

Management of Distal End Radius Fractures in Adults By Ligamentotaxis Using An External Fixator With Radial Distractor: A Prospective Study

Dr. Vineeth B Maligi¹, Dr. Hari Sivanandan M², Dr. Senthil Rajan³, Dr. Surendra R⁴, Dr. Vivek Kumar M⁵, Dr. Gadekar Shubham Adinath⁶

¹Post Graduate Junior Resident Dept of Orthopaedics Vinayaka Mission's Kirupananda Variyar Medical College & Hospitals, Vinayaka Mission's Research Foundation (DU) Salem, India 636308, Email: vineetbmaali183@gmail.com, ORCID ID - 0009-0001-9139-1443

²HOD and Professor, Dept of Orthopaedics Vinayaka Mission's Kirupananda Variyar Medical College & Hospitals, Vinayaka Mission's Research Foundation (DU) Salem, India 636308, Email: sivadr1983@gmail.com, Orcid: 0000-0003-0478-8061

³Assistant Professor, Department of Emergency Medicine Vinayaka Mission's Kirupananda Variyar Medical College & Hospitals, Vinayaka Mission's Research Foundation (DU) Salem, India 636308, Email: drsenthilrajan@gmail.com, ORCID ID: 0000-0003-0478-7064

⁴Senior Registrar, Department of Orthopaedics, Kalyan Nagar, Hosmat Hospitals, Bengaluru 560043, Email: drsurendra.ortho@gmail.com, ORCID ID: 0000-0003-0358-8654

⁵Post Graduate Junior Resident Dept of Orthopaedics Vinayaka Mission's Kirupananda Variyar Medical College & Hospitals, Vinayaka Mission's Research Foundation (DU) Salem, India 636308, Email: vivekkeviv1995@gmail.com, ORCID ID: 0009-0006-7090-2079

⁶Postgraduate junior resident, Department of Radiodiagnosis, Vinayaka Mission's Kirupananda Variyar Medical College & Hospitals, Vinayaka Mission's Research Foundation (DU), Salem, Tamilnadu, India 636308, Email ID scag8220@gmail.com, ORCID ID 0009-0004-7979-0339

Abstract

Background: Distal radius fractures are among the most common fractures encountered in orthopaedic practice, accounting for approximately one-sixth of all fractures presenting to emergency departments. Unstable and intra-articular fractures often result in loss of anatomical alignment, decreased wrist function, and post-traumatic arthritis if not managed appropriately. External fixation based on the principle of ligamentotaxis has emerged as an effective treatment modality for maintaining fracture reduction while minimizing additional soft tissue injury. This study was undertaken to evaluate the functional and radiological outcomes of distal end radius fractures managed using an external fixator with a radial distractor.

Methods: A prospective observational study was conducted on 40 adult patients with distal end radius fractures treated by ligamentotaxis using a UMEX external fixator with radial distractor. Patients fulfilling the inclusion criteria underwent surgical fixation followed by a standardized postoperative rehabilitation protocol. The mean age of the study population was 44.8 years. The external fixator was maintained for an average duration of 6.5 weeks, and patients were followed for a mean period of 9 months. Functional outcomes were assessed using the Modified Green and O'Brien Clinical Scoring System, while fracture union, anatomical restoration, and complications were evaluated clinically and radiographically.

Results: The majority of patients achieved satisfactory anatomical reduction and fracture union following treatment with external fixation. Functional assessment at the final follow-up demonstrated excellent to good outcomes in 90% of patients according to the Modified Green and O'Brien scoring system. The procedure provided stable fixation, restoration of radial length and alignment, and facilitated early rehabilitation. Complications were minimal and were managed successfully without significantly affecting the final functional outcome.

Conclusion: External fixation with radial distractor based on the principle of ligamentotaxis is a reliable and effective treatment option for unstable distal end radius fractures. It provides satisfactory anatomical restoration, stable fracture fixation, and excellent functional outcomes with a low complication rate. Successful treatment depends on careful patient selection, meticulous surgical technique, maintenance of reduction, and early supervised rehabilitation.

Keywords: Distal radius fracture; External fixation; Ligamentotaxis; Radial distractor; UMEX; Functional outcome; Modified Green and O'Brien score; Wrist fracture.

Introduction

Distal end radius fracture is one of the most common skeletal injuries encountered by orthopaedic and trauma surgeons. Distal end radius fractures are the most common fractures of the upper extremity, accounting for approximately one-sixth (16%) of all fractures treated in an emergency setting.

