

Prospective Evaluation of The Results of External Fixation of Unstable Fractures of Distal Radius - A Comparison Between Open and Close Fractures and an Analysis of Similar Studies

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Abstract

Background: Unstable or severely comminuted and intra-articular fractures of distal radius represent traumatic high energy injuries. Prospective study to evaluate the results of external fixation of such fractures was conducted from January 2017 to January 2020 in the Department of Orthopaedics. The aim of this study is to identify the results of external fixation of unstable fractures of distal radius and find out the best treatment options for such fractures under different clinical conditions by comparing the results for open and close fractures and analysis of similar studies.

Materials and Methods: 50 cases of unstable distal radius fractures, including 25 patients with open fractures and 25 patients with close fractures, were treated by external fixation. The patients had mean age of 33 years with 3:2 male female ratio. The fracture was anatomically reduced and fixed with external fixator. The mean follow up was of 24 months.

Results: Final assessment was done at 6 months postoperative follow up using the Sarmiento's modification of Lindstrom criteria for radiological outcome, showing excellent to good results in 60% cases among open fracture group and 80% cases among close fracture group, Mayo Wrist Score for functional outcome showing excellent to good results in 52% cases among open fracture group and 76% cases among close fracture group. Long term assessment done using Jakim's scoring system (for clinicoradiological correlation) at 24 months follow-up for all 50 patients, showed excellent to good results in 88% patients. Analysis of similar studies shows external fixation to be the most rewarding treatment option for varied clinical presentations of unstable fractures of distal radius.

Conclusions: Outcome at 6 months is significantly better in close fracture group as compared to open fracture group showing that good soft tissue cover is necessary for functional fracture healing. The long-term outcome in majority of the patients (44 cases) was excellent to good showing reliability of biological ligamentotaxis under various clinical presentations as suggested by analysis of similar studies. This treatment of choice leads to clinically rewarding functional, anatomical and radiological outcomes in unstable distal radius fractures.

Keywords: External fixation; Ligamentotaxis; Distal radius.

Introduction

Distal radius fractures are a real common appearance in the emergency rooms of orthopaedic surgeons. Traumatic causes of the fracture have increased in recent years due to an increase in number of road traffic accidents in the developing world. The fracture of distal radius caused by trauma is usually the result of high energy impact forces at the wrist joint. Often it is associated with compound wounds and multilevel soft tissue injury or loss. These patients, usually young adults, suffer from various degrees of bone comminution, bone loss and associated ligamentous complex injury. Treating such cases can turn out to be a surgeon's nightmare as functional results are made worse by limited range of motion, wrist

joint incongruity and arthritis, associated fingers stiffness and other complications related to the fracture causing delay in achieving required fitness for resuming work.

Overall majority of the distal radius fractures are extraarticular and are managed conservatively by close reduction and plaster immobilisation in all age groups. Distal radius fractures presenting after accidental trauma are usually intraarticular, comminuted and displaced with soft tissue injury. Operative options for treatment include percutaneous pinning of the distal fragment and immobilisation of the limb with pins in plaster, metal external skeletal fixation devices and open reduction and internal fixation. External fixation is generally accepted as superior to plaster immobilisation in young patients with intra-articular comminuted displaced distal radius fractures [1] as it prevents redisplacement of the fracture after reduction and utilizing the principle of ligamentotaxis provides a platform for biological healing of the fracture.

Over last 3 decades there has been an increase in number of patients undergoing surgical management such as external fixation and open reduction and internal fixation [2]. Although many authors have compared these 2 surgical techniques, there is still lack of evidence

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and no consensus regarding which gives the best outcome [3].

The aim of this study is to identify the results of external fixation of unstable fractures of distal radius and find out the best treatment options for such fractures under different clinical conditions by comparing the results for open and close fractures and analysis of similar studies. The work was approved by the institutional ethical committee and informed consent was taken from all patients.

