External fixation with or without supplementary intramedullary Kirschner wires in the treatment of distal radial fractures

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Objectives: To determine radiographic outcomes in the fracture of distal radius treated by close reduction and external fixation, with or without supplementary intramedullary Kirschner wires. **Methods:** At the Orthopedic Department of National Taiwan University Hospital, we carried out a retrospective study of distal radial fractures treated with close reduction and external fixation. A consecutive series of 20 fractures were treated (from March 1995 to June 1998) with external fixation only; later (from January 1999 to December 2001), 36 distal radius fractures were treated with external fixation supplemented with intramedullary wires. The fractures were evaluated via good-quality posteroanterior and lateral radiographs. In both groups, the radial height, radial inclination and volar tilting were measured on initial (preoperative) and immediate postoperative radiographs and on others taken immediately after the removal of external fixation. Overall results were based on objective radiographic and functional data as well as on subjective assessments with demerit-point scoring. Data were analyzed with a 2-tailed *t* test. **Results:** Radial height and radial inclination improved significantly immediately after surgery, but volar tilting of distal-radius deformity was little improved by treatment with external fixation alone. When external fixation was supplemented with intramedullary Kirschner wires, improvement in all 3 measurements was statistically significant. Clinical examination likewise found significantly better functional results in patients treated with the Kirschner wires. **Conclusion:** External fixation is a popular method to reduce osseous deformity of the distal radius, but can not assure maintenance of the reduction. Supplementing external fixation with intramedullary Kirschner wires can improve retention of fracture reduction during healing, resulting in better functional results.

Objectives : Déterminer les résultats radiographiques de fractures du radius distal traitées par réduction à peau fermée et ostéosynthèse externe, avec ou sans broches supplémentaires intramédullaires de Kirschner. **Méthodes :** Au département d'orthopédie de l'hôpital universitaire national de Taïwan, nous avons mené une étude rétrospective des fractures du radius distal traitées par réduction à peau fermée et ostéosynthèse externe. Une série consécutive de 20 fractures ont été traitées (entre mars 1995 et juin 1998) par ostéosynthèse externe seulement; plus tard (de janvier 1999 à décembre 2001), 36 fractures du radius distal ont été traitées par ostéosynthèse externe complétée par des broches intramédullaires. On a ensuite évalué les fractures au moyen de radiographies de bonne qualité en incidence postéro-antérieure et latérale. Dans les deux groupes, on a mesuré la hauteur radiale, l'inclinaison radiale et le basculement palmaire sur les radiographies prises initialement (avant l'opération) et immédiatement après, puis sur d'autres radiographies prises immédiatement après l'enlèvement de l'ostéosynthèse externe. Les résultats globaux reposaient sur des données radiographiques et fonctionnelles objectives ainsi que sur des évaluations subjectives avec notation par points. On a analysé les données à l'aide d'un test *t* bilatéral. **Résultats :** La hauteur radiale et l'inclinaison radiale se sont largement améliorées immédiatement après l'intervention, mais le basculement palmaire de la difformité du radius distal a très peu changé après un traitement par ostéosynthèse externe seulement. Lorsqu'on a ajouté à l'ostéosynthèse externe des broches intramédullaires de Kirschner, l'amélioration des trois mesures a été statistiquement significative. De même, l'examen clinique a révélé des résultats fonctionnels fortement plus élevés chez les patients traités au moyen de broches intramédullaires de Kirschner. **Conclusion :** L'ostéosynthèse externe est une méthode courante qui vise à diminuer la difformité osseuse d'une fracture du radius distal, mais elle ne peut garantir que la réduction se maintiendra. L'ajout de broches intramédullaires de Kirschner à l'ostéosynthèse externe peut améliorer la rétention de la réduction de la fracture pendant le traitement, assurant ainsi de meilleurs résultats fonctionnels.

