

Prospective Study of Surgical Management of Diaphyseal Fractures of Both Bones Forearm in Older Children Using Titanium Elastic Intramedullary Nailing at a Tertiary Care Hospital in Srikakulam

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ABSTRACT

BACKGROUND

Diaphyseal fractures of the forearm are one of the common fractures in the paediatric population. Closed reduction and cast immobilisation remain the standard treatment for paediatric diaphyseal forearm fractures owing to their unique remodelling potential. The main concern of conservative management is re-displacement of fracture in cast resulting in the unacceptable angular deformity in the forearm. Intramedullary fixation with titanium elastic nails for paediatric diaphyseal forearm fractures is becoming the trending surgical technique in those cases that warrant surgical intervention. The purpose of this study was to evaluate the functional outcome of the management of fracture of both bones forearm in the older children with titanium elastic nailing system.

METHODS

This was a prospective study done among thirty patients aged 5 to 16 years admitted to the Department of Orthopaedics at GEMS & Hospital, Ragolu, Srikakulam with diaphyseal fractures of both bones forearm from September 2017 to September 2019. We treated the patients by closed / open reduction and internal fixation with elastic stable intramedullary nailing. The patients were followed-up for six months.

RESULTS

We evaluated the patients clinically and radiologically after surgery. We assessed the outcome using modified Anderson's AO criteria for forearm fractures extracted from the international journal of current pharmaceutical and clinical research functions. All fractures united at an average of 9.1 weeks without any delayed or non-union. The results were excellent in 86.6 % of patients and good in 13.3 % of patients without significant complications. There were minor complications in 6 patients (20 %).

CONCLUSIONS

Titanium elastic intramedullary nailing is a safe, effective and minimally invasive surgical method for treatment of displaced both bones forearm diaphyseal fractures in older children. This technique gives relative stability with a three-point fixation principle resulting in secondary bone healing by promoting early callus, ideal for early mobilisation. The technique offers several advantages, including minimal incision, preservation of fracture haematoma, dynamic axial stabilisation, and shorter hospitalisation.

KEYWORDS

Both Bone Fracture Forearm, Titanium Elastic Nailing System, Early Mobilisation

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BACKGROUND

Diaphyseal fractures of the forearm are common in the paediatric age group, accounting for 6 % of the fractures in children. Closed reduction and casting remain the mainstay of management in both-bone forearm fractures in younger children because of rapid healing and tremendous remodelling potential. Complications of cast immobilization comprise of muscle atrophy, joint stiffness, pressure sores, and rarely compartment syndrome. Certain fractures require surgical intervention like displaced fractures, open fractures, fractures with unacceptable angulation, neurovascular compromise and conservative management failure.

The remodelling potential of children is determined by age, level of fracture and amount of angulation. Fuller¹ concluded that the loss of supination and pronation is proportional to the reduction of rotational mal-union. He noted that in mal-union, no spontaneous correction of deformity occurs in girls older than eight years and boys more than ten years of age. Children aged > 10 years do not remodel as predictably and hence near anatomic reduction is necessary in these older children to achieve a full range of motion.²⁻⁴ After conservative treatment, frequent problems, such as loss of reduction with the necessity of repeated manipulation and consolidation in inadequate alignment, caused impaired function. This issue led to a change in the treatment methods of unstable forearm fractures in children in order to provide better functional results.

Many operative techniques have been described to manage displaced paediatric forearm shaft fractures: pins and plasters, external fixation, plating, and intramedullary nailing.⁵ The use of an external fixator is usually not a preferred technique in these paediatric fractures. The technique of plating offers stabilization and anatomical reduction but requires more soft tissue dissection and periosteal stripping. This technique also has disadvantages like larger incision with a risk of infection, refracture after implant removal, and rarely radio-ulnar synostosis.

In the early 1980s, Métaizeau et al. described flexible stable intramedullary pinning of paediatric forearm fractures.^{6,7} which revolutionized the treatment of paediatric fractures. Elastic stable intramedullary nailing (ESIN) with Titanium elastic nail system (TENS) was a trending procedure for the unstable diaphyseal fractures of the forearm in children because of excellent results.⁸ This technique is more cosmetic, avoids unsightly incisions, and reduces the risk of infection and synostosis. N. Purushothaman et al.⁹ concluded in their study that titanium elastic nailing provides excellent results in terms of both radiological union and functional outcomes. They also stated that implant failure is also not commonly seen as axial loading is negligible in forearm fractures. Their elasticity, ease of insertion, and better rotational stability offer more tremendous advantages than rigid implants like rush nails, k-wires, and enders nails. Even removal of elastic nail is a minor procedure that requires small incisions unlike plate removal.

