International Journal of Orthopaedics Sciences

E-ISSN: 2395-1958
P-ISSN: 2706-6630
IJOS 2021; 7(4): 195-200

www.orthopaper.com
Received: 27-06-2021
Accepted: 29-07-2021

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A prospective study of surgical management in fracture of both bone forearm shaft using titanium elastic nailing system in pediatric patients

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DOI: https://doi.org/10.22271/ortho.2021.v7.i4c.2885

Abstract
Introduction: Both bone forearm fractures are common orthopaedic injuries in pediatric population which present significant challenges to the orthopaedic community. It is not only important to treat them adequately but also to recognize the overall impact a fracture can have on a child, possibly limiting physical activity. Forearm fractures comprise 40% or more of pediatric fractures.
Majority of these fractures can be treated conservatively with closed reduction and cast immobilization. A recognized failure rate has been reported up to 7% to 32%. Commonly two operative treatment modalities are employed at present: open compression plating and flexible intramedullary nailing. Each modality has advantage and disadvantage.
Objective: Assess the functional outcome and complications associated with Titanium Elastic Nailing System in fracture of both bone forearm in pediatric patients.
Materials and Methods: 20 Patients with both bone forearm shaft fracture aged between 6-16 years admitted to Chigateri General Hospital and Bapuji Hospital attached to J.J.M. Medical College Davanagere in the period from September 2019 to August 2021.
Results: In our study, majority of the patients were boys, with an average age of 10.5 years with mid 1/3rd shaft transverse fractures being the most common, and self-fall while playing was the most common mode of injury. The surgery required minimum dissection, short operation time with hardly any risks of intraoperative complications. The average fracture union time was 9 weeks with patients recovering near normal functions of forearm at the earliest.
We didn't encounter any major post-operative complications in our study, and 95% of the patients had excellent range of motion at wrist, elbow and radio-ulnar joints and 5% had satisfactory range of motion.
Conclusion: TENS nailing in both bone forearm shaft fractures in pediatric age group provides excellent results with advantages of early union, excellent recovery of function, minimal invasive and decreased time of surgery.

Keywords: Surgical management, orthopaedic community, pediatric population

Introduction
Both bone forearm fractures are common orthopaedic injuries in pediatric population which present significant challenges to the orthopaedic community. It is not only important to treat them adequately but also to recognize the overall impact a fracture can have on a child, possibly limiting physical activity. Forearm fractures comprise 40% or more of pediatric fractures. The forearm is considered as a functional joint, as supination and pronation occur in between the radius and ulna. For this reason anatomical or near anatomical reduction after their displaced fracture is a necessity to regain normal function. Forearm fractures are the most common injuries in paediatric age group, accounting 45% of all fractures in childhood. Approximately, 75 to 84% of forearm fractures occur in the distal third, 15 to 18% occur in the middle third and 1 to 7% occurs in the proximal third of the forearm [1]. The incidence of fractures shaft forearm bones is more common in 6-16-year-old children, with higher incidence in children between 12-16 years of age [2]. 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 [3]. In older children Many shaft injuries are effectively treated with skilful closed fracture care with pop casting,

but failures continue to occur despite good orthopaedic intentions. The failure rate is about 7 to 32% and hence there is a subset of fractures that demands surgical interventions, and these are irreducible fractures, unstable fractures and open fractures [4, 5]. Its skeleton is peculiarly formed by two separate bones, the radius and ulna. Two bones provide good range of rotation motion (ROM), while remaining light and stable [2]. Muscles, nerves and vessels are fixed on the turning bone (the radius) far away from the wrist and hand keeping the hand slim and dexterous. The functions of the hand and the forearm are complex and none of the best robots have yet been able to imitate them.

There are multiple surgical techniques to achieve adequate stabilization of these types of fractures, including plating, external fixation and intramedullary nailing [6-9]. Shoemaker *et al*. suggested that the ideal mode of fixation of paediatric forearm fractures should maintain alignment, be minimally invasive and inexpensive and carry an acceptable risk profile [4]. As compared to intramedullary fixation, ORIF with plates and screws has got several disadvantages such as large incisions with poor cosmesis, more soft tissue dissection, higher incidence of infections and second surgery for removal of implant with similar large incision and soft tissue dissection which is difficult than naïve surgery. As far as devices like k-wire, Steinmann pin, and Rush nail are considered, it can be used as intramedullary device, but these are rigid and have difficulty in insertion particularly in radius. To overcome this problem flexible intramedullary nail i.e. TENS (Titanium elastic nail system) is devised which provide three bony point fixation to maintain bony alignment [10].

