

Joshi's External Stabilization System versus K-Wire Fixation in the Management of Distal End of Radius Fractures – A Prospective Observational Study

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ABSTRACT

Background: Distal radius fractures (DRFs) are most common in orthopedic practice; however, the treatment strategies for optimal functional outcomes remain uncertain. Thus, this study compared the functional and radiological outcomes of percutaneous Kirschner-wire (K-wire) and Joshi's external stabilization system (JESS) in patients with DRFs.

Methods: This prospective observational study was performed over 21 months (August 2022 to April 2024) in the Department of Orthopedics of a tertiary care institute. Based on the surgeon's preference, a total of 60 adult patients with DRFs were assigned to two groups: the K-wire group or the JESS group. Functional outcome was assessed with the Gartland and Werley (GW) Score, while radiological outcomes included residual deformity, radial height, ulnar variance, and palmar tilt. The outcomes were evaluated in 1.5, 3, and 6-months.

Results: Both groups had a significant decrease in GW score, from 1.5 to 6-months ($p < 0.0001$); however, the groups did not differ significantly ($p > 0.05$). Moreover, both groups were comparable regarding residual deformity, radial height, and ulnar variance ($p > 0.05$), except significantly greater palmar tilt in the K-wire group ($p < 0.05$). At 1.5-, 3-, and 6-months, radial height had a significant correlation with ulnar variance ($r = 0.45$, $p < 0.05$). At 6-months, GW score and ulnar variance had a significant correlation ($r = 0.21$, $p < 0.05$) and significant association ($OR = 0.32$, $p < 0.05$).

Conclusions: Both K-wire and JESS provided significant and comparable functional outcomes in patients with DRFs. Moreover, both techniques had comparable radiological outcomes, except for significantly greater palmar tilt with the K-wire.

Key-words: Distal radius fracture, External fixation, Functional outcome, Gartland and Werley score, K-wire fixation, Ulnar variance

INTRODUCTION

Distal radius fractures (DRFs) are the most common fracture of the upper extremity, contributing to 18% of overall fractures and 75% of all forearm fractures treated in the orthopedic settings ^[1].

However, with traditional methods, including closed reduction and casting treatment of unstable, fractures, DRFs are difficult to treat owing to several issues such as collapse, loss of palmar tilt, radial shortening, and articular incongruity ^[2]. These complications can lead to pain, functional loss, and permanent deformity ^[3,4].

Traditional percutaneous Kirschner wire (K-wire) fixation and the Joshi External Stabilization System (JESS) are effective techniques for managing DRFs. K-wire fixation is commonly used for stable, non-complex fractures and shows satisfactory functional and radiological outcomes ^[5]. Thaware *et al.* reported solid union with improved radial height and ulnar variance ^[6] while Rex *et al.*

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observed enhanced grip strength and hand function 6-months post-treatment, supporting the role of K-wire in stable union and early mobilization [7].

Contrarily, JESS, developed by Shukla *et al.* in the early 1990s, based on Ilizarov's principles, is a lightweight, cost-effective fixator that requires minimal instruments. It is particularly effective for complex fractures where the ligament of the axis aids healing. Shukla *et al.* noted excellent fracture union and functional mobility [8], while Parkhi *et al.* emphasized good outcomes by maintaining reduction and enabling early mobilization, with minimal complications, making JESS a viable treatment option [9].

The literature suggests that achieving anatomical reduction is crucial for favorable outcomes in DRFs, with evidence demonstrating satisfactory results with both percutaneous K-wire fixation [10] and JESS [11-13] when applied appropriately. However, an extensive literature review suggested that a head-to-head comparison of K-wire fixation and JESS in patients with DRFs is lacking. To address this knowledge gap, the present study aimed to compare the percutaneous K-wire and JESS in the management of DRFs and evaluate intermediate-term functional and radiological outcomes

MATERIALS AND METHODS

Study Design and Ethics- This prospective observational study was conducted over 21 months (August 2022 to April 2024) in the Department of Orthopedics of a tertiary care institute. The study was approved by the Institutional Ethics Committee and written informed consent was obtained from the patients.

Population- The study included adult patients aged over 18 years with acute DRFs sustained within the past 2 weeks. The patients had either Type A extra-articular fractures; Type B1, B2, or B3 incorporating partial articular fractures (displaced and non-displaced), dorsal rim fractures with radial styloid involvement, or volar rim fractures, respectively; or Type C1 or C2 non-displaced intra-articular fractures. The patients were excluded if they had Type B3 fractures with significant comminution, ligament injuries of the distal radioulnar joint, old or malunited fractures, open wounds, nerve or tendon injuries, inflammatory joint diseases, or if they were medically unfit. Based on the treatment received, a total of 60 patients were categorized equally into two groups:

The percutaneous K-wire fixation group and JESS fixation group.

