Original Article

Dynamic vs static external fixation of distal radial fractures: A randomized study

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Abstract

Objectives: The present randomized study is conducted to compare the functional and anatomical outcomes of dynamic multiplanar external fixation against that of static external fixation in the management of displaced unstable comminuted fractures of the distal radius.

Materials and Methods: Sixty adult patients with displaced unstable comminuted fractures of the distal radius were randomly allocated either to the dynamic (n=30) or static (n=30) fixator groups. Patients in the dynamic fixator group were managed with closed reduction and application of Penning-type articulated fixator (Orthofix, Srl, Italy); the injured wrist was partially dynamized at 3 weeks. Patients in the static group were managed with monoplanar static external fixator of Joshi's external stabilizing system (JESS) type fixator. In both groups, the fixator was maintained for 6–8 weeks. The patients were followed-up over 2 years. The primary outcome measures were the functional outcome as measured using the Gartland and Werley and DASH scores and anatomical outcome as measured using the Lindstrom score. The secondary objective was to correlate anatomical and functional outcomes and to look at overall local complications.

Results: Palmar tilt was better restored in the Penning fixator group ($P<0.0001$). There was reduced loss of ulnar tilt ($P=0.05$) and radial height ($P=0.04$) in the Penning fixator group. Gartland and Werley score was better in the Penning fixator group at each time point of the follow-up. The DASH score was similar in the two groups at 2 years ($P=0.14$). There was poor correlation (0.19) between functional outcome and anatomical restoration at 2 years.

Conclusions: In the management of displaced unstable comminuted fracture of the distal radius, use of an articulated multiplanar external fixator, allowing partial dynamization of the injured wrist at 3 weeks, resulted in improved early functional and anatomical outcome as compared to static external fixation. However, there was no significant difference in functional outcome at 2 years.

Key words: Comminuted fracture, distal radius, dynamic external fixation

Introduction

Since their description by Colles in 1814, distal radial fractures remain a therapeutic challenge.[1] Collapse, loss of palmar tilt, radial shortening, and articular incongruity is frequent after closed treatment of unstable and comminuted intra-articular fractures of the distal radius, and these often results in permanent deformity, pain, and loss of function.[2] The closed reduction and immobilization of displaced fractures in a cast may lead to early displacement,hence skeletal fixation to maintain the reduction has been recommended.[3,4] The incorporation of transfixing Kirschner wires (K-wires) within the plaster or use of external fixation is recommended for severely comminuted fractures.[5]

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Many external fixation devices are described to achieve reduction and fixation of the fragments without loss of position and acceptable functional results.[6] The ligamentotaxis is the basic principle used by external fixation.[4,7] Prolonged rigid immobilization of the wrist in an external fixator leads to decreased blood supply to bone and soft tissues and causes periarticular fibrosis. This leads to osteoporosis, poor motion, and compromised functional outcome. Often, intense physiotherapy is required to rehabilitate these patients.[8] The early mobilization of the wrist leads to normalization of blood supply, hastened functional recovery, earlier resolution of wrist swelling, and decreased joint stiffness.[3,9,10] Functional bracing and crepe bandages have been used successfully in the treatment of stable distal radius fractures.[11] However, many fractures have severe comminution, leading to significant instability. Melone[12] found only 17% stable fracture patterns in 300 cases. The dynamic external fixators have been developed to provide mobilization of the wrist while reduction and fixation are maintained.[8] One such fixator was first designed by Penning[13] (1990). The device allows wrist flexion by a hinge joint, with the center of motion being at the capito-lunate joint. This is based on several anatomic studies.[14,15] The objective of this randomized controlled study was to compare functional and anatomical outcomes of management of displaced unstable and comminuted fractures of the distal radius in adult patients with dynamic multiplanar external fixation (Penning-type fixator; Orthofix, Srl, Italy) against those of patients managed with static monoplanar fixation (Joshi's external stabilizing system[16]).

