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Intramedullary Elastic Nailing Management for Fracture of Forearm Bones in Pediatric Patients

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ABSTRACT

Background: Forearm fractures are the third most prevalent in children, accounting for 40% of all fractures in children. Using titanium elastic nailing techniques to fix both fractures of the forearm revealed a lot of benefits.

Objective: This study aimed to determine if elastic nail fracture treatment improves the radiological and clinical outcomes in children. **Patients and methods:** 18 patients with fracture shafts of both bones forearm treated with intramedullary elastic nails were studied in Zagazig University Hospital and Sebha medical centre, Sebha, Libya for this prospective clinical trial. Patients returned for follow up visits nearly every 2 weeks following fixation for removal of suture. Then Serial radiographs were made after 2 weeks, 4 weeks, 6 weeks and 12 weeks after surgery. They were evaluated for callus formation and assessment of range of motion and any complications till complete bone healing.

Results: Between 8 and 14 weeks, the average time for union was 10.38 ±1.72 weeks. According to the Price score majority were excellent 77.8%, then good 16.7% and finally fair 5.6%, Only 2 cases 11.1% had complication (Surgical site infection, superficial radial nerve injury, and re-displacement). Complicated cases were significantly associated with road traffic accident and Fair price score. Excellent cases were significantly associated with younger age and shorter union time. **Conclusion:** For the treatment of displaced forearm fractures, Elastic Stable Intramedullary Nailing (ESIN) is a safe and effective option for young patients. Effective and definitive therapy of these fractures is still achievable with this less invasive approach. A functional outcome was attained without the need for corrective treatments, angulations, or repeated reductions.

Keywords: Elastic stable intramedullary nailing, Forearm fractures, Pediatric.

INTRODUCTION

Forearm fractures are the third most prevalent in children and account for 40% of all children fractures [(1)]. Due to the unique growing potential of young bones, closed reduction and plaster cast application has been the gold standard in treating these fractures. However, in older children, re-displacement is more likely to lead to angulation, rotation and shortening [(2)].

Treatment of distal radius and forearm fractures aimed at facilitating the union of the fracture at a position that restores elbow and forearm function [(3)]. For angulation, malrotation, and displacement, surgical surgery has been indicated in earlier studies [(4)]. Open reduction and plate osteosynthesis and closed reduction and internal fixation with titanium elastic nails are the most prevalent surgical procedures. Both bone forearm fractures in children were first described by **Metaizeau and Ligier** [(5)] who used elastic intramedullary nails.

Proponents of using flexible nails to treat forearm fractures argue that doing so reduces surgical dissection and keeps biologic components in place where the fracture occurs [(6)]. Smaller incision, minimum soft tissue interference, rapid osseous healing and maximal range of motion were just some of the advantages of titanium elastic nailing methods for the repair of both forearm fractures. Also, complication rate was reduced. When both bones of the forearm are fractured, intramedullary titanium elastic nailing is a viable treatment option in the pediatric population. When the implant protrudes out of the skin, oral antibiotics can be used to treat the infection. By burying the implant a little deeper under the skin, this problem was prevented implant failure , non-union, malunion, or osteomyelitis, may also lead to problems such compartment syndrome [(7)].

Elastic nails were used to treat children with fractures of both bones in the forearm, and this study was designed to examine the radiological and clinical outcomes.

SUBJECTS AND METHODS

This prospective clinical trial was conducted on 18 patients. Intramedullary elastic nailing was used to heal fractures of the forearm bone shafts in Zagazig University Hospital & Sebha medical center in Sebha, Libya.

Inclusion criteria: Compound forearm fracture (grade one or two) or displaced diaphyseal fracture in children aged 5 to 15 years.

Exclusion criteria: Patients more than 15 years or less than 5 years of age, with pathological fractures, malunion, nonunion or unfit for surgery all have been excluded from the trial.

Ethical approval:

All participants signed informed consent forms and the study was approved by Zagazig University' Research Ethics Committee (ZU-IRB#6235). We followed the World Medical Association's ethical code for human experimentation, the Helsinki Declaration.

