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Functional Outcome of Joshi's External Stabilization System Fixation Using Ligamentotaxis in Displaced Distal Radius Fracture

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ABSTRACT
Distal radius fractures account for almost one-sixth of all fractures in a casualty setting. The usual aim of distal radius fracture treatment is to restore the function of the wrist joint, of which the distal radius is an important part. To describe the functional outcome in patients presenting with displaced distal radius fractures who undergo Joshi's external stabilization system (JESS) fixation. An observational study was done among 32 working-age (18-55 years) patients presenting with unilateral displaced distal radius fractures (excluding volar displaced) and subsequently treated with JESS fixation. The outcomes of the patients were assessed using the Green and O'Brien Scoring System modified by Cooney *et al.* at six months and one year following the surgery. Radiographs were also taken postoperatively and during follow-up. Acceptable functional outcomes (good and excellent scores in the Green and O'Brien Scoring System) were observed in 78.1% of the study population. Though the functional outcome scores were higher among the younger age group, a statistically significant difference was not obtained. 96.9% of the patients had acceptable radiological reductions, and infection of the pin tracts complicated 9.4% of the cases. A significant improvement in outcome scores (p-value 0.0001) was observed between the outcome scores at six months and one year after surgery. JESS fixation is an easy and effective method for treating displaced distal radius fractures to achieve good to excellent clinical outcomes. The functional outcome scores were better in the younger age group and male patients, but no statistically significant difference was observed.

INTRODUCTION

Among all the fractures, the distal radius fractures are the commonest. It has been estimated that one-sixth of the fractures encountered in a casualty setting are distal radius fractures[1]. There is a bimodal age distribution for these fractures, with the first peak among young adults and the second among the elderly. The fracture mechanism can be as trivial as a simple falling on an outstretched hand, especially in the older age group. In younger patients, considerably more energy is required to cause fractures like in sports injuries and motorcycle accidents[2]. Worldwide, the incidence of distal radius fracture is increasing, especially among the younger age group.

The distal radius can be considered the most important bone of the wrist joint. Fractures of the distal radius will profoundly influence the movements of the wrist joint. Therefore, prompt treatment is required to restore the function of the wrist joint. The outcome of the distal radius fractures can reliably be predicted with the radiographically acceptable reduction of the distal radioulnar joint (DRUJ), which corresponds to anatomical reduction. Anatomical reduction is especially significant for the younger working-age group. For example, α 23-year-old athlete may want to resume competition, but an 80-year-old person usually only wants to return to activities of daily living. Therefore, treatment goals must be tailor-made to each patient. However, treatment should be determined not by age but by activity level[3].

Treatment of distal radius fractures widely varies according to the treatment goals, ranging from cast immobilization to operative management. Although a wide variety of management options are available for distal radius fractures, there seems to be no consensus regarding the optimal therapy[4]. In the study cast Immobilisation vs. Wire Fixation in the Management of Middle-aged and Elderly Patients with Distal Radius Fractures, Jordan *et al.* find that cast immobilization can lead to poor radiological outcomes, but the functional results are comparable to operative management in the elderly[5]. Still, poor radiological outcomes can lead to poor functional results, especially in the younger age group. Since a better radiologically acceptable fracture reduction is attained using operative methods, there is an increase in the popularity of the surgical fixation of distal radius fractures. Sander *et al.* suggest that the indications for surgery should correlate with the fracture's severity, not age[6].

Displaced fractures not reducible with closed manipulation are preferably treated by surgery. Operative treatment methods include percutaneous pinning, external fixator and open reduction with internal fixation. The number of people undergoing surgical fixation increases due to better outcomes associated with the anatomical reduction of the DRUJ and wrist joint. External fixators are used for the management of fractures to obtain and maintain reduction throughout the treatment period, usually without touching the fracture region. Joshi's external stabilization system (JESS) is an external fixator developed by Dr. B. B. Joshi *et al.* from Mumbai. Even though JESS is weaker than an Ilizarov fixator[7] because it is cost-effective and easily applicable, it can be used for various conditions, including burn scar contracture and clubfoot[8,9] and has a prominent place in managing displaced distal radius fractures.

External fixation is the technique of skeletal immobilization by fixing percutaneous pins into the bones and linking them to connecting rods placed external to the body, forming a rigid framework. JESS is an external fixator that works on the principle of ligamentotaxis, which uses continuous longitudinal force or distraction to bring fracture fragments to close together. The longitudinal distraction force causes the soft tissues surrounding the fracture to help mold the bony fragments and facilitate reduction. JESS is a simple, cost-effective technique with a minimal learning curve to master its application and can be an excellent alternative to cast immobilization, especially when good radiological outcomes are warranted.