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Fracture of the distal radius is a common problem, particularly in people (often older white women) with osteoporosis. The primary goals of treatment are the restoration of anatomic relationships (reduction), stable fixation during healing and recovery of wrist motion. Treatments vary from simple splinting[1] to surgical reduction with combined internal and external fixation.[2]

Improved clinical and radiological results in cases of unstable intra- or extra-articular fractures have prompted a global interest in more precise treatment for these troublesome conditions. In the past 25 years, there has been dramatic evidence that function is intimately related to malunion in distal radial fractures. Intra- and extra-articular malunion have both been shown to decrease function and lessen patient satisfaction with treatment outcomes.[3–6] Restoration of normal alignment and articular congruity after a displaced fracture can be difficult, but is essential to a good functional result.[7,8]

External fixation, currently widely used to treat these fractures, is minimally invasive. It uses traction to maintain fracture-fragment reduction,[9] so that additional trauma from dissection of the soft tissues around the fracture during open reduction and plate fixation is avoided.[10] Simple, stable and extra-articular fractures can be treated easily with closed methods, but unstable intra-articular fractures frequently require more invasive methods to reposition the fragments and maintain their relationships throughout healing.

Many authors[11–14] have reported significant losses of reduction, from pin loosening, infection and fixation failure. Over the past 2 decades, internal and external fixation techniques and devices for treatment of displaced fractures of the distal radius have become more sophisticated. 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 grafting techniques including bone-graft substitutes all have contributed to improving fracture stability and outcome.[15] Although there is some evidence to support the use of external fixation or percutaneous pinning,[16–18] their precise roles and methods have not been established.[19] The stability of distal-radius fracture fixation may be more dependent on the means to augment fixation than on the strength of an external fixator itself.[20]

Changes in radiological parameters have been reported[21] to correlate with detrimental effects after malunion of distal radius fractures; an increase in ulnar variance was found to minimize functional outcomes the most. Outcomes also tend to be influenced by age, hand dominance and articular involvement.[21] Results at our institute of a retrospective study[22] of a similar set of parameters were also less than satisfactory: immediate improvements in measurements of the height of the radial styloid (radial height) and radial inclination were gradually lost, decreasing significantly by the time of removal of external fixation.[22] Volar tilting of distal-radius deformity did not improve significantly with external fixation. Neither can external fixation effectively protect comminuted distal-radial fractures from loss of the reduction originally attained; severe comminution is often associated with shortening and redisplacement.[22]

In the study we report here, we used a standard protocol of closed reduction with external fixation augmented with percutaneous intramedullary Kirschner wires (imK) to treat distal radial fractures, and compared the results with those for external fixation alone.

Methods

Ours was a retrospective study of consecutive patients with distal radial fractures treated by closed reduction with external fixation, with or without supplementation with imK. Demographic information is presented in Table 1. All were treated at a single institution, the Orthopedic Department of National Taiwan University Hospital. Patient follow-up persisted until union of the fracture and removal of the fixation implant.

Our study design involved the evaluation of plain radiographs made at 3 events: *preop*, at the initial visit to our institute; *postop*, immediately after reduction (time of union); and *postfixation*, immediately after the removal of implants for external fixation. An overall result was assigned in each case, based not only on objective radiographic and functional data, but also on quantified subjective assessment.

We studied 2 consecutive series of cases of distal-radius fractures: 20 patients treated from March 1995 through June 1998 with external fixation alone (the EFA group, Fig. 1A); and 36 treated from 1999 through 2001 (inclusive) with exter-

Table 1

Clinical data on study patients with distal radial fractures treated by external fixation, alone or with imK augmentation

