

ANALYSING THE OUTCOME OF LIGAMENTOTAXIS OF UNSTABLE DISTAL RADIUS FRACTURES USING DYNAMIC EXTERNAL FIXATOR - A PROSPECTIVE STUDY

R. Subramaniyan¹, E. Rajaraman², V. Senthil Kumar³

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Corresponding Author:

Dr. E. Rajaraman,
Email: adhithyavel24@gmail.com

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¹Assistant Professor, Department of Orthopaedics, Government Pudukkottai Medical College, Pudukkottai, Tamil Nadu, India.

²Assistant Professor, Department of Orthopaedics, Government Pudukkottai Medical College, Pudukkottai, Tamil Nadu, India.

³Senior Civil Surgeon, Department of Orthopaedics, Government Head Quarters Hospital, Perambalur, Tamil Nadu, India.

ABSTRACT

Background: Distal radius fractures range from simple Colles' fractures to complex comminuted intra-articular patterns. Open reduction restores the anatomy and allows early mobilisation, but may risk fixation failure in unstable fractures. This study aimed to analyse the functional outcomes of early wrist mobilisation in complex unstable intra-articular distal radius (DR) fractures. **Materials and Methods:** This prospective study was conducted on 17 patients at Government Madurai Medical College from November 2011 to November 2013. Patients with DR fractures underwent closed reduction and Pennig Fixator with supplementary K-wires as needed. Early mobilisation, antibiotic therapy, and staged fixator dynamisation and removal were performed, with radiological and functional follow-up for up to 12 months. **Results:** Most fractures were closed (88%) and were AO types 23C1 and 23C2. Supplementary K-wires were used in 83% of cases, with dynamisation initiated at approximately 3 weeks and fixator removal at a mean of 6.5 weeks post-injury. At 3 and 6 months, functional outcomes improved, with 44% and 28% of patients achieving excellent and good results at 6 months, respectively (Mayo wrist score). Radiological parameters showed restoration of radial length, inclination, palmar tilt, and ulnar variance. At the final follow-up, 55% were pain-free, 61% returned to regular work, 66% regained full wrist motion, and 67% restored $\geq 75\%$ grip strength. Minor complications occurred in 22% of patients, mainly mild pin tract infections and malunion, with no major complications reported. **Conclusion:** Dynamic external fixation using ligamentotaxis supplemented with K-wires when needed provides stable fixation, promotes early wrist mobilisation, and prevents stiffness, yielding good functional and radiological outcomes.

INTRODUCTION

Fractures of the distal radius (DR) are among the most common fractures, accounting for 1/6th of all fractures. It usually occurs in elderly people with trivial trauma, frequently with a fall onto the outstretched hand.^[1,2] The overall prevalence of DR fracture is increasing each year, and most commonly in children < 18 years and adults > 50 years of age.^[2] DR fractures occur at the metaphyseal cortico-cancellous region and are related to osteopenia in older people.^[3,4] In young and active patients, it may occur due to high-velocity injuries and may involve the articular surface and ulnar styloid.^[5] Treatment goals are focused on preserving the hand and wrist function, realigning the normal osseous anatomy,

promoting bony union, avoiding complications and allowing early fingers, wrist, and elbow movements.^[6]

In 1814, Sir Abraham Colles first described an extra-articular distal radius fracture characterised by dorsal displacement, commonly resulting from a fall on an outstretched hand in elderly individuals with osteoporosis. He noted that this fracture pattern generally had a favourable prognosis, as its clinical features could be readily recognized and managed once the injury mechanism was understood. However, despite recovery of mobility and pain relief, a residual deformity often persisted permanently.^[7] In adults, the choice of treatment depends on fracture stability; an unstable DR fracture is usually defined as one that undergoes secondary

displacement after adequate reduction, although there is no universally accepted definition.^[7,8] The Lafontaine criteria (1989) are one of the broadly used criteria, which include five predictors of instability: dorsal angulation $>20^\circ$, dorsal comminution, intra-articular extension, associated ulnar fracture, and patient age > 60 years. Fractures meeting three or more of these factors are considered unstable and often require closer radiographic monitoring or surgical intervention.^[8]

