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Management of Diaphyseal Fractures of Long Bones in Children with Titanium Elastic Nails – A Prospective Study of 30 Cases.

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ABSTRACT

Background: There is a little disagreement concerning the treatment of long bone fractures in children less than 6 years (plaster of paris cast) and adolescents older than 16 years (locked intramedullary nailing). Controversy persists regarding the age between 6 to 16 years, with several available options. Whatever the method of treatment, the goals should be to stabilize the fracture, to control length and alignment, to promote bone healing, and to minimize the morbidity and complications for the child and his/her family. The objective of this prospective clinical study was to evaluate the results of operative treatment of pediatric long bone fractures in the age group between 5 to 16 years using titanium elastic nailing system (TENS) nails. **Methods:** All children and adolescent patients between 5-16 years of age with diaphyseal fractures of long bones were admitted at Mamatha general and superspeciality hospital, Khammam. Meeting the inclusion and the exclusion criteria during the study period were the subjects for the study. Totally, 30 cases were studied without any sampling procedure. Patients were followed up at 6, 12 and 24 weeks after surgery and assessed clinically and radiologically. The final outcome is assessed as per Flynn's criteria as excellent/ satisfactory/poor. **Results:** The final outcome was excellent in 22 (73.33%) cases, satisfactory in 8 (26.67%) cases and there were no poor outcome cases. **Conclusion:** Titanium elastic nail fixation is a simple, easy, rapid, reliable, excellent and effective method for management of pediatric long bone fractures between the age of 5 to 16 years, with shorter operative time, lesser blood less, lesser radiation exposure, shorter hospital stay, and reasonable time to bone healing.

Keywords: diaphyseal fractures, titanium elastic nails, paediatric fracture.

INTRODUCTION

Treatment of paediatric fractures dramatically changed in 1982, when Métaizeau and the team from Nancy, France, developed the technique of elastic stable intramedullary nailing (ESIN) using titanium nails. In the last two decades there was an increased interest in the operative treatment of paediatric fractures, although debate persisted over its indications1. There is a little disagreement concerning the treatment of long bone fractures in children less than 6 years (POP cast) and adolescents older than 16 years (locked intramedullary nailing).[1] Controversy persists regarding the age between 6 to 16 years, with several available options: traction followed by hip spica, external fixation, flexible stable intramedullary nails, plate fixation, and locked intramedullary nailing. Whatever the method of treatment, the goals should be to stabilize the fracture, to control length and alignment, to promote bone healing, and to minimize the morbidity and complications for the child and his/her family.[1] Orthopaedic surgeons will continue to be challenged to treat this age group with less morbidity at a lower cost, as no clear guidelines have been available until now despite efforts done initially by French surgeons, later on by European surgeons and recently by the Paediatric Orthopaedic Society of North America (POSNA).[2] Titanium elastic nail (TEN) fixation was originally meant as an ideal treatment method for femoral fractures, but was gradually applied to other long bone fractures in children, as it represents a compromise between conservative and

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surgical therapeutic approaches with satisfactory results and minimal complications.[2] Our objective in this study was to evaluate the results of operative treatment - outcome, safety and efficacy of Titanium Elastic Nailing for the treatment of diaphyseal fractures of long bones in children in the age group between 5 to 16 years.

MATERIALS AND METHODS

All children and adolescent patients between 5-16 years of age with diaphyseal fractures of femur and / or tibia admitted at KIMS hospital, Bangalore - meeting the inclusion and the exclusion criteria (as given below) during the study period were the subjects for the study . Inclusion criteria included: 5-16 years of age, Diaphyseal fractures, Simple fractures (closed fractures), ipsilateral fractures and Fracture with head injury. Exclusion criteria included: Metaphyseal fractures, Compound fractures, Pathological fractures. As soon as the patient was brought to 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 thigh including hip and knee joints OR – the leg including knee and ankle to assess the extent of fracture comminution, the geometry and the dimensions of the fracture. Routine investigations were done for all patients. After prior informed consent, a pre-operative anesthetic evaluation is done. Pre-op planning of fixation is made. Patients were operated as early as possible once the general condition of the patient was stable and patient was fit for surgery.

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.