Siddaram Patil et al.¹⁰ stated in their study that TENS can be successfully used regardless of fracture location and

fracture pattern. Brian A. Kelly et al.¹¹ concluded that incidence of fracture of paediatric forearm with in situ intramedullary implants is low. Intramedullary fixation with titanium elastic nails for paediatric diaphyseal forearm fractures is becoming the popular surgical technique in those cases that warrant surgical intervention. The purpose of this study was to evaluate the functional outcome of management of diaphyseal fractures of both bones forearm in older children using titanium elastic nailing system.

Objectives

1. To determine the demographic (age and sex distribution) of paediatric diaphyseal both bones fractures of forearm.
2. To study the advantages of TENS.
3. To study the duration of union, complications and functional outcome of closed / open reduction and internal fixation of displaced diaphyseal of both bones fractures of forearm in older children with TENS.

METHODS

All the patients between 5 - 16 years with both bone diaphyseal fractures of forearm admitted at GEMS hospital, Ragolu, Srikakulam from September 2017 to September 2019 meeting the below criteria were included in this prospective study.

Inclusion Criteria

- Children and adolescent patients between 5 to 16 years with displaced, unstable diaphyseal fractures of both bone forearm.
- Children with comminuted, segmental diaphyseal fractures of both bone forearm.
- Children with type 1 compound diaphyseal fractures of both bone forearm.

Exclusion Criteria

- Children with single-bone fractures.
- Children below five and more than 16 years of age.
- Children with type 2 & 3 compound fractures.
- Children unfit for surgery due to medical comorbidities, and those not willing for surgery.
- Children with un-displaced fractures.

We obtained approval from the institutional ethics committee, along with informed consent from all the patients posted for surgery. After a thorough clinical examination and radiography, pre-anaesthetic evaluation was done. Patients were posted for surgery as early as possible under supraclavicular block. We did closed / open reduction and internal fixation with elastic stable intramedullary nailing. All patients were given preoperative antibiotic prophylaxis, usually 3rd generation cephalosporin and an aminoglycoside half an hour before surgery.

We operated on the patients under aseptic conditions, with the patient in a supine position. The radius was approached through the lateral side of the distal metaphysis and ulna through the olecranon's tip. Nails of size 2.0 to 3.0 mm were usually used, depending on the medullary canal diameter. We checked the fracture reduction and stability intraoperatively with fluoroscopic guidance.

Post-operatively, IV antibiotics were given for two days and switched over to oral antibiotics on 3rd day, which were continued for one week. We immobilized the patients with an above elbow pop slab to encourage soft tissue healing. Patients were advised to do active finger movements postoperatively to reduce oedema. We removed stitches on the 10th postoperative day and continued the slab for up to 2 weeks. We started physiotherapy as early as possible and advised the patients to refrain from sports for eight weeks. We assessed the outcome using modified Anderson's AO criteria for forearm bone fractures.

Statistical Analysis

Data was entered and analysed by using MS Excel. Qualitative data was represented as percentages and quantitative data was represented as means and standard deviation.

Result	Union	Restriction of Movement	Function
Excellent	Union	Flex / Ext Nil to 15 Pron / Supin Nil to 15 Dors / Palmflex Nil to 15	No loss of function, no pain
Good	Union	Flex / Ext 15 to 30 Pron / Supin 15 to 25 Dors / Palmflex 15 to 25	Able to perform all the function, mild pain
Fair	Union	Flex / Ext 25 to 35 Pron / Supin 25 to 35 Dors / Palmflex 25 to 35	Moderate restriction of function, moderate pain
Poor	Non-union	With or without restriction of movement	Complete loss of function, severe pain

Table 1. Our Criteria Employed to Evaluate Functional Outcome

RESULTS

We operated on 30 patients of both bone forearm fractures with titanium elastic nails. We followed the patients at 4, 8 and 12 weeks with a final follow up at six months. We evaluated the patients both clinically and radiologically at each visit. At the end of 6 months' follow-up, we assessed the patients' outcome using Anderson's criteria. We achieved excellent results in 26 patients (86.6 %) and good results in 4 patients (13.3 %).