As the complex nature of the fracture pattern increases, metaphyseal comminution increases, and with intra-articular extension, the treatment of such fractures becomes more difficult.^[9] Since the fracture line involves the articular surface of the wrist joint, any attempted movement or loading around the joint may lead to the movement of fragments at the fracture site, which affects fracture healing. With significant joint surface involvement, if the wrist and adjacent carpal joints are kept immobilised over a prolonged duration, residual stiffness always occurs.^[9,10] Non-surgical methods such as closed reduction and immobilisation are mostly used for stable or minimally displaced DR fractures, while complex or comminuted patterns often require surgical fixation. One of the commonly used operative techniques is external fixation based on the principle of ligamentotaxis, where indirect reduction is achieved through ligamentous tension. This technique preserves vascularity, limits further displacement, and maintains radial length.^[11]

External fixation can be static, where the wrist is completely immobilised, or dynamic, allowing controlled wrist motion through a mobile hinge joint. Dynamic fixation has the advantage of precise fracture reduction while allowing early mobilisation, improving joint function, and minimising postoperative stiffness. However, complications such as pin-tract infection, residual pain, or limited wrist movement may still occur.^[12] Although several studies have emphasised radiological parameters, only a limited number of studies have analysed patient-centred functional outcomes. Hence, this study aimed to analyse the functional outcomes of early wrist mobilisation in complex unstable intra-articular DR fractures using ligamentotaxis with a hinged dynamic spanning external fixator.

MATERIALS AND METHODS

This prospective study was conducted on 17 patients at the Department of Orthopaedics and Traumatology, Government Madurai Medical College, from November 2011 to November 2013. The study was approved by the Institutional Ethics Committee. Written informed consent was obtained from all participants before their inclusion in this study.

Inclusion Criteria

Patients of both genders aged between 20 and 50 years who presented with unstable intra-articular or

extra-articular DR fractures. Fractures that required re-reduction after initial closed treatment. Only fractures that were < 3 weeks old at the time of presentation.

Exclusion Criteria

Patients with stable DR fractures are suitable for cast immobilisation, especially those with ipsilateral upper limb fractures precluding pin placement, noncompliance, or severe comorbidities. Compound fractures above Grade I, significant degenerative wrist arthritis, and fractures with neurovascular injury.

Methods

All skeletally mature patients presenting with pain, swelling, deformity, and wrist dysfunction following injury were included. Standard posteroanterior and lateral wrist radiographs were obtained, and demographic and injury data were recorded. Fractures were classified according to Frykman's system. Initial management involved closed reduction, below-elbow dorsal slab application under haematoma block, limb elevation, and analgesics.

Preoperative evaluation included routine blood investigations, chest radiography, ECG, and echocardiography for anaesthetic clearance. Surgery was performed within 1–6 days of admission. All procedures were conducted under ipsilateral supraclavicular block anaesthesia with prophylactic antibiotics, and a tourniquet was not used. The dynamic external fixator assembly (Pennig Fixator) consisted of clamps, distraction-compression modules, double ball joints, cams, collars, and conical pins (2.5–3.3 mm).

Under image intensifier guidance, closed reduction was achieved using ligamentotaxis and manual traction. Metacarpal pins were inserted into the second metacarpal, and radial pins approximately 4 cm proximal to the fracture site, avoiding neurotendinous injury. The fixator was assembled with the distal ball aligned at the capitulum joint line to maintain wrist kinematics. Reduction was refined using Gupta's manoeuvre, and supplementary K-wires were used for comminuted fractures or DRUJ instability.

Postoperatively, limb elevation and early finger, elbow, and shoulder mobilisation were encouraged. Intravenous antibiotics were given for two days, followed by oral antibiotics until suture removal on day 10. Patients were reviewed weekly for pin-site condition, fixator stability, and radiographic evaluation.

Dynamisation was initiated after 2–3 weeks, allowing 50° wrist motion. K-wires were removed at 3–4 weeks, and the fixator at 6–8 weeks, depending on fracture stability. Follow-up radiographs were obtained at 2, 6 weeks, and at 3, 6, and 12 months to assess union and alignment. Functional outcomes were assessed using the Mayo wrist score at 3 and 6 months, evaluating pain, function, motion, and grip strength. Radiographic parameters included radial length, inclination, palmar tilt, and ulnar variance. Final results were graded using Lidström criteria, and

complications were recorded as minor or major. Data were expressed as means, frequencies, and percentages.

