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THE CLINICAL OUTCOME OF ELASTIC STABLE INTRAMEDULLARY NAILS FOR BOTH BONE DIAPHYSEAL FOREARM FRACTURES IN CHILDREN 5 – 15 YEARS OLD

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ABSTRACT

Background: Diaphyseal forearm fractures in skeletally immature patients is common fractures, estimated around 40% of all pediatric fractures. Using of elastic nails has changed the management of displaced forearm fracture. **Objectives:** the aim of the study is to evaluate the clinical outcome of elastic stable intramedullary nails in treating both bones diaphyseal forearm fractures in children 5 to 15 years old. **Patients and Method:** A prospective case series study carried out in orthopedic unit in Al-Mosul teaching hospital from January 2021 to June 2022, with average follow up of 6 months. Forty-one patients were included in the study depending on the inclusion and exclusion criteria. Elastic-stable intramedullary nailing technique done to all patients under general anesthesia. Functional outcomes of these patients assessed by price et al criteria. **Results:** In the study sample 27 (66.4%) are males, 14 (33.6%) are females. Mean age of patients is 10.67 years ranges from 5 -15 years. Right forearm injured in 16 (39.03%) patients, while left forearm fractures occurred in 25 (60.97%) patients. Thirty-seven (90.24%) patients with closed fractures, while only four (9.75%) patients has type 1 or 2 open fractures. Closed reduction technique done in 33 (80.5%) patients, mini – incision / forceps or other reduction tools assisted technique done in six (14.63%) patients. Open reduction techniques performed for two (4.87%) patients. Entry site skin irritation is occurred in 2 (4.87%) patients, superficial infection is noted in 2 (4.87%) patients, paresthesia (superficial radial nerve irritation) is noted in 1 (2.43%) patients, migration of the nail tip is recorded in 1 (2.43 %) patients, olecranon bursitis occurred in 1(2.43%) patient . Average union time was 9.2 weeks; shorter union time recorded in association with younger age. Based on Price et al., criteria functional outcomes were calculated which showed excellent results in 37 (90.3%) patients, good in 3 (7.3%) patients, fair in one (2.4%) patient. **Conclusion:** Intramedullary fixation by Elastic intramedullary nails is successful treatment option because it is simple, safe and minimally invasive procedure. It provides many biological and mechanical advantages having low and manageable complications, and excellent clinical outcomes.

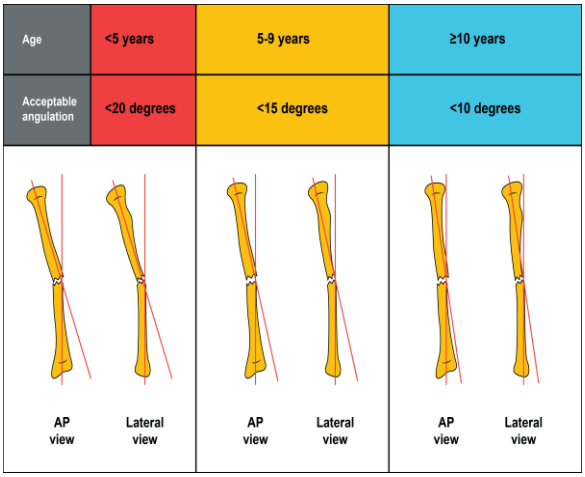
KEYWORDS: Elastic stable intramedullary nail, functional outcome, fractures of both bone forearm, Price criteria.

INTRODUCTION

The forearm fractures are common in the pediatric population, with an incidence of around 1 in 100 children each year, and the peak incidence occurs in the 5 to 15 years age group accounting for approximately 34% of the cases.[1] Both bone diaphyseal forearm fractures constitute around 5.4% of all fractures in children under 16 years of age.[2] Treatment of forearm shaft fractures aims to achieve and maintain acceptable reduction until bone union occurs. Decision-making as to accept or not to accept the reduction depends on multiple factors. These include patient age, fracture angulation and rotation, fracture location, and fracture displacement.[3] However, some authors have concluded that children of ten years of age or older, may tolerate no more than 8–10º of angular deformation in middle-third fractures, at most 30º in rotational deformation and not more than 100% of displacement.[4] Children under ten years of age may tolerate 10– 15º of angular deformation and 45º of malrotation in middle-third shaft fractures. Shortening of at most 10 mm thought to be acceptable at any age.[5]

(Table 1).

