Comparison of operating time, fluoroscopy exposure time, and functional and radiological results of two surgical methods for distal forearm fractures of both-bones in pediatric patients: Is it necessary to fix both bones?

Hakan Kocaoğlu1, Mahmut Kalem1, Mustafa Kavak2, Ercan Şahin3, Kerem Başarır3, Hakan Kınık1

1Department of Orthopedics and Traumatology, Ibn-i Sina Hospital, Ankara University, School of Medicine, Ankara, Turkey
2Department of Orthopedics and Traumatology, Eskişehir Osmangazi University, School of Medicine, Eskişehir, Turkey
3Department of Orthopedics and Traumatology, Bülent Ecevit University School of Medicine, Zonguldak, Turkey

ABSTRACT

Objectives: The aim of this study was to compare the functional results of internal fixation of both forearm bones versus fixation of the radius alone in the treatment of distal both-bone forearm fractures in children.

Methods: This study included a total of 34 children who were treated for distal forearm both-bone fracture. Patients were divided into two groups according to the technique used, which depended on the date of their surgery. Group 1 consisted of 18 children (14 males and four females; mean age: 10.3 years; age range: 7–16 years) who underwent both-bone fracture fixation using closed reduction and percutaneous pinning; Group 2 consisted of 16 children (12 males and four females; mean age: 10.1 years; age range: 6–15 years) who underwent only radius fracture fixation. The average follow-up was 65.6 months in Group 1 and 38.9 months in Group 2. Operating time, fluoroscopy exposure time, functional results (Mayo Wrist Score, visual analogue scale score, and range of motion), radiological results (time to union and malunion), and complications were recorded as outcome parameters.

Results: The mean operating time was 35 min (range: 30–45 min) in Group 1 and 19 min (range: 10–25 min) in Group 2 (p<0.001). The mean fluoroscopy exposure time was 54 sec (range: 40–70 sec) in Group 1 and 18 sec (range: 10–26 sec) in Group 2 (p<0.001). Only three patients in Group 1 and four patients in Group 2 exhibited <10° of limitation in pronation and supination. No significant differences were determined between the groups with respect to functional scores (p=1.000). Final follow-up radiographs showed no malalignment in either group. In terms of time to union, there was no significant difference between groups (p=1.000). Additionally, only three minor complications associated with the pin track (two patients in Group 1 and one patient in Group 2) were noted.

Conclusion: In children with distal both-bone fractures, fixation of the radius fracture alone may be considered as an alternative method of treatment to fixation of both forearm bones as it results in satisfactory functional and radiographic outcomes.

Level of Evidence: Level III, Therapeutic study

Distal metaphyseal forearm fractures often occur during childhood. Based on the rapid healing and remodeling potential of children, closed reduction and plaster casting have been the gold standard treatment method for many years (1). Because the acceptable degree of residual deformity has not been well established and considering the re-displacement risk, there has been a recent increase in the tendency toward surgical treatment (2).

In surgical treatment, following closed reduction, the fixation of both bones with percutaneous K-wire is the most commonly-used method (3-7).

Although the fixation of the distal radius with a percutaneous pin is a simple technique because of the wide diameter and trapezoid structure of the bone, the narrow diameter and square cross-section of the ulna, especially in the distal section, make its fixation with percutaneous K-wire more difficult (8). This has prompted research into alternative solutions, such as antegrad or retrograde transphyseal or transradioulnar fixation (1, 9, 10). There are studies in the literature showing that single-bone fixation was sufficient to treat both-bone diaphyseal forearm fractures; however, to the best
of our knowledge, there are no studies that have evaluated the efficacy of single-bone fixation treatment of distal metaphyseal forearm both-bone fractures in children (11-13).

The aim of this study was to retrospectively compare the functional results in patients with fixation of both bones with the results in patients with fixation of only the radius; both procedures were applied after closed reduction of a distal metaphyseal forearm both-bone fracture.

Materials and Methods

The Local Ethics Committee granted approval for the study and written informed consent was obtained from patients’ family members who participated in this study. Hospital records from January 2011 to December 2015 were retrospectively screened for patients treated with closed reduction and percutaneous K-wire fixation for distal metaphyseal forearm both-bone fractures. The study included patients with an open growth plate (age <16 years), an acute displaced distal metaphyseal forearm both-bone fracture, and indications for surgery. For this study, we used the AO Pediatric Comprehensive Classification of Long-Bone Fractures (AO PCCF) in which the metaphysis is defined as the square over the widest part of the physis of both bones on the anterior-posterior (AP) X-ray. Surgical indications were a complete displacement of the radius or an angulation of ≥20° of the radius, in which closed reduction alone would not ensure maintained stability.

