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A clinical study of management of comminuted distal radial fracture in adults by external fixation and ligamentotaxis

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Abstract
Background: The primary goals of distal radius fracture fixation are to put the pieces back where they belong and, most importantly, to do so by a method that does not compromise hand function. Displaced comminuted intra-articular fractures of the distal radius are difficult to treat; successfully by traditional non-operative methods. Thus, external fixation plays a very distinct role.
Materials and methods: Twenty adult patients with closed comminuted intra- articular fractures of the distal radius were treated by closed reduction and immobilization with an external wrist fixator during period from Dec 2018 to Nov 2019. Six weeks later, the fixator was removed. The patients then were observed for an average of 6 months to 1year.
Result: An excellent outcome was seen in 3 patients (15%) good outcome in 11 patients (55%) and a fair outcome in 5 patients (25%) and poor outcome in 1 patient (5%). Minor complication, pin tenderness were present but recovered completely after removal of the fixator.
Conclusion: External fixator is simple and inexpensive. Displaced severely comminuted intra-articular fractures should be treated with an external fixator. It effectively stabilizes fractures yet allowing for hand and prevents stiffness. It is difficult to regain volar tilt by ligamentotaxis and maintain it by external fixators. Most complications are minor and easily treated and do not affect Outcome. The ease of use of the implants and successful track record make it an extremely versatile tool for treating complex fractures of the distal radius.

Keywords: Distal radius, comminuted intra-articular fractures, external fixator and ligamentotaxis

1. Introduction
Treatment of displaced fractures of the distal end of the radius has changed over the course of time. In the past, closed reduction with immobilization in a plaster cast was considered the treatment of choice.
Dr. Abraham Colles, in reference to fractures of the distal aspect of the radius, stated: "One consolation only remains, that the limb will at some remote period again enjoy perfect freedom in all its motions, and be completely exempt from pain1; the deformity, however, will remain undiminished throughout life." In 1814, when Dr. Colles described the fracture, there was no anesthesia (1846), no aseptic surgery (1865), no radiography (1895), no electricity (1879).
Nearly 20% of all fractures that are treated in emergency departments in the United States involve the distal end of the radius and have a bimodal age distribution, with the adolescent or young adult and elderly populations being the most affected. About 50% of metaphyseal fractures of the distal aspect of the radius also have involvement of the radio carpal and/or distal radio ulnar joint2. Many fractures of the distal aspect of the radius are in fact relatively uncomplicated and are effectively treated with closed reduction and immobilization in a cast. However, fractures that are
either unstable or involve the articular surfaces can jeopardize the integrity of the articular congruence and/or the kinematics of these articulations. Most orthopedic surgeons today would agree that a patient with a malunited fracture of the distal end

of the radius who "enjoy[s] perfect freedom in all...motions, and [is] exempt from pain," is the exception, not the rule. The goal of the treating physician should then be to restore the functional anatomy by a method that does not compromise hand function. The fracture pattern, the degree of displacement, the stability of the fracture, and the age and physical demands of the patient determine the best treatment option.

Over the past twenty years, more sophisticated internal and external fixation techniques and devices for the treatment of displaced fractures of the distal end of the radius have been developed3. The use of percutaneous pin fixation; external fixation devices that permit distraction and palmar translation; low-profile internal fixation plates and implants; arthroscopically assisted reduction; and bone-grafting techniques, including bone-graft substitutes, all have contributed to improved fracture stability and outcome.

The method of immobilization that maintains the reduction with the least amount of surgical morbidity is the ideal treatment. Unstable fractures of the distal part of the radius have shown an inherent tendency toward loss of reduction after non- operative treatment4. In 1929, Bohler lamented that "reduction of this type of fracture-dislocation is obtained relatively easily5. However, in the most severe cases, the fragments cannot usually be maintained in good position by an unpadded plaster cast." It has been recognized that, often, the ultimate functional result will depend, in large part, on the anatomical restoration of the fractured radius.

External fixator technique was not popularized until the late 1970 when Vidal *et al.* [6] described the principal of tension on the ligaments and capsule allowing reduction and coined the term 'ligamentotaxis'.

It has been popular for the treatment of displaced, unstable fractures of the distal part of the radius because it combines a minimally invasive procedure with reduction by ligamentotaxis4. A number of both static and
dynamic external fixators are in common worldwide use. The preferred design depends on the anticipated difficulty in maintaining radial length and alignment.

