



## Wrist Radiographic Indices and Patients' Performance Following Three Surgical Methods for Management of Distal Radius Fractures: A Randomized Single-Blind Controlled Trial

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### Abstract

**Background.** Distal radius fracture has been reported as the most common type of extremity fractures in adults. No treatment method has been introduced definitely for this type of fracture, especially for maintaining hand function in the best state.

**The aim of this study** – to assess the functional and radiological outcomes following three surgical methods, including external fixation, K-wire and external fixation with pinning.

**Methods.** This parallel-designed randomized controlled trial was conducted on adult patients with intra-articular fracture of distal radius. The participants were allocated in three research groups with block random sampling, and were matched for their age and gender. Primary outcome was radiographic parameters, including radial inclination, radial height, ulnar variance and dorsal/palmar tilt. Secondary outcome was the patient's performance examined with DASH and PRWE questionnaires. All participants were followed 6, 12 and 24 weeks after the surgery for evaluation of these outcomes.

**Results.** Totally, 78 patients, including 42 male and 36 female with mean age of  $46.94 \pm 11.05$  years completed the research protocol. Although the four radiologic primary endpoints were in the normal clinical range after the intervention, a significant statistical difference was observed between the three groups ( $p < 0.001$ ). Also, both DASH and PRWE score showed a significant decrease after the therapeutic interventions ( $p < 0.001$ ).

**Conclusion.** The statistically significant difference in the research outcomes of the external fixation with pinning can show that this treatment method theoretically preserves the anatomical condition better than the other two methods, and probably has better functional effects on short-term and intermediate-term results following the surgery.

**Keywords:** distal radius fracture, surgical procedures, pinning, external fixation.

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## Рентгенометрические показатели лучезапястного сустава и функциональные результаты хирургического лечения переломов дистального отдела лучевой кости с применением трех методик: рандомизированное контролируемое исследование

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### Реферат

**Актуальность.** Переломы дистального отдела лучевой кости являются самым распространенными среди всех переломов конечностей у взрослых. Однако до сих пор не предложено единой методики лечения данных переломов, которая обеспечивала бы наилучшую сохранность функции кисти.

**Цель исследования** — оценить функциональные и рентгенологические результаты после трех вариантов хирургического лечения: внешней фиксации, фиксации спицами и внешней фиксации в сочетании со спицами.

**Материал и методы.** В параллельное рандомизированное контролируемое исследование было включены взрослые пациенты с внутрисуставными переломами дистального отдела лучевой кости. Методом блочной рандомизации они были разделены на три группы, сопоставимые по полу и возрасту. В качестве первого критерия оценки использовались рентгенометрические параметры: лучелоктевой угол, высота шиловидного отростка лучевой кости, локтелучевой индекс и тыльный/ладонный наклон. Вторым критерием была оценка функциональных результатов по шкалам DASH и PRWE. Контрольные осмотры пациентов проводились на сроках 6, 12 и 24 нед. после операции.

**Результаты.** На всех этапах исследования была проведена оценка функциональных результаты 78 пациентов (42 мужчины и 36 женщин), средний возраст которых составил  $46,94 \pm 11,05$  лет. Несмотря на то, что после хирургического вмешательства все четыре первичных рентгенометрических показателя были в пределах нормы, между тремя исследуемыми группами наблюдалась статистически значимая разница ( $p < 0,001$ ). Кроме того, отмечалось значительное снижение показателей по шкалам DASH и PRWE после операции ( $p < 0,001$ ).

**Заключение.** Статистически значимые отличия в результатах в случае выполнения внешней фиксации с использованием спиц могут свидетельствовать о том, что гипотетически данный метод лечения обеспечивает большую сохранность анатомии сустава, чем два других метода, и, вероятно, способствует получению лучших ближайших и среднесрочных функциональных результатов после операции.

**Ключевые слова:** перелом дистального отдела лучевой кости, хирургические методы лечения, фиксация спицами, внешняя фиксация.

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## INTRODUCTION

Distal radius fracture (DRF) has been reported as the most common type of extremity fractures in adults; constitute 17.5% of all fractures [1, 2].

