ORIGINAL ARTICLE

Radiological Assessment of Carpal Bones Instability in Conservatively Managed Distal Radius Fractures

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Abstract

Background: Fractures of the distal radius are the most common type of fracture, which affects ~15–18% of all skeletal fractures and are frequently associated with soft-tissue injuries that can alter carpal alignment. Progressive carpal malalignment may influence fracture stability and overall radiological outcome. The objective of the study was to determine carpal bone instability following non-operative management with the help of radiological parameters and to assess the final outcome of distal radius fractures that were managed conservatively for a minimum of 6 weeks. **Objectives:** The purpose of this study was to determine the incidence and pattern of carpal instability in distal radius fractures, which were managed with non-operative methods, and to evaluate the relationship between initial fracture characteristics and subsequent radiological alignment. **Materials and Methods:** A prospective study involving 104 patients with fractures of the distal radius treated by non-operative methods (closed reduction and casting) was conducted. Cases were selected based on the inclusion and exclusion criteria. X-rays were obtained pre-reduction, immediately post-reduction, and at the 6-week follow-up. Radial height, dorsal tilt, effective radiolunate flexion (ERLF), scapholunate angle (SLA), and radiolunate angle (RLA) were recorded. Based on ERLF, malalignment was categorized as midcarpal (ERLF <25°) or radiocarpal (ERLF >25°). **Results:** Midcarpal malalignment was observed in 84.6% (88/104), whereas 15.4% (16/104) demonstrated radiocarpal malalignment. Although immediate post-reduction films showed significant improvement ($P < 0.05$), loss of reduction was more prominent in the radiocarpal group. ERLF remained significantly elevated in the radiocarpal pattern at all-time points. SLA and RLA changes over time were also more unstable in this group. **Conclusion:** Two reproducible patterns of carpal bone malalignment accompany fractures of the distal radius. Malalignment of the radiocarpal joint is more resistant to correction and more frequently associated with instability during immobilization. ERLF was a sensitive parameter for classifying malalignment and predicting radiological outcomes.

Key words: Carpal instability, distal radius, effective radiolunate flexion, radiographic analysis, wrist injuries

INTRODUCTION

Fractures of the distal radius are among the most common types of skeletal injuries seen in orthopedics and often involve concomitant soft-tissue abnormalities, including injuries to the triangular fibrocartilage complex and intrinsic carpal ligaments. Most commonly involved groups are post-menopausal females and elderly males. These associated injuries may alter normal carpal mechanics and contribute to progressive malalignment during healing. Ligamentous injuries are the cause of single or multiple bony or ligamentous constraints in the wrist. In non-operative management of distal radius fractures, the

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correlation between malalignment of the carpal bone and loss of reduction by the course of time has been reported on various occasions.[1-3] Although the deforming forces and fracture characteristics of distal radius injuries are well documented, the behavior of the carpal bones, particularly the proximal row of carpal bones, remains a subject of ongoing interest.

Carpal malalignment after dorsally angulated distal radius fractures has been historically recognized as a contributor to functional disability. Traditional descriptions consider this malalignment an adaptive phenomenon that realigns the hand in response to altered radial anatomy. However, recent literature suggests that these adaptive patterns may appear not only after malunion develops but also during the immobilization period itself.[3] Quantitative assessment of alignment of the carpal bones using the effective radiolunate flexion (ERLF) angle has enabled the identification of two distinct patterns: midcarpal malalignment, characterized by ERLF <25°, and radiocarpal malalignment, defined by ERLF >25°. These patterns differ biomechanically and may influence stability and prognosis.[4,5]

Midcarpal malalignment reflects movement of the proximal carpal row that parallels distal radial angulation, whereas radiocarpal malalignment indicates global dorsal translation of the carpus independent of the lunate, suggesting more extensive involvement of the radio-carpal stabilizers. Given conflicting observations in the literature regarding the evolution and clinical significance of these patterns, evaluating carpal behavior through serial radiographs is essential.[6-8]

The present study aims to assess the frequency, characteristics, and progression of malalignment of carpal bones in conservatively managed fractures of the distal radius and to examine radiological parameters associated with instability. The radiological films were measured accurately, such as fracture displacement and associated carpal instability, with special attention to the proximal row. This study was established to measure and correlate various parameters in distal radius fractures in pre-reduction, post-reduction, and follow-up for a minimum of 6 weeks.

