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Functional and Radiological Outcome of Long Bone Fractures in Children (5-14 Years) Using Flexible Intramedullary Nail (FIN)

Deepak Singh[1], Sukhmin Singh[2], Nagaraj Manju Moger[3], Pritam Samanta[4]

[1]Senior Resident, Department of Orthopaedics, Vardhman Mahavir Medical College and Hospital, Safdarjung, New Delhi, India.
Email: drdeepaksingh24031988@gmail.com, ORCID ID: 0000-0001-7314-6391

[2]Senior Resident, Department of Orthopedics, Gautam Buddha Chikitsa Mahavidyalaya, Jhajhra, Dehradun, Uttarakhand, India.
Email: sukhmin92@gmail.com, ORCID ID: 0000-0001-9262-0650

[3]Senior Resident, Department of Orthopaedics, Vardhman Mahavir Medical College and Hospital, Safdarjung, New Delhi, India.
Email: nagarajmoger96@gmail.com, ORCID ID: 0000-0003-0712-5562

[4]Senior Resident, Department of Orthopaedics, Vardhman Mahavir Medical College and Hospital, Safdarjung, New Delhi, India.
Email: pritamsamanta.10@gmail.com, ORCID ID: 0000-0002-9767-9288

Abstract

Background: Treating fractures of long bones in children presents special challenges to the orthopaedic surgeons. In addition to smaller size, the presence of open physis and immature vascular patterns must be considered. Flexible intramedullary nailing (FIN) or titanium elastic nail (TEN) are preferred over conservative and other operative managements like traction, splints/ orthosis, plaster casts, external fixation, and open reduction and internal fixation using plates and screws nails for various long bone fractures in children older than five years. The purpose of the study was to find out clinical, functional and radiological outcome of long bone fractures in children between the age of 5 to 14 years treated using flexible intramedullary nail and report the complications associated with same. **Subjects and Methods:** A total 40 patients in the age group of 5-14 years with fractures of femur, tibia, humerus and radius/ulna were stabilized using flexible nailing. Clinical and radiological follow-up was done for a period of 3 years from October 2014 to October 2017. The functional results were analysed by using range of motion (ROM) in various joints and limb length and Radiological union was assessed by the identification of bridging callus at 3 cortices on antero-posterior and lateral radiographs. **Results:** Mean age at surgery was 9.77 years (range 7.29-12.25 years). The mean duration of surgery was 53 (35-90) minutes and the range of duration of hospital stay was 2-20 days. Delayed union (n=2) was the most common complication followed by superficial infection (n=1). 92.5% of cases achieved full range of motion, 82.5% cases were found radiological union within five weeks of operation. **Conclusion:** Based on our experience and results, we conclude that flexible intramedullary technique (FIN) as a minimal invasive procedure appears to be safe and reliable method that has good long-term results in the treatment of pediatric diaphyseal fractures of long bones in children aged 5-14 years. Early range of motion with bony union is achieved in most of patients but still require studies with larger data to validate the findings of this study.

Keywords: Elastic nailing, pediatric diaphyseal fractures.

Corresponding Author: Dr. Nagaraj Manju Moger, Senior Resident, Department of Orthopaedics, Vardhman Mahavir Medical College and Hospital, Safdarjung, New Delhi, India.
Email: nagarajmoger96@gmail.com

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Introduction

Pediatric trauma represents one of the largest challenges in paediatric healthcare as well as a great opportunity for positive impact on the same. Outpatient and inpatient side musculoskeletal trauma compromise largest share of paediatric injuries. The incidence of pediatric trauma is highest among developing nations.[1,2] Treating fractures of long bones in children presents special challenges to the orthopaedic surgeon. In addition to smaller size, the presence of open physis and immature vascular patterns must be considered. Historically several methods are used to treat paediatric long bone fractures and these include traction, splints/ orthosis, plaster casts, external fixation, and open reduction and internal fixation using plates and screws or intramedullary stabilization with a rod. The difficulties of non-surgical treatment while keeping children in plaster casts call for an alternative approach. Working parents, nuclear families with challenging home care, academic leaves and patient discomfort need to be considered while opting for non- surgical management. These modalities are not without complications. In addition, some require prolonged hospital admission, periods of inactivity and unsatisfactory bizarre scars. This has led to recent shift towards operative management that appears to produce better results than non-operative treatment but this paradigm in treatment has not been without some controversy.[3] Recent times have witnessed an upheaval