Elastic stable intramedullary nailing (ESIN) has become very common in the treatment of children's long bone shaft fractures. It was first reported for the treatment of long bones by French and Spanish surgeons at the late 1970s and early 1980s. The procedure is under active research and new innovations are being developed, for example by using biodegradable implants.

The forearm is necessary for the upper limb to function perfectly. Being so complex and important in relation to function of the upper limb, forearm injuries can lead to potentially hazardous consequences. There is no doubt that forearm shaft fractures are potentially harmful and challenging to manage. They are unique and they differ from fractures in any other long bones. They are one of the few paediatric fractures that show a real risk of complications and prolonged morbidity.

It is generally accepted that the closer the fracture is to the distal physis, the greater is the potential for remodelling. As a result more deformity can be accepted in the distal one third of diaphysis when compared to the middle and proximal one third of forearm.

Commonly two operative treatment modalities are employed at present: open compression plating and flexible intramedullary nailing. Each modality have their own advantages and disadvantages. There have been reports of increasing operative treatment of forearm shaft fractures. The purpose of this study is to assess the functional outcome and complications associated with Titanium Elastic Nailing System in fracture of both bone forearm in pediatric patients.

Material and methods

20 Patients having displaced diaphyseal fractures of both bones forearm, admitted in Bapuji Hospital and Chigateri General Hospital attached to J.J.M. Medical College, Davangere were considered for study after obtaining their parents/guardians consent. This was a prospective study conducted from September 2019 – August 2021. Sampling for this study was done by Convenience Sampling Method. Patients were analyzed clinically, radiologically and assessed for functional outcome with TENS application.

Inclusion Criteria

- Patients above 6 years and less then 16 years of age.
- Patients with displaced diaphyseal fractures and type I according to Gustilo

Anderson classification of both bones forearm.

- Patient fit for surgery.
- Patients whose parents/guardian have given their consent for the procedure.
- Patients with no previous forearm injuries, surgeries or any other pathology.

Exclusion Criteria

- Fractures in patients less than 6years and more then 16 years.
- Open fractures (Gustilo Anderson type II and III)
- Both bone fracture with compartment syndrome needing fasciotomy.
- Both bone fracture needing vascular repair

Surgical technique

- Type of anesthesia: General anesthesia / Brachial block.
- Scrubbing, Painting of the upper limb done.
- Pneumatic tourniquet was applied: Time noted.
- Draping of the upper limb done.
- Retrograde entry point for radius was taken & Antegrade entry point for ulna was taken in our study. Incision was taken as explained earlier. For radius it was near listers tubercle.
- Clinically and radiologically the deformity was assessed & closed reduction was tried.
- If reduction was not achieved even after 3-4 attempts by closed means then with the help of small incision at the fracture sites identified using C-ARM for one or both the bones the fracture site was exposed, reduction was achieved after appropriate manipulation and nailing done.
- Radius was first fixed after which ulna was fixed.
- The concept of 3 point fixation should be applied while nailing done.
- Care should be taken to maintain concavity of both the bones facing each other & to maintain the radial bow after final reduction as this maintains the interosseous membrane.
- The nail tip should be placed in the subchondral bone but should not enter the epiphysis so as to not to damage the growth plate.
- The nails are partially withdrawn and bent with the help of nail bender or "T" handle and cut off using Harrington cutter after which the retracted part is reinserted so that only about 5mm of nail is left outside of bone. The cut end should be smoothened so as not to irritate the skin.
- The incision sites are sutured and sterile dressing done.
- After closure of wound and dressing, moderate thumps are given at the elbow so as to achieve compression at the fracture site.