The functional outcome after distal radius fractures can be measured using Green and O'Brien Scoring System[10]. This system was subsequently modified by Cooney *et al.* which has four headings pain, occupation, range of motion and grip strength. If the hand is injured, then dorsiflexion-palmar flexion arc is used for scoring instead of grip strength. The evaluation of function can be done during the follow-up periods after the procedure

MATERIALS AND METHODS

This was a prospective observational study involving patients presenting with fractures of the distal radius and treated with JESS at our hospital from May 2022-june 2023. The inclusion criterion was fractures of the distal end of the radius limited to the age group 18-55 years, the group most probable to benefit best by intervention. The exclusion criteria were undisplaced fractures of the distal end of the radius where the JESS is not indicated, fractures with volar displacement in which plating is indicated and bilateral fractures of the distal radius where the wrist function cannot be compared against the unaffected side. For more straightforward data analysis, the patients were further subdivided into less than or equal to 40 and greater than 40 years of age. Thus it was estimated that a sample size of 28 patients is deemed satisfactory for describing the functional outcome.

JESS[12] is an external fixation system based on the principles of ligamentotaxis. When used for the management of distal radius fractures, JESS consists of applying four pins in the radius and the second metacarpal connected by a threaded or serrated connecting rod with provision for distraction. Two 3.5 mm Schanz pins are applied in radius 2-3 cm proximal to fracture, preferably under direct vision, to avoid injury to the superficial sensory branch of the radial nerve at the junction between the distal and middle third of the radius. The two 2.5 mm Schanz pins are applied in the proximal part of the second metacarpal's bare area between the first dorsal interossei and the extensor tendons through the JESS distractor slots. The distractor is then used to attain reduction by ligamentotaxis.

The outcome of treatment after JESS fixation was evaluated using the Green and O'Brien Scoring System, which assesses wrist function under four categories, namely pain, activity, range of motion and grip strength. Each has a minimum score of 0 and a maximum of 25. Written informed consent was taken from all subjects. A questionnaire containing questions like age, gender, side of the fracture, comorbidities, and complications was used. Sociodemographic details were recorded. For the indicated cases, a JESS fixator was applied after preoperative radiographs and follow-up radiographs were taken immediately after surgery. Criteria for acceptable reduction based on already established guidelines for the age group under study included radial inclination greater than 15 degree, radial length with <5 mm shortening, radial tilt with <5 degree dorsal tilt and articular incongruity with <2 mm step-off[14]. IV antibiotics were given for the first day and then for one-week oral antibiotics. Finger mobilization was initiated from the first post-op day. Pin tract care was advised comprising daily showers and dry dressings. At four weeks, in stable cases, JESS was removed and a short arm cast was applied. Casts were removed at six weeks and reviewed at six months and one year, along with fresh X-rays. In unstable cases, JESS was to be retained till six weeks, but no case in the study required retainment of JESS till six weeks. Outcomes of patients were assessed using the Green and O'Brien Scoring System modified by Cooney *et al.* at six months and one year following surgery. The final score of 80-89 is considered as good result and 90-100 is regarded as an excellent result, both of which are acceptable outcome results. Two-tailed t-test assuming unequal variance was performed to compare two age groups (<=40 years vs. >40 years) and two gender groups (males vs. females).

RESULTS AND DISCUSSIONS

All the patients in this study were treated on an outpatient basis. On average, the procedure of the JESS application took about 30 minutes. The JESS distractor was maintained for four weeks and further immobilization in the cast was done for two more weeks. Among the 32 patients who were studied, the mean age was 39.8 years, with a standard deviation of 10.06. Most patients were older than 40 years and in all the age groups, around two-thirds were males. All the patients in the study were right-handed and nearly two-thirds of the fractures were on the right side. As per the previously set exclusion criteria, patients with bilateral distal radius fractures were not included in the study to ensure that the functional outcome scores were measured objectively by comparing the function to the unaffected limb.

As expected, high energy trauma like road traffic accidents was the primary cause of the fracture in this study because the patient group belongs to the younger working-age group. Traumatic causes like falling from a standing height on an outstretched hand are classified as low-impact injuries. Low energy impact injury is the most common cause of distal radius fractures in the general population because these fractures are commonly seen in the osteoporotic elderly. In the strong bones of younger, a considerable force is required to cause distal radius fractures.A radiologically acceptable reduction was not attained in one patient with suboptimal functional outcome scores at six months and one year.Three patients (9.38%) had diabetes mellitus. All three had reasonable glycemic control and were on medications. Five (15.63%) patients (including one with diabetes) had hypertension. No other comorbidities were recorded in the study population. Three patients (9.38%) developed pin tract infection after the JESS fixation. Of these, one patient had diabetes mellitus and one had hypertension. All cases of infection had closed fractures and no infection was reported among the open fracture group.