Data collection- After enrollment in the study, a detailed history was taken and a thorough physical examination was performed in all the patients. Subsequently, routine laboratory investigations and x-ray of the forearm and hand (oblique/lateral views) were performed. The injuries were classified on the basis of fracture level and type. Finally, the radiographic and clinical outcome measures of both groups were assessed and compared.

In case of open fractures, debridement of the wound and thorough cleaning was done with normal saline. Closed/open reduction was achieved by traction and manipulation. To maintain reduction, percutaneous K-wire and JESS were used. An image intensifier (C-arm) was used as a guide. All the surgeries were performed by a single orthopedic surgeon.

Postoperatively, an X-ray was taken to evaluate the fixation. The patients were taught active mobilization of the unaffected fingers, elbow, and shoulder in the immediate post-operative period. Pin tract dressings were done regularly. The JESS and the K-wire were removed at 3- to 6-week intervals with immediate vigorous mobilization of the immobilized joint to avoid stiffness. The patients were followed-up for periodic evaluation at 1- and 3-week intervals, and then at 1.5-, 3-, and 6-month intervals to assess: stability of fixation, tenderness at fracture site, pin tract infections, and residual stiffness.

Postoperative Rehabilitation and Follow-Up Protocol-

Following surgery, the patients were monitored for 6-months, with specific assessments conducted at designated intervals:

At week 1, the patients were clinically assessed for any surgical site complications, including swelling, infection at the pin site, or displacement of wires or the external fixator.

At week 3, the wound dressing was changed, and x-ray examination was repeated to evaluate the progress of fracture healing, specifically the callus formation. Moreover, GW score was assessed to quantify the fracture alignment and displacement.

The GW score, a clinical assessment tool, evaluates the outcomes of DRFs, such as Colles' fractures [14]. It assesses various aspects of wrist and hand function

following fracture healing, including residual deformity, range of motion, level of pain, grip strength, and overall functional ability. The maximum possible score is 21, with a higher total score suggesting poorer hand and wrist function.

At 1.5-months, an X-ray examination was performed to determine if the fracture had healed adequately. If sufficient healing was observed, the implanted fixation device was removed, and another X-ray was taken to confirm its removal. Radiological parameters, including fracture union and alignment, were reassessed, along with the GW score.

The primary focus of 3-months follow-up visit was to reassess the GW score, which provides a comprehensive evaluation of fracture healing and alignment. Additional radiological parameters were assessed to monitor the overall progress. Similar parameters were assessed at 6-months, the final follow-up visit, to confirm the final outcome of the fracture treatment.

Sample size estimation- The sample size was calculated by the following formula:

$$n = \frac{(Z_{1-\alpha/2} + Z_{1-\beta})^2 (\sigma_1^2 + \sigma_2^2)}{(\mu_1 - \mu_2)^2}$$

A sample size of 60 subjects, 30 in each group, was sufficient to detect the difference between the groups, assuming a standard deviation of 39.7 and 0 in K-wire

group and JESS group, respectively, using a two-tailed Z-test of difference between means with 80% power and a 5% level of significance. Considering a dropout rate of 5%, the required sample size was 60 (30 per group).

Statistical Analysis- The data analyses were conducted using Epi Info version-6. The qualitative data were presented as frequencies and percentages, and the quantitative data were presented as mean (standard deviation). An independent sample t-test and the Chi-square test were used as tests of significance for the quantitative and qualitative data, respectively. The Spearman correlation coefficient was used to determine the correlation between DRF alignment, evaluated according to radiological criteria, and functional results, evaluated using the GW score. Multivariate logistic regression analysis was used to confirm the simultaneous effect of the GW score on radiological parameters associated with DRFs. The outcomes were presented as odds ratios (OR) with 95% confidence intervals (CIs). Statistical significance was determined at a $p < 0.05$.

RESULTS

The patients were predominantly male (77.3%), with a mean age of 41.7 (17.18) years. Most patients exhibited a radial height of 5 mm (40.0%), an ulnar variance of 2 mm (73.3%), and a palmar tilt 0° (46.7%) (Table 1).