Following a distal end radius fracture, restoration of the articular anatomy within a reasonable degree of congruity is essential for retaining normal wrist function. Distal radius fractures associated with high-energy trauma in younger adults with significant functional demands, as well as shearing-type fracture dislocations, can lead to

considerable functional disability if anatomical reduction is not achieved.

The radiocarpal and distal radioulnar joints are frequently disrupted in distal end radius fractures with intra-articular extension. Loss of articular congruity and altered joint kinematics may compromise long-term wrist function. Approximately 50% of metaphyseal fractures of the distal radius have intra-articular extension into either the radiocarpal or distal radioulnar joint. Preservation of articular congruity, combined with appropriate rehabilitation, remains the principal prerequisite for achieving excellent functional outcomes.

Ligamentotaxis is the principle of obtaining fracture reduction by applying continuous traction across the fracture through the surrounding intact soft tissues. Anderson and O'Neil were the first to apply this principle in maintaining reduction of distal end radius fractures using an external fixator. External fixation utilizes continuous distraction to restore radial length, alignment, and articular congruity while minimizing additional soft tissue damage.

In unstable intra-articular fractures, compressive forces tend to displace the fracture fragments, resulting in progressive radial shortening and collapse. The principle of ligamentotaxis effectively counteracts these deforming forces and has become an important advancement in the management of distal radius fractures. External fixation with a radial distractor maintains reduction by sustained distraction and provides adequate stability until fracture healing occurs.

Various treatment modalities have been described for distal radius fractures, including closed reduction and casting, percutaneous pinning, external fixation, open reduction with internal fixation, and combined techniques. The choice of treatment depends on patient age, fracture configuration, degree of comminution, bone quality, associated soft tissue injuries, and surgeon expertise. Among these modalities, external fixation based on ligamentotaxis remains an effective option for unstable extra-articular and intra-articular fractures, particularly in fractures with metaphyseal comminution where restoration of radial length and maintenance of reduction are critical.

Several studies have demonstrated satisfactory radiological and functional outcomes following external fixation for unstable distal radius fractures. Cooney et al. reported good to excellent functional outcomes in approximately 90% of unstable Colles' fractures managed with external fixation. Similarly, Jakim et al., Gunaki et al., and Yongyuth Siripakarn et al. documented excellent anatomical restoration and favorable functional results with ligamentotaxis, emphasizing the importance of anatomical reduction and early rehabilitation in achieving successful outcomes.

The present prospective study was undertaken to evaluate the efficacy of external fixation with a radial distractor based on the principle of ligamentotaxis in the management of distal end radius fractures. The study aimed to assess fracture union, restoration of anatomy, functional outcome using the Modified Green and O'Brien Clinical Scoring System, and procedure-related complications following treatment with the UMEX external fixator.

MATERIALS AND METHODS

Study Design

This prospective observational study was conducted in the Department of Orthopaedics at VMKV MCH Hospital Salem Tamilnadu India. The study included 40 consecutive adult patients with distal end radius fractures treated with a Universal Mini External Fixator (UMEX) with radial distractor based on the principle of ligamentotaxis. Ethical committee approval was obtained before commencement of the study.

Study Population

A total of 40 adult patients admitted with distal end radius fractures during the study period were enrolled consecutively according to predefined inclusion and exclusion criteria.

Inclusion Criteria

Patients fulfilling the following criteria were included in the study:

- Males and females aged 18–70 years
- Extra-articular distal radius fractures
- Intra-articular distal radius fractures
- Comminuted fractures of the distal radius
- Closed fractures and open fractures (Gustilo-Anderson Type I to Type III B)
- Fractures presenting within 3 weeks of injury
- Patients willing to undergo surgical treatment with external fixation

Exclusion Criteria

The following patients were excluded:

- Patients with associated neurovascular injuries
- Patients medically unfit for surgery
- Pathological fractures
- Fractures older than 3 weeks
- Patients unwilling for treatment with external fixation

Preoperative Evaluation

All patients underwent detailed clinical and radiological assessment.

Clinical evaluation included:

- Assessment of skin condition (open/closed injury)
- Peripheral vascular examination
- Neurological examination with special emphasis on the median nerve
- Assessment of flexor and extensor tendon function
- Distal radioulnar joint stability
- Evaluation for compartment syndrome
- Assessment of associated skeletal injuries

Radiological evaluation consisted of:

- Posteroanterior (PA) view
- Lateral view of the wrist

Routine investigations included complete blood count, blood grouping and typing, random blood sugar, serological investigations, and urine examination.