Reduction of pain is the most crucial aspect as far as the patient is concerned. Returning to previous activity is also an essential part of the functional outcome because it objectively measures morbidity reduction following the treatment. After the procedure, the patients were followed up at six months and one year to measure the functional outcome based on the Green and O'Brien score and the JESS was found to be helpful in the mitigation of pain in distal radius fractures allowing resumption of prior activity. All the patients had a poor range of motion after the procedure, probably because of stiffness of the wrist joint caused by prolonged immobilization. The grip strength was measured objectively by comparing it with the unaffected opposite side. The results were much better at the end of one year when compared to six months. Outcomes were much more favourable in

those <40 years, with just one patient having a low functional score. The mean of the functional outcome scores in males was better than in females. The distribution of functional outcome scores is detailed in Two-tailed t-test assuming unequal variance was performed to compare two age groups (<=40 years vs. >40 years) and two gender groups (males vs. females). The p-value for the age group comparisons was 0.2129, and that for gender comparisons was 0.1679. The tests failed to reject the null hypothesis (Ho). Therefore, the difference between the age and gender groups was not statistically significant. However, all groups showed statistically significant improvement in the outcome score at one year compared to the six-month levels (p-value 0.0001).

Table 1: Distributions of Functional Outcome Scores

Score category	Mean±standard deviation	
	6 months	1 year
pain	19.8 ± 3.2	23.4 ±2.4
occupation	21.9 ±4.7	23.9 ±2.5
Range of motion	11.7±3.7	15.3 ±4.2
Grip strength	17.5 ±6.5	21.1 ±5.6
Total score	70.9 ±14.6	83.8 ±10.0

Investigations: A CT scan is helpful for intra articular fractures, particularly for preoperative planning. MRI is useful in evaluating the soft-tissue injuries associated with 70% of the distal radius fractures, including TFCC injuries, scapholunate ligament injuries and lunotriquetral ligament injuries. However, as in the case of fractures in general, when a patient presents with a history of distal radius fracture, the initial investigation ordered is the plain radiographs of the wrist in two planes (anteroposterior and lateral)[19]. Based on the radiograph, the fracture is classified and appropriate treatment is decided considering the patient-specific needs. The normal radiological anatomy is to be understood to know the extent of the success of intervention as well.

Clinical Cases Case 1:

Fig. 1: Pre op Image Post op Image 1 Month Follow Up

Fig. 2: Clinical Images

Case 2:

Fig. 3: Pre op Image Post op Image 1 Month Follow Up

Fig. 4: Clinical Images

Case 3:

Fig. 5: Pre op Image Post op Image 1 Month Follow Up

Fig. 6: Clinical Image

Treatment and Complications: The goal of fracture treatment is to restore functionality and this depends on the patient's prior activity level. A successful outcome is correlated with the accuracy of anatomic reduction, restoration of anatomic relations and early efforts to regain movement of the wrist and fingers. The methods of treatment are broadly divided into non-operative and operative. Closed reduction with cast immobilization is the most commonly administered form of treatment for distal radius fractures, particularly in osteoporotic fractures in the elderly. Indications for this conservative therapy include extraarticular fracture, <5 mm radial shortening and dorsal angulation <5 degrees or within 20 degrees of the contralateral distal radius after a closed reduction. One troublesome complication to the conservative management is the rupture of the extensor pollicis longus tendon, most probably due to ischemia. It can also lead to acute carpal tunnel syndrome.

Operative techniques for treating distal radius include closed reduction and percutaneous pinning (CRPP), external fixation and open reduction and internal fixation (ORIF). Operative treatment is best suited for unstable distal radius fractures where conservative treatment would most likely fail. The outcomes for the CRPP procedure are excellent, provided proper case selection is first employed. An essential prerequisite for its success is the presence of a stable volar cortex. Techniques include the Kapandji intrafocal technique and the Rayhack technique with arthroscopically assisted reduction. ORIF utilizes plates and screws to help maintain reduction. Volar plating is preferred over dorsal plating. It can be combined with pinning and external fixation as well. Tendon irritation due to the implant is a possible complication.

