Elastic Stable Intramedullary Nails Utility in Treatment of Children Forearm Fractures

Ashraf Salim Ibrahim, Khaled Edris Abdelrahman, Mohamed Abdelfattah Sebaei, Yamen Safwat Abdeldayem
Orthopedic Surgery Department, Faculty of Medicine, Zagazig University, Egypt.
Corresponding Author: Ashraf Salim Ibrahim
Email: ashrafsallem80@gmail.com

Abstract

Background: Fractures of both bone forearm are the third most common fracture in children and account for 40% of all children fractures. Historically, closed reduction and plaster cast application has been the gold standard in management of these fractures due to the unique property of the growth potential of the immature bones. Nevertheless, there are increased chances of re-displacement leading to shortening, angulation and rotation, particularly in older children. 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. Operative intervention has been recommended in previous studies for angulation, malrotation and displacement. The available surgical options commonly done are open reduction and plate osteosynthesis and closed reduction and internal fixation with titanium elastic nailing. Surgical management with elastic intramedullary nail in children both bone forearm fracture has been first described by Metaizeau and Ligier.

Keywords: Elastic Stable Intramedullary Nails, Forearm Fractures.

Background

The forearm shaft consists mostly of the cortical bone, which is strong and needs great trauma energy to damage compared with the metaphysis. Falls are the most typical type of injury in cases of forearm fractures. Children’s carefree and vigorous play makes them vulnerable to skeletal injury. (1) When children fall, they commonly protect themselves by outstretching the upper extremity. (2) In this case, the hand is usually pronated during landing and the thenar takes the first blow against the ground. This leads to rapid supination of the pronated forearm. In this injury, the radius absorbs the highest load and fractures first compared with the ulna. (3) Because of the injury mechanism, there is usually both malalignment and rotational malformation in forearm shaft fractures. Malrotation of the forearm is probable if fractures of the radius and ulna are at different levels of the forearm.

Treatment Modalities in Children Forearm Fractures

Most children forearm fractures are best treated conservatively. Surgical treatment is indicated as the primary treatment for patients with open fractures, vascular injuries, a “floating elbow,” and severe soft tissue complications such as a compartment syndrome or tissue loss. Only after an unsuccessful attempt at closed fracture management surgery is indicated for the remainder of patients, with few exceptions. (4)

Certain fractures have a high risk of closed treatment failure including displaced proximal third radius fractures, displaced fractures in children over 10 years of age and mid-diaphyseal fractures with initial ulnar angulation greater than 15 °. Treatment of forearm shaft fractures aims to achieve and maintain acceptable reduction until bone union occurs. Because of the unique feature of the forearm as a joint,
and unlike other diaphyseal fractures, fractures of the radius and the ulna must be approached like other articular fractures. (5)

**Operative treatment:**
Options for surgical treatment include closed or open reduction and intramedullary nailing, open reduction and internal fixation utilizing plates and screws, and in rare circumstances external fixation. (6)

Intramedullary nailing has become the standard operative treatment method for skeletally immature patients and has demonstrated good results.(6)

**Indications**
Surgical treatment is indicated for:
1. Open fractures.
2. Severe soft tissue injury or compartment syndrome.
4. Floating elbow injuries.
5. Inability to obtain acceptable alignment via a closed reduction.
6. Unstable fractures that have lost alignment at follow-up.(7)

**Elastic Stable Intramedullary Nails**
In the late 1970s, Dr. Jean-Paul Métaizeau, Dr. Jean-Noël Ligier and Prof. Prévot (Head of the Department of children Orthopedics, University Hospital, Nancy) were working out a way to stabilize femoral fractures in children. They took up the idea and tailored the system to children's specific needs. Eventually, on 1979, Hubert Lanternier and J.N. Ligier performed their first ESIN for a 9-year-old child with femoral shaft fracture. (8)

Early constructs used three or four nails. Gradually, the idea of using only two elastic nails with opposing curves took shape. Within a few months, a finalized surgical technique was developed that had the additional advantage of eliminating the need for cast immobilization. On 1980, J.P. Métaizeau, used “only” two nails. However, in the two above-mentioned cases, a long-leg cast was associated with ESIN. As early as 1980, ESIN indications expanded dramatically. It was first used in diaphyseal fractures: femur, and then tibia, both bones of the forearm and humerus. (8)

