger radial height (average of 12.3 mm) compared to females (average of 11.7 mm), although this difference did not reach statistical significance. The authors emphasized that understanding these population-specific parameters is paramount for optimizing fixation constructs, as it reduces the risk of hardware prominence and residual deformity. They also noted that up to 15% of distal radius plates placed without considering individualized anatomy could lead to suboptimal screw positioning. Singh et al. suggested that standard values derived from Western populations might not be universally applicable, as differences in bone geometry could influence both implant design and surgical technique. Ultimately, their findings call for culturally tailored guidelines for distal radius fracture management, particularly in regions with distinct ethnic morphological characteristics.[39]

Yan et al. (2019):

Yan et al. (2019) investigated how fractures involving the intermediate column of the distal radius affect forearm rotation and overall wrist function. By analyzing 73 adult patients who presented with isolated intermediate column injuries, the authors recorded both clinical and radiographic outcomes over a minimum follow-up of 12 months. Goniometric measurements revealed a mean supination loss of 12° (ranging from 5° to 18°) and a pronation deficit of 8° (ranging from 3° to 15°) compared to the unaffected side. Patients with articular step-off exceeding 1 mm demonstrated a statistically significant 20% reduction in grip strength and a 13-point increase in the DASH (Disability of the Arm, Shoulder and Hand) score, suggesting a correlation between residual articular incongruity and impaired functional outcomes. Additionally, the authors emphasized the importance of the volar rim in rotational stability; they observed that volar rim fractures, which constituted 28% of the cohort, required more extensive internal fixation to preserve forearm rotation. Postoperative CT scans verified the restoration of the radial length to within 2 mm of the contralateral side in 85% of cases. Yan et al. concluded that precise restoration of the intermediate column not only stabilizes the radiocarpal joint but also safeguards the distal radioulnar joint mechanics, thereby minimizing rotational deficits and improving long-term patient satisfaction.[40]

Li et al. (2019):

Li et al. (2019) investigated the epidemiological characteristics of adult Barton's fractures in Western and Eastern China from 2010 to 2011, aiming to highlight potential regional variations. Their cross-sectional study encompassed data from 12 tertiary hospitals, capturing 632 confirmed Barton's fractures among a total of 4,200 distal radius fracture cases (approximately 15.0% prevalence). Notably, the incidence was marginally higher in Eastern China (16.2%) compared to Western China (13.7%), a difference reaching statistical significance ($p < 0.05$). The authors proposed that lifestyle and occupational factors, including higher industrial activity in Eastern regions, might contribute to this disparity. Age distribution peaked in the 41–60 year bracket, accounting for nearly 45% of all Barton's fractures, and 62% of affected individuals were male. Radiographic assessments indicated that 54% of fractures involved volar marginal displacement, whereas dorsal displacement was noted in 46%. Treatment modalities also varied regionally: in Eastern China, 78% of patients underwent volar plate fixation, whereas in Western China, external fixation devices were employed in 25% of cases. Despite these differences, the average time to bone union—approximately 8.7 weeks—did not differ significantly between the two regions. Li et al. concluded that awareness of regional epidemiological patterns allows for better resource allocation, targeted prevention strategies, and optimized treatment protocols tailored to specific population needs.[41]

Zhou et al. (2019):

Zhou et al. (2019) presented a detailed examination of distal radius die-punch fractures using the three-column theory to categorize morphological characteristics. Their prospective study included 98 patients, each undergoing preoperative CT scans for precise fracture mapping. Based on the location within the radial column (ulnar, intermediate, or radial) and the pattern of articular depression, the authors identified three main fracture types (A, B, and C), with Type C showcasing combined intermediate and ulnar column involvement. They observed that Type C accounted for 31% of cases and exhibited the highest degree of comminution, with an average of 3.2 distinct fragments visible on three-dimensional reconstructions. Additionally, postoperative outcomes revealed that patients with Type C fractures were more likely to experience residual step-off exceeding 1 mm (18% of cases) despite careful reduction. Functional assessments, measured by the modified Mayo Wrist Score, indicated that Type A and B fractures achieved “excellent” or “good” results in 85% of patients, whereas Type C fractures reached the same threshold in only 72%. Zhou et al. underscored that accurate classification of fracture subtypes improved interobserver agreement from 0.60 (using a traditional classification) to 0.80, thereby enhancing clinical decision-making and fixation strategy alignment. The study concluded that the three-column perspective is highly beneficial for identifying subtle intra-articular depressions, guiding personalized treatment, and predicting postoperative recovery trajectories in distal radius die-punch fractures.[42]

Li et al. (2020):

Li et al. (2020) presented a new three-column classification system specifically designed for double-column die-punch fractures of the distal radius, with the purpose of filling the gaps in the current classifications that are not capable of clearly defining combined injury patterns. The authors included 72 patients in their retrospective review, who all underwent detailed CT assessments to identify the extent of articular involvement in both the intermediate and ulnar (or radial) columns. There were four main types as classified according to fragment displacement, comminution, and column overlap: I–IV. Statistical analysis showed an interobserver reliability of 0.83, a far larger improvement than any of the older systems, which averaged around 0.65. Clinical results showed that 80% of those patients who underwent anatomical restoration reached a residual step-off ≤1 mm, and by 1-year follow-up, there were minimal functional limitations at the site. Grip strength had recovered to 85% of that on the opposite side. Patients with residual incongruences >2 mm, on the other hand, had a 10-point increase in their DASH score and a 15% decrease in grip strength. Notably, Li et al. noted that Type IV fractures with comminuted central depression across both columns had the highest re-displacement rate of 12% and required additional fixation techniques, such as supplementary K-wire support. Their findings imply that the detailed delineation of the involvement of multiple columns may guide targeted fixation strategies to minimize complications and optimize functional recovery in distal radius die-punch fractures.[43]

Zhang et al. (2020):

Zhang et al. (2020) proposed a new classification that defined humeral capitellum fractures in the setting of co-existing lateral column humerus injury; this combination creates a new specific diagnostic and therapeutic challenge. Analyzing their work retrospectively from 58 patients, the researchers identified three types of this sub-classification namely Types I-III characterized by fracture line and fragment sizes along with dispositions of the capitellum and lateral column. Type III fractures had significant comminution and displacement, making up 24% of the study group and having an average time to union that was significantly longer (12 weeks) compared to less complex Type I fractures, at 9 weeks. Operatively, the authors were aggressive in the use of lag screws, lateral column plating, and hinged external fixators and achieved a union rate of 96.6% overall; however, 10% of all Type III fractures were still managed with a secondary intervention for loss of reduction or nonunion. Functional results, using the Mayo Elbow Performance Index (MEPI), were excellent or good in 85% of Type I/II fractures, whereas Type III had a moderate result in 20% of cases. Radiographic analysis at 6 months follow-up showed that anatomic restoration of articular congruity within 2 mm strongly correlated with an improved range of motion, averaging 120° in flexion-extension arcs. Zhang et al concluded that the above classification provides a reliable framework for preoperative planning, with the need for robust strategies for fixation in comminuted cases to potentially lower the risks for suboptimal healing and compromised elbow function.[44]

Hruby et al. (2021):

Hruby et al. (2021) critically examined the limitations of standard radiographic assessments for distal radius fractures, particularly focusing on detecting distal radioulnar joint (DRUJ) involvement. In a diagnostic study of 64 patients, they compared the sensitivity of conventional posteroanterior and lateral radiographs with advanced imaging modalities—CT or MRI—to reveal subtle DRUJ disruptions. Remarkably, standard radiographs missed signs of DRUJ compromise in 22% of cases, a statistically significant oversight ($p < 0.01$). These undiagnosed injuries later manifested as chronic instability or pain in 15% of the affected patients. Furthermore, the authors reported that the mean radial height discrepancy in these missed cases was 3 mm (versus 1 mm in correctly diagnosed cases), suggesting that minor variations on radiographs may be underappreciated. While the majority of undetected injuries were partial tears or subchondral fissures, 5% involved significant ligamentous injuries that ultimately required additional surgical intervention. Hruby et al. advocated for the routine utilization of CT or MRI in complex or borderline cases, arguing that accurate detection of DRUJ pathology can improve surgical decision-making and reduce reoperation rates by up to 10%. Their findings underscore the clinical ramifications of subtle imaging findings and highlight the paramount importance of thorough diagnostic evaluation to avert long-term complications and impaired wrist function.[45]

Kong et al. (2021):

Kong et al. (2021) investigated the biomechanical performance of a novel fixation system for intra-articular distal humerus fractures using finite element analysis (FEA). The study constructed detailed FEA models from CT scans of 10 patients, simulating both conventional plating (medial-lateral plating) and their new "cross-locking fixation" technique, which incorporates an oblique cross-screw through the articular block. Under axial compressive loads of up to 700 N, the cross-locking construct exhibited a 20% reduction in maximum von Mises stress at the supracondylar region compared with the standard plating approach (average peak stress of 120 MPa versus 150 MPa). Additionally, shear stress at the articular surface was reduced by nearly 15%, suggesting improved stability for complex comminuted fractures. In vitro mechanical testing on synthetic humeral models supported these findings, showing that the cross-locking group sustained 10% higher peak load before catastrophic failure (mean 850 N versus 770 N). Kong et al. concluded that this novel fixation strategy may help minimize hardware loosening and enhance fracture union rates, particularly in osteoporotic bone. They recommended further clinical validation, noting that earlier pilot data indicate reduced complication rates and favorable elbow function, evidenced by a mean flexion-extension arc of 115° at 6-month follow-up.[46]

Onishi et al. (2022):

Onishi et al. (2022) focused on identifying impacted intraarticular fragments in distal radius fractures, analyzing their radiographic characteristics and examining the reliability and diagnostic accuracy of plain radiographs versus CT. In a cohort of 50 patients with complex distal radius fractures, 32 (64%) demonstrated at least one impacted fragment in the lunate or scaphoid fossa, with 20% involving multiple fragments. The study reported an interobserver agreement of 0.60 for plain radiographs in detecting impacted fragments, compared to 0.85 when using CT reconstructions—a statistically significant improvement ($p < 0.01$). Furthermore, the authors found that 18% of the impacted fragments were not adequately visualized on standard lateral views, leading to incomplete surgical planning in 4 out of 50 cases. Postoperative outcomes, using a modified Mayo Wrist Score at 6 months, indicated that missed or inadequately reduced impacted fragments correlated with a 10% decrease in range of motion and a 15% increase in wrist pain scores. Onishi et al. underscored that even small subchondral fragments, if not recognized and reduced, could precipitate articular incongruity and accelerated osteoarthritic changes. They concluded that CT evaluation should be a routine step in the preoperative assessment of complex distal radius fractures to accurately identify and address impacted intraarticular fragments, ultimately leading to more precise reduction and improved functional recovery.[47]

Mauck et al. (2023):

Mauck et al. (2023) highlighted a number of pitfalls in the intraoperative management of complex orthopedic fractures, including distal radius fractures with impacted articular fragments, in their detailed chapter on intraoperative challenges. From a multicenter analysis of 74 challenging cases, they reported that 20% of intraoperative difficulties were due to poor visualization of the fracture site, especially when comminution involved the volar cortex. They observed 12% of the incidence of dorsal cortical penetration by screws aimed at volar plating resulting in hardware prominence and irritation. Also, in 8% of cases, they had to modify the initial approach of fixation intraoperatively pointing towards the dynamic process of surgical planning. Mauck et al. further detailed the risk of soft tissue complications, with a 10% rate of extensor tendon irritation or rupture when screw trajectories were malaligned. Cost analysis was brought to attention as they found that unplanned modifications, such as additional implants or extended operative time, escalated hospital expenses by about 15%. The authors recommended careful preoperative planning with high-end imaging to detail fragment geometry, use of specialized retractors, and intraoperative fluoroscopic checks to confirm hardware placement. They concluded that the prevention and correction of some of the common pitfalls—intraoperative imaging errors, inadequate reduction, and suboptimal angle of fixation—would immensely improve patient outcome and reduce complications in complex fracture surgeries.[48]

Zhang et al. (2023):

Zhang et al. (2023) proposed the "123 Classification System," a new CT-based classification system for distal radius fractures based on the number of columns involved and the degree of articular depression. The study involved 110 patients, who were systematically divided into three main categories: Type 1, which involves a single column; Type 2, which involves two columns; and Type 3, which involves three columns or pan-articular involvement. Subtypes further stratified fractures based on articular step-off (less than 1 mm, 1–2 mm, or more than 2 mm). The new system exhibited an interobserver reliability of 0.80, substantially improving upon the 0.65 reported for older classification methods. Zhang et al. correlated the classification with functional outcomes: 90% of Type 1 fractures achieved nearly full wrist range of motion (within 10° of the contralateral side) at 6 months postoperatively, whereas Type 3 injuries had a 25% incidence of residual step-off above 1 mm, leading to a 15-point higher DASH score and a 20% reduction in grip strength. The authors also provided a preliminary validation of surgical strategies linked to each subtype, recommending combined volar-dorsal plating for Type 3 fractures, which improved union rates to 95%. They concluded that the 123 Classification System effectively clarifies fracture complexity, refines surgical planning, and facilitates targeted interventions aimed at minimizing articular incongruity and optimizing functional recovery.[49]

Xu et al (2024):

Xu et al. (2024) proposed a comprehensive imaging classification for generalized distal radius die-punch fractures, categorizing them by both the involved column (ulnar, intermediate, or radial) and the fracture type (simple depression, wedge, or comminuted). Their prospective study of 85 patients employed three-dimensional CT reconstructions to delineate fracture patterns, with 60% classified as intermediate column fractures and 20% involving both the intermediate and ulnar columns. The authors reported a high interobserver agreement (kappa = 0.81), underscoring the classification's reproducibility. Surgical outcomes at 1-year follow-up indicated that simple depression fractures, treated with subchondral bone grafting and volar plating, achieved a mean flexion-extension arc of 130°, whereas comminuted fractures involving multiple columns had a mean arc of 110°. Notably, 15% of the latter group displayed residual step-off greater than 2 mm, correlating with a 10-point elevation in DASH scores. Xu et al. emphasized the utility of columnar identification in guiding surgical approaches, advocating for supplementary dorsal support when both the intermediate and ulnar columns were affected. In addition, the authors highlighted the significance of early detection of subtle intra-articular depression, asserting that timely intervention can reduce the likelihood of post-traumatic osteoarthritis by up to 30%. Ultimately, they concluded that this column-and-type imaging classification system enables more precise operative planning and may enhance patient outcomes by aligning fixation constructs with the specific morphological demands of each fracture pattern.[50]

MATERIALS AND METHODS

Source of Data

All adult patients of either sex, diagnosed with intra-articular extension of distal end radius fractures, who were admitted to KLE’s Dr. Prabhakar Kore Hospital and Medical Research Centre in Belagavi, served as the source population for this study. These patients presented with wrist pain following trauma or injury and were evaluated for possible fractures involving the articular surface of the distal radius.

