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RESEARCH ARTICLE

THE RELATIONSHIP BETWEEN FRACTURE CONFIGURATION AND OPEN REDUCTION IN PEDIATRIC FOREARM FRACTURES

***Dr. Uğur YARADILMIŞ, Dr. Mehmet ÖZER, Dr. Mustafa Caner OKKAOĞLU, Dr. Ahmet ATEŞ, Dr. İsmail DEMİRKALE and Dr. Murat ALTAY**

Department of Orthopaedics and Traumatology, University of Health Sciences, Keçiören Health Practice and Research Center, Ankara, Turkey

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**Corresponding author:*
Dr. Uğur YARADILMIŞ

ABSTRACT

Background: In pediatric forearm fractures casting and conservative treatment follow-up, a relationship has been found between re-displacement and malalignment with complete fracture, quality of the first reduction, and proximal 1/3 fracture. For similar reasons, we believe that instability in the operating room also continues and some fractures require open reduction. ***Objective:*** The aim of this study is, to predict the fractures that require mini-open intervention and to evaluate the functional results of these unstable fractures. ***Methods:*** 69 patients treated with intramedullary kischner wire [Open reduction (n:45), closedreduction (n:24)] for a pediatric forearm fracture in our clinic were reviewed retrospectively. Information regarding the age, gender, left/right side were obtained from the patients' files, and data regarding preoperative fracture displacement, angulation, localization of radius and ulna fracture, type of injury of the radius fracture, and the level of fracture. The patients were evaluated radiologically with radial inclination index and functionally with the Price criteria regarding location. ***Results*:** Open reduction and fixation were applied to 45 patients (65%). Open reduction was required when the radius fracture was non-transverse, and the fracture localization progressed proximally (p=0.039, 0.049, 0.039). No relationship was found between open reduction with age, side, gender, angled fracture, and displacement. According to the Price criteria, an excellent result in the ratio of 94% was obtained. There was no difference in mini-open fixation regarding union duration and complications. Although the radial inclination index increased in proximal and non-transverse fractures (7.8% ± 1.9), this was not reflected in functional scores. ***Conclusion*:** In pediatric forearm fractures, if the fracture is proximal or not transverse, open reduction is needed mostly and open reduction intramedullary fixation is performed successfully in these fractures.

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INTRODUCTION

Forearm fractures are frequently seen in childhood. It constitutes 6% of all pediatric fractures (Cheng and Shen, 1993; Landin, 1997). Unless it is treated appropriately, malunion and movement limitation could be seen (Daruwalla, 1979). Forearm diaphyseal fractures can be generally treated by closed reduction and cast (Zionts *et al.,* 2005). The indications for surgical treatment can be defined as the inability to obtain an acceptable range by closed manipulation, fractures accompanied by neurovascular injuries, polytrauma cases, and open fractures (Hugston, 1962; Larsen, 1988). It has been noted that successful results were obtained by the application of intramedullarynail fixation (Richter, 1998). During the follow-up of closed reduction and casting, a relationship was found between re-displacement and malalignment with complete fracture, quality of the first reduction, missing the control appointment, and proximal 1/3 fracture (Younger and Tredwell, 1994; Crawford, 1988; Creasman *et al.,* 1984). For similar reasons, we believe that instability caused by fracture configuration continues inperoperative and some fractures require open reduction. The aim of this study is, to predict the fractures that require mini-open intervention and to evaluate the functional results of these unstable fractures.

MATERIALS AND METHODS

Seventy-eight patients who underwent pediatric forearm fracture surgery in our clinic between January 2013 and June 2018 were analyzed retrospectively (Figure 1). Patients under 15 years of age with casting more than 10 degrees of angulation and having cortex continuity of less than 50% after closed reduction and castings were included in the study. 8 patients with a plaque and 1 patient with multiple injuries were excluded from the study.