Materials and Methods

A total number of 50 cases of fracture distal radius were treated by external fixator. The inclusion criteria were (1) Patients with distal radius fractures of AO classification type 23-B and C or Frykman classification type 3-8 (2) Fractures of the distal radius which are (a) Dorsally displaced ($>20^\circ$) extraarticular fractures (with or without an undisplaced intraarticular component) with dorsal cortical comminution as seen on the lateral radiograph (b) Displaced intraarticular fractures with an articular step or gap in the radio carpal or radioulnar joint surface (c) Configuration is such that the fracture would be amenable to stabilisation via percutaneous fixation (Figure 1).

Exclusion criteria were (1) Proximal metaphyseal fractures (more than 2.5 centimetres from the articular surface) (2) Significant pre-existing radiological abnormality or metabolic bone disease (3) Previous fractures of distal radius of the same or contralateral limb. Baseline demographics and injury characteristics were recorded. The patients in young working age group 18–40 years were 40 in number. 10 patients belonged to age group 41–65 years. 30 patients were male and 20 were females. Right wrist was involved in 20 of our cases and left wrist was involved in 30 cases. Mode of injury was road traffic accident in 40 and fall on outstretched hand in 10 of our cases. 25 patients had close fractures among which 11 patients had minor skin abrasions. 25 patients had open fractures among which 17 cases had compound grade 1, 6 cases had compound grade 2 and 2 patients had compound grade 3 type fractures according to Gustilo Anderson Classification. AO and Frykman classification were used for the study. In our study of 50 patients, 26 sustained type VIII fracture, 18 had type VII fracture, 4 had type V fracture, and 2 had type III fracture. The number of cases in AO Type 23 were 15 in C3, 18 in C2, 11 in C1, 2 in B3, 2 in B2 and 2 in B1.



Figure 1: Distal radius fracture configuration is such that the fracture would be amenable to stabilisation via percutaneous fixation; for example, intraarticular fractures of the radial styloid are best fixed percutaneously with K-wires and external fixator to prevent latter collapse in plaster and hence prevent the loss of radial length and grip strength.