Out of 30 patients ranging from 6 - 15 years, 17 patients (56.6 %) were in 11 - 15 years' age group. Thirteen patients (43.3 %) were in the age group of 6 - 10 years. The mean age of our study was 11.7 years. Twenty-three patients (76.6 %) were males, and seven patients (23.3 %) were females. 23 fractures (76.6 %) were due to self-fall, five (16.6 %) due to road traffic accident, and the remaining two fractures (6.6 %) were due to fall from height. 18 patients (60 %) presented with a right forearm fracture, and 12 (40 %) with a left forearm fracture. Twenty-six patients (86.6 %) had a simple fracture, while four (13.3 %) had a type 1 compound fracture.

Complications	Number of Patients	%
Pain	02	6.6
Superficial infection	03	10
Deep	-	-
Compartment Syndrome	-	-
Inflammatory	-	-
Reaction to nails	-	-
Mal union	-	-
Delayed union	-	-
Non-union	-	-
Refracture	-	-
Nail migration	-	-
Rupture of tendons	-	-
Bursitis	01	3.3
Nerve palsy	-	-
Time of union (in weeks)		
≤ 6	04	13.3
6 - 9	18	60
9 - 12	08	26.6
Final outcome at 24 weeks		
Excellent	26	86.66
Good	04	13.33
Fair		
Poor		

Table 2. Demographic Data and Outcome of 30 Patients



Figure 1.
Range of
Movements –
Complete
Supination

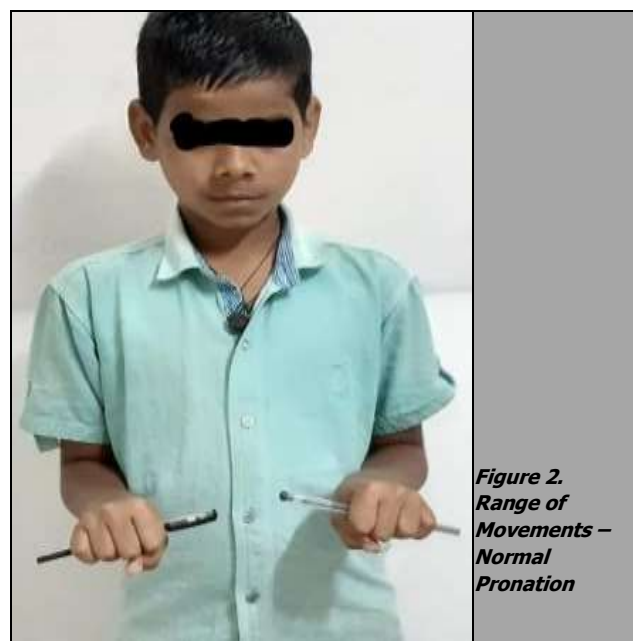


Figure 2.
Range of
Movements –
Normal
Pronation



Figure 3.
Pre-OP X-Ray



Figure 4.
Immediate Post OP X-Ray

In our study, we did a closed reduction in 27 patients (90 %), and an open reduction was needed in 3 patients (10 %) because of late presentation. We used 2.0 mm nails in five cases, 2.5 mm nails in 15 cases, 3 mm nails in ten cases. The operative procedure was completed within 50 minutes in most of the cases. The duration was more than 1 hr in three patients that required open reduction because of soft tissue interposition. There were minor complications in 6 patients (20 %). Three patients had a superficial infection, which subsided with oral antibiotics and regular dressings. One patient developed bursitis, and two patients developed pain due to nail irritation at the ulnar entry site which required early nail removal.

All the fractures united well with a mean period of 9.1 weeks. Fracture union was achieved in 4 patients (13.3 %) \leq 6 weeks, in 18 patients (60 %) between 6 - 9 weeks, and eight patients (26.6 %) between 9 - 12 weeks. No patients had non-union or delayed union. In our study, 26 patients (86.6 %) had restriction of movements at the forearm \leq 10°, and four patients (13.3 %) had restriction of movements between 10° - 30°.

DISCUSSION

Majority of diaphyseal forearm fractures in paediatric age group were treated conservatively with closed reduction and casting. However certain fractures in older children required operative management especially unstable and irreducible fractures because of unpredictable remodelling potential. Recent studies recommend the use of titanium elastic intramedullary nailing in paediatric forearm fractures because of excellent functional results.

The mean age of the patients in present study was 11.7 years with a range from 5 – 16 yrs. Most patients presented between 11 - 16 years (56.6 %). Similar observations were also made in 2019 by Amit Kumar et al.¹² with a mean age of 10.5 years and in 2016 by Kapila et al.¹³ with 11.2 years.

