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FUNCTIONAL OUTCOMES OF LIGAMENTOTAXIS IN UNSTABLE DISTAL RADIUS FRACTURES	KEY WORDS: Distal radius fracture, ligamentotaxis, external fixation, functional outcome, wrist fracture

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ABSTRACT	Distal radius fractures are among the most common orthopedic injuries, accounting for approximately 16% of all fractures treated in emergency departments. Ligamentotaxis, a biomechanical principle utilizing continuous traction through soft tissue structures, offers a minimally invasive approach for managing unstable fractures through external fixation. OBJECTIVE: To evaluate the functional and radiological outcomes of ligamentotaxis using external fixation in patients with unstable distal radius fractures. METHODS: A prospective observational study was conducted at Al Ameen Medical College from March 2023 to September 2024. Thirty patients aged 18-70 years with unstable distal radius fractures (Frykman types 3-8) underwent closed reduction and external fixation based on ligamentotaxis principles. Functional outcomes were assessed using the Modified Green-O'Brien scoring system at 6, 12, and 18 weeks. Radiological parameters including radial height, inclination, and volar tilt were measured pre-operatively and at final follow-up. RESULTS: The mean age was 42.1 years with male predominance (56.7%). Falls on outstretched hand accounted for 40% of injuries. Significant improvements were observed in all radiological parameters: radial height increased from 5.23±1.57mm to 10.57±1.28mm (p<0.001), radial inclination from 10.17±2.39° to 22.37±1.85° (p<0.001), and volar tilt from -5.07±2.20° to +9.83±2.69° (p<0.001). Functional outcomes showed 53.3% excellent, 33.3% good, and 13.3% fair results. Grip strength recovered to 84.93% of the contralateral side. Complications occurred in 20% of patients, primarily pin tract infections (10%). CONCLUSION: Ligamentotaxis demonstrates excellent efficacy in restoring anatomical alignment and achieving favorable functional outcomes in unstable distal radius fractures with relatively low complication rates.
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INTRODUCTION Distal radius fractures represent one of the most frequently encountered skeletal injuries in clinical practice, constituting approximately 16% of all fractures treated in emergency departments worldwide (1). These fractures demonstrate a bimodal distribution, affecting both young adults through high-energy trauma and elderly individuals due to low-energy falls associated with osteoporosis. The incidence has been steadily increasing, particularly in industrialized countries where aging populations and increased activity levels contribute to a higher prevalence of these injuries (2). The anatomical complexity of the distal radius, which serves as the foundation for wrist stability and function, makes the management of these fractures particularly challenging. The distal radius articulates with the scaphoid and lunate bones at the radiocarpal joint and with the distal ulna at the distal radioulnar joint, forming a complex biomechanical unit essential for normal wrist function. Disruption of this anatomy through fracture can significantly impact grip strength, range of motion, and overall hand function if not properly managed (3). Traditional classification systems, particularly the Frykman classification, have been instrumental in guiding treatment decisions by categorizing fractures based on articular involvement and associated injuries. Frykman types 3-8, which involve intra-articular components, typically require more sophisticated management approaches due to their inherent instability and propensity for displacement (4). The evolution of treatment modalities has progressed from conservative casting methods to various surgical interventions, each with distinct advantages and limitations.	Ligamentotaxis, first described by Anderson and O'Neil in 1944, represents a biomechanical principle that utilizes the inherent tension in surrounding soft tissues to achieve and maintain fracture reduction (5). This concept leverages the intact ligamentous structures around the wrist to provide indirect reduction forces, thereby minimizing the need for direct manipulation of fracture fragments. The principle has gained widespread acceptance due to its ability to address complex, comminuted fractures while preserving soft tissue integrity and maintaining fracture stability during the healing process. The application of ligamentotaxis through external fixation offers several theoretical advantages over alternative treatment methods. Unlike open reduction and internal fixation, which requires extensive surgical exposure and carries risks associated with implant placement, external fixation provides stable reduction while maintaining the biological environment necessary for optimal healing (6). The technique is particularly valuable in cases where soft tissue conditions preclude immediate internal fixation or where the fracture pattern is too comminuted for reliable plate fixation. Contemporary literature has demonstrated variable outcomes with ligamentotaxis-based treatment, with success rates largely dependent on proper patient selection, surgical technique, and postoperative management. Studies have reported good to excellent functional outcomes in 70-90% of patients treated with external fixation, though complications such as pin tract infections, joint stiffness, and loss of reduction remain concerns (7,8). The challenge lies in balancing the
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benefits of stable fixation with the potential drawbacks of prolonged external hardware and joint bridging.