Table 1: Acceptable variables for closed reduction in association with age.[3]



There are multiple surgical techniques to achieve adequate stabilization of these types of fractures, including intramedullary nailing, plating, pins and external fixation.[6] Generally, in both-bone forearm fractures, the order of fixation for the radius and ulna based on fracture pattern and comminution. Initial fixation of the fracture with less comminution will restore the length and facilitates reduction of the other bone. When both the fractures are simple, preferably radius should be fixed first as it makes the forearm more stable and makes it easy to address the ulna.[7] Elastic intramedullary nails were originally developed in the early 1980s by surgeons in Nancy, France. Since its introduction, elastic stable intra- medullary nailing (ESIN) for pediatric fracture management has gained increasing popularity because of its minimally invasive procedure.[8] In contrast to plate fixation, the use of ESIN prevents stripping of the soft tissue at the fracture site, leaves a small scar that is more likely to be cosmetically acceptable, and has an overall low complication rate. It also offers stable fixation without disturbance of the periosteal blood supply or removal of the hematoma, which contributes to fracture healing. This method also allows micro motion to stimulate the callus to bridge the fracture gaps. These factors have made ESIN the primary operative treatment for children's forearm shaft fractures.[9] Intramedullary nails function as an internal splint and provide three-point fixation to maintain bony alignment. 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. 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. The contraindications for nailing include active infection, narrow intramedullary canal, concomitant metaphyseal or epiphyseal fracture.[10]

Patients and Method

The study is prospective interventional study carried out in orthopedic unit in Mosul teaching hospital from January 2021 to June 2022 in Mosul city. Forty-one patients were included in the study depending on the inclusion and exclusion criteria. Patients between 5 and 15 years with closed displaced diaphyseal both bone forearm fractures with unacceptable closed reduction and patient with open displaced fractures (Type 1 and 2), according to Gustilo Anderson classification are included in this study. While patient younger than 5 years and older than 15 years, patient with open fractures (type3), pathologic fracture, isolated fracture ulna or radius shaft, fracture dislocation like monteggia and Galeazzi fractures and fracture associated with neurovascular injury were excluded from this study. The study approved by Arab Board for Medical Specializations. A verbal and written consent taken from the family of each patient before participation in the study. At admission, evaluation of the patient including detailed history, age, sex, time of injury, mode of injury and type of fracture either open or closed. General assessment of the patient done for the presence of associated systemic or other orthopedic injuries. All patients received analgesia and an I.V antibiotic in case of open fractures. A posterior above elbow slab applied to the fractured limb and elevation performed Figure (1)**.** Two radiographic views anterior-posterior and lateral including the elbow and wrist joint were done for evaluation of injuries. Operative management decided for patients with failure of closed reduction or completely displaced unstable both bone diaphyseal forearm fractures. Laboratory evaluation Complete blood count, as well as virology markers. Prophylactic antibiotics given to all patients in form of ceftriaxone vial i.v 1 hour before the operation with standard dose according to their weight. Preoperative planning carried on through assessment of the fracture, including rotation and the presence or absence of comminution.

Fig. 1: Above elbow, slap applied preoperatively for fracture immobilization.

Under general anesthesia, a tourniquet kept ready in case an open reduction needed. The patient placed in supine position on operation table with shoulder at edge of table and affected limb over the radiolucent arm board or radiolucent table Figure (2)**.** Whole of involved limb prepared and draped in standard methods. Limb kept free for adequate manipulation during the surgery Figure (3).

Fig. 2: Fluoroscopy, C- Arm.

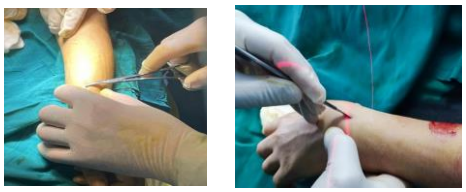
Fig. (3): patient preparation and Draping.

TENs of appropriate diameters chosen, the nail diameters are about two-thirds of the medullary isthmus of each bone or nail diameter of TENs is calculated by using the Flynn's formula. This means nail diameter = 0.4 x narrowest intramedullary width of bone. Radial and ulnar nails were generally the same size and shape. In some cases, a smaller ulnar nail can used than radial nail, depending on the child's anatomy (e.g., a 2.0 mm diameter ulnar nail and a 2.5 mm radial nail). Nails prepared for radius were contoured and bent to match the radial bow and to ensure restoration of the interosseous space. Contouring of nail is not required for ulna or only requires minimal pre bending of about 10° because the bone is almost straight. The nail tip curved or bended slightly 30° to 40° across a length of 3–4 mm at the metaphyseal diaphyseal junction, Because of its tapered tip, the nail resists bone penetration and canal wall contact during advancement Figure (4).

A B C D

Fig. 4: A, B, C, D, Elastic Nails contouring, and tip bending.

