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Evaluation of Both-Bone Forearm Fractures Fixation in Children by Elastic Stable Intramedullary Nailing

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ABSTRACT

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Background: Both-bone forearm fractures are common pediatric injuries that were traditionally treated with above-elbow plaster casting. However, casting is associated with complications including prolonged immobilization, loss of reduction, and refracture. Elastic stable intramedullary nailing (ESIN) has emerged as an effective alternative for internal fixation of pediatric both-bone forearm fractures.

Aim of the work: This study aimed to evaluate the radiological and functional outcomes of ESIN fixation of both-bone forearm fractures in children.

Patients and methods: This prospective study included 22 children aged 6-14 years with both-bone forearm fractures treated with ESIN between October 2022 and June 2023. Relevant clinical data was collected and radiographs were obtained post-operatively and at final follow-up (minimum 6 months) to assess fracture alignment and healing. Price scoring was used to evaluate functional outcomes.

Results: All fractures healed uneventfully at a mean of 7.37 weeks. Based on Price et al. scoring, 19 patients (86.3%) had excellent and the remaining three patients (13.7%) had good functional outcomes. Complications included nail protrusion\pain in two patients (9.0%) and pin tract infections in one patient (4.5%).

Conclusion: ESIN provides effective and reliable fixation for both-bone forearm fractures in children, allowing early mobilization with low complication rates and excellent clinical and radiological outcomes. It is a superior alternative to casting for these injuries.

Keywords: **Forearm Injuries; Intramedullary Fracture Fixation; Radius; Ulna.**

INTRODUCTION

Among children, fractures of the forearms are common, particularly involving both the radius and ulna bones [1]. These injuries rank as the third most frequent among children, following fractures at the end of the radius and fractures just above the elbow. The majority, around 75.0%, of these fractures occur at the lower part of the radius and ulna, with 15.0% in the middle, 5.0% in the upper part, and the remaining 5.0% distributed elsewhere [2, 3]. There is a debate surrounding the treatment of long bone fractures in children. Due to children's high bone remodeling capacity, many forearm fractures can be effectively managed by immobilizing the affected area with a cast after performing a non-invasive realignment procedure [4]. Non-surgical treatment continues to be the preferred and most effective approach for diaphyseal fractures in children, particularly in those under the age of six. For children aged nine years or older, acceptable levels of angular deformation for middle-third fractures are limited to 8–10°, rotational deformation to 30° at most, and displacement should not exceed 100.0% [5]. In older children, any lasting deformity from improperly healed fractures could restrict forearm movement and negatively impact function. In such cases, surgical intervention may be necessary for unstable, unreducible, or open diaphyseal fractures of the forearm [6]. Multiple options exist for stabilizing long bone fractures in children, including intramedullary nailing, plate and screw fixation, and external fixators. Intramedullary nailing is a preferred method due to its excellent outcomes and minimally invasive nature compared to plate fixation [7].

Metaizeau and Ligier initially introduced the use of elastic intramedullary nails for treating both-bone forearm fractures in children [8]. These implants function as internal splints. Over time, there has been a rise in using internal fixation for pediatric forearm fractures, with open reduction and rigid internal fixation using plates and screws (ORIF) yielding favorable outcomes for stabilizing unstable fractures in children's forearms [9]. In numerous cases, intramedullary nail fixation is favored over open reduction and plating for forearm bones because it avoids damaging the soft tissues and results in minimal surgical scarring, making it cosmetically pleasing. Elastic stable intramedullary nailing offers immediate stability to the affected bone area, facilitating early mobilization and swift return to regular activities with a minimal risk of complications [10]. In the pediatric population, intramedullary fixation can maintain satisfactory alignment during the healing process of fractures. The straightforward nature and minimal complications associated with intramedullary fixation have contributed to the widespread adoption of this approach for managing forearm fractures in children [11]. Hence, the objective of this research was to assess the immediate outcomes of employing the Nancy Nail for intramedullary fixation to treat diaphyseal forearm fractures in children aged 6 to 14 years. The objective of this study is to assess the clinical, radiological, and functional results of using elastic stable intramedullary nailing for treating diaphyseal fractures in both bones of the forearm in pediatric patients.

PATIENTS AND METHODS

Twenty-two participants were included in the current work. They were presented with fractures in both forearm bones, specifically in children aged 6 to 14 years, characterized by closed displaced fractures in the shafts of both forearm bones. Patients were selected from Damietta Al-Azhar University Hospital, Egypt, from October 2022 to June 2023.

Inclusion criteria: Children aged 6 years up to 14 years with one of the following:

- Fractures that cannot be re-aligned, whether due to soft-tissue blockage or not.
- Alignment that is considered unsatisfactory after attempted closed reduction, with angulation exceeding 15° or rotation exceeding 45° for children under 10 years old, and angulation exceeding 10° or rotation exceeding 30° for children above 10 years old.
- Unstable fractures in whom re-displacement occurred within 1 week of closed reduction and casting.

