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Original Research Article

Functional outcome of diaphyseal fractures of forearm in adolescents treated with TENS

Divyanshu Goyal*, S. L. Sharma, Laxmikant Meena, Ravindra Lamoria, Mahesh Bansal

Department of orthopaedics, SMS Medical College, Jaipur, Rajasthan, India

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***Correspondence:**
Dr. Divyanshu Goyal,
E-mail: drdivyanshugoyal@gmail.com

ABSTRACT

Background: A retrospective case series study was done on forearm diaphyseal fracture in adolescents treated with TENS (titanium elastic nailing system). Purpose of the study was analysis of functional outcome of TENS in forearm diaphyseal fractures in children between 12-18 year age group.
Methods: We retrospectively evaluated 30 patients operated by same senior surgeon during the period from March 2014 to February 2015 with closed diaphyseal forearm fractures in age group 12–18 years treated with TENS in whom closed reduction could not be achieved. Nail diameter taken as 33-40% of narrowest diameter of diaphysys were introduced proximally in ulna and distally in radius under image intensifier in closed manner. Postoperatively, patients encouraged for active shoulder, elbow and finger movements and suture removal done after 2 weeks. Patients were followed up for minimum period of one year.
Results: In terms of union and range of motion using Anderson et al criteria 24 patients had excellent results, 4 patients had satisfactory results and one patient had poor result having non-union of ulna. Two patients had superficial infection at the nail entry site which eventually resolved. One patient lost for follow up.
Conclusions: We conclude that TENS in both bone forearm fractures in adolescent age group in terms of union and range of motion is a minimally invasive and effective method of fixation.

Keywords: TENS, Forearm fracture, Adolescent forearm fracture, Adolescent diaphyseal fracture

INTRODUCTION

Forearm fractures have been reported as one of the most common paediatric fractures. Among children, 12–16 year age group adolescents have higher incidence.[1] Management of diaphyseal fractures of the forearm bones in adolescent without internal fixation has been quite challenging due to redisplacement even after successful closed reduction.[2] This leads to malunion of forearm bones and poor functional outcome.[3,4]

Therefore, it becomes necessary to manage these fractures with some form of internal fixation to achieve satisfactory union and range of motion and at the same without damaging the physis. Different methods of internal fixation are available including open reduction and plate fixation and closed reduction and elastic nailing. Disadvantages of plate fixation include large incision, more soft tissue damage, higher chances of infection, second surgery of similar magnitude for implant removal which is more cumbersome.[5]

Shoemaker et al suggested that the ideal fixation mode should maintain alignment, be minimally invasive and should have least complications. This has led to the use of intramedullary fixation devices. TENS allows early mobilization to achieve excellent range of motion as it provides three point fixation therefore mostly does not

require plaster of paris (POP) splint or cast and if required it is for shorter duration and is a minimally invasive procedure that spares physis, hence an overall satisfactory functional outcome. Also, implant removal is comparatively easy. Other devices for intramedullary fixation such as Kirschner wires/pins/nails lack these advantages and hence are inferior to TENS.[6,7]

In recent retrospective study Reinhardt et al, compared the outcome of both bone forearm fractures in older children 10-16 years of the age, after either intramedullary fixation or plate stabilisation. They found that intramedullary nailing and plate stabilisation were equally effective for forearm fractures in this age group and TENS has advantage of easy hardware removal. The study was however, limited in that the intramedullary fixation group had an average age of 12.5 years and plate stabilization group being somewhat older.[8]

Another study conducted by Shah et al, also attempted to investigate the fixation of adolescents both bone forearm fractures by comparing intramedullary fixation versus open reduction and internal fixation with plate. This study reports on group of adolescents including a number of quite mature patients, treated using a uniform protocol and stabilised with titanium elastic nails. The result reported strongly suggests that intramedullary fixation should be considered for stabilization of the forearm fractures seen in even older adolescents.[9]

The aim of our study was to evaluate clinical and radiological outcome of diaphyseal fractures of radius and ulna treated with titanium elastic nailing in 12 to 18 year age group of adolescent population.

METHODS

This prospective study was conducted during March 2014 to February 2015 at SMS Hospital Jaipur after approval from the review board.

This study included 30 patients of both sex and age group between 12 to 18 years admitted in the orthopaedic department with diaphyseal both bone forearm fractures. All cases were followed up for a minimum of 12 months period.

Patients who had isolated single forearm bone fractures, open injury, neuro vascular injury, undisplaced fractures and who refused to give consent were excluded from the study.

After admission proper radiographs were taken and a forearm slab was applied till the surgery. All routine pre-operative investigations were done and proper pre anaesthetic check-up was done.