The radius approached first in retrograde fashion by performing a 1 to 2cm longitudinal incision on the lateral side of the distal metaphysis. The entry point is either just proximal to the radial styloid (just proximal to the physis on the radial border). An alternate point of entry in some cases was dorsally adjacent to Lister's tubercle. Figure (5).



A B

Fig. 5: Entry site for the radius A, Near Radial Styloid B, Near Listers tubercle.

Using fluoroscopic guidance, an awl is inserted close to the physeal line after soft tissue has been dissected to safeguard the superficial radial nerve's dorsal branch or extensor tendons, a hole is done first perpendicularly and then obliquely towards the elbow, making sure not to penetrate the other cortex Figure (6,7)**.** The nail was introduced and gently advanced with the help of the Universal Chuck with T-handle for more delicate control using the surgeon wrist rotator movement for advancing the nail proximally up to fracture site. Figure (8.9)**.**

Fig. (6): AWL insertion at the radius.

Fig. (7): Identification of Super. Radial Nerve.

Fig. (8): Elastic nail insertion in the radius using universal Chuck with T-handle.

(A) (B) (C) (D) (E) (F) (G) (H) (I)

Fig. (9): (A), (B), (C), (D), (E), (F) (G), (H), (I) Fluroscopic shots for the radial nail procedure sequences.

The nail is introduced and pushed with a hammer if necessary Figure (10)**.**

Fig. 10: Hammer used to push the nail.

At this stage, fracture reduced by performed traction, counter-traction and suitable manipulation. Once the fracture reduced, nail advanced forwards up to neck of radius, which confirmed under fluoroscopy Figure (9). If the fracture not reduced with attempts of closed reduction, a stab incision done over the fracture site and an artery forceps or blunt tip instrument put to reduce the fracture. If the fracture still not reduced, then mini-incision performed to open manipulate and reduce the fracture. The nail end was twisted and cut close to the bone leaving enough ends for easy removal later but without any tenting the skin cut end of nail should not protrude more than 5 to 6 mm from the bone) Figure (11,12).

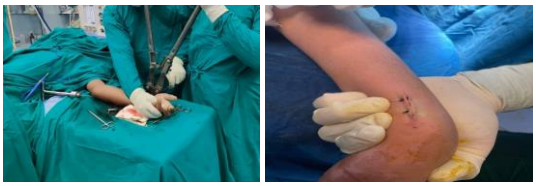


Fig. 11: Radial Nail tip twisting and cutting. Fig. (12): radial nail site of entry Wound Closure.

Ulna approached in antegrade fashion; Entry portal for ulna as made over dorsomedial aspect of proximal metaphyseal region (1 cm mini incision at the olecranon, distal to the growth plate). Alternate portal for the ulna by using lateral approach through the proximal metaphysis. The same procedure as the radius repeated advancing the nail to the distal ulnar epiphysis in antegrade fashion under C-arm control. Figure (13, 14, 15, 16, 17, 18).

Fig. (13): Entry site for the ulna.

Fig. (14): Awl insertion at ulna.

Fig. (15): Elastic nail insertion in the ulna using universal chuck with T-handle.

(A) (B) (C) (D) (E) (F) (G)

Fig. (16): (A), (B), (C), (D), (E), (F), (G), Fluroscopic shots for the ulnar nail procedure sequences.

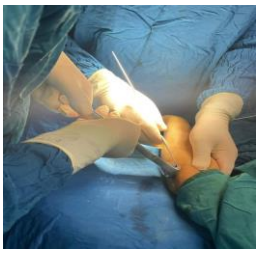


Fig. 17: Ulnar nail tip twisting and cutting

Fig. (18): Ulnar wound closure.

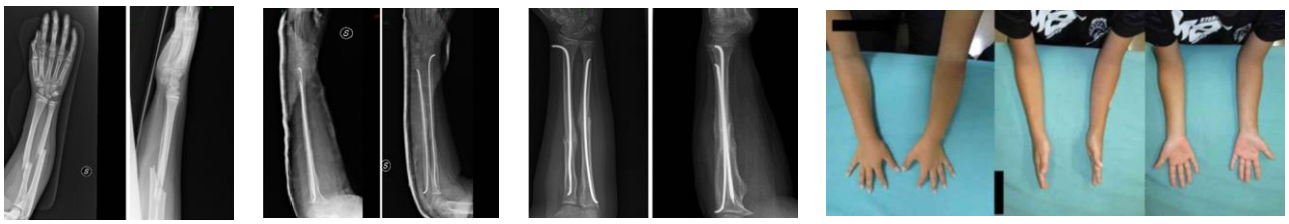
Checking free range of motion of the elbow and wrist done for all fractures at the end of the procedure by the surgeon, and intraoperative radiographs taken for confirmation of the reduction and pin placement. Finally, closure of the incisions over the entry portals or surgical incisions in standard fashion after copious irrigation, application of an above-elbow plaster slab done. The patient instructed to keep the limb elevated and the finger mobilization early in the postoperative period. Wound inspected & dressed on the second post-operative day.

