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Closed reduction and internal fixation with titanium elastic nailing system in pediatric both-bone forearm fractures

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ABSTRACT

Background: The present study is designed to analyse the postoperative clinical and functional outcome of closed reduction and internal fixation of pediatric both-bone forearm fractures with titanium elastic nailing system (TENS).
Methods: A total of 32 patients in the age group of 5 to 15 years with fracture both-bone forearm underwent closed reduction and internal fixation with TENS at our hospital. Patients with displaced fractures having angulation more than 10° and rotation of more than 45° or fractures with unacceptable reduction post conservative management were included in this study. For functional outcome, upper extremity rating scale (UERS) was used to evaluate the range of motion and grip strength.
Results: Patients were followed up for a period of 6 months. In all cases fracture united in the range of 6-14 weeks without any malunion. All 32 cases had excellent outcomes according to UERS score. Two patients had deficient forearm pronation of 10° and 15° respectively. Skin irritation and implant impingement was seen in two patients each at final follow-up.
Conclusions: Closed reduction and internal fixation with TENS seems to be a good treatment option for fixation of pediatric both bone forearm fractures. It gives excellent functional outcome in terms of range of motion and grip strength without any major complications.

Keywords: Radius and ulna, Forearm fractures, Intramedullary, Flexible titanium nailing, UERS

INTRODUCTION

Diaphyseal fractures of both-bone forearm are common in paediatric age group, comprising 40% of all pediatric fractures. Remodelling and spontaneous correction of deformities following a fracture is found to be the main peculiarity of paediatric bone because of its unique growth potential. Conservative treatment with closed reduction and immobilization in above-elbow plaster cast for 4–6 weeks has been the standard management of these fractures. Although the fracture unites readily, malunion is very common which may not remodel in older children. Compartment syndrome and stiffness of joints may sometimes be the other complications of conservative management with plaster cast.[1]

In children aged more than 10 years, the epiphyseal activity decreases and with this the remodelling potential of the growing bone also decreases. Due to this operative intervention is the treatment of choice for fractures with angulation >10°, malrotation >45° and displacement >50%. Various surgical modalities available for internal fixation includes plate osteosynthesis and intramedullary fixation. Plate osteosynthesis has an advantage of better reduction with rigid fixation but the need of open reduction and extensive periosteal stripping which leads to delayed union is its major disadvantage. Over the past few years, surgical intervention for paediatric fractures with nailing has increased with the introduction of various types of stable intra-medullary nails. Especially for fixation of paediatric both-bone fractures, the use of intra-medullary devices has increased to prevent displacement during the

healing phase. Various types of intra-medullary devices used are K-wires and Steinmann pins, as well as many designs of flexible nails.[2-4]

In the mid-19th century, ivory pins were used for fixation of forearm fractures. Those were gradually replaced by metal ones, such as the Küntscher nail. In 1930's, the Rush nail was introduced. It was a more flexible choice, based on the principle of a three-point fixation in the inner cortex. Küntscher and rush nails had various disadvantages including their rigidity and difficulty on insertion through the metaphysis of children's bones. Thus they were avoided. In 1980's, surgeons in Nancy France developed an elastic intramedullary nail, whose concepts apply up to nowadays in the treatment of long bone fractures in children.

The advent of elastic intramedullary nail fixation has revolutionized the treatment of displaced both-bone forearm fractures. Internal fixation with elastic intramedullary nail in paediatric both-bone forearm fracture was first described by Metaizeau and Ligier.[5] Biomechanically, these implants have shown to act as internal splints.

These elastic intramedullary nails have found to have various advantages, including immediate stability at the fracture site, thus permitting early mobilization and return to normal activities with low complication rate.[6] Furthermore, these elastic nails can be percutaneously inserted after reducing the fractures closed without exposing the fracture site and there is little in the way of surgical scar or soft tissue dissection and is therefore both cosmetically acceptable and surgically minimally invasive.

Even though conservative management with closed reduction and cast application has been the treatment of choice, this study focuses on the outcome of operative management for paediatric forearm diaphyseal fractures.

