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Percutaneous Transphyseal Intramedullary Pinning for Displaced Diaphyseal Forearm Fractures in Children

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Background: A prospective analysis of a case series of diaphyseal forearm fractures in children treated with percutaneous transphyseal intramedullary pinning is presented. **Methods:** Between 2004 and 2006, 30 children aged 9-15 years with displaced diaphyseal forearm fractures underwent percutaneous transphyseal intramedullary pinning. Both bones were fractured in 25 patients, four fractured only the radius, and one experienced ulna fracture. Eleven candidates had irreducible fractures, 13 had loss of reduction, and six had open fractures. Contoured Kirschner wires or Steinmann pins were introduced proximal to distal into the ulna and distal to proximal into the radius. All fractures were immobilized postoperatively with an above-elbow plaster cast for 4 weeks followed by a short-arm plaster cast for 2-4 weeks. **Results:** Closed reduction and pinning was successful in 20 cases, including 15 double-bone fractures and five single-bone fractures. Open reduction was completed in four fractures of both bones, and in six single-bone open fractures. Bone union was achieved in all patients at an average of 7 weeks. The ROM of the forearms was evaluated using the Daruwalla grading criteria. Excellent results were reported in 96% without significant complications after a mean follow-up of 20 months. **Conclusion:** Percutaneous transphyseal intramedullary pinning of pediatric forearm fractures revealed several advantages, including ease of application, a small incision for insertion and removal of instrumentation, a low rate of complications, unhindered bone healing, and good clinical and radiological results. This method is convenient, effective, and safe without any deleterious effects on subsequent growth of the radius and ulna.

Key words: intramedullary pinning, pediatric forearm fractures, transphyseal

INTRODUCTION

Fractures of forearm bones are the most common traumatic pediatric orthopedic injuries. The majority of these fractures can be treated well with closed reduction and cast immobilization due to the unique property of the growth potential of the immature skeletal. Nevertheless, there is a subset of patients in whom surgical intervention is indicated[1-3]. The most common indications for surgery are failure of closed reduction, open fractures, and fracture instability. In these situations, if left untreated, malunion is more likely to occur, which will disturb the function of the upper extremities[4,5].

A variety of surgical techniques are available to achieve adequate stabilization of these types of fractures, including plating[6], external fixation[7], and intramedullary nailing[8,9]. The wide variety of surgical options available is explained by the unique properties and problems in management of this fracture in children, who have an open physis with the bone still growing. One common characteristic of operative methods that use the previously noted hardware is avoidance of the physis, so as not to endanger the growth of the bone. The aim of this study was to analyze the results of 30 diaphyseal forearm fractures in children treated with percutaneous transphyseal intramedullary pinning with K-wires or Steinmann pins.

PATIENTS AND METHODS

At our institution, between 2004 and 2006, 30 children with displaced diaphyseal forearm fractures were treated using intramedullary K-wires or Steinmann pins. An unacceptable alignment was defined as less than 50% cortical contact between the fragments, and greater than 10^{o} of

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Table 1 Daruwalla* Grading of Surgical Results for Pediatric Forearm Fracture

Classification	Criteria of Limitation
Excellent	Movements equal on both sides
Good	≦ 20° of limited rotation on injured side
Fair	20° -40° of limited rotation on injured side
poor	>40° of limited rotation on injured side

* Daruwalla JS. A study of radioulnar movements following fractures of the forearm in children. *Clin Orthop Relat Res.* 1979;139:114-120

angulation in either the dorsal — volar or radial — ulnar plane. All patients were immobilized postoperatively in an above-elbow plaster cast for 4 weeks, followed by a short-arm plaster cast for 2 to 4 weeks. Patients underwent regular postoperative follow-up in the clinic at 2-week intervals.