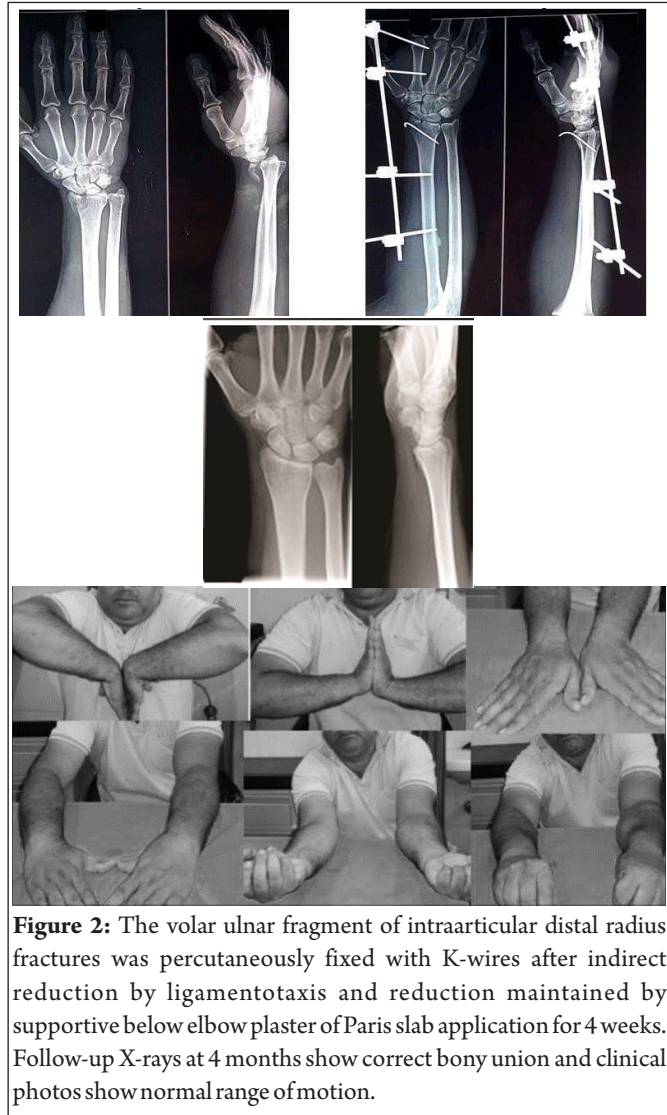


Figure 2: The volar ulnar fragment of intraarticular distal radius fractures was percutaneously fixed with K-wires after indirect reduction by ligamentotaxis and reduction maintained by supportive below elbow plaster of Paris slab application for 4 weeks. Follow-up X-rays at 4 months show correct bony union and clinical photos show normal range of motion.

Operative Procedure in Our Study

All surgeries were done within 1 week of injury under brachial block regional anaesthesia. Fracture was anatomically reduced and fixed with a spanning bridging external fixator having a distraction unit attached to the connecting rod. Indirect reduction (ligamentotaxis) was done by using multiplaner traction-countertraction method. Two 2.5 mm half threaded Schanz pins were placed in shaft radius on the dorsolateral surface after predrilling with 2.2 mm drill bit. Two 2 mm Schanz pins are placed near base of 2nd and 3rd metacarpals on lateral surface after predrilling with 1.8 mm K-wire. Clamps and connecting rod having an attached distraction unit are fixed to the pins and fracture manipulation and reduction was done under image intensifier. Once reduction is achieved, K-wires were used as an adjuvant for stabilization of fracture fragments to maintain anatomical reduction in 30 cases. The wrist was locked in a functional position of 15 degrees dorsiflexion after final reduction was confirmed in C-arm machine. Distal radioulnar joint instability was assessed and corrected by reducing and transfixing with K-wires from distal ulna to radius and applying an above elbow plaster of Paris slab for 4 weeks in 15 cases. The volar ulnar fragment of intraarticular distal radius fractures was percutaneously fixed with K

wires after indirect reduction by ligamentotaxis and reduction maintained by supporting below elbow slab application for 4 weeks in 2 cases (Figure 2).

Patients having open fractures were thoroughly washed, debrided and stay sutured for secondary healing. Patients were further managed with passive and active exercise physiotherapy of the adjoining joints to prevent muscle mass wasting. Fixator was removed after satisfactory clinical and radiological healing of fracture, at an average of 5 weeks after the surgery as an outpatient procedure. Monitored passive and active wrist mobilization was soon started. At 6 weeks light work was allowed. Heavy works were allowed at 10 weeks as tolerated by the patient. Follow up was done at every 15 days for first two months, monthly till 6 months and thereafter at every 3 months until the study completed. The average length of follow up was 24 months with maximum of 36 months. At each follow-up measurements of pain, range of motion and grip strength using handheld dynamometer were done and compared with the normal limb and physiotherapy was advised.

Observations

Final assessment was done in all patients on achieving clinically satisfactory fitness for continuing duty with on/off mild oral analgesics for at least 3 months with an average at 6 months follow up in the study using the Sarmiento’s modification of Lindstrom criteria for radiological outcome showing excellent to good results in 60% cases among open fracture group and 80% cases among close fracture group (Table 1) and Mayo Wrist Score for functional

Table 3: Calculation of Significance Values:

Volar Tilt				
	Mean	SD	t-value	p-value
Open	7	1.87	4.231	0.0001
Close	9.92	2.9		

Radial Height				
	Mean	SD	t-value	p-value
Open	7.84	2.27	3.262	0.002
Close	9.84	2.06		

Radial Inclination				
	Mean	SD	t-value	p-value
Open	16.04	4.25	2.122	0.039
Close	18.88	5.17		

Mayo Score				
	Mean	SD	t-value	p-value
Open	77.8	13.24	2.296	0.0261
Close	85.4	9.93		

outcome showing excellent to good results in 52% cases among open fracture group and 76% cases among close fracture group (Table 2). Results were calculated and significance values were compared for two patient groups, 25 cases having close fractures and 25 cases having open fractures, to testify the null hypothesis that external fixation provides equivalent results in both open and close unstable distal radius fractures irrespective of soft tissue cover (Table 3). This denotes that there is significant difference in the radiological and functional outcomes of external fixation of open and close unstable distal radius fractures. Thus, the above p-value which is < 0.05, disproving the null hypothesis, shows that external fixation gives statistically better results in terms of radiological and functional outcomes in close than open unstable distal radius fractures at 6 months follow up, signifying the important role of healthy soft tissue cover in biological fracture healing.