Characteristic	EFA group, *n* = 20	imK group, *n* = 36
Sex of patients	13 females, 7 males	7 females, 29 males
Mean age, SD (and range)	52.0, SD 24.2 (13–84)	62.3, SD 16.2 (23–89)
Mechanism of trauma	15 minor, 5 not minor	26 minor, 10 not minor
Dominance of injured hand	6 dominant, 14 not	18 dominant, 18 not
AO/ASIF fracture classification, no. of patients	A1: 2 A2: 4 A3: 1 C1: 4 C2: 7 C3: 2	A1: 1 A2: 8 A3: 11 C1: 5 C2: 6 C3: 5
Mean time to operation, SD (range)	3.8, SD 4.9 (1–22) d	7.0, SD 7.9 (0–30) d
To removal of implant	51.1, SD 13.4 (39–97) d	52.6, SD 10.4 (33–81) d

EFA = external fixation alone; imK = intramedullary Kirschner wires; SD = standard deviation

nal fixation supplemented with percutaneous imK (the imK group, Fig. 1B). No attempt was made to select these patients, and 1 well-trained surgeon (C.L.) was responsible for fixation of all the fractures.

Excluded from the study were patients who had received open reduction and internal fixation with plate and screws, who underwent closed reduction and cast immobilization without other fixation, or who had additional injuries. Patients were likewise excluded if perioperative radiographs, either the posteroanterior (PA) or lateral view, were unavailable.

All fractures were classified according to the Arbeitsgemeinschaft für Osteosynthesefragen (AO/ASIF) systems[23] by means of PA and lateral radiographs of the wrist made before and after reduction. These and other clinical data for the EFA and imK groups are summarized in Table 1.