The aim of our study was to assess the outcome of closed reduction and internal fixation with titanium elastic nailing system (TENS), in pediatric both-bone forearm fractures as regards union, time of union, post-operative complications and function using upper extremity rating scale (UERS).[7]

METHODS

After obtaining approval from the institutional research board and informed patient consent, this study was conducted in the department of orthopaedics at a tertiary care hospital in South Rajasthan from January 2020 to June 2021, on a sample size of 32 patients. Patients in the age group of 5 to 15 years with fracture of both-bones of the forearm on clinical and radiological examination were included in this study. Only displaced diaphyseal fractures which could not be corrected by closed reduction, with angulation more than 10° and rotation of more than 45° were included in this study. Patients with physeal injury, previous forearm surgeries, associated neuro-muscular disorders, patients with non-union, delayed union, compartment syndrome or pathological fracture were excluded from the study. A detailed history was taken, systemic examination was also done and along with routine blood investigations. X-ray of the forearm was done to confirm the diagnosis.

All undisplaced both-bone fractures were initially treated with closed reduction and POP cast application under traction on outpatient basis. In patients where reduction was achieved on check X-ray, the patient was continued with plaster of Paris (POP) cast for 6 weeks. For those where reduction was not acceptable or in displaced fractures where fragments were grossly displaced, angulated or malrotated, such patients were advised for operative treatment with TENS nailing.

After obtaining the operative consent, the patient was taken in supine position on the operating table and the affected arm was abducted so as to lie on radiolucent supporting arm table. Size of TENS measuring two-thirds of the medullary isthmus of each bone were selected using pre-op X-rays. Pre-contouring of nails approximately 3 times the diameter of the bone at the fracture site was done. Then, the awl was used to make entry point in the bones. Entry point in the radius was either just proximal to the radial styloid or through Lister's tubercle. The antegrade entry point in the ulna was either at the posterior aspect of the olecranon or a lateral approach through the proximal metaphysis. Because the radius is often more difficult to reduce, it was fixed first.

Radial nail was inserted manually with the help of T-handle for TENs into the medullary canal, with the nail tip at right angles to the bone shaft. Then, the nail was rotated through 180° with the T-handle, and the nail tip was aligned with the axis of the medullary canal. The nail was then advanced up to the fracture site with oscillating movements. After manual reduction under C-arm the nail was advanced with smooth oscillating movements into the proximal fragment metaphysis. Ulna nail was then introduced and progressed in similar manner such as radius nail. When the nails were correctly positioned in the opposite metaphysis, protruding nail ends were cut approximately 1 cm from the bone.

In all of our cases, closed reduction was done. None of the cases required mini-incision open reduction. Postoperatively above elbow POP slab was given to all patients for 2 weeks to encourage soft tissue healing.

All the patients were followed up regularly by clinical examination and X-rays taken immediately after operation, at 4 weeks, 8 weeks, 12 weeks and 24 weeks after surgery. Suture removal was done after 2 weeks and then patient was followed up for clinical outcome at 6 weeks, 12 weeks and 24 weeks. Physiotherapy was started in the form of flexion and extension of elbow at 3 weeks.

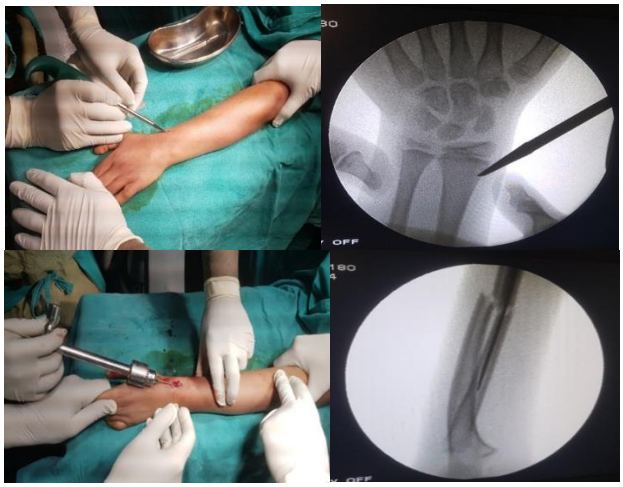

Figure 1: Radius fixation.

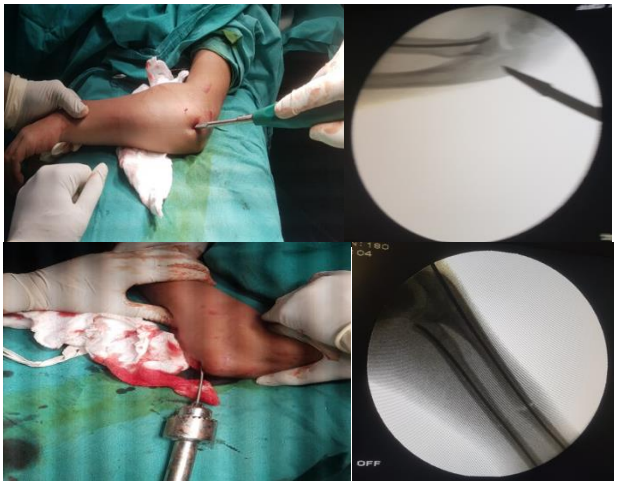

Figure 2: Ulna fixation.