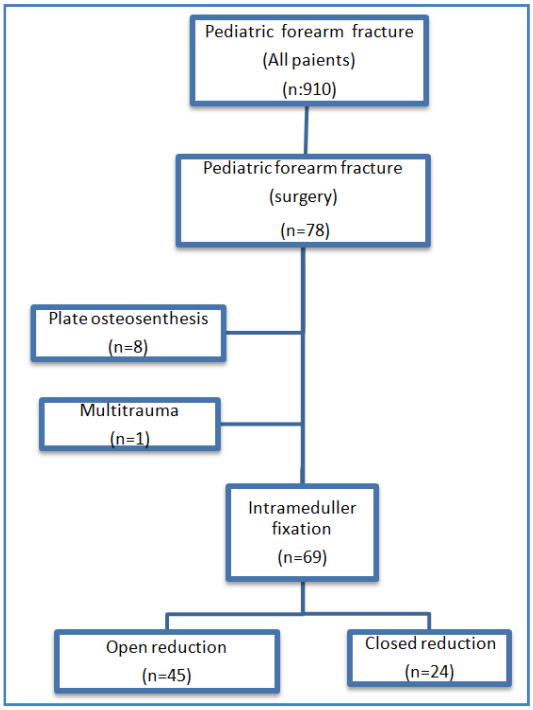

Figure 1. Follow up diagram

The fracture configurations of 45 patients who had undergone open reduction and 24 patients who had closed reduction were compared. The patients' age, gender, and side were noted according to their patient files. Preoperative fracture displacement, angulation, localization of the radius fracture (1/3 distal, middle and proximal), type of injury of the radius fracture (oblique, inverse oblique, transverse, spiral), localization of ulna fracture (1/3 distal, middle, proximal) and fracture level were evaluated and statistically grouped from direct radiographs according to patient distribution. The relationship between fracture configuration and demographic data with the open reduction was evaluated. Malalignment, duration of union, infection, and refracture were recorded in follow-up. They were evaluated according to the Price criteria in terms of functionality (Price *et al.,* 1990). Malalignment was evaluated by radial bow index and location. The radial bowpoint and the radial bow index were calculated by determining bicipitaltubercule of radius, the most medial point of the distal radioulnar joint and the deepest points of the radius shaft on the medial side from the front-back radiographs of the patients' last follow-up. Radial bow index over 10 was accepted as pathological (Schemitsch *et al.,* 1992; Firl *et al.,* 2004). Clinically no pain in the fracture line and radiologically the appearance of callus tissue in at least three cortexes in the front-back lateral radiographs were accepted as fracture union (Shah *et al.,* 2010). The inability to achieve the union in the fourth month, the delayed union and the absence of callus tissue at the sixth month were defined as nonunion.

Surgical Technique: The closed reduction under tourniquet in supine position was initially performed. The intramedullary kischner wire (K-wire) fixation of the radius or ulna first was the preference of the physician. Closed reduction was attempted 3 times; open reduction was initiated due to the failure. The open reduction was performed with a 2 cm mini-incision over the fracture line. The ulna was accessed from the proximal apophysis. The radius was accessed from the styloid or the lister tuberculum in the epiphysis proximal. Fixing was achieved especially after the radial inclination was maintained. The K-wire were bent externally and released.

Follow-up: Short arm splint was applied to the patients on the 1st day after the operation. Elbow joint movement and finger movements started immediately. Examination and radio graphical control were performed at 2-week intervals. The splint was removed on the 6th week, and the exercise for the wrist was initiated. In the event of bonding, the pins were taken off on the 8th week. The patients were called for controls on the 3rd and 6th months. All of the study procedures met the ethical standards of the institutional and national research ommittees and all of the tenets of the 1964 Helsinki declaration. Written informed consent was obtained from all of the participants. The study was approved by the ethics committee of Keçiören SUAM Hospital (28/11/2018, 32. meeting).

Statistics: Data were analyzed using SPSS 22 program, and 95% confidence level was achieved. In our analysis, frequency distribution and minimum maximum and average values were given for variables. The relationship between reduction and other properties was analyzed by Chi-square test. The relationship between reduction and radial bow location, radial bow index, union time, fluoroscopy number, surgery time was analysed by independent T-test.