Table 1: Demographic and radiological characteristics

Characteristics	n=60
Age, years, mean (SD)	41.72 (17.18)
Gender, n (%)	
Male	44 (73.3)
Female	16 (26.7)
Radial height, mm, n (%)	
-5	2 (3.3)
0	7 (11.7)
2	6 (10.0)
4	21 (35.0)
5	24 (40.0)
Ulnar variance, mm, n (%)	
-5	4 (6.7)
0	6 (10.0)
2	44 (73.3)
4	6 (10.0)

Palmar tilt (°)	
-5	2 (3.3%)
0	28 (46.7%)
2	2 (3.3%)
4	1 (1.7%)
5	10 (16.7%)
10	11 (18.3%)
12	6 (10.0%)

The majority of male patients were aged between 21 and 40 years (43.2%), while the majority of female patients were aged 41–60 years and ≥61 years (both 43.8%). Significantly greater proportion of males had an age of 40 years or less ($p=0.001$). The males predominantly sustained radius fractures due to a fall from a bike or bicycle (68.2%), while falls at home or the workplace

were the most common mechanism of injury in females (87.5%), suggesting a significant association between gender and mechanism of injury ($p=0.001$). Both males (70.5%) and females (75%) had fractures of the left radius, with no significant association between gender and the side of injury ($p=0.73$) (Table 2).

Table 2: Association of age, mechanism and side of injury with gender

Characteristics	Gender		p-value
	Male (n=44)	Female (n=16)	
Age, years, n (%)			
≤20	11 (25)	0 (0)	0.001
21-40	19 (43.2)	2 (12.5)	
41-60	9 (20.5)	7 (43.8)	
≥61	5 (11.3)	7 (43.8)	
Mechanism of injury, n (%)			
RTA	11 (25)	0 (0)	0.001
Fall at home or workplace	3 (6.8)	14 (87.5)	
Fall from bike/bicycle	30 (68.2)	2 (12.5)	
Side of injury, n (%)			
Right	13 (29.5)	4 (25)	0.73
Left	31 (70.5)	12 (75)	

In the K-wire group, a significantly greater proportion of patients were male ($p=0.04$) and had radius fractures due to falls from a bike or bicycle ($p=0.02$). Moreover, the mean palmar tilt was significantly greater in the K-wire group ($p=0.002$). In the JESS group, a significantly

greater proportion of patients had left-sided radius fractures ($p=0.02$). However, the treatment groups did not differ in residual deformity, radial height, and ulnar variance (all $p>0.05$) (Table 3).

Table 3: Comparison of various characteristics among treatment groups

Characteristics	JESS (n=32)	K-wire (n=28)	p-value
Gender, n (%)			
Male	20 (62.5)	24 (85.7)	0.04
Female	12 (37.5)	4 (14.3)	
Side of fracture, n (%)			0.02

Right	5 (15.6)	12 (42.9)	
Left	27 (84.4)	16 (57.1)	
Mechanism of injury, n (%)			
Road traffic accident	7 (21.9)	4 (14.3)	0.02
Fall at home or workplace	13 (40.6)	4 (14.3)	
Fall from bike or bicycle	12 (37.5)	20 (71.4)	
Residual deformity, n (%)	3 (9.4)	3 (10.7)	0.86
Palmer tilt, degrees, mean (SD)	2.09 (4.20)	5.82 (4.91)	0.002
Radial height, mm, mean (SD)	9.56 (2.70)	10.11 (2.23)	0.40
Ulnar variance, mm, mean (SD)	1.69 (1.33)	1.57 (1.26)	0.73

In both JESS and K-wire groups, GW score decreased significantly from 1.5 months to 6-months ($p < 0.0001$). At 1.5 months, the GW score was slightly greater in the K-wire group, while the GW score was greater in the JESS

group at 3- and 6-months. However, both groups did not differ significantly at any of the intervals (all $p > 0.05$) (Table 4).

Table 4: Comparison of post-operative Gartland and Werley Score

Intervals	JESS (n=32)	K-wire (n=28)	p-value
1.5-months	15.06 (3.45)	16.61 (4.53)	0.14
3-months	12.31 (3.13)	10.32 (5.31)	0.07
6-months	10.06 (2.97)	9.54 (2.13)	0.44
p	< 0.0001	< 0.0001	

At the 1.5- and 3-month follow-up, radial height had a positive, moderate, and significant correlation with ulnar variance ($r=0.53$, $p < 0.01$), suggesting that patients with greater radial height tend to have greater ulnar variance from 0 mm to 2 mm. While palmar tilt and GW score did not have a significant correlation with each other and with radial height as well as ulnar variance (all $p > 0.05$). At 6-months, in addition to a significant correlation

between radial height and ulnar variance ($r=0.53$, $p < 0.01$), GW Score had a positive, weak, and significant correlation with ulnar variance ($r=0.28$, $p < 0.05$), suggesting a slight tendency for patients with ulnar variance between 0 mm and 2 mm to have better functional outcomes. However, this relationship was weak (Table 5).

