Flexible Intramedullary Fixation of Pediatric Forearm Fractures - Report on Twenty-One Patients

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Objective: The aim of the study is to assess the outcome of treating pediatric forearm fractures with flexible intramedullary nails.

Setting: Orthopedic Department, Salmaniya Medical Complex, Kingdom of Bahrain.

Design: Retrospective study.

Method: Between May 2004 and April 2006, twenty one pediatric patients with displaced forearm fractures were treated with flexible intramedullary nails at SMC. The study group included 19 boys and 2 girls aged 6 and 14 years (mean 9.3). Closed reduction and percutaneous introduction of nails was tried in all patients; failure to do so, a mini incision was performed to facilitate the procedure.

Result: Closed reduction and percutaneous introduction of the nails was possible in 9 patients. In 8 patients, a mini incision was needed for either the radius or the ulna. In 4 patients, both the radius and ulna needed exposure through mini incision. The patients were followed-up for a period between 6.7 to 35.7 weeks (mean 18.7 weeks). All fractures were united in acceptable alignment and nails were removed at a mean interval of 18.7 weeks.

Conclusion: Nine pediatric patients had closed forearm fracture reduction and twelve patients needed mini incision; there were few minor complications and the outcome was satisfactory.

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Fractures of forearm bones in children are common; the rate is about 1 in 100[1]. Most of them can be treated conservatively. Union is rarely a problem. A number of important principles should be followed to achieve the ideal goal of fracture union without deformity or dysfunction. As long as the physes are open, remodeling can occur. The remodeling capacity depends on the age, the site of fracture, the direction of angulation and its magnitude. Rotational deformity does not remodel[2].

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Undisplaced fractures can be safely treated in cast. For displaced fractures closed reduction and casting is successful in the majority of cases. However, some fractures re-displace, and it becomes essential to reduce and fix them with either percutaneous nails or open reduction. Internal fixation can be achieved with plate and screws or with intramedullary devices.

Open reduction and internal fixation can provide accurate and stable fixation, but soft tissue exposure may lead to complications such as infection, neurovascular injuries, scarring and delayed union or non-union[2]. Removal of the plates may also be associated with significant complications.

Over the past 30 years, intramedullary fixation has become more popular than plates and screws for treatment of unstable forearm fractures in the pediatric population. Intramedullary fixation is considered a safe and effective method, but there are certain complications like compartment syndrome, non-union, and refracture after removal of the nails[2].

For unstable fractures, intramedullary fixation can be performed using a variety of implants such as K-wires, Rush pins, Steinman pins or flexible nails (Titanium elastic nails).

The aim of the study is to assess the outcome of treating pediatric forearm fractures with flexible intramedullary nails.

METHOD

Twenty-one children with displaced fractures of the forearm bones were treated with intramedullary fixation from May 2004 to April 2006. Nineteen were males and two were females, their age ranged 6-14 years (mean 9.3 years).

Percutaneous intramedullary fixation was performed following closed reduction of the forearm bones (n=9). A limited open reduction was needed for both bones (n=4) and for one bone only (n=8). The fracture was in the middle third in 14 cases, in distal third in 3 cases, and in the proximal third in 4 cases. The intramedullary nails used were of different sizes ranging from 2-3 mm in diameter, see Table 1.

Table 1: Showing the Number of Patients, the Age, Fracture Sites, Mode of Reduction, and the Type and Size of the Intramedullary Nails Used

Sex	Age	Fracture Site	Mode of fracture reduction	IMN size (mm)
F	8	Mid-shaft	MUA for both	2.5 both
M	6	Distal 1/3	OR # Rad. MUA # Ulna	2.5 both
M	8	Mid-shaft	MUA for both	2 both
M	12	Mid-shaft	OR # Rad. MUA # Ulna	3 both
M	9	Proximal 1/3	OR both	2 both
M	10	Proximal 1/3	OR # Rad. MUA # Ulna	2.5 both
M	12	Mid-shaft	OR # Rad. MUA # Ulna	2.5 2
M	10	Mid-shaft	MUA # Rad. Only	2
M	12	Mid-shaft	MUA # Rad. Only	3
M	6	Mid-shaft	MUA for both	2 both
M	10	Distal 1/3	OR # Rad. MUA # Ulna	2.5 both
M	14	Mid-shaft	MUA # ulna	3 both
M	13	Proximal 1/3	OR # Rad. MUA # Ulna	2.5 both
M	9	Mid-shaft	OR both	2.5 Rad. 2 Ulna
M	9	Mid-shaft	MUA both	2.5 both
M	8	Proximal 1/3 Rad Mid-shaft Ulna	MUA both	2.5 both
M	9	mid-shaft Ulna	OR	3
M	11	Mid-shaft	OR both	3 both
F	10	Mid-shaft	OR # Rad. MUA # Ulna	2 both
M	7	Proximal 1/3 Rad mid-shaft Ulna	OR # Rad. MUA # Ulna	2 both
M	10	Mid-shaft	MUA # Rad	2

MUA: manipulation under anesthesia
#: fracture
Rad: radius
OR: open reduction

Technique

Under general anesthesia, a pneumatic tourniquet is positioned in case an open reduction is needed. A closed reduction is attempted. If the reduction cannot be maintained because of instability, a percutaneous intramedullary nailing is performed without opening the fracture site. If an acceptable reduction cannot be obtained, then open reduction through limited approach and intramedullary fixation is performed.