All cases of the open fractures group had healed healthy wound at 6 months follow up. To find out the long-term clinical relevance of the above results, all 50 patients were followed up and assessed at 24 months postoperative follow up by Jakim’s scoring system (for clinico radiological correlation).

Clinical Subjective- In subjective evaluation 32 cases had excellent results with no pain and near normal function meaning no limitation of movements as compared to the normal side. 16 cases had mild occasional pain with slight limitation of movements. Only 2 cases had moderate pain which requires analgesics and slight limitation of movements. None patient had severe pain or limitation of movement.

Clinical Objective (Mobility)- In objective evaluation out of 50 cases, 38 cases had normal mobility and excellent results. 10 had loss of less than 30% of range of motion as compared to the normal side. Only 2 patients had minimal mobility (loss of 30-50% of range of motion). No patient had loss of greater than 50% of range of motion.

Clinical Objective (Grip Strength)- Out of 50 patients treated by

Table 1: Radiological Outcomes: Sarmiento’s modification of Lindstrom’s criteria.

External Fixation In Open Fractures					
Result	Deformity	Palmar tilt	Radial Shortening	Radial Inclination	Mean
Excellent	8	8	12	5	8 (33%)
Good	7	6	5	10	7 (27%)
Fair	7	7	5	8	7 (27%)
Poor	3	4	3	2	3 (13%)

External Fixation in Close Fractures					
Result	Deformity	Palmar tilt	Radial Shortening	Radial Inclination	Mean
Excellent	13	8	6	15	11 (41%)
Good	8	11	10	8	9 (38%)
Fair	2	4	9	2	4 (17%)
Poor	2	2	0	0	1 (4%)

Table 2: Functional Outcomes: Subjective evaluation of patients by Mayo score. Functional Score for Unstable Fractures

	Open		Close	
	No.	%	No.	%
Excellent	6	24	11	44
Good	7	28	8	32
Fair	8	32	5	20
Poor	4	16	1	4
Total	25	100	25	100

external fixation, 42 cases had normal grip strength as compared to the normal side. 6 cases had less than 15 % loss of grip strength. Only 2 cases had greater than 15% loss of grip strength.

Clinical Objective (Deformity)- 41 cases had no deformity at the wrist, 7 patients had slight deformity and 2 patients had obvious deformity in the form of radial deviation of hand and prominent lower end of ulna as compared to the normal side.

Radiological Evaluation

Radial Angle- In preoperative X-rays, the loss of radial angle was more than 12 degrees in majority of the cases. In postoperative X-rays, the radial angle was maintained in excellent position (23-18 degrees) in 27 cases out of 50 cases. In 17 cases radial angle was maintained in good anatomical position (17-13 degrees). 4 cases had radial angle between 12-10 degrees. Only 2 cases had radial angle less than 10 degrees.

Radial Length - The radial length was achieved up to 10 to 13 mm in 26 cases and up to 7 to 9 mm in 18 cases. 4 cases had 5 to 6 mm of radial length. Less than 5 mm of radial length resulted in 2 cases.

Volar Tilt- 30 out of 50 cases which were treated by ligamentotaxis had excellent maintenance of volar tilt (7-11 degrees). In 14 cases volar tilt was maintained in good position (3-6 degrees). In 5 cases volar tilt was maintained in fair position (1-3 degrees). Only 1 case had neutral volar tilt.

Negative Points- Out of 50 cases treated by ligamentotaxis, 2 cases had negative points due to radioulnar subluxation and 2 cases had incongruous joint with articular step off of 1 to 2 mm and 1 case had greater than 2 mm articular step off.