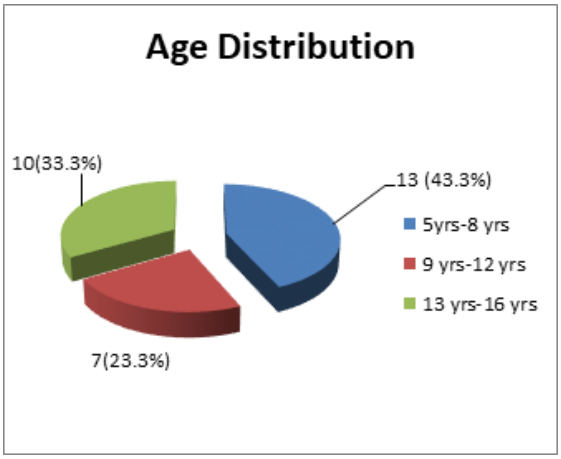
RESULTS

An outcome surgical study of 30 patients with Diaphyseal fractures of long bones is undertaken to study the outcome of Titanium elastic nail fixation for long bone fractures in children.

Table 1: Age distribution of patients studied.

Age in years	Number of patients	%
5-8	13	43.3
9-12	7	23.3
13-16	10	33.3
Total	30	100.0

In the present study 13(43.3%) of the patients were 5-8 years, 7 (23.3%) were 9 to 12 years and 10 (33.3%) were 13 to 16 years age group with the average age being 9.8 years.[Table 1 & Graph.1]

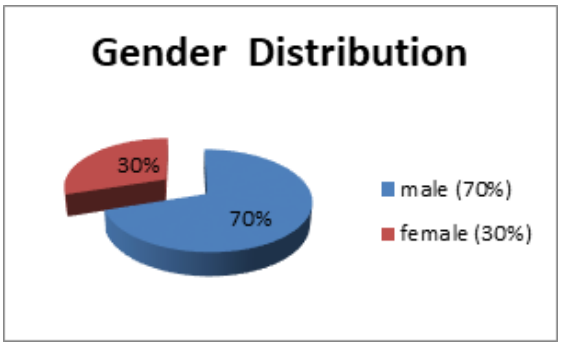


Graph 1: Age distribution of patients studied

There were 9 (30%) girls and 21 (70%) boys in the present study. [Table 2 & Graph 2]

Table 2: Gender distribution of patients studied.

Gender	Number of patients	%
Male	21	70.0
Female	9	30.0
Total	30	100.0



Graph 2: Gender distribution of patients studied.

In the present study RTA was the most common mode of injury accounting for 16 (53.3%) cases, self fall accounted for 11 (36.7%) cases and fall from height accounted for 3 (10%) of the cases. [Table 3]

Table 3: Mode of Injury of patients studied

Mode of injury	Number of patients	%
RTA	16	53.3
Self fall	11	36.7
Fall from height	3	10.0
Total	30	100.0

We studied 12 (40%) femoral, 10 (33.34%) tibial fractures, 4 (13.33%) humeral and 4 (13.33%) forearm bone fractures. [Table 4]

Table 4: Bone affected.

Bone affected	Number of Patients	%
Femur	12	40
Tibia	10	33.34
Humerus	4	13.33
Forearm bone	4	13.33
Total	30	100.0

In our study affected fractured bone was right side in 13 patients and 17 patients had left side bone fracture. [Table 5]

Table 5: Side affected.

Side affected	Number of patients	%
Right	13	43.3
Left	17	56.7
Total	30	100.0

In our study, transverse fractures accounted for 10 (33.3%) cases, communited fractures- 8 (26.7%), oblique fractures – 7 (23.3%), spiral fractures – 5 (16.7%) and there were no segmental fractures. [Table 6]

Table 6: Pattern of fracture.

Pattern of fracture	Number of patients	%
Transverse	10	33.3
Oblique	7	23.3
Spiral	5	16.7
Segmental	0	0.0
Communited	8	26.7
Total	30	100.0

Table 7: Time interval between trauma and surgery.

