Management of Fracture Both Bone Forearm by Operative Techniques

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Abstract

Background Forearm fractures are among the most common pediatric fractures. The location of the fracture and the age and skeletal maturity of the patient determine how much deformity can be tolerated and therefore which treatment methods are best. (1) Fractures of the radius & ulnar shafts account for only 3% to 6% of all children’s fractures. About 75% of fractures of the shaft of the radius and ulna are in the distal third, 15% in middle third and 5% in the proximal third. Monteggia fracture dislocation and complex injuries account for the remaining 5%. The standard treatment for stable and only slightly displaced forearm fractures in children is conservative treatment. However, certain types of forearm fractures require operative treatments such as plate osteosynthesis, pinning by K-wires, or elastic-stable intramedullary nailing (ESIN). The fracture is stabilized additionally by the interosseous membrane. This type of stabilization allows for micro movements at the site of fracture, which induces the formation of callus. The major benefit of the ESIN treatment compared with conservative treatments is early mobilization of the forearm and lower invasiveness of the procedure compared to plate osteosynthesis.

Background

Epidemiologic studies have shown that 18% of children will experience a fracture by the age of 9, with children between the ages of 5 and 14 having the highest fracture incidence. Due to the high incidence of fractures in children, it is important to treat them adequately and to recognize the potential psychosocial impact, a fracture can have on a child, possibly limiting physical activity and affecting their grades in school (1).

Forearm fractures in children are the most common long bone fractures, comprising about 13% of all pediatric fractures (2). The distal aspect of the radius and ulna is the most common site of fracture in the forearm. These fractures have been reported to be three times more common in boys; however, the increased participation in athletics by girls at a young age may be changing this ratio. Although these fractures occur at any age, they are most frequent during the adolescent growth spurt (3).

The forearm shaft consist mostly of the cortical bone, which is strong and needs great trauma energy to damage compared with the metaphysis(4).

Pediatric forearm fractures typically follow indirect trauma, such as a fall on an outstretched hand. Evans (5) described an indirect mechanism of axial compression force in varying directions and degrees of rotation, the latter accounting for different patterns of fragment angulation. The final degree of fragment displacement due to indirect trauma varies between greenstick and complete fractures, but the initial mechanism of injury is usually the same. In some cases, the force is not sufficient to completely displace the fracture, and therefore a greenstick fracture results. A greenstick fracture in one forearm bone may coexist with a complete fracture in the other (6,7).
Fig. 1: The most typical mechanism of injury resulting in children’s forearm shaft fractures is falling down while a child protects himself or herself with an outstretched, pronated upper arm. At the time of crash, the pronated forearm will absorb the trauma energy (arrow) and suddenly fracture to a supination position and bend dorsally.

Aims of fracture treatment:
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. It is not only a question of fracture healing but also of function of a broken joint and possible stiffness after injury.

Treatment Modalities in Pediatric Forearm Fractures

Conservative Treatment:
Most pediatric forearm fractures are best treated with closed reduction and long-arm cast immobilization. Surgical treatment is indicated as the primary treatment for those 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. 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°. An attempt should be made to treat children and adolescents with forearm fractures non-surgically at the outset, even if they fall into these “risk of failure” categories.

Operative Treatment

Indications

Surgical treatment is indicated for:
1. Open fractures
2. Severe soft tissue injury or compartment syndrome.
4. Floating elbow injuries (fixation of both humerus and forearm fractures in pediatric floating elbow injuries allows noncircumferential immobilization, thereby reducing the risk of compartment syndrome).
5. Inability to obtain acceptable alignment via a closed reduction.
6. Unstable fractures that have lost alignment at follow-up.
Surgical Procedures:
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. Intramedullary nailing has become the standard operative treatment method for skeletally immature patients and has demonstrated good results (14).

**Intramedullary Nailing:**

**Nancy nails biomechanics:**
Elastic stable intramedullary fixation is a minimally invasive and minimally traumatic surgical technique designed to treat fractures in children. Stabilization is achieved with Elastic stable intramedullary nails (ESIN) that have been pre-contoured to provide some elastic properties. This enables them to provide sufficient stability to permit early movement. Thus, ESIN is a biological and child-friendly method of osteosynthesis for transverse and oblique diaphyseal fractures in immature skeleton (15). ESIN provides fixation and allows rapid functional recovery. It avoids long and uncomfortable immobilization in a cast without increasing the risk of complications (16).