Many different external fixation devices have been developed and used. Even in severe fractures of the distal radius, they allow reduction and fixation of fragments without loss of position and good functional results. Clinical and anatomic studies show that ligamentotaxis is the basic principle used by external fixation. Through prolonged distraction by the fixator, tension is provided by the capsule ligamentous structures. Even in severe injuries, the soft tissues such as ligaments, retinacula, tendons, and periosteum remain intact.

2. Materials and method

In this study we include 20 cases of fracture of comminuted intra-articular distal radius fracture came to Shri Shankaracharya Institute of medical science, Bhilai (C.G.) from Dec 2018 to Nov 2019. Patients who met the criteria are admitted through OPD or casualty and treatment was given as standard guidelines after obtaining their informed written consent. Follow-up of patients was carried out at 6weeks for external fixator removal and then on average after 6 months to 1 year.

2.1 Inclusion criteria

- Male and female patients from age 20 to 60 years of comminuted intra- articular distal radius fracture who have given their consent for the procedure.
- Patients those are fit for surgery.

2.2 Exclusion criteria

- Patients medically unfit for surgery.
- Patients not willing for surgery.
- Patients below 20 years and above 60 years.
- Extra-articular fractures.

2.3 Methodology

After obtaining written informed consent from the selected patients, a careful history was elicited from the patients and/or attendants to reveal the mechanism of injury, the severity of trauma and evaluate their general condition and the local injury. It was done accordance to Acute Trauma Life Support protocol. Vital parameters were recorded. Methodical examination was done to rule out fractures at other sites or any other system injury. Local examination of injured forearm and hand such as attitude and position of affected upper limb compared with normal counterpart, any abnormal swelling and deformity, their level and direction. Palpation to check any local rise of temperature, soft tissue tenderness, any palpable step, breach in continuity of bone, any revealed abnormal mobility, Crepitus and shortening of forearm. Distal vascularity and sensory system was examined for pain and touch sensation in the radial, ulnar and medial nerve innervated areas. Movement: Flexion and extension of elbow, supination and pronation of forearm, dorsiflexion and palmar-flexion of the wrist were performed and any restriction of motion and pain observed.

Pre-operative radiological evaluation was done in two planes antero-posterior and lateral views and the fractures were classified according to Frykman's classification.7 The limb was then immobilized in below elbow plaster of Paris slab with sling. Pre- operatively routine blood and urine investigations were done, consent of patient or relative was taken prior to surgery. A dose of tetanus toxoid and antibiotic were given.

Implant and instruments

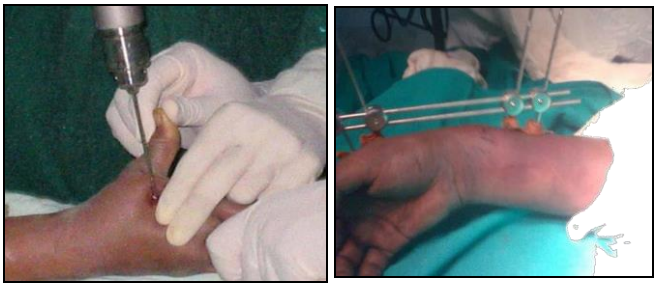
Surgical Technique: Under the effect of anesthesia (General anesthesia or brachial plexus block), the patient was placed supine on the operating table. Longitudinal traction was given with manual molding of the fracture fragments back into a more normal alignment (severe hyper-flexion or hyperextension is avoided). The wrist is maintained in mild flexion and ulnar deviation. The arm, fore-arm and hand were draped under aseptic precaution. The injured upper limb was placed on the side arm board. A stab incision was made approximately 10 cm proximal to the radial styloid over the

lateral aspect of the radius.

Through the stab incision the periosteum was displaced and the drill sleeve was fixed centrally. Care was taken not to injure the tendons, muscles, nerves in the process of drilling. The radius was drilled with 2.5mm drill bit, and 3.5mm schanz pin was fixed. A stab incision was made over the lateral aspect of the base of the 2nd metacarpal. It was drilled with 1.5mm drill bit and then fixed with 2.5mm schanz pin. Then the 4mm connecting rod was fixed to the schanz pins with the clamps. The other 2 schanz pins, inserted in the shaft of radius and the other in second metacarpal are fixed in similar fashion. Now the external fixation device is tightened and the reduction was carefully assessed clinically and under fluoroscopy; sterile dressings were done to the pins. Fingers were checked for capillary refilling, the fingers were left free to go through a full range of motion. No splint was given.