Time of interval between trauma & surgery	Number of patients	%
< 2days	6	20%
3-4 days	16	53.33%
5-7 days	6	20%
>7 days	2	6.67%
Total	30	100.0

In the present series, 6 (20%) patients underwent surgery within 2 days after trauma, 16 (53.33%) in 3 – 4 days, 6 (20%) in 5 – 7 days and 2 (6.67%) patients after 7 days. Among 2 cases in which duration was more than 7 days – one was case of Femur fracture – operated 8 days after trauma (admission) as they belong to lower socio economic status and took time to arrange for the expenses of the surgery. Another case was operated 10 days after trauma (admission) as the patient had abrasions at the incision site and we waited for it to heal. [Table 7]

In the present study, duration of surgery was < 30 mins in 1(3.3%) case, 30-60 mins in 13 (43.3%) cases, 61-90 mins in another 14 (46.7%) cases and 91-120 mins in 2 (6.7%) of the cases.[Table 8]

Table 8: Duration of surgery in minutes

Duration of surgery (min)	Number of patients	%
<30	1	3.3
30-60	13	43.3
61-90	14	46.7
91-120	2	6.7
Total	30	100.0

In our study, 21 (70%) cases were immobilized (long leg cast with a pelvic band for femur fracture / above knee POP cast for tibia fracture,"U"slab for humerus and A/E slab for forearm bone fractures) postoperatively for 6 weeks and such immobilization was for 9 weeks in rest of the 9 (30%) of the cases. The period of immobilization was followed by active hip and knee / knee and ankle mobilization with non-weight crutch walking for lower limb fractures, shoulder elbow and wrist mobilization for upper limb fractures. The average duration of immobilization was 6.9 weeks. [Table 9]

Table 9: Post-operative Immobilization.

Post-op immobilization	Number of patients	%
6 weeks	21	70
9 weeks	9	30
Total	30	100.0

The duration of stay in the hospital ≤ 7 days for 3 (10%) patients, 8-10 days for 12 (40%), 11-15 days for 11 (36.67%) and 4 (13.33%) patients stayed for more than 15 days. [Table 10]

Table 10: Duration of stay in hospital stay in days.

Duration of stay (days)	Number of patients	%
≤ 7	3	10
8-10	12	40
11-15	11	36.67
>15	4	13.33
Total	30	100.0

In our study union was achieved in <3 months in 24 (80%) of the patients and 3 – 4.5 months in 6 (20%). Average time to union was 12.1 weeks. [Table 11]

Table 11: Time for union

Time for union	Number of patients	%
< / = 12 weeks	24	80.0
>12 – 18 weeks	5	16.7
>18 – 24 weeks	1	3.3
Total	30	100.0

In our study full range of motion was achieved in 28 (93.33%) patients and there was mild restriction of movement in 2 (6.66%) patients. [Table 12]

Table 12: full range of motion.

Range of movements (degrees)	Number of patients	%
Full range	28	93.33
Mild restriction	2	6.66
Moderate restriction	0	0
Severe restriction	0	0
Total	30	100

In the present study, unsupported full weight bearing walking was started in <12 weeks for 17 (77.27%) of the patients, between 12 and 18 weeks in 4 (18.18%) and at 20 weeks in 1 (4.55%) among the total of 22 lower limb fractures. The average time of full weight bearing was 11.5 weeks. [Table 13]

Table 13: Time of full weight bearing

Time of full weight bearing	Number of patients (n=30)	%
≤ 12 weeks	24	80.0
>12 – 18 weeks	5	16.7
>18 – 24 weeks	1	3.3

In the present study, 2(6.67%) patients had developed pain at site of nail insertion during initial follow up evaluation which resolved completely in all of them by the end of 16 weeks. Superficial infection was seen in 1(3.3%) case in our study which was controlled by antibiotics. 1(3.33%) patients had shortening (femur – 1cm and) and 1(3.33%) had lengthening (femur – 1.2cm) No patient in our study had major limb length discrepancy (i.e. > ± 2cm). Some degree of angular deformity is frequent after femoral shaft fractures in children, but this usually remodels after growth. 1(3.33%) patients presented with varus (40) angulation 1(3.3%) patient presented with valgus (50) angulation. no patients had anteroposterior angulation. No patient in our study had significant rotational deformity. Proximal migration of the medial nail was noticed in one case in our study. During removal a cortical window was made and the nail was removed. [Table. 15A, 15B]

Table 15.A: Complications.