RESULTS

Among the 17 patients, most were male, with 13 males (76%) and 4 females (24%). The 20-30 years age group had the majority of males (29%), whereas females were most commonly seen in the 30-40 years age group (18%). [Table 1]

Table 1: Age and gender distribution

Age group (years)	Gender	
	Male	Female
20-30	5 (29%)	0
30-40	4 (24%)	3 (18%)
40-50	4 (24%)	1 (6%)

Table footer: Data are presented as frequencies and percentages.

The majority of reported fractures were due to road traffic accidents (RTA) (53%), while 47% resulted from accidental falls. The left wrist was more frequently involved (71%), and 16 patients (94%) had no other comorbidities. Closed fractures accounted for 88% of the cases, with only two cases (12%) with Grade I compound injuries. According to the AO classification, the most common types were 23C2 (33%) and 23C1 (28%), whereas, based on

Frykman's classification, Type VII (33%) and Type VI (28%) were the most common. Supplementary K-wire fixation was used in 83% of cases, and all wires were removed after 3 weeks postoperatively. Dynamisation was typically initiated after 3 weeks (72%), and fixator removal predominantly occurred at 6 weeks (61%), with a mean duration of 6.5 weeks. [Table 2]

Table 2: Baseline characteristics and fracture profile

Parameter	Category	Frequency n (%)
Mode of injury (n = 17)	RTA	9 (53%)
	Accidental self-fall	8 (47%)
Injured side (n = 17)	Right	4 (24%)
	Left	12 (71%)
	Both right and left	1 (6%)
Associated co-morbid conditions (n = 17)	Present	1 (6%)
	Absent	16 (94%)
Other associated fractures (n = 17)	Present	3 (18%)
	Absent	14 (82%)
Type of fracture - Open vs Closed (n = 18)	Closed fractures	16 (88%)
	Grade I compound	2 (12%)
	Grade II compound	0
AO Type (n = 18)	23-B2	2 (11%)
	23-B3	2 (11%)
	23-C1	5 (28%)
	23-C2	6 (33%)
	23-C3	3 (17%)
Frykman's fracture type (n = 18)	III	0
	IV	1 (5%)
	V	2 (10%)
	VI	5 (28%)
	VII	6 (33%)
	VIII	4 (24%)
Item	Supplementary K-wire stabilisation of comminuted fragments	15 (83%)
	Trans fixation K-wires for DRUJ stabilisation	15 (83%)
	Supplementary K-wires removed at ~3 weeks	18 (100%)
Dynamization - timing (started after a mean of 3.2 weeks)	After 2 weeks	1 (6%)
	After 3 weeks	13 (72%)
	After 4 weeks	3 (17%)
	After 5 weeks	1 (6%)
Fixator removal - timing (mean 6.5 weeks)	Removed after 6 weeks	11 (61%)
	Removed after 7 weeks	5 (28%)
	Removed after 8 weeks	2 (11%)

Table footer: Data are presented as frequencies and percentages. Abbreviations: DRUJ – Distal Radioulnar Joint; AO – Arbeitsgemeinschaft für Osteosynthesefragen (Association for the study of internal fixation)

At 3 months, most patients had good functional outcomes (56%), and 22% showed excellent results.

By 6 months, the percentage of patients with excellent outcomes improved to 44%. No patient had poor outcomes at either of the follow-ups. [Table 3]

Table 3: Functional outcome based on Mayo wrist score at 3 and 6 months

Mayo wrist score- functional grading	At 3 months	At 6 months
Excellent	4 (22%)	8 (44%)
Good	10 (56%)	5 (28%)
Fair	4 (22%)	5 (28%)
Poor	0	0

Table footer: Data are presented as frequencies and percentages.