Materials and Methods

A randomized controlled study was carried out at a level II military trauma center. Ethical committee approval was obtained prior to initiation of the study. Patients were included in the study if they (1) had a displaced unstable comminuted fracture of the distal radius, which was defined as any distal radial fracture with more than 20° of dorsal angulation, metaphyseal comminution with or without intra-articular extension, and more than 10 mm loss of radial height (also included in the study were displaced shear fractures); (2) reported within 7 days of injury (fresh fracture); (3) had an age >20 years; and (4) gave informed consent for operative care. The subjects were excluded if they had (1) an open fracture; (2) a pathological fracture; (3) an injury severity score (ISS) of >17; (4) ipsilateral upper limb fracture; (5) fracture of the scaphoid or scapho–lunate dissociation of the same wrist; (6) preexisting inflammatory or degenerative arthritis of the injured wrist, ipsilateral elbow, or shoulder (which would affect the functional outcome).

Patients were randomly allocated to one of the treatment group, using sealed opaque envelopes. Baseline demographics and injury characteristics were recorded. We recorded comorbidities using the Sangha score.[17] All fractures were classified as per the AO classification.[9] Presence of distal ulnar fracture was recorded separately.

Operative procedure

All surgeries were performed under regional anesthesia and within 24–48 hours of admission.

JESS fixator application: In all cases, closed reduction was performed [Figure 1]. In AO type B and C fractures, percutaneous fragment fixation screws (FFS) and/or K-wires were used in a cross fashion to stabilize the fracture. Satisfactory reduction was confirmed under the image intensifier and the JESS fixator was applied. The image intensifier was used to apply minimum distraction across the wrist joint to maintain reduction.

Penning wrist fixator application: In all cases, the fixator was applied before fracture manipulation. In AO type B and C fractures, the fixator was applied in a trans-articular fashion [Figure 2]. Once reduction was achieved, K-wires, 4-mm lag screw, and/or FFS were used as described earlier to stabilize the reduction. On achieving the desired reduction the wrist was locked with the proximal ball and socket joint. The hand was placed in a functional position, moving at the distal ball and socket joint, and then locked. Finally, under the image intensifier, the minimum required distraction was applied across the wrist. In all AO type A fractures, the fixator was applied in a periarticular fashion [Figure 3].

Distal radio-ulnar joint: Stability of distal radio-ulnar joint was assessed in all cases. If it was found unstable, it was reduced by supinating the forearm. Two transfixing K-wires were used through the distal ulna into the distal radius to stabilize the joint. While using the Penning fixator we were able to use an ulnar outrigger to stabilize the distal radio-ulnar joint when required [Figure 4].

In patients with periarticular fixation, wrist movements were started in the immediate postoperative period and gradually increased. In patients with AO type B and C fracture with the Penning wrist fixator, the wrist was partially dynamized at 3 weeks, allowing 30° range of wrist motion (20° palmar flexion to 10° dorsiflexion) by unlocking the distal ball and socket joint. Full mobilization of the wrist by unlocking both the ball and socket joints three times a day was started 5 weeks post surgery. The fixator was removed at 6 weeks in all patients with AO type A fracture and at 8 weeks in patients with type B and C fractures, irrespective of the patient's age and degree of comminution of the fracture. The rehabilitation program was continued for 4 weeks after removal of the fixator. Local complications like pin track infection and reflex sympathetic dystrophy (RSD) were recorded.

The functional outcome was assessed using Gartland and Werley[18] score (modified by Sarmiento[19]) recorded at 3 months, 6 months, and 2 years and using DASH[20] score recorded at 2 years. All the scores were recorded by a trained physiotherapist. At each follow-up, radiography was repeated. A record was kept of the volar tilt of the distal radial fragment, the loss of ulnar tilt of the distal radius, and loss of radial height (as compared to the uninjured side). The same was graded as per Lindstrom's[3] anatomical score (modified by Sarmiento[19]). Anatomical results were further recorded in a descriptive manner.