	Minor	Major	Nil	Total
No. of Patients	8	0	22	100
Percentage	26.67	-	73.33	100

Table 15.B. Complications

Complications	No. of cases	Percentage
Pain	2	6.6
Infection	1	3.3
Superficial	1	3.3
Deep	-	-
Inflammatory reaction	1	3.3
Delayed union and non union	-	-
Limb lengthening	1	3.3
< 2 cm	1	3.3
> 2 cm		
Limb shortening	2	6.6
< 2 cm	1	3.3
> 2 cm		
Nail back out	-	-
Mal alignment		
a. Varus angulation	1	3.3
b. Valgus angulation	1	3.3
c. Anterior angulation	-	-
d. Posterior angulation	-	-
e. Rotational malalignment	-	-
Bursa at the tip of the nail	-	-
Sinking of the nail into the medullary cavity	-	-

In the present study, the final outcome was excellent in 22 (73.33%) cases, satisfactory in 8 (26.67%) cases and there were no poor outcome cases. [Table 16, 17]

Table 16: Outcome

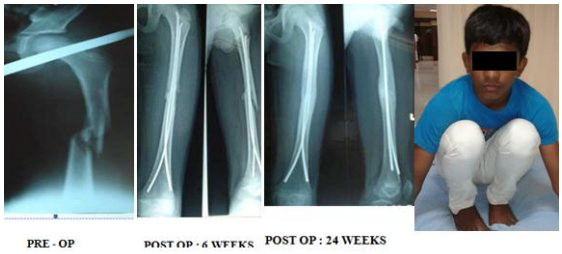
Outcome	Number of patients (n=30)	%
Excellent	22	73.33
Satisfactory	8	26.67
Poor	0	0.0

Table 17: Outcome for additional variables in the present study

Outcome Variables	Excellent (%)	Satisfactory (%)	Poor (%)
Range of movements	93.3	6.7	-
Time for union	80	20	-
Unsupported weight bearing	80	16.7	3.3

Clinical Photograph Of Operated Patients

Case 1:



Case 2:

DISCUSSION

In the present study 13(43.3%) of the patients were 5-8 years, 7 (23.3%)were 9 to 12 years and 10(33.3%) were 13 to 16 years age group with the average age being 9.8 years. J. N. Ligier et al studied children ranged from 5-16 years with a mean of 10.2 years.[2] Wudbhav N Sankar et al studied children ranged from 7.2-16 years with a mean of 12.2 years.[3]

There were 9(30%) girls and 21 (70%) boys in the present study. The sex incidence is comparable to other studies in the literature2. In their study J.N. Ligier et al out of 118 cases, 80 (67.7%) boys and 38 (32.3%) were girls. In the study of Gamal El-Adl et al. out of 66 patients, there were 48 (72.7%) male and 18 (27.3%) females.[4]

In the present study RTA was the most common mode of injury accounting for 16 (53.3%) cases, self fall accounted for 11 (36.7%) cases and fall from height accounted for 3 (10%) of the cases. J. M .Flynn et. al, in their study assessing 234 cases, 136(58.1%) were following RTAs, 46 (19.6%) were following self fall and remaining 43(28.8%) were as a result of fall from height.[5]

We studied 12 (40%) femoral, 10 (33.34%) tibial fractures, 4 (13.33%) humeral and 4 (13.33%) forearm bone fractures. In D.Furlan & Z. Pogorelic study had 42 (24.28%) femoral, 36(20.80%) tibial,[4,5] 53(30.64%) humeral and 42 (24.28%) forearm bone fractures.

In our study, transverse fractures accounted for 10(33.3%) cases, communited fractures- 8(26.7%), oblique fractures - 7(23.3%), spiral fractures – 5 (16.7%) and there were no segmental fractures. In their study J. N. Ligier et al. out of 123 femoral fractures studied 47 (38.2%) were transverse fractures, communited fractures- 25 (20.3%), oblique fractures - 7(23.3%), spiral fractures – 19 (15.4%) and 4 (3.2%) were segmental fractures.[2] Wudbhav N. Sankar studied 19 tibial shaft fractures out of which 9 (47.3%) were transverse, 7 (36.8%) were oblique, 2 (10.5%) were spiral and 1 (5.2%) was communited.[3]

In the present series, 6 (20%) patients underwent surgery within 2 days after trauma, 16(53.33%) in 3 – 4 days, 6(20%) in 5 – 7 days and 2(6.67%) patients after 7 days. Among 2 cases in which duration was more than 7 days – one case of Femur operated 8 days after trauma (admission) as they belong to lower socio economic status and took time to arrange for the expenses of the surgery. Another case was operated 10 days after trauma (admission) as the patient had abrasions at the incision site and we waited for it to heal. Average duration between trauma and surgery was 3.9 days in the study Gamal at el operated 56.1% of cases between 3-4 days after injury, 21.2% cases between 3 -4 days and 22.7% cases after 7 days4. K C Saika et al. operated 77.27% patients within 7 days of injury.[6]