The radial bone is approached through one cm longitudinal incision performed on the lateral side of the distal metaphysis. A hole is drilled in the bone with an awl, first perpendicularly and then obliquely towards the elbow. Then an appropriate size flexible intramedullary nail (with its proximal 5mm pre-bent at 30) is introduced and pushed retrograde with a hammer if necessary, to the fracture site. The fracture is reduced by external manipulation and the nail is pushed proximally and fixed into the proximal metaphysis. The distal end of the nail is then bent and cut 5-10 mm from the bone. The skin is closed with one stitch, see Figure 1.

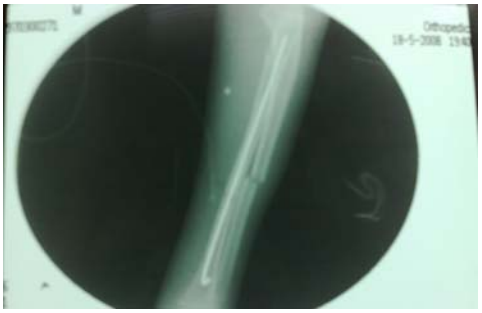

Figure 1(a) **Figure 1(b)**

Figure 1: X-Rays a) AP and b) Lateral Views Show Open Reduction Performed through a Mini Incision over Fracture of Radius and Internal Fixation with Percutaneous Flexible Intramedullary Nail

Same procedure is performed for the ulna starting either proximally and pushing the nail antegrade or starting distally and pushing the nail retrograde, Figure 2.

Figure 2(a): AP View Immediately after Surgery

Figure 2(b): Lateral View 4 Weeks after Surgery

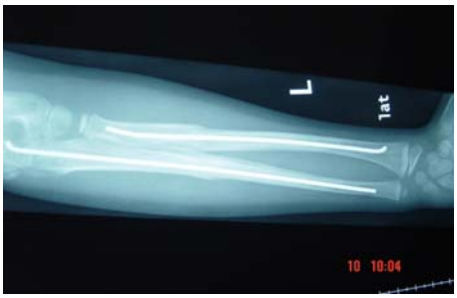

Figure 2(c): AP View after Full Union

Figure 2: X-Rays Showing the Stages of Healing Following Percutaneous Intramedullary Nailing of Both Forearms Bones Fractures in a Child

RESULT

The patients were discharged after one to three days after surgery. The children were then followed up in the clinic for a period ranging from 6.7 to 35.7 weeks (mean 18.7 weeks). Clinical and radiological evaluation of fracture union and any complication were reviewed. Nineteen patients showed satisfactory fracture union and good function. One patient showed mild limitation of forearm motion and one patient developed delayed union. Implant removal

was performed under general anesthesia for all patients after six weeks to nine months after surgery, Table 2.

Table 2: Hospital Stay and Postoperative Complications

	Date of operation	Hospital stay (days)	Date of nail removal	Complications
1.	16.05.04	1	26.01.05	-
2.	07.06.04	2	06.10.04	-
3.	14.06.04	1	04.01.05	-
4.	01.08.04	2	03.04.05	-
5.	12.08.04	3	12.10.04	-
6.	15.09.04	2	01.11.04	-
7.	11.10.04	2	03.07.05	-
8.	11.10.04	1	24.01.05	-
9.	07.11.04	1	19.06.05	-
10.	06.03.05	1	14.06.05	-
11.	13.04.05	2	23.05.05	ROM* Pr* 45° Sup 90°*
12.	20.04.05	1	30.08.05	-
13.	25.04.05	2	01.08.05	-
14.	04.05.05	3	13.07.05	-
15.	26.06.05	1	21.02.06	-
16.	07.09.05	1	25.02.06	-
17.	08.10.05	3	10.12.05	-
18.	20.10.05	3	24.06.06 # Rad. 25.12.05 # Ulna	Delayed union of # rad**
19.	30.01.06	2	06.05.06	-
20.	05.03.06	2	10.06.06	-
21.	14.04.06	1	01.07.06	-

*range of motion, pronation, supination
**fracture radius

DISCUSSION

Diaphyseal fractures of the radius and ulna in children are usually managed by closed reduction and cast immobilization. In contrast, treatment of adult forearm fractures using open reduction and internal fixation with plates is recommended to avoid malunion and loss of function[3-6]. Operative options for internal fixation of children's forearm fractures include plating, intramedullary nailing, and pins if indicated. Complication rates were significantly different between the closed and operative groups. Comparing treatments in pediatric both-bones fractures revealed significantly more complications with operative techniques[7]. Although there is a risk of malunion in children older than 10 years, operative intervention does not guarantee full restoration of motion or avoidance of complications[8,9].

