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Surgical Management of Fracture Both Bone Forearm in Pediatric Using Elastic Stable Intramedullary Nail

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ABSTRACT

Background: In children, forearm fractures are among the most prevalent types of fractures Operative procedures such as, pinning with K-wires, plate osteosynthesis as well as elastic-stable intramedullary nailing (ESIN) are necessary for these fractures.

Objective: This study aimed to assess treating and outcomes of pediatric forearm fractures with elastic stable intramedullary nailing (ESIN).

Patients and methods: At Orthopedic Departments of Zagazig University Hospital and Tripoli University Hospital, 8 skeletally immature patients with diaphyseal forearm fractures were studied in prospective cohort research. The study was carried out from November 2020 to May 2021. Pre-operative X-ray and CT were done and the patient was prepared for surgery. Elastic-stable intramedullary nailing technique was done to all patients, all patients were regularly followed clinically and radiographically for 1 week and then 2, 4, 6, 12 week after end of surgery.

Results: we found that all patients progressed to union without the need for any further surgical intervention with good functional outcome as regards forearm rotation. One case had residual radius angulation more than 20 degree, no case had residual ulna angulation, 2 cases had superficial infection, 1 case had superficial radial nerve palsy and 1 case had elbow joint stiffness.

Conclusion: Intramedullary fixation by flexible intramedullary nails (ESIN) is successful treatment option and recommended for pediatric patients with 4-14 years of age or older because it is simple safe and minimally invasive procedure and effective method of treatment that provides many biological and mechanical advantages.

Keywords: Fracture both bone forearm, Elastic stable intramedullary nail.

INTRODUCTION

Fractures of the forearms are the most prevalent among children. Treatment procedures are most suited to the patient's age and level of skeletal maturity, which influence how much deformity is tolerated [(1)]. Three to six percent of all fractures in children are radial and ulnar shaft fractures. The distal third of the radius and ulna shafts account for 75% of fractures, 15% of the middle third, and 5% of the proximal third. The remaining 5% could be of complex injuries as well as Monteggia fracture dislocations [(2)].

It is not uncommon to see a toddler with a fractured forearm, compared to an adult. Fractures result in a periosteum that is thicker and less easily torn [(3)]. There are more cancellous bones while smaller medullary canals around the epiphysis of long bones in children compared to the epiphysis in adults. In children, torsional as well as greenstick fractures are prevalent. Anatomical alignment isn't usually important because of a child's ability to repair their bones, therefore open reduction is infrequently necessary [(4)]. For children with stable and only slightly displaced forearm fractures, conservative treatment is the most common method of care [(5)]. Operative therapies such as, pinning of the fracture by K-wires, plate osteosynthesis as well as elastically stable intramedullary nailing are required for some forearm fractures (ESIN) [(6)]. The interosseous membrane acts as an additional support for the fracture [(7)]. Fracture callus development is encouraged by this type of stability. When comparing ESIN to other treatment options, early forearm mobilisation and reduced procedure invasiveness are the two biggest advantages [(8)]. A three- to four-week period of postoperative immobilisation using a back slap above the elbow. With 3 weeks, the quantity of callus formation is comparable to the amount of callus formation that occurs after conservative treatment [(9)].

Treating pediatric forearm fractures with elastic stable intramedullary nailing (ESIN) with assessment of the outcomes are the goals of this study.

PATIENTS AND METHODS

At Orthopedic Departments of Zagazig University Hospital and Tripoli University Hospital where 8 skeletally immature patients with diaphyseal forearm fractures were incorporated in prospective cohort research. The study was carried out from November 2020 to May 2021.

Ethical approval:

All participants signed informed consent forms that were submitted them to Zagazig University's Research Ethics Committee and the study was allowed (ZU-IRB#6057). We followed the World Medical Association's ethical code for human experimentation (The Helsinki Declaration).

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Inclusion criteria: Simple diaphyseal forearm fracture from both sexes, aged from 4-14 years old, with closed fractures.

Exclusion criteria: Open fractures, comminuted fractures, pathological fractures, and Monteggia as well as Galeazzi fractures.

