# Clinical Outcomes of Management of Pediatric Diaphyseal Forearm Fractures Using Flexible Elastic Nailing

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## Abstract:

***Background:*** Diaphyseal forearm fracture are common injuries among children, its treated either conservatively or surgically, closed reduction cast immobilization remain the current gold standards for treating these injures, but angular & rotational malunion result in functional disability in older children. Intramedullary nailing of forearm fracture is an alternative method especially in case of failed closed reduction and cast immobilization. The aim of our study is to value the outcome of using flexible elastic nail in pediatric diaphyseal forearm fractures.

***Methods:*** This study is a prospective study was conducted in Erbil city from January 2016 to January 2017 on forty-nine pediatric patients with diaphyseal forearm fractures treated surgically with titanium elastic nailing system (TENS), thirty-three boys & sixteen girls, twenty-one fractures on right side and twenty-eight on left side, age range between 5-15 years with mean age of 9 ± 3.1three patients had polytraumatic injury , the fracture had been classified according to descriptive classification, Average follow up was11±2months for 43 children.

***Result:*** In 43 of 49 patients, the operative procedure was done as primary treatment, completed within the first 24 hours after injury. In six of the patients, secondary displacement occurred after attempted conservative therapy, and in those cases the procedure was performed after 8 ± 3 days. Operating time averaged 42 ± 15 min. The average time that radiographs showed bridging callus on the antero-posterior and lateral views was 13 weeks for both radius and ulna, Ten of the 49 patients were given above-elbow splints postoperatively, Implant removal was performed after an average of 6.3 ± 1.7 months, the radiological results are documented regarding angulation and displacement.

The functional results are documented, there were no observed cases of refracture, 6 months after hardware removal all patients pain free with no limitation of movement and activities, 37 patients were rated as excellent outcome, three with good out come and three with poor out comes.

***Conclusion:*** Flexible elastic nail is an effective and minimally invasive method of diaphyseal forearm fractures with excellent results in terms of bony union and functional out comes with minimal complications and without jeopardizing the integrity of the physes.

***Keywords:*** Pediatrics diaphyseal forearm fractures, Flexible elastic nail, Displacement, Functional outcomes.

## Introduction:

Fractures of one or both forearm bones (radius and ulna) are common injuries in children. A survey of pediatric fractures in Edinburgh in 2000 found diaphyseal (shaft) fracture of the forearm bone was the sixth most common fracture, amounting to (5.4%) of fractures in children under 16 years of age. Nearly twice as many males as females incurred these fractures, which occurred at an average age of 7.8 years. The majority of fractures resulted from falls [1].

Diaphyseal forearm fractures are common injuries among children, comprising (3%) to (6%) of all pediatric fractures [2, 3, 4]. Closed reduction and cast immobilization remain the current gold standard for treating most of these fractures, as studies show that up to (85%) of patients with displaced forearm fractures achieve satisfactory results from closed reduction [5, 6].

Most cases can be managed successfully with closed reduction and cast immobilization. However, angular or rotational maluni on of a diaphyseal forearm fracture can result in functional disability, especially in older children. The loss of function can be minimized by restoration of normal alignment. There seems to be no direct correlation between angular displacement and rotation in the forearm. The acceptable degree of displacement to achieve successful outcomes is controversial, leaving much of the decision on treatment to the treating physician's judgment [7].

During the last two decades, however, the treatment strategy of displaced forearm shaft fractures has radically shifted in central Europe [8, 9, 10]. This development was influenced by two essential factors. One factor was the presence of complications and poor results of conservative therapy, and the other was the establishment of a secure, minimally-invasive operative fixation technique [11].

A recent observational study showed an increase in the rate of intramedullary (IM) nailing of forearm shaft fractures from (1.8%) to (22%) as an alternative to closed reduction and cast immobilization over a 10-year period [10]. Further, Schmittenbecher [10] has shown that surgical management of diaphyseal forearm fractures at their institution has increased from (1%) between 1976 and 1985 to (40.4%) between 1998 and 2000 [12].

Complications include hardware migration, neurological deficits, delayed union, nonunion, compartment syndrome, extensor pollicis longus (EPL) tendon rupture, and wound problems, including infections [7]. Surgical stabilization is a recommended treatment option for children who fail initial conservative treatment [13, 14, 15].