Postoperative X ray including elbow and wrist joints in both AP and lateral view taken on second post-operative day. Post-operative immobilization used for few weeks postoperatively to support the limb, to decrease postoperative pain and to decrease soft tissue irritation at the entry points. Patient discharged in the second post-operative day if there is no complaint in matter. Analgesics is given to the patient as needed, IV antibiotics were given for 2 days post operatively if it was closed reduction and for 5 days if it was open reduction followed by oral antibiotics till suture removal. Stitches removed after 2 weeks of follow-up. Physiotherapy started as early as possible, Patient advised to perform shoulder and finger movements early in the next day after the operation. Above elbow slab applied for 2 – 3 weeks, then changed to below elbow slab or splint for another 3 weeks. Active and passive mobilization of elbow and wrist joint started early. However, weight lifting, other resistant type of activities, supination and pronation movements prohibited at least for 6 to 8 weeks after surgery. Followed by exercises to strengthen the forearm muscles, improve flexibility, and decrease stiffness. All patients followed-up after one, two, four, six, 12 weeks and 24 weeks from the date of discharge. Full assessment of clinical and radiological bone healing done in each follow up visit. Radiological assessment included full-length anteroposterior and lateral radiographs was done for alignment, quality of bone healing, and to measure limb-length discrepancy, any loss of reduction, and any implant related complications. Patients were assessed clinically for residual pain, range of motion, functional daily activities, limb-length discrepancy, and any rotational malalignment of the injured extremity. Final clinical and radiological results were evaluated using The Grading system of Price et al. The nails removed after clinical and radiological union (Table2). Patients informed at the time of surgery that they would need to attend hospital for a day for removal of the implant under general anaesthesia when the fractures united.

Table 2: Functional outcomes using Price et al. Criteria.

Outcome	Symptoms	Loss of rotation
Excellent	No complaint with strenuous activity	< 15°
Good	Mild complaint with strenuous activity	15° - 30°
Fair	Mild complaint with daily activities	31° - 90°
Poor	All other results	> 90

Preoperative and postoperative radiological & clinical follow up sequences Figure (19).



(A) (B) (C) (D)

Fig. (19): Preoperative and postoperative radiological & clinical follow up. (A) Preoperative, (B) at the 2nd week, (C) at the 6th week. (D) Range of motion (Supination & Pronation) at 12th weeks.

For data analysis, SPSS version 23.0 used to demonstrate percentage, mean and standard deviations. Chi-square test applied to compare the patient's age, type, site of the fracture and method of fixation, and bone union time.

RESULT

Forty one patients of both bone forearm diaphyseal fractures included in this study, 27 (66.4%) are males, 14 (33.6 %) are females, 16 (39.03%) patients are 10 years old or younger, while 25 (60.97 %) patients are older than 10 years. The mean age of patients was 10.67 years. Right forearm injured in 16 (39.03%) patients, while left forearm fractures occurred in 25 (60.97%) patients. (Table 3). In 33 patients, the operative procedure 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 performed after an average period of 5 – 10 days after injury.

Table 3: Demographic characteristics, Gender, age, side of the fractures.

Characteristics	Number of Patients	Percentage
Gender		
Male	27	66.4%
Female	14	33.6 %
Age		
Age ≤ 10 years	16	39.03%
Age > 10 years	25	60.97 %
Side		
Right	16	39.03%
Left	25	60.97 %

According to the mechanism of injury, sport related

injuries, accidental fall occurred in 26 (63.4 %) patients, fall from height occurred in 8 (19.5 %) patients, while road traffic accident is the cause of the fractures in 7 (17.1%) patients (Table 4).

Table 4: Mechanism of the injury.

Mechanism of injury	Number	Percentage %
Sport related activity / Fall	26	63.4 %
Fall from height	8	19.5 %
Road traffic accident	7	17.1%

Of the 41 patients included in this study, 37 (90.24%) patients suffered from closed fractures, while only 4 (9.75%) patients has type 1 or 2 open fractures (Table 5). According to the site of injury, 26 (63.41%) patients has fractures in the middle 3rd, 6 (14.6%) patients has fractures in the proximal 3rd, while 9 (21.9%) patients injured in the distal 3rd of the forearm bones. Concerning the pattern of the fractures, transverse fracture is noted in 23 (56.1%) patients, oblique fracture in 9 (21.95%) patients, Spiral fracture in 6 (14.63%) patients and comminuted fracture occurred in 3 (7.317%) patients.