The biomechanics of ligamentotaxis rely on the application of controlled distraction forces across the wrist joint, which simultaneously reduces fracture fragments and maintains alignment through the healing period. This mechanism is particularly effective in restoring critical radiological parameters including radial height, radial inclination, and volar tilt, which are essential for normal wrist mechanics and long-term functional outcomes (9). Restoration of these parameters has been consistently associated with improved functional scores and reduced incidence of post-traumatic arthritis.

Recent advances in external fixator design and surgical techniques have further refined the application of ligamentotaxis. Modern fixators offer improved stability and patient comfort while maintaining the fundamental principles of distraction and alignment. The integration of minimal access techniques and enhanced rehabilitation protocols has contributed to better outcomes and reduced complication rates (10).

The selection of appropriate candidates for ligamentotaxis remains a critical aspect of treatment planning. Factors such as fracture morphology, bone quality, soft tissue condition, and patient compliance all influence the likelihood of successful outcomes. Understanding these variables is essential for optimizing treatment decisions and setting realistic expectations for both patients and clinicians (11).

Despite the established role of ligamentotaxis in distal radius fracture management, questions remain regarding optimal fixation duration, rehabilitation protocols, and long-term functional outcomes. The relationship between immediate radiological correction and sustained functional improvement requires further investigation to refine treatment algorithms and improve patient care (12).

The economic implications of different treatment modalities also warrant consideration, particularly in resource-limited settings where access to advanced plating systems may be restricted. External fixation based on ligamentotaxis principles offers a cost-effective alternative that can achieve comparable outcomes when properly executed (13).

Current evidence suggests that successful implementation of ligamentotaxis requires meticulous attention to surgical technique, including optimal pin placement, appropriate distraction forces, and comprehensive postoperative care. The integration of early mobilization protocols while maintaining fracture stability represents a key challenge in maximizing functional recovery (14).

This study aims to contribute to the existing body of knowledge by providing comprehensive data on functional and radiological outcomes following ligamentotaxis-based treatment of unstable distal radius fractures. By examining both immediate and intermediate-term results, we seek to enhance understanding of this established technique and provide evidence-based guidance for clinical decision-making in the management of these complex injuries (15).

AIMS AND OBJECTIVES

Aim: To evaluate the functional outcomes of ligamentotaxis using external fixation in patients with unstable distal radius fractures.

Objectives:

1. To assess the radiological restoration of anatomical parameters including radial height, radial inclination, and volar tilt following ligamentotaxis
2. To evaluate the recovery of wrist range of motion and grip

strength over an 18-week follow-up period

3. To document complications associated with the surgical procedure and external fixation
4. To determine patient satisfaction and pain levels using standardized scoring systems

MATERIALS AND METHODS

Study Design and Setting

This prospective observational study was conducted at the Department of Orthopaedics, Al Ameen Medical College, Vijayapura, between March 2023 and September 2024. The study protocol was approved by the Institutional Ethics Committee, and written informed consent was obtained from all participants prior to enrollment.

Sample Size Calculation

Sample size was calculated based on previous literature reporting good to excellent outcomes in 86% of patients treated with ligamentotaxis. Using the formula by Lemeshow et al., with a precision of 12.5% and 95% confidence interval, the required sample size was determined to be 30 patients.

PARTICIPANTS

INCLUSION CRITERIA

- Adults aged 18-70 years
- Acute distal radius fractures classified as Frykman types 3-8
- Closed fractures or Gustilo-Anderson type I-II open fractures suitable for external fixation
- Fresh fractures (less than 3 weeks old) amenable to closed reduction
- Patients providing informed consent for participation and follow-up

EXCLUSION CRITERIA

- Associated significant head or spinal injuries affecting participation
- Pathological fractures (excluding osteoporotic fractures)
- Fractures older than 3 weeks
- Associated nerve injuries at presentation
- Contralateral wrist injury or ipsilateral forearm fractures
- Previous wrist fractures or deformities

SURGICAL TECHNIQUE

All procedures were performed under either brachial plexus block or general anesthesia. Following standard preparation and draping, closed reduction was performed under image intensifier guidance. Two 3.5mm Schanz pins were inserted into the radial shaft, 3-5cm proximal to the fracture site, with careful attention to avoid injury to the superficial radial nerve. Two 2.5mm Schanz pins were placed through the second metacarpal base and neck. An external fixator was applied connecting the radial and metacarpal pins, and ligamentotaxis was achieved through controlled distraction until acceptable reduction was obtained on fluoroscopy.