All participants in this research were subjected to the following:

History and clinical examination: The patient's age, gender and mechanism and time of injury were all recorded in a thorough medical history. Medical history,

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medications, and general assessment of the patient were all taken into consideration for the presence of systemic or other orthopedic ailments.

Radiological evaluation: As part of the diagnostic process, an x-ray of any sore area and plain AP/Lateral views of the forearm (from the elbow to the wrist joint) have been performed in order to detect any related fractures.

Laboratory evaluation: Complete blood picture, liver & kidney function tests, blood sugar, as well as virology markers.

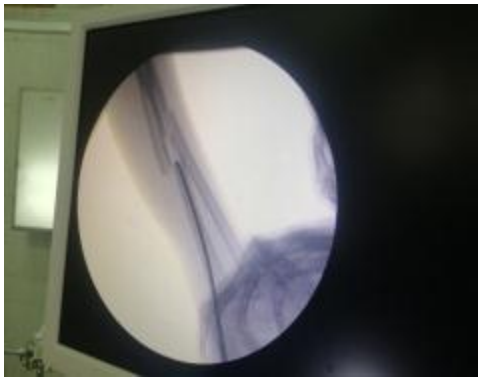
Operative technique: All patients received general anesthesia. Broad spectrum prophylactic intravenous antibiotic (3rd generation cephalosporin) was given for patients with simple fracture within half an hour before surgery.

The steps of procedure: Draping was performed in sterile settings. On the x-ray, the diameter of the narrowest point of the medullary canal was used to determine the nail's size. The diameter of the one nail must be 40% of the diameter of the smallest canal. "0.40 x diameter of the medullary canal = nail size." Radial and ulnar nails were generally the same size and shape. In some cases, a smaller ulnar nail can be utilised than a radial nail, depending on the child's anatomy (e.g., a 2.0 mm diameter ulnar nail and a 2.5 mm radial nail). During progress, the nail's tapered tip protects against bone penetration and catching on the canal walls. At the metaphyseal/diaphyseal junction, the nail tip was bent slightly (30–40°) across a length of 3–4 mm at its leading end, so as to gently "take the turn." It is possible to access the radius in two ways: first, by performing a 1- to 2-cm-long longitudinal micro incision on the distal lateral radius, which is performed over the radial styloid between the first and second flexor compartments. After dissection of soft tissue to protect the dorsal branch of the superficial radial nerve, the awl is inserted proximal to the physeal line under fluoroscopic guidance.

Then an appropriate size flexible intramedullary nail is introduced. Nail diameters range from 2.0 mm to 3.0 mm on average, depending on the child's bone structure and other factors. The lighter weight universal chuck with T-handle in place of the inserter allowed for more sensitive control of the nail as it was introduced and advanced. After fracture reduction by gentle manipulation, the nail is inserted into the proximal metaphysis and anchored in place. The nail's distal end was twisted and sliced 5-10 millimeters away from the bone after that. Open reduction would be attempted if the closed method failed. The fracture site is punctured with a tiny skin incision. Proximal lateral to the olecranon, the skin was incised 1.5 to 2 cm longitudinally, roughly 3 cm distal to the apophysis, antegrade from the lateral cortex. To make an incision, an awl was directed distally, 3 cm distal to the apophysis and immediately before the posterior border, or about 4 mm laterally to the posterior crest of olecranon. A T-handle was used to implant the nail, and mild oscillating movements were used to advance it distally to the fracture site. Closure of the access points and placement of an above-elbow plaster slab are the final steps.

Patient assessment and postoperative follow up:

Patients return for follow up visits nearly every 2 weeks following fixation for removal of suture. Then Serial radiographs were made after 2, 4, 6 and 12 weeks after surgery were evaluated for callus formation and assessment of range of motion and any complications till complete bone healing. The **Price *et al.*** [8] criteria were used to evaluate patients at the end of the follow-up period**.**



(A)

(B)

Figure (1): (A) Incision at the distal end of radius, the entry point. (B) Introducing the elastic nail

Statistical analysis

In order to analyze the data acquired, it was loaded into a computer and run via the Statistical Package of Social Services, version 25 (SPSS). Tables and graphs were used to present the findings. The Shapiro–Wilk test was used to examine the distribution properties of variables as well as the homogeneity of variance. The quantitative data were reported in the form of the mean, median, standard deviation, and confidence interval. The frequency and proportions of qualitative data were used to present the information. For quantitative independent data, the student's t test (T) and the Mann-Whitney test (MW) were employed to examine the data as needed. To examine qualitatively independent data, researchers employed the Pearson Chi-Square test and the Chi-Square for Linear Trend (χ^2). P value equals or less than 0.05 was considered significant.