Before surgery, all fractures were immobilized using a below-elbow Plaster of Paris slab with limb elevation to reduce swelling and facilitate accurate pin placement. Fractures were classified according to both the Frykman and AO classification systems.

Anaesthesia

All patients underwent surgery under either general anaesthesia or regional anaesthesia, depending on the anaesthesiologist's assessment and patient suitability.

Implant Used

The Universal Mini External Fixator (UMEX) consisted of:

- Two 3.5-mm Schanz pins for the radius
- Two 2.5-mm Schanz pins for the second metacarpal
- Four Aesculap clamps

- One distractor rod

Surgical Technique

Patients were positioned supine on the operating table with the affected upper limb placed on a radiolucent arm board. Following standard aseptic preparation using betadine and saline solution, a pneumatic tourniquet was applied. Closed reduction was performed under fluoroscopic (C-arm) guidance. In open fractures, wound debridement was carried out before fixation.

Two stab incisions were made approximately 8 cm proximal to the radial styloid, with the second incision approximately one inch proximal to the first. After careful protection of surrounding tendons, nerves, and vessels, the radius was drilled using a 2.5-mm drill bit, and 3.5-mm Schanz pins were inserted bicortically.

Similarly, two stab incisions were made over the base and shaft of the second metacarpal. These were drilled using a 1.5-mm drill bit, followed by insertion of 2.5-mm Schanz pins.

The fixator clamps and distractor rod were assembled, and longitudinal distraction was applied. Gentle manual moulding with wrist flexion and ulnar deviation was performed to restore radial length, alignment, and articular congruity. Reduction was confirmed under image intensifier guidance, after which the external fixator was securely tightened. Adequate ligamentotaxis achieved with the UMEX radial distractor was confirmed fluoroscopically.

Postoperative Management

Active mobilization of the fingers, thumb, elbow, forearm, and shoulder was initiated on the first postoperative day.

Dressings were changed on the third postoperative day, and pin sites were cleaned regularly.

Patients were discharged on the fifth postoperative day with instructions regarding alternate-day pin-site care.

Clinical and radiological assessment of fracture healing was performed at approximately 6 weeks. Once fracture union was evident clinically and radiologically, the external fixator was removed without anaesthesia, followed by application of a below-elbow Plaster of Paris slab for an additional 2 weeks.

Patients were advised to avoid heavy lifting for 4–6 weeks after fixator removal. Formal wrist physiotherapy commenced at approximately 8 weeks, including flexion-extension, radial-ulnar deviation, pronation-supination, and underwater exercises.

Follow-up

Patients were reviewed at:

- 1 week
- 6 weeks
- 3 months
- 6 months
- 9 months
- Final follow-up up to 12 months

Each follow-up included clinical examination, radiographic assessment of fracture union, assessment of wrist range of motion, evaluation of complications, and functional assessment. The mean follow-up duration was 7.3 months (range 6–12 months).

Outcome Measures

The primary outcome measure was functional outcome, assessed using the Modified Green and O'Brien Clinical Scoring System, which evaluates:

- Pain
- Functional status

- Range of motion
- Grip strength
- Secondary outcome measures included:
 - Clinical fracture union
 - Radiological fracture union
 - Maintenance of anatomical reduction
 - Procedure-related complications

Sample Size

Based on institutional records indicating approximately 20–30 surgically managed distal radius fractures per year, a minimum sample size of 40 patients was calculated using Cochran's formula and included consecutively during the study period.

RESULTS

A total of 40 adult patients with distal end radius fractures were included in this prospective study. The study population was analyzed with respect to age, sex, mechanism of injury, side involved, fracture type, fracture classification, complications, and functional outcome.

Age Distribution

Table 1. Age distribution of the study population (n = 40)

Age group (years)	Number of cases	Percentage (%)
18–30	10	25
31–40	6	15
41–50	8	20
51–60	10	25
61–70	6	15
Total	40	100

Our study involved patients between 18 and 70 years of age. The youngest patient was 19 years old and the oldest was 67 years, with a mean age of 44.8 years.

