

## Research Article

# Pediatric forearm fractures with tens: freedom of movements

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### ABSTRACT

**Background:** A prospective analysis of a case series of diaphyseal forearm fractures in children treated with titanium elastic nails is presented.

**Methods:** Between 2012 and 2014, 30 children aged 5-15 years with displaced diaphyseal forearm fractures underwent titanium elastic nailing. Both bones were fractured in 25 patients, four fractured only the radius, and one experienced ulna fracture. Eleven candidates had unstable irreducible fractures, 13 had loss of reduction, and six had open fractures. Titanium elastic nails were used to stabilize the fractures. All fractures were immobilized postoperatively with an above-elbow plaster slab for 2 weeks till the swelling is completely resolved followed by encouraging range of motion exercises.

**Results:** Closed reduction and TENS 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.

**Conclusions:** Titanium elastic nails fixation of pediatric forearm fractures revealed several advantages, a small incision for insertion, a low rate of complications, unhindered bone healing, and good clinical and radiological results thus achieving maximum range of motion at the earliest.

**Keywords:** Children and adolescents, Pediatric, Radius and ulna, Forearm fracture, Fracture fixation, TENS, Diaphyseal

### 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 bones. Nevertheless, there is a subset of patients in whom surgical intervention is indicated.<sup>1-3</sup> 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.<sup>4,5</sup> Controversy exists as to what constitutes acceptable angulation, displacement, and rotation. A variety of surgical techniques are available to achieve adequate stabilization of these types of fractures, including plating<sup>6</sup>, external fixation and intramedullary nailing.<sup>7-9</sup> 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 physics with the bone still growing. Children aged <10 years do not remodel as predictably; thus, reduction standards are less uniform.<sup>10-13</sup> Operative intervention has been recommended in prior studies for angulation >10°, malrotation displacement >50%.<sup>11,12,14,15</sup>

This article analyzes the results of 30 diaphyseal forearm fractures in children. All patients in this study underwent flexible intramedullary nail fixation.

## METHODS

At our institution, between 2012 and 2014, 30 children with displaced diaphyseal forearm fractures were treated using titanium elastic nails. An unacceptable alignment was defined as less than 50% cortical contact between the fragments and greater than 10° of angulation in either the dorsal-volar or radial-ulnar plane. All patients were immobilized postoperatively in an above-elbow plaster slab for 2 weeks. Patients underwent regular postoperative follow-up in the clinic at 2-week intervals and range of motion exercises are encouraged. 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 antero-posterior and lateral radiographs. The ROM of forearms in all patients was evaluated using the grading criteria of Daruwalla (Table 1).<sup>4</sup> 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.

**Table 1: Daruwalla\* grading of surgical results for pediatric forearm fractures.**

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

### Operative 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 titanium flexible intramedullary nail (with its proximal 5 mm 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 cut 5-10 mm from the bone. The skin is closed with one stitch. Same procedure is performed for the ulna starting distally and pushing the nail retrograde (Figure 1).



**Figure 1: Complete pronation and supination at 1 month follow-up.**

## 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 a mean age of 9 years (range: 5-15). The right forearm was fractured in 17 patients, and 13 patients suffered fracture of the left forearm. 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 %).

**Table 2: Summary of patient demographics and outcomes.**

No. of patients	30
Average age in years	09 (5-15)
Follow up (wks)	20 (10-36)
Union time (wks)	07 (6-9)
Outcomes*	29 Excellent, 1 Good
Complications	None

### 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 TENS fixation was successful in 20 cases, including 15 both-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 fracture. 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 non-unions 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<sup>4</sup>, and one patient had a good result (Figure 1). The patient who experienced a good result was a 14-year-old boy with 8° volar angulation at the radial bone and limitation in supination of about 5° upon final follow-up. No further surgical intervention was performed because the deformity involved the non-dominant 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. 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 months (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.<sup>16</sup> 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.<sup>17</sup> The classic methods of open reduction with plating could offer anatomical reduction sparing the physis and could provide early mobilization of joints.<sup>6</sup> 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.<sup>18</sup> 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%.<sup>19</sup> In rare instances it has even led to radio-ulna synostosis.<sup>20</sup> 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.<sup>7,21</sup> There is a growing trend toward flexible or titanium elastic intramedullary nailing for fixation of forearm fractures in children.<sup>8,22,23</sup> 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 micro-motion to stimulate the callus to bridge the fracture gaps. Intramedullary nailing of forearm bone fractures in children offers an alternative form of fixation with few reported complications.<sup>24-26</sup> Intramedullary nails function as an internal splint and provide three-point fixation to maintain bony alignment.<sup>27</sup> 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.<sup>8</sup> 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.<sup>12</sup> Patients with longer operative times were at higher risk of developing compartment syndrome.<sup>13</sup> Rod removal is a minor procedure that does not create stress and thus decreases the risk of refracture. 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.<sup>8,9,24,25,28,29-31</sup>

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.<sup>24</sup>

Early pilot studies of fracture-fixation technique in children were developed in France using flexible intramedullary rods.<sup>8,9,25</sup> Verstreken et al reported limited series of six patients.<sup>9</sup>

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.<sup>25</sup>

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.<sup>25,31</sup> Stanley and Wilkins reported on 50 patients with mid shaft fractures of the radius and ulna treated with closed reduction and percutaneous intramedullary pinning.<sup>25</sup> 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.<sup>25</sup> All fractures healed within 7 weeks. All intramedullary rods were removed in the outpatient department. 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.<sup>29,30</sup> Recent series have shown that in non-comminuted fractures, the non-union rate is <10% and the functional results approximate those achieved with plating.<sup>25</sup> 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.<sup>8,9,24,25</sup> These excellent clinical results

support the use of this technique in the operative treatment of forearm fractures in the pediatric patient.

## CONCLUSION

Closed reduction and TENS was successful in 20 cases, including 15 both-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.

In conclusion, independent of the age group all unstable and potentially unstable fractures of the paediatric forearm shaft should be approached surgically, as the functional results after this study found to be excellent. This somewhat aggressive attitude is justifiable with the use of titanium elastic nails allowing for a minimally invasive technique allowing for the maximum freedom of motion at the earliest.

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