Postoperatively a crepe bandage and above elbow POP slab was applied over the affected forearm and arm pouch was

given. The patient was instructed to keep the limb elevated and move the affected side fingers and shoulder joint. Wound was inspected & dressed on the 2nd post-operative day. Post-operative x ray was taken on 2nd post-operative day.

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. Patient was discharged on post-operative day 2 for closed reduction and on post-operative day 5 after wound inspection and dressing with forearm in arm pouch. Patient was advised to perform shoulder and finger movements. On 10th post-operative day the wound was inspected and sutures were removed.

Follow-up

All the patients were followed up at 4, 8, 12 weeks and till one year or till the implant is removed whichever is earlier. At each follow-up x-rays of forearm in anteroposterior and lateral views were taken and analyzed for union i.e, presence of bridging periosteol callus in three or four cortices. Patients were checked clinically for wrist, elbow Flexion - extension and supination, pronation movements. Union was assessed radiologically.

Table 1: Demographic data and outcome of 20 patients

Variables		Number (percentage)
Gender	Male	12(60)
	Female	08(40)
Mean Age		10.5yrs
Side	Right	12(60)
	Left	08(40)
Site	Distal 3rd	6(30)
	Middle 3rd	12(60)
	Proximal 3rd	2(10)
Type of surgical procedure	Closed reduction and internal fixation	14(70)
	Open reduction and internal fixation	06(30)
Outcome	Excellent	19(95)
	Good	01(05)
	Fair	00
	Poor	00
Complications		07(35)
Average time of union		09 weeks
Average time for implant removal		06 months

Results

In our prospective study which is conducted in between September 2019 to August 2021, there were 20 patients of fracture both bone forearm included out of which 12(60%) patients were male and 8(40%) were female. The mean age of the patient was 10.5 years. 12 (60%) patients had right side fracture and 8 (40%) had left side fracture. Out of 20 patients six (30%)patients need open reduction due to soft tissue interposition. Outcome was measured according to Anderson *et al*. criteria and 19 (95%) patients had excellent outcome and rest of them had good outcome. Among 07 patients which developed complications three patients developed superficial infection and were managed by oral antibiotics. The rest four patient had implant related irritation at entry portal which get relieved only after removal of the implant. The average time for union was nine weeks and the average time for implant removal was six months.

X-rays of patients

Pre-Op X Ray Immediate Post-Op 4 Month Post-Op

1 Year Post Op

Post Implant Removal

Clinical picture of patient

Discussion

Initially all paediatric both bone forearm fractures are managed conservatively. But now there is a change in the management of these fractures, because of the higher complications following conservative management. These fractures have a higher tendency to go for malunion due to improper reduction and redisplacement following closed reduction and casting. In a study conducted by Kay *et al*. [11] children aged more than 10 years will have a remarkable decrease in forearm movements due to closed reduction manoeuvres resulting in angulation more than 10°. Surgical treatment should be considered in patients with unstable forearm fractures, if acceptable alignment cannot be achieved with closed reduction manoeuvres. Surgical intervention by classical fixation technique of open reduction and plating with physis sparing, provides anatomical reduction and stable fixation with earlier mobilisation of the joints [11]. The conventional plating methods has the disadvantage of surgical dissection to open the fracture site, loss of fracture hematoma, periosteal stripping, implant removal, higher chance of refracture due to stress shielding effect due to plating and possible neurovascular injury. Vainionpaa *et al*. [12] stated that out of 10 patients, 5 had restricted forearm movements with loss of functional outcome because of the soft tissue compromise, treated with plate fixation. There is a 42% rate of neurovascular complications following implant removal of plates and screws after osseous union in the forearm [13]. Radio-ulnar synostosis can also be found in some rare cases [14].

Recent studies regarding fractures of forearm fixation in paediatric population suggest intramedullary nailing has registered excellent outcomes and also has the advantage of nailing than plating in paediatric population [3, 15]. Intramedullary nailing helps in early union, decreases the infection risk and synostosis, and prevents making long incisions required for plating and its removal [5]. But the use of kirschner wire for fixation of these fractures intramedullary also had many disadvantages like penetration of k - wire, infection at the pin sites, restriction of movements in the involved forearm, delay in union of fractures.