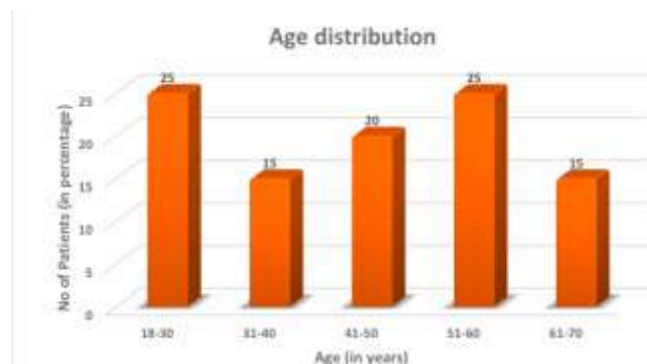


Figure 1. Age distribution of study participants

Sex Distribution

Table 2. Sex distribution of the study population

Sex	Number of cases	Percentage (%)
Male	27	67
Female	13	33
Total	40	100

Out of the 40 patients included in our study, 27 (67%) were males and 13 (33%) were females.

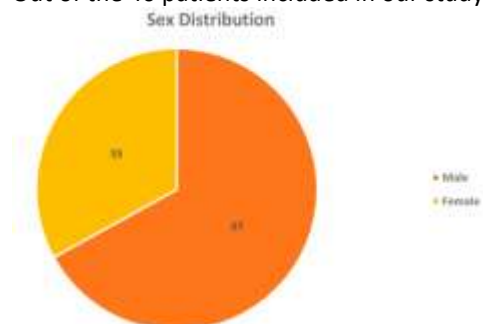


Figure 2. Sex distribution of study participants.

Mode of Injury

Table 3. Mode of injury

Mode of injury	Number of cases	Percentage (%)
Road traffic accident	13	33
Fall on outstretched hand (FOOH)	23	57
Fall from height	4	10
Total	40	100

Fall on an outstretched hand (FOOH) was the commonest mechanism of injury, accounting for 23 patients (57%), followed by road traffic accidents (33%) and fall from height (10%).

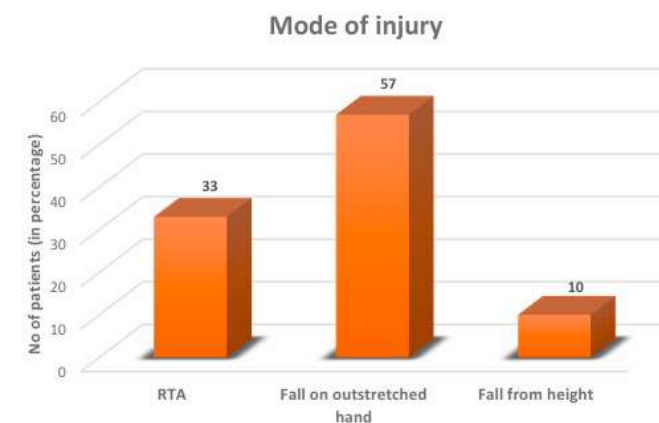


Figure 3. Distribution according to mode of injury.

Side Affected

Table 4. Side involved

Side	Number of cases	Percentage (%)
Right	22	55
Left	18	45
Total	40	100

The right wrist was involved more frequently (55%) than the left wrist (45%).

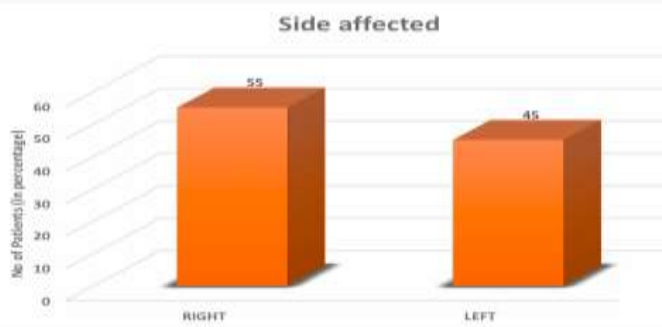


Figure 4. Distribution according to side affected.

Type of Fracture

Table 5. Type of fracture

Fracture type	Number of cases	Percentage (%)
Closed	37	93
Open	3	7
Total	40	100

The majority of fractures were closed injuries (93%), whereas 3 patients (7%) sustained open fractures.

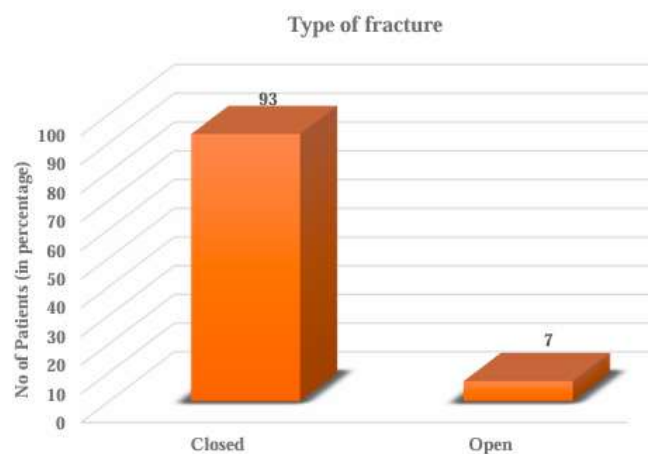


Figure 5. Distribution according to fracture type.