Results- External fixation showed excellent results in 28 cases, good results in 16 cases and fair results in 6 cases according to Jakim's scoring system, with none patient showing poor results at 24 months follow up (Table 4).

Complications- In this study, 7 cases had infection of the open fracture wound, 4 cases had pin-site infection, 2 cases had complex regional pain syndrome and radial sensory neuritis, and 2 cases had pin loosening as their post-operative complications. Open wound infections were treated by generous wound debridement, saline wash and stay suturing for healing by secondary intention, regular wound dressings and intravenous antibiotics according to culture and sensitivity reporting. Pin-site local infection was treated by sterile dressing and a short course of oral antibiotics. Proper patient training and education regarding pin tract dressing and personal hygiene at regular follow up visits resulted in low infection rates. Wrist and finger stiffness significantly improved after exercise physiotherapy. At 2 years follow-up all observations matched with the normal limb findings in 44 patients.

Table 4: Final results at 2 years follow-up using Jakim's scoring system.

Assessment	Points	Number of cases
Excellent to good	100-80	44
Fair	79-70	6
Poor	<70	0

An analysis of similar studies, evaluating the results of external fixation of unstable fractures of distal radius and comparing them to results of other treatment methods, was meticulously done to find out the most rewarding treatment options for unstable distal radius fractures under various clinical presentations. A comprehensive literature search was carried on PubMed, Google Scholar, the Cochrane Library and various Journal Sites from inception to January 2020 and 14 studies were found having similar objectives with 100 or more number of cases. Of these 5 were Prospective Randomised controlled trials, 7 were Meta-analysis and 2 were Systematic Reviews (Table 5).

Discussion

The fractures of distal radius have been the most common bone injury to humans. Distal radius fractures unite readily because of larger surface area of the cancellous bone present. The main problem in unstable fractures has been the maintenance of reduction during the healing phase. There is usually no difficulty in obtaining initial reduction but redisplacement is common in plaster cast because of triangular zone of compression on dorsal and radial aspect of radius leaving behind a cortical defect after reduction. The loss of palmar tilt and radial shortening causes midcarpal instability disrupting the congruence of distal radio ulnar joint. This causes pain in the joint by altering wrist biomechanics and interferes in pronation supination movements. Palmar extrinsic ligaments of the wrist that are attached to distal radius act as a sling to achieve and maintain articular reduction after indirect reduction of fracture fragments by multiplaner ligamentotaxis is done. Sustained controlled distraction across the radiocarpal joint directly neutralizes axial load in bridging external fixation. Accurate articular reduction, achievable in majority of cases by ligamentotaxis alone, can be obtained in complex unstable fractures by minimum open reduction, judicious indirect reduction and augmentation with kirschner wires and controlled distraction by distraction unit attached to the connecting rod of external fixator. Intact soft tissue cover recovers the good blood supply to the fracture ends resulting in quick uneventful biological healing of the injury.

The best treatment option for different types of fractures may be determined by comparing different methods. The use of any treatment option requires intelligent use of surgeon's own judgement based on the fracture pattern, degree of fracture displacement and comminution, previous experience with the procedure, clinical condition and functional requirements of the patient. Analysis of similar studies shows external fixation to be the most rewarding treatment option for varied clinical presentations of unstable fractures of distal radius. Final results obtained by external fixation in all of the analysed studies show close resemblance to the findings of the present study. Long term outcomes of this treatment are very rewarding enabling complete return to pre-injury status. Analysis shows that for unstable distal radius fractures external fixation provides equivalent results at short term which gradually get better at long term follow up, as compared to open reduction and internal fixation by volar locking plate.

Conventional stable internal plate fixation and precise reduction usually requires a fairly extensive surgical approach to the bone to create compression at the fracture site for primary bone healing.

