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The Influence of Ulnar Styloid Process Fixation on Range of Motion and Grip Strength in Distal Radius Fractures

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ABSTRACT

Distal radius fractures are often accompanied by ulnar styloid fractures, with a varying incidence reported between 21% and 65%. The impact of these concurrent fractures on functional outcomes such as range of motion, grip strength and patient-reported outcomes is contentious, with studies presenting mixed results. The work evaluated the impact of ulnar styloid fixation on functional recovery in patients with distal radius fractures, specifically assessing range of motion, grip strength and radiological outcomes. This prospective, comparative study involved 60 patients with concomitant intra-articular distal end radius and ulnar styloid fractures. Patients were randomly allocated into two groups: Group 1 underwent distal radius fixation only, while Group 2 received both distal radius and ulnar styloid fixation. Outcomes measured included range of motion in various planes, grip strength compared to the non-operative hand and radiological union, assessed at multiple time points up to 9 months postoperatively. The study found that Group 2 consistently exhibited superior functional outcomes across most assessed parameters, including flexion-extension range of motion and grip strength, particularly notable from 6 months onwards. Radioulnar arc and wrist deviations also favoured Group 2, suggesting a more stable and functional recovery trajectory. Ulnar styloid fixation in the presence of distal radius fractures enhances functional recovery, supporting its consideration in surgical planning. This approach appears particularly beneficial for improving range of motion and grip strength, potentially due to increased stability and alignment of the distal radioulnar joint.

OPEN ACCESS

Key Words

Distal radius fracture, ulnar styloid fracture, ulnar styloid fixation, functional outcomes, range of motion, grip strength, triangular fibrocartilage complex, distal radioulnar joint instability

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INTRODUCTION

Distal radius fractures frequently occur alongside ulnar styloid process fractures, with studies citing an incidence between 21-65%[1,2]. The impact of these concurrent fractures on functional outcomes, such as range of motion, grip strength and patient-reported outcomes, remains a subject of debate[1-5]. While some research suggests that ulnar styloid fractures do not significantly affect these outcomes, others report a negative influence, particularly noting issues like ulnar-sided wrist pain and distal radio-ulnar joint (DRUJ) instability[6,7]. This discrepancy is further complicated by the involvement of the triangular fibrocartilage complex (TFCC), which is attached to the ulnar styloid and often disrupted in such fractures[8,9]. Research indicates varying clinical implications based on the fracture location on the ulnar styloid., fractures at the base, where the TFCC is attached, have been linked to higher incidences of TFCC tears and subsequent DRUJ instability[1]. Nonunion at the base can lead to chronic DRUJ instability, adversely affecting wrist function and mobility. Although some studies have found no significant differences in outcomes for distal radius fractures with or without ulnar styloid fractures, the level of the styloid fracture is often overlooked-a critical factor since approximately 41% of ulnar styloid fractures occur at the base[9].

Given the mixed evidence and potential for significant impact on patient recovery and joint stability, The study aims to assess and compare the range of motion (ROM) across various wrist movements, grip strength recovery and radiological outcomes between two groups with distal radius fractures, treated with and without ulnar styloid fixation. Objectives include evaluating ROM in flexion, extension, radial and ulnar deviations and radio-ulnar arcs at multiple time points, alongside assessing grip strength relative to the non-operative hand. Additionally, the study will analyze the radiological union of the distal radius and ulnar styloid, using statistical analysis to determine the significance of any differences observed, guiding evidence-based clinical decisions regarding fracture management strategies.

MATERIALS AND METHODS

Study Design: This prospective, comparative study was conducted over 18 months at the Central Institute of Orthopaedics, Vardhman Mahavir Medical College, Safdarjung Hospital, New Delhi.

Study Population: Sixty patients diagnosed with intra-articular distal end radius and ulnar styloid fractures were included. They were randomly allocated into two groups of 30 each. Group 1 underwent distal radius fixation without ulnar styloid fixation, while Group 2 received fixation for both fractures.

Inclusion Criteria: Participants were skeletally mature individuals with intra-articular fractures of the distal radius and ulnar styloid, intervened within one week of trauma.

Exclusion Criteria: Excluded were patients with prior wrist injuries, pathological fractures, radio-carpal arthritis, polytrauma involving the ipsilateral extremity, metabolic disorders, pregnancy, or corticosteroid therapy.