External fixation relies on ligamentotaxis for maintaining reduction. One significant drawback is the inability to restore palmar tilt. Therefore, external fixation is frequently combined with other procedures like pinning to mitigate this restriction. External fixation is especially useful in an open fracture where regular wound care needs to be given. There are two types of external fixation based on whether the fixator crosses/spans the wrist joint or not. Non-spanning external fixation is useful when the distal fragment is large enough to be pinned and connected to the fixator framework. Spanning external fixation crosses the wrist joint, does not fix the distal fragment and relies solely on ligamentotaxis for reduction. When used in distal radius fractures, JESS is a form of spanning external fixator connecting the proximal fragment of the fractured radius and the second metacarpal crossing the wrist joint. In addition to the complications inherent to all distal end of radius fractures such as malunion, nonunion and stiffness, the external fixators can also cause pin-related complications like infection and iatrogenic injury to the superficial branch of the radial nerve. Post-procedure radiological imaging can help adjust the amount of distraction applied at the fracture site.

Functional Outcome in the Study Group: The most common fracture mechanism in the study group was a road traffic accident rather than a simple fall on an outstretched hand, probably because the strong bones of the younger adults required considerable force for the fracture to occur. Most of the patients in the study were free of comorbidities because, in our institution, JESS is generally used in patients without any associated significant illness. Radiologically acceptable reductions were achieved in all but one patient (about 97%). Due to data constraints, the association between the outcome and reduction could not be assessed. Three patients (9.4%) developed pin tract infection

following the surgery and were treated successfully with antibiotics.

The functional outcome scores following JESS fixation were measured at six months and one year after the procedure during the follow-up visits using the Green and O'Brien scoring system. The mean outcome scores were 70.9±14.6 at six months and 83.8±10.0 at one year. A score of 80 or more is considered acceptable. Around 40.6% of the patients had acceptable functional outcome scores (i.e., more than 80) at six months following surgery which grew to 78.1% by one year. The outcome scores were also better in the younger males, although no statistically significant difference was perceived. The findings were comparable to similar studies undertaken previously[11-20,21,22]

Table 2: Prestation of Acceptable Functional Outcomes.

Study	Mean age	Acceptable functional outcomes
Jupiter *et al.* 1996[20]	42 years	83.60%
Shukla *et al.* 2013[11]	40 years	77.80%
Kapoor *et al* 2000[21]	39 years	80%
Chaudhary *et al.* 2014[22]	43 years	66%
Our study	40 years	78.10%

The fractures of the distal radius are quite common, and various treatment options are available to manage them. External fixators are invaluable in the case of open fractures because better wound care can be provided. The lack of internal implants also makes the post-surgical infection less worrisome. One significant difficulty faced after continuous immobilization is the stiffness of joints which has significantly affected the functional outcome scores. Prolonged and intense physiotherapy may be required in such cases for recovery, as evidenced by the improvement in the range of motion scores at one year after surgery. Newer techniques like dynamic external fixators show much promise in the early mobilization that may lead to better functional outcomes due to the decreased chance of joint stiffness. However, the choice of management should be patient-centric, which takes the patient's requirements to the center stage. There is no need for aggressive strategies in an older adult whose functional needs will be much less than a young and active adult.

Different types of fractures may occur due to the anatomy of the distal radius and the effects of forces in different directions. It is not feasible to have a successful outcome using the same approach and materials for different types of fractures[23]. Many external fixation devices are described to achieve reduction and fixation of the fragments without loss of position and acceptable functional results[24]. The ligamentotaxis is the basic principle used by external fixation[25]. 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[26]. The early mobilization of the wrist leads to normalization of blood supply, hastened functional recovery, earlier resolution of wrist swelling and decreased joint stiffness[27]. The dynamic external fixators have been developed to provide mobilization of the wrist while reduction and fixation are maintained[26]. JESS fixator application in our study allowed sound fracture union with functional mobility in our study. Our study reflects a typical experience from the semi urban parts of India where different patient factors have to be considered when choosing the best available treatment. Treatment advised should be based on the best evidence, however patient preferences and cost effectiveness should be considered in choosing the final treatment. In conclusion JESS is a good option in patients with displaced distal end radial fractures.

CONCLUSION

JESS, a highly effective technique available for treating distal radius fractures, has an easy learning curve and cost-effectiveness, yielding an acceptable functional outcome in most patients with minimal complications and pitfalls. When properly applied to the indicated fracture patterns, it can result in a radiologically acceptable reduction in most cases. Knowledge regarding classification systems aids in understanding whether ligamentotaxis can be used for a specific fracture pattern or not. Emphasis on early mobilization and physiotherapy can definitely enhance the functional outcome.

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