Patients were excluded from the study if they had an open fracture, a pathological fracture, definite physis damage, a wrist injury at the initial trauma site, or follow-up of <1 year. A total of 47 patients treated with closed reduction and percutaneous K-wire fixation of a distal forearm fracture were enrolled in the study. Thirty-nine patients were excluded: one had a fracture of the ipsilateral ulna diaphysis as the result of a subsequent fall, two had open fractures, four had accompanying physis fractures, and six had an insufficient follow-up time. Thus, 34 patients who met the inclusion criteria were evaluated in terms of demographic data, operating time (skin incision-to-skin closure), time to fracture union, fluoroscopy exposure time, radiological and functional evaluations, and complications. The mechanisms of injury included a fall while walking or running (n=15), sports activity (n=9), and pedestrian accident (n=3) (Table 1).

The same fluoroscopy imaging unit (OEC® 9900 Elite, General Electric Healthcare, USA) was used by the same radiology technician in all cases. All the operations were performed by a single surgeon with ≥10 years of experience in pediatric orthopedics. Before August 2013, fixation was applied to both bones (Group 1) and after that date, fixation was applied to only the radius (Group 2).

Starting in August 2013, the authors’ clinical observation—that fixation of the ulna caused prolonged fluoroscopy exposure and a longer surgical time—led to this change in the surgical technique. All operations were performed using general anesthesia and with the patient in a supine position with the arm placed on a hand-arm table. Under fluoroscopic guidance, reduction was performed with traction and closed manipulation and was checked with AP and lateral images. If the desired quality of reduction was not achieved, a K-wire (Karaoglu Surgical Tools, Samsun, Turkey) was used as a percutaneous shoehorn from the dorsal fracture line to achieve reduction (14). Then, the K-wire was advanced retrograde from the styloid to cross the fracture. A second K-wire was used retrograde from the dorsoulnar side close to the wrist to cross the fracture. The size of the K-wires used was determined by the size of the radius and the geometry of the fracture. The ends of the K-wires were bent, then cut and left over the skin.

After fixation of the radius, the quality of the ulna reduction was evaluated. If sufficient reduction could not be obtained with closed manipulation, reduction was achieved with the aid of a percutaneous K-wire. In Group 1, fixation of the ulna was achieved with antegrade and retrograde cross pins, an intramedullary method, or a combination of the two, depending on the age of the patient and the location and geometry of the fracture (Figure 1). No additional fixation was applied to the ulna for patients in Group 2— even if K-wire-aided reduction was necessary (Figure 2).

Postoperatively, a long arm splint was applied to the arm while the arm was in a neutral position. Patients were called in for follow-up examinations at 1, 3, and 6 months. When sufficient fracture healing was confirmed, at approximately the fourth week, the K-wires were removed (4). If a delayed union was observed, the patient was called in for X-ray follow-up every 2 weeks. Passive exercises were initiated with transfer to a partial splint at 4-6 weeks. The children were then permitted to resume their routine daily activities. No formal physical therapy was prescribed. In weeks 4-6, following removal of the splint, the range of motion (ROM) was evaluated. Additional radiographic evaluation was used to confirm remodeling, according to the amount of angulation in the fracture line.

Patients were called in for functional and radiological evaluation. All the functional evaluations and measurements were made by one of the authors (HK). At the final evaluation, the elbow ROM was assessed with a goniometer and compared with that of the contralateral elbow, and the wrist function was assessed using the Mayo Wrist Score (MWS). ROM and restrictions to ROM were measured in categories of 10-degree increments. Appearance and patient satisfaction with the forearm were assessed using a 10-cm visual analogue scale score (VAS) and a simple questionnaire (15, 16). The radiographic measurements of union time and malalignment were evaluated using Centricity PACS-IW software (General Electric Healthcare, Chicago, IL, USA). Radiographic angulation

### MAIN POINTS

- In children with distal both-bone fractures, fixation of the radius fracture alone has satisfactory functional and radiographic outcomes.
- With one-bone fixation technique, the operation time is reduced to half.
- Less fluoroscopy exposure is required with one-bone fixation technique.
was considered malalignment if it exceeded 10 degrees. Thus, radiological data were classified in categories of 10 degrees.