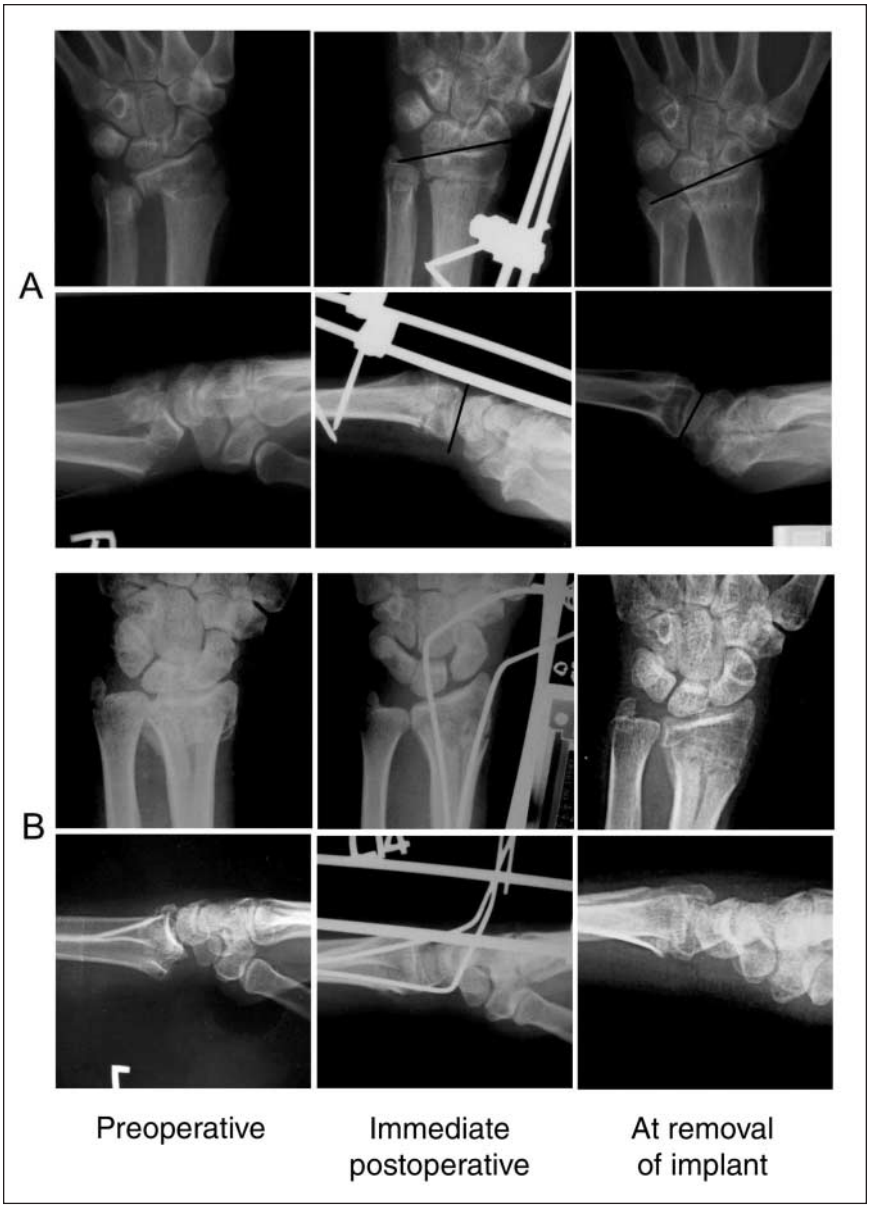

FIG. 1. Representative cases of distal radius fracture treated with initial closed reduction, (A) without and (B) with fixation with two 1.8-mm intramedullary Kirschner wires, followed in either case by external fixation. In the latter case (B), 1 wire was drilled between Lister's tubercle and the radial styloid, and the other in the sagittal plane at a 45° angle, 3–5 mm away from the dorsal lip of the radial radius. Each was then inserted into the intramedullary space manually with a more horizontal angle.

Treatment

All wrist fractures were initially managed in the emergency department with closed reduction followed by immobilization in an above-the-elbow plaster splint. The injuries were later treated in an operating theatre by experienced surgeons. When used, 2 Kirschner wires for supplementary imK were inserted before external fixation was applied. All operations were guided with intraoperative fluoroscopy.

Physical therapy was initiated on the first day after surgery. Patients were advised to avoid supporting weight with that hand for at least 12 weeks. Further physical therapy, including range of motion of the fingers, wrist (pronation and supination) and elbow, was continued for 12 weeks after the fixator(s) were removed.

Radiographic evaluation

All images were assessed in a blinded fashion by 2 independent orthopedic surgeons (J.S.S. and S.M.H.) and the pairs of measurements averaged. When measurements varied by more than 50%, the 2 observers together re-evaluated the images and a third, consensus measurement was made.

Good-quality standardized PA and lateral radiographs were available for evaluation in each case, recorded at preop, postop and postfixation. The PA view involves abduction of the patient's humerus so that the elbow is at the same level as the shoulder; in the lateral view, adduction of the humerus with the elbow flexed at 90°.

Three radiographic measurements are routinely recorded at our institution in injuries involving displacement of the distal radius: radial height and inclination in the PA view, and the volar tilt of the distal radial articular surface in the lateral view.[24–26] Radial height is measured as

the distance between 2 lines perpendicular to the long axis of the radius, one drawn at the tip of the radial styloid and another at the distal ulnar articular surface. Radial inclination is measured as the angle between a line drawn through the tip of the radial styloid and the medial corner of the lunate facet and a line perpendicular to the long axis of the radius.

Functional evaluations

Residual deformity was also one of the objective evaluations of functional assessment in this study. Range of motion of the elbow, wrist and fingers on both the injured and the contralateral side were measured clinically 6 months after the surgery. Grip strength of both hands was measured with a commercially available dynamometer (Heinrich C. Ulrich, Ulm, Germany).

An overall result was determined according to objective radiographic and functional data along with the patient's subjective assessment, with use of demerit-point scoring,[27] of pain, restriction of function and complications (as excellent, good, fair or poor).

Data analysis

Comparisons of measurements made at the 3 events were analyzed to evaluate the stabilization effect of isolated versus augmented external fixation. A 2-tailed 2-sample unpaired Student's t test was used to assess statistical significance, with a p value of 0.05 or less considered to be significant.