## Anatomy:

Whereas the ulna is relatively straight and static, the radius is curved and rotates over the ulna during supination and pronation. Each bone has proximal and distal physes, with the distal physes contributing the most growth (i.e., 75% for the radius, 80% for the ulna) [2]. This polarization of growth is consistent with the observation that distal fractures demonstrate a higher remodeling potential than do fractures closer to the elbow [16].

## Mechanism of Injury:

Most forearm injuries are the result of indirect trauma. A fall on an outstretched hand coupled with a rotational component to produce fracture is common. Single bone forearm fractures are far less common and are typically the result of direct trauma. However, single bone forearm fractures of the ulna or radius should always raise suspicion for a Monteggia or Galeazzi fracture- dislocation, respectively [16].

## Classification:

Classification systems have not been useful for pediatric forearm fractures. Descriptive terminology is often used to give meaning based on anatomic location (e.g., proximal middle and distal), pattern (e.g., comminuted, transverse and oblique), direction of angulation (e.g., apex volar and dorsal), degree of displacement, associated soft-tissue injury (closed versus open), and feature sofimmature bone (e.g., complete, green-stick, or plastic deformation). The Gustilo-Anderson classification system is used to classify open fractures. Pediatricforearmfracturesaretypicallydescribedascompleteorgreen-stick, with the previous lymentioned descriptors applied as appropriate [16].

## Patients and Methods:

In the time period from January 2016 to January 2017, 49 children with forearm shaft fractures were treated operatively with TENS. Of these 49 children, there were 33 boys and 16 girls with an average age of 9 ± 3.1 years, table (1). Twenty-one fractures were on the right side, and 28 on the left, table (1).

Three patients had polytraumatic injuries. According to the descriptive classification there were eight proximal ulna fractures in combination with a distal radius fracture, 31 middle both bone fractures and 10distalboth bone fractures. Seven patients (14.28%) had a first-grade open fracture according to the Gustilo and Anderson classification. Twenty-two patients sustained their injuries through a fall on a flat surface, thirteen had bicycle accidents, seven fell while climbing trees and seven were pedestrians hit by automobiles. The indications for operative management are shown in table (2).

## Inclusion criteria:

1. Agebetween5 and15.
2. Closeddisplacedfractures.
3. Unacceptableclosedreduction.
4. Open displaced fractures (type 1 and 2).

## Exclusioncriteria:

1. Ageyounger than 5 years and older than 15 years.
2. Greenstickfractures.
3. Undisplacedfractures.
4. Acceptablereduction.
5. Open fractures (type3).
6. Pathologic fracture.
7. Monteggia and Galeazzi fracture.

In total 43 patients, postoperative courses were observed for greater than 12 months. Four patients did not present for follow-up after hard are removal, and in four cases the patients were followed for less than 1 year. Average follow-up was11± 2 months.

**Table (1):** Characteristics of patients with pediatric diaphyseal forearm fracture (n=49).

| Variables | No (%) |
|---|---|
| Age (mean±SD=9±3.1) | |
| 5-8 years | 17(34.69) |
| 8-15 years | 32(65.31) |
| Gender | |
| Male | 33(67.34) |
| Female | 16(32.66) |
| Fracture side | |
| Right | 21(42.85) |
| Left | 28(57.15) |

**Table (2):** Mechanism and patterns of pediatric diaphysealforearm fracture (n=49).

| Variables | No (%) |
|---|---|
| Descriptive classification | |
| Proximal | 8(16.32) |
| Middle | 31(63.28) |
| Distal | 10(20.4) |
| Mechanism of injury | |
| Falls | 22(44.9) |
| Bicycle accidents | 13(26.54) |
| RTA | 7(14.28) |
| Falls from climbing trees | 7(14.28) |
| Open fracture | 7(14.28) |
| Polytrauma | 3(6.12) |
| Complete | 20(40.81) |
| Re-displacement(conservative treatment) | 6(12.24) |
| Angulation>10° | 11(22.44) |

## Operative technique:

All patients were operated under general anesthesia in a dorsal decubitus position. The affected arm was positioned free on a radiolucent operating table. A titanium nail was selected corresponding to approximately one-third the medullary canal diameter. The implants were introduced in the distal radius and proximal ulna as described by Lascombes [9]. Signed consents were taken from all patient parents with details of the procedure and all the risks were explained to them.