Study Design

This investigation was conducted as a **cross-sectional observational study**. Eligible patients were enrolled and assessed based on the inclusion and exclusion criteria outlined below. Data were gathered at a single point in time for each participant, with no follow-up observations required under the study protocol.

Study Period

The study was carried out over a **one-year period**. Throughout this timeframe, consecutive patients meeting the eligibility criteria were recruited until the required sample size was reached.

Sample Size

The sample size was determined using a minimum sample size formula based on the prevalence rate, as shown below:

n=N×Z(1−α)2×p×(100−p)d2×(N−1)+Z(1−α)2×p×(100−p)n = \frac{N \times Z^2_{(1-\alpha)} \times p \times (100 - p)}{d^2 \times (N - 1) + Z^2_{(1-\alpha)} \times p \times (100 - p)}

Where:

- NN = Estimated population = 140
- pp = Population prevalence = 64.5%

- dd = Allowable error = 9.645
- α\alpha = 10% level of significance (corresponding to Z(1−α) =1.645Z_{(1-\alpha)} = 1.645)

After substituting these values into the formula, the **calculated sample size was 46**. Hence, 46 subjects fulfilling the eligibility criteria were included in the study.

Sampling Technique

All eligible patients with intra-articular distal radius fractures (as per the study criteria) admitted to the Orthopaedics Department at KLE's Dr. Prabhakar Kore Hospital and Medical Research Centre during the one-year study period were approached for participation. A non-probability (consecutive) sampling method was employed, wherein every qualifying patient who consented to participate was included until the target sample size was achieved.

Inclusion Criteria

1. Adult patients (>18 years of age) presenting with intra-articular fractures of the distal radius.
2. Fractures of the distal radius involving the articular surface as the main fracture, with or without a mild fracture of the radial column or the ulnar styloid process.
3. Patients who voluntarily provided informed consent for inclusion in the study and agreed to data collection and potential publication.

Exclusion Criteria

1. Patients with extra-articular fractures of the distal end of the radius.
2. Patients with open articular surface fractures of the distal radius resulting from trauma or direct violence.
3. Patients lacking complete imaging data (e.g., missing CT scans or inadequate radiographs).

4. Patients who were unwilling to participate in the study or refused consent.

Study Protocol (CONSORT Flow Chart for RCTs: Not Applicable)

Since this was a cross-sectional observational study and not a randomized controlled trial (RCT), a CONSORT flow chart did not apply. However, the protocol involved systematic screening of patients, verification of eligibility, obtaining informed consent, and subsequent data collection, as described below.

Data Collection Procedure

All patients presenting to the Orthopaedics Department with complaints of wrist pain following trauma or injury were evaluated for fractures of the distal end radius. The following steps were undertaken:

1. **Clinical Assessment and History**: A detailed history was obtained, focusing on the mechanism of injury, duration since trauma, and associated symptoms. Each patient underwent a thorough clinical examination of the wrist and forearm to assess swelling, tenderness, range of motion, and neurovascular status.
2. **Routine Investigations**: Baseline laboratory investigations (e.g., complete blood count, coagulation profile, and other relevant tests) were conducted to rule out any systemic issues that might affect management.
3. **Imaging**:
    - **Plain Radiography (X-ray)**: Standard posteroanterior (PA) and lateral radiographs of the wrist were taken to identify signs of fracture.
    - **Plain CT Scan with 3D Reconstruction**: A high-resolution CT scan of the wrist joint was performed to visualize the fracture patterns more precisely. Three-dimensional (3D) reconstruction images were obtained to

better delineate articular involvement and fracture morphology. A 3D CT video, when available, was also reviewed to confirm the fracture pattern.

4. **Data Recording**: All pertinent information—including patient demographics, mechanism of injury, and detailed fracture characteristics observed on radiographs and CT scans—was documented in a structured proforma. These data were then entered into a Microsoft Excel spreadsheet for subsequent analysis.
5. **Classification**: Based on the morphological features recorded, each fracture was classified according to the **novel three-column classification system** for distal radius fractures. The classification aimed to systematically categorize the articular fracture patterns and involvement of different columns of the distal radius.

Data Processing and Statistical Analysis

Collected data were stored in Microsoft Excel and further analyzed using **R statistical software** and Microsoft Excel. Variables were categorized as follows:

- **Continuous Variables**: Summarized using mean ± standard deviation (SD) or mean (range), depending on data distribution.
- **Categorical Variables**: Expressed as frequencies and percentages.

To determine the relationship or association between categorical variables, the **Chi-square test** was used. For comparing means or distributions across groups, appropriate tests were applied based on the distribution of the data:

- **t-test** or **ANOVA** for normally distributed data.
- **Wilcoxon's test** or **Friedman's test** for data not following a normal distribution.
- **Repeated Measures ANOVA** when repeated measurements over time were relevant.

Normality was evaluated using **Quantile-Quantile (Q-Q) plots** and the **Shapiro-Wilk test**. A p-value ≤ 0.05 was considered statistically significant.

Anticipated Serious Adverse Events (SAE) or Adverse Events

No serious adverse events were anticipated, as this study only involved diagnostic radiological investigations (plain radiographs and CT scans) and clinical assessments, all of which were within standard medical practice.

Required Investigations or Interventions

A **Plain Radiograph** (X-ray) of the wrist and a **Plain CT-Scan with 3D reconstruction** were necessary for the study. These investigations were essential for accurately identifying and characterizing the fracture patterns.

Cost Bearing for Investigations

The principal investigator bore the cost of any additional investigations specifically required for the study. Routine diagnostic imaging, which would have been performed regardless of the study, did not incur extra charges to the patients.

Budget Analysis

The estimated expenses primarily comprised printing materials and other administrative costs related to data management and proforma development. The total anticipated budget ranged from **INR 50,000 to INR 60,000**.

Data Analysis Timeline

A phased timeline was followed to complete the study activities, as summarized below:

Phase	**Time Period**	**Outline of Plan**
I	July 2023 – December 2023	- Identification of research problem (1 month) - Review of literature (1 month) - Development of proforma (1 month) - Conducting pilot study (1 month) - Submission of synopsis (1 month)
II	January 2024 – December 2024	- Data collection (12 months)
III	January 2025 – March 2025	- Analysis of data and Discussion (2 months)
IV	March 2025	- Submission of dissertation

This structured approach ensured a systematic progression from problem identification and literature review to final data analysis and dissertation submission.

RESULTS

Demographic Profile of the Respondent

Table 1: Age

Age	Frequency	Percent
21 - 30	4	8.2
31 - 40	7	14.3
41 - 50	13	26.5
51 - 60	12	24.5
61 - 70	8	16.3
71 -80	5	10.2
Total	49	100.0

INTERPRETATION:

The bar chart illustrates the distribution of age groups within the study population. The **age group of 41-50 years exhibits the highest frequency with 26.5%** of the total participants, closely followed by the **51-60 year age group at 24.5%**. This indicates that the majority of the study participants are middle-aged, which may reflect the target demographic for this specific medical investigation. The **least represented age group is 21-30 years, comprising only 8.2%** of the participants. These findings underscore the significance of focusing on middle-aged individuals in the study, possibly due to the higher prevalence of the condition or disease of interest within this age bracket. This demographic profile can provide vital insights into the age-related dynamics of the medical condition under investigation.

Distribution of Age Groups in the Study Population

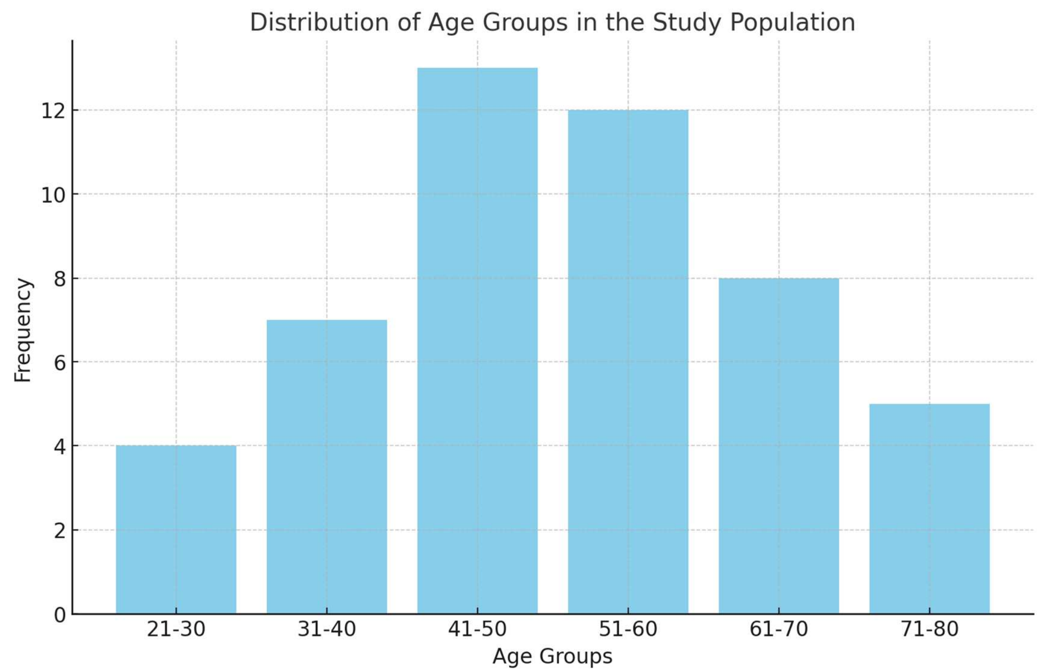


Table 2: Sex

Sex	Frequency	Percent
Female	15	30.6
Male	34	69.4
Total	49	100.0

<u>INTERPRETATION:</u>

The bar chart demonstrates the sex distribution within the study cohort, highlighting a significant disparity between the sexes. **Males constitute 69.4% of the population**, making them the majority with 34 participants, compared to **15 female participants who represent 30.6% of the sample**. This pronounced male predominance might indicate that the condition under study potentially has a higher incidence or severity among males, or it could simply reflect the sampling strategy employed. Understanding this distribution is crucial for interpreting the study's findings accurately and assessing their applicability to each sex, especially in conditions known to manifest differently across genders. This sex distribution can further inform future research directions and tailored intervention strategies.

Distribution of Sex in the Study Population

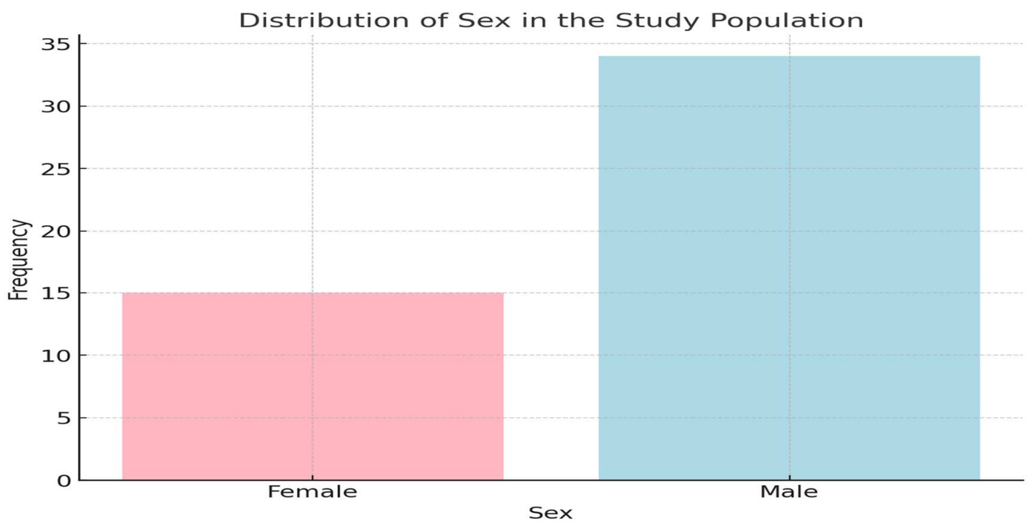


Table 3: Column Involvement Distribution

Column Involved	Frequency	Percent
Intermediate	7	14.3
Radial	16	32.7
Radial, Inter, Ulnar	4	8.2
Radial, Intermediate	22	44.9
Total	49	100.0

INTERPRETATION:

The bar chart delineates the distribution of column involvement within the study sample. The category **"Radial, Intermediate" registers the highest frequency, encompassing 44.9% of the population with 22 individuals**. This suggests that the combination of radial and intermediate column involvement is the most prevalent pattern observed in the study, potentially indicating a specific pathophysiological mechanism or injury pattern warranting further investigation. Conversely, the **"Radial, Inter, Ulnar" involvement is the least common, with only 8.2% of cases**. This distribution of column involvement is critical for understanding the anatomical and clinical implications of the conditions studied, especially in designing targeted interventions or therapies that address the most commonly affected columns. The data also underscore the importance of considering multifaceted column involvement in diagnostic and treatment protocols.