Antibiotics (Tab. Taxim 500mg 12 hourly for 5 days) were given along with analgesics as needed. The average duration from the date of injury to date of operation was 1-3 days.

Stab Incision



Post-operative care and rehabilitation: Check X -rays were taken in both Antero- posterior and lateral views on post-operative day one. The reduction of the fracture was confirmed and any displacement of fracture was studied. Tension across the wrist generated by the external fixation device should provide enough ligamentotaxis, so that on an Antero-posterior radiograph the radiocarpal articulation was seen to be 1 mm wider than the midcarpal joint.

Active exercises of fingers and thumb were commenced from the day of operation. Immediate post-operative check X–rays were taken in both AP and lateral views. The reduction of the fracture is confirmed. Third post-operative day the dressing were removed. The pins were cleaned with spirit on every alternate day for one week; later the patient was educated regarding pin site care. The patient was taught exercises for the hand. Pronation and supination of the forearm and active movement of the elbow and shoulder were advised throughout the period of the healing.

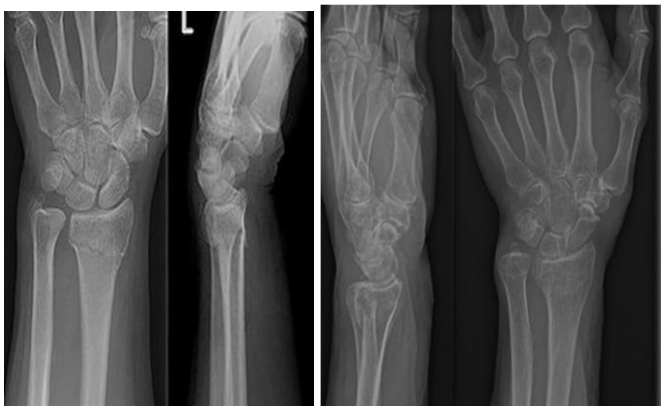
Follow up protocol - The patients were called back for follow up after 6 weeks for external fixator removal, then after 6 months. Also, in between if necessary, and depending on functional status of the upper limb further follow up, visits are advised. Patients were assessed subjectively for pain at the fracture site, clinically for tenderness. Range of movements of wrist was recorded.

Assessment of results: The assessment of anatomical and functional outcome was made according to modified Gartland and Werley scoring system. Demerit score system modified after Gartland and Werley (1951) [8]

The results were considered excellent (0-2), good (3-8), fair (8-18) and poor (19-33) depending upon score.

X Ray AP and lateral view (Frykman Type III)

Pre-OP Post-OP



After Removal (at 6weeks) After 6 months follow up

Dorsi Flexion Palmar Flexion

Supination Pronation

3. Results

We studied 20 patients with comminuted intra-articular fracture distal end of radius prospectively at Shri Shankaracharya Institute of medical science, Bhilai for 1-year period. The age of the patients ranged from 20 to 60 years. 16 were men and 4 were women. The mechanism of injury was a fall (low impact) in 12 patients and a motor vehicle accident (high impact) in 8 patients. The dominant side was injured in 14 cases and the non-dominant side in 6 cases.

All patients had unilateral closed fractures of the distal part of the radius. According to the Frykman classification, 4 fractures were Type III (20%), 3 were Type IV (15%),2 were Type V (10%),4 were Type VI (20%), 4 were Type VII (20%), and 3 were Type VIII (15%). 3 patients with high impact type injuries had additional fractures,1 patient had fracture shaft of ipsilateral femur, 1 had fracture of both bones of leg and 1 had fracture of the right patella.

3 patients had no deformity of the wrist and there was no pain. Limitation of motion of wrist and fore-arm was less than 20% to that of the normal. They did not have any complications and hence the result was rated as excellent.

11 patients had no deformity of the wrist. Occasional pain and some limitation of motion were present initially. The limitation of motion of wrist and fore-arm was less than 20% to that of normal. 1 patient had superficial pin tract infection which was controlled with local dressing and oral antibiotics. Hence the result was rated as good.

On subjective evaluation, 5 patients had pain, limitation of motion and restricted activities around the wrist. Range of motion-of wrist and fore-arm had limitation to less than 50% to that of normal. In this group 2 patients had ulnar styloid process prominence and the result was rated as fair.

1 patient who was operated 12 days after injury, had dinner fork deformity with pain, limitation of motion and restricted activities around the wrist. There was limitation of motion more than 50% associated with slight crepitation and the result was rated as poor.