Prophylaxis antibiotics were given to all patients in form of ceftriaxone vial i.v 1 hour before the operation with standard dose according to their ages. Under general anesthesia, a pneumatic tourniquet is positioned in case an open reduction is needed. A closed reduction is attempted, 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 long itudinalincisionper formed on the lateral side of the distalmetaphysis. Aholeisdrilledin the bone with anawl, first perpendicularly and then obliquely towards the elbow. Then an appropriate size titanium 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 distalend of the nail is then cut 5-10 mm from the bone. The skin is closed with one stitch Same procedure is performed for theulna starting proximally and pushing the nail ante grade (Figure 1).

Under general anesthesia, closed reduction was done under image intensifier. After achieving satisfactory reduction, ulna was fixed by antegrade nailing through the lateral surface of olecranon about 1.5 to 2 cm distal to physis.

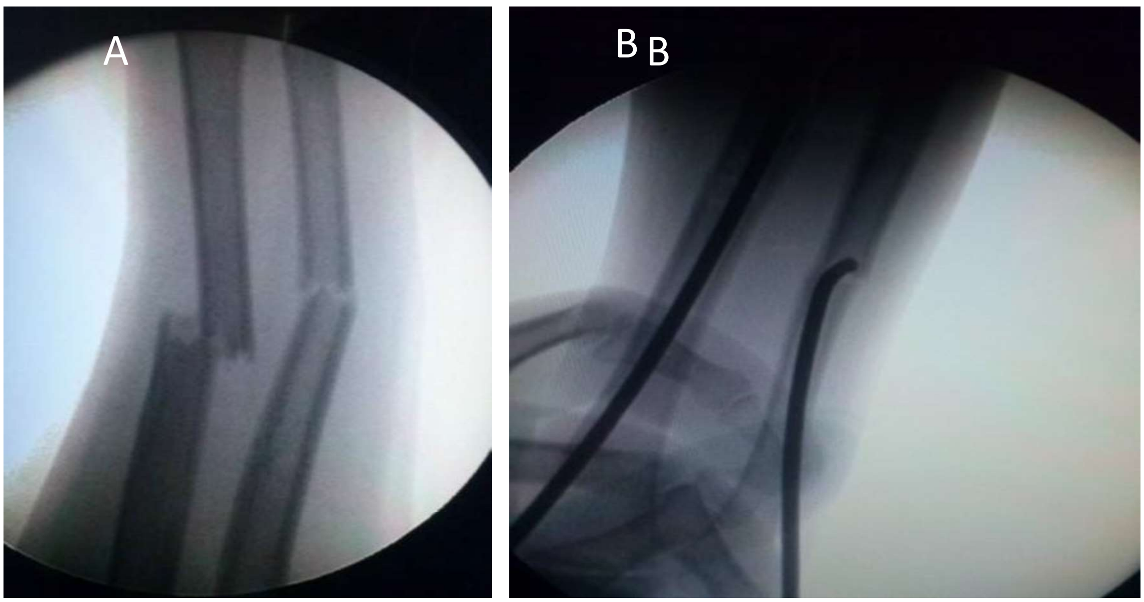


**Figure (1):** Fracture of middle third both bones of 7 years old boy operated with closed elastic nail fixation.

## Postoperative care

While in hospital, patients were given postoperative antibiotics in form of cefixime (suparx) syrup 200mg once daily for 7 days P.O, regular doses of paracetamol according to their weight with additional drops of tramadol as needed for pain. After discharge, patients were given prescriptions for paracetamol as needed.

Three indications for temporary application of an above- elbow slab was followed in the study protocol: (1) for soft tissue injury, (2) for pain reduction, and (3) for protection against rotation in cases in which the fracture had a comminuted third fragment in one or both bones. While the duration of splinting for points 1 and 2 was dependent on the symptomatic variables, for patients fulfilling the point 3 criteria, the splint was kept in place for 3 weeks. If none of the above indications was met, the patient was treated with immediate mobilization and therapy. Parents and children were informed that the arm could be used as tolerated, in terms of discomfort for the child.

## Results:

In 43 of 49 patients, the operative procedure was done as primary treatment, completed within the first 24 h after injury. In eight of the patients, secondary displacement occurred after attempted conservative therapy, and in those cases the procedure was performed after 8 ± 3 days. Operating time averaged 42 ± 15 min. Average fluoroscopy shoots was 23 ± 47min. The diameter of the nails was 2.0 mm in five cases, 2.5mm in24 cases, and 3.0 mm in 20 cases.