Analysis 2: Column Involvement Distribution

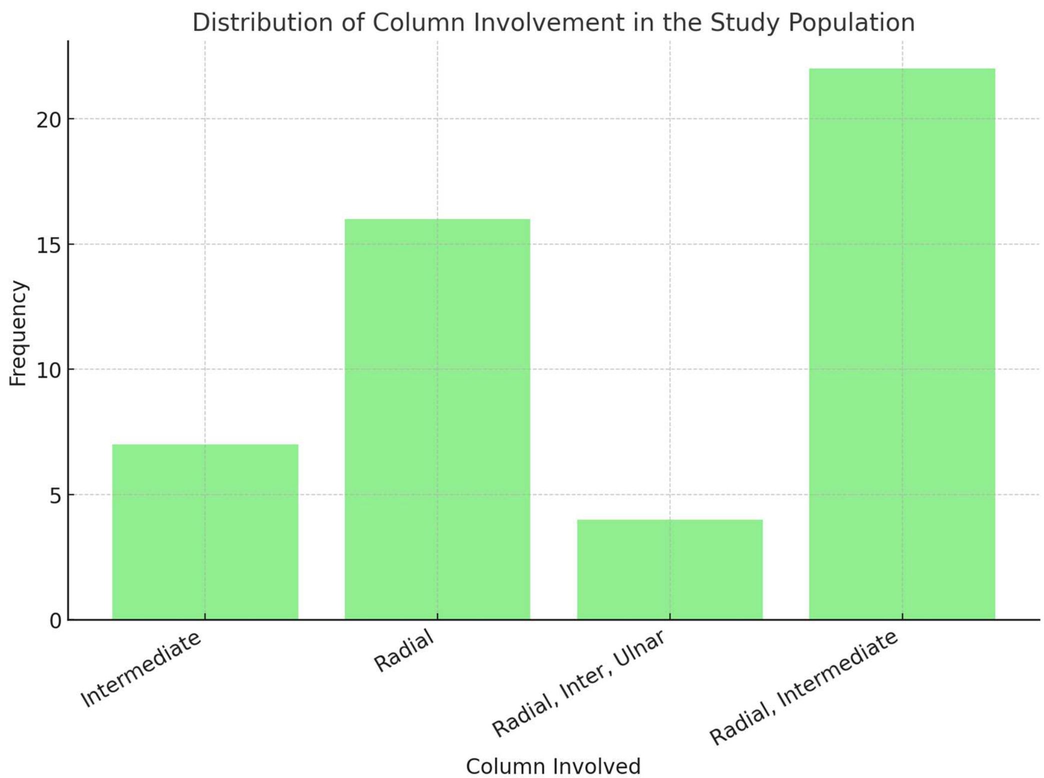


Table 4: Distribution of Mechanisms of Injury in the Study Population

Mechanism of Injury	Frequency	Percent
FOOSH	5	10.2
RTA	36	73.5
Trivial Trauma	8	16.3
Total	49	100.0

INTERPRETATION:

The bar chart represents the distribution of the mechanisms of injury among the study population, showcasing a marked predominance of injuries resulting from **road traffic accidents (RTAs), which account for 73.5% (36 cases) of the total**. This significant finding highlights RTAs as the primary causative factor for the injuries observed in the study, underscoring the need for enhanced road safety measures and trauma care systems. In contrast, **falls on an outstretched hand (FOOSH) and trivial trauma represent smaller proportions, with 10.2% and 16.3% respectively.** This distribution assists in understanding the epidemiology of the injuries studied and may guide public health interventions aimed at reducing the incidence and severity of such injuries, particularly those stemming from RTAs.

Distribution of Mechanisms of Injury in the Study Population

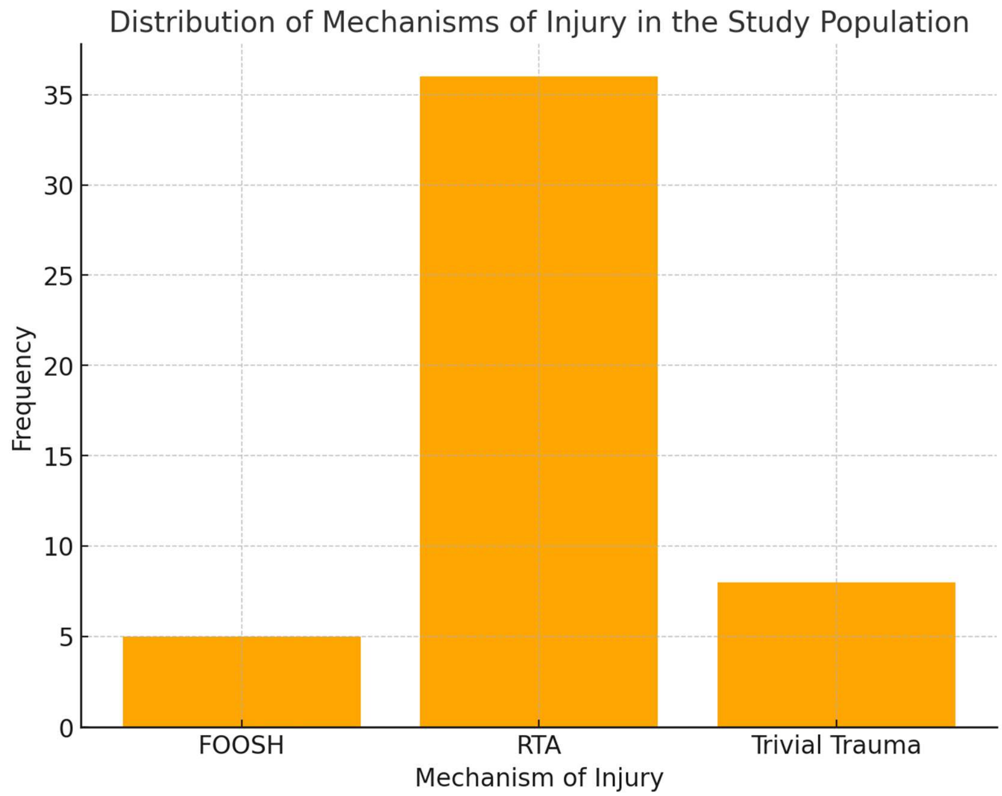


Table 5: Distribution as per Fernandez Classification

Fernandez type	Frequency	Percent
NC	19	38.8
Type II	4	8.2
Type III	23	46.9
Type V	3	6.1
Total	49	100.0

INTERPRETATION:

The bar chart illustrates the distribution of Fernandez types within the study population, revealing that **Type III is the most prevalent, accounting for 46.9% (23 individuals)** of cases. This suggests that the injuries classified under Type III are particularly common in the studied condition, perhaps due to specific biomechanical or epidemiological factors. Notably, the **'NC' (Non-Classified) group also constitutes a significant portion at 38.8% (19 cases)**, indicating a substantial number of injuries that do not fit neatly into the established classification types. This nmn to accommodate diverse injury patterns. The other **Fernandez types, Type II and Type V, are less frequent, with 8.2% and 6.1% respectively,** suggesting that these injury types are comparatively rare in this population. This distribution is pivotal for understanding the complexity and variability of injuries and may assist in tailoring treatment strategies and improving classification systems for better clinical outcomes.

Distribution of Fernandez Types

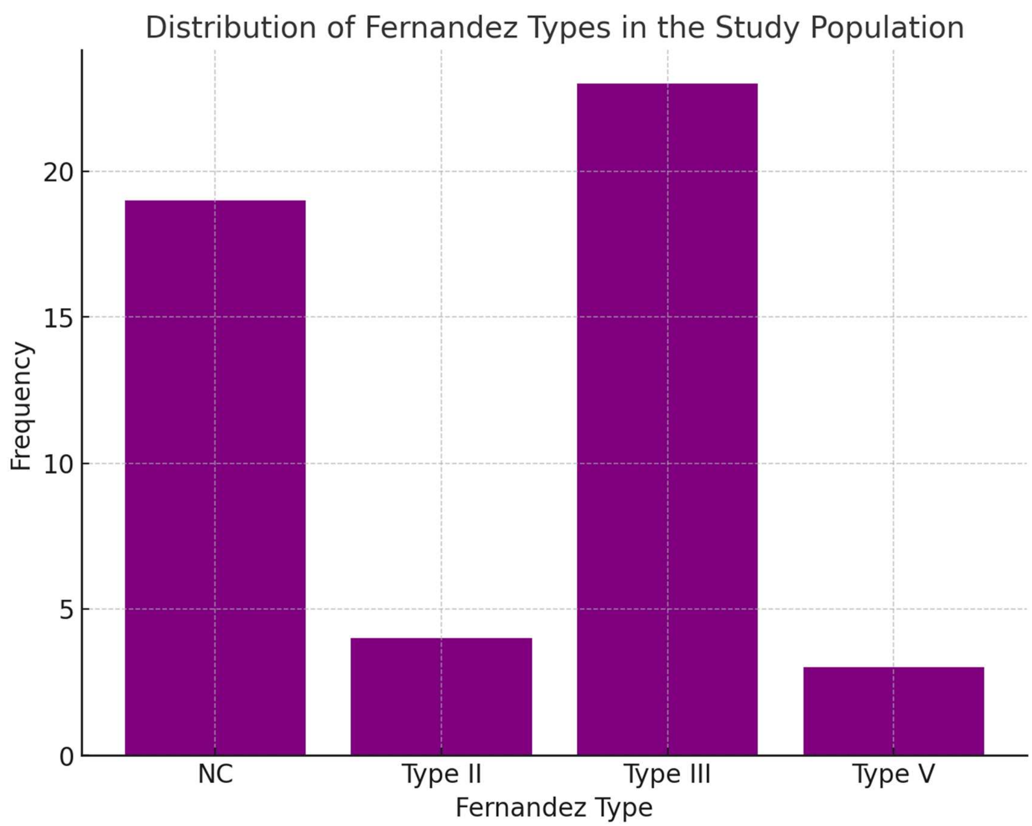


Table 6: Age Distribution as per Fernandez Classification

	Fernandez type				Total
Age	NC	Type II	Type III	Type V	
21 - 30	2	0	1	1	4
31 - 40	4	1	2	0	7
41 - 50	9	0	4	0	13
51 - 60	1	2	9	0	12
61 - 70	2	1	5	0	8
71 -80	1	0	2	2	5
Total	19	4	23	3	49
Pearson chi-square = 29.192, p-value = 0.015					

<u>INTERPRETATION:</u>

The grouped bar chart depicts the age distribution by Fernandez type among the study population, offering a clear visual of how different injury types vary across age groups. Type III is the most frequent across several age groups, peaking in the 51-60 range with nine cases, which suggests a higher susceptibility or different risk factors for this type within this age cohort. Conversely, Type II appears more often in the 51-60 age group relative to others. Notably, Type V shows its presence uniquely in the 21-30 and 71-80 age groups, which may indicate specific injury patterns or clinical presentations in these age extremes. The 'NC' (Non-Classified) type is most prevalent in the 41-50 age group, indicating that this age group may exhibit more complex or less typical injury patterns not easily classified into existing Fernandez types. The statistical analysis, indicated by a Pearson chi-square value of 29.192 with a significant p-value of 0.015, confirms that the differences in type distributions across age groups are statistically significant, suggesting age-related patterns in injury types that could influence clinical management and preventive strategies.