Exclusion criteria: Pathological, comminuted or open fractures, patient unfits for surgery, patients complicated by compartmental syndrome and neglected fractures after 2 weeks.

Ethical consideration: The study was submitted for approval by the Damietta Faculty of Medicine Al-Azhar University Medical Research Ethics Committee.

Clinical evaluation: Each participant in this research underwent a thorough clinical evaluation, involving a comprehensive examination of medical history and physical condition. This assessment encompassed a systematic evaluation of the entire body through primary and secondary surveys, as well as resuscitation measures. A detailed inspection of the affected limb was routinely conducted, with specific focus on vascular health by examining pulsations along the radial artery. Additionally, a meticulous evaluation of motor and sensory function of the ulnar, radial, and median nerves was performed to rule out any nerve-related injuries. The surrounding soft tissue was carefully examined for signs such as swelling, open wounds exposing bone, bleeding, abrasions, or tissue loss. The radius and ulna bones were palpated thoroughly, while the elbow and wrist joints on the same side were assessed for signs of swelling, tenderness, and limitations in range of motion.

Radiographic evaluation: Every patient underwent both anteroposterior (AP) and lateral (LT) radiographic imaging of the full forearm region, encompassing the elbow and wrist, to accurately assess forearm fractures.

Surgical technique: The operation was planned once the edema had decreased. All patients were administered general anesthesia. Patients were provided with broad-spectrum prophylactic intravenous antibiotics within thirty minutes prior to the surgery. Surgical procedures were conducted in a sterile environment. The size of the nail was determined based on the narrowest point of the medullary canal seen on an x-ray. The nail's diameter should be greater than 40.0% of the smallest diameter of the canal (0.40 x medullary canal diameter = nail size). Typically, radial and ulnar nails had similar sizes and shapes. However, depending on the child's anatomy, a smaller ulnar nail might be used compared to a radial nail in some instances (e.g., a 2.0 mm ulnar nail and a 2.5 mm radial nail). The nail's tapered tip is designed to prevent bone penetration and contact with the canal wall during insertion. To navigate the turn smoothly, the nail tip was gently curved (30–40°) over a length of 3–4 mm at the metaphyseal/diaphyseal junction. Under fluoroscopic guidance, an awl was carefully inserted near the anatomical landmark after dissecting the soft tissue to protect the superficial radial nerve's dorsal branch. Subsequently, an appropriately sized flexible intramedullary nail was inserted.

The nail sizes typically varied from 2.0 mm to 3.0 mm based on the child's bone characteristics. Moderate manipulation was employed to align the fracture and secure the nail in position. The distal end of the nail was twisted and trimmed a few millimeters away from the bone to ensure stability. If closed reduction was unsuccessful, open reduction would be considered. A small skin incision was made at the fracture site for access. A longitudinal skin incision of 1.5 to 2 cm was made proximally and laterally to the olecranon, approximately 3 cm distal to the apophysis in an antegrade direction from the lateral cortex. An awl was directed distally for the incision, positioned 3 cm below the apophysis and just before the posterior border, or approximately 4 mm lateral to the posterior crest of the olecranon. A T-handle was utilized to insert the nail, and gentle oscillating motions were employed to gradually advance it distally towards the fracture location. After closing the incision points and applying an above-elbow plaster slab, the next steps involve patient evaluation and postoperative care.

Post-operative: Patients are scheduled for follow-up appointments every 2 weeks' post-fixation for suture removal. Subsequent to this, serial radiographs are taken at 2-, 4-, 6-, and 12-weeks post-surgery to assess callus formation, range of motion, and any complications until the bone has completely healed. Patients were mobilized gradually from the 1st postoperative day with passive exercises. A continuous passive motion under the supervision of experienced physiotherapists was started the next day. Sutures were removed after 2 weeks, and the patients were followed up at 2, 4, 8, and 12 weeks and after removal of the nails 3-6 months after the union of fractures post-operatively. Post-operative X-rays were evaluated and clinical assessment for neurological status, the range of motion, and any other complications.

Final assessment: At the end of the six-month follow up children were evaluated for full function according to the criteria established by **Price *et al*.** **[12]**, which includes considering pain levels and the range of motion of the forearm in terms of supination and pronation.

Statistical Methods: The data was coded, entered, and analyzed using Microsoft Excel. Subsequently, the data was transferred to the Statistical Package for the Social Sciences (SPSS version 24.0) software for further analysis. Qualitative data was presented in terms of numbers and percentages, while quantitative data, representing continuous variables, was reported as mean ± standard deviation (SD).