Results

Osseous deformity of the distal aspect of the radius at 3 different stages of treatment is illustrated in Fig. 2. Details of these data are listed in Table 2.

Surgical corrections of radial height and inclination were significant in both groups ($p < 0.05$), but volar tilting was statistically improved only in the imK group ($p < 0.0005$). All 3 corrections were gradually lost in the EFA group and significantly differed between groups by the time fixation was removed (Table 2).

Analyses of perioperative changes (preop v. postop measurements) and longer-term differences (preop v. postfixation measurements) showed results that were significantly better in the imK group ($p < 0.001$, Table 3). Improvements in radial height ($p = 0.021$) and inclination ($p = 0.006$) were well maintained in the presence of imK supplementation.

Clinical examinations of range of motion in the injured wrist 6 months after surgery revealed significantly better extension and flexion ($p < 0.0001$), pronation and supination ($p < 0.0005$) and radial and ulnar deviation ($p < 0.05$) in the imK group than in EFA patients (Table 4). Moreover, when grip power was compared between the injured and the uninjured wrist, imK patients achieved nearly 76% of the contralateral wrist's grip, whereas those in the EFA group averaged just under 50% ($p < 0.0005$).

Discussion

External fixation, with its minimal invasiveness, remains in wide use to treat fractures of the distal radius. But as reported by many authors,[13,14] significant losses of reduction occur, attributable to pin loosening, infection and fixator failure. When Seitz and colleagues[16] investigated the technique of "augmentation" of external

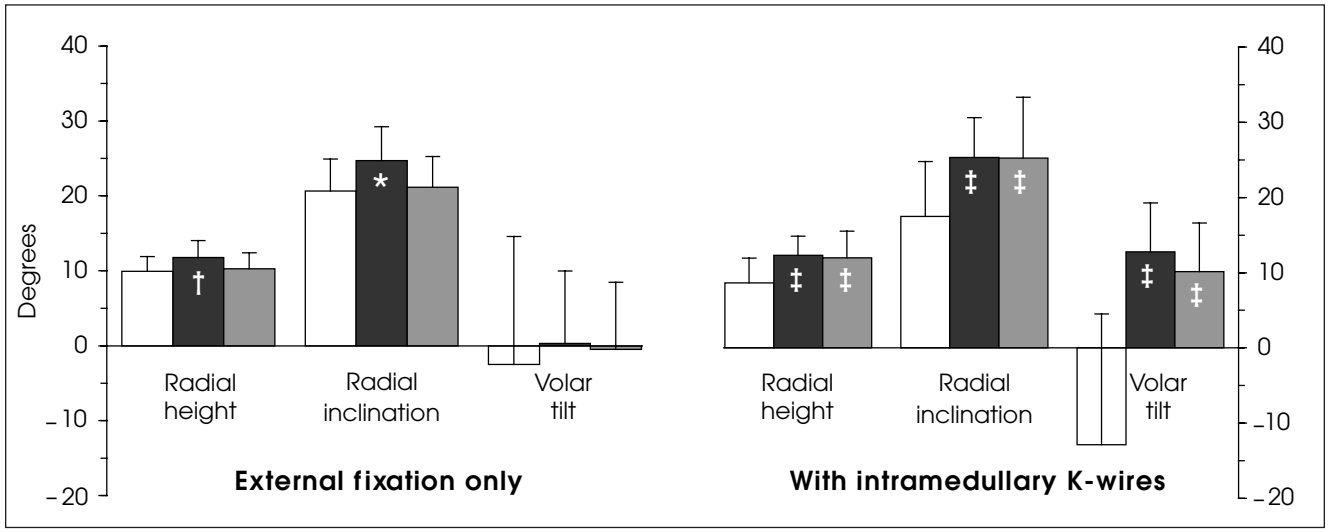

FIG. 2. The effect of unsupplemented and supplemented external fixation in the treatment of distal radius fractures. Measurements were taken from radiographs recorded at the initial visit (before reduction: white columns), immediately after surgery (black columns), and immediately after fixator removal (grey columns). Improvements over pre-reduction values were generally significant (*$p < 0.05$; †$p < 0.005$; ‡$p < 0.0005$) except for volar tilting in patients treated with external fixation alone. In fractures treated with intramedullary Kirschner wires augmenting external fixation, all 3 improvements were significant at $p < 0.0005$, and the reductions were better preserved (also $p < 0.0005$ compared with initial measurements).