Age Distribution by Fernandez Classification

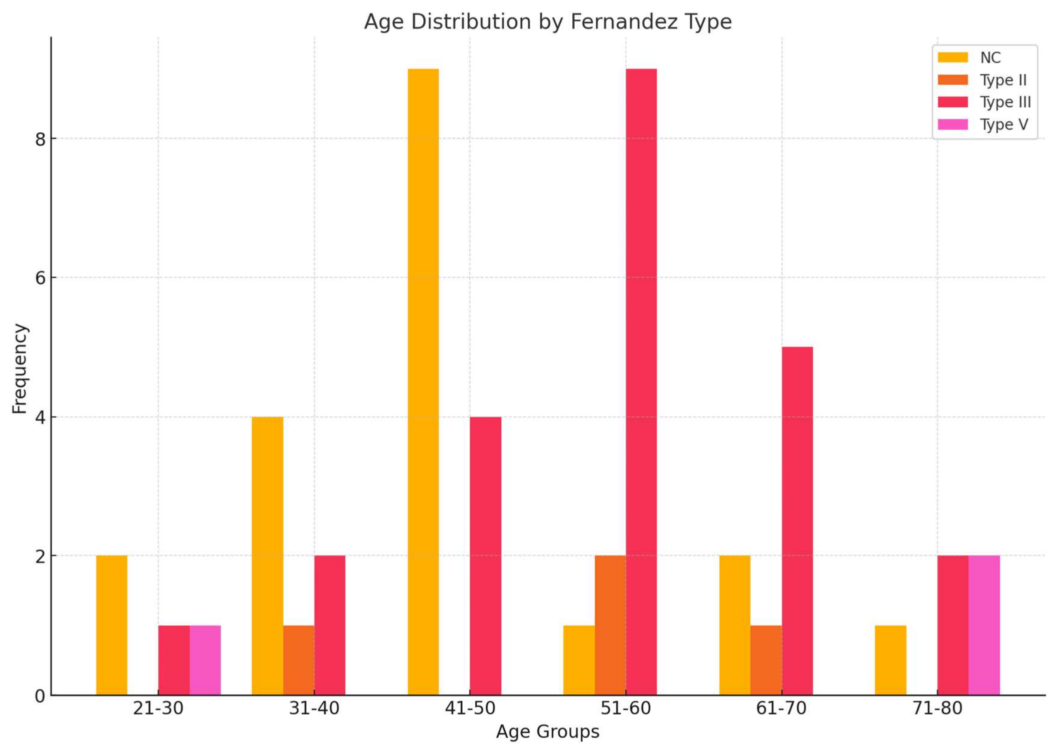


Table 7: Gender distribution as per Fernandez classification

	Fernandez type				Total
Gender	NC	Type II	Type III	Type V	
Female	6	1	8	0	15
Male	13	3	15	3	34
Total	19	4	23	3	49
Pearson chi-square = 1.580, p-value = 0.664					

INTERPRETATION:

The grouped bar chart illustrates the distribution of Fernandez types stratified by gender, revealing distinct patterns between males and females. Notably, males exhibit a higher frequency across all Fernandez types, especially notable in the 'NC' and 'Type III' categories, where males have 13 and 15 cases, respectively, compared to 6 and 8 in females. This distribution suggests that males are more prone to these types of injuries, or perhaps more males were included in the study. Type V injuries were only observed in males, indicating a possible gender-specific vulnerability or exposure to injury mechanisms leading to this classification. The absence of Type V injuries among females might also highlight differences in the nature or reporting of injuries between genders. The Pearson chi-square test yields a value of 1.580 with a p-value of 0.664, suggesting no significant statistical difference in the distribution of Fernandez types between genders, indicating that while there are numeric differences, they might not be statistically meaningful within the context of this study population. This analysis is critical for understanding potential gender-related disparities in injury types and may inform gender-specific preventive or treatment strategies.

Gender Distribution by Fernandez Type

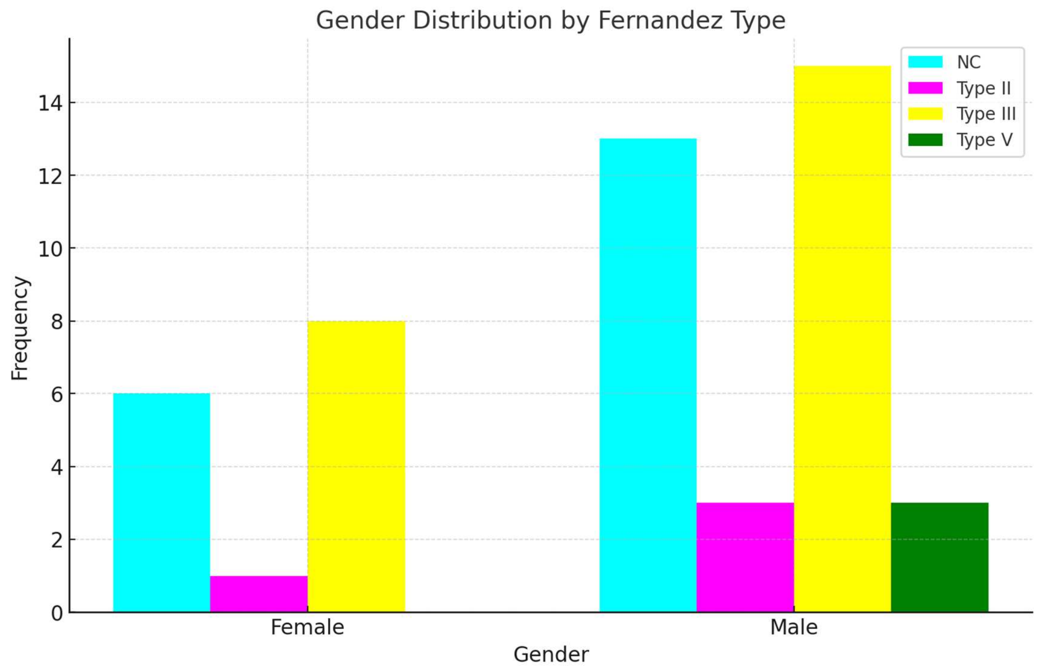


Table 8: Column Involved as per Fernandez classification

Column Involved	Fernandez type				Total
	NC	Type II	Type III	Type V	
Intermediate	0	0	7	0	7
Radial	15	1	0	0	16
Radial, Inter, Ulnar	0	1	0	3	4
Radial, Intermediate	4	2	16	0	22
Total	19	4	23	3	49
Pearson chi-square = 71.651, p-value = <0.001					

<u>INTERPRETATION:</u>

The grouped bar chart showcases the distribution of Fernandez types across different columns involved in the study population, revealing marked variations that suggest specific injury patterns. The "Radial, Intermediate" category demonstrates a predominant presence of Type III injuries with 16 cases, indicating a particular susceptibility of this column combination to such injuries. Conversely, the "Radial" category is heavily skewed towards 'NC' (Non-Classified) with 15 cases, suggesting either a broader range of injury types that do not fit well within the other defined Fernandez types or a higher incidence of complex injuries.

The "Radial, Inter, Ulnar" category is the exclusive group for Type V injuries, all three cases falling within this classification, underscoring a specific pattern or severity of injury associated with involvement of all three columns. The complete absence of any Fernandez types other than Type III in the "Intermediate" column, which solely accounts for all seven Type III cases in this category, points to a strong correlation between intermediate column injuries and this specific Fernandez type.

The highly significant Pearson chi-square value of 71.651 with a p-value of less than 0.001 indicates that the distribution of Fernandez types across different columns involved is not due to random chance and represents meaningful clinical patterns. This data is crucial for understanding the biomechanical and clinical implications of different column injuries and can significantly impact clinical approaches to diagnosis, treatment, and potentially, prevention strategies tailored to specific injury patterns observed in various columns.

Column Involvement by Fernandez Type

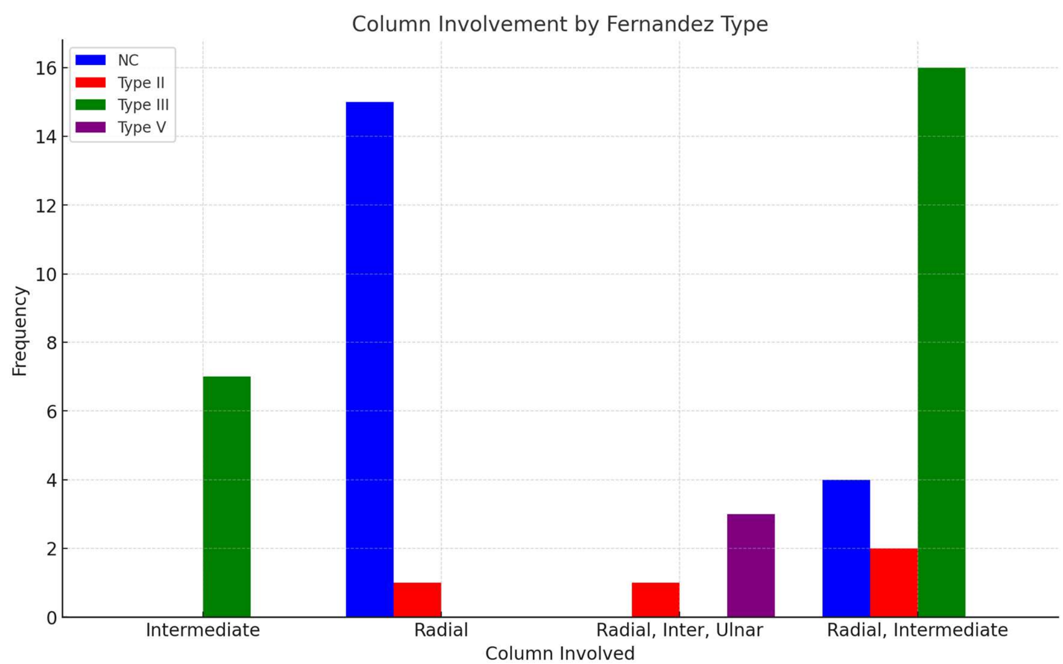


Table 9: Mechanism of Injury and Fernandez type

Mechanism of Injury	Fernandez type				Total
	NC	Type II	Type III	Type V	
FOOSH	2	0	3	0	5
RTA	16	3	14	3	36
Trivial Trauma	1	1	6	0	8
Total	19	4	23	3	49
Pearson chi-square = 5.423, p-value = 0.491					

<u>INTERPRETATION:</u>

The grouped bar chart elucidates the distribution of Fernandez types stratified by the mechanism of injury, providing significant insights into how different types of trauma are associated with specific injury classifications. Road Traffic Accidents (RTAs) predominate the dataset, with the highest occurrences across all Fernandez types, notably presenting 16 cases of 'NC' and 14 of Type III, which might suggest a higher impact or complex nature of injuries resulting from RTAs. FOOSH (fall on an outstretched hand) injuries, while fewer in total, show a relatively balanced distribution across 'NC' and Type III, which could indicate a specific injury pattern resulting from this mechanism.

Trivial trauma, though least frequent, still presents a notable proportion of Type III injuries with 6 cases, hinting at potential underestimations of injury severity from seemingly minor incidents. The absence of Type V injuries in both FOOSH and trivial trauma suggests these mechanisms may not typically result in the most severe classifications of injuries as per the Fernandez categorization.

The statistical analysis yields a Pearson chi-square of 5.423 with a p-value of 0.491, indicating that there is no statistically significant difference in the distribution of Fernandez types across different mechanisms of injury. This suggests that while the absolute numbers vary, the proportionate impact of each injury mechanism on the distribution of Fernandez types is not statistically distinct within this cohort, pointing towards a more generalized impact of these mechanisms across the classifications. This analysis aids in understanding the relationship between the etiology of trauma and specific patterns of injury, which is crucial for targeted prevention and tailored therapeutic strategies.

Mechanism of Injury by Fernandez Type

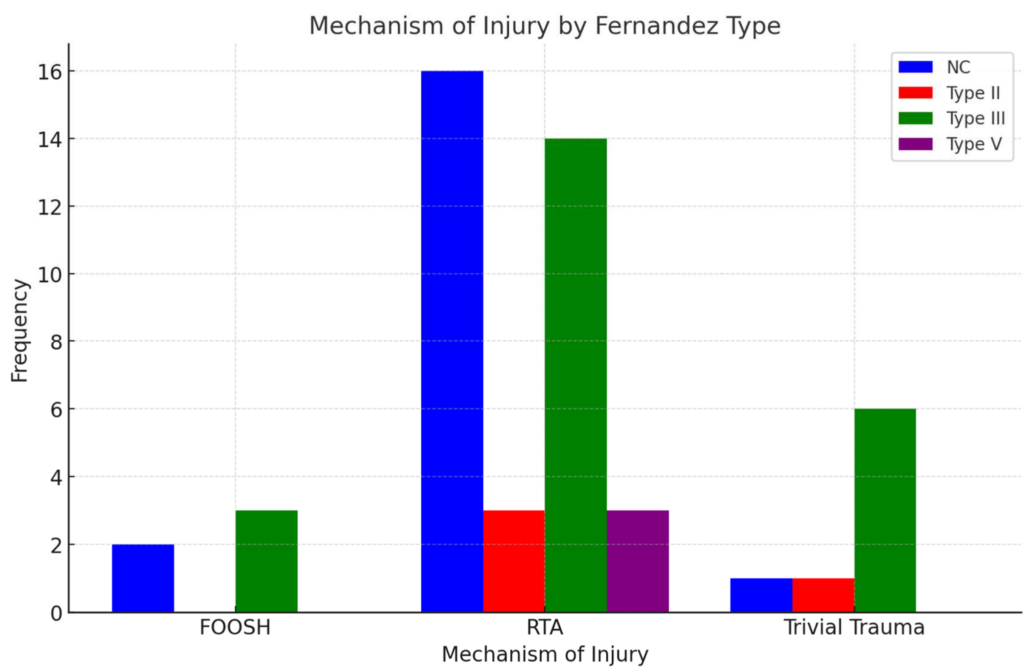


Table 10: Age and Column Involved

	Column Involved				Total
Age	Intermediate	Radial	Radial, Inter, Ulnar	Radial, Intermediate	
21 - 30	0	2	1	1	4
31 - 40	0	4	1	2	7
41 - 50	2	7	0	4	13
51 - 60	3	1	0	8	12
61 - 70	0	2	0	6	8
71 -80	2	0	2	1	5
Total	7	16	4	22	49
Pearson chi-square = 28.926, p-value = 0.016					

INTERPRETATION:

The grouped bar chart delineates the age distribution by column involvement, revealing nuanced insights into how column injuries vary across different age groups. The "Radial, Intermediate" column involvement peaks dramatically in the 51-60 age group with eight cases, suggesting a particular susceptibility or a higher incidence of injury within this demographic. This could imply more complex or severe injury patterns that affect multiple columns, prevalent among older individuals.

Conversely, the "Intermediate" column shows its highest frequencies in the 41-50 and 51-60 age groups, further indicating that older age groups might experience more diverse types of column injuries. Interestingly, the "Radial, Inter, Ulnar" involvement, though less frequent overall, appears more prominently in the oldest

(71-80) and youngest (21-30) age brackets, perhaps reflecting specific injury mechanisms or vulnerabilities in these age extremes.

