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ORIGINAL ARTICLE

PERCUTANEOUS FIXATION OF FRACTURES OF FOREARM BONES IN CHILDREN

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ABSTRACT

Background: Forearm fractures are the most common fractures in children, representing 40 to 50 percent of all childhood fractures. The aim of this work is to evaluate the results of percutaneous intramedullary fixation of fractures of forearm bones in children. The aim of this work is to evaluate the results of percutaneous intramedullary fixation of fractures of forearm bones in children.

Methods: Between February 2017 and February 2018, 12 patients who are younger than the age of closure of epiphysis exhibited to Zagazig General Hospital suffering from displaced fractures of shaft of both bones of the forearm, all patients were treated by closed reduction and percutaneous intramedullary fixation by K-wires with a period of (6 - 12) month with mean 6.6 moths follow up.

Results: At the end of follow up, the operations were succeeding in all cases. According to Price et al criteria, 8 patients (66.7%) were classified as excellent results, 4 patients (33.3%) were classified as good results and no patients were classified as fair or poor results. No complication detected after the end of follow up period.

Conclusions: Closed reduction percutaneous intramedullary fixation of pediatric displaced diaphyseal forearm fractures by K-wires is a safe, reliable, minimally invasive procedure and effective method of treatment. Based upon this study, it is concluded that displaced fractures of both forearm bones in children are preferred to be intramedullary fixed with K-wires when surgery is indicated with excellent and good results.

Keyword: Forearm fractures, Intramedullary fixed with K-wires

INTRODUCTION

In one large series, forearm shaft fractures of the radius ranked as the third most common fracture after distal radial fractures and supracondylar humeral fractures[1]. In addition, midshaft forearm fractures are the most common sites for refracture in children and among the most common sites of pediatric open fractures[2].

Approximately 75 % to 84 % of forearm fractures occur in the distal third with another 15 % to 18 % in the middle third, while 1 % to 7 % of cases occur in the proximal third[3]. A small percentage are bilateral, and as many as 13 % have an associated supracondylar fracture[4].

Initial preoperative translation of more than 100% (no cortical contact) has been correlated with a greater chance of tissue interposition that requires a mini-open reduction[5].

The goal of treatment of forearm and distal radius injuries is to facilitate union of the fracture in a position that restores functional range of motion to the elbow and forearm[6]. Most shaft injuries present no unusual challenges and require nothing more than skillful closed reduction and cast immobilization due to the unique property of the growth potential of the immature skeleton[7]. There is a relatively high incidence of re-displacement, malunion and consequent limitation of movement. Perfect anatomical reduction is not always necessary since remodeling of malunion may correct any residual deformity[8]. Except in very young children, residual angulation of the forearm greater than 10° should be corrected since remodeling is unpredictable. Angulation has been shown to affect the range of pronation and supination of the forearm[9].

The most common indications for

surgery are failure of closed reduction, open fractures, and fracture instability. When operative intervention is indicated different techniques can be employed such as intramedullary nailing, osteosynthesis with plate and screw fixation and external fixators. Intramedullary nailing has been shown to produce excellent clinical results and in contrast to plate fixation is considered as a minimal invasive procedure [10].

METHODS

12 patients who are younger than the age of closure of epiphysis exhibited to Zagazig General Hospital (Between February 2017 and February 2018) suffering from displaced fractures of shaft of both bones of the forearm, all patients were treated by closed reduction and percutaneous intramedullary fixation by K-wires with a period of (6 - 12) month follow up.

Open fractures, pathological fractures, undisplaced fractures and that needed open reduction were excluded from the study.

Written informed consent:

Written informed consent was obtained from all participants and the study was approved by the research ethical committee of Zagazig General Hospital. The work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Technique:

Under general anesthesia, the patient was placed supine on the operating table and the fracture was analyzed with an image intensifier. In radius, the wire was inserted by surgical drilling through Lister's tubercle or the radial styloid **(Figure 1)** while in ulna, the wire was inserted through the tip of the olecranon **(Figure 2)**. The limb was then placed in above elbow plaster cast with the elbow at 90 degrees of flexion, and the forearm at mid pronation.

Post-operative care:

Intravenous antibiotics were given for 3 days post- operative. Postoperative radiographs were obtained to check the reduction and adequacy of the fixation. Analgesics were taken until complete resolution of pain.

Follow up:

The mean duration of follow up was 6.6 months. The minimum follow up period was 6 months and the maximum was 12 month. Patients were followed up at 2 weeks with AP and lateral X-ray views in cast to check for adequacy of fixation and fracture position. At every follow up visit the patient was examined clinically and radiologically and encouraged to continue active exercises to reach normal range of motion. At the last follow-up visit, patients were assessed for the range of motion of the injured side as compared with the contralateral uninjured side including forearm pronation and supination as well as elbow and wrist flexion and extension.