**The difference between rigid and elastic internal fixation:**

**Rigid internal fixation:**
Due to the rigidity of the construct that is critical to “primary bone union” and “cortical callus” formation, no external callus can develop because the 2ry bone healing response is abolished. The appearance of external callus is even considered as evidence of technical failure.

![Fig. 2: A both-bone forearm fracture treated with open reduction and mini plate fixation(17).](image)

**Elastic internal fixation:**
Contrary to rigid fixation, elastic fixation needs some degree of relative movement to promote formation of the external callus, which is the physiological callus that forms most rapidly, and has the highest biomechanical strength (18).

![Fig. 3: Typical course in ESIN-fixed forearm shaft fractures, a) unstable fracture; b) fixation by ESIN; c) day 28—sufficient callus formation; d) day 90: consolidation and remodeling finished (19).](image)
Effect of ESIN on healing with external callus

ESIN uses three basic principles to promote optimal development of external callus:

1. **Tissue Preservation:**

ESIN relies on bone and soft tissue to stabilize the intramedullary construct and promote fracture healing. Therefore, the remaining living tissues at the fracture site are necessarily preserved. Closed internal fixation avoids further muscle weakening and periosteal damage. It also offers the advantage of preserving the fracture hematoma and its osteogenic potential suspected by McKibbin and evidenced by Mizuno (20). On the other hand, ESIN is likely aggressive to the medullary vessels but not to a dramatic degree. For instance, it does not seem to adversely affect healing by external callus. In addition, free motion of the nails is maintained in the medullary canal, which explains the lower susceptibility to infection as compared to the traditional intramedullary nails (18).

Viability of the periosteum is critically important to the repair process, where periosteum has been destroyed, no external callus can develop, as can be seen in some high-energy open fractures. One must not aggravate severe initial damage with open surgery or periosteal stripping (18).

2. **Elimination of Deleterious Stresses:**

Study of fracture healing showed that a callus bridge consisting of longitudinally oriented cells forms between the fragments, and that a certain degree of movement is necessary for optimal development of the external callus (21).

The best way to promote development of the external callus is to allow for movements that assist in building the bridging callus, and eliminate those which may break this bridge. Compression traction stimuli are known to promote the formation of external callus, whereas torsional and shearing stimuli have a deleterious effect (22).

In diaphyseal fractures, a perfect ESIN construct consisting of two intramedullary nails with opposing curves can convert negative stimuli to positive ones. However, achieving a well-balanced construct is a little more complex. Significant contouring is necessary to provide the nail with an adequate elastic restoring force when subjected to angulation forces. The angle of curvature must be greater than the actual curvature of the nail in the medullary canal. In a construct with two opposing curves, both nails must have identical curves, and the entry holes must be symmetrically located on the bone (whenever possible) so as to avoid angular deviation. Three-point contact with the bone is standard: the preferred anchoring site is the metaphysis opposite the entry hole, where dense cancellous bone provides the best stability in all three planes. The entry site has always less axial and rotatory stability. The main technical difficulty lies in accurate positioning of the apices of the curves at the fracture site where the spread should be greatest; this sometimes requires additional contouring locally (18).

Both-bone forearm fracture is a special case. One single intramedullary nail in each bone is sufficient: the two nails and the adjacent joints make up a strong frame-like construct. However, as usual, both nails are initially contoured to the same shape, and are positioned so that their respective concavities face each other (22).

3. **Stability and Role of Soft Tissues:**

Soft tissues, and particularly, tendons and ligaments play three major roles:

- **Rotatory Stability:** Owing to their oblique position relative to the fractured bone, muscles and tendons act in the same way as the shrouds that hold the mast up on a sailboat, and they can resist significant angular deviations, as well as rotational malunion (23).
- **Trophic Role:** Muscle contractions, which are enhanced by ESIN, play trophic role by increasing local nutritional supply. This creates an oxygen-rich atmosphere, which promotes production of osteoprogenitor cells, thus eliminating the chondroblast stage (21).

- **Morphological Role:** Muscle contractions also have an influence on the morphology of callus. Normally, the randomly oriented initial callus which arises from the damaged tissues gradually takes on a regular elongated shape (23).