Statistical analysis with a Pearson chi-square value of 28.926 and a p-value of 0.016 indicates that these differences across age groups are statistically significant, underscoring age-related patterns in column involvement that are not due to chance. This data is crucial for understanding the epidemiology of column injuries and can significantly influence clinical strategies, from prevention through to treatment, tailored to the anatomical and biomechanical challenges presented by different age groups.

Age Distribution by Column Involved

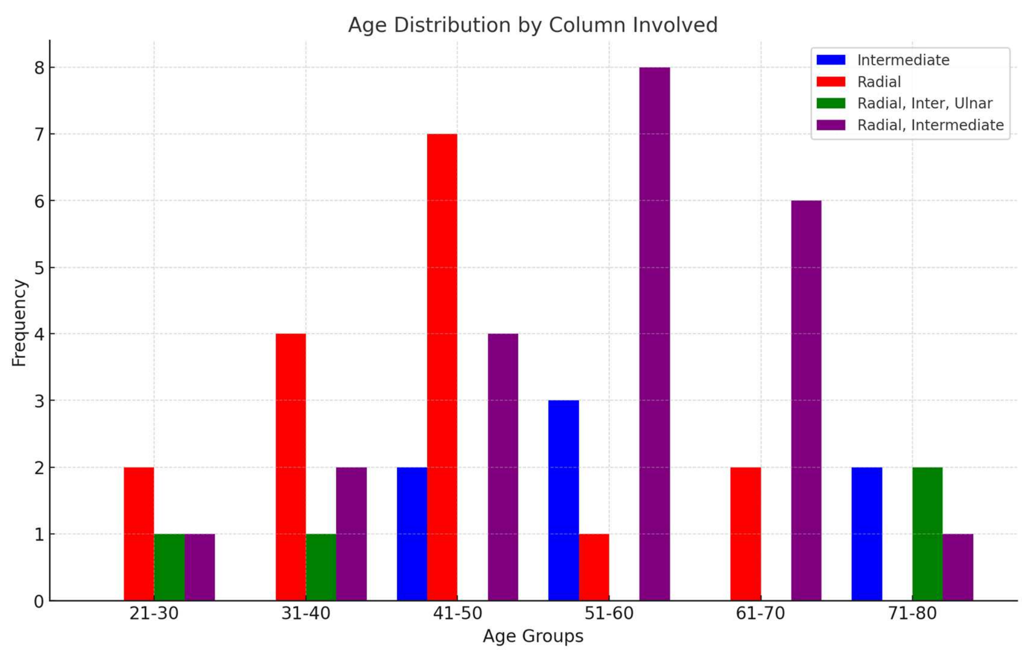


Table 11: Gender and Column Involved

Gender	Column Involved				Total
	Intermediate	Radial	Radial, Inter, Ulnar	Radial, Intermediate	
Female	3	5	0	7	15
Male	4	11	4	15	34
Total	7	16	4	22	49
Pearson chi-square = 2.277, p-value = 0.517					

INTERPRETATION:

The bar chart presents the distribution of column involvement by gender within the study, offering a clear depiction of how different injury patterns are distributed between males and females. Notably, males demonstrate a higher frequency in all categories of column involvement, with particularly pronounced differences in the "Radial, Intermediate" and "Radial, Inter, Ulnar" categories, where males have 15 and 4 cases respectively compared to 7 and 0 in females. This suggests a potential gender-related disparity in the occurrence of complex multi-column injuries, which may be influenced by differences in exposure to injury mechanisms or physiological differences between genders.

Females show significant involvement in the "Radial, Intermediate" category, which is the most common form of column injury among them, indicating a specific pattern of susceptibility. Despite these differences, the Pearson chi-square statistic is 2.277 with a p-value of 0.517, indicating that there is no statistically significant difference in the pattern of column involvement between genders within this sample.

This analysis is crucial for assessing whether gender-specific preventive measures or treatment approaches are warranted based on the pattern of injuries observed.

Gender Distribution by Column Involved

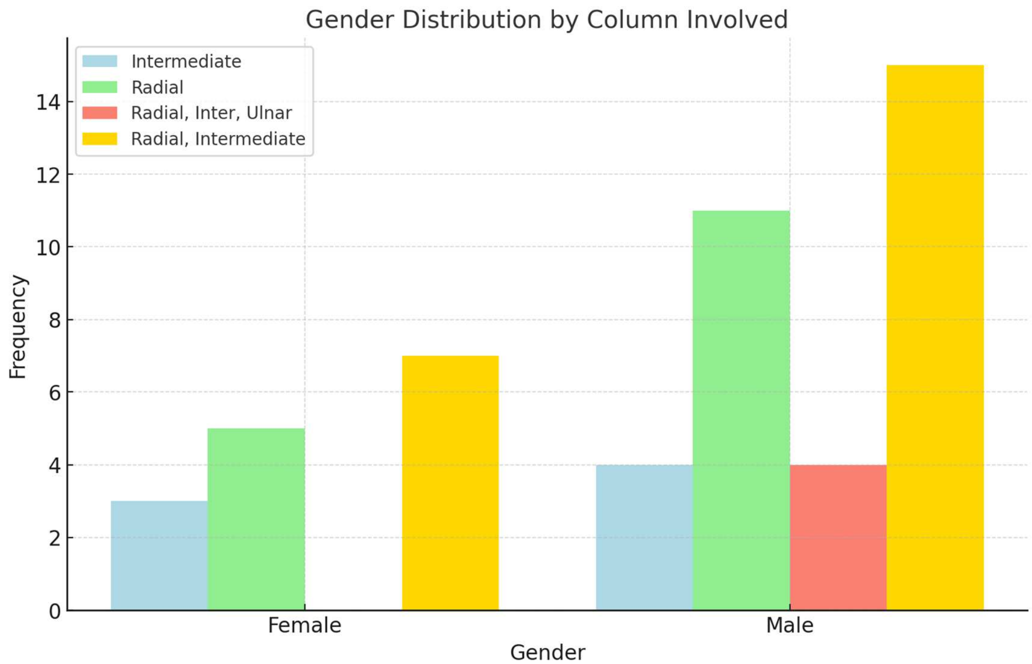


Table 12: Mechanism of Injury and Column Involved

	Column Involved				Total
Mechanism of Injury	Intermediate	Radial	Radial, Inter, Ulnar	Radial, Intermediate	
FOOSH	2	0	0	3	5
RTA	2	14	4	16	36
Trivial Trauma	3	2	0	3	8
Total	7	16	4	22	49
Pearson chi-square = 17.258, p-value = 0.041					

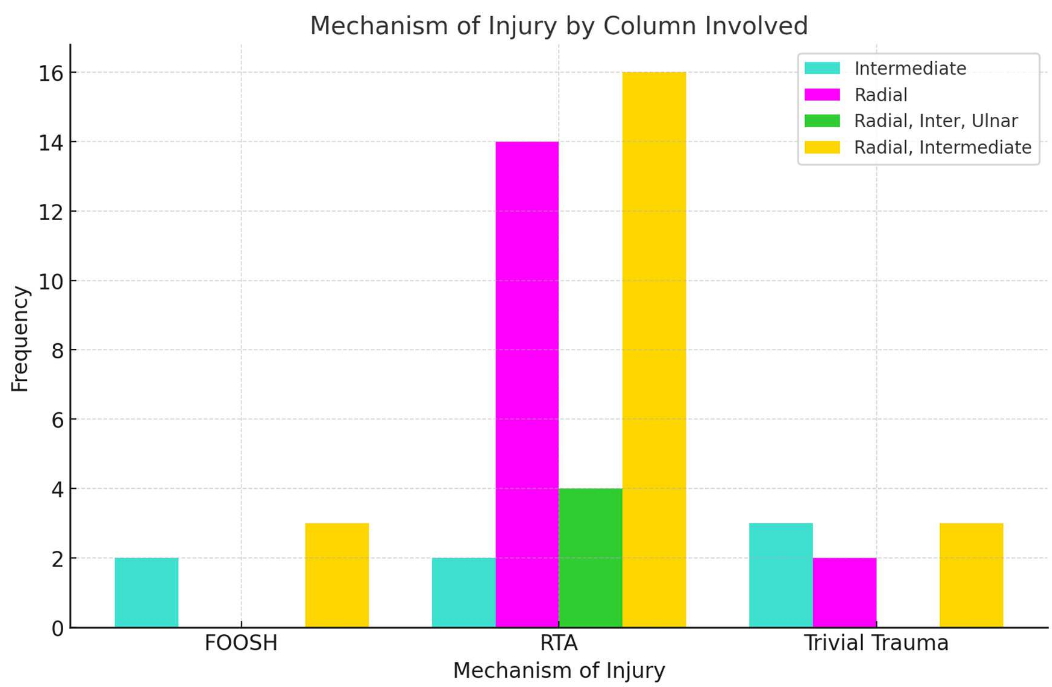
<u>INTERPRETATION:</u>

The bar chart delineates the distribution of column involvement stratified by the mechanism of injury, offering critical insights into how different injury causes are associated with specific column injuries. Road Traffic Accidents (RTAs) dominate the dataset, particularly in the "Radial" and "Radial, Intermediate" columns, with 14 and 16 cases respectively, underscoring the severe impact and the high likelihood of complex injuries associated with vehicular accidents. This suggests that RTAs are a major contributor to more serious, multiple-column injuries.

The "FOOSH" mechanism, typically associated with falls on an outstretched hand, shows a notable presence in the "Intermediate" and "Radial, Intermediate" categories, indicating specific patterns of impact distribution during such falls. Trivial trauma, despite being generally considered less severe, shows a spread across "Intermediate" and "Radial, Intermediate" columns, which might point to underestimation of the potential severity of injuries from minor incidents.

The statistical analysis, indicated by a Pearson chi-square value of 17.258 with a p-value of 0.041, suggests that the differences in column involvement across mechanisms of injury are statistically significant. This highlights the importance of understanding specific injury mechanisms to tailor preventive and treatment strategies appropriately, focusing on the most affected columns and the most common injury mechanisms within the studied population.

Mechanism of Injury by Column Involved



DISCUSSION

Distal End radius fractures are among the most common skeletal injuries encountered in orthopedic practice, especially in individuals subjected to high-energy trauma or in older populations with reduced bone density [51,52]. Because the distal radius is integral to wrist function, fractures involving its articular surface can lead to profound functional disability, pain, and eventual arthrosis if not adequately addressed [53,54]. Over the decades, multiple classification systems have been proposed to better describe these fractures, guide treatment plans, and ultimately predict outcomes. Traditional classifications, including the Frykman, Melone, AO, and Fernandez systems, provide varied perspectives on fracture patterns, displacement, and the mechanisms of injury [55,56]. However, they sometimes fall short in capturing the subtle morphological variations of complex intra-articular fracture lines, especially in high-energy injuries or multi-column disturbances.

In response to these limitations, the concept of three-column fixation and three-column classification has gained traction. The distal radius is anatomically divided into three columns: the radial, intermediate (sometimes referred to as central), and ulnar columns. Each column may be involved to a different degree based on the energy of trauma, direction of force transmission, and the inherent bone quality of the patient [57,58]. The novel three-column classification system utilized in this study aims to specifically elucidate which anatomical portion(s) of the distal radius are involved in the fracture. This approach facilitates a targeted treatment strategy where each column can be stabilized according to its involvement and the fracture's complexity [58,59].

The present study examined 49 patients with intra-articular fractures of the distal radius, categorizing these fractures according to the three-column model and examining potential correlations with demographic factors (such as age and sex), mechanisms of injury (e.g., fall on outstretched hand [FOOSH], road traffic accidents [RTA], and trivial trauma), and Fernandez fracture types. Given the relatively recent emphasis on precise anatomic restoration, a number of studies have evaluated the importance of accurate articular reduction, the stability of different columns, and how such classifications correlate with outcomes and complication rates [60,61]. Comparisons with recognized schemes, such as the Fernandez classification, can highlight how effectively the three-column approach delineates fracture morphology and helps predict functional prognoses.

This discussion will first revisit key findings from the descriptive and inferential analyses: demographic patterns, the prevalence of various column involvements, and differences observed among Fernandez types. It will then compare these outcomes to previous investigations, including both classic works on distal radius fracture classification and more recent contributions focusing on high-energy, intra-articular, and multi-planar fracture patterns [53,62]. Conflicting or supportive evidence from the literature will be discussed, underscoring the complexity of managing such fractures. Finally, we will explore the limitations of our study—particularly those related to sample size, retrospective data collection, and radiological assessment constraints—and propose directions for future research, including prospective, multicenter studies and advanced imaging or arthroscopic assessment to refine the three-column classification. Ultimately, these results reaffirm the necessity of individualized fracture analyses for distal radius injuries, while highlighting the potential advantages of a more nuanced classification system that can link morphological variation to clinical decision-making and outcomes.

1. Demographic Factors (Age and Sex)

A) Age Distribution

Our study population showed a relatively balanced distribution across adult age groups, with the highest incidence in the 41–50 and 51–60 age ranges, each accounting for roughly 26.5% and 24.5% of cases, respectively. In total, these middle-aged and older adult groups accounted for over half of the fractures. The prevalence of distal radius fractures in these age brackets mirrors other epidemiological data indicating that individuals in the fourth to sixth decades are highly susceptible to wrist fractures, often due to decreased bone mineral density and an increased likelihood of high-energy trauma in daily activities or occupational hazards [64,65].