Figure [1]: The equipment needed for inserting elastic nails and the accessibility of titanium nails in different sizes

RESULTS

Demographic data: The average age of the participants fell between 6 and 14 years, with a mean age of 10.4 ± 2.62 years. The study comprised 15 male and 7 female participants, indicating a male-to-female ratio of 2:1, with males being the predominant gender among the participants **(Table 1)**.

Mode of injury: Approximately 77.2% of the cases involved diaphyseal forearm fractures resulting from falls onto an outstretched hand. Road traffic accidents accounted for 9.0% of the fractures, while another 9.0% occurred during sports activities. Falls from heights represented 4.5% of the cases **(Table 1)**.

Fracture distribution: Approximately 77.2% of the fractures occurred in the middle third of the forearm, 18.1% in the proximal third, and 4.5% in the distal end **(Table 1)**.

Associated injuries: Two patients presented with ipsilateral clavicle fracture and one patient presented with contralateral clavicle fracture with no other associated injuries **(Table 1)**.

Injury to surgery interval: All patients in the study underwent surgery within a week after the injury, with most surgeries performed on the same day as the injury. The average time from injury to surgery was 1.45 ± 1.1 days, ranging from 0 to 4 days.

Post-operative complication: Two patients had reported nail pain and protrusion, one patient had developed skin irritation and one patient had pin site infection no other complication had occurred **(Table 2)**.

Limitation of forearm rotation: The limitation of rotation ranged from 0 degrees to 25 degrees with mean ± SD = 4.32 ± 7.91 degrees. 15 (68.0%) patients hadn't lost movement at the forearm, 7 (32.0%) had movement at the forearm by 10-25 degrees and no one had a loss of movement at the forearm by more than 25 degrees **(Figure 3)**.

Functional outcome: Functional assessments followed Price et al.'s criteria, which evaluate the level of restriction in forearm rotational movement. Excellent outcomes were observed in children with forearm fractures who underwent elastic nailing, as per these criteria **(Table 3)**.

Duration till bony union (weeks): On average, bony union occurred around 7.37 weeks, ranging from 6 to 11 weeks. Approximately 72.0% of patients experienced radiological union before 9 weeks, while the remaining patients achieved it after 11 weeks **(Figure 4)**.

Table (1): Demographic and clinical characteristics of studied patients

Variables		Statitics (n=22)
Gender (n,%)	Male	15 (68.1%)
	Female	7 (31.8%)
Mode of injury (n,%)	Fall on our stretched hand	17 (77.2%)
	Road traffic accident	2 (9.0%)
	Sport injury	2 (9.0%)
	Fall from height	1 (4.5%)
Site of fracture (n,%)	Proximal third	4 (18.1%)
	Middle third	17 (77.2%)
	Distal third	1 (4.5%)
Associated injuries (n,%)	Ipsilateral clavicle fracture	2 (9.0%)
	Contralateral clavicle fracture	1 (4.5%)

Table (2): Post-operative complications of the studied cases

Post-operative complications	No of patients
Skin irritation	1 (4.5%)
Pin site infection	1 (4.5%)
Nail protrusion\ Pain	2 (9.0%)
Elbow stiffness	0 (0.0%)
Wound infection	0 (0.0%)
Refracture	0 (0.0%)

Table (3): Functional outcome of the studied cases

Functional outcome (Price *et al*. criteria)	No. of patients
Excellent	19 (86.3%)
Good	3 (13.6%)
Fair	0 (0.0%)
Poor	0 (0.0%)