rising trend in the use of intramedullary fixation in the paediatric population by the orthopaedic community because of its advantages [operations can be done through small incisions without significant trauma to tissue, reduction can be performed as either a closed or an open procedure, thus the pathological bone area may be exposed and if required, biopsied, fracture haematoma, the periosteum and the surrounding soft tissue are spared to encourage accelerated formation of callus, being elastic not stiff nail can rapidly induce callus with subsequent secondary fracture healing, metal nails can be left in place without negatively affecting the healing of the bone disease, since, according to the prevailing opinion in the literature; no negative influence on the growth of the affected bone has been demonstrated to date and the removal of the implants is simple, quick and atraumatic over orthodox conservative and open reduction followed by fixation technique.[4] This interventionist attitude among the paediatric orthopaedic surgeons could be attributed to many factors including impositions by the modern world as well as new ergonomic instrumentations (like nail-bending instruments for altering the curvature of large-diameter nails, slotted hammer which can slide along the nail when it is fixed to the T-handle, cannulated impactors to push the nail at the end of the operation so as to leave a sufficiently long end above the bone surface for later removal but without inducing skin impingement) and in the field of implants including elastic stable intramedullary nail (ESIN), now called as flexible intramedullary nailing (FIN). The complication rates associated with FIN have been reported to be minimal. A review of the English literature has revealed that most of the reports regarding complications associated with this method relate to their use for treating femoral and tibial fractures. Currently, elastic nails are used in fractures in children over five years of age, mainly in the femoral shaft and the shaft of the forearm bones.[5,6,7,8,9,10,11,12,13,14,15,16]

The purpose of the study is to study the clinical, functional and radiological outcome of long bone fractures including femur, tibia, humerus and radius/ulna in children of 5 to 14 years age group treated using flexible intramedullary nail and report the complications associated with the same.

Subjects and Methods

This was a prospective non-randomized clinical study done over a period of 3 years from October 2014 to October 2017, conducted in the Department of Orthopedics at a tertiary care center in west India. The study was conducted in paediatric and adolescent patients of 5 to 14 years of age with fractures of long cylindrical bone admitted from OPD and Causality and were treated with titanium elastic nails and followed for period of 24 months. Inclusion criteria were 1) Diaphyseal fractures of femur, tibia, humerus, radius and ulna, 2) Simple and closed fractures, 3) Fracture without head injury. The patients were excluded if 1) Patients below 5 or above 16 years of age, 2) Metaphyseal fractures, 3) Compound fractures, 4) Pathological fractures associated with bone tumor, cerebral palsy, neuromuscular disorders or osteoporosis.

Ethical approval for the research study was obtained from the Institutional ethics committee. As soon as the patient was brought to OPD or casualty, patient's airway, breathing and circulation were assessed. Then a complete survey was carried out to rule out other significant injuries. Plain radiographs of AP and lateral views of the involved extremity including one joint above and one joint below were taken to assess the extent and geometry of fracture, and thus the fulfillment of selection criteria. On admission to ward, a detailed history was taken, relating to the age, sex, occupation (if any), mode of injury, and past and associated medical illness. Systemic examination was performed to recognize any preexisting medical and surgical illness such as cardiovascular, respiratory or renal disease. Local examination was conducted to know about the deformity, extent of swelling, local tenderness, and abnormal mobility. The neurovascular status was recorded in each case. Any associated injury was recorded and treatment carried out accordingly. Patients were operated as early as possible once the general condition of the patient was stable and patient was fit for surgery. Assessment was done at 6,12 and 24 weeks and at 1 year. At each follow up patients were assessed clinically and radiologically, and complications, if any were noted. Final follow-up outcome was assessed both clinically and radiologically. Following parameters were evaluated as a part of clinical assessment: 1) Range of movement, 2) Measurement of limb length – noted for shortening / lengthening, 3) Any restriction of joint motion at joints above & below the fracture site.

Radiologically union was assessed by the identification of bridging callus at 3 cortices on antero-posterior and lateral radiographs.

Nail Selection

For nail the diameter of the individual nail was selected as per Flynn et al formula.