Comparing our results to earlier studies, Court-Brown and Caesar [68] also highlighted a peak in distal radius fractures in the elderly, particularly related to osteoporotic changes. However, our findings demonstrate that even middle-aged individuals (41–50) remain significantly affected, possibly reflecting urban lifestyles and the higher incidence of road traffic accidents in certain regions. Furthermore, as per Nellans et al. [69], the incidence of distal radius fractures in people over 50 is especially high in females, consistent with the onset of post-menopausal osteoporosis. Our data partially corroborate this notion, though the overall highest age range (41–50 years) may reflect local demographics and the fairly robust representation of road traffic accidents.

B) Sex Distribution

In the current sample, men accounted for 69.4% of the fractures, whereas women comprised 30.6%. This contrasts with the classical epidemiological notion that women have a higher risk of osteoporotic fractures (including distal radius fractures) in older age [69,70]. One likely explanation is that a large proportion of our cases involved high-energy mechanisms such as road traffic accidents (73.5%), where men are often overrepresented in terms of risk exposure [52,59].

Previous research by Biyani et al. [55] found a more balanced distribution between men and women in younger adults presenting with high-energy fractures, whereas older women dominated low-energy fractures associated with osteoporosis. Our data also showed that the majority of older age fractures involved women; however, the overall dominance of men in the sample underscores a region-specific or population-specific factor, such as higher rates of male involvement in physically demanding jobs or traffic-related exposures [52,58].

2. Column Involvement

A) Distribution and Patterns

The three-column classification in our cohort indicated that the radial column alone was involved in 32.7% of cases, the intermediate column alone in 14.3%, and the combination of radial and intermediate columns in 44.9%. Complete tri-columnar involvement (radial, intermediate, and ulnar) was seen in 8.2% of the fractures. This finding suggests that multi-column involvement is not uncommon (over half of the cases), emphasizing the complexity of intra-articular distal radius fractures.

These observations align closely with studies that employ three-column concepts. Rikli and Regazzoni [54] were among the early proponents of approaching distal radius fractures via column-based fixation, highlighting that the intermediate (central) column is key to radiocarpal congruency, whereas the radial column is critical for radial height and inclination. Likewise, Mehta et al. [57] observed that multi-column involvement typically occurs with higher-energy mechanisms, requiring thorough assessment of each column's displacement to guide internal fixation strategies.

B) Relationship with Age

We found a statistically significant association ($p = 0.016$) between age groups and column involvement. Specifically, older patients (51–60 and 61–70) tended to have combined radial and intermediate column fractures more frequently, while some of the youngest (21–30) presented with radial or multi-column (radial, inter, ulnar) but in relatively smaller numbers. This may imply that older, osteopenic bone yields to mechanical stress in a more complex pattern, especially when subjected to high-energy forces [52]. Additionally, trivial trauma in older patients might cause a "fracture cascade" spanning multiple columns if the bone quality is poor [58].

C) Relationship with Gender

No significant association between gender and specific column involvement ($p = 0.517$) was observed, suggesting that once a fracture occurs, the morphological pattern transcends gender differences. These results parallel those by Hauck et al. [56] who found that although men and women can differ in age of presentation, the fracture morphologies across genders do not necessarily show distinct patterns when energy levels of trauma are comparable.

3. Mechanism of Injury

A) Distribution

Road traffic accidents (RTA) were the predominant mechanism of injury in our study (73.5%), followed by trivial trauma (16.3%) and FOOSH (10.2%). Globally, FOOSH has classically been associated with distal radius fractures in older patients; however, many recent series point to a rise in high-energy injuries (e.g., RTA, sports injuries) as a frequent cause of complex intra-articular fractures in younger populations [58,68]. Our study population appears to echo these findings, signifying that the socio-demographic context—particularly in high-traffic or industrial regions—affects fracture incidence.

B) Relationship with Column Involvement

A significant association was noted between mechanism of injury and column involvement ($p = 0.041$). Cases resulting from RTAs frequently involved the radial and intermediate columns, or sometimes all three columns, whereas FOOSH injuries more often inflicted isolated column involvement (either intermediate or radial-intermediate). This finding highlights that high-energy impacts may generate complex, comminuted fractures spanning multiple columns, whereas low-energy falls may concentrate load transmission through a particular column—often the radial column [58,59].

C) Relationship with Fernandez Type

Although the chi-square test for mechanism of injury and Fernandez type was not significant ($p = 0.491$), we still observed a predominance of high-energy RTA fractures in Type III patterns (shear or impacted articular fractures). This aligns with

Fernandez's original description, where Type III fractures often involve compression of the lunate fossa or shearing of the articular surface, typically associated with greater force application [51,62]. FOOSH injuries, traditionally linked to simple extra-articular or minimally displaced fractures, accounted for only 10.2% of cases in our series, reflecting the high-energy bias in the local setting.

4. Fernandez Classification Type

A) Overall Distribution

Type III fractures were the most common (46.9%), followed by "No Classification (NC)" (38.8%), Type II (8.2%), and Type V (6.1%). The high prevalence of Type III underscores the complexity of these fractures, which involve intra-articular comminution and significant articular surface compromise [51,62]. Since Fernandez proposed five fracture patterns primarily based on mechanism (shear, bending, compression), certain fracture patterns may not align well with a purely mechanism-focused classification, hence the category labeled as "No Classification (NC)" or an atypical pattern.

B) Comparative Literature

Fernandez classification is widely used but can sometimes be challenging to apply in multi-fragmented or multi-columnar patterns where features overlap. Our "NC" group (38.8%) highlights this limitation. Fernandez's system was initially intended to guide a logical stepwise approach to reduction and stabilization [62]. However, in severely comminuted intra-articular fractures, especially from high-energy causes like RTAs, the exact "mechanism-based" subtyping can become blurred, as multiple concurrent forces (bending plus shearing plus compression) may act on the distal radius [62,63].

Studies by Jupiter et al. [53] and Orbay and Fernandez [52] have recognized these complexities, suggesting that hybrid fracture patterns often do not fit neatly into a single Fernandez category. Our results corroborate these observations and support the concept that classification systems focusing on anatomic columns may sometimes provide clearer guidelines on the extent of reconstructive needs than mechanism-based classifications alone.

C) Relationship with Age

We observed a statistically significant association ($p = 0.015$) between age and Fernandez type, with older patients (>50 years) showing a higher incidence of Type III fractures. This is perhaps related to the compromised bone stock in older adults, which predisposes them to intra-articular impaction and fragmentation under even moderate forces [70]. Younger patients more often exhibited Type NC or minimal shearing patterns, though the small sample in the youngest age group (21–30) makes it difficult to draw definitive conclusions. Notably, some older patients (71–80) also had Type V fractures, typically associated with the highest energy or hyperextension mechanisms, reinforcing the role of compromised bone quality in sustaining more severe injury patterns [58,59].

D) Relationship with Gender

We did not observe a significant correlation ($p = 0.664$) between gender and Fernandez types. This is congruent with the premise that once the energy and direction of force are sufficient to produce an intra-articular fracture, the morphological pattern is less influenced by sex and more by bone quality and the precise vector of trauma [68].

5. Correlation of Fernandez Type with Column Involvement

Among the most striking findings was the strong correlation ($p < 0.001$) between column involvement and Fernandez type. For instance, all cases with isolated intermediate-column fractures were classified as Type III, whereas purely radial-column fractures were most often labeled as NC or Type I. Meanwhile, tri-columnar involvement was present in fractures that fell under Type V or Type II, highlighting a shared overlap between the multi-column concept and the recognized complexity of certain Fernandez subtypes.

This finding reinforces the notion that while Fernandez classification captures mechanism-based patterns, the three-column approach elucidates exactly which anatomical segment is disrupted. The synergy between these two systems suggests that implementing both can yield a comprehensive overview: the probable mechanism (Fernandez type) and the specific structural involvement (columns). In turn, surgeons can tailor their fixation approach—particularly relevant when bridging plates, external fixators, or combined volar-dorsal plates are considered for reestablishing anatomical congruity [52,60,].

A) Comparison to Previous Studies

Research by Mathoulin et al. [71] on arthroscopically assisted management of distal radius fractures has emphasized the necessity of understanding whether the radial column or the lunate fossa (part of the intermediate column) is depressed or sheared. Similarly, Bronstein et al. [73] found that malalignment of the intermediate column significantly reduced forearm rotation, underscoring the functional significance of that column. The novel classification used here resonates with these findings, as it highlights structural details often critical to wrist kinematics.

Several authors have suggested that stable fixation of the intermediate column is mandatory for preventing midcarpal instability and early arthritic changes [57,59,60] Our results, indicating that the intermediate column was involved in well over half of the fractures (alone or in combination), confirm the central importance of its accurate reduction. Studies by Dario et al. [72] and Mehta et al. [57] also reported high rates of articular incongruity and postoperative stiffness when intermediate-column fractures were not perfectly reduced, highlighting that in multi-columnar fractures, the risk of suboptimal healing is heightened if each fragment is not meticulously addressed.

6. Clinical Relevance and Possible Interpretations

Given the multi-factorial nature of distal radius fractures, a classification system that acknowledges the morphological distribution (three-column classification) in tandem with mechanisms (Fernandez) is highly advantageous. Complex intra-articular fractures in the older population with compromised bone stock will likely require more extensive fixation strategies, such as buttressing the intermediate column or bridging the wrist joint temporarily with external fixation to maintain length and alignment [61,74]. For younger patients sustaining high-energy trauma, advanced imaging (CT or arthroscopy) is invaluable for recognizing subtle multi-column disruptions not readily seen on plain radiographs [67,71].

Moreover, the demographic patterns in this series highlight how local epidemiology—particularly the prevalence of RTAs—can shift the typical distribution seen in Western cohorts where FOOSH in older females is more common [68,69].

This discrepancy underscores that classification systems and surgical algorithms must be adaptable to regional contexts, bone health, and the typical mechanism of injury.

7. Alignment with or Deviations from Prior Research

While our findings are largely consistent with established literature on the prevalence of complex, multi-column injuries in high-energy trauma, certain deviations were observed. Notably, the high representation of men and the somewhat lesser proportion of fractures due to FOOSH deviate from some North American or European studies emphasizing osteoporotic, low-energy fractures in women [69,70]. This gap highlights the need to interpret epidemiologic data through a socio-geographic lens: regions with significant industrialization or motor vehicle congestion may present with a distinct fracture pattern distribution.

Additionally, the large subset of “No Classification” fractures in the Fernandez system (nearly 40%) reaffirms the critique that purely mechanism-based classifications might underclassify or leave ambiguous those fractures with combined patterns [51,62]. In contrast, the three-column system in our study clearly delineated structural involvement for each fracture, presenting a stronger correlation with actual morphological patterns. Still, it is essential to note that the three-column system requires careful preoperative imaging and radiographic angles for accurate assignment, as malrotation or slight obliquities on plain radiographs can obscure column definition [63,67].

Limitations and Future Scope

Limitations

Several limitations of our study should be acknowledged:

1. **Sample Size and Single-Center Data**: With 49 patients included, the sample size is relatively modest. While the results provide compelling evidence, a larger, multicenter dataset would strengthen the generalizability of these findings [51,69].

2. **Retrospective Design**: Our analysis relied on chart reviews, retrospective imaging assessment, and documented follow-up. This approach may introduce biases related to incomplete documentation, recall bias, or inconsistencies in radiographic acquisition angles [67].

3. **Limited Imaging Modalities**: Although standard radiographs and, in select cases, CT scans were used, arthroscopic or three-dimensional CT evaluation was not universally employed. Such advanced imaging might reveal more intricate fracture lines and subtle cartilage damage, refining the classification further [71].

4. **Lack of Outcome Measures**: We focused primarily on morphological distribution, with no longitudinal assessment of functional outcomes (e.g., range of motion, grip strength, patient-reported outcome measures). This gap makes it difficult to directly correlate morphological patterns with long-term clinical and functional results [60,75].

5. **No Standardized Treatment Protocol**: Patients were managed according to the attending surgeon’s preference, which could include different fixation methods (volar plates, external fixators, K-wire fixation, or combined approaches). Heterogeneity in treatment protocols might influence union rates and complications, although that was not explicitly measured in this study.

Future Scope

1. **Prospective, Multicenter Trials**: A larger, prospective cohort across multiple centers can verify whether the three-column classification reliably predicts functional outcomes and complications. Such trials could incorporate standardized treatment algorithms to reduce variability and confirm the reproducibility of this classification scheme [52,56].

2. **Advanced Imaging Techniques**: Routine use of 3D CT scans and/or arthroscopy could further elucidate subtle fractures lines, particularly in the intermediate column, thereby refining classification accuracy. Correlating these advanced imaging findings with final outcomes (including the development of post-traumatic arthritis) may substantiate or modify the three-column approach [57,71].

3. **Integration with Biomechanical Studies**: Cadaveric biomechanical studies analyzing load distribution through each column would help validate the theoretical rationale for the three-column classification [73]. Such research could explore how specific disruptions in the radial or intermediate column affect wrist kinematics and how stable fixation can restore function.

4. **Functional Correlation**: Future investigations should include validated patient-reported outcome measures—like the PRWE (Patient-Rated Wrist Evaluation) or DASH (Disabilities of the Arm, Shoulder, and Hand) questionnaire—to correlate morphological patterns with actual functional recovery. Understanding which columnar involvements most critically affect outcome would inform surgical priorities [60,75].

5. **Comparative Trials of Classification Systems**: Finally, comparing the three-column classification to AO, Frykman, Melone, and other widely used systems in a single prospective series may clarify each system's strengths and weaknesses. Incorporating multiple raters to assess inter- and intra-observer reliability would also ensure that the new classification is both reliable and valid in clinical use [66].