Implant removal:

The mean time of removal of K-wires was 6.7 weeks, the earliest was 5 weeks and the latest was 10 weeks. No anesthesia was required.

Statistical analysis:

The collected data were computerized and statistically analyzed using SPSS program (Statistical Package for Social Science) version **18.0**. Qualitative data were represented as frequencies and relative percentages. Quantitative data were expressed as mean ± SD (Standard deviation). Chi square test was used to calculate difference between qualitative variables in different groups. Mann Whiteny test was used to calculate differences between qualitative variables in 2 groups in not normally distributed data. The significance Level for all mentioned statistical tests done. The threshold of significance is fixed at 5% level (P-value):
*P value of >0.05 indicates non-significant results.

*P value of <0.05 indicates significant results.

*P value of <0.01 indicates highly significant results.

RESULTS

At the end of the follow up period, patients were assessed by the criteria of Price et al[15]. (**Table 1)** Results showed that 8 patients (66.7%) were classified as excellent results, 4 patients (33.3%) were classified as good results and no patients were classified as fair or poor results. (**Table 2)**

Factors that may affect the final outcome:

Age: There were no statistical significance differences between cases had good outcome and cases had excellent in age. (**Table 3)**

Side and level affected: 8 patients with affection of right side (66.7%) and 4 patients with left side affection (33.3%), 10 of them Rt handed (83.3%) and 2 of them Lt handed (16.7%), 9 patients was the level of injury in middle 1/3 of forearm (75%) and 3 patients was in distal 1/3 (25%). All had excellent results except 4 patient had good result (3 right side affection and 1 left side affection). There were no statistical significance differences between cases had good outcome and cases had excellent in side or level affected. (**Table 4)**

Mechanism of trauma: 8 patients (66.7%) of both bones forearm fractures resulting from falling on outstretched hand (FOOSH), and 2 patients (16.7%) resulting from road traffic accidents (RTA) and 2 patients (16.7%) resulting from direct trauma. All had excellent results except 4 patient resulting from falling on outstretched hand (FOOSH) had good result. There were no statistical significance differences between cases had good outcome and cases had excellent in mechanism of trauma. (**Table 5)**

Associated fractures: 10 patients (83.3%) without associated fractures, whereas 2 patients (16.7%) with associated fractures (8.3% ipsilateral mid 1/3 clavicle and 8.3% ipsilateral mid 1/3 femur). All patients with associated fractures had good results. There were no statistical significance differences between cases had good outcome and cases had excellent in frequency of associated fractures. (**Table 6)**

Associated medical conditions: 25% of the studied cases (3 patients) had associated medical conditions (16.7% had bronchial asthma and 8.3% had Type I DM). All patients with associated medical conditions had excellent results**.** There were no statistical significance differences between cases had good outcome and cases had excellent in frequency of associated medical conditions. (**Table 7)**

Time of fracture union and implant removal: the mean time for fracture union and removal of K-wires was 6.7 weeks the earliest was 5 weeks and the latest was 10 weeks. There were no statistical significance differences between cases had good outcome and cases had excellent in time of fracture union and implant removal. (**Table 8)**

Range of motion: 7/12 patients had a difference between the two sides in supination / pronation at the end of follow up. 3 patients had excellent results and 4 patients had good results. There were statistical significance increase in cases had difference in forearm rotation among good cases. (**Table 9)**

Complications: pin tract infection occurred in 3/12 (25%) patients. All patients with complications had excellent results. There were no statistical significance differences between cases had good outcome and cases had excellent in frequency of complications: (**Table 10)**

Table (1): Price et al criteria.

Outcome	Symptoms	Loss of forearm rotation
Excellent	No complaints with strenuous activity	Up to 10 degrees
Good	Mild complaints with strenuous activity	From 11 to 30 degrees
Fair	Mild complaints with daily activity	From 31 to 90 degrees
Poor	All other results	More than 90 degrees

Table (2): Operation outcome according to the criteria of Price.

Variable	(n=12)	
	No	%
Operation outcome:		
Excellent	8	66.7
Good	4	33.3
Fair	0	0
Poor	0	0

Table (3): Relation between outcome & age among the studied cases.

Variable	Good (*n*=4)		Excellent (n=8)		MW	P
Age: (year)						
Mean ± SD	8 ± 1.15		6.75 ± 2.71		**1.75**	**0.14 NS**
Median	8		6.5			
Range	6 - 12		3 - 11			
Variable	**No**	**%**	**No**	**%**	χ^2	**P**
Age group:						
3 – 7 years	2	50	4	50	**0**	**1 NS**
8 – 12 years	2	50	4	50		

Table (4): Relation between outcome & side and level affected among the studied cases.