Appropriate dosage of cefuroxime antibiotic intravenous was given and cleaning of whole affected limb with povidione iodine scrub was done immediately before the surgery.

Operative technique

All operations done by same senior surgeon and done in laminar OT with all aseptic precaution under general anaesthesia or supra clavicular block on a radiolucent OT table, closed reduction was done under image intensifier. After achieving satisfactory reduction, radius was fixed by retrograde nailing through dorsal aspect of distal radius proximal to radial physis and just medial to leister's tubercle. Utmost care was taken not to injure extensor tendons and superficial radial cutaneous nerve. Ulna was fixed by antegrade nailing through the lateral border of the olecranon just distal to the physis in the metaphysis. Nail length was determined by placing the nail on the draped forearm under the fluoroscopic guidance. Nail diameter was determined by measuring width of the canal at the narrowest point of the diaphysis in both AP and lateral view and taken as 33-40% of it according to Flynn et al.[10] The radius of curvature must be about 50-60 times greater than diameter of nail. The apex of curvature must be located on fracture site. Nail was also prebent 30 degrees at the tip. Nail contouring is most useful to control the corrective forces and adjust them according to local stress. Varus/valgus angulation can be addressed by directing the nail tip medially or laterally to contour the angulation forces. Similarly, in the sagittal plane, a recruvatum angulation can be corrected by directing the nail tip posteriorly and a flexion angulation by directing the tip nail so that the concave side face anteriorly. The ends were bent and cut flush to the bone leaving enough length for subsequent removal and buried under the skin in all cases.

Table 1: Classification of functional outcome.

S. no.	Result	Union	Flexion-extension at elbow	Pronation–supination forearm
1.	Excellent	Bony union	<10 degree loss	<25% loss
2.	Satisfactory	Bony union	<20 degree loss	<50% loss
3.	Unsatisfactory	Bony union	>30 degree loss	>50% loss
4.	Poor	Non union	+/- loss of motion	+/- loss of motion

Post-operatively majority of patients required no external immobilization. However, depending on fracture stability, in some patient's POP splint was given maximum up to 3 weeks in more comminuted fractures.

The patients were asked to report immediately for check-up if there is fever, abnormal swelling and pain at the site of operation. Start active finger movements as soon as possible. Patients were discharged after 48 hours and

called after 2 weeks for stitch removal. Patients were encouraged to do active shoulder, elbow, wrist and finger movements. After stitch removal patients were called for follow up at 2, 6 week, 3 month, 6 month and 1 year.

At every visit patients were assessed on subjective ground clinically and radiologically.

Clinical and functional outcomes were assessed on the basis of Anderson et al criteria.

RESULTS

30 patients involved in this study were followed up to one year. One patient lost for follow up after six weeks.

The youngest patient was 12 years old and oldest was 18 years with average age being 14.23 years.

Fracture both bone forearm was more common in male children than female, incidence being 21 and 9 respectively (Table 2).

Table 2: Distribution of cases according to gender.

Gender	No. of cases	Percentage
Male	21	70
Female	9	30

In this study right side 63.33% (19 cases) were more frequently involved than left side 36.66% (11 cases) (Table 3).

Table 3: Distribution of cases according to side involved.

Side involved	No. of cases	Percentage
Right	19	63.33
left	11	36.66

It was noticed that fracture site in 66.66% (20 cases) were middle third, 20% (6 cases) were lower third and 13.33% (4 cases) were in upper third (Table 4).

Majority of patients (96.55%) 28 cases had good range of motion (24 had excellent and 4 had satisfactory) (Figure 1 and 2). One patient had non-union of ulna with decreased range of motion.

Most common complication encountered in this study was development of superficial infection at the nail entry site in two patients (6.66%) which resolved eventually on giving antibiotics. One case went into non-union.

In our study majority of patients showed bridging callus within 4-6 weeks (79.5%). Earliest seen in 3 weeks and last one was around 12 weeks.

Out of 30 patients, 28 patients had radiological and clinical evidence of solid union. In one patient ulna went into non-union. The average time for complete radiological union for radius was 6-7 weeks and for ulna 7-8 weeks.

Figure 1: Shows pre-op and post-op and final follow up radiographs; (a) pre-op radiograph lateral view; (b) immediate post-op radiograph lateral view; (c) pre-op radiograph AP view; (d) immediate post op radio graph AP view; (e) radiograph at 3 months after union and removal of implant.