MATERIALS AND METHODS

Study design and population

This prospective observational study was conducted over 18 months from June 2024 to November 2025 and included 104 consecutive patients presenting with closed distal radius fractures in the orthopedic outpatient department and the Emergency Ward of Saveetha Medical College Hospital, Chennai, Tamil Nadu. All participants were adults (≥18 years) with radiographically confirmed fractures managed by non-operative methods. Fractures were classified according to the AO classification. All patients underwent non-operative management, i.e., closed reduction with a below-elbow plaster of Paris (POP) slab application for 1 week, which was then converted to a POP cast. The position was the conventional position of the wrist in neutral rotation, slight palmar tilt, and ulnar deviation. The mean patient age was 50.4 ± 16.1 years, with equal gender distribution (52 males and 52 females). Fractures were classified using the AO/OTA system and recorded accordingly.

Inclusion criteria

- Age ≥18 years
- Closed distal radius fractures
- Management with closed reduction and casting
- Complete radiographic records at all stages.

Exclusion criteria

- Open fractures
- Ipsilateral upper-limb fractures
- Pre-existing wrist deformities or arthritis
- Patients requiring re-manipulation or surgical fixation
- Missing/inadequate radiographs.

Treatment

Closed reduction was performed under appropriate analgesia. A cast extending from below the elbow to the metacarpophalangeal joints was applied with the wrist in a neutral position, mild ulnar deviation, and slight flexion. Follow-up evaluations were conducted regularly.

Radiographic assessment

Standard posteroanterior and lateral wrist radiographs were obtained:

1. Pre-reduction
2. Immediate post-reduction
3. 6 weeks' follow-up.

Measurements included

Radial height (mm), dorsal/volar tilt (°), scapholunate angle (SLA), radiolunate angle (RLA), and ERLF (°).

ERLF was calculated with the formula:

$$\text{ERLF} = \text{Dorsal tilt} + 11° - \text{RLA}$$

Carpal malalignment was categorized as:

Midcarpal malalignment: ERLF angle <25° (ERLF <25)°

Radiocarpal malalignment: ERLF angle more than 25° (ERLF >25°).

Statistical analysis

Data were analyzed using standard statistical software. Means were compared using unpaired and paired t-tests. $P < 0.05$ was considered statistically significant.

RESULTS

The data collected from the ERLF angle were suggestive of two different carpal malalignment patterns; the first was an ERLF angle <25°, whereas the second pattern was an ERLF angle >25°. We appreciated the dorsal radiocarpal subluxation because the lunate was observed to be dorsally tilted relative to the distal radial articular surface. No noticeable changes were noted in the scaphocapitate and radioscaphoid angle during the course of the study. In all parameters, there was considerable improvement ($P < 0.05$), which indicates that the treatment fell within acceptable limits.

Patient distribution: Of the 104 patients, 59% had AO Type A fractures, 30% had Type C, and 11% had Type B patterns. Midcarpal malalignment was found in 88 patients (84.6%), and radiocarpal malalignment in 16 patients (15.4%) [Table 1].

Comparison of radiographic parameters

While observing the radial height parameters, the mean difference was not significant. Dorsal tilt values also differed according to the type of carpal alignment, with greater radiocarpal instability than midcarpal instability observed during the post-reduction period. On post-reduction, dorsal tilt and radial height mean values were corrected in a larger number, but at 6 weeks follow-up, values were not corrected to some extent, in evaluating the radiocarpal instability group [Table 2].

Based on the midcarpal and radiocarpal basis of malalignment (ERLF), all radiological parameters were independently evaluated; no significant mean differences were observed in scapholunate angle according to the type of carpal malalignment except during the 6-week period [Tables 3 and 4]. Effective radiocarpal instability was significantly higher in all radiocarpal instability groups when compared to the midcarpal instability group.