RESULTS

Of the 910 patients who applied to the emergency department for a forearm fracture, 78 patients (%8.5) were treated surgically. Sixtynine patients (%90) fixation with K-wire. The mean age of the patients was 11.42±3.15 (5-15). 70% of the patients were in the 10-13 age range. 64 patients (94.2%) were male, and 5 patients (5.8%) were female. While 48.5% of the patients were right-handed, 51.5% were left-handed. 8 patients had Gustilo Anderson type 1 open fracture. Open reduction and fixation were applied to 45 patients (65%). In the case of oblique or reverse oblique radius fractures, 83% of the fractures were detected by open reduction, while open reduction observed in the ratio of 59% in transverse fractures ($p = 0.039$). Based on the fracture location in the radius, as proximal reached the fracture becomes open reduction. While open reduction was required in distal in the ratio of 50%, open reduction was required in proximal by 82% ($p = 0.049$). When the ulna was examined, 100% open reduction was required in the proximal fracture, and 60% open reduction was required while in the distal middle and distal. 45 patients (65%) needed open reduction. Open reduction was not related to age, side, gender, the angle of the fracture and displacement. The relationship between fracture configuration and open reduction is given in Table 1. When the relationship between the first fixation of the fracture and the open reduction is considered, open reduction is required in the ratio of 58.3% when the ulna fracture is initially fixed, and 72.7% open reduction is required when the radius is initially fixed. The relationship between the first fixation and the open reduction was not observed ($p = 0.317$). The average duration for union was found to be 8.4 ± 4.1 weeks; There was no difference found between open reduction (8.6 ± 4.1 weeks) and closed reduction (8.2 ± 3.9 weeks). There was no increase in complications in the open reduction group. In the open reduction group, operation time is longer and flouros copy is usedmore (Table 2). The mean radial bow point was localized at 61.8% ± 6.4 of the radius length. The mean radial bow index was found to be 5.8% ± 1.4. No significant difference was observed between the open (56.1% ± 6.1) and the closed reduction (66.4% ± 5.6).

Table 1. Analysis of the Relationship Between Reduction and Variables

		Open reduction	Closed reduction	P
Age		11,8	10,2	0,503
Gender	Male	41 (63,1%)	24 (36,9%)	0,132
	Female	4 (100%)	0 (0%)	
Angulation	<20	32(71%)	13 (29%)	0,718
	>20	14 (58,3%)	10 (41,6%)	0,691
Deplasment	<%100	29 (67,5%)	14 (32,5%)	
	>%100	17 (65,4%)	9 (34,6%)	
Same location	Yes	22 (70%)	10 (30%)	0,854
	No	24 (64,7%)	13 (35,3%)	
Radius	Transvers	25 (59,5%)	17 (40,5%)	0,039*
	Oblik/Ters Oblik	19 (82,6%)	4 (17,4%)	
Radius location	Proximal	18(81,8%)	4 (18,2%)	0,049*
	Middle	16 (64%)	9 (36%)	
	Distal	11(50%)	11 (50%)	
Ulnalocation	Proximal	9 (100%)	0 (0%)	0,015*
	Middle	19 (61,3%)	12 (38,7%)	
	Distal	17 (58,6%)	12 (41,4%)	
Open reduction	Ulna	8 (100%)	0 (0%)	
	Radius	6 (100%)	0 (0%)	
	Both	31 (100%)	0 (0%)	
First fixation	Radius	24 (72,7%)	9 (27,3%)	0,317
	Ulna	21 (58,3%)	15 (41,7%)	

Table 2. Comparison of dataobtained in patients' follow-up

	Open reduction (n:45)	Closed reduction (n:24)	P
Radial bow location	56.1±6.1	%66.4±5.6	0.080
Radial bow index	5.5±2.6	6±2.1	0.278
Union duration	8.6±4.1	8.2±3.9	0,752
Nonunion	0	1	0,556
Infection	4	3	0,134
Refracture	1	0	0,218
Surgery time (minute/patients)	74±17.2	52±14.6	0.014*
Fluoroscopy (number of image/patients)	52±9	36±7	0.032*

Figüre 2. Radial bow index (x) and location (y): a) proximal fracture, b) middle fracture

There was no difference found between open reduction (5.5% ± 2.6) and closed reduction (6% ± 2.1). In the proximal and non-transverse fractures (7.8% ± 1.9) the increase in radial bow index was observed but not at the pathological limit. According to the Price criteria; 3 patients were observed to be in good condition, and 1 patient was observed to be in moderate condition. One patient was observed with a delayed union. This patient had a proximal 1/3 fracture, the radial inclination index was high, and the Price index was moderate. Duration of union of the patient were also equal. There was no deep infection. Seven patients with superficial infection were treated with oral antibiotics and superficial debridement. Refracture was observed in one patient. In the third month of the fracture, the patient with post-trauma was treated with open reduction intramedullary fixation.