Follow-up examination of patients included progress of fracture healing, range of motion (ROM), angular deformities, and measurement of limb length. Union was assessed clinically by the absence of pain and tenderness. Radiological assessment included the presence of a bridging callus and partial obliteration of the fracture line on two views. Angular deformity was measured on conventional anteroposterior and lateral radiographs. The ROM of forearms in all patients was evaluated using the grading criteria of Daruwalla[4] (Table 1). A goniometer was used to measure the ROM and comparison was made with the normal limb. Limb length discrepancy was assessed clinically at final follow-up by measuring the distance between the lateral epicondyle of the humerus to the tip of the radial styloid process.

Operative technique

Under general anesthesia, the patient is placed in a supine position with the affected arm on a lateral table. A small skin incision is made over the dorsal aspect of the radial styloid process. Under fluoroscopic control, a standard 0.062" K-wire (1.6 mm×22.9 cm) or 5/64 inch Steinmann pin (2.0 mm×22.9 cm; both products, Zimmer, Inc., Warsaw, IN, USA) is introduced through the distal radius. The size of the implant was chosen depending on the size of forearm bones. The standard 0.062" K-wire was chosen for the forearm bones with a narrowest width of the medullary canal of less than 0.5 mm and the 5/64 inch Steinmann pin was chosen for forearm bones with a narrowest width of the medullary canal greater than 0.5 mm. The implant is then advanced proximally across the fracture. The tip of the implant is prebent, which assists in the progress of the implant across the fracture, as well as in

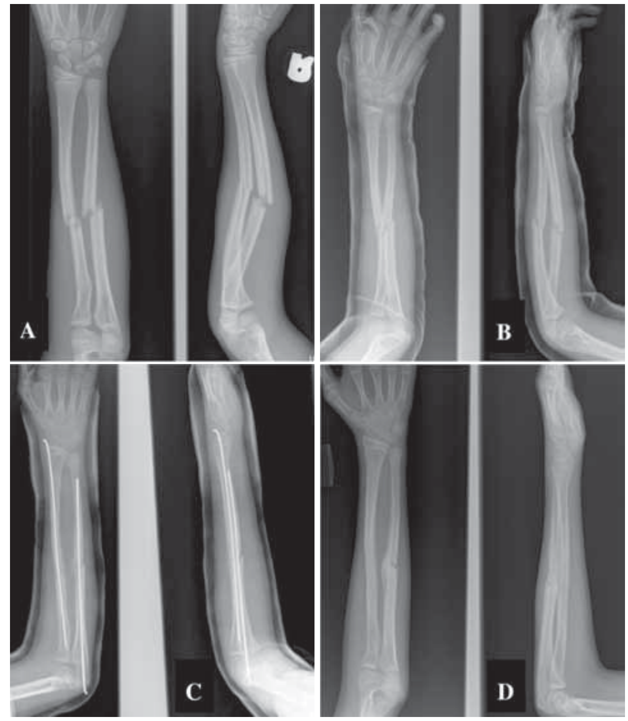

Fig. 1 A-D. Radiographs of the forearm in an 11-year-old girl. (A) An unstable fracture of both bones of the forearm is shown. (B) Loss of reduction is noted when the long-arm cast is changed at week 3 followup. (C) Radiographs obtained after closed reduction and intramedullary fixation with 5/64 Steinmann pins. (D) Radiographs obtained 2 weeks after pin removal. The fracture is well aligned and healed.

reduction of the fracture. The outer implant is cut, bent, and buried subcutaneously. The procedure is repeated for the ulna, except that antegrade introduction of the implant is used, starting from the tip of the olecranon (Fig. 1). The portal incision is closed with one suture.

When indicated, an open reduction was performed by a mini-open procedure. A small skin incision is made at the level of the fracture. In patients with open fractures, the fracture is identified through the traumatic wound. A 3 mm thick Steinmann pin is introduced between the fracture fragments. Manipulation of the fracture with the Steinmann pin under fluoroscopic guidance is conducted until acceptable reduction is reached.

