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Original Article

PERCUTANEOUS INTRAMEDULLARY K-WIRES FIXATION OF PEDIATRIC SHAFT BOTH BONE FOREARM FRACTURES

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Abstract

Background: *Radius and ulna fractures, or both-bone forearm fractures, are the third most common injuries in children, and diaphyseal forearm fractures are common injuries that represent between 3 and 6 of all pediatric fractures. 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. In addition, midshaft forearm fractures are the most common sites for refracture in children and among the most common sites of pediatric open fractures. 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. The most common indications for surgery are failure of closed reduction, open fractures, and fracture instability.* ***Objective:*** *This study's objective is to improve outcome of pediatric both bone forearm fractures using minimally invasive procedure by intramedullary K-wires.* ***Patients and Methods:*** *A prospective study was conducted on sixty children who underwent percutaneous intramedullary K-wires fixation of shaft both bone forearm fractures, at orthopedic and traumatology department of Sohag university hospital. They treated between February 2023 till February 2024 and follow-up for 6 months.* ***Results:*** *According to the Anderson et al. criteria, 90% of the patients were excellent (54 patients), 10% of the patients were satisfactory (6 patients), 0% of the patients were unsatisfactory, and 0% of the patients were failure.* ***Conclusion:*** *K-wires are a good option for fixation of pediatric shaft both bones forearm fractures. All of the patients included in the study experienced complete union over the observation period, and the majority had good range of motion and strength.*

Keywords: *Fracture fixation, Intramedullary, Fracture forearm.*

1. Introduction

Radius and ulna fractures, or both-bone forearm fractures, are the third most common injuries in children [1], and diaphyseal forearm fractures are common injuries that represent between 3 and 6 of all pediatric 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]. In addition, midshaft forearm fractures are the most common sites for refracture in children and among the most common sites of pediatric open fractures [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]. 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 screws 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].

2. Patients and Methods

Sixty children who underwent percutaneous intramedullary K-wires fixation of shaft both bone forearm fractures, at orthopedic and traumatology department of Sohag university hospital. They treated between February 2023 till February 2024 and follow-up for 6 months in this prospective study.

2.1. *Ethical consent*

An approval of the study was obtained from Institutional Review Board and Ethical Committee. Every patient signed an informed written consent for acceptance of the operation.

2.2. *Inclusion criteria*

a) Patients who are between 4 to10 years old from both genders and suffering from simple displaced fractures of shaft both bone of the forearm.

b) Complete clinical and radiographic data.

2.3. *Exclusion criteria*

a) Poly-traumatized patients with other associated fractures.

b) Patients with undisplaced fractures of shaft both bone of the forearm.

c) Patients with open fractures of shaft both bone of the forearm.

d) Patients with pathological fractures of shaft both bone of the forearm.

e) Patients with malignancy.

f) Patients with malnutrition.

g) Chronic diseases as renal, hepatic, cardiac patients.

2.4. *Preoperative assessment*

a) Clinical evaluation:

- General: Blood pressure, pulse, cardiovascular, neurological and respiratory assessment.
- Local: pain, tenderness, edema, swelling, deformity, wounds, range of motion and skin condition.

b) Radiological assessment: standard AP and lateral radiographs of the injured forearm was used to identify, evaluate the fracture and to detect the presence of other concomitant bone lesions.

c) Laboratory assessment: routine laboratory investigations for any surgery such as Complete blood count (CBC), Bleeding and coagulation profile, Random blood glucose level, Liver and Kidney function tests.

2.5. *Surgical technique*

2.5.1. Anaesthesia and positioning

Under general anaesthesia, the patient was rendered unconscious during the procedure. Prophylactic antibiotic was administered. A small towel roll was placed at upper arm while the patient was positioned supine on a radiolucent surgical table. An image intensifier was utilized during the procedure.

2.5.2. Procedure

In radius bone, the wire inserted by surgical drilling through Lister's tubercle by penetrating the dorsal cortex and the surgical drilling was then slowly lowered to an angle of 45° relative to the shaft axis and was advanced at this angle until it reached the medullary canal. In other cases, the wire was inserted through the radial styloid by penetrating the styloid through radial side and then the surgical drilling was slowly deviated medially toward the ulna and was advanced until reached the medullary canal. After the k-wire had arrived to the closed fracture site, the k-wire was introduced into the proximal fragment by indirect manipulation of the fragment under c-arm. While in ulna bone, the wire inserted by surgical drilling through the tip of the olecranon by penetrating the cortex and was advanced until it reached the medullary canal. After the k-wire had arrived to the closed fracture site, the k-wire was introduced into the distal fragment by indirect manipulation of the fragment under c-arm. When the wires were correctly positioned, the protruding wire ends were cut outside the skin and then bent. An anteroposterior and lateral views were taken with the image intensifier to ensure that the k-wire end didn't penetrate the head of radius or the head of ulna and to ensure the reduction and fixation of fracture site.