The mean radial length increased from 1.1 mm preoperatively to 8.28 mm postoperatively, and was maintained at 6.67 mm at the final follow-up. Radial inclination improved from 4.67° to 17.17° postoperatively and remained at 14.33° at the follow-

up. Palmar tilt was maintained near normal (7.3° preoperatively to 7.44° postoperatively), while ulnar variance was normalised from 1.04 mm to 0 postoperatively. [Table 4]

Table 4: Comparison of radiological parameters at different time intervals

Radiological parameters (Mean)	Pre-operative	Post-operative	At final follow-up
Radial length (mm)	1.1	8.28	6.67
Radial inclination (°)	4.67	17.17	14.33
Palmar tilt (°)	7.3	7.44	6.39
Ulnar variance (mm)	1.04	0	1.11

Table footer: Data are presented as mean values. Abbreviations: mm- millimetres; °- degrees.

At 6 months follow-up, 55% of the patients reported no pain, and 33% experienced only mild occasional pain. Most (61%) returned to regular employment, whereas 39% resumed restricted work. Range of motion recovery was satisfactory, with 66% achieving full (100%) wrist mobility and 22% reaching 75-99% of normal motion. Grip strength

was restored to ≥75% of the opposite side in 67% of patients. Deformity was absent in 78% of patients, and 55% achieved excellent results based on Lidström grading. Minor complications occurred in 22% of patients, predominantly mild pin tract infections and malunion, with no major complications reported.[Table 5]

Table 5: Functional and radiological outcomes with complications at final follow-up (n=18)

Parameter	Category	Frequency (%)
Pain intensity at 6 months	No pain	10 (55%)
	Mild occasional pain	6 (33%)
	Moderate tolerable pain	2 (12%)
	Severe intolerable pain	0
Ability to return to work at 6 months	Returned to regular employment	11 (61%)
	Restricted employment	7 (39%)
	Able to work, but unemployed	0
	Unable to work because of pain	0
Range of motion at 6 months (% of normal side)	100%	12 (66%)
	75%-99%	4 (22%)
	50%-74%	1 (5%)
	25%-49%	1 (5%)
	0%-24%	0
Grip strength (% of opposite side)	100%	5 (28%)
	75%-100%	7 (39%)
	50%-75%	6 (33%)
	25%-50%	0
	0%-25%	0
Deformity at final follow-up	None	14 (78%)
	Mild deformity	2 (11%)
	Moderate acceptable	2 (11%)
	Severe unacceptable	0
Lidström's grade	Excellent	10 (55%)
	Good	4 (23%)
	Fair	4 (22%)
	Poor	0
Complications	Minor	4 (22%)
	Major	0
	None	14 (78%)
Type of complications	Minor pin tract infections	2 (11%)
	Major pin tract infections	0
	Fixator dysfunction / Failure	1 (5%)
	Pin bending / Pin breakage	0

	Malunion / Deformity	4 (22%)
	Reflex sympathetic dystrophy	0

Table footer: Data are presented as frequencies and percentages.

DISCUSSION

Distal radius fractures are among the most common skeletal injuries, leading to pain, deformity, and functional impairment. It occurs following high-velocity trauma in young adults and low-energy falls in the elderly. This study evaluated the functional and radiological outcomes of unstable intra-articular DR fractures managed using Pennig fixator based on the principle of ligamentotaxis, with or without supplementary K-wire stabilisation.

Our results demonstrated favourable functional and anatomical outcomes, with 44% (n=8) achieving excellent and 28% (n=5) good functional results, while 55% (n=10) achieved excellent and 23% (n=4) good anatomical results, with no poor outcomes. These outcomes are comparable to those of previous studies on Pennig fixator in DR fractures. Dienst et al. studied 30 cases of closed comminuted and intra-articular DR fractures treated with a Pennig fixator and reported excellent functional outcomes in 20% of cases and good outcomes in 67%, with anatomical results showing 50% excellent and 47% good outcomes.^[13] Similarly, Kulshreshtha et al. achieved excellent functional results in 70% and good results in 30%, along with better anatomical outcomes than static external fixation. However, their series included all fracture types and both bridging and non-bridging configurations, with only 23% of patients presenting with AO type C fractures.^[14] Thus, indicating that Pennig fixator provides reliable anatomical restoration and favourable functional recovery in unstable DR fractures. It supports early wrist mobilisation and effective fracture stabilisation without major complications.