DISCUSSION

Pediatric forearm fractures are frequently seen. Conservative treatment is often sufficient. Acceptance criteria for conservative treatment are; 15 degrees of angulation below 10 years of age after closed reduction and casting, 45 degrees malrotation and bayonet up to 1 cm short; 10 degrees of angulation and 30 degrees of malrotation above 10 years of age (Daruwalla *et al.,* 1979; Sarmiento *et al.,* 1992; Tarr *et al.,* 1984). Despite this accepted opinion, Matthews et al. stated in their in cadaveric studies that casting with 10 degrees can cause pronation or supination loss up to 20 degrees (Mattthews *et al.,* 1982). Nowadays, surgeons believe that surgery is easier to prevent both cast squeezing and to avoid orthopedic court-cases. Plaque-screw osteosynthesis, intramedullary K-wire, and elastic intramedullary nail are used in surgical treatment. Intramedullary fixation is often used as a biological fixation route for less tissue dissection, and more cosmetic advantages (Shoemaker *et al.,* 1999; Yalcinkaya *et al.,* 2010). Although the intramedullary nailing for rotational stability is controversial, Blasier and Salaman reported that the strong periosteum contributes to rotational stability in pediatric patients (Blasier *et al.,* 1993).

In our study, 69 forearm fractures were identified mini open or closed by means of intramedullary K-wire. 94% excellent results were obtained according to the Price criteria. Functional results are seen well in these fractures due to high re-modelization of children (Blasier *et al.,* 1993; Yalcinkaya *et al.,* 2010). Open reduction was performed in 45 (65%) patients. When fracture configurations were examined, open reduction was required in proximal and non-transverse fractures. An open reduction in the ratio of 50% was required in distal in radius and 82% open reduction was required in proximal (p=0.049). When the ulna was examined, 100% open reduction was required in the proximal fracture and 60% open reduction was required in the middle and distal. Proximal fractures have always been a problem because of the muscle (Murray *et al.,* 1995). In the conservative treatment of proximal and complete fractures, the casting was tried on the extension of the elbow determined as unstable (Walker and Rang, 1991). Walker and Rang reported that 13 proximal 1/3 patients successfully treated with extension splint (Walker and Rang, 1991; Watson Jones, 1940). No relationship was found between fracture level, complete fracture (100% displacement), casting and open reduction requirement. Davis *et al.* highlighted in their conservative follow-up that the complete fractures were 25% reduction loss (Davis and Green, 1976). This situation in conservative treatment was not seen as a risk factor for open surgery. Malalignment radial bow location and radial bow index were examined (Schemitsch *et al.,* 1992; Firl *et al.,* 2004). No difference was observed between the patients who underwent closed-reduction and the patients who underwent open-reduction in terms of the radial bow index. Radial bow location of open reduction was found to be 56.1% ± 6.1 and it was observed to be more proximal (p=0.080). In proximal and non-transversal fractures (7.8% ± 1.9) the radial bow was observed higher. We suggest open reduction and anatomically stable detection in case of proximal and non-transgenic unstable fractures to prevent malalignment.

Similar results were observed in children with the open reduction regarding the duration of union time, infection and refracture with closed reduction (p=0.752, 0556, 0.134, 0.218). The reason that we could think of is that despite the open reduction, both the incision is small, and the biology is not deteriorated by intramedullary fixation. Kischner wire were left externally and removed at the 8th week. Although there was no deep infection, superficial infection was observed in 7 of our patients. There was no difference between open and closed reduction. Leaving K-wire on the outside was not seen as a risk for infection. Duration of union was found to be appropriate. In one of our patients (1.5%), a delayed union was observed, and K-wire was removed according to the union criteria. Refracture was seen in one of our patients (1.5%). Küçükkaya *et al.* applied K-wire removal on the 8th week in the case of union. In comparison with plaque, no additional surgery is required for less refracture and implant extraction (Küçükkaya *et al.,* 1998).

There are some studies suggesting the patients who underwent nail application instead of intramedullary K-wire had early movements. Radial inclination rates become more appropriate but more complication rates and the second surgical need for implant extraction are the weaknesses of the intramedullary nail (Franklin *et al.,* 2012). In open reduction group, as closed reduction has been tried firstly, it increases the operation time and flouroscpy usage. It's seen that operation time and fluoroscopy usage is increased especially if the fracture is unstable and closed reduction is tried again and again. The significant limitation of our study was the retrospective nature and the operation of the patients by many surgeons. Another difficulty in the study was the appropriate radiography for radial inclination measurements.

Conclusion

In pediatric forearm fractures after surgery decision is made, open reduction is generally necessary and mini open reduction and intramedullary fixation is found to be safe and successful. If the fracture is more proximal and non-transverse, need for open reduction increases. If closed reduction is tried again and again in proximal and non-transverse fractures, this increases operation time and fluoroscopy usage.

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