Frykman Classification

Table 6. Distribution of fractures according to Frykman classification (n = 40)

Frykman Type	Number of Cases	Percentage (%)
I	0	0
II	0	0
III	2	5
IV	9	23
V	7	17
VI	6	15
VII	9	23
VIII	7	17

The majority of fractures belonged to Frykman Type IV (23%) and Type VII (23%), followed by Type V (17%), Type VIII (17%), Type VI (15%), and Type III (5%). No patients had Type I or Type II fractures.

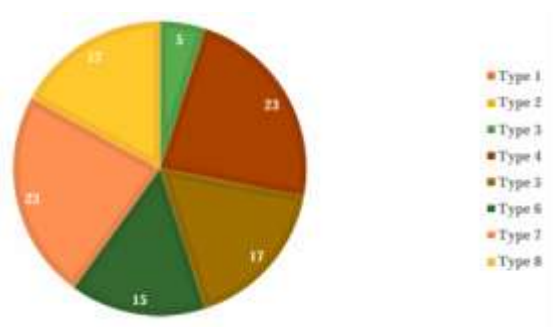


Figure 6. Distribution of fractures according to Frykman classification.

AO Classification

Table 7. Distribution of fractures according to AO classification (n = 40)

AO Classification	Number of Cases	Percentage (%)
A1	0	0
A2	0	0
A3	0	0
B1	3	7
B2	3	7
B3	7	18
C1	9	23
C2	13	32
C3	5	13

According to the AO classification, Type C fractures predominated, accounting for 27 (68%) of the 40 fractures. C2 fractures were the most common subtype (32%), followed by C1 (23%), B3 (18%), C3 (13%), B1 (7%), and B2 (7%). No Type A fractures were encountered in the present study.

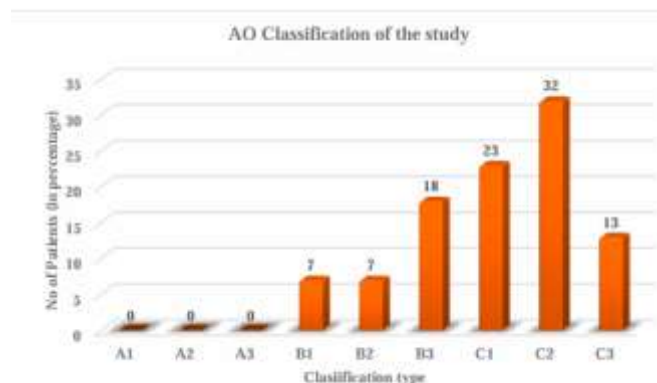


Figure 7. Distribution of fractures according to AO classification.

Postoperative Complications

Table 8. Postoperative complications (n = 40)

Complication	Number of Cases
Residual pain	5
Malunion	1
Pin tract infection / Pin loosening	0
Reflex sympathetic dystrophy (RSD)	1
Restricted wrist movements	1
Finger stiffness	1
Shoulder-hand syndrome	1

Residual pain was the most frequently observed complication, occurring in 5 patients. One patient each developed malunion, reflex sympathetic dystrophy, restricted wrist movement, finger stiffness, and shoulder-hand syndrome. No cases of pin tract infection or pin loosening were observed.

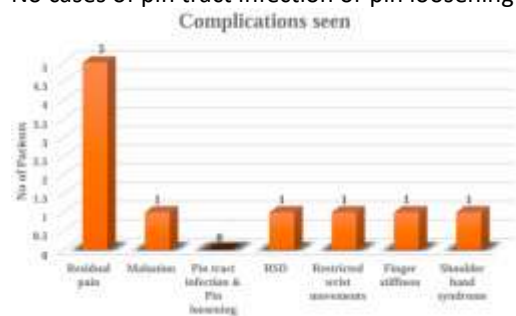


Figure 8. Distribution of postoperative complications.

Functional Outcome

Table 9. Functional outcome according to the Modified Green and O'Brien Clinical Scoring System (n = 40)

Functional Outcome	Number of Cases	Percentage (%)
Excellent	14	35
Good	22	55
Fair	3	7.5
Poor	1	2.5

At the final follow-up, 36 patients (90%) achieved excellent or good functional outcomes, whereas 3 patients (7.5%) had fair results and 1 patient (2.5%) had a poor functional outcome according to the Modified Green and O'Brien Clinical Scoring System.