**The ESIN is formed of:**

**Tip of the nail:**
The special bend of the tip of the nail allows it to glide more easily. The form of the tip also insures that the nail hits and glides well at an appropriate angle on the contralateral cortex. The height of the tip of the nail is adjusted to match the diameter of the nail. This guarantees that the height of the tip will also fit properly within the medullary canal.(9)

**End of the nail:**
The tip of the nail corresponds with a marking at the end of the nail. Both are directed anteriorly on the nail. This orientation is provided so the direction of the tip can be determined without image intensification. (9)

**Length of the nail:**
Nails are available up to 45 cm. Nails of some producers have a unique length. Thus, preoperatively the desired length of the nails does not need to be determined. This allows for more precise placement of the
nails. Other nailing systems are available with different standard nail lengths according to the nail diameter. (9)

End caps:
With very unstable fractures in older children, the axial stability can be improved by using end caps in critical situations. The use of end caps or similar mechanisms in situations with axial instability can help to prevent shortening. This is usually accomplished with a drill hole at the end of the nail for locking. To provide these alternative mechanisms, the nails have to be of predetermined lengths. (9)

Elastic stable intramedullary nailing (ESIN), using flexible titanium nails, has recently become the primary method of surgery in forearm shaft fractures in children. It has produced results equally good as plate and screw fixation in cases of unstable fractures with several advantages when compared with plate and screw fixation. (2).

Figure (1): Different nails sizes. (2)

Elastic nail biomechanic:
In theory, elastic stable intramedullary nailing (ESIN) is based on three-point stabilization by means of opposite tension of two parallel implants in the same intramedullary canal. In the forearm, both bones are fixed separately with single nails. Therefore, stability is dependent on the two nails mandatorily orientated with the tips towards each other. In the forearm, the two separate nails in two separate bones together form opposing elastic concavity at the level of the fractures. For this reason, both bones should be fixed, regardless of opposing reports supporting single bone nailing. (9)

ESIN will not fill the medullary canal, in contrast to rigid intramedullary implants. The flexibility of ESIN facilitates callus formation by enabling minimal movement in the fracture. It is still strong enough to maintain satisfactory alignment. However, rotational alignment is not guaranteed. (10)

Two nails with a diameter of about 40% of the minimum diameter of the intramedullary canal are used. Too large nail may impinge upon the bone cortices. It may also distract the ulnar fracture when inserted in an antegrade direction, because the ulna is usually narrowest distal to the fracture. The bone with worse displacement is nailed first. Most commonly, the radius is more displaced and more difficult to nail compared with the superficially located ulna. (11).
Figure 2: Corkscrew phenomenon: the two nail crossing each other in the medulla. (12)

A : Bending/Bowing stability
B : Axial stability

Figure (3): Different aspect of stability produced by ESIN. (12)

R = restoring force of the nail, S = shear force, C = compressive force, F = force acting on the bone
The entry points:

There are two entry points for the radius, the first one, on the dorsal side; a 2–3 cm longitudinal incision is made over the palpable Lister’s tubercle incision was made. Next the subcutaneous tissue was spread and the fascia was incised to expose the tubercle. After retracting the tendons, the awl was placed directly just proximal to the tubercle between second & third extensor tendon compartments approximately 1-2 cm proximal to the physis. Care was taken to avoid injury to the tendons. The awl was directed anteromedially to perforate the posterior cortex. While introducing the awl, it was ensured that the opposite cortex was not breached. The nail was introduced using T-handle and advances to the fracture site by gentle oscillating movements dorsal tubercle. (13)

While the second one, on lateral side of the radius just above the distal physis by longitudinal mini incision 1 to 2-cm performed on radial styloid between the 1st and 2nd extensor compartments. (14)

![Figure (4): The radius entry points.](67)

The ulna is best reached proximally and distally. The antegrade introduction is recommended with the assistance of fluoroscopy. The skin is incised 1.5–2 cm transversely over the proximal lateral aspect of the olecranon, 3 cm distal to the apophysis. (14)