Patient Preparation: Primary and secondary surveys were conducted according to ATLS protocol, ensuring immediate assessment of airway, breathing and circulation and ruling out other major injuries. IV fluids were initiated for resuscitation and limb immobilization was ensured with a plaster slab or Kramer wire. Analgesics, antibiotics and tetanus toxoids were administered as necessary.

Detailed history-taking included age, sex, occupation, mode of injury, past medical history and allergies. Thorough clinical examination and X-rays, including wrist and elbow joint views, were performed for fracture classification. Preoperative assessments included checking the skin incision site, routine investigations and patient consent.

Surgical Procedure: Patients were randomized for surgery under regional (supraclavicular/axillary/ interscalene blocks) or general anesthesia. The surgical team comprised an orthopedic surgeon, residents and a nurse.

For Distal Radius Fixation: An 8-cm incision was made over the forearm between the radial artery and the flexor carpi radialis. Fracture reduction and fixation were achieved using pre-contoured variable angle volar locking plates or pre-contoured volar T plates. In a V-shape, the incision was extended distally at the wrist crease to provide wider exposure and prevent scar contracture. After exposing the fracture site, the pronator quadratus was elevated and fracture reduction was performed under fluoroscopic guidance. Volar plates were positioned and fixed with screws, followed by reattachment of the pronator quadratus.

Ulnar Styloid Fixation Involved: A straight, longitudinal incision was made over the distal ulna between the tendons of the extensor and flexor carpi ulnaris. Careful exposure of the fracture site was performed, with attention to avoiding injury to the dorsal branch of the ulnar nerve. K-wires were used for fixation and the extensor retinaculum was repaired as necessary.

Post-Operative Clinical Assessment in 3Months/ 6Months/9Months: The following measurements of the range of motion of the wrist are measured using a goniometer (measured in degrees): Flexion, Extension, Flexion-extension, Radial deviation, Ulnar deviation, Radioulnar arc, Pronation arc, Supination arc

Wrist Range of Motion to Be Measured: The grip strength of both hands was measured using a standard adjustable hand grip dynamometer in a standing position with an elbow in full extension and shoulder neutrally rotated and adducted. The value will be recorded in pounds and expressed in percentage value to that of the normal hand.

Statistical Analysis: Data analysis was performed using SPSS version 24.0. Continuous variables were displayed as Mean±Standard Deviation (SD), while categorical variables were expressed in absolute numbers and percentages. The analysis of continuous variables that followed a normal distribution was carried out using the Student's t-test. Comparisons of nominal categorical data across different groups were made using the Chi-square test or Fisher's exact test, depending on suitability. A $p<0.05$ was considered as statistically significant.

RESULTS AND DISCUSSIONS

Table 1: Combined Range of Motion and ARC Measurements

Time Duration	Measurement	Group 1 Mean±SD	Group 2 Mean±SD	P-value
6 weeks	Flexion ROM	42.57 ± 1.33	47.13 ± 1.66	<0.001
	Extension ROM	35.03 ± 2.25	37.20 ± 1.52	<0.001
	F-E ARC	77.60 ± 2.22	84.33 ± 2.26	<0.001
	R-U ARC	20.67 ± 2.37	21.90 ± 2.23	0.042
3 months	Flexion ROM	53.03 ± 1.56	59.77 ± 2.94	<0.001
	Extension ROM	42.80 ± 1.54	49.57 ± 2.76	<0.001
	F-E ARC	95.83 ± 2.38	109.33 ± 4.19	<0.001
	R-U ARC	35.70 ± 3.03	36.80 ± 2.43	0.126
6 months	Flexion ROM	72.80 ± 1.63	76.10 ± 1.06	<0.001
	Extension ROM	49.73 ± 2.32	59.87 ± 2.89	<0.001
	F-E ARC	122.53 ± 2.95	135.97 ± 3.17	<0.001
	R-U ARC	43.63 ± 1.71	51.20 ± 1.85	<0.001
9 months	Flexion ROM	77.43 ± 1.55	78.13 ± 1.04	0.044
	Extension ROM	57.70 ± 1.69	67.37 ± 1.73	<0.001
	F-E ARC	135.13 ± 2.37	145.50 ± 2.03	<0.001
	R-U ARC	53.43 ± 2.16	58.53 ± 1.38	<0.001