Overall, our findings advocate for the utility of a more anatomically nuanced system—such as the three-column classification—in identifying the morphological intricacies of intra-articular distal radius fractures. Future research harnessing larger sample sizes, standardized imaging, and robust clinical follow-up can further solidify the role of this classification approach in guiding management strategies and predicting patient outcomes.

CONCLUSION

In conclusion, this study underscores the pivotal role of a structured and anatomically precise classification for distal radius fractures, particularly when dealing with intra-articular extensions that compromise multiple columns. By integrating the three-column classification with traditional frameworks such as the Fernandez system, clinicians can gain a more holistic understanding of fracture patterns and tailor treatment to each patient’s individual needs. Ultimately, these findings advocate for meticulous preoperative imaging, careful surgical planning, and possibly the addition of advanced modalities (e.g., CT, arthroscopy) to ensure optimal reduction and fixation of each column, thereby minimizing the risk of secondary displacement, osteoarthritis, and functional impairment in both younger high-energy trauma patients and older individuals with compromised bone density.

SUMMARY

The present study set out to explore the morphological distribution of intra-articular fractures of the distal radius using a novel three-column classification system. Distal radius fractures have long been recognized as one of the most commonly encountered orthopedic injuries, and their complexity increases substantially when they extend into the articular surface. Classic classification systems such as Frykman, Melone, AO, and Fernandez have all provided invaluable insights for clinicians; however, new approaches continue to emerge in an attempt to capture the nuanced morphologies observed in high-energy trauma, osteopenic bone, and comminuted patterns. The three-column system aims to divide the distal radius into radial, intermediate, and ulnar columns, directing more precise strategies for anatomical reduction and stable fixation. In this investigation, we analyzed 49 patients to elucidate how demographic factors, mechanisms of injury, and existing Fernandez types align with the involvement of one or multiple columns.

Epidemiologically, our sample highlighted several notable trends. Although advanced age (50 years and above) is often associated with osteoporotic fractures resulting from low-energy falls, our data showed that many fractures also occurred in middle-aged adults (41–60). Men overwhelmingly outnumbered women in the entire cohort (69.4% vs. 30.6%), a finding attributed primarily to the predominance of road traffic accidents (73.5%), an etiology where males generally exhibit higher exposure. Despite traditional assumptions that older females are most susceptible to distal radius fractures (especially via falls on outstretched hands), regional and occupational factors appear to powerfully shape the demographic pattern, leading to a unique distribution in which men sustain high-energy fractures via RTAs and, to a lesser extent, trivial trauma.

When subcategorizing these fractures, the three-column classification brought out critical details about the exact location of fracture lines in relation to the distal radius columns. While isolated radial-column involvement (32.7%) and combined radial-intermediate involvement (44.9%) collectively dominated, intermediate-only (14.3%) and tri-columnar involvement (8.2%) emphasized the heterogeneous nature of these injuries. Notably, we discovered significant correlations between age and column involvement ($p = 0.016$), as well as between mechanism of injury and column involvement ($p = 0.041$). These results lend credence to the hypothesis that bone quality (diminishing with advancing age) and high-energy forces (e.g., RTAs) play instrumental roles in creating multi-fragmented or multi-columnar fractures, reflecting the complexity of the traumatic vectors at play.

Moreover, correlating the Fernandez classification with the three-column system highlighted both overlaps and gaps. Fernandez Type III fractures (which involve significant articular surface compromise) were the most common in our series, aligning with high-energy etiologies and often implicating the intermediate column. Meanwhile, a substantial proportion (38.8%) of fractures were categorized as “No Classification (NC)” under Fernandez’s framework. This observation underscores the potential limitations of traditional mechanism-based classification systems in scenarios where multiple forces combine, producing complex morphologies that may not fit neatly into standard subtypes. Our findings thus reinforce that the three-column approach offers an anatomically oriented perspective that can facilitate targeted surgical planning—particularly important in older adults with fragile bone and younger individuals sustaining severe injury via road traffic accidents.

- **Key Observations and Takeaways**
  - **Demographics**: Middle-aged adults (41–60 years) constituted the largest fraction of distal radius fractures, with an overall predominance of male patients.
  - **Mechanism of Injury**: High-energy trauma (particularly road traffic accidents) represented the chief etiology, influencing both multi-columnar fracture patterns and the frequent occurrence of Type III Fernandez fractures.
  - **Column Involvement**: More than half of the fractures involved either multiple columns or solely the radial and intermediate columns, suggesting that simultaneous multi-columnar disruption is a hallmark of high-energy or osteopenic fractures.
  - **Fernandez Classification vs. Three-Column**: A major share of fractures were classified as Type III, which correlated well with intermediate-column involvement. However, many “atypical” or “NC” fractures in the Fernandez system revealed the potential for anatomically oriented classifications—like the three-column system—to capture the full complexity of the fracture.
  - **Clinical Implications**: Understanding column-specific disruption is vital for operative planning, as intermediate-column involvement in particular can greatly impact wrist stability, midcarpal alignment, and long-term functional outcomes.

BIBLIOGRAPHY

1. Colles, A. (1814). On the fracture of the carpal extremity of the radius. *Edinburgh Medical and Surgical Journal*, *10*, 182–186.

2. Chung, K. C., & Spilson, S. V. (2001). The frequency and epidemiology of hand and forearm fractures in the United States. *The Journal of Hand Surgery, 26*(5), 908–915.

3. Nellans, K. W., Kowalski, E., & Chung, K. C. (2012). The epidemiology of distal radius fractures. *Hand Clinics, 28*(2), 113–125.

4. Jupiter, J. B., & Fernandez, D. L. (2002). Comparative classification for fractures of the distal end of the radius. *The Journal of Hand Surgery, 27*(5), 748–761.

5. Cooney, W. P. (1993). Management of Colles' fractures. *The Journal of Hand Surgery, 18A*(4), 593–594.

6. Wicart, P., & Seringe, R. (2006). Distal radius fractures in children: Prediction of outcome. *Orthopaedics & Traumatology: Surgery & Research, 92*(8), 546–550.

7. Walch, G., Ascencio, G., & Boulahia, A. (1999). Distal radius fractures: Current concepts and perspectives. *Orthopaedics & Traumatology: Surgery & Research, 85*(4), 478–486.

8. DiBenedetto, M. R., & Lubbers, L. M. (2018). The distal radioulnar joint and triangular fibrocartilage complex: A review. *The Journal of Hand Surgery, 43*(1), 47–53.

9. Scheck, M. (1962). Die-punch fractures of the distal radius. *Journal of Bone & Joint Surgery - American Volume, 44A*(8), 1628–1631.

10. Trumble, T. E., & Wagner, W. (1993). Intrafocal (Kapandji) pinning of distal radius fractures with and without external fixation. *Hand Clinics, 9*(4), 541–551.

11. Wolfe, S. W., Hotchkiss, R. N., Pederson, W. C., & Kozin, S. H. (2011). *Green's Operative Hand Surgery* (6th ed.). Philadelphia: Elsevier.

12. Orbay, J. L., & Badia, A. (2007). Technique tip: Modified volar approach for distal radius fracture fixation. *Techniques in Hand & Upper Extremity Surgery, 11*(2), 107–110.

13. Beharrie, A. W., Beredjiklian, P. K., & Bozentka, D. J. (2004). Functional outcomes after open reduction and internal fixation for treatment of displaced distal radius fractures in patients over 60 years of age. *The Journal of Orthopaedic Trauma, 18*(10), 680–686.

14. Rozental, T. D., & Blazar, P. E. (2006). Functional outcome and complications after volar plating for dorsally displaced, unstable fractures of the distal radius. *The Journal of Hand Surgery, 31A*(3), 359–365.

15. Müller, M. E., Nazarian, S., Koch, P., & Schatzker, J. (1990). *The Comprehensive Classification of Fractures of Long Bones*. Berlin: Springer.

16. Frykman, G. (1967). Fracture of the distal radius including sequelae—Shoulder–hand–finger syndrome, disturbance in the distal radioulnar joint and impairment of nerve function: A clinical and experimental study. *Acta Orthopaedica Scandinavica, 108(Suppl)*, 3–109.

17. Melone, C. (1984). Articular fractures of the distal radius. *Orthopedic Clinics of North America, 15*(2), 217–236.

18. Fernandez, D. L. (1984). Distal radius fracture: The rationale of a classification. *Chirurgie de la Main, 3*(4), 255–263.

19. Cooney, W. P. (2006). The importance of good classification systems. *Hand Clinics, 22*(2), 187–188.

20. Golden, G. N. (1963). Treatment and prognosis of Colles' fracture. *The Lancet, 281*(7291), 511–515.

21. Mackenney, P. J., McQueen, M. M., & Elton, R. (2006). Prediction of instability in distal radial fractures. *The Journal of Bone & Joint Surgery - American Volume, 88A*(9), 1944–1951.

22. Fernandez, D. L., & Jupiter, J. B. (1996). *Fractures of the Distal Radius: A Practical Approach to Management*. New York: Springer.

23. Arora, R., Lutz, M., & Gabl, M. (2005). Volar plate fixation of unstable distal radius fractures: Early functional and radiological outcome in a prospective study. *Journal of Orthopaedic Trauma, 19*(3), 163–168.

24. Gilad, I., & Arcan, M. (1986). Three-dimensional mathematical model of the human hand. *Journal of Biomedical Engineering, 8*(1), 65–71.

25. Ozer, K., & Gillani, S. (2009). The use of computed tomography in surgical planning for distal radius fractures. *Orthopedic Clinics of North America, 40*(2), 225–229.

26. Kreder, H. J., & Hanel, D. P. (1995). Evaluation of the distal radius fracture with computerized tomography. *Techniques in Orthopaedics, 10*(1), 30–38.

27. Chan, P. S., & Leong, J. C. (1984). The use of computed tomography in distal radius fractures. *The Journal of Hand Surgery, 9B*(2), 157–159.

28. Zhou, J., Tang, W., Xiao, J., Zhang, C., Shen, Y., & Li, Z. (2019). Morphological classification of distal radius die-punch fractures based on a three-column concept. *BMC Musculoskeletal Disorders, 20*(1), 400.

29. Li, D., Liu, Y., Li, D., Wang, X., & Chen, J. (2020). A novel three-column classification for double-column die-punch fractures of the distal radius: Mechanisms, imaging characteristics, and clinical significance. *Journal of Orthopaedic Surgery and Research, 15*(1), 1–7.

30. Watson, H. K., & Weinzweig, J. (2001). The wrist. *Journal of the American Society for Surgery of the Hand, 1*(2), 125–148.

31. Fernandez, D. L., & Jupiter, J. B. (2002). *Fractures of the distal radius: A practical approach to management*. Springer Science & Business Media.

32. Chen, N. C., & Jupiter, J. B. (2007). Management of distal radial fractures. *The Journal of Bone and Joint Surgery*, 89(9), 2051-2062.

33. Giannoudis, P. V., Tzioupis, C., Papathanassopoulos, A., Obakponovwe, O., & Roberts, C. (2010). Articular step-off and risk of post-traumatic osteoarthritis. Evidence today. *Injury*, 41(10), 986-995.

34. Nandakumar, S. V. (2010). *Comprehensive study of operative management of fractures of distal end radius* (Master's thesis, Rajiv Gandhi University of Health Sciences, India).

35. Zhang, J., Ji, X. R., & et al. (2016). New classification of lunate fossa fractures of the distal radius. *Journal of Orthopaedic Surgery and Research*, 11(1), 124. http://doi.org/10.1186/s13018-016-0455-1

36. Sun, H., Zhu, Y., He, Q. F., Shu, L. Y., Zhang, W., & Chai, Y. M. (2017). Reinforcement strategy for lateral rafting plate fixation in posterolateral column fractures of the tibial plateau: The magic screw technique. *Injury*, 48(12), 2814-2826.

37. Ma, Y., Yin, Q., & et al. (2017). Image classification for Die-punch fracture of intermediate column of the distal radius. *Radiologia Medica*, 122(12), 928-933. http://doi.org/10.1007/s11547-017-0797-8

38. Yang, Y., Yin, Q., & et al. (2018). A new classification and its value evaluation for intermediate column fractures of the distal radius. *Journal of Orthopaedic Surgery and Research*, 13(1), 221. http://doi.org/10.1186/s13018-018-0925-8

39. Singh, T. S. P., Sadagatullah, A. N., & Yusof, A. H. (2015). Morphology of distal radius curvatures: a CT-based study on the Malaysian Malay population. *Singapore Medical Journal*, 56(10), 562.

40. Yan, B., Chen, Y., & Yin, W. (2019). Influence of distal radius fractures involving the intermediate column on forearm rotation. *Journal of Orthopaedic Surgery and Research*, 14, 1-5.

41. Li, S. L., Li, A., & et al. (2019). [Epidemic characteristics of adult Barton's fractures between Western and Eastern of China from 2010 to 2011]. *Zhonghua Yi Xue Za Zhi*, 99(1), 62-66. Chinese. http://doi.org/10.3760/cma.j.issn.0376-2491.2019.01.014

42. Zhou, J., Tang, W., & et al. (2019). Morphological characteristics of different types of distal radius die-punch fractures based on three-column theory. *Journal of Orthopaedic Surgery and Research*, 14(1), 390. http://doi.org/10.1186/s13018-019-1453-x

43. Li, D., Liu, Y., & et al. (2020). Identification of a novel three-column classification for double-column die-punch fractures of the distal radius. *Experimental and Therapeutic Medicine*, 19(3), 1871-1877. http://doi.org/10.3892/etm.2020.8434

44. Zhang, Y., Hu, J., Li, X., & Qin, X. (2020). Humeral capitellum fracture combined with humeral lateral column injury: A novel classification system and treatment algorithm. *Injury*, 51(4), 955-963.