The lateral cortex of the olecranon is perforated with the awl directed obliquely in a distal direction. The nail is inserted and advanced distally to the fracture site. (14)
Advantages of the ESIN:

The implants are inserted into the bone far from the fracture site in order to avoid further damage and to keep the hematoma intact. The procedure is minimally invasive and relatively simple to apply. The method can be used in children of different ages since there is great assortment of implant sizes. Hardware removal is relatively free of complications and easier than removal of a plate. Early mobilization may be allowed and some advises not using a cast. Others recommend casting beyond ESIN because of the relatively great physical activity of children. ESIN becomes more difficult with delayed time of operation as callus formation increases and the bone marrow becomes obstructed.

Disadvantages of the ESIN:

Include the relatively common need of minor but direct exposure to the fracture in order to achieve open reduction. Conversion from closed to open treatment should be considered not more than after ten minutes of manipulation or after 2 to 3 failed attempts to nail the fracture.

Complications:

Intraoperative:

1- Bursting of fragment iatrogenic: Bursting of a third fragment due to inadequate manipulation, and nail perforation of cortical bone of the distant fragment, resulting in reduced stability.

2- Superficial radial nerve injury: This nerve is considered an injury as traction based neuropraxia which resolved with time. This nerve injury can occur during primary nailing or at the time of implant removal. Adequate exposure of radial entry site with meticulous soft tissue dissection is utmost to prevent neuropraxia.

3- Extensor Pollicis Longus Tendon Injury: In this type of injury, there are two entry points for retrograde intramedullary nailing of the radius which are described as: proximal to the growth plate in line with the styloid process or to second at the Lister’s tubercle. The latter is commonly chosen for metaphyseal distal fractures. A lesion of the EPL tendon as a complication after ESIN is reported at a
rate of 1.5% to 1.9%. As the tendon passes ulnary to the Lister’s tubercle, it is prone for lesion as it has direct contact with the ESIN. (20)

Postoperative:

1- **Nail prominence:** - The most commonly reported complication related to ESIN involves nail such as skin breakdown, superficial or deep infection, effusion at the adjacent joint and stiffness due to soft-tissue irritation bursitis, reoperation to perform nail trimming or nail advancement. (21)

2- **Delayed union and nonunion:** - After ESIN of forearm, they most commonly occur in the mid-diaphysis of the ulna, although they have been reported in the radius as well. Malunion after ESIN of forearm fractures in children is uncommon. A number of studies have reported minor (<15) loss of forearm rotation after ESIN, without radiographic evidence of Malunion. Loss of the normal radial bow because of insufficient fracture reduction or insufficient prebending of the radial nail can cause loss of forearm rotation. (21)

3- **Compartment syndrome:** - Compartment syndrome should be suspected in any child who is not reasonably comfortable 3 to 4 hours after adequate reduction and immobilization of a forearm fracture. The risk of compartment syndrome is higher with open fractures and fractures that are difficult to reduce and require extended operative efforts and multiple passes or “misses” with intramedullary devices during efforts at indirect reduction and internal fixation. The floating elbow injury has been associated with a rate of compartment syndrome as high as 33%. In children, the three A’s of increasing analgesia, anxiety, and agitation are the most reliable clinical signs of a pending compartment syndrome. Forearm compartment syndrome is best treated with fasciotomy, releasing both the superficial and deep volar compartments and the mobile wad. Both the lacertus fibrosis and the carpal tunnel should be released as part of the procedure. (22)

4- **Skin infection / irritation:** - Overt wound infections are rare and most commonly manifest as skin irritation or breakdown. Fernandez et al. reported a 1% rate of infection/wound complications. This can manifest as skin contusions due to small surgical incision, painful bursa at the olecranon insertion, or complications of open fractures. At the distal radial insertion site, ensuring proper exposure by extending the incision distally can optimize soft tissue handling. This will prevent stretching of the skin and soft tissue in order to accommodate an obliquely inserted nail. At the olecranon insertion site, care must be taken to ensure that the nail tip will not be prominent against resting surfaces. (14)

**References**


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