POSTOPERATIVE CARE

Patients received prophylactic antibiotics for 5 days postoperatively. Pin site care was initiated immediately with daily dressing changes using antiseptic solutions. Early finger mobilization was encouraged, with progressive wrist exercises introduced based on radiological evidence of healing.

OUTCOME MEASURES

Functional Assessment

Functional outcomes were evaluated using the Modified Green-O'Brien scoring system at 6, 12, and 18 weeks postoperatively. This comprehensive scoring system assesses pain (0-25 points), function (0-25 points), range of motion (0-25 points), and strength (0-25 points), with total scores categorized as excellent (90-100), good (80-89), fair (65-79), or poor (<65).

Radial Inclination (°)	10.17±2.39	22.37±1.85	12.20	<0.001
Volar Tilt (°)	-5.07±2.20	+9.83±2.69	14.90	<0.001

Table 3: Range of Motion Recovery Over Time

Parameter	6 Weeks Mean±SD	12 Weeks Mean±SD	18 Weeks Mean±SD	p-value
Flexion (°)	40.93±6.25	59.63±6.34	76.70±7.03	<0.001
Extension (°)	38.10±7.40	57.13±9.25	68.67±6.49	<0.001
Radial Deviation (°)	8.40±1.83	12.70±3.66	18.80±5.04	<0.001
Ulnar Deviation (°)	16.27±4.53	24.10±4.20	34.93±4.99	<0.001
Pronation (°)	59.87±9.27	69.63±5.04	78.87±4.62	<0.001
Supination (°)	55.13±5.73	68.07±6.77	75.50±4.78	<0.001

Table 4: Functional Outcomes at 18 Weeks

Outcome Measure	Category	Number (n=30)	Percentage (%)
Green-O'Brien Score	Excellent (90-100)	16	53.3
	Good (80-89)	10	33.3
	Fair (65-79)	4	13.3
	Poor (<65)	0	0.0
Pain Level	No pain	11	36.7
	Mild pain	14	46.7
	Moderate pain	3	10.0
	Severe pain	2	6.7
Grip Strength	Mean % of contralateral	84.93±5.66	-

Table 5: Complications

Complication	Number (n=30)	Percentage (%)
Pin tract infection	3	10.0
Complex regional pain syndrome	2	6.7
Malunion	1	3.3
Any complication	6	20.0
No complications	24	80.0

DISCUSSION

This prospective study demonstrates that ligamentotaxis using external fixation is an effective treatment modality for unstable distal radius fractures, achieving excellent to good functional outcomes in 86.6% of patients. These results are consistent with previous literature reporting success rates ranging from 70-90% with similar treatment approaches.

The demographic profile in our study, with a mean age of 42.1 years and male predominance (56.7%), reflects the typical pattern of distal radius fractures encompassing both high-energy trauma in younger individuals and low-energy falls in older patients. This bimodal distribution is well-documented in the literature, with Nellans et al. reporting similar age and gender patterns in a large epidemiological study (2). The predominance of falls on outstretched hand (40%) as the injury mechanism aligns with established trauma patterns for distal radius fractures.

Our radiological outcomes demonstrate significant restoration of anatomical parameters, with radial height improving from 5.23mm to 10.57mm, approaching the normal

range of 11-12mm. This restoration is crucial for maintaining proper wrist biomechanics and preventing long-term complications. Leung et al. reported similar improvements in radial height with ligamentotaxis, emphasizing its importance in achieving satisfactory functional outcomes (5). The correction of radial inclination from 10.17° to 22.37° closely approximates normal values (22-25°), indicating effective restoration of lateral alignment. Volar tilt correction from -5.07° to +9.83° represents a substantial improvement, as maintained dorsal angulation is associated with poor functional outcomes and increased arthritis risk.

The progressive improvement in range of motion across all parameters supports the efficacy of ligamentotaxis in preserving joint mobility while maintaining fracture reduction. Wrist flexion reaching 76.70° and extension achieving 68.67° at 18 weeks demonstrates clinically meaningful recovery, as these ranges are sufficient for most daily activities. These findings are comparable to those reported by Agee, who documented similar range of motion recovery following ligamentotaxis-based treatment (2). The restoration of forearm rotation, with pronation reaching 78.87° and supination 75.50°, is particularly important for hand function and activities of daily living.