45. Hruby, L. A., Haider, T., Laggner, R., Gahleitner, C., Erhart, J., Stoik, W., ... & Thalhammer, G. (2021). Standard radiographic assessments of distal radius fractures miss involvement of the distal radioulnar joint: A diagnostic study. *Archives of Orthopaedic and Trauma Surgery*, 1-8.

46. Kong, L., Wang, Y., Lu, Q., Han, Y., & Wang, F. (2021). Biomechanical properties of a novel fixation system for intra-articular distal humerus fractures: A finite element analysis. *Journal of Orthopaedic Surgery and Research*, 16, 1-14.

47. Onishi, T., Omokawa, S., Shimizu, T., Kawamura, K., Nagashima, M., & Tanaka, Y. (2022). Impacted intraarticular fragments of distal radius fractures: A radiographic characterization and analysis of reliability and diagnostic accuracy. *Journal of Orthopaedic Science*, 27(2), 384-388.

48. Mauck, B. M., & Calandruccio, J. H. (2023). The pitfalls of difficult intraoperative challenges. In *Orthopedic Clinics, E-Book: Intraoperative Challenges*, 55(1), 113.

49. Zhang, J., Yao, X., Song, Y., & Yin, P. (2023). 123 Classification system: Establishment and preliminary evaluation of CT-based classification for distal radius fracture.

50. Xu, W., Wei, X., Zhao, K., Yang, Y., Liu, J., Zhang, Z., & Yin, Q. (2024). Imaging classification by column and type of the generalized distal radius die-punch fractures. *Current Medical Imaging*, 20(1), e15734056261118.

51. Fernandez DL. Distal radius fracture: the rationale of a classification. *Chir Main.* 2001;20(6):411–25.

52. Orbay JL, Fernandez DL. Volar fixed-angle fixation of distal radius fractures: a long-term follow-up. *J Hand Surg Am.* 2002;27(6):969–76.

53. Jupiter JB, Fernandez DL, Toh CL, et al. Operative treatment of volar intra-articular fractures of the distal end of the radius. *J Bone Joint Surg Am.* 1996;78(12):1817–28.

54. Rikli DA, Regazzoni P. Fractures of the distal end of the radius treated by internal fixation and early function. *J Bone Joint Surg Br.* 1996;78(4):588–92.

55. Biyani A, Simison AJ, Klenerman L, et al. Fractures of the distal radius and ulna. *J Hand Surg Br.* 1995;20(3):357–64.

56. Hauck W, Holzer N, Fellmann J, et al. Distal radius fracture management with different fixation devices in elderly patients: prospective study. *Arch Orthop Trauma Surg.* 2015;135(3):323–9.

57. Mehta JA, Bain GI, Heptinstall RJ. Anatomical reduction of intra-articular fractures of the distal radius: an arthroscopically-assisted approach. *J Bone Joint Surg Br.* 2000;82(1):79–86.

58. Qomariah Y, Umer M, Lakhani M, et al. Non-bridging external fixation for distal radius fractures. *J Pak Med Assoc.* 2018;68(Suppl 3(1)):S56–9.

59. Wright TW, Horodyski M, Struchin L. Functional outcome of unstable distal radius fractures. *J Hand Surg Am.* 2005;30(4):743–9.

60. MacDermid JC, Richards RS, Donner A, et al. Responsiveness of the PRWE and DASH outcome measures. *J Hand Surg Am.* 2000;25(2):330–5.

61. Hayes AJ, Duffy PJ, McQueen MM. Bridging and non-bridging external fixation in the treatment of unstable fractures of the distal radius. *J Bone Joint Surg Br.* 2008;90(1):1–7.

62. Jupiter JB, Fernandez DL. Comparative classification for fractures of the distal end of the radius. *J Hand Surg Am.* 1997;22(5):765–6.

63. Souer JS, Ring D, Matschke S, et al. Comparison of plates with and without distal locking screws for fixation of dorsally displaced fractures of the distal radius. *J Hand Surg Am.* 2008;33(6):754–63.

64. Jupiter JB, Toh CL, Fernandez DL. The assessment and management of the distal radius fracture: the perspective of the orthopaedic surgeon. *Eur J Plast Surg.* 1997;20(6):217–24.

65. Gartland JJ, Werley CW. Evaluation of healed Colles' fractures. *J Bone Joint Surg Am.* 1951;33(4):895–907.

66. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *J Chiropr Med.* 2016;15(2):155–63.

67. Kwon BC, Sheetz KK, Bollen SR. Intra-articular distal radius fractures: the significance of computed tomography scanning and the role of arthroscopy in assessing articular congruity. *Injury.* 2001;32(8):615–22.

68. Court-Brown CM, Caesar B. Epidemiology of adult fractures: a review. *Injury.* 2006;37(8):691–7.

69. Nellans KW, Kowalski E, Chung KC. The epidemiology of distal radius fractures. *Hand Clin.* 2012;28(2):113–25.

70. Hollevoet N, Verdonk R. Outcome of distal radius fractures in relation to radiological parameters. *Scand J Plast Reconstr Surg Hand Surg.* 2003;37(3):138–42.

71. Mathoulin C, Beghe P, Sallen V, et al. Arthroscopic management of distal radius fractures. *Hand Clin.* 2017;33(4):767–775.

72. Dario P, Matteo G, Carolina C, et al. Surgical treatment of distal radius fractures using a volar locking plate: the importance of the subchondral support. *Eur J Orthop Surg Traumatol.* 2014;24(5):723–9.

73. Bronstein AJ, Trumble TE, Tencer AF. The effects of distal radius fracture malalignment on forearm rotation: a cadaveric study. *J Hand Surg Am.* 1997;22(2):258–62.

74. Trumble TE, Wagner W, Hanel DP, et al. Intrafocal (Kapandji) pinning of distal radius fractures with and without external fixation. *J Hand Surg Am.* 1998;23(3):381–94.

75. Grewal R, MacDermid JC. The risk of adverse outcomes in extra-articular distal radius fractures is increased with malalignment in patients of all ages but mitigated in older patients. *J Hand Surg Am.* 2007;32(7):962–70.

ANNEXURE – I

PROFORMA FOR DATA RECORDING

STUDY OF MORPHOLOGICAL DISTRIBUTION OF INTRA-ARTICULAR FRACTURES OF DISTAL-END RADIUS BASED ON NOVEL THREE COLUMN CLASSIFICATION SYSTEM

Patient name: Date of scan:

Age: Sex: Ip No:

1. Classification according to Novel 3 column classification (column involved):

a) Radial column b) Intermediate column c) Ulnar column

2. Classification of fracture according to Fernandez Classification:

3. Mechanism Of Injury

4. Side Involved:

5. Comments IF Any:

ANNEXURE – II

INFORMED CONSENT FORM

STUDY OF MORPHOLOGICAL DISTRIBUTION OF INTRA-ARTICULAR FRACTURES OF DISTAL-END RADIUS; BASED ON NOVEL THREE COLUMN CLASSIFICATION SYSTEM.

Objectives: To examine the morphological characteristics of distal radius fractures and assessing its consistency in clinical setting along-with comparing classification outcomes to existing standard systems

Name of Student/Principal Investigator:

Name of Guide/Co Investigators:

Introduction: Fractures of the wrist joint are very common fractures seen in general practice. Fractures involving the joint surface (also known as articular surface) are very commonly associated with loss of range of motions. So, fixation of these fractures after understanding the type, exact location, exact displacement and morphological features of the fracture; will help in getting maximum functional outcome for the patient. Hence; patients who are voluntarily ready to share the data for this study will be able help a large amount of population.

Explanation of procedure: All patients having joint surface (also known as intra-articular involvement) of the wrist joint fracture will be asked to get one 3D CT-Scan done. Data received will then be analysed and studied for classifying the intra-articular distal end radius fractures.

Withdrawal from participation in the study: Participation in this study is voluntary. You will be free to decide whether to participate in this study or continue participation once enrolled. In case you decide to withdraw your participation, you are free to do so. However, please convey the decision to the principal investigator.

Possible benefits from participating in the study: You will not get any benefits by participating in this study. The data gathered will help population at large.

Possible risks from participating in the study: There are no risks involved in participating in this study.

Privacy and confidentiality: The information collected from you will be coded, to prevent any person to identify you. Your identity will never be revealed. The data collected from you will be kept confidential and only processed or aggregated data will be used for publication.

Financial incentives: You will not receive any payment for participating in this study.

Cost of investigations: Done during the course of study will be paid by the participant.

Authorization for publication of aggregated data: Results obtained after processing of the aggregated data will be published for scientific purpose and or presented to scientific groups. However, your identity will never be revealed. If you have any question or complaints regarding your right as study participant you may contact Dr Harsha Hegde, Chairperson, Ethical committee of JNMC, 0831-2473777 Extension 4052.

Legal rights: By signing this consent form, we are not waving any of your legal rights

CONSENT STATEMENT

I am making a voluntary decision to participate in the study; **STUDY OF MORPHOLOGICAL DISTRIBUTION OF INTRA-ARTICULAR FRACTURES OF DISTAL-END RADIUS; BASED ON NOVEL THREE COLUMN CLASSIFICATION SYSTEM**".

My signature below indicates that I have decided to participate and I have read the information provided above or the information provided above has been read to me in the language that I understand best. I was given the opportunity to ask questions and that they have been answered to my satisfaction.

Name of the participant:

Signature/left thumb impression of participant:

Name of the witness:

Signature/left thumb impression of witness:

Name of the investigator:

Signature of the investigator:

ANNEXURE – III

Sr. NO	Unique Patient Code	Gender	Age	Date Of The Scan	Column Involved	Mechanism of Injury	Fernandez type
1	P W	Female	72	23-09-2022	Radial, Intermediate	FOOSH	NC
2	S K	Female	68	25-12-2022	Radial	Trivial Trauma	Type II
3	B K	Male	52	28-12-2022	Radial, Intermediate	RTA	Type III
4	P M	Female	43	03-01-2023	Radial	RTA	NC
5	M K	Female	52	16-01-2023	Intermediate	Trivial Trauma	Type III
6	C S	Male	72	04-02-2023	Intermediate	Trivial Trauma	Type III
7	S N	Female	62	12-02-2023	Radial, Intermediate	FOOSH	NC
8	P P	Male	49	29-03-2023	Radial, Intermediate	RTA	Type III
9	R V	Male	60	03-04-2023	Radial, Intermediate	RTA	Type II
10	B K	Male	49	05-05-2023	Radial, Intermediate	RTA	NC
11	S N	Male	33	14-12-2023	Radial	RTA	NC
12	J T	Male	49	23-11-2023	Intermediate	Trivial Trauma	Type III
13	G D	Female	56	28-03-2023	Radial, Intermediate	RTA	Type III
14	P P	Male	49	29-03-2023	Radial	RTA	NC
15	A W	Male	38	30-01-2024	Radial, Inter, Ulnar	RTA	Type II
16	D I	Female	35	12-02-2024	Radial, Intermediate	RTA	Type III
17	M S	Male	49	16-08-2022	Radial, Intermediate	RTA	NC
18	S M	Male	63	09-06-2022	Radial, Intermediate	RTA	Type III
19	A M	Female	67	22-06-2024	Radial	Trivial Trauma	NC
20	R K	Female	74	08-06-2024	Intermediate	FOOSH	Type III
21	R B	Male	41	26-05-2024	Radial, Intermediate	RTA	Type III
22	SN	Male	42	13-05-2024	Radial	RTA	NC
23	R M	Male	23	23-04-2024	Radial	RTA	NC
24	G K	Male	60	22-04-2024	Intermediate	RTA	Type III

25	D S	Male	54	17-04-2024	Radial, Intermediate	Trivial Trauma	Type III
26	G H	Male	49	16-04-2024	Radial	RTA	NC
27	S M	Male	31	12-04-2024	Radial, Intermediate	RTA	Type III
28	R A	Male	44	29-03-2024	Intermediate	RTA	Type III
29	V A	Female	56	18-03-2024	Radial, Intermediate	RTA	Type III
30	G K	Female	59	17-05-2024	Intermediate	FOOSH	Type III
31	M S	Male	59	16-03-2024	Radial, Intermediate	RTA	Type II
32	S S	Male	21	16-03-2024	Radial, Intermediate	RTA	Type III
33	V B	Female	52	14-03-2024	Radial, Intermediate	RTA	Type III
34	M K	Male	30	05-03-2024	Radial,	RTA	NC
35	V U	Male	72	25-02-2024	Rad, Int, Ulnar	RTA	Type V
36	P S	Male	58	07-02-2024	Radial, Intermediate	Trivial Trauma	Type III
37	S R	Male	40	06-02-2024	Radial	RTA	NC
38	M K	Female	52	16-01-2023	Radial	RTA	NC
39	R B	Male	65	26-01-2023	Radial, Intermediate	RTA	Type III
40	B K	Male	25	05-05-2023	Radial, Int, Ulnar	RTA	Type V
41	V C	Male	65	24-05-2023	Radial, Intermediate	Trivial Trauma	Type III
42	B M	Male	41	29-09-2024	Radial	RTA	NC
43	M K	Male	47	25-09-2024	Radial	RTA	NC
44	R D	Female	68	11-09-2024	Radial, Intermediate	FOOSH	Type III
45	M H	Male	36	09-09-2024	Radial	RTA	NC
46	R C	Male	48	03-09-2024	Radial	RTA	NC
47	V K	Male	73	29-08-2024	Radial, Int, Ulnar	RTA	Type V
48	A Y	Female	34	29-08-2024	Radial	RTA	NC
49	B R	Male	64	04-09-2024	Radial, Intermediate	RTA	Type III