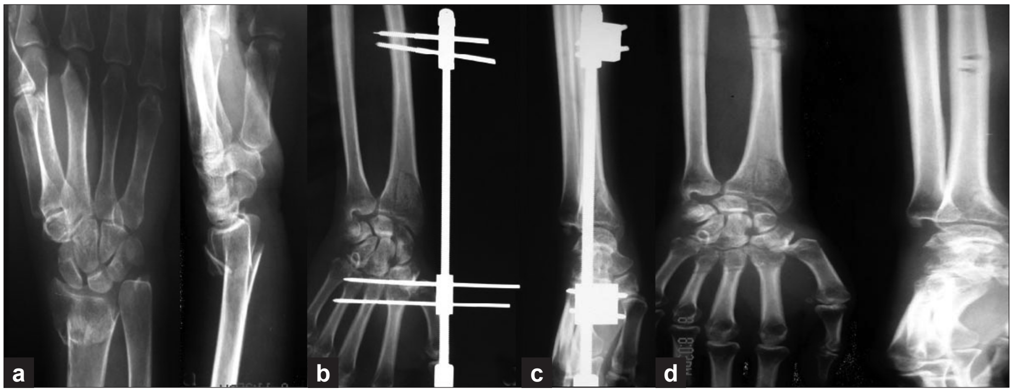

Figure 1: (a) X-ray of wrist joint anteroposterior and lateral view showing AO type A fracture of distal end radius. (b and c) Postoperative radiographs after application of JESS fixators. (d) Radiographs at removal of fixator

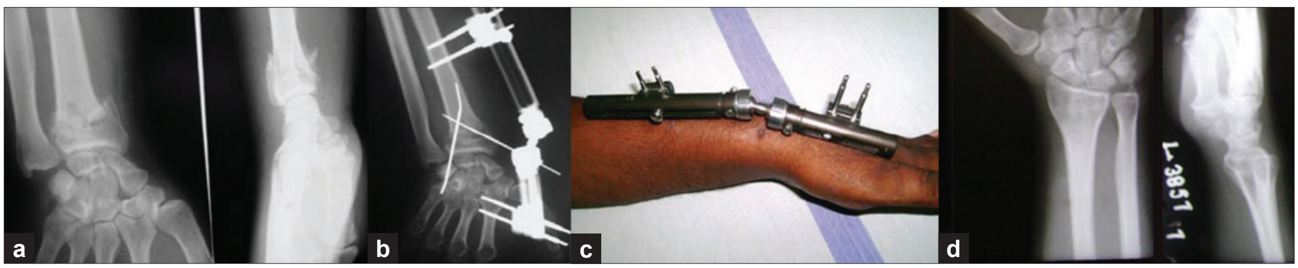

Figure 2: (a) X-ray of wrist joint anteroposterior and lateral view showing AO type C intra-articular fracture of the distal radius. (b) Penning fixator applied, additional fragment fixation screws used in a crossed fashion to stabilize the fracture. (c) Clinical picture of the patient with fixator *in situ*. (d) Radiograph of the wrist at 2 years follow-up

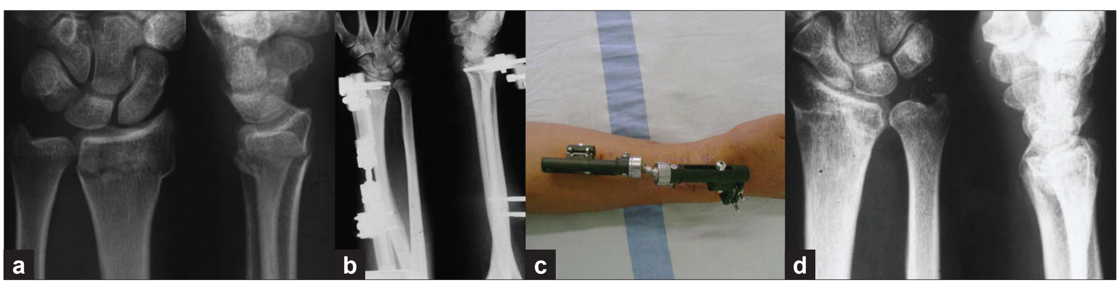

Figure 3: (a) X-ray of wrist joint anteroposterior and lateral view showing AO type A unstable extra-articular fracture of the distal radius in a young soldier. (b) Closed reduction done followed by application of Penning fixator. (c) Penning fixator applied using a T-clamp in a radio-radial (periarticular) fashion. (d) Radiographs taken at 2 years