fixation, in which percutaneous Kirschner wires are used as a lateral buttress to secure the radial styloid fragment, their reported rate of results that were satisfactory overall was 92%. In our previous study,[22] we found that despite excellent reduction of radial height and radial inclination, volar tilt of the distal radius was seldom well restored with external fixation, and that supplementary imK with multiple Kirschner wires in various directions showed no significant additional benefit for stability.

Later, manual reduction and antegrade imK fixation was reported[28] as an effective treatment for distal radius fractures, with prevention of dorsal angulation and a low rate of soft-tissue complications (although radial shortening was not controlled effectively). In our current study, we compared the results of a standard protocol of closed reduction, percutaneous imK augmentation and external fixation to treat distal radial fractures with those of external fixation alone.

Distal radius fractures are common injuries occurring more frequently than any other fracture,[29] and remain one of the most frequent skeletal injuries treated by orthopedic or trauma surgeons.[30,31] Much of the literature has reported that both the severity of anatomic interruption at injury[32–37] and the residual anatomic deficit after treatment, i.e., quality of reduction,[33,38–40] are crucial in determining the physical impairment in grip and range of motion as outcome measures.

In the distal radial fractures we treated with external fixation alone, measurements of radial height and inclination showed significant improvement; but the imK procedure had more benefit in their correction, and the improvements were maintained well.

In the group we treated with augmented fixation, improvements were significant for all 3 measures. Although volar tilt of the distal radius was improved in the EFA group, those changes did not attain statistical significance (Fig. 2). Supplementary imK contributed significantly in the correction of volar tilt after distal radius fracture.[17]

Supplementation with imK did not contribute to the correction of radial height and inclination in the immediate postoperative measurement, but did contribute to the correction of volar tilt (Table 2). Furthermore, the correction of radial height, radial inclination and volar tilt were well maintained in the imK group (Table 2). Supplementation with imK improves the stabilization effect of external fixation (Table 3).

In a series of 103 unstable distal radius fractures treated with external fixation, Klein and coauthors[41] reported good maintenance of the radial height and radial angle with an external skeletal fixator, but found that volar tilt could not be reconstituted sufficiently. Like Weber and Szabo,[42] we also found that improvements to volar tilt were also difficult to maintain.[22] The most important factor affecting the functional outcome was radial height followed by volar tilt. Carpal instability was also an indicator of poor functional results.[28] Radial shortening was strongly correlated with the final functional outcome.[43,44] Kihara and associates[45] defined the volar tilt as an important prognostic factor in Colles' fractures; restoration of the volar tilt appears to be the major factor in regaining normal wrist function after fracture; loss of the volar tilt can lead to ulnar impingement and eventually to dorsal carpal collapse.

Our clinical findings support the concept of augmentation of external

Table 2

Mean measurements from radiographs (and SD), comparing treatment groups

Distal radial variable and time	EFA group *n* = 20	imK group *n* = 36	*p* value
Radial height, mm			
Preoperative	9.9 (2.0)	8.6 (3.3)	0.062
Immed. postoperative	11.8 (2.3)	12.3 (2.5)	0.207
Immed. postfixation	10.3 (2.1)	12.0 (3.5)	0.024
Radial inclination, °			
Preoperative	20.6 (4.3)	17.5 (7.3)	0.042
Immed. postoperative	24.7 (4.5)	25.3 (5.3)	0.333
Immed. postfixation	21.1 (4.1)	25.3 (8.1)	0.019
Volar tilting, °			
Preoperative	–2.5 (17.1)	–12.9 (17.4)	0.018
Immed. postoperative	0.3 (9.6)	12.8 (6.5)	<0.001
Immed. postfixation	–0.5 (8.9)	10.1 (6.5)	<0.001