According to recommendations, nail/medullary canal diameter ratio (ND/MCD) was meant to be greater than 40% in femur, tibia and forearm bones, and more than 33% in humerus. Nail sizing is crucial for titanium flexible nails and was determined by measuring the width of the isthmus of the long bone in two views and averaging the both dimensions, after subtracting 20% for the magnification factor. If single nail is being used its diameter should be more than 60% of the narrowest diameter of isthmus of the medullary canal. The length of the nail was selected by laying over the extremity and evaluated under fluoroscopy to confirm the appropriate length.[17,18,19]

Surgical Technique

All patients were operated under GA. The patient was positioned on a radiolucent table with access to the Image intensifier. The bone was exposed with a longitudinal incision and the soft tissues spread in the same direction with help of blunt tip scissors. The periosteum was also incised along the incision line and the cortex exposed. The outer cortex was perforated with a sharp curved awl and the

awl angled to enter the medullary cavity. It was ensured that the entry point should be in the middle of the width of the presenting cortex in lateral view. After making the entry points, the nails were inserted with the curved tip into the medullary cavity. The nail was manually pushed with the help of a T insertion handle until resistance was met and then gently hammered with the curve tip sliding on the inner cortex. Once the nails reached the fracture ends, especially in the femur where both nails were inserted first up to the fracture site, the fracture site was manipulated to allow reduction. Reduction was confirmed with image intensifier and correct passage of the nail was done. The nails were inserted retrograde in the femur, humerus and ulna and antegrade in the radius and tibia. Two nails of equal sizes appropriate for the width of the medullary cavity were selected. Varus or valgus angulation can be corrected by rotation of the nail 180° by T handle in such a way concavity faces the same direction of deformity. Once across the fracture site, the nails were inserted up to the metaphysis with the tips facing opposite directions to give good three-point purchase in the cancellous bone. The nails were left and cut 1.5 cm long and bend to lie along the bony cortex to prevent skin and soft tissue impingement. In some cases, the trailing ends are not required to bend and they are simply kept to lie against the cortical wall after trimming.

Post-operatively, patients were immobilized with long leg cast with a pelvic band for femur fracture or with above knee POP cast for tibia fracture for 6 weeks and such immobilization was continued for another 2-3weeks based on radiological assessment. The period of immobilization was followed by active hip and knee/knee and ankle mobilization with non-weight bearing crutch walking for lower limb fractures, active shoulder and elbow/elbow and wrist mobilization for upper limb fractures. Full weight bearing was started by 8-12 weeks depending on the fracture configuration and callus response. In case of forearm bone fractures, we immobilized the patient for 3 weeks in a posterior slab followed by allowing ROM exercises for elbow and wrist with sling for another 3 more weeks. Fracture were either splinted or placed into a soft dressing and kept on a sling comfortably for 10–14 days except ipsilateral upper extremity injury. No routine physical therapy was prescribed. Early mobilization without restriction was permitted for patients with isolated injuries. Patients with lower extremity fractures were permitted to bear weight on the upper extremity as tolerated.

Statistical Analysis

Descriptive statistics like numbers, percentages, average, standard deviations, were used. Data was presented in the form of tables and graphs wherever necessary. Inferential statistical tests like Chi- square and Fisher's exact probability test were applied to know the association between incidence of complications and clinical variables.

Results

During the period 2014-2017, 40 patients of age between 5-14 years of age group with various diaphyseal long bone fractures in children were treated by closed /open reduction and Titanium Elastic nail fixation. Majority of our patients (40%) were in >9-11 years age group. The average age of the patients was 9.77 ± 2.48 years. Road traffic accidents (RTA) were the most common mechanism of injury comprising approx- 52.5% patients, followed by simple fall and fall from height, each comprising 17.5 %. Sports related injuries were least common making only 5% of the total. Transverse fracture was the most common type in our study, comprising of 62.5%. Spiral fractures were least common, being only 7.5% of the total cases. Femur was the most common bone involved (57.5%), with fractures of middle one-third of shaft, being commonest. The injury surgery interval ranged from 0 to 7 days. Majority of the cases (55.5%) were operated within 2 days of injury, and 73% of total patients were treated within 4 days from trauma. The mean injury-surgery interval was 2.6 days, with a standard deviation of 1.66 days. Closed reduction was done in 35 cases and open was required in remaining 5 patients. The mean operative time in our study was 53 minutes, with a standard deviation of 12.39 mins. The Operative time ranged from 35 minutes to 90 mins in our study. The period of hospitalisation ranged from 2 to 20 days in our patients. Majority of patients (62.5%) were discharged within 10 days. Only 15% patients needed hospitalisation for more than 20 days. The time for radiological union of fractures in this series ranged from 3 weeks to nine weeks, with a mean of 4.72 weeks and standard deviation of 1.12 weeks [Table 1]. Majority of fractures (82%) showed radiological within 3 weeks (Figure 1). Only two cases had delayed union, but they also had union at 8 weeks and 9 weeks. No cases of non-union were reported. We assessed range of movement at joints proximal and distal to the fracture site in all patients at 24 weeks. Only 3 patients had mild restriction of movement. Rest all of the patients had full range of movement [Figure 2]. No patient had moderate or severe restriction of movement. Complications were seen in 3 cases with superficial wound infection in one case and delayed union in two cases.