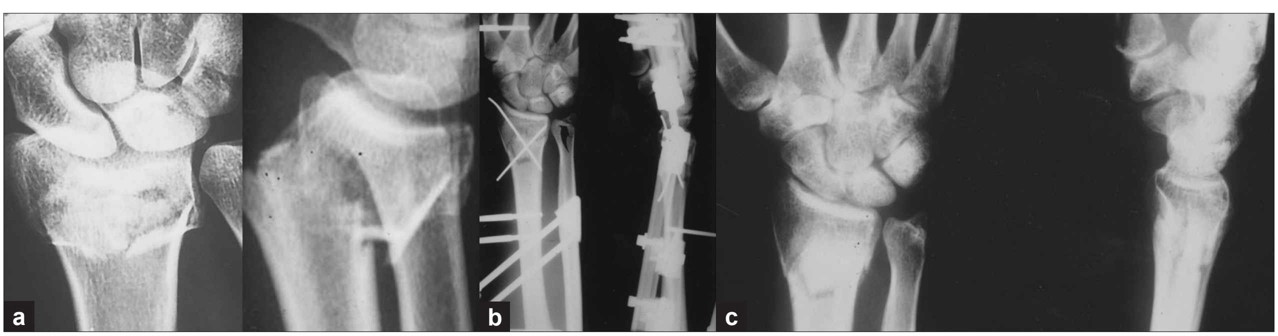

Figure 4: (a) X-ray of wrist joint anteroposterior and lateral view showing comminuted intra-articular fracture of distal radius; AO type C. (b) Penning fixator applied, fracture reduced, and unstable radioulnar joint stabilized using ulnar outrigger. (c) Radiographs taken at 6 months

A statistical analysis was performed using Stata® software version 10 (StataCorp LP, Texas, USA). The patient demographics and baseline injury data were compared in the two groups to identify possible confounders. Gartland and Werley scores assessed at each examination were pooled and regressed on two indicator variables:

1) management modality (JESS fixator vs Penning fixator) and 2) follow-up time. The fracture type, side of injury (dominant or nondominant), presence of ulnar fracture, and Sangha score were added to the regression model for statistical adjustment. The Wald test was used to investigate the overall effect of management and follow-up time on functional outcome and to look for any interaction between management and time. If the overall management effect was statistically significant, these differences were quantified. Since we had single time point results of DASH scores we used a nonparametric test (rank sum test) for comparison of the two groups. Simple regression analysis was done to look for effect of defined confounders. We tried to correlate the two functional scores and the anatomical score using Spearman correlation coefficient. The occurrences of complications were compared between groups using univariable Fisher's exact test, and surgical treatment effect was quantified by the relative risk (RR) (along with its 95% confidence interval).

Results

Sixty patients with the same number of fractures were included and equally assigned to the two treatment group between April 2006 and December 2007. The follow-up rate was 100%. The mean age of patients treated with JESS fixator was 41.2 years, which was comparable to that of the patients treated with the Penning fixator (43.0 years). The patients were predominantly males: 67% (n=20) in the JESS fixator group and 70% (n=21) the Penning fixator group). In both groups, most of the patients were soldiers (n=18 in each). The mean Sangha comorbidity score was 2.1 in the JESS fixator group as against 3.5 in the Penning fixator group. The dominant hand was injured in twelve (40%) patients in JESS fixator group as against fifteen (50%) in the Penning fixator group. Road traffic accident and falls were the predominant (>80%) modes of injury in both groups. The average ISS in the JESS and Penning fixator group was 4.7 and 4.3, respectively. As per the AO classification, the JESS fixator group had 14 type A, 4 type B, and 12 type C fractures. The Penning fixator group had 17 type A, 6 type B, and 7 type C fractures. Associated ulnar styloid or head fracture was present in 14 patients (47%) in the JESS fixator group as against 8 patients (27%) in the Penning fixator group [Table 1].

The mean delay between the time of injury and surgery was 3.5 days (range: 1–7 days). The average operative time was 48 minutes (range: 25–85 minutes) in the JESS group as against 32 minutes (range: 20–65 min) in the Penning fixator group. In type C fractures (n=18), we used K-wires and FFS to stabilize the fracture and support the articular fragments. In six cases in the JESS fixator group, after application of the fixator, on applying distraction force the fracture reduction was lost and hence during the surgery we had to reapply the pins to correct the wrist position in order to maintain reduction on distraction.