All patients were subjected to the following:

1. History taking and detailed orthopedic examination and clinical evaluation.
2. After primary stabilization of the patient:
   Plain X-ray films with an anteroposterior view and Lateral view radiographs of the entire forearm. Then above elbow POP slab was applied for all patients.
3. All patients had full preoperative lab investigation before surgery including:
   complete blood picture, random blood sugar, viral screen, coagulation studies (PT/PTT) as well as kidney and liver function tests.
4. **Surgical 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. Nail size was determined using the diameter of the narrowest point in the medullary canal on an x-ray. Nail diameter must be 40% larger than the smallest canal's diameter. “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 utilized 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). Because of its tapered tip, the nail resists bone penetration and canal wall contact during advancement. There, the nail tip was curved slightly (30–40°) across a length of 3–4 mm at the metaphyseal/diaphyseal junction, so as to softly "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. 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. 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. In order to stabilize the nail in place, moderate manipulation is used to reduce the fracture. A few millimeters from the bone, the distal end of the nail was twisted and cut. 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.

Figure (1): Insertion of the nail.

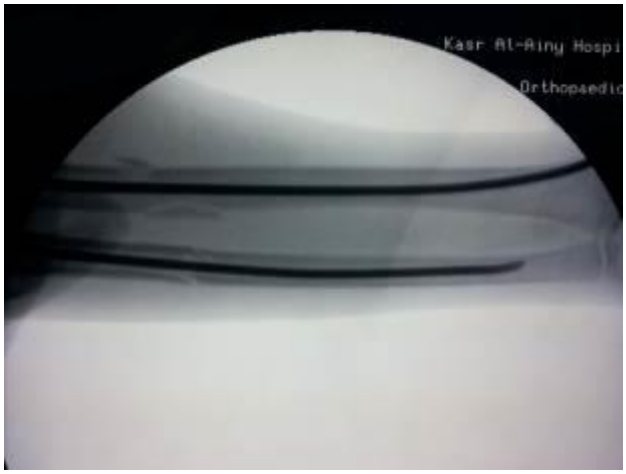

Figure (2): Final positioning of nail.

Statistical analysis:

In order to analyze the data acquired, the data were 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 was 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

Age was distributed as 9.33 ± 2.97 years ranging from 5 to 15 years old, with 61.1% being males and 38.9% being females (7 patients) **(Table 1).**

Union time was distributed as 8.61 ± 1.50 weeks with minimum 7 and maximum 12 weeks. Regarding VAS it was distributed as 2.44 ± 1.38 **(Table 2).**

Time of surgery was after 27.55 ± 8.93 hours with minimum 18 and maximum 48 H. As regards Operation duration, it was distributed as 53.05 ± 10.72 minutes and hospital stay were 3.33 ± 1.02 days, and main reduction type was closed with 88.9% and open 11.1%. The majority of postoperative range of motion (ROM) were excellent at all patients then good and fair. According to Mayo score, which tasted 4 subscales (pain, ROM, stability and daily function), excellent were the majority followed by good then fair **(Tables 3, 4).**

One case had residual radius angulation more than 20 degree, no case had residual ulna angulation, 2 cases had superficial infection, 1 case had superficial radial nerve palsy and 1 case had elbow joint stiffness **(Table 5).**

Fair outcome was significantly associated with older age, longer time till operation, longer hospital stays and longer union time. Also, it was significantly associated with assault, open reduction, residual radius angulation, superficial radial nerve palsy and joint stiffness **(Table 6).**

Table (1): The study group's age and sex composition

		Age (years)	
Mean ± SD		9.33 ± 2.97	
Median (Range)		8.50 (5-15)	
		N	%
Sex	Male	11	61.1
	Female	7	38.9
	Total	18	100.0

Table (2): Distribution of union time and VAS scores among the test subjects

	Union time (Weeks)	VAS
Mean ± SD	8.61 ± 1.50	2.44 ± 1.38
Median (Range)	8.0 (7-12)	2.0 (1-6)