Table 5: Types, site and patterns of the fractures.

Characteristics	Number of Patients	Percentage
Type of fracture		
Closed fracture	37	90.24%
Open fracture (type 1, 2)	4	9.75%
Site of fracture		
Proximal 3rd	6	14.6%
Middle 3rd	26	63.41%
Distal 3rd	9	21.9%
Pattern of the fracture		
Transverse	23	56.1%
Oblique	9	21.95%
Spiral	6	14.63%
Comminuted	3	7.317%

According to the elastic nail size, 2 mm elastic nail is used in 6 (14.63%) patient, 2.5 mm nails is used in 22 (53.6%) patients, 3 mm nails is used in 13 (31.70%) patients (Table 6).

Table (6): Nails diameter.

Nail diameter	Number	Percentage %
2 mm	6	14.63%
2.5 mm	22	53.6%
3 mm	13	31.70%

According the method of fixation, closed reduction technique is used in 33(80.5%) patients, mini – incision/forceps or other reduction tools assisted technique is used in 6 (14.63 %) patients due to the difficulty in reduction, open reduction techniques is used for 2 (4.87%) patients, those with failure of closed reduction, soft tissue interposition, and severe displacement (Table 7).

Table 7: Methods of Fixation.

Method of fixation	Number	Percentage %
Closed reduction	33	80.5%
Mini – incision / Forceps assisted reduction.	6	14.63 %
Open reduction	2	4.87 %

The union evaluated clinically and radiologically through the follow up visits, and defined clinically by painless limb movement and radiologically by the presence of a bridging callus on AP & lateral x- ray view.[21] The minimum time to union was 7 weeks while the maximum time to union was 14 weeks, with mean time to union was 9.2 weeks ±1.09 SD. The union time is mainly affected by age, site and type of fracture, Method of fixation as discussed in the tables **(**Table 8, 9, 10, 11)

Table (8): Association between union time and age.

Age	Number	Mean union time
Age ≤ 10 years	16	8.6 wks
Age > 10 years	25	9.8 wks

Table 9: Association between union time and type of the fracture.

Type of fracture	Number	Mean Union Time
Closed fracture	37	9.4 wks
Open fracture	4	10.8 wks

Table 10: Association between union time and Site of the fracture.

Site	Number	Mean Union Time
Proximal 3rd	6	10.3 wk
Middle 3rd	26	9.4 wks
Distal 3rd	9	8.1 wks

Table 11: Association between union time and method of fixation.

Method of fixation	Number	Mean Union Time
Closed reduction	30	9.6 wks
Mini – incision / Forceps assisted reduction	8	9.7 wks
Open reduction	3	10.3 wks

Functional outcomes is studied accourding to the Price et al. Criteria, excellent outcomes is recorded in 37 (90.3%) patiens, good outcomes occured in 3 (7.3 %) patients, fair outcomes is noted in 1(2.4 %) patiens. Poor results are not noted in this study (Table 12).

Table 12: Functional outcomes using Price et al. Criteria.

Outcome	Symptoms	Loss of rotation	Number	%
Excellent	No complaint with strenuous activity	< 15°	37	90.3%
Good	Mild complaint with strenuous activity	15° - 30°	3	7.3 %
Fair	Mild complaint with daily activities	31° - 90°	1	2.4 %
Poor	All other results	> 90	0	0 %

Excellent cases were significantly associated with younger age and shorter union time. Complicated cases were significantly associated with RTA, open fracture and Fair price score. Entry site skin irritation is most common complication recorded, occurred in two (4.87 %) patients. Superficial infection is noted in 2 (4.87 %) patients, which are managed by oral antibiotics and daily dressing and passed smoothly after that (Figure 20). Paresthesia, superficial radial nerve irritation is noted in 1 (2.43 %) patients, all of them are healed well and got better during the period of follow up, giving no long term sequalae. Migration of the nail tip recorded in one (2.43 %) patients, those are investigated for infection firstly and they have negative infection screen managed by daily dressing, and early nail removal after clinical and radiological union is observed. Olecranon bursitis occurred in one (2.43 %) patient, which are doing well after removal of the nail and bursectomy. Malunion, nonunion is not noted in this study. As well Neurovascular injury, compartment syndrome, refracture, significant limb length discrepancy, which are not recorded in this study (Table 13).