RESULTS

Patient demographics and clinical data

Of the pediatric patients with forearm fracture included in this study, there were 22 male and 8 female patients with

Table 2 Results of Diaphyseal Fracture Treated with Percutaneous Transphyseal Intramedullary Pinning

Surgical indication	N	Male	Female	Average age (yrs)	Closed reduction	Mini-open reduction	Implant removal (wks)	Time to bone union (wks)	Functional result*
Irreducible fracture	11	8	3	10	7	4	7-10	7-9	Good Excellent
Loss of reduction	13	10	3	11	13	0	6-9	6-8	Excellent
Open fractures	6	4	2	13	0	4	7-10	7-9	Excellent
Total	30	22	8		20	8			
Mean (range)				12			8	7	

* Daruwalla JS. A study of radioulnar movements following fractures of the forearm in children. *Clin Orthop Relat Res.* 1979;139:114-120

a mean age of 12 years (range: 9-15). The right arm was fractured in 17 patients, and 13 patients suffered fracture of the left arm. Only those fractures that involved the middle third of the radius and ulna were included in the study. Both bones were fractured in 25 (83.3%) patients. The radius only was fractured in four (13.3%) patients, and the ulna only was fractured in one (3.3%). There were six (20%) open fractures (Gustilo and Anderson Type I). All patients had isolated forearm fractures without associated injuries. The mechanism of injury was sports related in 20 patients (66.6%), a fall from a height at home in five (16.7%), and a traffic accident in five (16.7 %).

The reasons for percutaneous transphyseal intramedullary pinning were irreducible fracture in 11 (36.7%) patients, loss of reduction in 13 (43.3%), and open fracture in six (20%).

Surgical outcome

Open reduction was performed in 10 patients. Six patients had open fractures. Closed reduction failed in four of the patients with closed fracture because of soft tissue interposition between the fracture fragments.

Closed reduction and intramedullary pinning was successful in 20 cases, including 15 double-bone fractures and 5 single-bone fractures. Open reduction with a mini-open procedure was carried out in four fractures that affected both bones and in six open fractures (Table 2). The average period of follow-up was 20 months (range: 10-36).

Time to bone union

All of the fractures healed within an average of 7 weeks (range: 6-9). No nonunions or delayed unions were found. There was no notable difference in the healing time either for fractures of both bones or for isolated radial or ulnar fractures. Furthermore, there was no difference in healing time for the subset of patients that required a mini-open reduction.

Range of motion and angular deformity

Twenty-nine patients had an excellent result according to the grading criteria of Daruwalla[4], and one patient had a good result. The patient who experienced a good result was a 14-year-old boy with 8^{o} volar angulation at the radial bone and limitation in supination of about 5^{o} upon final follow-up. No further surgical intervention was performed because the deformity involved the nondominant forearm without any inconvenience in daily activities.

Limb Length Discrepancy

There was no limb length discrepancy in any patient at final follow-up.

Complications

No notable complications were encountered in the study patients. Skin ulcerations and superficial wound infection were noticed at the outer end of wire tips in one radial portal and two ulnar portals. These ulcerations healed after removal of the hardware. No deep infection was seen in our patients.

Hardware removal

All implants were routinely removed under intravenous sedation. The average time for removal of the implants in this study was 8 weeks (range: 6-10). There were no complications after implant removal in our patients.

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[10]. In previous decades, the philosophy of treatment for pediatric forearm fractures was different. Complete fractures were more frequently treated by surgical intervention, especially in older child with limited remodeling capacity[11]. The classic methods of open reduction with plating[6] could offer anatomical reduction sparing the physis and could provide early mobilization of joints. However, the disadvantages of surgical intervention included the need for surgical dissection, removal of implants, risk of refracture from the screw holes, or further neurovascular compromise. Vainionpaa et al.[12] reported restricted forearm rotation in five out of 10 patients treated with plate fixation, with loss of function outcome due to soft tissue component. Plate removal is also associated with neurovascular complications, with a rate in the forearm as high as 42%[13]. In rare instances it has even led to radio-ulna synostosis[14]. There is a growing trend toward flexible or elastic stable intramedullary nailing[8,16,17] for fixation of forearm fractures in children. Although this method can overcome the aforementioned disadvantages, more experience in technique is required for the insertion and removal of the elastic nails. Additionally, the use of an external fixator[7] has limited indications and is not seen as a first-line treatment in management of forearm diaphyseal fractures in children[15].