In Table 1, the combined range of motion and arc measurements are reported across multiple time points. For flexion range of motion (ROM), Group 1 began with an average of 42.57 degrees at 6 weeks, progressing to 53.03 degrees at 3 months, 72.80 degrees at 6 months and reaching 77.43 degrees at 9 months. Group 2 showed a similar upward trend starting from 47.13 degrees, increasing to 59.77 degrees, then 76.10 degrees and finally 78.13 degrees at the respective time points. Extension ROM in Group 1 started at 35.03 degrees, increased to 42.80 degrees, then 49.73 degrees and peaked at 57.70 degrees. Group 2 began with 37.20 degrees, rose to 49.57 degrees, then to 59.87 degrees and culminated at 67.37 degrees. The Flexion-Extension arc (F-E ARC) started at 77.60 degrees for Group 1 and 84.33 degrees for Group 2 at 6 weeks, with subsequent readings showing a consistent increase over time, reaching 135.13 and 145.50 degrees respectively by 9 months. The Radio-Ulnar arc (R-U ARC) displayed starting values of 20.67 degrees for Group 1 and 21.90 degrees for Group 2, with the final measurements at 9 months being 53.43 and 58.53 degrees respectively.

Table 2: Combined Deviation Measurements

Time Duration	Measurement	Group 1 Mean±SD	Group 2 Mean±SD	P-value
6 weeks	Radial Deviation	7.07 ± 1.66	7.10 ± 1.40	0.933
	Ulnar Deviation	13.60 ± 1.43	14.80 ± 1.77	0.005
3 months	Radial Deviation	13.00 ± 1.64	13.30 ± 1.34	0.441
	Ulnar Deviation	22.70 ± 2.26	23.50 ± 1.96	0.149
6 months	Radial Deviation	17.47 ± 1.64	19.83 ± 1.37	<0.001
	Ulnar Deviation	26.17 ± 1.09	31.37 ± 1.03	<0.001
9 months	Radial Deviation	20.27 ± 1.26	24.00 ± 0.95	<0.001
	Ulnar Deviation	33.17 ± 1.80	34.53 ± 1.17	0.001

In Table 2, the deviations of radial and ulnar movements between the groups are provided. At 6 weeks, radial deviation for Group 1 was recorded at 7.07 degrees, virtually unchanged at 7.10 degrees in Group 2, with no significant movement by 3 months. However, by 6 months, these deviations widened with Group 1 at 17.47 degrees and Group 2 at 19.83 degrees, extending further by 9 months to 20.27 and 24.00 degrees respectively. Ulnar deviation began at 13.60 degrees in Group 1 and 14.80 degrees in Group 2, with modest increases to 22.70 and 23.50 degrees at 3 months, before a more noticeable difference at 6 months with 26.17 degrees in Group 1 and 31.37 degrees in Group 2. By 9 months, the deviations further escalated to 33.17 degrees in Group 1 and 34.53 degrees in Group 2.

Table 3: Pronation and Supination Measurements

Time Duration	Measurement	Group 1 Mean±SD	Group 2 Mean±SD	P-value
6 weeks	Supination	27.30 ± 1.49	27.83 ± 1.51	0.174
	Pronation	25.67 ± 1.85	25.60 ± 2.99	0.918
3 months	Supination	37.47 ± 2.90	38.03 ± 3.67	0.510
	Pronation	35.40 ± 2.46	34.93 ± 2.53	0.472
6 months	Supination	62.67 ± 3.74	59.63 ± 2.54	<0.001
	Pronation	42.20 ± 1.63	49.90 ± 2.63	<0.001
9 months	Supination	62.83 ± 1.53	67.57 ± 1.87	<0.001
	Pronation	57.33 ± 1.49	57.57 ± 1.63	0.566

In Table 3, which focuses on pronation and supination measurements, the results indicate slight variations across the time points. For supination, at 6 weeks, Group 1 had a mean of 27.30 degrees compared to Group 2's mean of 27.83 degrees. These values slightly increased by 3 months to 37.47 degrees for Group 1 and 38.03 degrees for Group 2. A significant change was observed by 6 months, where Group 1 reported 62.67 degrees of supination and Group 2 reported a slightly lower value of 59.63 degrees. By 9 months, the trend reversed with Group 2 achieving a higher supination of 67.57 degrees compared to Group 1's 62.83 degrees. Pronation measurements showed less

variation initially, with Group 1 measuring 25.67 degrees and Group 2 slightly lower at 25.60 degrees at the 6-week mark. At 3 months, the measurements remained close, with Group 1 at 35.40 degrees and Group 2 at 34.93 degrees. However, by 6 months, a noticeable difference emerged with Group 1 at 42.20 degrees and Group 2 significantly higher at 49.90 degrees. At 9 months, both groups converged closely again, with Group 1 measuring 57.33 degrees and Group 2 slightly higher at 57.57 degrees.