RESULTS

The average age was 11.66 ± 3.04, with a range of 5 to 15 years. Most of them (12 cases) were above age of 10 years. Regarding sex distribution, male was majority with 77.8% and females were 22.2% (Table 1).

The right side was the major side with 66.7% and left 33.3%. Regarding mode of injury, FD was majority with 66.7%, and DT & RTA 16.7% each (Table 2).

Time to union was distributed with minimum 8 weeks and maximum 14 weeks. Most of them (55.56%) achieved full union at 10 weeks or earlier (Table 3).

As regards Price score, the majority were excellent 77.8%, then good 16.7% and finally fair 5.6% (Table 4).

16 patients (88.9%) had no complications, while two patients (11.1%) had complications. Both of them had SSI, but one of them had superficial radial nerve injury and the other had redisplacment of the fracture after fixation along with superficial skin infection (Table 5).

Complicated cases were significantly associated with RTA and Fair price score (Table 6).

Excellent cases were significantly associated with younger age and shorter union time (Table 7).

Table (1): Distribution of sexes and ages in the study group (N=18)

		Age	
Mean ± SD		**11.66 ± 3.04**	
Median (Range)		**13.0 (5-15)**	
		N	**%**
Sex	**Female**	**4**	**22.2**
	Male	**14**	**77.8**
	Total	**18**	**100.0**

Table (2): Injury characters distribution among studied group (N=18)

		N	%
Side	**Left**	**6**	**33.3**
	Right	**12**	**66.7**
Mode of Injury	**DT**	**3**	**16.7**
	FD	**12**	**66.7**
	RTA	**3**	**16.7**
	Total	**18**	**100.0**

DT: Direct trauma, FD : Fall down, RTA: road traffic accident

Table (3): Time to union distribution among studied group (N=18

	Time to Union/ weeks
Mean ± SD	**10.38 ± 1.72**
Median (Range)	**10.0 (8-14)**

Table (4): Price score distribution among studied group (N=18)

		N	%
Price score	**Excellent**	**14**	**77.8**
	Good	**3**	**16.7**
	Fair	**1**	**5.6**
	Total	**18**	**100.0**

Table (5): Complication distribution among studied group (N=18)

		N	%
Complication	**NO**	**16**	**88.9**
	SRNI	**1**	**5.55**
	SSI	**2**	**11.1**
	Re-displacement	**1**	**5.55**
	Total	**18**	**100.0**

Table (6): Relation with complication (N=18)

			No	Complicated	t/ X^2	P
Age			**11.68±2.98**	**11.50±3.85**	**0.080**	**0.938**
Time to Union			**10.31±1.66**	**11.00±2.82**	**0.521**	**0.609**
Sex	**Female**	**N**	**3**	**1**		
		%	**18.8%**	**50.0%**		
	Male	**N**	**13**	**1**	**1.0**	**0.31**
		%	**81.2%**	**50.0%**		
Side	**Left**	**N**	**6**	**0**		
		%	**37.5%**	**0.0%**		
	Right	**N**	**10**	**2**	**1.12**	**0.28**
		%	**62.5%**	**100.0%**		
Mode of Injury	**DT**	**N**	**3**	**0**		
		%	**18.8%**	**0.0%**		
	FD	**N**	**12**	**0**	**11.25**	**0.004***
		%	**75.0%**	**0.0%**		
	RTA	**N**	**1**	**2**		
		%	**6.2%**	**100.0%**		
Price score	**Excellent**	**N**	**13**	**1**		
		%	**81.2%**	**50.0%**		
	Good	**N**	**3**	**0**	**8.59**	**0.014***
		%	**18.8%**	**0.0%**		
	Fair	**N**	**0**	**1**		
		%	**0.0%**	**50.0%**		
Total		**N**	**16**	**2**		
		%	**100.0%**	**100.0%**		