There were 23 male children (76.6 %), and seven female children (23.3 %) in present study. Parajuli et al.¹⁴ studied 50 patients in 2011, in which 38 were males (76 %) and 12 were females (24 %). In 2016 Shivanna et al.¹⁵ did a study in which 22 were males (73.3 %) and eight were female s(26.6 %). Divyanshu Goyal et al.¹⁶ did a study on 30 patients in which 21 patients (70 %) were males and 9 (30 %) were females.

In the present study, fall on an outstretched hand was the most common injury mode, accounting for 76.6 % (23 patients), road traffic accidents in 5 patients (16.6 %) cases, and fall from height in 2 patients (6.6 %). Similar results were reported in 2018 by Kishorchand Naorem et al.¹⁷ in which the mode of injury was a fall while playing in 70 % of patients, road traffic accidents in 16.67 % of patients, and fall from height in 13.3 % of patients.

In our present study, 18 children (60 %) had a fracture of the right forearm, and the rest 12 patients (40 %) had a fracture of the left forearm. In 2017 Dincer et al.¹⁸ reported similar results on 154 children with forearm fractures wherein 98 (63.6 %) patients had an injury on the right side, and 56 (36.4 %) had an injury on the left side. Harish K et al.¹⁹ did a study on 27 children out of which 11 patients (41 %) had left forearm fractures and 16 (59 %) had right forearm fractures.

There were 26 simple (closed) fractures constituting 86.6 % of total patients. There were four compound fractures (Gustilo and Anderson grade I) constituting 13.3 % of total patients.

These results were comparable with a study conducted in 2016 by Mohammad Ruhullah et al.²⁰ in which 18 % of patients had an open fracture and the remaining 82 % had closed fractures.

In 2017 Poojan Kumar Rokaya et al.²¹ did a study on 36 patients out of which 32 cases (88.9 %) were closed fractures and 4 cases (11.1 %) were open fractures. This result can be because the injuries in children are usually low energy injuries.

There were fractures at proximal 1 / 3rd in 9 patients (30 %), middle 1 / 3rd in 15 patients (50 %), and distal 1 / 3rd in 6 patients (20 %). In 2019 Ajay Kumar Sankhla, Laxmi Meena²² did a study on 50 patients in which fractures involved proximal third of shaft in 15 patients (30 %), middle third in 28 (56 %) and distal third in 7 patients (14 %). In a study done by Vishwanath C et al.²³ on 50 patients, 30

patients had middle 1 / 3 fractures (60 %), 12 patients had distal 1 / 3 fractures (24 %), 8 patients had proximal 1 / 3 fractures (16 %).

Amit Kumar et al.¹² concluded in their study that in proximal 3rd fractures in older children where chance of re-displacement is high and remodelling potential is low, elastic nailing is a good option, as it is minimally invasive, having low complications.

We did close reduction and internal fixation under fluoroscopy in 27 patients (90 %). However, three patients (10 %) required open reduction and internal fixation in those who presented late to the hospital. In 2019, Biswajit Sahu et al.²⁴ studied 40 children in which closed reduction was done in 37 patients (92.5 %), and three patients (7.25 %) required mini-open reduction.

In 2016, Daoud Makki et al.²⁵ stated in their study that both-bone fractures have higher rates of closed reduction than single-bone fractures. They reported an 80 % chance of successful closed reduction of at least one bone. They stated that open reduction should be performed when a few attempts of closed reduction have failed and that open reduction of radius, if required should be performed through a volar approach.

In our study, the average time between trauma and surgery was 4.3 days with most cases presenting within 5 days. One case presented after 6 days, two cases after 7 days.

Studies	Excellent	Good	Fair
Present study	86.6 %	13.3 %	-
Syed Ifthekar et al. ²⁸	90.62 %	9.37 %	-
Biswajit Sahu et al. ²⁴	87.5 %	10 %	2.5 %
Recep Dincer et al. ¹⁸	82.7 %	15.9 %	1.4 %
Mahesh Goyal et al. ³²	89 %	11 %	-
Bijaya Kumar Lamay ³⁴	87.5 %	10 %	2.5 %

Table 3. Functional Results in Various Studies

Siddaram Patil et al. reported an average time of 3.96 days between trauma and surgery with 2 cases presenting late after 1 week. Rajeev Dwivedi et al.²⁶ reported an average time of 2.75 days in 20 patients with a range from 2 - 5 days.

In our study, three patients (10 %) developed a superficial infection with an overall complication rate of 20 %. There were no major complications. In 2010 Flynn JM et al.²⁷ reported an overall complication rate of 14.6 % in 144 children. They concluded in their study that intramedullary nailing was frequently not "minimally invasive" and that an open fracture site delayed healing. They further stated that compartment syndrome was more frequent when IM nailing was done on the day of injury and older children had poorer outcomes and higher rates of delayed union.