The fractures with more than 2 mm step-off in the radiocarpal joint and greater than 10° dorsal tilt are recommended to be treated surgically. Different surgical techniques and hardware have been introduced for the management of distal radial fractures. No one method can be used for all injuries, and, the surgeon should choose a proper approach based on the patient's condition [3, 4]. These treatment approaches are expected to promote pain-free movements of the wrist, the patient's ability to do his/her activities, and to prevent from degenerative articular changes in the future [5]. Timely surgery of these fractures has been recommended to achieve better long-term outcomes, and also, less disabilities of the arm, shoulder, and hand [6, 7].

External fixation (EF), open reduction and internal fixation with Kirschner wire (K-wire), and external fixation and pinning are important surgical approaches for management of these fractures [8]. These treatment approaches might have potential complications, ranging from skin incisions, cosmetic appearance, and related surgical adverse events which impact the patient's satisfaction and functional outcomes [9].

Different measures have been introduced to assess the treatment outcomes following the surgical procedures for DRF; functional and radiographic parameters are among the most important indices for this purpose [10, 11, 12].

Given no treatment method has been introduced definitely for this type of fracture, especially for maintaining hand function in the best state, this study aimed to evaluate the functional and radiological outcomes of three surgical methods.

## METHODS

### Trial design and blinding

The present study was conducted as a parallel single-blind randomized clinical trial. The patients did not know the type of surgical procedure chosen by the surgeon for treatment.

### Patients

All adult patients with intra-articular fracture of distal radius (type C complete articular fracture based on AO/OTA Classification of Fractures and Dislocations [13]) referred to the emergency departments, outpatient clinics and orthopedic departments of three state hospitals affiliated to Babol University of Medical Sciences, north of Iran who were candidate for surgical treatment were included in the study, by census. The participants were allocated in three research groups with block

random sampling. The three groups were matched for their age and gender.

The inclusion criteria were: people aged 18–65 years with intra-articular fracture of the distal radius caused by trauma. Exclusion criteria included: pathological fractures other than trauma (tumor, disease or other reasons), simultaneous fracture of the upper limb on the same side, patients who did not want to participate in the research, Sudeck's atrophy, and patients who had clear osteoporosis on radiographs.

### Sample size

Considering a study power of 80% at a confidence level of 95%, and a decrease of 2 units in the pain severity in three study groups and a drop of 10%, the sample size was determined to be 30 individuals in each group (totally 90).

### Interventions

The patients were divided into three groups: K-wire technique for group 1, external fixation for group 2, and external fixation with pinning for group 3. All surgical procedures were carried out with a standard protocol under general or local anesthesia.

K-wire technique (group 1) was carried-out with closed reduction, and fixation with pins (3 or 4 pins were used depending on the shape of the fracture). In this method, closed reduction of the DRF was performed under the C-arm guide in the operating room, and the pins were placed crosswise. One or two pins were placed from the styloid process of the radius, and one or two pins from the opposite side. After making sure of the correct reduction, the long arm cast was taken. The conducted reduction and fixation were controlled with anteroposterior (AP) and lateral radiographic views during the surgical operation. The patients underwent immobilization cast for 6 weeks, 4 weeks of long cast and 2 weeks of short cast.

The external fixator (for group 2) was placed using 2.5 mm Schanz pins in the second metacarpal bones and 3.5 mm pins in the radius, proximal to the fracture site. In this method, under the C-arm guide in the operating room, reduction of DRF was performed. The reduction was checked with AP and lateral radiographic views. Subsequently, one Schanz pin was placed in the distal part of the fracture and inside the second metacarpal bone, and another one was placed inside the shaft of the radius, the wrist was placed under tension, and after sufficient distraction, the rods were placed on the Schanz pins, and finally the next Schanz pins were placed distally and proximally. The fixator included four Schanz pins, two rods and eight rods to Schanz-clamps to fix the rod. Finally, after making sure of the correct reduction, the long arm splint was taken [14]. The external fixator was removed 6 to 8 weeks after the intervention. No additional wire was used in these patients.