Table 1: Age distribution according to outcome

AGE	Excellent	Good	Fair	Poor	P value
11-20	1(33.33%)	(0%)	(0%)		**0.017**
21-30	2(66.67%)	7(63.64%)	1(20%)	Significant	
31-40		4(36.36%)	0(0%)	1(100%)	
41-50			2(40%)		
51-60			2(40%)		
Total	3(100%)	11(100%)	5(100%)	1(100%)	

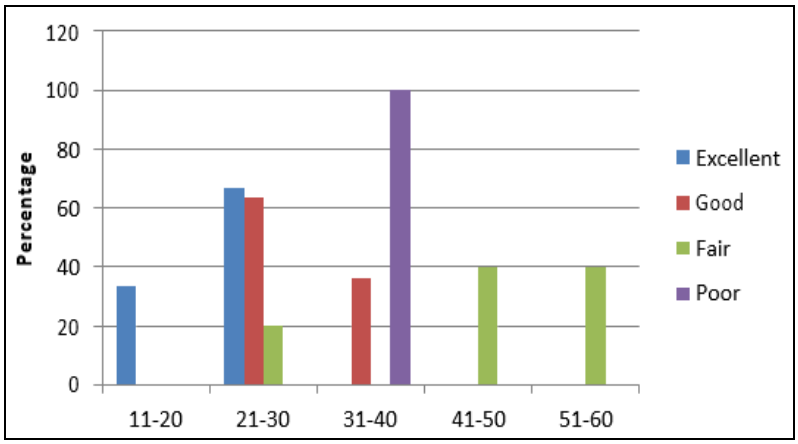


Fig 1: Age distribution according to outcome

Table 2: Sex distribution according to outcome

Sex	Excellent	Good	Fair	Poor	P value
Male	2(66.67%)	10(90.91%)	4(80%)	(0%)	0.16
Female	1(33.33%)	1(9.09%)	1(20%)	1(100%)	NS
Total	3(100%)	11(100%)	5(100%)	1(100%)	

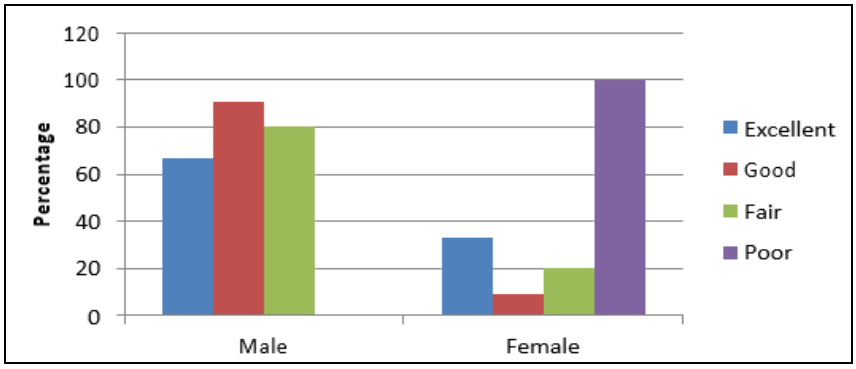


Fig 2: Sex distribution according to outcome

Table 3: Injury type according to outcome

Injury	Excellent	Good	Fair	Poor	P value
Fall	(0%)	4(36.36%)	3(60%)	1(100%)	0.22
RTA	3(100%)	7(63.64%)	2(40%)	(0%)	NS
Total	3(100%)	11(100%)	5(100%)	1(100%)	

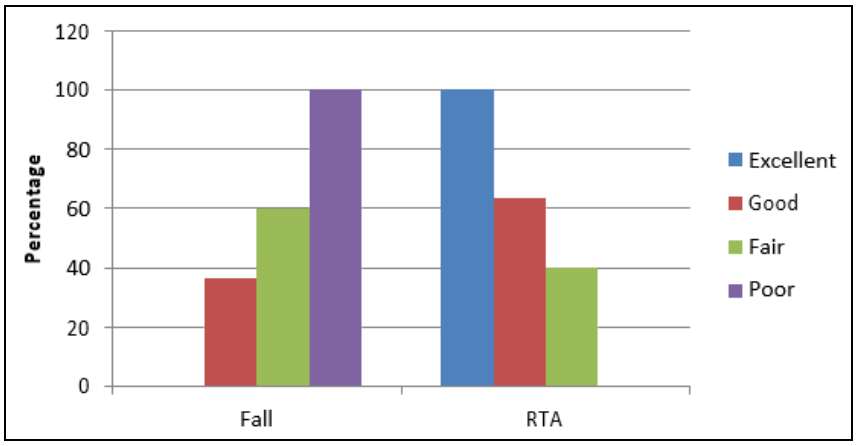


Fig 3: Injury type distribution according to outcome

Table 4: Side type according to outcome

Side	Excellent	Good	Fair	Poor	P value
Not Dominant	2(66.67%)	3(27.27%)		1(100%)	0.09
Dominant	1(33.33%)	8(72.73%)	5(100%)		NS
Total	3(100%)	11(100%)	5(100%)	1(100%)	