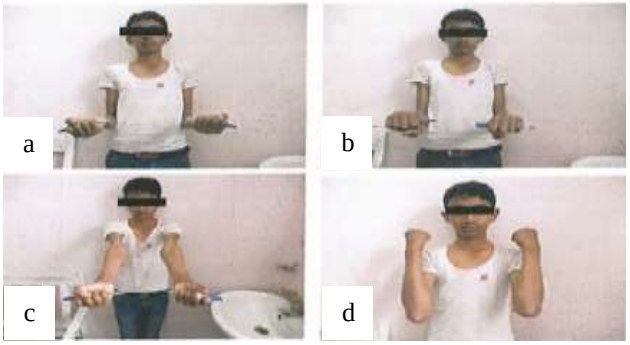

Figure 2: Shows range of motion at final follow up; (a) full range of supination; (b) full range of pronation; (c) full extension at elbow; (d) full flexion at elbow.

Based on Anderson et al criteria, excellent results were obtained in 24 cases (80%), satisfactory in 4 cases (13.33%) and poor or failure in one patient. One patient lost for follow up after 6 weeks (Table 5) (Figure 3).

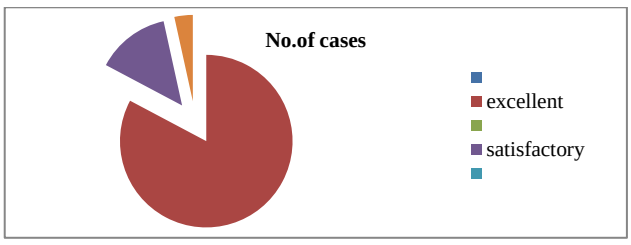

Figure 3: Results according to Anderson criteria.

Table 4: Distribution of cases according to fracture site.

Fracture site	No. of cases	Percentage
Proximal	4	13.33
Middle	20	66.66
Distal	6	20

Table 5: Results based on Anderson criteria.

Result	No. of cases	Percentage
Excellent	24	80
Satisfactory	4	13.33
Poor	1	3.33

DISCUSSION

Historically most diaphyseal fractures in children were treated by closed reduction and casting. However, fractures tend to redisplace especially in older children and when at more proximal location. Reduction criteria have been a matter of great debate. According to Price et al, angular deformity >10° and complete displacement account for unacceptable reduction.[11] Children younger than 9 years tend to tolerate greater deformity much better than older ones due to better remodel potential.[12,13] Franklin et al defined successful treatment of paediatric forearm fractures should result in painless and complication-free outcomes with functional pronosupintation.[13] It has been shown that 15 to 20 degrees of angulation in middle third forearm fractures can lead to major loss of forearm rotation.[9] Disuse osteopenia, muscle atrophy, skin breakdown, refracture, synostosis and elbow stiffness are some of the complications associated with conservative management. Loss of reduction is the most common complication in paediatric forearm fractures, with rates between 10 and 60%.[14,15]

In older children where remodelling capacity is less and where acceptable reduction cannot be achieved or redisplacement occurs after initial reduction, surgical operation should be considered. Considering these factors, we chose surgical intervention over conservative management. Commonly two methods are used for fixation, either open reduction internal fixation with plate or closed reduction and intramedullary fixation.

Open reduction and internal fixation with plates have an advantage of anatomical reduction with maintenance of radial bow.[16] Other advantages include early mobilisation and high fixation strength.[17] On the other hand plate fixation has disadvantages like excessive surgical dissection, neurovascular injury, hardware irritation, another major surgery of equal magnitude for implant removal, refracture after plate removal, peri-prosthetic fractures if plate not removed.[16,18-20]

Various studies have shown that IM nailing can provide acceptable fracture reduction, stabilization for fracture healing, results in minimal cosmetic deformity, and facilitates easy removal of implants after treatment.[21,22] It does not disturb the periosteal blood supply and fracture hematoma. Also, it allows micro motions at the fracture site which are beneficial for callus formation. It works on the principle of three point fixation thus does not allow angulation, translation or rotation post reduction. Some of the reported complications of this technique include superficial nail site infections, skin irritation at nail insertion sites, implant migration or failure (bent or broken pins), loss of reduction, refracture, tendon injury, decreased range of motion, delayed union/non-union.[23-26]

Amit et al described the results of treatment of 20 unstable diaphyseal fractures of the forearm in adolescent patients by closed intramedullary nailing. All fractures healed within 4-7 weeks. No cross-union, non-union, pseudarthrosis, or infection occurred. They stated that the advantages of this method are (a) maintenance of accurate reduction, (b) reduction of complication rate, (c) negligible cosmetic defect, and (d) removal of the internal fixation device under local anesthesia.[27] Our results are consistent with this study.