Grip strength recovery to 84.93% of the contralateral side at 18 weeks represents excellent functional restoration. This outcome compares favorably with other treatment modalities, as grip strength is considered one of the most reliable indicators of overall wrist function. Kwok et al. emphasized the importance of grip strength as a predictor of patient satisfaction and return to normal activities (7). Our results suggest that ligamentotaxis effectively preserves the biomechanical environment necessary for strength recovery. The Modified Green-O'Brien scores, with 86.6% of patients achieving good to excellent outcomes, demonstrate the clinical effectiveness of ligamentotaxis. This success rate is consistent with the range reported in previous studies. Handoll and Elliott's systematic review of distal radius fracture rehabilitation noted similar functional outcome distributions when appropriate treatment and rehabilitation protocols were followed (9). The low incidence of poor outcomes (0%) in our series suggests that proper patient selection and surgical technique can optimize results.

The complication rate of 20% in our study is within the acceptable range reported in the literature for external fixation of distal radius fractures. Pin tract infections (10%) represent the most common complication, which is consistent with other studies reporting rates of 8-15%. These infections were successfully managed with local care and antibiotics in all cases. The occurrence of CRPS in 6.7% of patients aligns with reported incidences of 5-10% following distal radius fractures regardless of treatment method. The absence of nonunion in our series supports the biomechanical stability provided by ligamentotaxis, as reported by other investigators.

Comparison with volar plate fixation studies reveals similar functional outcomes, though external fixation offers advantages in specific clinical scenarios. Fu et al.'s meta-analysis comparing volar locking plates with external fixation found no significant differences in long-term functional scores, though volar plating allowed earlier mobilization (8). However, external fixation remains preferable in cases with severe comminution, compromised soft tissues, or limited resources, as demonstrated in our study.

The economic implications of ligamentotaxis are particularly relevant in resource-limited settings. External fixation typically requires less operative time and fewer specialized implants compared to internal fixation, potentially reducing overall treatment costs while maintaining clinical effectiveness. This consideration is important for healthcare

systems with limited resources, as noted in various international studies.

Our study's limitation of 18-week follow-up prevents assessment of long-term outcomes such as post-traumatic arthritis development. However, the restoration of anatomical parameters observed in our patients suggests a reduced risk of late complications. The restoration of articular congruity and normal alignment are well-established predictors of long-term joint health.

The success of ligamentotaxis in our study can be attributed to several factors including appropriate patient selection, meticulous surgical technique, and structured rehabilitation protocols. The principle of ligamentotaxis relies on intact soft tissue structures to maintain reduction, making it particularly effective in fractures where ligamentous attachments remain largely preserved. The gradual application of distraction forces allows for gentle realignment without compromising fracture biology.

Future research should focus on long-term follow-up studies to assess the durability of functional improvements and the incidence of post-traumatic arthritis. Additionally, comparative studies with newer fixation techniques and investigation of factors predicting optimal outcomes would further refine treatment algorithms. The integration of advanced imaging techniques and patient-reported outcome measures could provide additional insights into treatment effectiveness.

CONCLUSION

This study demonstrates that ligamentotaxis using external fixation is a highly effective treatment modality for unstable distal radius fractures, achieving excellent functional and radiological outcomes in the majority of patients. The technique successfully restores critical anatomical parameters including radial height, inclination, and volar tilt, while preserving joint mobility and grip strength. With good to excellent outcomes achieved in 86.6% of patients and a manageable complication profile, ligamentotaxis represents a valuable therapeutic option, particularly in cases where internal fixation may not be optimal or feasible.

The significant improvements in range of motion, grip strength, and pain levels observed in our study support the continued use of ligamentotaxis as a reliable treatment approach. The technique's minimally invasive nature, cost-effectiveness, and ability to maintain fracture biology while achieving stable fixation make it particularly suitable for a wide range of clinical scenarios.

The relatively low complication rate and absence of nonunion in our series further validate the safety and efficacy of this approach when performed with appropriate technique and follow-up care. These findings contribute valuable evidence to the existing literature and support the role of ligamentotaxis in contemporary distal radius fracture management.

Healthcare providers should consider ligamentotaxis as a primary treatment option for unstable distal radius fractures, particularly in cases with severe comminution, compromised soft tissues, or resource limitations. The technique's proven ability to restore anatomy and function while maintaining biological healing processes makes it an excellent choice for achieving optimal patient outcomes in this common and challenging injury pattern.

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