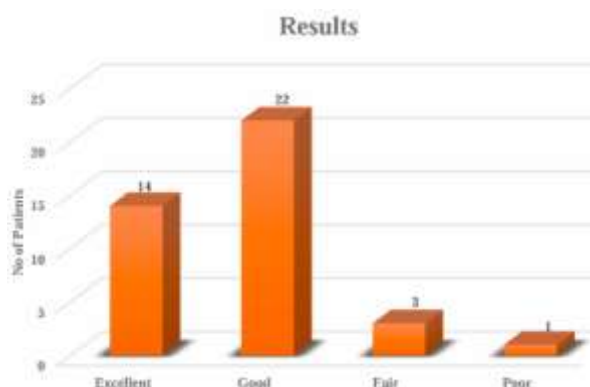


Figure 9. Functional outcome of the study population

Associated Injuries

Associated skeletal injuries were present in 8 patients (20%). These included:

- Ipsilateral clavicle fracture – 1 case
- Ipsilateral bimalleolar fracture of the ankle – 1 case
- Compression fracture of the L1 vertebra – 1 case
- Multiple rib fractures – 1 case
- Contralateral segmental ulna fracture – 1 case
- Contralateral calcaneal fracture – 1 case
- Ipsilateral neck of femur fracture – 2 cases

Duration of External Fixation

The external fixator remained in situ for 6 weeks in 30 patients (75%), 7 weeks in 6 patients (15%), and 8 weeks in 4 patients (10%). The mean duration of external fixation was 6.5 weeks.

Follow-up

Patients were followed for a minimum of 6 months, with a mean follow-up duration of 7.3 months.

Fracture Union

All fractures achieved clinical and radiological union within 12–14 weeks, with a mean union time of 12.6 weeks. No cases of delayed union or non-union were encountered during the follow-up period.

DISCUSSION

The present prospective study was undertaken to evaluate the functional and radiological outcomes of unstable distal end radius fractures treated by ligamentotaxis using a Universal Mini External Fixator (UMEX) with radial distractor. A total of 40 adult patients were included and followed prospectively. The results of the present study were analyzed and compared with previously published literature.

Distal end radius fractures remain one of the most frequently encountered fractures in orthopaedic practice. The primary goals of treatment are restoration of radial length, radial inclination, volar tilt, and articular congruity to achieve pain-free wrist function. External fixation based on the principle of ligamentotaxis has been widely accepted as an effective treatment modality for unstable distal radius fractures, particularly those associated with metaphyseal comminution and intra-articular extension.

In the present study, the mean age of the patients was 44.8 years, with the majority of patients belonging to the 18–30 years and 51–60 years age groups. These findings are comparable with those reported by Cooney et al., Jakim et al., and Kapoor et al., who observed that distal radius fractures commonly occur in younger individuals following high-energy trauma and in older individuals due to osteoporotic bone and low-energy falls.

The present study demonstrated a male predominance (67%), with females accounting for 33% of the study population. Similar observations have been reported in previous studies from developing countries, where high-energy trauma such as road traffic accidents predominantly affects the economically active male population.

The most common mechanism of injury in the present study was fall on an outstretched hand (57%), followed by road traffic accidents (33%) and fall from height (10%). Similar injury patterns have been reported by Cooney et al., Vaughan et al., and several Indian studies, emphasizing that falls remain the principal mechanism of distal radius fractures, whereas road traffic accidents are more common among younger adults.

The right wrist was involved slightly more frequently (55%) than the left (45%). This finding is consistent with most published studies and may be attributed to the predominance of the dominant upper limb during protective reflexes at the time of injury.

According to the Frykman classification, the majority of fractures belonged to Type IV and Type VII, whereas AO classification revealed that Type C fractures constituted 68% of all cases, with C2 fractures being the commonest subtype. These findings indicate that most patients sustained complex intra-articular fractures requiring stable fixation and maintenance of reduction. Similar fracture distributions have been reported in studies evaluating unstable distal radius fractures treated with external fixation.

The principle of ligamentotaxis effectively restored radial length and alignment in the majority of patients. Continuous distraction through intact soft tissues maintained reduction throughout fracture healing while minimizing additional soft tissue dissection. The external fixator also provided sufficient stability to permit early mobilization of adjacent joints, thereby reducing stiffness and improving functional recovery.