To avoid these complications and to use the advantages of intramedullary fixation, titanium elastic nailing system is used. They act as internal splints, providing 3 point fixation of fractures which helps in maintaining the alignment [16]. Reduction of fracture end to end is achieved, which helps in controlling rotational alignment and reduced motion at the fractured area promotes external callus formation by the conversion of shear stress into compression [4].

In our study patients were distributed from 6 years to 14 years of age with most common age group being 10-12 years, Mohammad Ruhullah *et al*. (2016) [17] in their study had average age group 10.04 years and Vishwanath *et al*. (2017) [18] the average age group was 11.25 years. In our current study 60 % of the patients were boys with male to female ratio is 3:2, Mohammad Ruhullah *et al*. (2016) [17] in their study had 65.8% boys and 34.2% girls, Shivanna *et al*. (2014) [19] study had 70.1% of boys and remaining 29.1% of girl, Vishwanath *et al*. (2017) [18] the 70 % were boys 30% were girls. In current study 75% of injuries due to accidental self fall at home or while playing, 15 % due to fall from bicycle, and 10% due to RTA, Kishorchand Naorem *et al*. [20] during 2015 to 2017 had 70% had accidental fall,16.67% had RTA and 13.3% had fall from height.

In current study of radius fracture 70% were noted in mid 1/3rd shaft, 20% were noted in proximal 1/3rd shaft and in 10% distal 1/3rd shaft,ulna fracture 65% were noted in mid

shaft, 25% were noted in proximal shaft and in 10 % noted in distal shaft, Mohammad Ruhullah *et al*. (2016) [17] in their study had 69.6% mid shaft fractures, 17.7% had proximal shaft fractures and 12.6% were distal shaft fractures. The average time taken for fracture union in our study is 9 weeks with a range of 7- 11 weeks, Mohammad Ruhullah *et al*. (2016) [17] in their study had a average union time of 9 weeks, Kishorchand Naorem *et al*. (2015- 2017) [20] series had all fractures united by 16 weeks.

In our study we were able to fix 12 cases by closed reduction, in 3 cases radius fracture site was opened, in 1 case ulna fracture was opened and in 4 cases both bones fracture sites were opened to achieve reduction, Mohammad Ruhullah *et al*. (2016) [17] in their study had 90% closed reduction and 10% was through open reduction, Shivanna *et al*. (2014) [19] study had 82.2% had closed reduction and remaining were by open reduction.

In our study noted that 19 cases had excellent results while 1 cases had satisfactory results at the end of 4 months by Anderson *et al* scoring. Study conducted by Furlan D *et al*. [21] in unstable both bone forearm fractures in peadiatric age group, showed the advantages of intramedullary nailing. They concluded nailing using elastic nail is the preferred method in children as it is less invasive and gives excellent functional outcome, as well as cosmetic results. Wall L *et al*. [22] demonstrated a retrospective study on 32 cases of age group between 12- 18 years, who were treated using intramedullary nailing for fractures of both bone forearm and concluded flexible nailing in the treatment of forearm both bone fractures provides early union of fracture and shows excellent results in adolescents age group.

Chen CE *et al*. [23] suggested in his study that fractures of both bone forearm in paediatric age group requiring fixation should be attended with intramedullary nailing using titanium elastic nailing system. Haoqi Cai *et al*. [24] in his study on 52 patients between 4- 14 years of age recommended the usage of prebent elastic nail by intramedullary fixation is a better technique for the management of distal radius fracture at the metaphyseal diaphyseal junction showing better reduction of fracture, solid fixation and minimal migration.

Conclusion

Titanium elastic nails fixation of pediatric forearm fractures revealed several advantages, a small incision for insertion, a low rate of complications, unhindered bone healing, and good clinical and radiological results thus achieving maximum range of motion at the earliest In paediatric patients with both bone forearm fractures, intramedullary nailing with titanium elastic nails provides excellent results in terms of both radiological union and functional outcomes. This technique has more merits than conventional plating methods as it is less invasive, simple and easily reproducible procedure with better cosmesis. As axial loading is negligible in forearm fractures, implant failure is also not commonly seen. Thus TENS can be advocated for its use in paediatric population due it its excellent objective and subjective results.

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