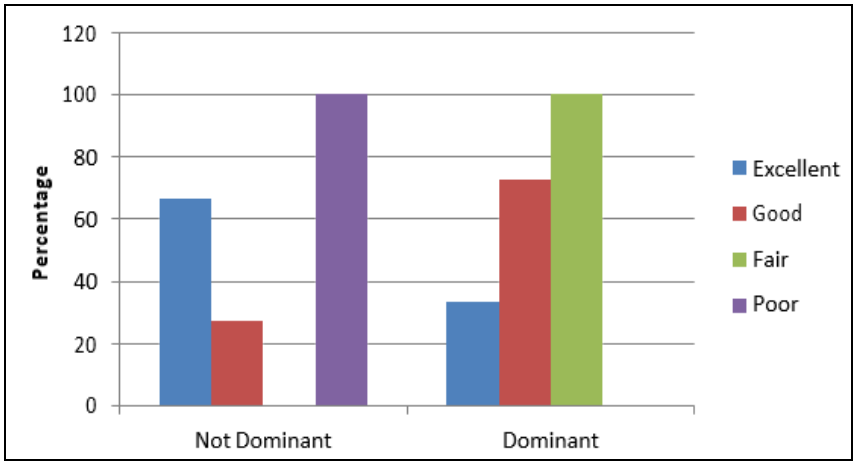


Fig 4: Side type distribution according to outcome

Table 5: Frykman type distribution according to outcome

AGE	Excellent	Good	Fair	Poor	P value
III	1(33.33%)	1(9.09%)	2(40%)		
IV	1(33.33%)	1(9.09%)	1(20%)		
V		2(18.18%)	(0%)		0.89
VI		3(27.27%)	1(16.67%)		NS
VII	1(33.33%)	2(18.18%)	(0%)	1(100%)	
VIII		2(18.18%)	1(16.67%)		
Total	3(100%)	11(100%)	5(100%)	1(100%)	

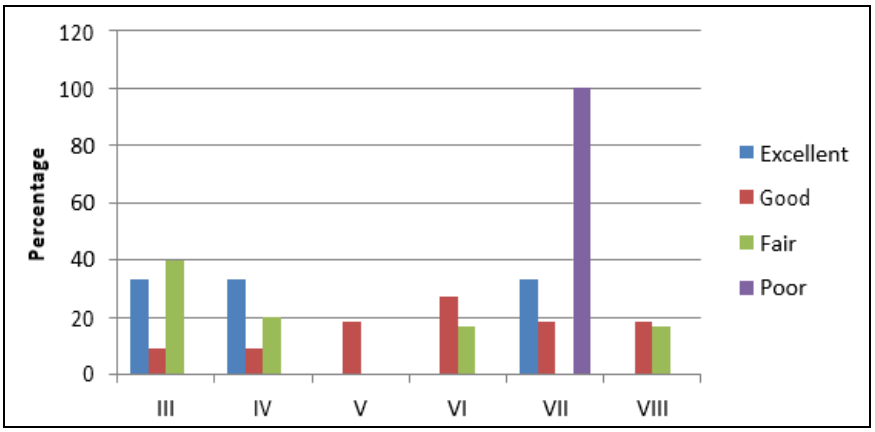


Fig 5: Frykman type distribution according to outcome

Discussion

Although Abraham Colles was evidently satisfied with the results of his treatment of distal radial fractures in 18141, more recent authors have drawn attention to the high prevalence of unsatisfactory results. In 1952, DePalma9 hypothesized that a residual dorsal tilt of the distal end of the radius of more than 5 degrees led to a poor result. Gartland and Werley8 found that immobilization of a distal radial fracture in a cast resulted in a 60 percent loss of reduction and an unsatisfactory result with regard to pain and loss of function in nineteen (32 per cent) of sixty patients. Cole and Obletz10 documented radial shortening of three millimeters or more in twenty-two (67 percent) of thirty-three patients and radial shortening of six millimeters or more in eleven patients (33 percent) after fixation with pins and plaster. Chapman *et al*. [11] reported radial shortening of five millimeters or more in twenty (25 percent) of eighty patients who had been managed with the same technique; a complication led to a reoperation in thirteen patients (16 percent). Short *et al*. [12] found that loss of volar tilt after a distal radial fracture led to progressive load on the ulnocarpal and radioscaphoid articulations, which caused pain and early degenerative disease. Taleisnik and Watson13 reported an association between malunion of the distal end of the radius and dynamic midcarpal instability**.**