**Biomechanical properties of ESIN**

The biomechanical principles of ESIN are based on the symmetrical bracing of two elastic nails inserted into the metaphysis, each supporting the inner cortical contact. This produces the following four aspects of stability (24).

\[ F = \text{force acting on the bone, } R = \text{restoring force of the nail, } S = \text{shear force, } C = \text{compressive force}\]

_Fig. 4: Different aspect of stability produced by ESIN (24)._
Specifications of the nails

Nail materials:
There are two types, **stainless steel** and **titanium**. The first nails were made of stainless steel. Later, a shift to the use of titanium occurred on the ground that titanium had better elastic properties and that elasticity been the single most important factor in the success of this method. In a child aged less than 10 years, stainless steel and titanium nails yield similar results. In adolescents, especially if obese, where the nails are subjected to critical dynamic stresses, stainless steel offers greater stiffness than titanium, and its restoring force is twice higher than that of titanium. A stainless steel nail is equivalent to a titanium nail that is 0.5 mm larger, which is not negligible (25).

Nail sizes:
It is available in six diameters: 1.5-4.0 mm in 0.5 mm increments. The 1.5mm diameter TEN is 300mm long. All other size diameters come in a length of 440mm. If one were to define a mathematic formula for nail diameter, it would be: \( \text{NAIL DIAMETER} = 0.4 \times \text{diameter of the medullary canal} \), as the diameter of the nail must be at least 40% of that of the medullary canal.

![Fig. 5: Different nails sizes(26).](image)

Nail contouring:
It is recommended that the nails are pre-contoured in order to achieve 3-point contact. The degree of curvature of the nail should be approximately 3 times the diameter of the bone at the fracture site. Adding more curves with pre-contouring can increase the contact force on the inner cortex. This can be definite advantage in the stabilization of unstable fractures(27).

The apex of the curvature should be at the level of the fracture. Thus, when fractures are not in the midshaft, it may be easier to place the apex at the appropriate location by pre-contouring of the nail (24).
Fig. 6: Pre-contouring the nails to three times the diameter of the isthmus, with maximal bend at the level of the fracture(26)

Factors leading to failure of ESIN
Elastic nails, like any other form of treatment, demand understanding, strict adherence to the technique, and adequate instrumentation, as most of the reported failures of the method have been derived from an incorrect use of the technique or inadequate indication(26).

A. Incorrect size of the nails or using nails of different diameters
B. Wrong technique as wrong level of entry or different points of entry of the two nails producing different contact with inner cortex leading to different strength of nails which can result in axial deviation, what’s known as: crock screw effect.
C. Use of only one nail which is not keeping with the basic biomechanical principles and thus can’t be considered stable system, forearm is an exception.

Fig. 7: Corkscrew phenomenon: the two nail crossing each other in the medulla(23).
Preoperative Planning:
Intramedullary nailing can be done percutaneously or with minimal surgical exposure using flexible nails (1.5–2.5 mm diameter). The nail diameter should fill approximately two thirds of the canal isthmus (28). The implant is advanced across the fracture site via a closed or limited open reduction. Dual bone fixation is most common, but occasionally single-bone fixation provides adequate stabilization of the fracture reduction. Antegrade and retrograde intramedullary nailing techniques have been described for the ulna, while retrograde nailing is standard for the radius. The order of bone fixation is variable between surgeons and may be determined based on which bone is the most difficult to reduce and most unstable (29). Antegrade nailing is utilized for the ulna, with insertion across the olecranon apophysis. The antegrade insertion site is directly posterior to the olecranon, which provides a direct path to the canal. Alternately, insertion can be done through the metaphysis just distal to the apophysis on the lateral aspect of the ulna (anconeus starting point). Significant complications have not been reported with either entry site (29).
Attention is then directed to the radius, which is fixed in a retrograde fashion. The dorsal physeal sparing entry site is located at the proximal aspect of Lister’s tubercle. Alternatively, a lateral entry point may be used via the floor of the first dorsal extensor compartment.

Fig 8: In ESIN, nails are implanted from the lateral or dorsal distal radius(30).

One third of closed forearm fractures treated with intramedullary nailing require an incision at the fracture site to achieve a reduction and facilitate nail passage (14,31). Open reduction of the ulna is performed utilizing a 1–2 cm incision made on the subcutaneous border of the ulna at the fracture site. The radius is opened in a similar manner using a small volar incision for distal and middle third fractures. Proximal third radius fractures can be approached via a volar incision, although some surgeons prefer a dorsal approach.

Postoperative care:
postoperative immobilization by back slap above elbow for 3-4 weeks and start early mobilization. The patients’ clinical notes were reviewed with particular reference to any complications encountered, ongoing
symptoms and the need for secondary treatment or surgery. A radiological review was carried out examining the quality of the initial reduction and final fracture healing. (9)

**Complications:**
Residual radial angulation, and ulnar angulation, superficial wound infection, joint stiffness, superficial radial nerve palsy. (9)

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**References**


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