EFA = external fixation alone; Immed. = immediate; imK = fixation supplemented with intramedullary Kirschner wires; SD = standard deviation

Table 3

Changes in distal radial measurements treated with external fixation, alone or with imK augmentation

Variable and times compared	Treatment; mean (and SD) EFA group *n* = 20	imK group *n* = 36	*p* value
Radial height, mm			
Postop – Preop	1.9 (2.7)	3.7 (3.0)	0.014
Fixation – Preop	0.4 (2.5)	3.5 (3.5)	<0.0005
Fixation – Postop	–1.5 (1.7)	–0.3 (2.2)	0.021
Radial inclination, °			
Postop – Preop	4.1 (6.7)	7.9 (7.0)	0.026
Fixation – Preop	0.5 (5.4)	8.3 (7.7)	<0.0002
Fixation – Postop	–3.6 (3.9)	–0.1 (5.3)	0.006
Volar tilting, °			
Postop – Preop	2.8 (18.1)	26.2 (18.1)	<0.0001
Fixation – Preop	2.0 (14.1)	23.0 (16.4)	<0.0001
Fixation – Postop	–0.8 (11.0)	–3.1 (6.4)	0.163

– = minus; EFA = external fixation alone; Fixation = postfixation (immediately after removal of implant); imK = intramedullary Kirschner wires; Postop = immediate postoperative; Preop = preoperative; SD = standard deviation

fixation of unstable distal radial fractures with imK. In this study, we validated that supplementing external fixation with imK can effectively correct the radial height, radial inclination and volar tilt and, even more, can improve retention of the fracture reduction during fracture-healing, resulting in better function (Table 4).

The strengths of the present study are that all patients were treated by the same surgeon and physical therapist using standardized implants and the same techniques. Its weaknesses include data collection in a retrospective manner, the small number of patients in each treatment group, a short follow-up period and a failure to measure inter-observer errors in radiographic interpretation or functional evaluation.

Conclusion

A variety of clinical studies have confirmed laboratory data correlating malunion with poor function. Soft-tissue, intercarpal ligament and distal radio-ulnar joint disruption in these patients further worsen outcomes. Importantly, anatomic position at fracture union rather than at presentation has the strongest correlation with long-term functional results. Although residual articular malalignment may be better tolerated in older patients who sustain lower-energy injuries, the lengthening lifespan and increased activity of our expanding elderly population heightens the importance of anatomic articular restoration. Nonetheless, this study clearly supports the contention that the placement of intramedullary Kirschner wires can improve retention of fracture reduction during healing, resulting in better functional outcome.

Competing interests: None declared.

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Table 4

Functional evaluation of distal radial fractures treated by external fixation alone (EFA) or with imK augmentation

Measurement	Treatment; mean (and SD)		*p* value
	EFA group	imK group	
Extension, °	14.1 (13.0)	35.3 (17.9)	<0.0001
Flexion, °	19.1 (13.7)	41.5 (17.9)	<0.0001
Pronation, °	29.4 (19.4)	64.3 (27.6)	<0.0001
Supination, °	62.0 (13.4)	82.8 (31.1)	<0.0005
Radial deviation, °	13.3 (4.6)	15.6 (2.8)	0.0236
Ulnar deviation, °	16.9 (6.5)	20.2 (3.3)	0.0192
Grip power, % of contralateral	49.5 (21.4)	75.8 (18.0)	<0.0001

imK = intramedullary Kirschner wires; SD = standard deviation

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