The intra operative problems and complications are summarized in table (3). The average time that radiographs showed complete fracture healing on the antero-posterior and lateral views was 13 weeks for both radius and ulna.

Ten of the 49 patients (20.4%) were given above-elbow splints postoperatively, for an average duration of 11 ± 7.6 days (range 4–21 days). Implant removal was performed after an average of 6.3 ± 1.7 months. The radiological results are shown in table (4).

In the case of one child, an extension deficit of 10° at the elbow joint was present after a 3-week immobilization. This deficit remained during the entire follow-up period of 14 months. The functional results are summarized in table (5). There were no observed cases of re-fracture.

At the time of the first control visit 6 months after hardware removal, all patients were pain-free and without limitation in activities of daily living, play or sport activities. Accordingly, 37patients were rated with excellent outcomes, three with good out comes, three with poor out comes and there were no fair outcome observed, figure (2).

**Table (3):** Number of problems and complication safer elastic stable intramedullary nailing (n=49).

| Complications | No (%) |
|---|---|
| Open reduction required | 3(6.12) |
| Soft-tissue irritation by protruding nail end | 7(14.28) |
| Secondary shortening of a nail required | 3(6.12) |
| Compartment syndrome | 0(0) |
| Infection | 0(0) |
| Cortex perforation | 0(0) |
| Implant displacement or breakage | 0(0) |
| Non-unionordelayed union | 0(0) |
| Cross union | 0(0) |

**Table (4):** Radio logical results after elastic stable intramedullarey nailing in forearm fractures (mean±SD) (n=49).

| | Anteroposterior view | | Lateralview | |
|---|---|---|---|---|
| | Radius | Ulna | Radius | Ulna |
| Initialangulation | 40±21° | 30±20° | 45±21° | 30±22° |
| Finalangulation | 0±22° | 0±21° | 0±23° | 0±21° |
| Initialdisplacement | 55±45% | 55±46% | 100±37% | 30±42% |
| Final displacement | 0±1.5% | 0±1.5% | 0% | 0% |

**Table (5):** Functional results after elastic stable intramedullary nailing follow-up > 12 months (mean ± S D) (n=41).

| Variable | Results |
| --- | --- |
| Supination | 89±5° |
| Pronation | 88±3° |
| Loss of forearm rotation | 5±1° |


**Figure (2):** Preoperative AP (A) and lateral (B) radiographs of the forearm demonstrating a both-bone fracture in a 13-year-old boy. Postoperative AP (C) and lateral (D) radiographs of the forearm after elastic nail stabilization. AP (E) and lateral (F) radiographs of the forearm at 5 months postoperatively.

## Discussion:

Most diaphyseal fractures in children are treated conservatively with plaster casting. Where acceptable closed reduction cannot be achieved or maintained in patients with completely unstable forearm fractures, surgical intervention is required [(4)]. Complete fractures were more frequently treated by surgical intervention, especially in older child with limited remodeling capacity [(17)]. The frequency of need for open reduction in a previously closed fracture was given as (5–16%) in the literature. The most common cause of this was soft- tissue interposition [(11)].

The classic methods of open reduction with plating could offer anatomical reduction sparing the physes and could provide early mobilization of joints. However, the disadvantages of surgical intervention included the need for surgical dissection, risk of infection, removal of implants, risk of refracture from the screw holes, or further neurovascular compromise. In rare instances, it has even led to radio-ulna synostosis [18].

Recently there is a growing technique towards titanium elastic intramedullary nailing for fixation of forearm fractures in children. This technique offers stable fixation without disturbance of the periosteal blood supply and fracture hematoma, which contributes to fracture healing. This technique also allows for micro-motion at fracture site to stimulate the callus formation to bridge the fracture gaps.

End-to-end reduction helps to control rotational alignment, and micro motion at the fracture site promotes the formation of external callus by converting shear stress into fracture compression [9]. Titanium intramedullary nails function as an internal splint and provide three-point fixation to maintain fracture alignment to promote rapid union [19], reduces the risk of infection and synostosis, and avoids unsightly incisions that are necessary for plate fixation and hardware removal [20]. Intramedullary titanium nail removal is a minor procedure that does not create stress and thus decreases the risk of refracture.