TABLE 5						
No.	Study Population and study citation	Design	Sample size	Objectives comparison group	Outcome measuring criteria	Measurable outcomes, Results and Author conclusion
1	Australia [4]	Meta-analysis	228	ORIF	Anatomical, Radiological, Functional and Clinical scoring method	No statistically significant difference in results.
2	Norway [5]	RCT	111	VLP	Mayo Wrist score	No statistically significant difference in results
3	China [6]	Meta-analysis of RCTs	445	VLP	QuickDASH Score	EF had less reoperation rate due to complications. 2 methods had similar Functional recovery at 12 months follow-up
4	Macedonia [7]	Systematic Review	647	ORIF	PRWE, DASH Score	No significant difference in results
5	India [8]	RCT	110	VLP	Green O'Brien scoring system	EF showed superiority over VLP after 1-year of injury
6	Germany [9]	RCT	102	VLP	Objective (Range of motion, Grip strength), Patient related outcomes (quality of life, pain), Radiological score	EF using multiplaner K wires is a suitable treatment option in intra and extra articular fractures of the distal radius even in osteoporotic bones
7	China [10]	Meta-analysis	750	ORIF	DASH Score	No statistically significant difference in results. Results at 1-year follow-up favour EF group
8	Canada [11]	Meta-analysis	707	ORIF	DASH Score	No significant difference in results
9	United Kingdom [12]	RCT	130	VLP	Patient Evaluation Measure, QuickDASH, EuroQoL-50 score	No significant differences in results at 12 weeks and 1 year
10	Netherlands [13]	Meta-analysis	174	VLP	Disabilities of the Arm, Shoulder and Hand (DASH) Score	No clinically relevant difference post 3 months follow-up
11	USA [14]	Meta-analysis, Systematic Review	1011	VLP	DASH Score, Anatomical, Functional, Clinical Score	EF results in better grip strength and wrist motion.
12	USA [15]	RCT	179	ORIF	SF6 bodily pain subscale score, Jebsen score, Radiological score	No statistically significant difference in results. EF group has more rapid return of functions and a better functional outcome at 2years follow up
13	USA [16]	Meta-analysis	1520	ORIF	Anatomical, Functional, Clinical results	No significant difference in results
14	USA [17]	Systematic Review	3371	ORIF	Anatomical, Radiological, Functional and Clinical scoring method	Supports EF as treatment of choice

RCT: Randomised controlled trial, EF: External fixation, VLP: Volar locking plate, ORIF: Open reduction and internal fixation

This aggravates the necrosis produced by initial injury and risks of delayed healing, infection and possibly refracture. Recent decades witnessed the evolution of internal fixation of fractures with a change of emphasis from mechanical to biological priorities. Early solid callus is encouraged by more flexible fixation while less precise,

indirect reduction will reduce operative trauma, and this is the basic principle of bridge plating, external fixator and internal fixator like devices. The aim is to produce best biological conditions for healing rather than absolute stability of fixation and this approach has given early solid union [18]. Bridge plating and external fixator both

provide flexible fixation, but external fixator is the only system which allows the surgeon to control the flexibility of fixation and modify the loading of fracture area as healing progresses.

Volar locking plating requires demanding degrees of skill and surgical expertise to minimise the biological complications following extended traumatic and iatrogenic causes and has a steep learning curve. It provides long term treatment which is not a primary objective in fracture management of readily uniting cancellous distal radius. Restoration of function is the principle objective of both non-operative and operative treatment. External fixator provides flexible fixation enhancing callus formation and solid union. Flexible fixation does not compromise the restoration of early and complete function of wrist and allows painless function and reliable healing. The aim is to reduce the infrequent but possibly severe complications such as sequestration and infection due to bone necrosis with less emphasis on avoidance of delayed or non-union which is more easily managed. The repair of dead bone requires long term stability to allow creeping substitution and internal remodelling and therefore the combination of necrosis and instability may be deleterious [18].