2.6. *Postoperative management*

- The limb was immobilized and placed in above elbow plaster cast/slab with the elbow at 90° of flexion, and the forearm at mid pronation up to 1 month.
- Intravenous antibiotics were given for 3 days post-operative.
- Postoperative radiographs were obtained to check the reduction and adequacy of the fixation.
- Analgesics were given until complete resolution of pain.

2.7. *Follow up*

All patients underwent clinical and radiological surveillance for six months.

- Patients were followed up at 2 weeks with AP and lateral X-ray views in cast/slab to check for adequacy of fixation and fracture position.
- K-wires and cast/slab were removed after 4 weeks post-operatively.
- At each follow-up visit (2 weeks, 1 months, 3 months and 6 months) the patient was examined clinically and radiologically and encouraged to continue active exercises to reach normal range of motion. AP and lateral forearm radiographs were taken to assess ongoing fracture consolidation and to detect any complications, such as hardware migration, secondary displacement, malunion, delayed union, nonunion or refracture.
- At the last follow-up visit, patients were assessed for the range of motion of injured side as compared with the contralateral uninjured side including forearm pronation and supination as well as elbow and wrist flexion and extension.
- At the end of the follow up period, patients were assessed by Anderson et al. criteria for assessment of functional outcome, tab. (1). At the same time, the presence of complications such as hardware migration, secondary displacement, malunion, delayed union, nonunion, growth arrest, pin tract infection, refracture, or joint stiffness was recorded.

Table (1) Anderson et al. criteria

Result	Union	Flexion and extension at wrist joint	Supination and pronation
Excellent	Present	< 10° loss	< 25 % loss
Satisfactory	Present	< 20° loss	< 50 % loss
Unsatisfactory	Present	< 30° loss	> 50 % loss
Failure	Non-union with or without loss of motion		

3. Results

According to the Anderson et al. criteria, 90% of the patients were excellent (54 patients), 10% of the patients were satisfactory (6 patients), 0% of the patients were unsatisfactory, and 0% of the patients were failure, tab. (2)

Table (2) Distribution of the studied patients regarding the Anderson et al. criteria

Result	Number	Percent
Excellent	54	90%
Satisfactory	6	10%
Unsatisfactory	0	0%
Failure	0	0%

3.1. *Factors affecting the final outcome*

- **Age:** There was no statistically significant relationship between age and final outcome, tab. (3).

Table (3) Relation between final outcome and age of the patients

Age group	Net result				Total
	Satisfactory		*Unsatisfactory*		
	Number	Percent	Number	Percent	
4-	15	100 %	0	0 %	15
5-	9	100 %	0	0 %	9
6-	9	100 %	0	0 %	9
7-	3	100 %	0	0 %	3
8-	0	0 %	3	100 %	3
9-10	18	85.7 %	3	14.3 %	21
Total	54		6		**60**
Mean	9		1		
S. D.	**6.841**		**1.549**		
P value	**0.997**				

- **Sex:** There was no statistically significant relationship between sex and final outcome, tab. (4).

Table (4) Relation between final outcome and sex of the patients

Sex	Net result				Total
	Satisfactory		*Unsatisfactory*		
	Number	Percent	Number	Percent	
Male	42	87.5 %	6	12.5 %	48
Female	12	100 %	0	0 %	12
Total	54		6		**60**
Mean	27		3		
S. D.	**21.213**		**4.243**		
P value	**0.942**				

- **Affected side:** There was no statistically significant relationship between affected side and final outcome, tab. (5).

Table (5) Relation between final outcome and affected side of the patients

Side	Net result				Total
	Satisfactory		*Unsatisfactory*		
	Number	Percent	Number	Percent	
Right	33	100 %	0	0 %	33
Left	21	77.8 %	6	22.2 %	27
Total	54		6		**60**
Mean	27		3		
S. D.	**8.485**		**4.243**		
P value	**0.9998**				

- **Site of fracture:** There was no statistically significant relationship between site of fracture and final outcome, tab. (6).

Table (6) Relation between final outcome and site of fracture

Site	Net result				Total
	Satisfactory		*Unsatisfactory*		
	Number	Percent	Number	Percent	
Distal shaft	18	100 %	0	0 %	18
Mid shaft	36	85.7 %	6	14.3 %	42
Proximal shaft	0	0 %	0	0 %	0
Total	54		6		**60**
Mean	18		2		
S. D.	**18.014**		**3.464**		
P value	**0.935**				

- **Associated injury:** There was no statistically significant relationship between associated injury and final outcome, tab. (7).