In the external fixation with pinning (group 3), the procedure of fixation was conducted with the same technique mentioned for the group 2. In addition to, 2 or 3 pins were used for fixation of the fracture site, depending on the patient's condition. In this method, under the C-arm guide in the operating room, the closed reduction of DRF was performed. The reduction was checked in the AP and lateral radiographic views. After making sure that the reduction was correct, the long arm splint was finally applied.

The patients of the three study groups were taken a wrist radiograph, immediately after the surgery. They were discharged from the hospital 24 hours after the intervention, while were prescribed to take an appropriate antibiotic medication (cephalosporin of the first generation) for three days, and were advised to move their fingers, actively.

Radiography was repeated two weeks after the intervention; and the patients were followed to check the fracture reduction. Subsequently, the participants were followed 4 weeks after the intervention to shorten the cast in group 1 patients. The last visit was performed at the time of pin or external fixator removal.

Physiotherapy was requested for all patients after the operation.

### OUTCOMES ASSESSMENT

Primary outcome was radiographic parameters, including radial inclination, radial height, ulnar variance and dorsal/palmar tilt [15]. These markers were assessed immediately after the surgery, then the 6<sup>th</sup>, the 12<sup>th</sup> and the 24<sup>th</sup> weeks after the intervention.

Secondary outcome was the patient's performance. All participants were followed 12 and 24 weeks after the surgery for evaluation of this outcome. The Persian version of the Disabilities of the Arm, Shoulder and Hand (DASH) outcome measure, and Patient Rated Wrist Evaluation (PRWE) questionnaire were used for assessment of the patient's performance [15, 16].

DASH questionnaire includes 30 items. Normal DASH score is less than 15; a score of zero means no disability, and a score of 100 indicates severe disability [16].

The PRWE questionnaire contains 15 items, 5 of which are about intensity and repetition of

pain and 10 questions about the patient's ability to perform daily activities. A score of 100 means severe disability [15].

### Statistical analysis

The collected data was analyzed using SPSS statistical software (version 26). Chi-square, t-test, and paired t-test were used for data analysis. P-value less than 0.05 was considered as the significant level.

### RESULTS

Totally, 78 patients, including 42 (53.8%) male and 36 (46.2%) female with mean age 46.94±11.05 (a range of 19-65) years completed the research protocol. Participant flow is presented as Figure 1 to show the number of participants in each group who were randomly assigned, received intended treatment, and were analyzed for the research outcomes.

Baseline characteristics of the participants in three research groups is presented in Table 1. This table represents no significant difference between these groups about their age, gender and the side of hand injury ( $p>0.05$ ).

Radiographic indices have been compared between the study groups in Table 2. This table shows that although the four radiologic measures (radial inclination, radial height, ulnar variance and dorsal/palmar tilt) were in the normal clinical range after intervention, a significant statistical difference was observed between the three groups ( $p<0.001$ ). Also, an example of radiographic images before and after the three mentioned procedures is shown in Figure 2.

When the groups were compared 2 by 2 about the height of the radius, no significant difference was observed between the two groups of K-wire and external fixation after the surgery on the 0 day ( $p = 0.249$ ), 6 weeks ( $p = 0.135$ ), 12 weeks ( $p = 0.066$ ) and 24 weeks ( $p = 0.216$ ) after the surgery; however, the group of external fixation together with pin had a significant difference with external fixation ( $p<0.05$ ). The height of the radius in the third group was better than that of the other groups.

Patients' performance following the three mentioned surgical interventions has been summarized in Table 3. Both DASH and PRWE score showed a significant decrease after the therapeutic interventions ( $p<0.001$ ).