Variable	Good (*n*=4)		Excellent (n=8)		χ^2	P
	No	%	No	%		
Side:						
Rt	3	75	5	62.5	**0.19**	**0.67 NS**
Lt	1	25	3	37.5		
Level						
Middle 1/3	3	75	6	75	**0**	**1 NS**
Distal 1/3	1	25	2	25		

Table(5): Relation between outcome & mechanism of trauma among the studied cases.

Variable	Good (*n*=4)		Excellent (n=8)		χ^2	P
	No	%	No	%		
Mechanism:						
FOOSH	4	100	4	50	**3**	**0.22 NS**
RTA	0	0	2	25		
Direct	0	0	2	25		

Figure (1): K-wire is advanced up to the fracture site then to the proximal metaphysis of radius.

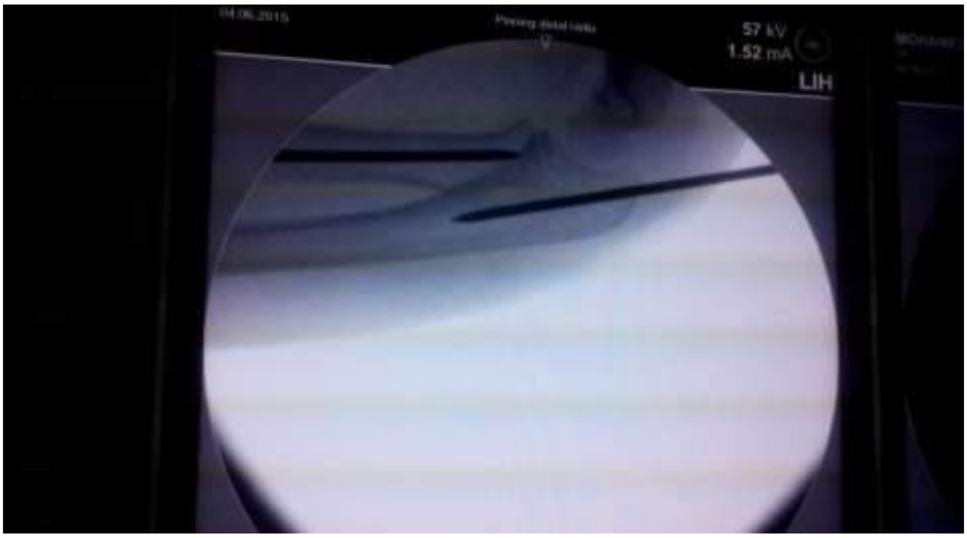

Figure (2): K-wire is advanced down to the fracture site then advanced down to the distal metaphysis of ulna.

DISCUSSION

Most diaphyseal fractures in children are treated by closed reduction and casting. Where acceptable closed reduction cannot be achieved or maintained in patients with completely unstable forearm fractures, surgical intervention is required[21]**.** The classic methods of open reduction with plating[12]**.** could offer anatomical reduction sparing the physes and could provide early mobilization of joints.

There is a growing trend towards intramedullary fixation of forearm fractures in children[22]**.** Additionally the use of an external fixator has limited indications and is not seen as a first-line treatment in management of forearm diaphyseal fractures in children[23]**.**

Intramedullary fixation has been the preferred method in recent studies[17]**.** This surgery offers stable fixation without disturbance of the periosteal blood supply or removal of the hematoma, which contributes to fracture healing. The percutaneous use of K-wires or Steinmann pins requires no dissection or special instrumentation, as the insertion land- marks are subcutaneous and easily palpable. Excellent clinical and functional results have been achieved in other studies through the use of K-wires for intramedullary fixation of diaphyseal forearm fractures in children[19]**.** In our series, we reported excellent (8 patients) and good (4 patients) results in children with unstable forearm fractures treated by intramedullary fixation with K-wires.

Abalo et al[24]**.** treated 184 children with displaced forearm fractures with K-wire fixation. Based on Anderson criteria, in their study 27% of the patients attained excellent, 45% satisfactory and 23% unsatisfactory results. In 5% of the patients union failed.

Various studies have shown that intramedullary nailing can provide precise fracture reduction, maintains stabilization for fracture healing, results in minimal cosmetic deformity and facilitates easy removal of implants after treatment[11,20]**.** Because of the low complication rate, these authors recommended intramedullary nailing for most children older than 10 years and children younger than 10 years for whom conservative treatment failed[18]**.**

There is a variation in the implant used in intramedullary fixation. While Verstreken et al[13]**.** and Toussaint et al[25]**.** used titanium pins, Amit et al[14]**.** used Rush pins and Lascombes et al[18]**.** used pins made of titanium or of high quality steel. This variation in the implant used had no effect on the final results. In support of this conclusion is the comparative study performed by Calder et al[26]**.** in 2003 between K-wires and elastic stable intramedullary nail (ESIN) and demonstrated no difference in outcome between the two implants.