Table (3): Movement assessment distribution among studied group

		N	%
Supination	Fair	2	11.1
	Good	5	27.7
	Excellent	11	61.1
Pronation	Fair	2	11.1
	Good	5	27.7
	Excellent	11	61.1
Elbow movement	Fair	3	16.6
	Good	6	33.3
	Excellent	9	50.0
Wrist movement	Fair	2	11.1
	Good	6	33.3
	Excellent	10	55.6
	Total	18	100.0

Table (4): The Mayo Clinic Outcome Score distribution in the research sample

		Mayo score	
Mean ± SD		87.27 ± 9.63	
Median (Range)		90.0 (68-98)	
		N	%
Mayo	Fair	3	16.7
	Good	5	27.8
	Excellent	10	50.5
Stewart and Hundley	Fair	2	11.1
	Good	6	33.3
	Excellent	10	50.5
	Total	18	100.0

Table (5): Complication distribution among studied group

		N	%
Residual radius angulation	-VE	17	94.4
	+VE	1	5.5
Residual ulna angulation	-VE	18	100
	+VE	0	0
Superficial infection	-VE	16	88.8
	+VE	2	11.1
Superficial radial nerve palsy	-VE	17	94.4
	+VE	1	5.5
Elbow joint stiffness	-VE	17	94.4
	+VE	1	5.5
	Total	18	100.0

Table (6): Relation with outcome

			Excellent & good	Fair	t/ X^2	P
Age			8.66±2.52	12.66±3.21	2.412	0.028*
Time of surgery /H			24.80±6.53	41.33±6.11	4.031	0.001**
Operation time/M			52.33±9.97	56.66±16.07	0.627	0.539
Hospital stay/D			3.0±0.65	5.0±1.0	4.472	0.00**
Union time/ W			8.26±1.16	10.33±2.08	2.488	0.024*
Sex	Male	N	8	3	2.29	0.130
		%	53.3%	100.0%		
	Female	N	7	0		
		%	46.7%	0.0%		
Mechanism of injury	Assault	N	0	2	11.35	0.003*
		%	0.0%	66.7%		
	FFH	N	12	1		
		%	80.0%	33.3%		
	Sport	N	3	0		
		%	20.0%	0.0%		
Reduction technique	Closed	N	15	1	11.25	0.001*
		%	100.0%	33.3%		
	Open	N	0	2		
		%	0.0%	66.7%		
Residual radius angulation	-VE	N	17	0	18.0	0.00*
		%	100.0%	0.0%		
	+VE	N	0	1		
		%	0.0%	100.0%		
Residual ulna angulation	-VE	N	14	3	0.212	0.64
		%	93.3%	100.0%		
	+VE	N	1	0		
		%	00%0	0.0%		
Superficial infection	-VE	N	12	1	2.71	0.099
		%	80.0%	33.3%		
	+VE	N	3	2		
		%	20.0%	66.7%		
Superficial radial nerve palsy	-VE	N	15	1	11.25	0.001*
		%	100.0%	33.3%		
	+VE	N	0	2		
		%	0.0%	66.7%		
Joint stiffness	-VE	N	15	1	11.25	0.001**
		%	100.0%	33.3%		
	+VE	N	0	2		
		%	0.0%	66.7%		
Total		N	15	3		
		%	100.0%	100.0%		

Figure (3): 7 years old male patient had history of fall down on his Lt. hand from a horse, which led to Lt. forearm mid-shaft both-bone fracture complaining of forearm pain, limitation of movement and swelling with deformity. A) Plain x-ray, AP – Lat view was done and show fracture both-bone Lt. Forearm. B) Fracture operated and fixed by close reduction and elastic nail for both bone forearm AP and lateral views post-operative x-rays, C) Radiographs done at 3-month follow-up showed that both the radius and ulna fractures had healed completely, D) Full ROM post operation

DISCUSSION

An additional procedure may be necessary in up to 25% of cases when the forearm fractures dislocated while being monitored [10]. A reduction is not appropriate if the patient has an angular deformity more than 10 degrees or a complete displacement, according to a number of authors [11].

Angular deformity more than or equal to 15 degrees on radiographs taken at the time of admission was found in all cases of diaphyseal forearm fractures treated with flexible intramedullary nails in our research. **Daruwalla *et al.*** [12] reported that forearm fractures with an angulation more than 10 degrees should be treated surgically since the bone rebuilding potential in these regions is restricted.