Correction of the volar angle to 6.5° was achieved in the Penning wrist fixator group as against 0.6° in JESS fixator group ($P<0.0001$). At 6 months the average volar angle of the distal radius in the Penning fixator group was 4.3° as against −1.7° (dorsal angulation) in the JESS fixator group ($P<0.0001$). The mean loss of ulnar tilt in the JESS fixator group was 5.2° as against 3.7° in the Penning fixator group ($P=0.053$). At 6 months the JESS fixator group had lost a mean of 6.7° of ulnar tilt, whereas the Penning fixator group had lost 5.9°. The Penning fixator group lost a mean of 1.3 mm of radial height postoperatively as compared to a loss of 2.5 mm in the JESS fixator group ($P=0.038$). At 6 months the average loss of radial height was 3.1 mm in the Penning fixator group as against 4 mm in the JESS fixator group ($P<0.0001$). Postoperative Lindstorm score was 1.9 in the JESS fixator group as against 0.7 in the Penning fixator group ($P=0.052$). At 6 months, the mean Lindstorm score was 3.5 in the JESS fixator group as against 2.6 in the Penning fixator group. The same score was also analyzed in a categorical manner as described by Lindstorm and Sarmiento [Figure 5].

The mean postoperative Gartland and Werley score as assessed at 3 months was 7.0 in the JESS fixator group as against 5.5 in the Penning fixator group ($P=0.0387$). Both groups showed significant improvement in function over the 2-year follow-up ($P<0.0001$). At 2 years, the mean score was 4.4 in the JESS fixator group as against 1.7 in the Penning fixator group [Figure 6]. The same score was also analyzed in a categorical manner. There was significant difference in the categorical outcome at 2 years ($P=0.015$); in Penning fixator group 70% (n=21) patients had excellent results and 30% (n=9) had good results, whereas in the JESS fixator group 25% (n=8) had excellent results, 65% (n=20) had good results, and 10% (n=3) had fair results. There was no significant difference in the mean DASH score between the two groups at 2 years ($P=0.14$). The mean DASH score was 14.0 in the JESS fixator group as against 11.2 in the Penning fixator group [Figure 7].

At 2 years, the DASH score had poor correlation with the Gartland and Werley and the Lindstorm scores (0.3; $P=0.06$ and 0.19; $P=0.23$, respectively). However, there was better correlation between the Gartland and Werley score and the Lindstorm anatomical score at 2 years (0.64; $P<0.0001$) [Figure 7].

Five patients (25%) had pin tract infection in the JESS fixator group as against four (20%) in the Penning fixator

Table 1: Patient demographics and injury characteristics of the two cohorts

Factors	JESS fixator (n=30)				Penning fixator (n=30)			
	n	%	Mean	SD	n	%	Mean	SD
Age (years)			41.2	6.9			43.0	6.6
Gender								
Male	20	67			21	70		
Female	10	33			9	30		
Occupational status								
Soldier	18	60			18	60		
House wife	10	37			9	30		
Retired active	2	3			3	10		
Body mass index			24.8	4.8			25.3	3.7
Comorbidity (Sangha index)			2.05	0.58			3.5	0.69
< 3	25	84			15	50		
3 - 6	4	13			9	30		
>7	1	3			6	20		
Dominant hand fractured								
Yes	12	40			15	50		
No	18	60			15	50		
Mode of injury								
Fall	12	40			12	40		
RTA	13	43			12	40		
Sports	5	17			6	20		
Injury severity score			4.7	0.6			4.3	0.61
0 - 5	20	67			22	73		
>5 - 10	9	30			6	20		
> 10	1	3			2	7		
AO classification								
A	14	47			17	57		
B	4	13			6	20		
C	12	40			7	23		
Associated ulnar styloid/head fracture								
Yes	14	47			8	27		
No	16	53			22	73		