Table 13: Types of Complications.

Type of complication	Number	Percentage %
Entry site skin irritation	2	4.87 %
Entry site superficial infection	2	4.87 %
Parasthaesia / Superficial radial nerve irritation – injury	1	2.43 %
Migration of Nail tip	1	2.43 %
Olecranon Bursitis	1	2.43 %
Malunion, non-union	0	0 %

(A) (B)

Fig. 20: Types of complication. (A) Skin Irritation. (B) Superficial infection.

The patients included in this study followed up by regular visits for a mean time of 24 weeks .The mean operation time was 41.4 mints, ranged from 30 – 60 minutes. Mean fluoroscopic shoots used was 33.7 shots per operation. A meantime for hospital stay was 1.2 day; most of the cases discharged home in the next day after operation. Nail removal was performed on an average of 8 ± 2 months (range 5 - 12 months) following primary fixation as a day case procedure and was free of complication in all patients. In one patients, nails removed at 3-4 month due to superficial wound complication at nail entry site. There was retrograde migration of ulnar pin with skin penetration requiring acute removal after 4 month of surgery in only one patient. (Table 14)

Table 14: Mean age, Average Follow up period, Union time, Hospital stay, Operative time, Flouroscopic shots.

Number of patients	**41**
Mean age distribution	10.67 years
Mean follow up time	24 wks.
Mean union time	9.2 wks
Mean time for hospital stay	1.20 day
Mean operative time	41.4 Min.
Mean fluoroscopic shoots	33,78 shots
Average time for implant removal	8 month (range 5 – 12 month)

DISCUSSION

Restoring stability and early mobilization are the key steps in reducing malunion and provide full functional range of movements in pediatric both bone forearm fractures. Traditional method of treatment with closed reduction and casting of fixing both bone diaphyseal forearm fractures had its own fallacy such as failure of reduction, malunion, angulation and loss of function.[11] In studies conducted by *Thomas et al, Kay et al, Eric N. Bowman et al*, showed failure of reduction was 39%, 64% and 51% respectively and failure rates were more in