One typical postoperative problem after TENS is the painful soft-tissue irritation from a protruding nail end [10, 21]. In the present study, this problem occurred in seven patients, and in five cases it was necessary to perform a secondary shortening of the nail end. Recommended solutions to this problem have included using a nail with a rounded olive-shaped end [22], or placing a cap on the end [10], methods that should cover the sharp edge of the trimmed nail end. Much more importantly, however, are two operative techniques recommended to avoid this soft-tissue irritation.

The first recommendation is to split the necessary skin, subcutaneous tissue and fascia sufficiently (1–2cm). The other recommendation is to withdraw the nail after placement in the radius or ulna approximately 1-2 cm, and to shorten it sufficiently so that it can be sunk into the canal [11].

The necessity of postoperative immobilization was judged controversial in the literature. Lascombes [9] reports that he used an above-elbow cast for 5–6 weeks postoperatively for his first 29 cases. All other cases were treated without cast immobilization. In another investigation, 20 of 30 children were immobilized in a cast for 2–3 weeks postoperatively; the exact criteria for immobilization, however, were not given [23]. In the present study, 39 of 49 fractures were treated with immediate mobilization, with no evidence of disadvantage. The additional, temporary application of an above-elbow splint for pain therapy, to support soft-tissue swelling as well as to protect against rotation in cases with additional bony fragments (AO type B fractures) was still utilized [11].

The complication rate after TENS for diaphyseal forearm fractures is minimal, these concern essentially temporary nerve injuries and superficial wound infections that occur when the protruding nail end perforates the skin [10]. In the present study, no temporary nerve injury was present. In all cases, a dorso-radial approach was used as described by Lascombes [9]. In order to avoid a lesion of the superficial branch of the radial nerve, a dorso-ulnar approach is recommended for the distal radius [10].

The treatment of displaced diaphyseal forearm fractures leads to poor results when sufficient angulation is present to promote deficits in pronation/ supination [10]. More studies [24, 25] have shown that even 101 of angulation can lead to decreased rotational mobility. Hertlein [26] showed in a prospective, comparative study that the presence of angulation greater than 10° was significantly rarer (P<0.05) in patients treated with TENS than in patients treated conservatively. In a study from Lee et al. [27], all forearm fractures healed after TENS with angulation less than 5°.

The functional results described in the literature for diaphysealforearm fractures stabilized with TENS were all good [9, 25, 28]. After an average follow-up of 3.5 years, Lascombes [9] assessed (92%) of patients with an excellent result, with complete recovery of elbow range of motion. In another study after an average follow-up of 3.1 years, only three of 28 children maintained a mild deficit in pronation or supination of the forearm [28]. Richter et al. [23] observed only three of 30 patients with a supination deficit of 10° after an average of 6 months follow-up.

Secondary displacement, which is a particular problem for conservative management of these injuries, and leads to malunion or need for re-reduction, is very seldom observed in patients treated with TENS. A comparative study showed that fewer radiologic investigations were necessary after TENS than after conservative therapy [26], in our study no such complication observed.

Another typical complication of forearm fractures treated conservatively is refracture, which has been quoted to occur in (6–10%) of patients [9]. Refracture occurs only rarely after TENS treatment, in approximately (0.5%) of cases [10]. Shoemaker [29] reported that in his cohort of 32 patients, there were three cases of loss of reduction as well as two refractures which occurred after implant removal.

In this set of patients, however, the implants were removed after only 4 weeks, before complete bony union. In order to gain the most advantage from the procedure, therefore, the literature recommends not removing the implant before 3–5 months after operation [30]. In the present investigation, the implants were not removed until the fracture line was no longer visible radiologically, and there was presence of good homogeneous callus.

In the pediatric patient, non- union has not been reported in the literature, and good/excellent functional results are report edinnearly (95%) of cases [9, 31]. These excellent clinical results support these titanium elastic intramedullary nails in the operative treatment of forearm fractures in the pediatric patient. In our study, excellent results observed in 37 cases out of 41 with 4 good results.

## **Conclusion**:

In conclusion, all unstable and potentially unstable fractures of the pediatric forearm shaft in older children 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.

EINS is a modality which aids in the maintenance of radial bow and interosseous space between forearm bones while sparing the physes, thus achieving good functional results in terms of forearm movements. From the present study, we conclude that EINS is an effective and minimally invasive method of fixation of forearm fractures with excellent results in terms of bony union and functional outcomes with minimal complications.

Therefore, we strongly recommend its use in management of pediatric diaphyseal forearm fractures. The need for repeat reductions, angulation, and corrective procedures was not observed, so that good functional results were achieved.

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