Table 1: Study Details

No. of Patients	**40**
Gender	31 males 9 females
Age	9.77 ± 2.48 years
Type of fracture	Transverse- 25 Oblique - 8 Spiral- 3 Communited- 4

Bone involved	Femur- 23 Tibia- 5 Humerus- 7 Forearm- 5
Operative time	53 ± 12.39 minutes
Time to union	4.72 ± 1.12 weeks
Range of motion	Full ROM- 37 Mild restrictions-3

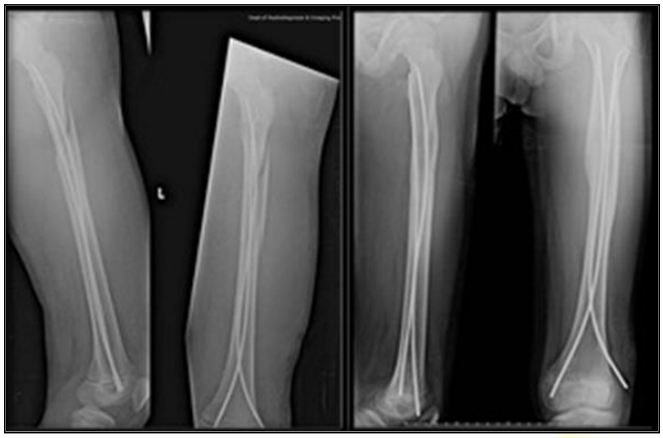

Figure 1: Shaft of femur fracture with immediate post operative and 1 year follow up radiograph

Figure 2: Research themes identified, GS; google scholar

Discussion

Diaphyseal fractures of long bones in pediatric population poses a difficult task for orthopedic surgeon to maintain a balance between bone healing and early mobilization. Earlier only transverse or oblique fractures were considered ideal indication for elastic nailing. However, such is the versatility of the method that the indications have widened considerably with time and personal experience.[20,21,22] The essential prerequisite is accurate pre-bending of the intramedullary nail so that the apex of the bend will lie at the fracture site. A second nail of equal diameter is prepared to provide a diametrically opposed curve at the fracture site. The diameter of the nail should be two-fifths of the internal diameter of the medullary canal. Skeletal traction and application of a cast had remained the preferred method for treatment of diaphyseal fractures in children for a long time due to the relatively conservative approach and a low incidence of permanent function impairing complications. Recent times have witnessed an upheaval rising trend in the use of intramedullary fixation in the paediatric population by the orthopaedic community. This interventionist attitude among the paediatric orthopaedic surgeons could be attributed to many factors including impositions by the modern world as well as the major technical developments in field of implants including elastic stable intramedullary nail (ESIN), now called as flexible intramedullary nailing (FIN).[23,24,25,26,27]

The fracture heals typically within eight to ten weeks and the presence of the nails does not appear to impair bone healing.[28] Non or delayed union is very uncommon and when it occurs may be related to the use of nails of inadequate diameter.[29,30] Otherwise, complications seem to be limited to discomfort or skin tenting at the sites of insertion of the nail.

Our study included 40 patients from age of to 5 to 14 years with diaphyseal fractures. The union rate was 100 % with average time for radiological union was 3 weeks. J. N. Ligier et al,[22] reported the average time to union as 7 weeks in their series. In study reported by Erik N Kubaik et al,[25] the average time for union was 7 weeks. Our study showed excellent results in terms of radiological union.

There are distinct advantages in terms of short operative time, short duration of hospital stay, fracture stability and early return to function, reasonable bone healing time, good functional outcome and low incidence of complications. Intramedullary nailing can be thought of as an internal splint that maintains length and alignment but permits sufficient motion at fracture site to generate excellent callus formation and stability, which is ideal for early mobilization. Because of early weight bearing, rapid healing and minimal disturbance of bone growth, FIN may be considered to be a physiological method of treatment. Use of FIN for definitive stabilization of diaphyseal fractures of long bones in children is a reliable, minimally invasive, and physeal protective treatment method.

Conclusion

Orthopaedic surgeons have been motivated to consider alternatives to traction and cast to avoid adverse physical, psychological and social consequences of prolonged immobilization of school aged children. Our study results

shows that FIN can be used successfully regardless of fracture location and fracture pattern. We believe that understanding the principles of this technique is paramount to achieving good results.

Flexible intramedullary technique (FIN) is a minimal invasive procedure which appears to be safe and reliable method that has good long-term results in the treatment of pediatric diaphyseal fractures of long bones in children. However, a larger study population is warranted to generalize the results to population.

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