Flynn *et al.* [11] technically, one bone fixation is less time-consuming, the stability of the ulna eliminates an undesirable bow and serves as a pivot point from which the radius can be held in place in an improved position. However, the non-fixed bone may return to its original position and the reduction may be lost [13]. Flexible intramedullary nail fixation of the fracture shafts of both the radius and ulna was included in our investigation to prevent secondary displacement. Even if one of the fractures is undisplaced, we now routinely fix both bones in two bone forearm fractures. **Amit *et al.*** [14] showed that Closed intramedullary nailing, rather than a plate fixation, was preferred because of the proper reduction, lower complication rate, negligible cosmetic defect, and ability to remove the rods under local anaesthetic once the procedure was completed.

Just 1.1% of patients in this study required a small open reduction because soft tissue interposition (difficult reduction) prevented the passage of the flexible intramedullary nail over the fracture site, according to the results of the current study. Comparable to **Richter *et al.*** [15] research (closed reduction 84%). According to **Cullen *et al.*** [13] (open reduction 75%). Intramedullary nailing of a juvenile diaphyseal fracture can be accomplished with either a closed or open reduction.

An investigation by **Kapoor *et al.*** [16] on forearm fractures in children treated with elastic stable intramedullary nails found that the average time for union of fractures was seven weeks, which is similar to that in the current study. It was found that 45 children between the ages of 5 and 15 were treated with titanium elastic nailing and immobilised postoperatively with an above-the-knee plaster slab for two weeks until the swelling had completely subsided, followed by encouraging range of motion exercises, as reported by **Maruthi *et al.*** [17].

A 16.7% complication rate has been found in the current analysis of individuals. In patients treated with intramedullary nailing, **Yalcinkaya *et al.*** [18] found a complication rate of 4-38%, whereas **Flynn *et al.*** [11] found a 14.6% overall complication rate in patients having intramedullary nailing. The most common complication occurring in their series were delayed union, compartment syndrome, infection, skin irritation by hard ware and pin back out. **Price *et al.*** [19] reported that no deep infection, nerve palsy, compartment syndrome, malunion, nonunion, or refracture were seen in any of the patients studied.

One or two patients in our study experienced a less-than-satisfactory outcome. Unions stayed together on average for 8.61 weeks (range 7-12). In all cases, elbow motion was restored to its full extent. However, a patient's ability to supinate and pronate was severely restricted during a physiotherapy session. A patient's ulnar nail entrance site was infected superficially, but this was managed satisfactorily with oral antibiotics and daily dressings. The superficial branch of the radial nerve was affected by necurapraxia in a single patient, but the condition was eventually alleviated. Remaining angulation of the radius was documented in one case, but the patient failed to follow up with the outpatient department. In one patient, a union was held up. There have been no reports of refracture following the removal of the implant. Comparable outcomes have been obtained with those of **Parajuli *et al.*** [20] who reported great results in 47 (94%) of their patients, but minor issues such as skin irritation, the back out of the ulnar implant, and a skin breakdown with exposed implant occurred in eight (16%) of their patients. Preliminary comparative study that was conducted by **Sahin and colleagues** [21]. They reported that 43 patients who had both-bone forearm fractures and had intramedullary fixation surgery were divided into two equal groups by random number generator. Others 20 patients received the elastic stable intramedullary nail and 20 received the K-wire**.** The average age of the group was 11.60 years old, with 5 females and 35 males participating. Preoperatively, just a small percentage of patients received cautious preoperative care. All perioperative statistics were the same between the two groups of patients. This is consistent with both the radiographic and functional findings. One pin track infection and one re-fracture delayed the union.

CONCLUSION

Intramedullary fixation by flexible intramedullary nails (ESIN) is successful treatment option and recommended for pediatric patients with 4-14 years of age or older because it is simple safe and minimally invasive procedure and effective method of treatment. It provides many biological and mechanical advantages. Flexible intramedullary nails (ESIN)

become popular and cheap with less complication. It is strong enough to resist deformity of fracture.