Table (7): Excellent cases relation with complication

			Excellent	Good and fair	t/ X^2	P
Age			**11.13±3.06**	**14.33±0.57**	**3.724**	**0.002***
Time to Union			**10.0±1.41**	**12.33±2.08**	**2.437**	**0.027***
Sex	**Female**	**N**	**3**	**1**		
		%	**20.0%**	**33.3%**		
	Male	**N**	**12**	**2**	**0.25**	**0.61**
		%	**80.0%**	**66.7%**		
Side	**Left**	**N**	**5**	**1**		
		%	**33.3%**	**33.3%**		
	Right	**N**	**10**	**2**	**0.0**	**1.0**
		%	**66.7%**	**66.7%**		
Mode of Injury	**DT**	**N**	**3**	**0**		
		%	**20.0%**	**0.0%**		
	FD	**N**	**10**	**2**	**1.2**	**0.54**
		%	**66.7%**	**66.7%**		
	RTA	**N**	**2**	**1**		
		%	**13.3%**	**33.3%**		
Total		**N**	**15**	**3**		
		%	**100.0%**	**100.0%**		

(A) **(B)**

Figure (2): (A) Preoperative x-ray (AP & LAT) RT forearm, **(B)** AP & LAT x-ray 6-week postoperative a six-years old boy presented to orthopedic casualty with history of fall down which led to midshaft fracture of both bone of right forearm. The patient was operated at the same day and was fixed by elastic stable intramedullary nail. The fracture was completely united within 6 weeks and the final outcome was excellent according to Price score.

DISCUSSION

The shafts of the radius and ulna are among the most common causes of orthopaedic care for youngsters. Using a proper closed reduction and successful plaster cast immobilisation, particularly in children under the age of 10, is a favourable treatment choice, according to the research [(9)].

It is impossible to fully utilize one's hand without regaining full pronation and supination function after treating radius and ulna fracture shafts. There is a higher risk of redistribution with conservative treatment, which leads to a higher probability of failure. Open reduction with plate fixation or intramedullary nailing is the two most common surgical options for fractures of the forearm bones. Forearm fractures treated with intramedullary nailing instead of compression plating are less invasive, take less time to operate on, have better cosmetic results, need less soft tissue dissection, are easier to remove the hardware from, and allow for early motion [(10)].

It is noteworthy that ESIN is an excellent implant for reduction and fixation that cannot totally replace manual reduction. 93.3 percent of children's forearm fractures can be adequately treated with cast fixation alone, according to large-scale clinical case studies [(11)].

The current study found that the mean age was 11.66 ± 3.04 years with a minimum of 5 years and a maximum of 15 years, and that 78.1 percent of the participants were males and 22.2 percent were females. **Ifthekar *et al.*** [(9)] discovered that 78.12 percent (n=25) of patients were males, which is in agreement with our findings. There was a 3.6:1 male to female ratio.

For Titanium elastic nail, **Abdulkareem & Hwaizi** [(12)] found that the mean age of the 23 patients was 9.43 ± 3.23 years.

The current study showed that the right were the major side with 66.7% and left 33.3%. Regarding mode of injury FD was majority with 66.7%, and DT & RTA 16.7% each, which is in agreement with the study of **Ifthekar *et al.*** [(9)] who found that regarding modes of injury, fall during play accounted for majority of the cases (81.25%, n=26), road traffic accident accounted for 9.4% (n=3), and fall from height accounting for 9.37% (n=3). In contrast, majority of the patients in their study had fractures on the left side accounted for 62.5% (n=20).

The current study showed that the mean time of union was 10.38 ± 1.72 weeks with minimum 8 and maximum 14 weeks. This is in agreement with the study of **Ifthekar *et al.*** [(9)] who found that mean duration of union was 9.5 ± 1.3 weeks ranging from 8 to 12 weeks. Similarly, **Garg *et al.*** [(13)] observed clinical and radiological union within 13 weeks after the procedure in 19 of 20 patients. They also found that the average time for union was nine weeks by **Kumar *et al.*** [(14)].