Intramedullary fixation has been the preferred method in recent studies[18,19]. This surgery offers stable fixation without disturbance of the periosteal blood supply or removal of the hematoma, which contributes to fracture healing. This method also allows for micromotion to stimulate the callus to bridge the fracture gaps. The percutaneous use of K-wires or Steinmann pins requires no dissection or special instrumentation, as the insertion landmarks 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[20,21]. In our series, we reported excellent results in 96% of 30 children with unstable forearm fractures treated by intramedullary fixation with K-wires or Steinmann pins.

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[3,20]. In our technique, we insert the K-wire or Steinmann pins from the radial styloid and from the olecranon, crossing the epiphyseal plate to reach the fracture site just counter to the pin. These landmarks are easy to palpate and do not require dissection; thus, nearby tendons and neurovascular structures are not endangered. We prefer to use smooth K-wires or Steinmann pins inserted from easily assessable landmarks with careful image intensifier guidance. Most patients can be successfully treated with only a few attempts at passing the K-wires or Steinmann pins across the growth plate, thus minimizing disturbance of the growth plate. Upon final assessment, we did not find any child in our series with premature closure of the growth plate. Our findings are in accordance with a series of over 200 cases of percutaneous transphyseal K-wiring for pediatric distal radius fractures[22]. No adverse effects were observed following use of this technique in the treatment of fractures of the radius and ulna.

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 investigation. This idea is supported by Luhman et al.[18] and Shoemaker et al.[20] Cases of refracture and loss of reduction after removal of K-wires before 4 weeks have also been reported by Shoemaker et al. No such complications were encountered in our study. In the cases reported in our study, above-elbow plaster casts were applied for 4 weeks. Once a bridging callus appeared on radiographs, the fracture was considered stable enough to enable torsional stresses. The long-arm cast was removed, with subsequent application of a short-arm plaster cast for 2 to 4 weeks, thus allowing early movement of the elbow joints. Implants were removed in less than 7 weeks in the majority of patients.

There has been discussion as to whether the hardware for fixation should be left outside the skin (transcutaneous) or buried inside the skin. We buried the hardware inside the skin, which is an idea supported by Shoemaker et al.[20] Once infection develops in a transcutaneous pin site, it may be deep, necessitating surgical debridement and long-term intravenous antibiotics[20]. Additionally, removal of transcutaneous K-wires in the clinic can be traumatic for some children. For these reasons, we adopted the practice of burying the hardware under the skin. This minimizes the risk of deep infection, and we can remove the hardware safely after bone healing.

The preferred case for intramedullary pinning is a patient with any type of diaphyseal fracture pattern with minimal or no comminution of the fracture. It is also well suited to patients with open fractures. Conversely, intramedullary pinning does not provide the rigid strength to maintain length or to resist the torsion forces exerted by a comminuted or bony defect lesion against a plate or external fixator. Supplemental plaster cast immobilization after intramedullary fixation is still recommended. The technique of intramedullary pinning obviates the additional soft tissue stripping needed for plating, which reduces the time to union and risk of infection[19].

Unsuitable cases for intramedullary pinning of forearm fractures include those with extensive comminution, large soft tissue defects, and metaphyseal or epiphyseal fractures. Comminution compromises the axial stability of the reduction, and plate fixation is preferred in this instance. Patients with large soft tissue defects are better treated with more rigid internal fixation to allow for optimum wound care and to minimize the need for postoperative splinting. Intramedullary fixation is reserved for patients with diaphyseal fractures, with a more conventional crossed pinning technique preferred for patients with metaphyseal and epiphyseal fractures[20].

In conclusion, the method of percutaneous transphyseal intramedullary pinning with immobilization in the management of displaced diaphyseal fractures of forearm bones in children is a safe minimally invasive method with no deleterious effects on the growth plate. This technique provides stability without significant disturbance of the fracture hematoma or interference with the endosteal and periosteal blood supply. Percutaneous transphyseal intramedullary pinning with immobilization provides good functional outcomes.

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