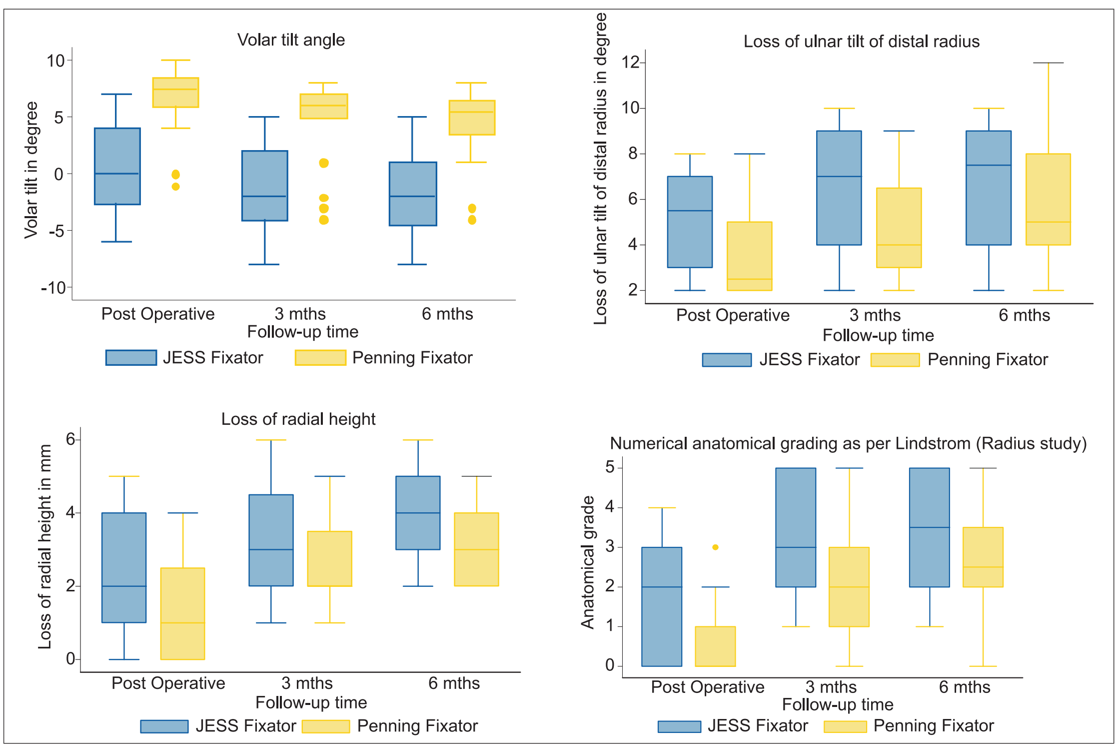

Figure 5: Box plots showing anatomical outcome in the two cohorts

group. Three patients (15%) in the JESS fixator group developed RSD as against two (10%) in the Penning fixator group. Two patients in each group (10%) experienced radial neuritis. There was no significant difference in the complication rates between the two groups (*P*=0.20).

Subgroup analysis (transarticular vs periarticular fixation)

We did a subgroup analysis using interaction for AO type A fractures. There were a total of twenty AO type A distal radial fractures managed (JESS fixator n=9; Penning fixator n=11). In the Penning fixator group all these fractures were managed by periarticular fixation, whereas in the JESS fixator group transarticular fixation was done. The mean postoperative Gartland and Werley score as assessed at 3 months was 7.7 in the periarticular fixator group as against 3.6 in the periarticular fixator group. Both groups showed improvement in function over 2 years of follow-up. At 2 years, the mean score was 5.2 in the transarticular fixator group as against 0.2 in the periarticular fixator group. The DASH score in the periarticular fixation group assessed at 2 year was better. The mean DASH score was 14.7 in the transarticular fixator group as against 7.5 in the periarticular fixator group [Figure 8].

Discussion

Dynamic external fixation was first introduced by Clyburn[8] in 1987. He proposed to reduce the final disability associated with an unstable fracture of the distal radius by facilitating early motion of the wrist. Similar results were obtained by Penning and coworkers using their design of a dynamic fixator.[13,21–22] Klein *et al.* in their small study showed that dynamization of the wrist at 3 weeks may lead to improved function.[23] Our study revealed significant advantage in terms of anatomical restoration and early functional outcome of early dynamization using the Penning fixator for displaced unstable comminuted fractures of the distal radius. However, the patient-reported function, as assessed by DASH score, was similar in the two groups at 2 years. Our results are at variance with the results obtained in a randomized trial conducted by Sommerkamp *et al.*[24] and by McBirnie *et al.*[25] The Penning fixator group consistently restored the palmar tilt of the distal radius, and loss of ulnar tilt and radial height was less than in the JESS fixator group. In both groups there was evidence of loss of achieved anatomical correction over 6 months of follow-up. Early wrist movements by unlocking the ball and socket joint did not lead to accelerated loss of reduction as compared to static fixation, which is in contradiction to the results of Sommerkamp *et al.* Our study concluded that none of the fixators were able to reliably restore or maintain the anatomy of the distal radius over mid-term follow-up. This compares well with the comparative study of McBirnie and coworkers. Better anatomical restoration did not ensure better function at 2-year follow-up as assessed