Elmstedt E *et al*. noted a slower recovery in the over 60 age group and concluded that some patient with non- operatively treated distal radius fractures still experience some impairment a decade after injury [14]. He was unsatisfied with the available methods of treatment.

Cooney *et al*., in 1979, critically reviewed external fixation for the treatment of distal radial fractures and reported an improved volar tilt. Since then, external fixation has become a popular and reliable method for the treatment of these frequently seen fractures [15].

Jenkin NH noted better grip strength and a higher proportion of excellent results both were subjectively and objectively in the external fixation group in comparison to the group treated by other modalities of treatment [16].

Aktekin *et al*. found that wrist extension, ulnar deviation, palmar tilt and radial height better in those treated with external fixator in comparison to the group treated by other modalities of treatment [17].

Common algorithm for unstable distal radial fractures is external fixation, supplemental fixation with Kirschner wires and frequently the use of a bone graft or bone substitute.

The external fixator is a versatile tool in the treatment of comminuted intra-articular fractures of the distal radius. Our standard reduction procedure is similar to the conservative management of these fractures. During reduction, continued traction results in controlled distraction of the fracture and facilitates manipulation. This technique is simpler than other techniques. The procedure is performed during a short hospital stay. The external fixator is reliable in terms of maintaining reduction of axis as well as of radial length. Comminuted intra-articular fractures with dorsoulnar fragments can be reduced with ligamentotaxis [Vidal *et al*]. [6]

In our study, a patient [11] was operated 12 days after injury, he ended with poor results. The soft tissue changes that had occurred within these twelve days prevented adequate dorsiflexion and ulnar deviation. Hence we recommend external fixator to be applied within seventy-two hours to achieve favorable results. Fair results were obtained in patients- [12, 13, 15, 17, 18]. We had a high rate of favorable results and low rate of complications.

The relatively long period of immobilization (6-8 weeks) had no adverse effects on the long-term functional outcome. The fixator can therefore be left according to the radiologic evidence of fracture healing. Our prospective study of the results of distal radius fractures treated by external fixation emphasizes that-

1. External fixation for distal radius fracture is a safe and reliable method in terms of fracture fixation with good functional results and a low complication rate in particular when external fixation is the primary treatment.
2. Eight weeks of fixation are well tolerated, and the fixator can be left in place according to the radiologic evidence of fracture healing.

Careful review of the recent literature reveals that external fixation appears to have benefits that outweigh associated complications and, as such, make it an attractive treatment option for fractures of the distal radius that require surgical treatment. External fixation is an easy, minimally invasive, and reliable method that restores the anatomy and function after unstable fracture of the distal radius thus, consider it as a treatment of choice for these fracture.18 Both its ease of use and successful track record make it an extremely versatile tool for the treatment of these injuries.

4. Conclusion

External fixation of the distal radius has evolved from its early beginnings in pins and plaster fixation. The current designs of fixators are well established and can be used to reliably treat many fractures about the wrist.

In our study external fixator was used in 20 patients with comminuted, intra-articular fracture distal end of radius. The mechanism of injury was fall in 12 patients and RTA in 8

patients. 3 patients had associated injuries. The external fixator was maintained for 6 weeks. Favorable results were obtained in 70% of the cases.

The rate of serious complications is low. With careful dissection and placement of the pins, injury to the superficial sensory branch of the radial nerve and extensor pollicis longus tendon can be avoided. Aggressive pin-tract care can prevent many superficial infections from occurring. Most complications are minor and easily treated and do not affect outcome.

The external fixator is simple and inexpensive. It effectively stabilizes fractures yet allowing for finger movement and prevents stiffness. When comminuted, intra- articular fractures are treated by conventional methods, pain and restriction of joint motion are not uncommon. But when treated by external fixator using ligamentotaxis principle anatomical reduction is predictably achieved at fracture site. Though some cases have residual joint stiffness, pain and arthritis can be prevented.

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