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Evaluation of functional outcome of forearm fracture in children treated with elastic nail (TENs)

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Abstract--Background: Forearm fractures are one of the most common injuries sustained by children and both bone forearm fractures are estimated around 40% of all pediatric fractures. Pediatric forearm fractures occur in approximately 1 in 100 children per year. Forearm shaft fractures in children are usually treated with closed reduction and cast immobilization and a good functional outcome is obtained, but few patients with gross displacement, angulations, soft tissue swelling due to edema, children nearing skeletal maturity, proximal third fractures, open fractures and displacement after closed manipulation and cast immobilization require surgical intervention. Greater controversy exists regarding the optimal method of fixation in children. Fractures in this age group that cannot be maintained in acceptable alignment with closed reduction can be treated with either intramedullary nails or open reduction and internal fixation with plates. The purpose of this study was to investigate the indications, techniques, clinical results, functional outcomes, possible complications and means of avoiding them in unstable forearm fractures in children treated with titanium elastic nails (TENs).

Methods: Our prospective interventional study included Forty five children after application of inclusion and exclusion criteria, consent for study was taken from the parents. Surgery was performed under regional and general anaesthesia with standard institutional protocols. Fractures were reduced and fixed with titanium elastic nails. Demographic data, mechanism of injury, type of fracture (open or closed fracture and grading of open fracture), site of fracture, time for fracture to unite, any complications noted during and after surgery, range of movement of elbow and wrist, functional outcomes of limb were evaluated in each patient based on Price criteria and Grace-Eversmann scoring system. **Results:** Of the 45 children one child had left the study and 42 had excellent outcome and 2 had good outcome. Superficial infection was noted in 3 children warranting early implant removal. No major complications were seen. **Conclusion:** Flexible nailing is a versatile and efficient application of internal fixation for shaft fractures of both bones of the forearm in children, has an excellent functional outcome, and manageable complications.

Keywords---children, pediatric forearm fractures, titanium elastic nails (TENs),

Introduction

Forearm shaft fractures in children are usually treated with closed reduction and cast immobilization and a good functional outcome is obtained, but few patients with gross displacement, angulations, soft tissue swelling due to edema, children nearing skeletal maturity, proximal third fractures, open fractures and redisplacement after closed manipulation and cast immobilization require surgical intervention.

To achieve satisfactory outcome forearm shaft fractures needs anatomical reduction and maintenance in well applied cast till the fracture heals. A well moulded cast cannot be applied when there is gross swelling of forearm as it may lead to compartment syndrome, even if well padded cast is applied, reduction is lost once swelling subsides and patient would need re manipulation under anesthesia, which may not be successful most of times. Casting in pediatrics forearm fracture to be done by well trained and experienced surgeon, otherwise, chances of complications and poor outcome are high, even studies show positive correlation with re angulation when the reduction is performed by less experienced surgeons [1,2].

In last few years there has been high incidence of high energy trauma in children with gross displacement, swelling and open fractures. We attribute this to increase use of motor vehicles and thus road traffic accidents. Greater controversy exists regarding the optimal method of fixation in children. Fractures in this age group that cannot be maintained in acceptable alignment with closed reduction can be treated with either intramedullary nails or open reduction and internal fixation (ORIF) with plates. The advantages of intramedullary fixation over plating include small incisions, short duration of anesthesia, limited soft-

tissue dissection, rapid union, and excellent recovery of motion [3,4,5,6]. The purpose of this study was to investigate the indications, techniques, clinical results, functional outcomes, possible complications and means of avoiding them in unstable forearm fractures in children treated with titanium elastic nails (TENs).

Material and Methods

Our prospective interventional study was conducted at Shivamogga Institute of Medical Sciences, a tertiary teaching hospital, over a period of 5 years after Ethical clearance obtained from institutional ethical committee. Forty five children got enrolled for this study after application of inclusion and exclusion criteria, consent for study was taken from the parents. The Surgery was performed by two surgeons, forearm was splinted with above elbow posterior slab for 4 weeks after the surgery, slab was removed and elbow and wrist mobilized with sling for four more weeks. Radiographs were taken immediately after surgery and at 2, 6, 10, 12 and 18 weeks. TENs were extracted after 18 weeks once solid union is visualized in radiographs, if any local complications at entry site of nail is encountered, then nail was removed as early as 6 to 8 weeks to prevent spreading of infection. At each follow up visit patient underwent thorough clinical and radiological evaluation, and final follow up is after 6 months postoperative. Demographic data, mechanism of injury, type of fracture (open or closed fracture and grading of open fracture), site of fracture, time for fracture to unite, any complications noted during and after surgery, range of movement of elbow and wrist, functional outcomes of limb were evaluated in each patient.