In the present study, duration of surgery was < 30 minutes in 1(3.3%) case, 30-60 minutes in 13 (43.3%) cases, 61-90 minutes in another 14 (46.7%) cases and 91-120 minutes in 2 (6.7%) of the cases. Among the 2 cases in which duration was more than 90 minutes – one was case of femur which was proximal third fracture which took 96 minutes and other was case of femur which was communited fracture at the middle third which took 93 minutes. The extended duration of surgery in these cases was due to difficulty in reduction and passage of nail across the fracture site. The average duration of surgery in our study was 59.9 minutes. Khurram Barlas et al. study, the average duration of surgery was 70 mins7. In a study by K C Saikia et al., the duration of surgery ranged from 50 – 120 minutes with a median of 70 mins.[6]

In our study, 21 (70%) cases were immobilized (long leg cast with a pelvic band for femur fracture / above knee POP cast for tibia fracture,"U"slab for humerus and A/E slab for forearm bone fractures) postoperatively for 6 weeks and such immobilization was for 9 weeks in rest of the 9 (30%) of the cases. The period of immobilization was followed by active hip and knee / knee and ankle mobilization with non-weight crutch walking for lower limb fractures, shoulder elbow and wrist mobilization for upper limb fractures. The average duration of immobilization was 6.9 weeks. The average length of immobilization in plaster was 9.6 weeks in Gross R.H. et al study.[8]

John Ferguson et al treated 101 children with immediate hip spica casting. They immobilized children on an average duration of 10 -12 weeks with spica casting.[9] The advantage of the present study was early mobilization of the patients.

The duration of stay in the hospital ≤ 7 days for 3(10%) patients, 8-10 days for 12(40%), 11-15 days for 11(36.67%) and 4 (13.33%) patients stayed for more than 15 days. Among the 4 patients who stayed for more than 15 days, in 2 cases time interval between trauma (admission) and surgery was more therefore they stayed for 18 and 20 days respectively. One though operated within 3 days of injury, developed superficial infection which had to be dressed regularly, so stayed for 18 days. Another case that was operated 5 days after injury (admission) that stayed for 22 days waiting for his insurance scheme to be sanctioned. The average

duration of hospital stay in the present study is 11.6 days. The mean hospital stay was 12 days in Kalenderer O et al study17.Average hospitalization time was 11.4 days in the study conducted by Mann DC, et al.[10]

Gross RH, et al conducted a study on cast brace management of the femoral shaft fractures in children and young adults. The average length of hospitalization in their study was 18.7 days.[11] Compared to the above studies conducted on conservative methods and cast bracing, the average duration of hospital stay was less in our study i.e. 11.6 days. The reduced hospital stay in our series is because of proper selection of Patients, stable fixation and fewer incidences of complications.

In our study union was achieved in <3 months in 24 (80%) of the patients and 3 – 4.5 months in 6 (20%). Average time to union was 12.1 weeks. Oh C.W et al reported average time for union as 10.5 weeks.[12] Aksoy C, et al compared the results of compression plate fixation and flexible intramedullary nail insertion. Average time to union was 7.7 (4 to 10) months in the plating group and 4 (3 to 7) months for flexible intramedullary nailing.[21]

In our study, closed reduction of the fracture, leading to preservation of fracture hematoma, improved biomechanical stability and minimal soft tissue dissection led to rapid union of the fracture compared to compression plate fixation.

In the present study, unsupported full weight bearing walking was started in <12 weeks for 17 (77.27%) of the patients, between 12 and 18 weeks in 4 (18.18%) and at 20 weeks in 1 (4.55%) among the total of 22 lower limb fractures. The average time of full weight bearing was 11.5 weeks. Wudbhav N. Sankar et al. in their study allowed full weight bearing between 5.7 – 11.6 weeks an average of 8.65 weeks.[3]

In the present study, 2(6.67%) patients had developed pain at site of nail insertion during initial follow up evaluation which resolved completely in all of them by the end of 16 weeks. J.M.Flynn et al. reported 38 (16.2%) cases of pain at site of nail insertion out of 234 fractures treated with titanium elastic nails.[5]