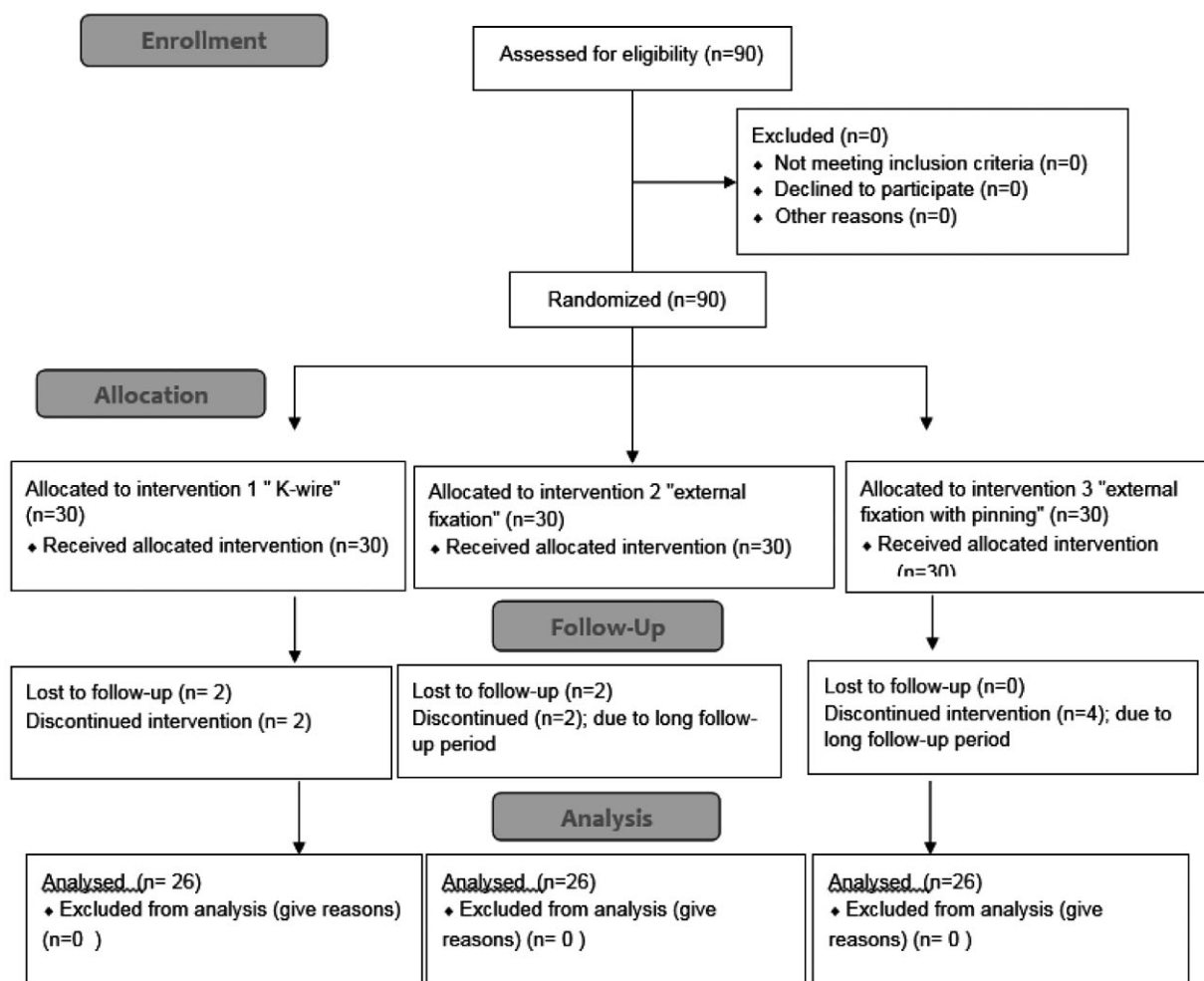


Fig. 1. Flow diagram of the study

Baseline characteristics of the participants in three research groups

Table 1

Characteristics	Study groups			p-value
	K-wire (n = 26)	External fixation (n = 26)	External fixation with pinning (n = 26)	
Gender (Number/Percent)				
Male	15 (57.7)	14 (53.8)	13 (50.0)	0.857
Female	11 (42.3)	12 (46.2)	13 (50.0)	
Age (Mean±SD)	46.50±12.14	47.69±10.18	46.62±11.39	0.914
The side of fracture (Number/Percent)				
Right	10 (38.50)	16 (61.50)	9 (34.60)	0.108
Left	16 (61.50)	10 (38.50)	17 (65.40)	