		Left extremity	*Right extremity*
A. Shoulder: active motion			
Severe	Abduction 0–30°	☐ [0]	☐ [0]
Moderate	Abduction 31–120°	☐ [1]	☐ [1]
Mild	Abduction 121–160°	☐ [2]	☐ [2]
None	No dynamic deformity (161–180)	☐ [3]	☐ [3]
B. Elbow: active motion			
Severe	Extension >30°	☐ [0]	☐ [0]
Moderate	Extension 16–30°	☐ [1]	☐ [1]
Mild	Extension 5°–15°	☐ [2]	☐ [2]
None	No dynamic deformity (<5°)	☐ [3]	☐ [3]
C. Forearm: active motion (examine with elbow 45–90°)			
Severe	Supination 0–45°	☐ [0]	☐ [0]
Moderate	Supination 46–90°	☐ [1]	☐ [1]
Mild	Supination 91–135°	☐ [2]	☐ [2]
None	Supination 136–180°	☐ [3]	☐ [3]
D. Wrist: active motion (examine with elbow 45–90°)			
Severe	Dorsiflexion 0–45°	☐ [0]	☐ [0]
Moderate	Dorsiflexion 46–70°	☐ [1]	☐ [1]
Mild	Dorsiflexion 71–90°	☐ [2]	☐ [2]
None	Dorsiflexion 91–180°	☐ [3]	☐ [3]
E. Hand			
Ineffective grasp/release (any wrist position)		☐ [0]	☐ [0]
Effective grasp/release (dependent upon wrist position)		☐ [1]	☐ [1]
Effective grasp/release (thumb-independent, 2 or 3 finger pinch)		☐ [2]	☐ [2]
Effective grasp/release (any wrist position)		☐ [3]	☐ [3]

For example, in the UERS, full pronation is defined as 0° and full supination as 180° to provide a continuous range of motion for analysis. Traditionally, forearm rotation from 20° to 100° might be described in three different ways: (1) pronation from neutral to 70° and supination from neutral to 10°; (2) pronation lacking 20° and supination lacking 80°; or (3) pronation of 0–70° with supination 0–10°.

Figure 3: Upper extremity rating scale (UERS).

Figure 4: Left both-bone forearm fracture of a 13 year old boy; X-ray (a) pre-op, (b) post-op, and (c) 12 weeks follow-up; clinical picture (d) supination, (e) pronation, and (f) wrist dorsiflexion.

Supination and pronation was started after 4-6 weeks depending on follow up X-ray. All patients were followed up for a minimum period of 24 weeks. TENS was removed in all patients at 6 months after insertion. Results were analysed in reference to union, symptoms, and range of motion of adjacent joints using UERS criteria for outcome evaluation.[7]

RESULTS

32 patients of fracture both-bone forearm were admitted in our institute form January 2020 to May 2021. All the patients were included in this study. The mean age in our study was 10.69 years, with maximum patients being in the age group of 9-12 years. In our series of 32 patients, 24 patients (75%) were males and 8 patients (25%) were female. Right forearm was injured in 17 patients (53%) and left forearm was injured in 15 patients (47%).

Most of the forearm fractures were caused by fall on outstretched hand (56%). Next common cause was fall from height (28%). Some patients (16%) had history of road traffic accidents. All patients presented with complaints of pain and deformity in the forearm. All the demographic data is shown in Table 1.

Table 1: Demographic data (N=32).

Characteristics	N (%) or mean
Age distribution	10.69 years (5-15 years)
Sex distribution	
Male	24 (75)
Female	08 (25)
Side of injury	
Right	17 (53)
Left	15 (47)
Nature of injury	
Fall on outstretched hand	18 (56)
Fall from height	9 (28)
RTA	5 (16)
Fracture distribution	
Middle third	20 (62)
Distal third	07 (22)
Proximal third	05 (16)
Type of fracture	
Open/compound	02 (6)
Closed	30 (94)

Majority of the fractures were located in the middle third region of the forearm (62%) followed by distal third (22%) and proximal third (16%). Associated injuries were seen in 2 patients. One patient had ipsilateral tibia fracture and one had head injury. All these associated injuries were treated conservatively.