Inclusion criteria

- Age between 5 to 16 years
- Irreducible fractures
- Unacceptable closed reduction
- Unstable fractures
- Open displaced fractures (Gustilo Anderson type 1 and 2)

Exclusion criteria

- Age beyond range of 5 to 16 years
- Greenstick fractures
- Isolated fracture ulna or radius shaft
- Undisplaced fractures
- Acceptable reduction
- Fracture associated with neurovascular injury
- Open fractures (Gustilo Anderson type 3)
- Fracture dislocation like Monteggia and Galeazzi

Surgical Technique

All of our patients were operated under regional anesthesia with additional general anesthesia in young uncooperative patients. Placed in supine position on operation table with shoulder at edge of table and affected limb over the radiolucent arm board. Whole of involved limb prepared and draped, limb is kept

free for adequate manipulation during the surgery. Every patient was given prophylactic antibiotics 30 min prior to incision. TENs of appropriate diameters were chosen, the nail diameters were about two-thirds of the medullary isthmus of each bone. Nails meant for radius were contoured to give smooth bend to match the physiological radial bow. We fixed ulna first before radius, but if there is comminution then lesser comminuted bone is fixed first. Contouring of nail is not required for ulna. We operated on radius fracture before ulna for fracture in upper third of both bone forearm bones; otherwise the radius is often difficult to reduce once ulna is fixed.

Entry point for ulna was made percutaneous over the posterior border of olecranon process, using drill bit and under fluoroscopic guidance. Nail is negotiated into distal fragment under fluoroscopic guidance, in case of three to four failed attempts to pass the nail into distal fragment, open reduction was done with minimal incision over the fracture site. Nail is pushed up to distal ulna, nail bent and cut at appropriate length, so that nail is subcutaneous and just palpable but not prominent enough to cause skin irritation, wound complications and impingement of elbow in extension. The radius were approached through one cm longitudinal incision over dorsum of wrist proximal to physis, interval between 2 and 3 dorsal compartment used to gain access to radius, near lister's tubercle. Care was taken to avoid injury to superficial radial nerve and extensor tendons over dorsum of wrist. Appropriate sized flexible intramedullary nail with its proximal 5mm pre-bent at 30° was introduced into intramedullary canal under fluoroscopy, The fracture was reduced by external manipulation and the pre-bent nail was pushed proximally and advanced through fracture site and was stopped short of the physis, at the level of bicipital tuberosity. If an acceptable reduction cannot be obtained, or unable to negotiate the nail into proximal fragment even after four attempts then open reduction is performed. The distal end of the nail was bent and cut 5-10 mm from the bone for easy removal. Relationship between the radial styloid and the bicipital tuberosity as well as the ulnar styloid and the coronoid process checked under fluoroscopy for rotational alignment, Wound was copiously irrigated before closure.

All patients were given long arm posterior splint for four weeks, suture removal done at two weeks. Arm Sling given for another four weeks after removal slab. The patient was instructed to avoid excessive loading of the involved limb until adequate callus formation is visualized in x rays taken 6 weeks. Early range of exercises was started, but Supination and pronation was allowed only after six weeks and results were evaluated as per Price criteria^[7] [Table 1].

Results

We studied 45 patients, out of which one patient lost in follow up, after surgery. So results are for 44 patients who included 39 Males and 5 female. Of the 44 patients 29 had injured right forearm while left forearm was injured in 15. Average age was 12.2 years. The Mechanism of injury was fall from bicycle in 13, followed by sports related activity in 8, road traffic accidents in 16, fall from height in 5, fall while walking on plain floor in 2 children. The time interval between injury and presentation to hospital was ranged from 6 hours to 7 days with median duration 14 hours. The average Time interval between injury and

surgery was 3 days. 33 patients were anesthetized with supraclavicular block and 11 patients needed additional General anesthesia. Tourniquet was used in only 5 patients. Mean duration of surgery was 27 min. Of the 44 patients we treated, 4 patients had compound fractures (Gustilo Anderson type 1 and type 2). Closed reduction could be achieved in 21 patients while remaining 13 patients needed open reduction. Open reduction was needed in patients who were operated more than week after the injury or were well built with increase girth of forearm, grossly displaced fracture with edema in forearm and in proximal forearm fractures. All the patient had complete union of fracture with average time 7.2 weeks. Implant removal was done at 18 weeks, but in 8 patients, implants were removed 28 to 32 weeks as delayed the follow up. In 3 patients nails were removed at 8 weeks due to superficial wound complication at nail entry site. According to price et al criteria 42 children had excellent outcome and only 2 had good outcome with 20 degree restriction in supination and pronation.

Table 1: Price et al criteria

Outcome	Symptoms	Loss of forearm 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

Grace-Eversmann ^[8]scoring system was used to assess functional outcome. With the use of a forearm goniometer, the ranges of pronation and Supination were evaluated according to the neutral zero method, with the elbow flexed 90 degrees, and were recorded as a percentage of the range of motion on the contralateral side. The results were rated as per table 2.

Table 2 - Grace-Eversmann scoring system

Excellent	fracture had united and >90% of the normal forearm rotation arc
Good	fracture had united and 80% to 89% of the rotation arc
Acceptable	fracture had united and 60% to 79% of normal forearm rotation
Poor	nonunion or < 60% normal forearm rotation

42 patients had excellent and two patients had good results according to Grace and Eversmann score. Major complications, such as limb length discrepancy affecting the extremity functions, angular or rotational deformity, radio-ulnar synostosis, or restricted elbow movement were not encountered.