Current study showed that according to **Price score** majority were excellent 77.8%, then good 16.7% and finally fair 5.6%, which is near to the study of **Sahu *et al.*** [(15)] reported that 35 (87.5%) showed excellent results, 4 patients (10%) showed good results, and one patient (2.5%) showed fair result. Also **Ifthekar *et al.*** [(9)] found that in 90.63% (n=29) patients, excellent functional results were achieved and good functional results were achieved in 9.37% (n=3) patients

Using the Price *et al.* criteria, **Kumar *et al.*** [(14)] found that 57 (95 percent) of the patients had outstanding outcomes and the others had good outcomes.

At the end of the follow-up period, **Ameen *et al.*** [(16)] 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.

The current study showed that only 2 cases (11.1%) had complication (SSI), which is in agreement with the study of **Ifthekar *et al.* [9]**, who 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. A superficial infection developed in three of the seven patients (11.66 percent) who had problems, according to **Kumar *et al.* [14].** Aside from these two patients, the other four all experienced implant-related entry portal discomfort that was alleviated only by removing the implant in question. Among the 31 patients studied by **Acharya *et al.* [17]**, five experienced minor problems, such as skin irritation around the conspicuous ulnar nail (n = 2), superficial nail insertion site infection (n = 2), and backing out of the ulnar nail (n =1), necessitating early removal of the nail. Patients with ulnar entry site infection were treated with oral antibiotics **[7].** To avoid this problem, the implant was buried further under the skin in successful cases. Our investigation found no further problems, such as non-union, malunion, bone infection, compartment syndrome, as well as implant failure. **Fernandez *et al.* [18]** 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. **Makki *et al.* [19]** reported a total complication rate of 11.8%, with 5.88% reoperations in children because of refracture. In most of the published reports, refracture represents the most common complication, or after implant removal, with ESIN in situ. As forearm fractures are known to be more susceptible to refracture in children, and intramedullary forearm fixation removal has been often reported in the literature, this is not surprising **[19, 20].**

The current study showed that complicated cases were significantly associated with RTA and Fair price score and excellent cases were significantly associated with younger age and shorter union time. **Ameen *et al.* [16]** found that there were no statistical significant differences between cases that had good outcome and cases that had excellent in age.

Intramedullary nailing has been shown to be superior to plating in the treatment of fractures of the forearm in children, according to numerous studies. Implantation of intramedullary nails aids in early union, reduces infection risks, and eliminates the need for lengthy incisions required to remove plates. Kirschner wire fixation of these intramedullary fractures also had many drawbacks, including penetration of the k-wire, infection at the pin sites, restricted movement in the forearm, and a delay in union **[6]**. **Ameen *et al.* [16]** found that pin tract infection occurred in 3/12 (25%) patients. All patients with complications had excellent results. There were no statistical significant differences between cases had good outcome and cases had excellent in frequency of complications. Also there were no statistical significance differences between cases had good outcome and cases had excellent in mechanism of trauma.

Conclusion:

Both forearm fractures were successfully fixed using elastic nailing techniques, which give three bony points of fixation to ensure bone alignment. In addition to making it easier to insert, flexibility allows for greater micromotion at the fracture site, which aids in the production of callus. In addition to having low problems and great results in terms of radiological union, clinical and functional outcomes, these rigid intramedullary devices, such as k-wire, Steinmann pin and rush nail, have additional advantages. Consequently, this treatment should be used to treat displaced and irreducible forearm fractures in children under the age of 12. When both bones of the forearm are fractured, intramedullary titanium elastic nailing is a viable treatment option in the pediatric population. Children as young as three years old can use the ESIN to repair misplaced forearm fractures, according to these findings. Primary definitive therapy of these fractures is still possible with this minimally invasive approach. We didn't see a need for more reductions, angulation, or other remedial treatments, thus we got great outcomes. The same parameters need to be studied in a bigger sample size and for a longer period of time in comparative multicenter investigations.

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