Table 4: Grip Strength Measurements

Time Duration	Group 1 Mean±SD	Group 2 Mean±SD	P-value
6 weeks	9.13 ± 1.83	10.10 ± 1.75	0.041
3 months	21.50 ± 4.32	23.30 ± 3.69	0.088
6 months	31.30 ± 4.23	40.30 ± 4.41	<0.001
9 months	52.03 ± 7.19	56.87 ± 5.54	0.005

Table 4 presents the grip strength measurements, starting at 6 weeks where Group 1 had an average grip strength of 9.13 pounds and Group 2 slightly higher at 10.10 pounds. By 3 months, both groups showed improvement, with Group 1 reaching 21.50 pounds and Group 2 slightly ahead at 23.30 pounds. A substantial separation in values became evident by 6 months., Group 1's grip strength was 31.30 pounds compared to Group 2's 40.30 pounds. This trend continued into the 9-month mark, with Group 1 achieving 52.03 pounds of grip strength and Group 2 further ahead at 56.87 pounds. This table tracks the progressive increase in grip strength over time for both groups, with Group 2 consistently maintaining a higher strength level across all time points.

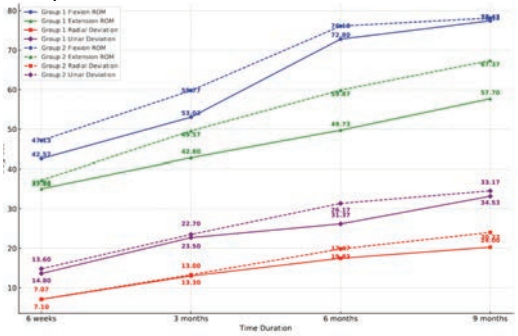

Fig. 1: Comparison of Movements and Deviation Across Time

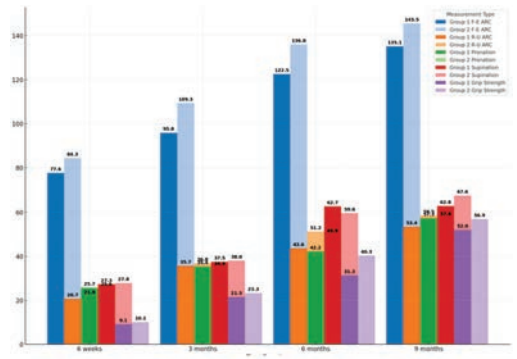

Fig 2: Overview of Recovery Measurements Over Time

Over the course of 18 months, this study compared the functional rehabilitation of patients who had distal radius fractures with and without concurrent ulnar styloid fixation. The data provide valuable insights into the impact of ulnar styloid fixation on the pace of recovery. These insights are delineated in the following section, taking into account grasp strength, range of motion and wrist deviations.

In respect to range of motion (Table 1), Group 2 had consistent superiority over Group 1 in measurements of flexion, extension and arc. The deviation measurements (Table 2) revealed that both radial and ulnar deviations increased gradually with time, with Group 2 exhibiting greater deviations on average, especially at later time intervals. Pronation and supination exhibited comparable trends (Table 3), with marginal variations at first but more conspicuous enhancements after nine months, with Group 2's pronation particularly benefiting. Both groups experienced an improvement with strength of grip over time (Table 4), but Group 2 maintained consistently higher strength levels at each time interval, indicating a more substantial restoration in grip functionality. As a whole, this study indicate that Group 2, which underwent fixation of both the distal radius and ulnar styloid, obtained more favourable results in all aspects.