Discussion

Forearm fractures are one of the most common injuries sustained by children and both bone forearm fractures are estimated around 40% of all pediatric fractures. Pediatric forearm fractures occur in approximately 1 in 100 children per year^[9]. When confronted with a pediatric diaphyseal forearm fracture, the treating orthopedic surgeon must be aware of the guidelines for acceptable fracture alignment during fracture healing to allow for optimal functional results. As with

most pediatric fractures, there is a greater remodeling potential in younger patients, designated as younger than 8 years of age, and less potential in older patients, those older than 11 years of age. Generally 15 to 20 degrees of angulation in children younger than 8 years of age and 10 degrees of angulation in older children are considered acceptable and can be treated with immobilization and without additional reduction. However, surgical intervention in the young child is still indicated for open fractures, fractures slightly before skeletal maturity, irreducible fractures with or without soft-tissue interposition, and unstable fractures after closed reduction. Calder et al.^[10] obtained excellent results following intramedullary fixation using K-wiring and ESIN with no difference in outcome between K-wires and ESIN, although they felt that ESIN offers the advantages of lower complication rates than that of intramedullary K-wire fixation, and improved forearm rotation. As the child becomes older the site of fracture moves proximally, and proximal diaphyseal fracture is difficult to treat due to increased chance of re-displacement even after successful closed reduction^[11]. Metaizeau JP et al^[12] as early as 1984 concluded that Flexible medullary nailing is an excellent method when operative treatment of fractures like tibia, femur, humerus and forearm in children, when indicated. This closed surgical procedure has a low complication rate.

Though many authors advocated immediate mobilization of forearm after TENS fixation, we immobilized the fractured limb with above elbow slab in neutral forearm rotation, cause patients tend to keep forearm in pronation when not splinted in neutral rotation. To be successful in closed treatment and accurate prediction of a patient's final outcome, it is essential to pay full attention to the rotational element of the deformity on admission (Prommersberger et al)^[13]. To obtain optimal results after non-operative management, a neutral position of the forearm in the cast is recommended to gain maximum pronation and supination rotational arc of motion in forearm. Lascombes P et al^[14] studied the results of elastic stable intramedullary nailing (ESIN) of 85 forearm fractures in children and reported that 92% had excellent results with a full range of movement. There were neither nonunions nor infections. They recommended TENs in the treatment of displaced forearm fracture in children older than 10 years of age, and in younger children when conservative treatment fails. Patel A et al^[15] and Zhao L, et al^[16] concluded there were no statistically significant differences in functional outcome or time to fracture union between plating and IM nailing but IM nailing significantly reduced the operation time and complication rate. Though Brooker B et al^[17] in 2014 reported nine cases of Extensor pollicis longus(EPL) rupture following the insertion of an TENS for the management of a diaphyseal fracture of the radius and recommend a radial entry point. In our study none of patients had EPL injury in spite of dorsal entry between second and third compartment, end of nail was always bent and cut to avoid injury to EPL by attrition. We removed nail at 18 weeks, after confirming consolidation of fracture in x-rays, Mehlmann C 2010 recommended in the literature that nail removal should not be performed before 4 to 6 months after insertion.

In our study twelve patients (27.3%) underwent open reduction for radius, comparable to study by Balakrishnan M. Acharyan et al^[18]. Open reduction was done only in patients operated more than week from time of injury, well built children with increase girth of forearm, grossly displaced fracture with edema in

forearm. We observed that Open reduction and fixation of fractures took more time to heal. Time for healing of fractures in our study was 6 weeks to 10 weeks with average time of 7.2 weeks. Fernandez FF et al 2009^[19] in their large study on 537 patients had 6 non unions in ulna, 5 were treated with open reduction, he advocated minimal surgical trauma in case open reduction The surgical trauma needs to be as minimal as possible in cases with open reduction with as little as possible compromise of the blood circulation of the affected bone

Kruppa C et al^[20] in 2017 study of 88 patients noted complication in 8.9% which included re-fracture with ESIN in situ, re-fracture after ESIN removal, mal-union, EPL rupture, Infection, Limitation of range of motion. In our series, minor complications were noted in 5 (16.12%) patients. No nonunion or mal unions occurred, and no deep infections were noted, which was in line with other studies. In 3 patients nail from ulna extracted at 8 weeks and 2 patients from radius, for superficial wound complication at nail entry site. One limitation of the present study is its non-comparative nature. A similar study with a non-operative control group or a comparative study with another operative technique with a longer follow-up would be ideal for a definite conclusion

Conclusion

Flexible nailing is a versatile and efficient application of internal fixation for shaft fractures of both bones of the forearm in children, has an excellent functional outcome, and manageable complications.

Conflicts of Interests The authors have no conflicts of interests to declare

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