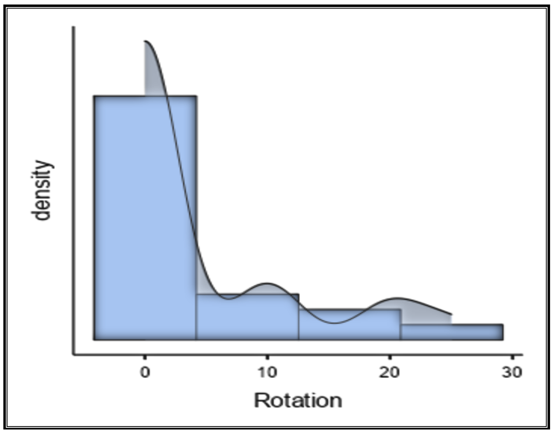

Figure [2]: Limitation of rotation

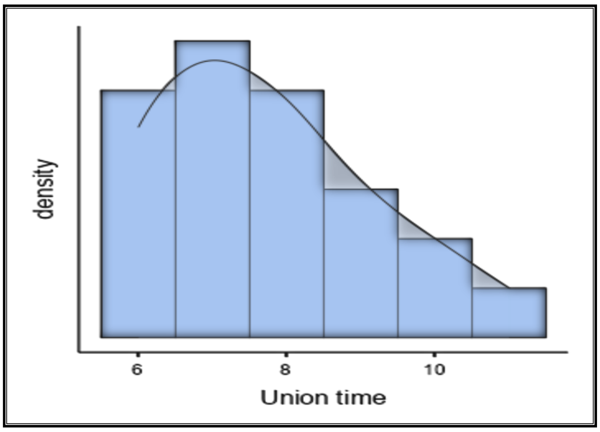

Figure [3]: Time needed till the union

DISCUSSION

The forearm is a crucial part of the upper limb that is essential for various movements. Any alterations in the shape of the radius and ulna can impact the flexibility of the joint [13]. Malunion, in particular, can lead to issues with mobility at the wrist and elbow. Achieving exact anatomical alignment is not always critical due to bone remodeling in growing children, so surgical realignment is seldom required [14].

Traditionally, treating forearm fractures in children involved closed reduction followed by immobilization in a plaster cast. Nonetheless, fractures in older children and those closer to the elbow are prone to re-displacement. There has been ongoing debate regarding the acceptable degree of malediction. Angles exceeding 10 degrees and complete displacement are considered inadequate reduction. Younger children are more resilient to deformities compared to older children because of their enhanced bone remodeling capacity [15].

All 22 participants in this research underwent surgery in which fractures in both the radius and ulna were stabilized using a titanium elastic nail. This study observed limited rotation (4.32±7.91 degrees), mostly favorable functional outcomes, bony union in about 7.37 weeks, and minimal post-operative complications like nail pain and skin irritation. In this study, most children fell within the 9-13 years' age range, with an average age of 10.4 years. Comparable findings were reported by **Dwivedi *et al*.** [16] (10.31 years), **Kapila *et al*.** [17] (11.2 years) and **Garg *et al*.** [18] (11.8 years). Therefore, the average age of occurrence can be estimated to be around 11 years.

In our study, we found that forearm shaft fractures were predominantly located in the middle third (77.2%), followed by the proximal third (18.1%) and distal third (4.5%). In **Kapila *et al*.** [17]'s research, they observed a correlation between fracture location and age. Proximal fractures were more prevalent in older children (11-14 years), middle fractures were common in the same age group, while distal fractures were frequent in younger children (6-10 years)

In our study, there was a low incidence of complications. (9.0%) of the patients had nail protruding and pain. (4.5%) of the patients had Skin irritation and Pin site infection. No other complications occurred. **Makki *et al*.** [19] reported an overall complication rate of 11.8% cases. However, in their research, neuropraxia of the sensory branch of radial nerve were the most common.

In the **Dwivedi *et al*.** [16]'s study, 40.0% of patients reported at least one complication. Out of 10 complications, 6 were asymptomatic. One patient had developed superficial radial nerve palsies, which resolved spontaneously without treatment. One superficial wound infection. Two patients developed a pin site irritation. These differences may be due to different sample sizes in each study.

Additional research has found that IM nailing can achieve accurate fracture alignment, maintain stability for healing, lead to minimal visible deformity, and allow easy implant removal after treatment. However, IM nailing is not without risks. Reported complications include nail site infections, skin irritation where nails are inserted, fracture displacement after hardware removal, nail migration or breakage, loss of proper alignment, refracture, nerve and tendon damage, decreased mobility, prolonged or incomplete healing, formation of scar tissue, and compartment syndrome. While IM nailing offers benefits, it is important to be aware of potential complications. Close monitoring and follow up are needed to address any issues that may arise [2, 16].

At the last follow-up in our research, 68.0% of patients did not experience decreased forearm movement, 32.0% showed movement restriction between 10-25 degrees, and none had a loss exceeding 25 degrees. Corresponding findings were seen in **Kapoor *et al*.** [20]'s study, where 16.0% of patients exhibited limited forearm motion during a 24-week follow-up.

In our study, bony union typically took 7.37 weeks, ranging from 6 to 11 weeks, with approximately 72.0% of patients achieving radiological union before 9 weeks, while the remainder achieved it after 11 weeks. **Kapila *et al*.** [17] reported a mean time to radiological bony union of 9.2 weeks (range: 6–13 weeks).

Study limitation: The major limitation of the current study is the small sample size. A larger sample size multicenter is recommended for more generalization of the results. Also, we have not compared the outcome of closed with open nailing in our study, future studies for comparison are recommended.

Conclusion: Utilizing elastic stable intramedullary nails for pediatric forearm fractures is a minimally invasive procedure yielding outstanding outcomes with satisfactory results. Overall, out outcomes of this study are excellent too good with no poor results and a reasonable complication rate. Surgical intervention with elastic nails is recommended for all potentially unstable and significantly displaced forearm shaft fractures in children, given the favorable functional outcomes observed.

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