Grip Strength Recovery: Significant enhancements in grip strength were observed among whose fixation of both the distal radius and ulnar styloid (Group 2), comparing to those where fixation of only the distal radius (Group 1). Significantly, during the 6-month and 9-month assessments, Group 2 shown an exceptionally enhanced grasp strength. This finding is consistent with prior investigations that propose how ulnar styloid fixation, which promotes stability at the ulnar aspect of the wrist, could potentially improve hand function and strength restoration following a fracture.

Zenke *et al.* evaluated the recovery of grasp strength as a percentage of the contrarily injured side in an independent investigation. 90% of the participants in the group without fractures shown grip strength at the final follow-up, compared to 92.5% in the group with fractures at the ulnar styloid base and 94.7% in the group with fractures at the point. At each time point evaluated, there was no significant differences with grip strength between these groups (Mann-Whitney U test, $p>0.05$)[2,10].

In line with our research, identified a clinical disparity in DASH scores (3.40 points, 95% confidence interval 1.33-5.48) among patients lacking ulnar styloid fractures, as reported in a meta-analysis. An analysis of wrist evaluation scores, range of motion, grasping

strength, pain scores and joint stability after treatment did not reveal any statistically significant differences[11]. Additionally, Jianmin Wang (2023) discovered that the type of Styloid fracture of the ulna has a substantial influence on joint mobility and treatment efficacy. Patients undergoing treatment for simpler type I fractures demonstrated superior postoperative mobility and higher efficacy rates (96.15% vs. 69.57%, p<0.05) in comparison to those with complex type II fractures, which are linked to increased dislocation rates. The ulnar styloid fracture significantly impacts the stability and quality of recovery in Fracture of the distal radius treatments, thereby influencing functional outcomes[12].

Range of Motion: The advantages for ulnar styloid fixation are further corroborated by the results of range of motion (ROM). At each time point, Group 2 shown superior flexion and extension ranges of motion. The notable distinctions that were identified as early as six weeks remained consistent during the nine-month follow-up period. The improved structural integrity and decreased DRUJ instability resulting from ulnar styloid fixation may account for this, particularly in light of the high incidence of TFCC injuries associated with these fractures. Furthermore, these results are supported by the flexion-extension arc and radioulnar arc analyses, Group 2 demonstrated superior functional outcomes, indicating that potential complications, such as DRUJ instability, were effectively managed.

According to the findings of Zenke *et al.,* while at 12 weeks there was no statistically significant distinction in grip strength between the non-fixation and fixation groups, by the final follow-up, the fixation group had achieved 94.0% grip strength on the contralateral side. This suggests that any long-term disparities were limited[13].

The statistical association between functional outcomes with distal radius fractures and ulnar styloid fractures is supported by numerical findings from recent studies. The research conducted by Habby T. Jacob revealed noteworthy reductions in pronation, supination and ulnar deviation among individuals who had sustained ulnar styloid fractures. Specifically, supination exhibited a substantial limitation (p=0.004) and ulnar deviation decreased by an average of 4° (p=0.05)[14].

Comparing patients with unresolved ulnar styloid fractures at the base to those without any ulnar styloid fractures, Souer *et al.* examined functional outcomes with distal radius fractures. An undetected fracture at the base of the ulnar styloid did not significantly affect the overall prognosis, according to the findings of their research. However, a discernible pattern of reduced grip strength was observed with a sustained untreated ulnar styloid fractures 6 months after the injury. Specifically, the contralateral side exhibited 71% of the strength compared to 79% in individuals without ulnar fractures. This corresponded to an average deviation of 28% (95% confidence interval: -215.3-20.6 percent., p=0.03). In addition, at the twenty-four-month follow-up, these patients demonstrated decreased flexion (54° versus 59°, mean difference 25°, 95% confidence interval: -11.7° to-0.8°., p=0.02) and ulnar deviation (32° versus 36°, mean difference 4°, 95% confidence interval: -7° to-0.1°., p=0.05)[15].

Orthopaedic practitioners must consider the biomechanical significance of the ulnar styloid with wrist function and stabilisation when devising treatment and rehabilitation strategies to promote recovery and prevent permanent disabilities.