Table 1: Distribution of fracture types and instability patterns (*n*=104)

Fracture type	Midcarpal instability (*n*=88) (%)	Radiocarpal instability (*n*=16) (%)	Total
A2	52 (59.1)	7 (43.7)	59
A3	9 (10.2)	2 (12.5)	11
C1	15 (15.9)	2 (12.5)	1
C2	10 (11.4)	2 (12.5)	12
C3	3 (3.4)	3 (18.7)	6
Total	88	16	104

Case no-1

Pre-reduction anteroposterior and lateral radiographs of the wrist showed increased SLA with abnormal radial height and radial inclination, suggestive of a distal radius fracture with altered radiological parameters. Post-reduction radiographs demonstrated slight improvement in radial height and radial inclination. At 6 weeks' follow-up, anteroposterior and lateral radiographs showed further improvement in radial height and radial inclination [Figure 1a-c].

Case no-2

Pre-reduction anteroposterior and lateral radiographs of the wrist showed decreased radial height. On the lateral view, the lunate was not collinear with the radius, indicating radiocarpal instability, with an ERLF angle >25° [Figure 2a and b].

Post-reduction radiographs showed slight improvement in radiological parameters. At 6 weeks' follow-up, anteroposterior and lateral radiographs demonstrated persistent displacement of distal radius fracture fragments, with the lunate remaining non-collinear on the lateral view, suggestive of radiocarpal instability and an ERLF angle >25° [Figure 2c].

DISCUSSION

The demographic characteristics of the study population correspond with known epidemiological trends, with a mean age of around 50 years and equal representation of men and women. In this study, both intra- and extra-articular fractures were included in the study, which included both young and old age patients. In older adults, distal radius fractures are commonly associated with osteoporosis and are predominantly extra-articular. Whereas in young individuals, it is caused mainly by high-energy trauma.[9] The male-to-female ratio was 1:1. The inclusion of both extra-articular and intra-articular fracture types reflects the broad clinical spectrum encountered in everyday practice. Although this study included all aged individuals with both intra- and extra-articular fractures, no relationship has been established between the final result and the sex of the patients.[10]

Radiocarpal and midcarpal instability was observed in more than 85% of patients in pre-reduction X-rays, after reduction, where parameters were found to be slightly improved in post-reduction radiographs, but on the 6th week follow-up X-rays, redisplacement and instability patterns were found to reappear.

Table 2: Radial height and dorsal tilt

Parameters	Radial height			Dorsal tilt		
	Pre-reduction	Post-reduction	At 6 weeks	Pre-reduction	Post-reduction	At 6 weeks
Midcarpal instability						
Mean	4.7	9.4	6.2	23.1	4.9	14.7
SD	2.1	2.8	2.4	15.0	9.0	11.0
Radiocarpal instability						
Mean	4.0	7.7	5.2	25.4	10.3	19.0
SD	2.2	2.0	2.0	7.1	9.3	9.2
P-value	0.18ns	0.05ns	0.09ns	0.586ns	0.026ns	0.107ns

SD: Standard deviation

Table 3: Scapholunate angle and effective radiolunate flexion

Parameters	Scapholunate angle			Effective radiolunate flexion angle		
	Pre-reduction	Post-reduction	At 6 weeks	Pre-reduction	Post-reduction	At 6 weeks
Midcarpal instability						
Mean	61.2	50.1	61.6	11.7	12.8	14.6
SD	16.7	16.4	16.9	3.8	3.0	4.0
Radiocarpal instability						
Mean	53.1	49.2	51.0	32.8	18.7	27.1
SD	8.0	8.0	8.8	4.3	4.5	4.4
P-value	0.69	0.992	0.014	<0.001	<0.001	<0.001

SD: Standard deviation

Table 4: Radiolunate angle

Instability type	Radiolunate angle		
	Pre-reduction	Post-reduction	At 6 weeks
Midcarpal instability			
Mean	22.3	3.2	11.4
SD	13.5	7.5	8.3
Radiocarpal instability			
Mean	2.6	2.5	3.1
SD	4.4	5.4	5.5
P-value	<0.001	0.75	<0.001

SD: Standard deviation

In this study, the proportion of patients with abnormal dorsal tilt decreased from 57% before reduction to 3% after reduction, while abnormal scapholunate and radiolunate angles decreased from 49% to 24% and from 66% to 7%, respectively. At the 6-week follow-up, the corresponding proportions were 22%, 30%, and 19%, respectively. The pre-reduction and post-reduction angles and 6-week follow-up were similar to those of the studies performed before.