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REFERENCES

1. **Ryan L, Teach S, Searcy K *et al.* (2010):** Epidemiology of pediatric forearm fractures in Washington DC. J Trauma, 69:200-6.
2. **Sinikumpu J, Lautamo A, Pokka T *et al.* (2012):** The increasing incidence of paediatric diaphyseal both-bone forearm fractures and their internal fixation during the last decade. Injury, 43: 362-6.
3. **Clarke N, Shelton F, Taylor C *et al.* (2012):** The incidence of fractures in children under the age of 24 months--in relation to nonaccidental injury. Injury, 43 (6): 762-5.
4. **Jordan R, Westacott D (2012):** Displaced paediatric distal radius fractures when should we use percutaneous wires? Injury, 43 (6): 908-11.
5. **Hedström E, Bergström U, Michno P (2012):** Injuries in children and adolescents- -analysis of 41,330 injury related visits to an emergency department in northern Sweden. Injury, 43 (9): 1403-8.
6. **Nugraha H, Adiantono A (2017):** Epidemiology of fractures and dislocations in children. Folia Medica Indonesian, 53 (1): 81-85.
7. **Shah A, Lesniak B, Wolter T *et al.* (2010):** Stabilization of adolescent both-bone forearm fractures: a comparison of intramedullary nailing versus open reduction and internal fixation. J Orthop Trauma, 24 (7): 440-7.
8. **Mostafa K (2017):** Displaced supracondylar fractures of the humerus in children. The Egyptian Orthopedic Journal, 52 (2): 153-58.
9. **Rokaya P, Rawal M, Khan J *et al.* (2017):** Elastic stable intramedullary nailing in pediatric diaphyseal forearm bone fracture. Int J Res Orthop., 3 (2): 190-96.
10. **Bould M, Bannister G (1999):** Refractures of the radius and ulna in children. Injury, 30 (9): 583-586.
11. **Flynn J, Jones K, Garner M *et al.* (2010):** Eleven years' experience in operative management of pediatric forearm fracture. J Pediatric Orthop., 30 (4): 313-319.
12. **Daruwalla J**, **Vopat M, Kane P *et al.* (2014):** Treatment of diaphyseal forearm fractures in children. Orthopedic Reviews, 6 (2): 1-6.
13. **Cullen M, Roy D, Giza E *et al.* (1998):** Complications of Intramedullary Fixation of Pediatric Forearm Fractures. J Pediatric Orthop., 18 (1): 14-21.
14. **Amit Y, Khuntia S, Swaroop S *et al.* (2020):** Paediatric Long Bone Fractures Managed with Elastic Intramedullary Nails: A Retrospective Study of 30 Patients. Cureus, 12 (4): 123-128.
15. **Richter D, Ostermann P, Ekkernkamp A *et al.* (1998):**Elastic intramedullary nailing: a minimally invasive concept in the treatment of unstable forearm fractures in children. J Pediatr Orthop., 18 (4): 457-61.
16. **Kapoor V, Theruvil B, Edwards S *et al.* (2005):** Flexible intramedullary nailing of displaced diaphyseal forearm fractures in children. Injury, 36 (10): 1221–1225.
17. **Maruthi C (2015):** Treatment of Pediatric Forearm Fractures with Titanium Elastic Nails. Indian Journal of Orthopedics Surgery, 1 (4): 251-254.
18. **Yalçinkaya M, Doğan A, Ozkaya U *et al.* (2010):** Clinical results of intramedullary nailing following closed or mini open reduction in pediatric unstable diaphyseal forearm fractures. Acta Orthop Traumatol Turc., 44 (1): 7-13.
19. **Price C (2010):** Acceptable alignment of forearm fractures in children: open reduction indications. J Pediatr Orthop., 30: 82-84.
20. **Parajuli N, Shrestha D, Dhoju D *et al.* (2011):** Intramedullary nailing for pediatric diaphyseal forearm bone fracture. Kathmandu Univ Med J., 9 (35): 198-202.
21. **Şahin N, Akalın Y, Türker O *et al.* (2017):** ESIN and K-wire fixation have similar results in pediatric both-bone diaphyseal forearm fractures. Ulus Travma Acil Cerrahi Derg., 23 (5): 415-420.