The mean duration of external fixation was 6.5 weeks, which is comparable to the duration reported by Cooney et al., Jakim et al., and Gunaki et al. Removal of the fixator after evidence of clinical and radiological union allowed commencement of structured wrist rehabilitation without compromising fracture stability.

All fractures in the present series achieved clinical and radiological union, with a mean union time of 12.6 weeks. No cases of delayed union or non-union were observed. These findings compare favorably with previous studies, which have consistently demonstrated high union rates following external fixation based on ligamentotaxis.

Functional assessment using the Modified Green and O'Brien Clinical Scoring System revealed excellent results in 35%, good results in 55%, fair results in 7.5%, and poor results in 2.5% of patients. Thus, 90% of patients achieved excellent to good functional outcomes, which is comparable with the results reported by Cooney et al., Jakim et al., Kapoor et al., and Yongyuth Siripakarn et al., who also documented satisfactory functional recovery following external fixation for unstable distal radius fractures.

Postoperative complications were relatively few. Residual pain was the most common complication, followed by isolated cases of malunion, reflex sympathetic dystrophy, restricted wrist movements, finger stiffness, and shoulder-hand syndrome. Importantly, no cases of pin tract infection or pin loosening were encountered. The low

complication rate observed in the present study may be attributed to meticulous surgical technique, proper pin placement, regular pin-site care, and early supervised rehabilitation.

The findings of the present study support the concept that restoration of anatomical alignment remains one of the most important determinants of successful functional outcome. Maintenance of radial length and correction of dorsal angulation significantly improve wrist biomechanics and reduce the incidence of post-traumatic arthritis and functional disability.

One of the major strengths of external fixation is that it preserves fracture biology by avoiding extensive surgical exposure while providing adequate stability through ligamentotaxis. This makes it particularly useful in comminuted fractures, osteoporotic bone, and fractures associated with compromised soft tissues.

However, external fixation also has certain limitations. In fractures with severe articular comminution, depressed intra-articular fragments may require supplementary fixation with Kirschner wires or open reduction to achieve optimal reduction. Furthermore, patient compliance with pin-site care and postoperative physiotherapy plays an important role in determining the final functional outcome.

Overall, the findings of the present study are comparable with those reported in national and international literature and reaffirm that ligamentotaxis using a UMEX external fixator with radial distractor is a safe, reliable, minimally invasive, and effective treatment modality for unstable distal end radius fractures, producing satisfactory anatomical restoration, high union rates, and excellent functional outcomes with minimal complications.

CONCLUSION

External fixation using a Universal Mini External Fixator (UMEX) with radial distractor based on the principle of ligamentotaxis is an effective method for the management of unstable distal end radius fractures. The technique provides satisfactory restoration of radial length, radial inclination, volar tilt, and articular congruity while preserving the biological environment of fracture healing.

In the present prospective study of 40 patients, external fixation resulted in reliable fracture union, satisfactory anatomical reduction, and excellent functional recovery. According to the Modified Green and O'Brien Clinical Scoring System, 90% of patients achieved excellent to good functional outcomes, demonstrating the effectiveness of ligamentotaxis in maintaining fracture reduction and facilitating early rehabilitation.

The procedure was associated with a low complication rate, with no cases of delayed union, non-union, pin tract infection, or pin loosening observed during the follow-up period. Most complications encountered were minor and responded well to appropriate conservative management.

Based on the findings of the present study, it can be concluded that external fixation with a radial distractor is a safe, reliable, minimally invasive, and cost-effective treatment modality for unstable distal end radius fractures, particularly in fractures with metaphyseal comminution and intra-articular extension. Careful patient selection, meticulous surgical technique, maintenance of reduction, regular pin-site care, and structured postoperative rehabilitation are essential for achieving optimal functional outcomes.

The results of this study are comparable with previously published national and international literature and support the continued use of ligamentotaxis as an effective treatment option for appropriately selected distal end radius fractures.

Strengths of the Study

- Prospective study design.
- Standardized surgical technique using the Universal Mini External Fixator (UMEX) with radial distractor.
- Uniform postoperative rehabilitation protocol for all patients.
- Functional outcome assessed using the validated Modified Green and O'Brien Clinical Scoring System.
- Both radiological and functional outcomes were evaluated.

- Low incidence of postoperative complications.
- Complete follow-up of all enrolled patients with no loss to follow-up.