The improvement in our study was evident in grip strength, overall wrist range of motion, and pain reduction during follow-up. Supplementary K-wire fixation was employed in 16 cases, particularly in those with DRUJ subluxation. Radioulnar transfixation was performed in 83% of these fractures to enhance distal stability. Most patients reported only minor complications, and no major complications were observed. Superficial pin-tract infections occurred in 11% (n=2) of the cases and resolved with local pin-site care and a short course of broad-spectrum oral antibiotics. This rate was lower than that reported by Anderson et al., who observed 37.5% (n=9) pin-tract infections.^[15]

Modi et al. compared dynamic and static external fixation in unstable DR fractures and found that both methods yielded similarly good results with comparable complication rates. Although wrist motion can irritate the pin-skin interface, thereby increasing the risk of superficial infection, most cases reported were resolved with conservative measures.^[12] Alvarez Lopez et al. reported infection rates ranging from 10% to 39%, with most cases

responding to standard pin-site care and having no impact on final functional outcomes.^[16] Hence, the Pennig fixator with supplementary K-wire stabilisation ensures stable fixation and satisfactory wrist function with a low complication rate.

Factors contributing to the lower infection rate in our study likely include improved soft tissue perfusion from early wrist mobilisation and meticulous pin placement after manual reduction, as suggested by Graffe and Jupiter.^[17] Importantly, there were no cases of reflex sympathetic dystrophy (RSD), radial nerve irritation, wound complications, neurovascular compromise, pin loosening, finger stiffness, or malunion-related functional impairment, except for four malunions seen in closed AO type C3 fractures, comparable to findings reported by Anderson et al.^[15] Early wrist mobilisation with supplementary K-wire fixation likely contributed to maintaining fracture alignment through limited ligamentotaxis, preventing over-distraction, and reducing the risk of RSD.^[18]

The combination of Pennig dynamic wrist-spanning external fixator with supplementary K-wire stabilisation was particularly beneficial for maintaining articular congruity in multi-fragmented fractures. Anderson et al. and others have similarly emphasised K-wire augmentation to prevent late collapse in fractures managed with ligamentotaxis-based methods.^[15,19] Pennig fixator prevents over-distraction while allowing controlled motion, which reduces the incidence of complex regional pain syndrome (CRPS) and stiffness.^[20] Early wrist mobilisation with Pennig fixator and supplementary K-wire stabilisation helps in better soft-tissue recovery, maintains fracture alignment, and minimises complications such as infection, stiffness, and CRPS.

Compared with static fixators, dynamic devices have better functional outcomes and controlled early motion, which accelerates recovery and joint rehabilitation. Our findings confirm that Pennig dynamic external wrist-spanning fixation with selective K-wire supplementation is an effective, stable, and minimally invasive technique for treating unstable comminuted and intra-articular DR fractures. It is associated with soft tissue preservation, early wrist motion, reliable maintenance of anatomical alignment, favourable long-term functional and radiological outcomes, and a low complication rate. Although volar locking-plate fixation is currently preferred for certain fracture patterns due to direct visualisation and stable internal fixation, Pennig dynamic external fixation is still a reliable and cost-effective alternative. This is especially in resource-limited settings and in cases with extensive comminution or soft-tissue compromise where open reduction and internal fixation may not be possible.

Limitations

It was a small, single-centre study without a control group for direct comparison with other fixation methods, such as static external fixation or volar plating. The follow-up period was too short to assess long-term functional outcomes, late complications or post-traumatic arthritis. Subjective assessments, such as pain and function, may have been influenced by patient variability.

CONCLUSION

Dynamic wrist-spanning fixation, combined with early wrist mobilisation and supplementary K-wire stabilisation, provides excellent functional and anatomical outcomes. It is associated with stable fixation, articular congruity, early rehabilitation, and low complication rates. We recommend a large multicentre randomised controlled trial comparing Augmentation versus open reduction and volar plating for comminuted intra-articular DR fractures, focusing on early wrist mobilisation and long-term outcomes.

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