children more than 10 years of age as bone remodeling is less. Causes for these complications were complete displacement of fracture ends with no contact, angulations of more than 10 degrees and malrotation of more than 45 degrees.[12.13.14] *Shoemaker et al and Flynn et al* in their literatures have suggested that a reduction is unacceptable if the patient has an angular deformity >10° or complete displacement.[15] Rodriguez- Merchan in their literature clearly mentioned that rotational deformity does not remodel at all.[4] Because of that, a move toward increased surgical intervention for the treatment of pediatric forearm fractures has been advocated. The types of operative stabilization include plating and intramedullary nailing. Although plating ensures anatomical reduction and stable fixation, it has the disadvantages of exposing the fracture site, increasing the risk of nonunion, and being associated with a higher infection rate and risk of refractures. Since introduction of the ESIN, many authors have reported good results with titanium intramedullary nailing. According to Shoemaker et al, the ideal mode of fixation of pediatric forearm fractures should maintain alignment, be minimally invasive and inexpensive, and carry an acceptable risk profile, compared with open reduction and osteosynthesis with plate-screw fixation, intramedullary nailing meets these criteria.[15] The current study found that the mean age of patients was 10.67 years, with 60.97% of patients were older than 10 years old and 39.03 % of patients were 10 years old or younger, with a minimum of 5 years and a maximum of 15 years. Therefore, majority of patient were more than 10 years who need surgical intervention more frequently than those less than 10 years. Abdulkareem & Hwaizi found that the mean age of the 23 patients was 9.43 ± 3.23 years.[16] Mohammad Ruhullah et al. in their study had average age group 10.04 years.[17] Older mean age as observed by Vishwanath et al. the average age group was 11.25 years.[18] and Garg NK et al., (11.8 years).[19] In our current study 66.4% of the patients were boys and 33.6% were girls which is comparable to the study of Mohammad Ruhullah et al. which found that 65.8% boys and 34.2% girls,[17] Shivanna et al. study had 70.1% of boys and remaining 29.1% of girl[3], Vishwanath et al. the 70 % were boys 30% were girls.[18] Ifthekar et al. discovered that 78.12 percent (n=25) of patients were males.[5] Kapil Mani KC et al has mentioned that the incidence of fracture is higher in male children, because they are more aggressive and frequently engaged in the outdoor sports activities so they sustain fracture more frequently than the female children do.[20] The current study, reveal that the left side forearm more affected with 60.97 %, while right side 39.03%, which goes with the results found by Ifthekar et al. which found that the, majority of the patients in their study had fractures on the left side accounted for 62.5%.[5] Kapil Mani KC et al has mentioned that incidence of fracture is higher in left upper limb as compared to right side, because left hand is usually non-dominant, and used as protective function while patients is falling on the ground.[20] According to the mechanism of injury, the current study found that the most common mechanism of injury is a fracture with sport related activities or fall on the ground while walking or running, which occur in 63.4 % of patients, followed by Fall from height which occur in 19.5 % and road traffic accidents which occurs in 17.1%. The study of Ifthekar et al. found that regarding modes of injury, fall during play accounted for majority of the cases (81.25%,), road traffic accident accounted for 9.4% and fall from height accounting for 9.37%.[5] Kishorchand Naorem et al had 70% had accidental fall, 16.67% had RTA and 13.3% had fall from height.[21] The study done by Landin LA et al. on 8682 patients in majority of the patients the commonest mode of injury was fall on an outstretched hand. Other mode of injury was road traffic accidents.[22] In contrast, in the study of Tredwell SJ et al the commonest mode of injury was fall followed by Road traffic accident.[6] In our study, incidence of fracture is occurred in 63.4% in midshaft region of forearm, 14.6% in Proximal 3rd in and 21.9% in distal 3rd. Mohammad Ruhullah et al in their study, had 69.6% mid shaft fractures, 17.7% had proximal shaft fractures and 12.6% were distal shaft fractures.[17] It is thought that midshaft region of the forearm is commonly injured because of more angulatory force that comes in action, while patient falls on the ground. In our study closed reduction was achieved in 80.5% of patients while in 14.63 % of patients, reduction is done by blunt tipped instrument like artery forceps with mini incision. Open reduction was required in 4.87 % of patients especially those with delayed admission for surgical treatment because of soft tissue interposition. This is nearly comparable to Richter et al. research closed reduction 84%,[23] and Cullen et al. study closed reduction 75%.[9] In the study conducted by Cumming D et al., out of 19 patients they required to open the fracture in four cases as they were not able to achieve closed reduction before nail insertion.[24] Mohammad Ruhullah et al. in their study, had 90% closed reduction and 10% was through open reduction.[17] Shivanna et al. study had 82.2% had closed reduction and remaining were by open reduction.[3] In the study of EL Banna EG et al. they able to reduce all the cases by closed means and were able to pass intramedullary nail successfully.[25] Whereas Alam W et al. study closed reduction can be done in 72% of patients only.[26] We do not recommend the repeated failed closed reduction but rather to do with small mini-incision technique to reduce soft tissue insult. Yalcinkaya et al. concluded that closed reduction or open reduction with a mini incision yield similar functional results and a similar complication profile in the treatment of pediatric unstable diaphyseal forearm fractures.[27] Though we did not compare the results of open Vs close technique but results in both techniques were good to excellent. In current study, postoperatively above elbow POP slab was applied in all patients ranging from 2 – 3 weeks then converting to below elbow slap / splint for another 2 – 3 wks., depending upon callus formation evident radiographically. The mean duration of immobilization was 5.1 weeks in our case study. Abalo A et al. in their study also observed that casting was