Table (7) Relation between final outcome and associated injury of the patients

Injury	Net result				Total
	Satisfactory		*Unsatisfactory*		
	Number	Percent	Number	Percent	
No	54	90 %	6	10 %	60
Yes	0	0 %	0	0 %	0
Total	54		6		**60**
Mean	27		3		
S. D.	**38.184**		**4.243**		
P value	**0.811**				

- **Associated medical condition:** There was no statistically significant relationship between associated medical condition and final outcome, tab. (8).\

Table (8) Relation between final outcome and associated medical condition of the patients

Associated medical condition	Net result				Total
	Satisfactory		Unsatisfactory		
	Number	Percent	Number	Percent	
No	54	90 %	6	10 %	60
Yes	0	0 %	0	0 %	0
Total	54		6		**60**
Mean	27		3		
S. D.	**38.184**		**4.243**		
P value	**0.811**				

- **Time lapse before surgery:** There was no statistically significant relationship between final outcome and the time interval between trauma and the time of surgery, tab. (9).

Table (9) Relation between final outcome and time lapse before surgery

Time	Net result				Total
	Satisfactory		*Unsatisfactory*		
	Number	Percent	Number	Percent	
< 5 days	45	88.2 %	6	11.8 %	51
5 – 9 days	3	100 %	0	0 %	3
> 9 days	6	100 %	0	0 %	6
Total	54		6		**60**
Mean	18		2		
S. D.	23.431		3.464		
P value	0.879				

4. Discussion

Most diaphyseal forearm 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 [11]. The common 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 [13]. 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 [14]. Intramedullary fixation has been the preferred method in recent studies [15]. 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 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 [16]. Abalo et al. [17] 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 patient's 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 [18,19]. 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 [20]. There is a variation in the implant used in intramedullary fixation. While Verstreken et al. [21] and Toussaint et al. [22] used titanium pins, Amit et al. [23] used Rush pins and Lascombes et al. [20] 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. [24] in 2003 between K-wires and elastic stable intramedullary nail (ESIN) and demonstrated no difference in outcome between the two implants. Although some authors did not use postoperative immobilization and allowed an early postoperative motion [25]. Others advised the use of postoperative immobilization for a brief period [16,26]. 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. [15]and Shoemaker et al. [16]. 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/slab 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. [16]. Khalil et al [27] and Lascombes et al. [20] also reported that 5% of their patients developed refracture. Cullen et al. [28] 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. In our study, refracture after removal of k-wires 4 weeks post-operatively was reported in six patients (10%). The most common functional deficit after malunited forearm fractures is particularly reduced motion of pronation and supination. More authors [29-31] came to a similar conclusion, as price et al. [29] have suggested that when malunion is greater than 10° angulation in the middle third, rotation can be limited by 20-30°. Daruwalla [32] recommended 10° as the maximum acceptable angulation for older children and proximal shaft fractures. Matthews et al. [31] 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 [33]. Matthews was reported that only 2 of 17 patients with persistent malunion (defined as angulation of 20°) noted a functional or cosmetic problem [3]. 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 [16]. In our technique we insert the K-wire from the radial styloid or Lister tubercle and from the olecranon. In our study, we reported that 90% of the patients were excellent (54 patients), 10% of the patients were satisfactory (6 patients), 0% of the patients were unsatisfactory, and 0% of the patients were failure according to Anderson et al. criteria. The complications that were encountered in our study are:

- **Firstly**, was refracture after removal of k-wires 4 weeks post-operatively in six patients (10%), which was resolved by 4 weeks cast.
- **Secondly** was infection at the entry point in three patients (5%), which was resolved by daily dressing and antibiotics.
- **Thirdly** was the k-wire missing the ulna medullary canal tract intraoperative in three patients (5%), which was resolved by inserting the wire through the head of ulna.

The main advantages of our technique are:

- No soft tissue irritation which can occur by the prominent tip of the elastic nails at the entry point under the skin, in our study we cut the protruding wire ends outside the skin and then bent it.
- No need for skin incision.
- No need for another operation to remove the k-wires.

However, this study had some limitations:

- The study was conducted only on sixty children.
- It was a randomized prospective study with no control group.
- Short duration of follow-up 6 months.

5. Conclusions

1) Fixation of pediatric shaft both bones forearm fractures using a percutaneous intramedullary K-wires are an effective method of treatment in selected cases. 2) K-wires are a good option for fixation of pediatric shaft both bones forearm fractures. It provides a minimally invasive method of fixation, better cosmosis and good functional outcomes. 3) All of the patients included in the study experienced complete union over the observation period, and the majority had good range of motion and strength. The procedure has low morbidity and good overall results.

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