Syed Ifthekar et al.²⁸ noticed an overall complication rate of 12.5 %. They reported in their study that only two patients had superficial skin infection and two patients had nail impingement out of 30 patients. Amit Kumar et al. reported a complication rate of 11.66 %. They did a study on 60 patients, three out of them developed superficial infection and four reported implant related skin irritation.

In our study, the average time for fracture union was 9.1 weeks with no cases of non-union.

There was no difference in time for fracture healing between fractures reduced by closed methods or open

methods. Dirgha Raj RC et al.²⁹ did a study on 73 patients treated with tens.

They reported an average time of 9.10 ± 1.81 weeks while time taken for union in children less than 10 years was 7.67 ± 1.25 weeks and that for children ≥ 10 years was 10.17 ± 1.25 weeks.

They noticed that time taken to heal the fractures reduced by open methods was slightly longer as compared to the fractures reduced by closed methods. Balakrishnan M. Acharya et al.³⁰ reported an average time of fracture union of 7.9 weeks in a study on 31 patients with forearm fractures managed with tens. Similar findings were reported in 2018 by Syed Ifthekar et al. in which the fracture union's meantime was 9.5 weeks.

In our study at 24 weeks, no patient had a loss of movement at the wrist and elbow. In 2005 Fernandez et al.³¹ studied the outcome between plating and nailing (ESIN) in children's forearm fractures. He reported no loss of movements at wrist and elbow in a group of patients managed by ESIN.

At 24 weeks, 26 patients (86.6 %) had a loss of movement at forearm by less than 10° , four patients (13.3 %) had a loss of movement at forearm by $10^\circ - 30^\circ$, and no patient had a loss of movement at forearm by more than 30° . The final results are similar to a study conducted in 2005 by

Kapoor V et al.³² 16 % of patients had a loss of motion at the forearm. Siddaram Patil reported that out of 30 patients, 28 patients (93.3 %) had full range of movements and 2 patients (6.6 %) had mild restriction of movements. In a study by Biswajit Sahu et al. On 40 patients, 35 patients had a loss of movement at the forearm by $\leq 15^\circ$ (87.5 %), four patients had a loss of movement by $15 - 30^\circ$.

The outcome was excellent in 26 patients (86.6 %) and good in 4 patients (13.3 %) in the present study. In 2010, Shah et al.³³ reported 83 % excellent results in a study on flexible titanium nailing in pediatric forearm fractures. In 2013, Mahesh Goyal et al.³⁴ reported 89 % excellent results in a study on 30 patients. Bijaya Kumar Lamay et al.³⁵ did a study on 40 patients, out of which 35 cases (87.5 %) showed excellent results and 10 % good results.

In 2016, Sheng-Hudu et al.³⁶ stated that single-bone intramedullary fixation of radius provides excellent outcomes and is a sufficient and effective method in treating both-bone forearm fractures in younger children. They further stated that dual bone fixation however is needed in older children (> 10 yrs.) to provide fracture stability, a shorter period of cast immobilization and joint stiffness.

In 2016, Liang Zhao et al.³⁷ reported that open reduction with plating had better anatomical correction of location of the radial bow than intramedullary nailing; however, percentage of patients with a loss of rotation in plating group was not reduced. They further concluded that plating was associated with a higher complication rate than intramedullary nailing.

In 2018, Bingqiang Han et al.³⁸ concluded in their study that refracture is rare in paediatric forearm fractures treated with ESIN and is often caused by second trauma. The male gender and distal third location of original fracture are risk factors for refractures, and the latter is independent risk

factor for refracture. They recommend the use of a short arm brace 2 - 3 months after cast removal for children with forearm fractures.

CONCLUSIONS

Although forearm fractures in children can be treated conservatively, they often lead to complications like malunion and restriction of movements. Based on our results, we conclude that elastic stable intramedullary nailing is a safe and effective technique for managing diaphyseal fractures of both bone forearm in children. It gives elastic mobility promoting rapid union at fractures site and stability, ideal for early mobilisation. This technique provides excellent results in terms of both radiological union and functional outcome.

The limitation of our study were small series of cases, short period of follow up, and lack of a comparative group. A similar study in future with another operative technique as comparative group would make our results more reliable. Considering the good results obtained in our study we recommend this technique for management of unstable diaphyseal forearm fractures in older children.

Data sharing statement provided by the authors is available with the full text of this article at jebmh.com.

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