Table 5: Correlation of radiographic parameters and Gartland and Warley score

Correlation	Palmar tilt (°)	Radial height (mm)	Ulnar variance (mm)	Gartland and Werley Score
At 1.5-months				
Palmar tilt (°)	1	-0.08	-0.17	0.22
Radial height (mm)	-0.08	1	0.53**	-0.15
Ulnar variance (mm)	-0.17	0.53**	1	-0.13
GW score	0.22	-0.15	-0.13	1
At 3-months				
Palmar tilt (°)	1	-0.08	-0.17	-0.22
Radial height (mm)	-0.08	1	0.53**	-0.05

Ulnar variance (mm)	-0.17	0.53**	1	0.11
GW score	-0.22	-0.05	0.11	1
At 6-months				
Palmar tilt (°)	1	-0.08	-0.17	-0.01
Radial height (mm)	-0.08	1	0.53**	0.10
Ulnar variance (mm)	-0.17	0.53**	1	0.28*
GW score	-0.01	0.10	0.28*	1

GW score= Gartland and Werley Score

On regression analysis, the Gartland and Werley score at 6 months was significantly associated with ulnar variance (OR: 0.32, p=0.03), but not with palmar tilt (OR: 0.03, p=0.79) and radial height (OR: -0.07, p=0.63) (Table 6).

Table 6: Logistic regression analysis for associations of radiographic parameters with GW score at 6-months

Variables	Odds ratio	(95% CI)	p-value
GW score	-	-	-
Palmar tilt (°)	0.03	-0.12, 0.15	0.79
Radial height (mm)	-0.07	-0.39, 0.24	0.63
Ulnar variance (mm)	0.32	0.03, 1.28	0.03*

GW score= Gartland and Warley score

DISCUSSION

The principal findings of the study suggested significantly greater palmar tilt in the K-wire group than the JESS group, while the groups were comparable regarding residual deformity, radial height, and ulnar variance. The GW score decreased significantly from 1.5-months to 6-months in both groups. However, both the groups did not differ significantly at any of the intervals. Radiologically, at 1.5-, 3-, and 6-months, ulnar variance correlated significantly with radial height. Moreover, at 6-months, ulnar variance had a significant correlation and association with the GW score.

External fixation, which uses ligament taxis for maintaining reduction, is particularly beneficial in open fractures where regular wound care is required. In DRFs, JESS is a form of spanning external fixator, effectively treating unstable, comminuted intra-articular fractures. Moreover, the JESS aims to maintain ligament distraction to stabilize fragments till union, while adhering to pin tract care and early mobilization [15]. The K-wire fixation is another commonly employed technique for managing DRFs, particularly in less complex cases. Its significant advantage is fragment-specific fixation, which preserves radial height, palmar tilt, ulnar variance, and carpal alignment, leading to better functional outcomes [16].

In the present study, the patients treated with JESS and K-wire fixation experienced significant improvement in the functional scores over time, with a significant decrease in GW score from 1.5-months to 6-months suggesting progressive recovery in wrist function with good mobilization and grip strength. A study reported that the JESS application for DRFs resulted in good to excellent functional outcomes in 82.2% of cases, thus demonstrating its efficacy in achieving sound fracture union and functional mobility [8]. Another study reported that percutaneous K-wire application for DRFs resulted in good (33.33%) to excellent (51.11%) functional outcomes in an 84.44% of cases on 6-month follow-up with GW score [17]. However, a few complications, including residual pain and dorsal angulation, were observed post-operatively in the majority of cases but were within acceptable limits, thus demonstrating K-wire efficacy in achieving good functional outcomes.