Table 2

Wrist radiologic indices following three surgical interventions for distal radius fracture, Mean±SD

Characteristics/ Study groups	Radial inclination p-value <0.001				Radial height p-value <0.001				Ulnar variance p-value <0.001				Dorsal/palmar tilt p-value <0.001			
	Day 0	6 <sup>th</sup> week	12 <sup>th</sup> week	24 <sup>th</sup> week	Day 0	6 <sup>th</sup> week	12 <sup>th</sup> week	24 <sup>th</sup> week	Day 0	6 <sup>th</sup> week	12 <sup>th</sup> week	24 <sup>th</sup> week	Day 0	6 <sup>th</sup> week	12 <sup>th</sup> week	24 <sup>th</sup> week
K-wire (n = 26)	20.71 ± 2.29	20.71 ± 2.22	19.02 ± 3.44	19.09 ± 3.29	10.09 ± 1.18	10.17 ± 1.11	9.33 ± 1.3	9.31 ± 1.26	0.28 ± 1.30	0.23 ± 1.29	0.48 ± 1.29	0.51 ± 1.28	4.59 ± 4.06	4.53 ± 3.85	4.11 ± 3.80	4.12 ± 3.87
External fixation (n = 26)	20.78 ± 2.29	21.06 ± 2.32	20.29 ± 3.35	19.68 ± 3.46	10.51 ± 0.58	10.65 ± 0.56	10.03 ± 0.84	9.81 ± 0.84	0.10 ± 1.06	0.85 ± 1.06	0.18 ± 1.10	0.30 ± 1.06	5.50 ± 2.22	5.75 ± 1.96	6.13 ± 2.52	5.82 ± 2.52
External fixation with pinning (n = 26)	22.57 ± 2.35	22.57 ± 2.34	21.60 ± 2.80	20.88 ± 2.87	11.38 ± 0.75	11.48 ± 0.78	11.28 ± 0.84	10.88 ± 0.91	-0.29 ± 1.57	-0.24 ± 1.64	0.04 ± 1.55	0.18 ± 1.57	6.61 ± 2.16	6.85 ± 2.17	6.37 ± 2.28	6.11 ± 2.32
Total	21.35 ± 2.44	21.45 ± 2.41	20.37 ± 3.34	19.89 ± 3.26	10.66 ± 1.01	10.77 ± 1.00	10.21 ± 1.29	10.00 ± 1.20	-0.32 ± 1.33	0.02 ± 1.35	0.23 ± 1.32	0.33 ± 1.31	5.57 ± 3.02	5.71 ± 2.92	5.54 ± 3.08	5.35 ± 3.07





**Fig. 2.** An example of radiographic images before and after the three surgical procedures:  
 a – K-wire method before surgery;  
 b – K-wire method after surgery;  
 c – external fixation before surgery;  
 d – external fixation after surgery;  
 e – external fixation with pinning before surgery;  
 f – external fixation with pinning after surgery

Table 3

**Patients’ performance following three surgical interventions for distal radial fracture, Mean±SD**

Characteristics/Study groups	DASH score		PRWE score	
	12 <sup>th</sup> week	24 <sup>th</sup> week	12 <sup>th</sup> week	24 <sup>th</sup> week
K-wire (n = 26)	47.70±8.17	35.70±8.66	53.17±7.78	41.59±7.21
External fixation (n = 26)	42.05±9.92	30.85±8.96	48.46±9.44	33.40±7.47
External fixation with pinning (n = 26)	38.43±8.78	28.26±9.52	43.46±7.22	30.51±7.57
Total	42.74±9.68	31.61±9.46	48.36±9.03	35.17±8.71

p-value <0.001.

**DISCUSSION**

This research aimed to evaluate the wrist radiographic parameters and patients’ performance after three surgical interventions for management of distal radial fracture.