Intramedullary nailing of forearm bone fractures in children offers an alternative form of fixation with few reported complications[10-12]. Intramedullary nails function as an internal splint and provide three-point fixation to maintain bony alignment[4]. End-to-end reduction helps control rotational alignment, and limited motion at the fracture site promotes the formation of external callus by converting shear stress at the fracture site into fracture compression[13]. Intramedullary fixation promotes rapid union, reduces the risk of infection and synostosis, and avoids unsightly incisions that are necessary for plate fixation and hardware removal[14]. Patients with longer operative times were at higher risk of developing compartment syndrome[15]. Rod removal is a minor procedure that does not create stress and thus decreases

the risk of refracture. Limitation of forearm rotation is comparable with that described in nonoperative treatment series[8,9,11,16,17].

Intramedullary fixation of forearm fractures has been long reported in the adult literature and only more recently has been applied to the treatment of forearm fractures in children[7,10,11,13, 18-21].

Amit et al described the results of treatment of 20 unstable diaphyseal fractures of the forearm in adolescent patients treated with closed intramedullary nailing. All fractures healed within 6 weeks. Cross-union, non-union, infection, refracture, or significant loss of motion range were not reported. Amit et al favored that technique rather than plate fixation because of the appropriate reduction, reduced complication rate, negligible cosmetic defect, and the ability to perform rod removal under local anesthesia[10].

Early pilot studies of fracture-fixation technique in children were developed in France using flexible intramedullary rods[11,13,21]. In 1988, Verstreken et al reported limited series of six patients[21]. A postoperative immobilization was not used. Rapid union occurred, and patients returned to sports two months after injury. All patients obtained full range of motion, and there were no reported complications. In the largest reported series, Prevot et al reported 125 fractures of the forearm in 122 patients treated with elastic stable intramedullary nailing (ESIN) of the radius and ulna[11]. Indications for surgery were unstable fracture (26%), failure of conservative treatment (18%), refracture (12%), and initial operative treatment for adolescents (42%). Average age at operation was 10 years. Curved stainless steel pins with a diameter of 1-3 mm were used. A limited surgical approach was necessary for reduction in 10% of cases. After surgery, patients were placed in a sling and were allowed to move the upper extremity as tolerated. At one year, 98% of patients had range of motion with loss of no more than 20° of the contralateral side. Reported complications included tendon injury (two patients), refracture (five patients), delayed healing (one patient), skin irritation by pins (11 patients), transitory nerve hypesthesia (three patients), bent pin (two patients), and broken pin (one patient). 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.

Two series on intramedullary fixation of pediatric forearm fractures were recently presented in the United States[11,20]. Stanley and Wilkins reported on 50 patients with mid shaft fractures of the radius and ulna treated with closed reduction and percutaneous intramedullary pinning[11]. Reduction was achieved through a limited open approach to one or both bones in their first six patients. Once surgical skill was developed, the remaining patients were treated with closed reduction and percutaneous intramedullary pinning. Intramedullary pins (Kirschner wires) were used for fracture fixation. All fractures healed in about 8 weeks. Reported complications included one infection treated with antibiotic therapy and rod removal after fracture healing and one injury to the superficial branch of the radial nerve. There was no reported loss of reduction after initial fracture fixation and no reported long-term complications with forearm rotation. Gates et al reviewed 15 patients with forearm fractures who underwent intramedullary fixation of one or both bones using smooth Steinmann pins[11]. All fractures healed within 7 weeks. All intramedullary rods were removed in the office. All fractures healed without infection, malunion, refracture, or significant rotational deficit. These authors concluded that this technique is safe, effective and prevents displacement. The technique is indicated primarily in children older than 10 years with unstable fracture patterns.

The use of intramedullary fixation of forearm fractures in the adult population has been criticized because of the high rate of non-union and decreased functional results reported with this technique[18,19]. Recent series have shown that in non comminuted fractures, the non-union rate is <10% and the functional results approximate those achieved with plating[11]. In the pediatric patient, non-union has not been reported in the literature, and good/excellent functional results are reported in nearly 95% of cases[10,11,13,21]. These excellent clinical results support the use of this technique in the operative treatment of forearm fractures in the pediatric patient.

CONCLUSION

A retrospective review of 21 children with unstable forearm fractures treated with flexible intramedullary nail fixation is presented. Intramedullary nail fixation of both bones was performed in 17 patients, radius in 3 cases, and ulna in one case. A limited open approach to one or both bones was necessary for insertion of the intramedullary nail in 12 cases.

The two complications occurred were delayed union and mild limitation of forearm motion. However, the functional outcome was excellent.

It is recommended to use this technique for unstable pediatric forearm fractures instead of open reduction and plating.

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