Kang et al found that in 90 consecutive paediatric patients treated with intramedually nailing, all ultimately were pain free and unlimited in their activities; however, there were 11 complications, including 1 compartment syndrome.[28]

In a recently conducted retrospective study by Kruppa et al, 201 consecutive patients with 202 forearm fractures were analysed. Age averaged 9.7 years (range 3–16 years). Fifteen (7.4%) fractures were open. Fractures were 82.2% diaphyseal both-bone forearm fractures. Follow-up averaged 10.2 months (range 0.7–176.3 months). Complications were 10 re-fractures, 2 malunions, 3 extensor pollicis longus tendon ruptures, 1 superficial wound infection, and 2 limited ranges of motions. Fourteen (6.9%) children required a secondary operative intervention for their complication. Time to implant removal averaged 3.8 months (range 0.4–16.3 months). They concluded elastic stable intramedullary nailing is a minimally invasive and reliable technique with a low complication rate. Both-bone forearm fractures and single bone fractures, and also Monteggia and Monteggia-equivalent fractures can be successfully treated with this method. As a major complication, re-fractures are frequently seen, even with ESIN in situ.[29] Higher re fracture rates can be attributed to early implant removal and improper physiotherapy.

All authors have not got the same good result with this technique. Few have claimed complication rate as high as 42% with intramedullary fixation.[5] Most of them claim that with increasing age of patients complication rate increases.

In a study conducted by Cullen et al, they found that older adolescents (mean age 13 year) treated with IM fixation demonstrated a higher complication rate, with a total of 18 complications occurring in 50% of patients.[23] Schmittenbecher et al, in a series of 532 patients treated with IM nailing, reported 10 cases of delayed union with an average age of 12.3 years.[26] In another study, Flynn et al found that IM fixation led to a higher rate of complications (14.6%) in patients of 10 years of age and older.[10]

Most of the studies conducted have average age of the patient 10 or less. There are few studies conducted in the elder age group of children. In our study age group lies between 12 to 18 years with average age being 14.23 years. We got excellent result in 80% of the patients and satisfactory in 13%, overall good results in 93% patients in terms of union and range of motion.

In a level 4 evidence study conducted by Wall and Lindley, the mean age of the patients was 14.1 years. 15.6% had limited postoperative range of motion. All patients in the older age group, 15–18 years of age, had a normal range of motion. A decrease in radial bow was not associated with limitation in motion. There was a 98% union rate. Only three major complications occurred, two refractures and one ulnar hardware migration, and subsequent radius non-union occurred in the one grade 3b injury. They concluded flexible intramedullary nailing of both bone forearm fractures provides reliable bony union and excellent postoperative clinical results in adolescents.[30] Age group of patients in our study and results of our study are consistent with this study.

In another study conducted by Martus, he compared paediatric and adolescent age group results treated with intramedullary fixation for forearm fractures. Post-operative compartment syndrome occurred in 3 isolated forearm fractures with a significant younger mean age (6.0 vs.10 year, p=0.031). Overall, complications were significantly more frequent in children older than 10 years of age (25/101) as compared with younger children (13/104, p=0.031). In particular, delayed union was more common in children over the age of 10 years (9/101 vs. 1/104, or=9.99, p=0.009). Outcomes were good or excellent in 91% of fractures. There was no statistical association of patient age with a fair or poor outcome.[31]

Another study conducted by Shah et al, also attempted to investigate the fixation of adolescents both bone forearm fractures by comparing intramedullary fixation versus open reduction and internal fixation with plate. This study reports on group of adolescents including a number of quite mature patients, treated using a uniform protocol and stabilised with titanium elastic nails. The result reported strongly suggests that intramedullary fixation should be considered for stabilization of the forearm fractures seen in even older adolescents.[9]

We faced very few complications with TENS in this study. One patient had superficial infection at nail entry site of ulna which was managed with oral antibiotics and nail was removed as soon as union was achieved. Another patient went into non-union for ulna. This was managed with removal of nail and plating along with bone grafting. Complications were few and manageable. We did not face complications like compartment syndrome, breakage of implant, neuro vascular injury, tendon injury or refracture after implant removal.

Overall, TENS has good results in adolescent forearm fractures if principles of closed reduction and three point fixation followed without damaging the surrounding soft tissue with the help of an image intensifier.

Our study has certain limitations like no control group in the form of conservative or plate fixation method. We did not include open fractures in our study and sample size can be larger.

CONCLUSION

We conclude that TENS in both bone forearm fracture in adolescent age group in terms of union and range of motion is a minimally invasive and effective method of fixation without significant complication rate.

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