Following the mentioned surgical interventions, a statistically significant difference was observed between the three groups about the height of the radius, although the height of the radius was in the normal range (8–12 mm) in all groups and the difference was not clinically significant. Of course, when the groups were compared 2 by 2 about the research outcomes, the height of the radius had better condition in the third group than that of the others. Furthermore, radial height did not collapse within 6 months after external

fixation with pinning; while in the other two methods, a radial shortening was observed. Multiple evidence represented the radial height as one of the important prognostic factors in treating distal radial fracture [17], however, there is discrepancy in the way that radial height is measured and reported, that influences on comparison of the findings in different studies [18]. Current research showed that this outcome was the best in the third group.

The radial inclination is closely related to the height of the radius, and both of these measures can be representative for axial compression of the radius. Some previous studies showed an association between the loss of radial angle greater than 10° and unfavorable score of DASH [20]. In current trial,

although the radial angle was in the normal range (16–29°) following the operation, a statistically significant difference was observed between the three groups. Similar to the findings of radial height, radial angle in the third group was better than the other groups.

In this research, the average of ulnar variance was in the normal range (+2 to -4) in postoperative assessment of all groups. Although a statistically significant difference was observed between different treatments, the difference was not clinically significant. The external fixation group with pinning had the best outcome about ulnar variance than that of other groups. In the study of H.P. Huddleston et al. showed that fixating the radius in -4 mm of ulnar negativity significantly decreased radial translation after sectioning the volar radioulnar ligament and triangular fibrocartilage complex (TFCC) [20]. Similar evidence reported that positive ulnar variance one year after distal radial fracture was clearly associated with unfavorable DASH score and weakness of grip [21, 22].

Palmar tilt was in the normal range (0-22°) in three groups; although, there was a statistically significant difference between the groups. This difference was not clinically significant; and the third group had the best condition in all follow-up periods. Different evidence exists about the impact of palmar tilt on postoperative functional outcomes. It can be due to differences in measurement methods and performance definitions in various studies. Falk et al showed no significant difference in postoperative functional assessment between the cases with non-anatomical restoration of the volar tilt with -5° to 5° with patients who had an anatomical volar tilt between 6° and 15° [23]. A dorsal tilt over 10° is an important cause of radiocarpal instability after distal radial fractures; and can be associated with unfavorable postoperative DASH results.

## DISCLAIMERS

**Funding source.** This study has been financially supported by Babol University of Medical Sciences.

**Disclosure competing interests.** The authors declare that they have no competing interests.

**Ethics approval.** The research protocol was approved by the Ethics Committee of Babol University of Medical Sciences with approval number: IR.MUBABOL.HRI.REC.1397.246; and was registered in the website of Iranian Registry of Clinical Trials (IRCT20190221042782N1; available at: <https://en.irct.ir/trial/38920?revision=86960>).

**Consent for publication.** The authors obtained written consent from patients to participate in the study and publish the results.

Mean DASH score was about 43 at the third month, and decreased to about 32 at the sixth month of postoperative assessment. These scores were higher than the normal range which should be below 15. This outcome was better in the third group compared to other two methods, and the patients undergoing this treatment intervention are expected to have better performance. A recent network meta-analysis compared short-term (up to 3 months) and intermediate-term (3 to 12 months) of DASH and PRWE scores following different treatment approaches of distal radial fractures and reported that internal fixation with volar lock plating made no increase in 1-year complication rates compared to other treatment options. They proposed shared decision-making with patients to identify patient preferences regarding recovery to determine optimal treatment [24].

Mean PRWE score was about 48 at the third month and improved to about 35 at the sixth month. Similar to DASH score. This research endpoint was better in the third group; patients underwent external fixation with pinning had better performance after six months following the surgery.

The sample size, and study design are strong points of this research. The patients were followed for six months; and this can be a limitation of this study. Long-term follow-up of patients is recommended for future studies.

## CONCLUSION

The statistically significant difference in the research outcomes of the external fixation with pinning can show that this treatment method theoretically preserves the anatomical condition better than the other two methods, and probably has better functional effects on short-term and intermediate-term results following the surgery.

## ДОПОЛНИТЕЛЬНАЯ ИНФОРМАЦИЯ

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