According to the type of fracture i.e. transverse, spiral, oblique or segmental all the fractures were classified using AO classification system. More than 50% of the fractures in our study were simple complete spiral or oblique. Only 19% of the fractures were multi-fragmentary. Based on the presence or absence of external injuries, the majority of the cases that presented to us were closed fractures. Only 2 cases were compound and both were Gustilo Anderson type-1.

All the patients were operated within 1 week of injury. Mean duration of surgery was found to be 31.84 minutes (range 24 to 46 minutes). Mainly three sizes of TENS nail measuring 1.5 mm, 2 mm and 2.5 mm were used in pediatric fracture both bone forearm fixation. In our study most commonly used TENS nail was 2 mm (50%).

Most common complications with TENS nailing in this study at 6 weeks follow-up included skin irritation and implant impingement which contributed to about 6% each. No other complications like pin site infection, mechanical block due to implant protrusion, wound infection, elbow stiffness, nail migration or refractures were seen in this study.

Average time to bony union was found to be 8.03 weeks, range being 6 to 14 weeks. In 97% of the patients, radiological union was seen before 10 weeks and more than half of the patients, achieved union before 8 weeks.

The functional outcome was graded using UERS which is shown in Figure 3. Mean UERS score at 6 weeks follow-up was 14.75, which improved to 15 at 12 weeks follow-up and remained the same at 24 weeks follow-up (Table 2). We found excellent results in all the patients at 6 weeks follow-up itself and it remained the same at final follow-up.

Table 2: UERS score.

Follow-up period	6 weeks	12 weeks	24 weeks
Mean UERS score	14.75	15	15

At final follow-up two patients had deficient forearm pronation of 10° and 15° respectively. No other functional impairment was seen in any of the patients.

DISCUSSION

In children, fracture of both- bones is a common injury. Closed fixation with TENS is one of the emerging options, although conservative management is known as the gold standard treatment for most forearm fractures of the immature skeleton. The trend towards operative management especially in older children, is due to their lesser remodelling potential and chances of malunion.

In the present study, majority of children were in the age group of 9-12 years, with a mean age of 10.69 years. Similar observations were also made by Garg et al (11.8 years) and Qidwai et al (11 years). We had fracture both-bone forearm at proximal third in 5 (16%) patients, middle

third in 20 (62%) and at distal third in 7 (22%) patients. Majority of the fractures were in the middle third. Rajesh et al in their study on paediatric forearm fractures reported 20 patients (40%) with fractures in proximal third, 23 (46%) in middle third and 7 (14%) in distal third.[8] Males were significantly higher and comprised about 75% of the patients in our study. Similar results with 70% of male predominance were observed in other studies.[2] It may be because of the involvement of males in outdoor activities like sports, farming and road traffic accidents.

In our study, all displaced both-bone forearm fractures with angulation more than 10° and rotation of more than 45° were treated with closed reduction and internal fixation with titanium elastic nails. In a study conducted by Kay et al children aged more than 10 years had a remarkable decrease in forearm movements due to closed reduction maneuvers resulting in angulation more than 10°.[9] Treatment of these forearm fractures through non operative treatment had more complications than operative treatment.[10] Hence surgical treatment should be considered in patients with unstable forearm fractures, if acceptable alignment cannot be achieved with closed reduction maneuvers. The remodelling potential particularly in older children is limited, hence fractures with complete displacement should commonly be addressed by surgical treatment.

Furlan et al in his study on unstable both bone forearm fractures in paediatric age group, showed the advantages of intramedullary nailing.[11] They concluded that nailing using elastic nails is the preferred method in children, as it is less invasive and gives excellent functional outcome, as well as cosmetic results.

Salonen et al in his retrospective study of 75 paediatric patients recommended TENS nailing as implant of choice for the unstable forearm fractures, even though minor complications can be seen.[12] In our study all unstable fractures showed excellent functional outcome with minimal postoperative complications after fixation with TENS nailing.