**Statistical analysis**

Statistical evaluation was performed using the Statistical Package for Social Sciences version 11.5 software (SPSS Inc., Chicago, IL, USA). Normality of variables was tested by the Shapiro–Wilk test. Numerical variables reflecting normal distribution were stated as mean ± standard deviation (SD) and those not reflecting normal distribution as median (minimum-maximum) values. Categorical variables were stated as number (n) and percentage (%). As there were two groups, differences between the groups in numerical variables not showing normal distribution were evaluated with the Mann–Whitney U test, and relationships between categorical variables were determined with the Pearson chi-square test and the Fisher Exact test. A value of p<0.05 was accepted as statistically significant.

**Table 1.** Patient demographics and follow-up data (Group 1: Both-bone fixation; Group 2: Radius-only fixation)

|                     | Group 1 (n=18)       | Group 2 (n=16)       | p     |
|---------------------|----------------------|----------------------|-------|
| Mean Age (years)    | 10.3 (7–16)          | 10.1 (6–15)          | 0.746 |
| Gender              |                       |                      |       |
| Male                | 14 (77.8%)           | 12 (75%)             | >0.999|
| Female              | 4 (22.2%)            | 4 (25%)              |       |
| Side                |                      |                      |       |
| Dominant            | 10                   | 10                   | 0.681 |
| Non-dominant        | 8                    | 6                    |       |
| Injury mechanism    |                      |                      |       |
| Fall                | 9                    | 6                    | 0.860 |
| Sports activity     | 5                    | 4                    |       |
| Pedestrian accident | 1                    | 2                    |       |
| Mean follow-up time* (months) | 65.6 | 38.9 | <0.001 |
| Mean operating time* (minutes) | 35 (30–45) | 19 (10–25) | <0.001 |
| Mean fluoroscopy time* (seconds) | 54 (40–70) | 18 (10–26) | <0.001 |
| ROM Limitations (Pronation/Supination) | 3 (<10°) | 4 (<10°) |       |
| MWS                 |                      |                      |       |
| Excellent           | 15                   | 13                   | >0.999|
| Good                | 3                    | 3                    |       |
| VAS                 |                       |                      |       |
| VAS 0–1             | 16 (89%)             | 14 (87%)             | >0.999|
| VAS 2–3             | 2 (11%)              | 2 (13%)              |       |

ROM: range of motion; MWS: Mayo wrist score; VAS: visual analogue scale score

*p<0.01

**Figure 1.** a-d. A 10-year-old male patient treated with the both-bone percutaneous pinning method. (a) Preoperative anterior-posterior (AP) radiograph of the forearm. (b) Early postoperative (before discharge) AP images of reduction by two K-wires. (c) Final follow-up (46 months postoperative) AP radiograph. (d) Final follow-up (46 months postoperative) lateral radiograph
Results

Between January 2011 and December 2015, a total of 112 children were treated in our hospital for fractures of both bones in the distal metaphyseal forearm. Of those 112 patients, closed reduction and percutaneous K-wire fixation were used in 47 patients who were initially enrolled in this study. All patients had distal metaphyseal fractures according to the AO PCCF definition. Following the exclusion of 13 patients, the evaluation was conducted on a total of 34 patients who met the study inclusion criteria. Group 1 consisted of 18 patients with fixation of both the radius and the ulna. Group 2 consisted of 16 patients with fixation of only the radius. All operations were performed within 24 hours of the injury. The elbow was immobilized with a splint during the period before the surgery.

There were no significant differences between Groups 1 and 2 in age, gender, the side of the injury, and the mechanism of the injury (p>0.05 for all). In the perioperative data, the mean operating time and the mean fluoroscopy time of Group 2 were found to be significantly shorter (p<0.001 for both) than those for Group 1 (Table 1).

In three patients with double-bone fixation and four with single-bone fixation, <10° pronation–supination ROM restriction was observed; total ROM was >120°, and none of these patients was aware of the restriction. There was no ROM restriction in other directions. No statistically significant difference was determined between the groups in terms of functional scores (p=1.000) (Table 1).

On the final follow-up radiographs, no malignment of >10° was observed in the radius and ulna. There were no significant differences between the two groups in terms of the time to union. At approximately 4 weeks after surgery, clinical and radiographic union were determined.