Wrist Deviations: Observations of variations in ulnar and radial deviations began to favour Group 2 at the 6-month follow-up. Initially, there were little to no differences, which were probably obscured by immobilisation. The advantages of ulnar styloid fixation gradually became apparent, as it improved the balance and functionality of wrist movements. May *et al.* (2002) found that ulnar styloid fractures substantially increase the risk of distal radioulnar joint instability, highlighting the criticality of ulnar styloid fixation[16]. At 24 months, trends such as decreased flexion and ulnar deviation and diminished grasp strength (71% vs. 79%) provide advantages of fixation[17]. In contrast, a ulnar styloid nonunion has no appreciable impact on wrist deviations or rehabilitation following a fracture. Zhang *et al.* (2016) found that grasp strength, wrist motion and DASH scores between groups that ulnar styloid fracture union or not[18]. In ulnar styloid fractures cases did not have an impact on overall outcomes, however, a noteworthy variation in palmar tilt was observed, which did not have an affect on the general function of the wrist[19]. When considering distal radius fractures, the overall efficacy of ulnar styloid fixation may differ based on patient-specific factors and the characteristics of the fracture itself, although it may in certain instances contribute to improved prognoses.

Pronation and Supination: Although there were no noticeable differences in the first stages, Group 2 had enhanced pronation at 6 months and improved supination at 9 months. The increasing impact of ulnar styloid fixation over time is indicated by this pattern, potentially attributed to improved tendon alignment and decreased interference from scar tissue. Daumillare *et al.* (2019) uncovered a fall for

pronation-supination strength among individuals with ulnar styloid fractures, highlighting the significance of treating these fractures[20]. In addition, fractures of the ulnar styloid base promoted supination by 9.05° and pronation by 9.40°, respectively, with only a partial recovery following fixation, according to Pidgeon[21]. Buijze *et al* and Li *et al.* in their works showed that ulnar styloid fractures had no significant impact on pronation or supination, suggesting that the effect varies depending on individual cases[22,23].

Clinical Implications: These findings emphasise the significance of taking into account ulnar styloid fixation when treating distal radius fractures, particularly at the base where the triangular fibrocartilage complex is connected. This method has the potential to result in better functional outcomes, such as increased grip strength and range of motion (ROM) and possibly a faster and more thorough recovery.

In contrast to patients who sustained isolated distal radius fractures, Parham Daneshvar *et al.* found that the reestablishment of wrist flexion and grasping strength was significantly more sluggish in individuals who concurrently sustained ulnar styloid fractures. Three months after the incident, patients with ulnar styloid fractures had significantly weaker grip strength compared to those without fractures (17±9 kg vs. 20±12 kg, p=0.02). While the difference decreased after six months, wrist flexion was still considerably lower at three months (42°±18 vs. 49°±14, p=0.03) and six months (50°±19 vs. 55°±17, p=0.04), but became equal by the twelve-month mark. Significantly, at the age of six months, there were notable distinctions in supination (60°±22 vs. 70°±12, p=0.01) and grip strength (20±9 kg vs. 24±10 kg, p=0.04). However, at twelve months, the only notable disparity noted was in radial deviation (14°±5 vs. 18°±8, p=0.02).

In addition, Hideyoshi Sawada *et al.* (2016) observed that although the rate of bone healing in ulnar styloid fractures was notably higher in the fixation group, there were no significant differences in clinical outcomes such as grip strength, range of motion and Hand20 scores. This suggests that fixation may not be required when treating distal radius fractures using open reduction and internal fixation with a volar locking plate system[24].

Douglas M. Sammer and his colleagues likewise concluded that the existence, dimension, or healing condition of ulnar styloid fractures did not have any effect on the results reported by patients following treatment for distal radius fractures. Their investigation verified that these characteristics did not have predictive value for the results assessed by the Michigan Hand results Questionnaire (MHQ), indicating that ulnar styloid fractures may not always require fixation[25].

Limitations and Future Research: While this study provides valuable insights, it also has limitations, including the absence of long-term follow-up beyond 9 months and the limited sample size. Future research should aim to include larger cohorts and extend follow-up duration to fully assess the long-term benefits and potential complications of ulnar styloid fixation. Additionally, the role of TFCC injuries in these outcomes warrants further exploration to refine surgical techniques and rehabilitation protocols.

CONCLUSION

Overall, the study has the significance of considering ulnar styloid fixation in the management of distal radius fractures. The enhanced grip strength, improved ROM and favourable deviations in wrist movements with both fractures fixed suggest a more stable and functional recovery trajectory, emphasizing the need for a comprehensive approach to fracture management.

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