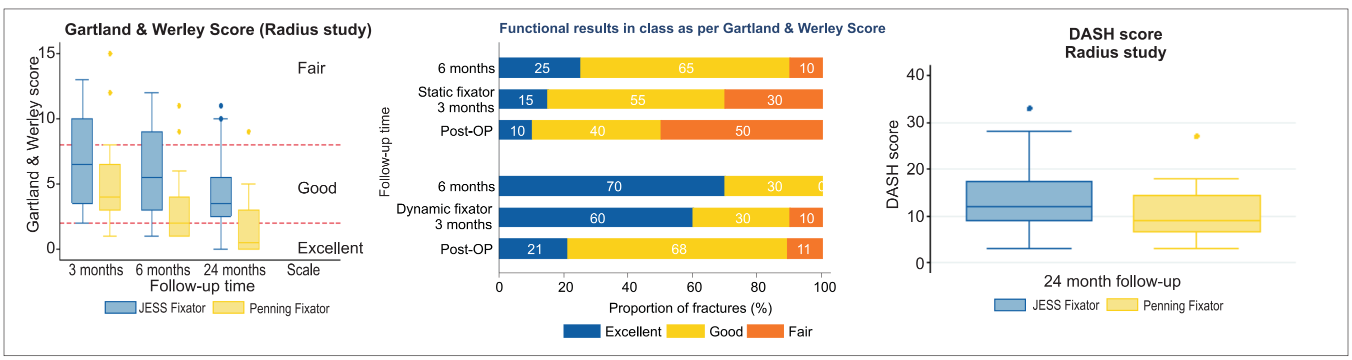

Figure 6: Graphics showing numerical and categorical Gartland and Werley scores and DASH score in the two cohorts

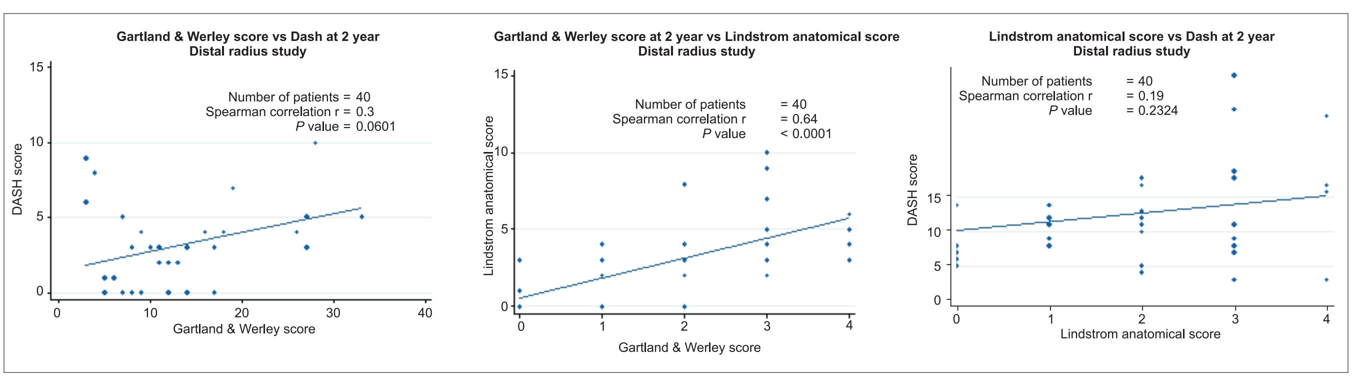

Figure 7: Two way scatter plot showing the correlation between functional and anatomical outcomes in the two cohorts at 2 years