Two patients in Group 1 developed superficial pin-site infections; both patients recovered with oral antibiotics and daily dressings. In one patient in Group 2, the K-wire had advanced subcutaneously because of pin migration; this was removed under sedation.

Re-displacement or re-angulation was not observed in any of the patients during the postoperative follow-up period. At the final follow-up examination, none of the patients had non-union, radioulnar synostosis, vascular damage, premature physeal closure, or residual angulation.

Discussion

Distal forearm fractures are frequently seen in children. Because of the remodeling potential after union, they are managed differently from similar injuries in adults (17). In recent years, there has been an increase in surgical management if acceptable alignment cannot be obtained without surgical intervention or cannot be maintained, taking into consideration the risk of re-displacement (2-7).

Single-bone fixation for diaphyseal both-bone forearm fractures was first described by Flynn and Waters, in view of the better clinical results observed in radiological images and the remodeling potential in childhood; subsequent studies reported that comparable functional and radiological results were obtained with one-bone fixation (18-21).

Although the most common wiring technique is percutaneous K-wiring using two cross wires in non-Kapandji fashion, there
are several other techniques for the fixation of these fractures (22). Kapandji’s intrafocal method utilizes intrafocal wires introduced from the fracture line to the cortex of the proximal fragments. In the Py-Desmanet method, the K-wires extend from the cortex of the distal fragment to the proximal intramedullary canal, taking advantage of the K-wires’ elasticity (23, 24). Intrafocal wiring has the advantage of sparing the physis, but this comes at the expense of maintaining fracture stability in the presence of dorsal comminution at the fracture site (25). Cross-wires, either piercing through the proximal cortex or as in the Py-Desmanet technique, are inherently more stable (26).

In a review by Westacott et al. that compared single- or both-bone fixation, the functional results of single-bone fixation were reported to be comparable to those of both-bone fixation (12). Du et al. compared the two methods and obtained similar functional results with both methods and acceptable radiological angulation (<10°) in the ulna in patients treated with only radius fixation (27).

In the literature, the fixation of the radius is more frequent, as it has a more complex function, it is important in terms of preserving forearm function, and it is thought that the alignment of the ulna will recover (28, 29). In the current study, when the high remodeling potential of distal metaphyseal fractures as compared to proximal fractures was taken into account, the surgeon’s preference for fixating both bones changed over time, and only-radius fixation was applied in the later cases (30, 31). This change yielded comparable functional and radiological results.

In the treatment of forearm fractures, it has been demonstrated that single-bone fixation shortens the operating time. In addition, the use of fluoroscopy in closed fixation methods increases the exposure to radiation with its associated risks; therefore, changing the treatment method when possible has been recommended to minimize exposure (32-34). Another point that should be kept in mind when selecting the treatment method is that, as the operating time increases so does the possibility of technical error, and the operating time should also be considered in terms of productive use of operating theaters (35, 36). In the current study, shorter operating times and shorter fluoroscopy times were obtained with single-bone fixation than those with double-bone fixation.

Percutaneous fixation with K-wire applied around the hand and wrist may result in complications, most often pin site infection but also osteomyelitis, tendon rupture, nerve lesion, and pin loosening or migration (37). Another problem in the treatment of fractures in this region is that a large part of ulnar growth originates from the distal physis, and deformity and/or arrest in long-term forearm growth may be seen as a result of damage to the ulnar growth plate, although we did not observe these problems in our series (38).

Alnaib et al. applied percutaneous radius-only fixation in the treatment of forearm shaft fractures and reported that complication rates were lower than those of studies in which both-bone fixation had been applied (11).

The results of the current study on treatment of distal metaphyseal forearm both-bone fractures indicated that radius-only fixation had functional results comparable to those of both-bone fixation and afforded reductions in the duration of surgery and radiation exposure.

Limitations of the current study were primarily that it was retrospective in design and that the number of patients was relatively low.

In the current study, comparison of both-bone and radius-only fixation methods for distal metaphyseal forearm both-bone fractures in similar pediatric patient groups showed that the functional results were similar. The differences between the two methods were found to be in the surgery and fluoroscopy durations. On the basis of the results of this study, radius-only fixation can be recommended as an alternative method for fractures of both distal forearm bones in children.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Ankara University School of Medicine (Decision no: 17-871-16 Date: 16 November 2016).

Informed Consent: Written informed consent was obtained from the parents of the patients who participated in this study.

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