required for the mean period of 6 weeks.[28] Whereas, Lascombes P et al. in their study on 85 forearm fractures in children treated using curved elastic nail after closed reduction, advised immediate mobilization after operative procedure.[29] Qidwai et al in their study did not advise the use of posterior slab for early mobilization.[30] The current study showed that the mean time of union was 9.2 weeks with minimum 7 and maximum 14 weeks. This is in agreement with the study of Ifthekar et al. who found that mean duration of union was 9.5 ± 1.3 weeks ranging from 8 to 12 weeks,[5] and comparable to study done by Ruhullah M et, al. (mean time for union 9 week),[17] Kapilla R (mean time of union 9.2 week)[31] and Ali AM (mean time for union 10 weeks)[32], Kumar et al found that the average time for union was nine weeks.[33] In contrast Garg et al. observed clinical and radiological union within 13 weeks after the procedure mainly because of older age group taken by this study.[19] whereas the study done by Kapoor et al. on forearm fractures in children treated with elastic stable intramedullary nails found that the average time for union of fractures was seven weeks, because of younger age group taken by their study.[8] In current study, union time is less in children less than 10 years with mean of 8.6 wks, while union time is more in patients more than 10 years with mean of 9.8 weeks, which goes with the study done by Pugh et al which mentioned that fracture union time is longer in children more than 10 years by 2 weeks or more as compared to children less than 10years with 8.4 and 6.4 weeks respectively.[34] Similarly Altay M et al. demonstrated the union time 7.8 and 6.3 weeks in children more than or less than 10 years respectively.[7] For assessment of final functional outcome we used Price et al criteria, and obtained excellent result in majority of the patients (90.3%) and good results were obtained in 7.3 % of patients and 2.4 % fair outcome, which occur in one patients suffering from open fracture and aged more than 10 years, no poor outcomes is occurred in this study. This results of outcomes is nearly comparable with the study *of* Richter D et al. done on 30 patients of forearm fracture treated with Titanium elastic nail, excellent functional outcome was observed in 80%, good in 16.6% and fair in 3.3% of the children.[23] Which near to the study of Sahu et al. reported that 35 (87.5%) showed excellent results, 4 patients (10%) showed good results, and one patient (2.5%) showed fair result.[35] Also Ifthekar et al. found that in 90.63% patients, excellent functional results were achieved and good functional results were achieved in 9.37% of patients.[5] A series of 50 patients treated by Parajuli NP et al the outcomes according to Price criteria were excellent in 94 %, good in %6 and no poor results were encountered.[16] Kapilla R et al., in which 92% patients had excellent results and 8% had good results.[31] In contrast Ameen et al. discovered that 8 of the patients (66.7 percent) were categorized as excellent, while 4 of the patients (33.3 percent) were classified as good and no one was classified as fair or poor.[36] The procedure of inserting intramedullary nails is not without the possibility of complication. In our study, we noticed an overall complication rate of 17.3%, Out of 41 patients, two patients had superficial skin infection and two patients Entry site skin irritation, one patients for each of Superficial radial nerve irritation – injury, Migration of Nail tip, Olecranon Bursitis respectively. The complication rates in this study are nearly similar to a study done by Flynn JM et al[37], where the overall complication rates were 14.6%. *Cumming D et* al in a study done on the use of elastic intramedullary nails, reported a complication rate of 16%.13 The common complications occured in the above series were skin irritation by hard ware, superficial skin infection, delayed union, migration of nail tip.[24] Yalcinkaya et al. found a complication rate of 4-38%, The most common complication occurring in their series were delayed union, compartment syndrome, infection, skin irritation by hard ware and pin back out.[27] The study of Ifthekar et al. found that the overall complication rate reported in patients was 12.5%. Out of 32 patients, two patients had surgical site infection and two patients had nail impingement.[5] Among the 31 patients studied by *Acharya et al.,* five experienced minor problems, such as skin irritation around the conspicuous ulnar nail superficial nail insertion site infection, and backing out of the ulnar nail necessitating early removal of the nail.[38] Current study complication profile is also comparable to the complication rate reported by Ruhullah M et al.[17] Lascombes et al.[29] and Parajuli NP et al.[10] The most common complication occurring in thier studies were superficial infection and skin irritation by hard ware. Entry site superficial infection is recorded in two patients in this study, which are managed by oral antibiotics and daily dressing and passed smoothly without leading to deep infection or osteomyelitis. Prominent implant with skin irritation was noted in two patients. In this study, all the nails buried under the skin leaving the tip 4-5 mm out of cortex for later ease of removal**.** Kelly et al. Found no significant difference between buried and exposed intramedullary implants after fixation of pediatric forearm fractures.[39] Temporary hypoesthesia in the area of superficial radial nerve as found in one patients. We consider this nerve injury as a traction based neuropraxia, which resolves with time. Lyman et al encountered three cases of superficial radial nerve palsy among 86 titanium elastic nailed patients.[2] We did not get compartment syndrome, radioulnar synostosis, nonunion & refracture as complication in this series. In contrast, Fernandez et al. in one of the biggest published cohorts of 553 children, treated with ESIN for forearm fractures, reported a rate of complication of 14.64% mostly refractures (4.88%), followed by delayed union and radial nerve injury.[40] Makki et al. reported a total complication rate of 11.8%, with 5.88% reoperations in children because of refracture.[41] In this study the implants were not removed until the fracture is completely united clinically and radiologically, and the fracture line was no longer visible radiologically, with presence of good homogeneous callus. The average time for implant removal in this study was 8 months ranging from 5 to 12

months, this is going with the Hahn MP et.al literature that recommends not removing the implant before 3 - 5 months after operation.[42]

CONCLUSIONS AND RECOMMENDATIONS

Intramedullary fixation by Elastic intramedullary nails is successful treatment option because it is simple, safe and minimally invasive procedure. It provides many biological and mechanical advantages having low and manageable complications, and excellent clinical outcomes. This study is not without limitations. The results have been much validated if it were a comparative study and a larger sample size.

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