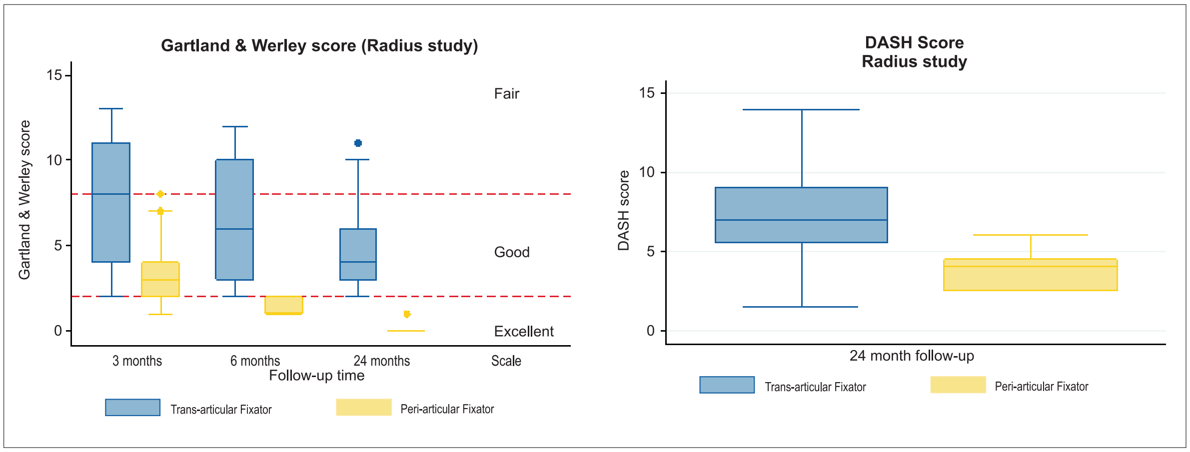

Figure 8: Box plots of Gartland and Werley and DASH scores at 2 years in the AO type A fractures as per treatment (transarticular vs periarticular external fixation)

by the DASH scores. Similar results have been published by many authors.[26] The Gartland and Werley score, which is a combined subjective (patient-oriented) and objective (surgeon-oriented) score, showed better correlation with the anatomical outcome. Restoration of anatomy may lead to improved restoration of objective measurement of joint movement and function but it has little effect on subjective functional outcome.

It seems that non-bridging external fixation of AO type A fractures achieves better functional and anatomical outcome. These results compare well with those seen by McQueen and coworkers.[27] The pins in the distal fragment permit the surgeon to have direct control, which allows exact repositioning. There is no mechanical restriction of wrist movement with a non-bridging fixator and this allows immediate postoperative mobilization of the wrist. Non-bridging external fixation may be the treatment of choice for unstable fractures of the distal radius in which external fixation is contemplated and there is sufficient space in the distal fragment. Larger clinical trials are needed to confirm the utility of non-bridging external fixators in this subgroup of fractures.

Our study has a few limitations. Most of our patients were active males below 60 years of age and had good bone stock. Hence it may not be possible to extrapolate our results to an older age-group or postmenopausal female patients with poor bone quality. Another limitation of our study is that 60% of the patients were soldiers. Although the patient data was anonymised and it was made explicit to the subjects that any data from the study would not be used beyond the purview of the study, the patient-reported outcomes may have been biased in case of soldiers who may have wanted to hide any disability. It was not possible to blind the subjects to the treatment in both the groups. The major strength of our study is the 100% follow-up rate.

Over last decade there have been numerous clinical trials that have tried to find the best method of management for displaced unstable comminuted distal radial fractures. A Cochrane review[28–30] of the subject concluded that there is still no robust evidence to support any specific modality of treatment. Our study used a specific design (Penning fixator) of dynamic external fixator and compared its result with that of a static fixator (JESS type). When used as a transarticular (bridging) fixator for management of displaced unstable comminuted distal radial fractures in young adults, the Penning fixator did demonstrate better anatomical restoration and early objective functional results as compared to the static fixator. The limited range of wrist movement that it allowed at 3 weeks did result in improvement in early functional outcome; however, it did not have significant difference on patient-reported function at 2-year follow-up.

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