It is considered that compound fractures are inherently unstable. In our study 2 cases had open injury and both were Gustillo Anderson type I. The wound measured not more than 2 cm in any dimension. In such fractures, thorough debridement was done prior to internal fixation. A Lyman et al in her study found twenty-one (4.6%) of 456 fractures were open: 14 were treated with titanium elastic nailing, five with closed reduction and cast, and two with plate-and-screw fixation.[13]

Pogorelic et al in his study reported that 37 patients had underwent fixation followed by closed reduction, whilst in the other 15 due to difficulty in reduction and soft tissue interposition, open reduction was required.[11] In our study all patients were treated with closed reduction and none of them required opening the fracture site.

In our study the average time to union was found to be 8 weeks. In 97% of patients, radiological union was seen before 10 weeks and more than half of the patients achieved union before 8 weeks. Bony union is said to be achieved following a radiological sign of callus formation involving at least 3 cortices and no signs of fracture mobility clinically. None of our cases went into non-union. These results are comparable to study by Kapoor et al in which the mean time for union was 7 weeks and in Singh et al it was 9 weeks.[14,15]

Most common complications seen in our study were skin irritation (6%) and implant impingement (6%). No other complications like pin site infection, mechanical block due to implant protrusion, elbow stiffness, wound infection, nail migration or refractures were seen in this study. Complication rate in our study was 12% which was found similar as recorded by Flynn et al at 14.6% and Singh et al at 16%.[15,16]

To achieve normal rotational movements of forearm it is necessary to maintain the radial bow, angular and rotational alignment, along with interosseous space. In the present study the forearm movements were assessed using UERS.[7] We found excellent results in all of the patients at 6 weeks follow-up itself. None of the patients had good, fair or poor results. Two patients had limitation of terminal forearm pronation ranging 5-15° at final follow-up. In a study by Kapila et al 8% patients showed loss of movement at forearm by 15-30°, and no patient had loss of movement at forearm more than 30°.[8] According to Price et al criteria, they recorded 46 patients (92%) with excellent results and four patients (8%) with good results. Similar results were observed by Parajuli et al in which 94% patients had excellent results and 6% had good results.[17]

Implant removal in all patients was done at the postop period of 6 months in our study. Although the follow up period mandated in this study was only 6 months, yet no cases of refracture after implant removal has been reported amongst these cases till the compilation of this study. Lyman et al noted refracture in only one case which had undergone implant removal at 4.5 months post index operation.[13] Various studies have reported the rate of refracture following surgery with ESIN ranges from 0 to 4.4%.[18] Thus we recommend against removing the nails sooner than 6 months after surgery.

In the pediatric patient, non-union has not been reported in the literature, and good/excellent functional results are reported in nearly 95% of cases. These excellent clinical results support the use of this technique in the operative treatment of displaced both bone forearm fractures in the pediatric patient.

Our present results were comparable with other studies by Flynn et al, Kang et al, and Jeffery et al which has been summarized in Table 3.[16,19,20]

Table 3: Comparison with other studies.

Study	Number of patients	Mean age (years)	Implant used	Average time of union radiologically	Functional criteria	Functional outcome	Complications (%)
Our study	32	10.69	TENS	8.03 weeks	Upper extremity rating scale	Excellent 32, good 0, fair 0 , and poor 0	4 minor complications
Flynn et al[16]	103	10.6	Titanium nails	6.9-8.6 weeks	Children hospital of Pheladelphia forearm fracture fixation outcome classification	Excellent=77.0%, fair=14.6%, and poor=7.8%	Major-4 (3.8), and minor-11 (10.6)
Richter et al	30		Titanium nails	13 weeks	Tscherne score	Excellent=80 %, good=6.6%, and fair=3.3%	Minor-4 (13.3)
Kang et al[19]	90	8.4	Elastic nails	2.9 months (1.1 to 8.7)	Daruwalla criteria	Excellent 59, good 17, fair 5, and poor 9	Superficial radial nerve palsy 2 compartment syndrome 1, delayed union 1, malunion 1, remodelled wound- related problems 7, and failure to remove implant 1
Martus et al[20]	203	9.7	TENs 97%, 3% k-wires or Steinman pins		Clavien-Dindo classification with modifications	Excellent 163, good 24, fair 5, and poor 13	Overall complication 21% 17% were grade 2 or greater

CONCLUSION

Closed reduction and internal fixation with TENS seems to be a good treatment option for fixation of pediatric both bone forearm fractures. It gives excellent functional outcome in terms of range of motion and grip strength without any major complications.

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Conflict of interest: None declared
Ethical approval: The study was approved by the institutional ethics committee

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