Limitations of the Study

- Relatively small sample size (40 patients).
- Single-center study.
- Absence of a comparison group treated with alternative fixation methods such as volar locking plate fixation or percutaneous K-wire fixation.
- Follow-up duration was limited and may not reflect long-term outcomes such as post-traumatic arthritis.
- Grip strength assessment was based on clinical evaluation rather than instrumented dynamometry.

Clinical Relevance

Ligamentotaxis using a UMEX external fixator provides stable fixation while minimizing soft tissue disruption. It represents an effective treatment option for unstable distal end radius fractures, especially in resource-limited settings where external fixation remains economical, reproducible, and technically straightforward. The technique allows satisfactory restoration of wrist anatomy and function with a low complication profile when combined with appropriate postoperative rehabilitation.

REFERENCES

1. Cooney WP III, Linscheid RL, Dobyns JH. External pin fixation for unstable Colles' fractures. *J Bone Joint Surg Am.* 1979;61(6A):840–845.
2. Anderson R, O'Neil G. Comminuted fractures of the distal end of the radius treated by skeletal transfixion in plaster cast. *J Bone Joint Surg Am.* 1944;26:509–519.
3. Agee JM. External fixation. Technical advances based upon multiplanar ligamentotaxis. *Orthop Clin North Am.* 1993;24(2):265–274.
4. Kapoor H, Agarwal A, Dhaon BK. Displaced intra-articular fractures of distal radius: A comparative evaluation of results following closed reduction, external fixation and open reduction with internal fixation. *Injury.* 2000;31(2):75–79.
5. Jakim I, Pieterse HS, Sweet MB. External fixation for intra-articular fractures of the distal radius. *J Bone Joint Surg Br.* 1991;73(2):302–306.
6. Knirk JL, Jupiter JB. Intra-articular fractures of the distal end of the radius in young adults. *J Bone Joint Surg Am.* 1986;68(5):647–659.
7. Jupiter JB. Current concepts review: Fractures of the distal end of the radius. *J Bone Joint Surg Am.* 1991;73(3):461–469.
8. Frykman G. Fracture of the distal radius including sequelae—shoulder-hand-finger syndrome, disturbance in the distal radio-ulnar joint and impairment of nerve function. *Acta Orthop Scand Suppl.* 1967;108:1–153.
9. Melone CP Jr. Articular fractures of the distal radius. *Orthop Clin North Am.* 1984;15(2):217–236.
10. Fernandez DL. Fractures of the distal radius: Operative treatment. *Instr Course Lect.* 1993;42:73–88.
11. Fernandez DL, Jupiter JB. *Fractures of the Distal Radius: A Practical Approach to Management.* 2nd ed. New York: Springer; 2002.
12. Müller ME, Nazarian S, Koch P, Schatzker J. *The Comprehensive Classification of Fractures of Long Bones.* Berlin: Springer-Verlag; 1990.
13. Rüedi TP, Buckley RE, Moran CG, editors. *AO Principles of Fracture Management.* 2nd ed. Stuttgart: Thieme; 2007.
14. Mackenney PJ, McQueen MM, Elton R. Prediction of instability in distal radial fractures. *J Bone Joint Surg Am.* 2006;88(9):1944–1951.

15. Handoll HHG, Madhok R. Surgical interventions for treating distal radial fractures in adults. *Cochrane Database Syst Rev.* 2003;(3):CD003209.
16. Handoll HHG, Huntley JS, Madhok R. External fixation versus conservative treatment for distal radial fractures in adults. *Cochrane Database Syst Rev.* 2007;(3):CD006194.
17. Handoll HHG, Madhok R. External fixation versus internal fixation for distal radial fractures in adults. *Cochrane Database Syst Rev.* 2007;(3):CD006194.
18. Chung KC, Shauver MJ, Birkmeyer JD. Trends in the United States in the treatment of distal radial fractures in the elderly. *J Bone Joint Surg Am.* 2009;91(8):1868–1873.
19. Orbay JL, Fernandez DL. Volar fixation for dorsally displaced fractures of the distal radius: A preliminary report. *J Hand Surg Am.* 2002;27(2):205–215.
20. Lichtman DM, Bindra RR, Boyer MI, Putnam MD, Ring D, Slutsky DJ, et al. Treatment of distal radius fractures. *J Am Acad Orthop Surg.* 2010;18(3):180–189.
21. Walenkamp MMJ, Bentohami A, Beerekamp MSH, Peters RW, van der Heiden R, Goslings JC, et al. Functional outcome in patients with unstable distal radius fractures, volar locking plate versus external fixation: A meta-analysis. *Strategies Trauma Limb Reconstr.* 2013;8(2):67–7