Fair to poor results among one third cases in our study due to moderate pain at 6 months follow-up were because of low muscle strength in older adults weakened by high energy trauma, slow soft tissue recovery owing to malnutrition in patients of low socioeconomic status and generalised osteoarthritis due to growing age among manual labourers. Aggressive physiotherapy, muscle strengthening range of motion exercises as well as calcium and vitamin supplementation over months resulted in gradual remodelling of bone and improvements in overall functional and clinical recovery of these patients producing good results at longer follow up. Vitamin C reduces the prevalence of complex regional pain syndrome after wrist fractures. A daily dose of 500 mg for fifty days is recommended and was encouraged in our study [19]. Chronic regional pain syndrome that complicated 2 of our cases was successfully treated by a combination of psychiatric therapy, occupational therapy, pain management therapy, passive and active range of motion exercises.

Unstable distal radius fractures resulting from high energy trauma due to road traffic accidents in young adults are invariably associated with multilevel soft tissue injury and comminuted multifragmentary fracture of the subchondral cancellous bone. These fracture fragments are too many and too small for providing rigid hold to plate screws. Without proper space and hold for screws, interfragmentary compression and rigid fixation is hard to achieve failing the aim of primary healing in such case scenarios. Open reduction and internal fixation of such fractures can infrequently lead to some deleterious complications such as screw cutouts, osteolysis around screws, avascularity of fracture fragments, necrosis and eventually infection and loss of limb functions. These drastic complications are totally avoidable and it's unnecessary to take such risks when a safer, acceptable and cost-effective method of treatment in the form of external fixation is available.

Successful fracture treatment is a race between implant failure and bone healing. As most studies report similar functional results regardless of surgical method at 1 year or later, burden of complications is of prime importance. In a registry study from Sweden with 36618 patients, there were significantly more

reoperations for plating patients due to tendon or nerve symptoms than for external fixation patients [20]. Plating procedure itself puts the patients at risk of osteoarthritis owing to the invasive nature of surgical method, thereby, decreasing the cost-effectiveness of treatment.

In unstable fractures the reduction is well maintained by external fixator using the principle of ligamentotaxis. This technique is a simple to learn, quick to perform and least traumatic surgical procedure that effectively maintains the reduction till the fracture unites solidly. No postoperative plaster immobilization and joint movement restriction of unaffected joints of the limb is needed; thereby, beneficially limiting complications related to the fracture such as finger, elbow and shoulder stiffness. Passive physiotherapy of these joints must be started as early as possible after operation. Patient compliance is good because of less pain due to minimal surgical dissection. The process of achieving accurate restoration of the articular surface requires traction-countertraction, correction of the deformity by multiplaner manipulation, achieving anatomical reduction by judgemental deviation of the wrist joint, fixing unstable fracture fragments with K-wires and locking the fixator in such a manner that the reduction is maintained. The compact ligaments anatomy of the wrist joint keeps the comminuted fracture fragments aligned till congruent union occurs. Proper placement of external fixator results in clinically rewarding functional results. The fracture heals quickly and physiotherapy, both passive and active, enables early return to work with normal movements and grip strength. Surgical trauma is avoided by achieving close reduction and the wrist joint is fixed to heal biologically, with the wrist ligaments achieving and maintaining reduction so as to result in an anatomically congruent articular surface restoration. Distal radius fractures treated by external fixation gives clinically rewarding excellent to good results in majority of patients with fitness to resume heavy duty as early as after 10 weeks. Uniform distraction during treatment prevents radial shortening and preserves the radioulnar biomechanics. Implant related complications are minimal and good patient education results in quick return to functional activity.

Clinical Message

We recommend external fixation as first line of treatment for unstable distal radius fractures because of the following advantages: (1) Reduction of fracture can be done without opening the fracture site. (2) Distal radioulnar joint is also very well stabilized through ligamentotaxis. (3) Intra and postoperative reduction can be done by distractor rod. (4) No postoperative immobilisation in plaster is needed and physiotherapy of adjoining joints can be started immediately after operation reducing the complications later on. (5) It maintains the reduction till fracture unites. (6) The surgical technique is simple in conception, quick in performance and does not require any secondary operative procedure. (7) The scar marks are almost invisible and major complications are rare.

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