Overall, both groups demonstrated significant improvement in functional outcomes over time, with no significant differences at any of the follow-up intervals. This suggests that long-term functional outcomes are comparable between the two techniques. Though direct comparison in patients with DRFs is not available, Singh *et al.* reported comparable functional and radiological outcomes with K-wires and JESS in patients with metacarpophalangeal fractures [18]. Mahesh *et al.* found

that JESS was significantly more effective than K-wire in patients with extra-articular metacarpal fractures [19]. In the present study, the K-wire group showed a significantly greater mean palmar tilt, leading to better initial functional outcomes compared to the JESS group. Jianda *et al.* noted that palmar tilt and ulnar variance are key prognostic factors in DRF patients, with normal palmar tilt enhancing wrist mechanics, grip strength, and range of motion [20]. However, excessive tilt can alter load distribution, causing pain and reduced function. Caruso *et al.* noted that acceptable radiographic measurements of palmar tilt were associated with better functional outcomes in DRF patients [21].

In the present study, while both treatment groups did not differ significantly in residual deformity, radial height, or ulnar variance, the greater palmar tilt in the K-wire group may have contributed to maintaining wrist stability and alignment, which are crucial for optimal healing and recovery. However, the lack of significant correlation between palmar tilt and other radiological parameters in the current study suggests that while palmar tilt is important, it may not be the sole determinant of radiological success. Kamal *et al.* emphasized that restoring normal palmar tilt is important for wrist function, but the overall alignment and fracture stability also play significant roles [22]. This multi-factorial nature of recovery indicates that achieving an optimal palmar tilt alone may not guarantee favorable outcomes; rather, it should be considered alongside other radiological parameters.

Comparable radiological outcomes indicate that both techniques are capable of achieving comparable alignment and stability of the fracture site post-treatment. This is supported by previous studies emphasizing that K-wire fixation can be a reliable method for achieving satisfactory radiological outcomes [23,24]. Moreover, JESS is shown to provide effective radiological results [8]. Research indicates that both K-wire and JESS can achieve similar radiological outcomes. Mahesh *et al.* reported comparable rates of successful fracture healing and alignment between the two methods for extra-articular metacarpal fractures [19]. However, JESS was noted to provide better stability and enable early mobilization, potentially enhancing functional recovery.

In the present study, at 1.5-, 3-, and 6-months, radial height had a significant positive correlation with ulnar

variance, suggesting that patients with greater radial height tend to exhibit higher ulnar variance. This is consistent with other studies that emphasize the importance of maintaining radial height for optimal radiological outcomes in DRFs [25,26]. When the radial height is restored effectively, it stabilizes the wrist joint, thereby influencing the ulnar variance positively [23]. This relationship underscores the importance of achieving anatomical reduction during surgical interventions to ensure optimal functional outcomes.

At 6-months, a positive, albeit weak, significant correlation was observed between ulnar variance and GW score. This finding suggests that patients exhibit ingulnar variances between 0 mm and 2 mm tend to achieve better functional outcomes. The correlation, while significant, indicates that the relationship is not strong, implying that other factors may also influence functional recovery in patients with DRFs, such as the complexity of the fracture, the quality of surgical reduction, and individual rehabilitation efforts. For instance, Schindelar *et al.* found that while ulnar variance is important, functional outcomes are also affected by the overall alignment and stability of the wrist following treatment [27]. However, the significant correlation between ulnar variance and the GW Score can be attributed to the biomechanical implications of ulnar variance on wrist function.

The regression analysis further revealed that the GW score at 6 months was significantly associated with ulnar variance, but not with palmar tilt or radial height. This lack of correlation may suggest that while palmar tilt and radial height are important for achieving anatomical alignment, they may not directly influence functional outcomes as strongly as ulnar variance does. The GW Score, which combines both subjective and objective assessments of wrist function, may be more sensitive to changes in ulnar variance, reflecting its critical role in overall wrist stability and function [28,29].

LIMITATIONS

To the best of our knowledge, this is the first study to directly compare the JESS and K-wire in patients with DRFs. In addition to the assessment of radiological outcomes, we used the validated GW scoring system to evaluate the functional outcomes, which enhances the credibility of the findings by enabling standardized comparison. However, the study had a few limitations,

including a small sample size and single-centre settings. Additionally, the study focused only on two treatment modalities, the K-wire and the JESS, which may not encompass the full spectrum of available treatment options, such as volar locking plates, which have been shown to yield superior outcomes in certain fracture types. Lastly, the functional outcomes were analyzed at 6-months, thus large comparative studies assessing the long-term outcomes are required.

CONCLUSIONS

To conclude, both K-wire and JESS led to significant improvement in functional outcomes; however, both the techniques did not differ significantly. Radiologically, both techniques were comparable in terms of residual deformity, radial height, and ulnar variance, except significantly greater palmer tilt with the K-wire. Throughout the follow-up period, radial height correlated significantly with ulnar variance, while, at the end, ulnar variance and GW score had a significant correlation.

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