Carpal bone angles describe the positional relationship of the carpal bones to the longitudinal axis of the radius. However, in an intact radius, this axis has a fixed orientation relative to its articular surface, limiting the usefulness of these measurements when assessing deformity after distal radius fractures.[11-14] For this reason, ERLF is considered a superior parameter in fractured distal radius cases because it incorporates the effects of dorsal tilt and the RLA. Based on ERLF values, carpal malalignment is divided into midcarpal and radiocarpal patterns. Fractures demonstrating ERLF <25° are categorized within the midcarpal malalignment group.[15-17] In this pattern, the radiocarpal capsule and the intrinsic carpal ligaments remain intact. Malalignment is due to a compensatory adjustment at the midcarpal level, with the lunate moving together with the distal radial fragment as a functional radiolunate unit.

When ERLF exceeds 25°, the deformity is classified as a radiocarpal malalignment pattern. This represents a deviation beyond the normal physiological range, with a global dorsal displacement at the radiocarpal joint producing dorsal translation of the lunate contact zone. In these cases, the fractured fragment distal rotates dorsally independent of the lunate. Previous reports have suggested that this pattern may be associated with additional ligamentous injury and scapholunate instability.[18-20] Consistent with earlier reports, fractures that lose reduction, both during and after immobilization, tend to progress toward a radiocarpal malalignment configuration.[21-22] Batra et al., who evaluated both conservatively treated and surgically managed distal radius fractures, found that radiocarpal malalignment correlated with poorer functional outcomes.[23]

Figure 1: (a) Pre-reduction anteroposterior and lateral radiographs of the wrist showing increased scapholunate angle with abnormal radial height and radial inclination. (b) Immediate post-reduction anteroposterior and lateral radiographs of the wrist showing slight improvement in radial height and radial inclination. (c) 6-week follow-up anteroposterior and lateral radiographs of the wrist showing improvement in radial height and radial inclination

Figure 2: (a) Pre-reduction anteroposterior and lateral radiographs of the wrist showing decreased radial height and non-collinearity of the lunate on lateral view, suggestive of radiocarpal instability with effective radiolunate flexion (ERLF) angle >25°. (b) Immediate post-reduction anteroposterior and lateral radiographs of the wrist showed slight improvement in radiological parameters. (c) 6-week follow-up anteroposterior and lateral radiographs showing distal radius fracture fragments with persistent non-collinearity of the lunate on lateral view, suggestive of radiocarpal instability with ERLF angle >25°

The elevation of the SLA commonly observed on pre-reduction radiographs of displaced distal radius fractures is thought to reflect the functionally flexed posture of the wrist caused by the dorsal tilt of the distal radial fragment. Therefore, an increased SLA should not be interpreted as a definite scapholunate ligament injury unless it is accompanied by a pathological scapholunate gap >3 mm.[21-23] During wrist flexion, the scaphoid flexes to a greater extent than the lunate – on average by about 17° – resulting in a column-like motion of the proximal carpal row, with the radiolunate joint showing the least movement.[24,25] In most cases, both the elevated SLA and the apparent midcarpal instability characterized by lunate extension can be corrected once the fracture is reduced.[26-28] In our series, 56 patients (52.3%) in the midcarpal instability group demonstrated a pre-reduction SLA >60°. Changes in SLA and RLA across time points further demonstrated the dynamic nature of carpal behavior under altered load distribution. Although increased SLA was observed in many patients, especially in the midcarpal group, it likely reflected positional effects and not necessarily scapholunate ligament disruption.[29,30]

The recurrence of the same instability pattern despite initial correction suggests that intrinsic soft-tissue constraints strongly influence carpal mechanics, even during immobilization. These observations emphasize the importance of early recognition of radiocarpal malalignment, as these patients may benefit from alternative treatment strategies, including surgical fixation.

CONCLUSION

Distal radius fractures managed conservatively demonstrate two main carpal malalignment patterns: midcarpal and radiocarpal. Radiocarpal malalignment is harder to reduce, more prone to redisplacement during immobilization, and may warrant consideration of alternative treatment methods. Carpal angle measurements are most meaningful on post-reduction films, as abnormalities, particularly increased SLAs, often reflect altered fracture mechanics rather than true ligament injury. ERLF is a useful adjunct for identifying malalignment patterns and predicting radiological outcomes. Recognizing these early radiographic features helps clinicians anticipate prognosis and better counsel patients regarding conservative versus other treatment options.

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