Many authors stated that fractures of forearm bones in children occur around the age of 10 years[27,28]**.** In the literature, no particular age is taken as a criterion for internal fixation, but approximately 10 years is the age beyond which a child with a midshaft malunion will probably not show satisfactory remodeling[12]**.**. In our study the age of the studied cases ranged from 3 to 12 years with mean 8.17 years. Also 50% of the cases were from 3 to 7 years and 50% were from 8 to 12 years.

Many studies reported that the incidence of pediatrics forearm fractures was more common in males than in female[27,29]**.** s. This observation can be explained by the fact that males are more involved in sports and traffics than females so they are more prone to injuries. While other reported almost equal incidences. In our study there were 6 males (50%) and 6 females (50%)

Although some authors did not use postoperative immobilization and allowed an early postoperative motion[30]**.** others advised the use of post-operative immobilization for a brief period[19,31]**.** Supplemental plaster cast immobilization after intramedullary fixation is still recommended, as the rotational stability of pediatric forearm fractures treated by intramedullary pinning is still under investigations. This idea is supported by Luhmann et al[17] and Shoemaker et al[19]**.** They have recommended a supplemental plaster cast immobilization after intramedullary fixation by K-wires. Because intramedullary K-wire is not a rigid fixation and an early postoperative motion may predispose to redisplacement of fracture, we used postoperative immobilization in the form of long arm cast for 5 - 10 weeks in order to protect the fracture until a sufficient amount of callus is formed to prevent redisplacement.

Cases of refractures and lost reduction after removal of K-wires have also been reported by Shoemaker et al[19]**.** Khalil et al[27]and Lascombes et al[18]**.** also reported that 5% of their patients developed refracture. Cullen et al[37]**.** reported a case where nails were removed very early at the time of fracture union 6 weeks post injury and the patient re-fractured 4 weeks later. No such complications were encountered in the present study.

The mean time to union in our study was 6.7 + 2.89 weeks (the earliest was 5 weeks and the latest was 10 weeks). This was similar to the results obtained by Ali et al[28]**.** Khalil[27]**.** Ahmad et al[29]**.** Kose et al[30]**.** and El Khadrawe[32]**.**

The most common functional deficit after malunited forearm fractures is particularly reduced motion of pronation and supination. More authors[15,33,34]**.** came to a similar conclusion, as price et al[15]**.** have suggested that when malunion is greater than 10^o angulation in the middle third, rotation can be limited by $20\text{-}30^o$. Daruwalla[35]**.** recommended 10^o as the maximum acceptable angulation for older children and proximal shaft fractures. Matthews et al[34]. found similar results in a cadaveric study.

Most activities of daily living could be accomplished with 100 degree of forearm rotation equally divided between pronation and supination[36]. Matthews was reported that only 2 of 17 patients with persistent malunion (defined as angulation of 20^{o}) noted a functional or cosmetic problem[34].

Given the potential failure of nonoperative management (1.5% to 31%), the importance of minimizing angular deformity to preserve normal forearm rotation and operative management of pediatric forearm fractures has become increasingly popular[12,21]. In our study there were 7/12 patients had a difference between the two sides in forearm rotation.

In the current study, Complications were detected in 3 patients (25%). Calder et al[26]. reported 16% complication rate, Lascombes et al[18]. reported 20%, Luhmann et al[17]. reported 24%, Shoemaker et al[19]. reported 25% complication rate while Cullen et al[37]. reported 50% complication rate. On the other hand, no complications were reported in the series of Verstreken et al[13]. and Amit et al[14].

Superficial pin site infections following pinning of forearm fractures in children are rare. Fernandez[16].reported on five superficial infections in 553 children. In our study, we saw three superficial infections in children treated operatively which was successfully controlled by local pin site care and short course of oral antibiotics. Most authors reported superficial pin site infection in their studies between 5% and 15% of their patients[18,27,28].

Other studies have advocated the insertion of the wire from the metaphysis of the distal radius and proximal ulna to spare the growth plate and epiphysis, but the technique requires a larger bending angle to pass the pins through the medullary canal[19]. In our technique we insert the K-wire from the radial styloid or Lister tubercle and from the olecranon. Our findings are in accordance with a series of over 200 patients of percutaneous transphyseal K-wiring for pediatrics distal radius fractures[40].

In the current study no cases of non-union, compartmental syndrome or cross synostosis occurred. This was also reported by many authors[18,27,28,30,32,38,39].

CONCLUSION

Percutaneous intramedullary fixation of pediatric forearm fractures by K-wires is a safe, minimally invasive procedure and effective method of treatment.

Based upon this study, it is concluded that displaced fractures of forearm bones in children are preferred to be intramedullary fixed with K-wires when surgery is indicated with excellent and good results.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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