Superficial infection was seen in 1(3.3%) case in our study which was controlled by antibiotics. J.M.Flynn et al. reported 4 (1.7%) cases of superficial infection at the site of nail insertion out of 234 fractures treated with titanium elastic nail5. Pin tract infection is a major disadvantage of external fixation application. Bar-on E, et al reported 2 cases of deep pin tract infection in their patients treated with external fixation.[13]

All patients had full range of hip and ankle motion in the present study and 2 (6.66%) patients had mild restriction in knee flexion at 12 weeks, but normal range of knee flexion was achieved at 8 months. J.M.Flynn et al. reported 2 (0.9%) cases of knee stiffness out of 234 fractures treated with titanium elastic nails.[5]

This is the most common sequel after femoral shaft fractures in children and adolescents. 1(3.33%) patients had shortening (femur – 1cm and) and 1(3.33%) had lengthening (femur – 1.2cm) No patient in our study had major limb length discrepancy (i.e. > ± 2cm). Beaty et al. reported two patients had overgrowth of more than 2.5 cm necessitating epiphysiodhesis, after conservative treatment.[14] Ozturkman Y. et al observed mean leg lengthening of 7mm in 4 (5%) patients and mean shortening of 6mm in 2 (2.5%) children.[15] Cramer KE, et al noted average limb lengthening of 7mm (range 1-19mm) in their study.[16] Clinically significant limb discrepancy (> 2cm) did not occur in any patient in their study56. Wudbhav N.Sankar in their study of 19 tibial shaft fractures reported no leg length discrepancy.[3] John Ferguson et al noted more than 2cm shortening in 4 children after spica treatment of pediatric femoral shaft fracture.[9] In the present study, limb length discrepancy of more than 10mm was present in 2 (10%) cases 49. Comparing to limb length discrepancy in conservative methods, limblength discrepancy in our study was within the acceptable limits.

In the present series, nail back out was not seen in any of the cases. Carrey T.P. et al out of 38 cases, noted nail back out in one case in their study, which necessitated early removal.[18]

Some degree of angular deformity is frequent after femoral shaft fractures in children, but this usually remodels after growth. Varus/valgus malalignment: 1(3.33%) patients presented with varus (4o) angulation 1(3.3%) patient presented with valgus (5o) angulation.

J.M.Flynn et al. reported 10 (4.3%) cases of minor angulation out of 234 fractures treated with titanium elastic nails.[5] Heinrich SD, et al reported 5° of varus angulation in one child in their study and 11 % of fractures had an average varus or valgus malalignment of 6°.[19]

Herndon WA, et al compared the results of femoral shaft fractures by spica casting and intramedullary nailing in adolescents. They noticed varus angulation ranging from 7 to 25° in 4 patients treated with spica casting and no varus angulation in surgical group.[20] The varus and valgus malalignment that occurred in our study are within the acceptable limits.

In the present study, no patients had anteroposterior angulation. Ozturkman Y, et al noted an anterior angulation of 7° and a posterior angulation of 6° in 2 patients respectively.[15] Herndon WA, et al noticed anterior angulation ranging from 8° to

35° in patients treated with traction and spica casting.[20] 8% of the patients had an average anterior or posterior angulation of 8° in Heinrich SD, et al study.[19]

A difference of more than 10° has been the criterion of significant deformity. No patient in our study had significant rotational deformity. Heinrich SD, et al out of 183 fractures studied, reported 8o out toeing in 4 children and two children with 5o in toeing following flexible intramedullary nailing. No patient in our study had significant rotational deformity.[19]

Proximal migration of the medial nail was noticed in one case in our study. During removal a cortical window was made and the nail was removed. Bar-on E, et al noticed proximal migration of the nail in one case.[13]

In the present study, the final outcome was excellent in 22 (73.33%) cases, satisfactory in 8 (26.67%) cases and there were no poor outcome cases. In D.Furlan5 and Z.Pogorelic study,[4] the final outcome was excellent in 89% cases, satisfactory in 11% cases and there were no cases showing poor outcome.

Outcome for additional variables in the present study

Outcome Variables	Excellent (%)	Satisfactory (%)	Poor (%)
Range of movements	93.3	6.7	-
Time for union	80	20	-
Unsupported weight bearing	80	16.7	3.3

CONCLUSION

Based on our experience and results, we conclude that elastic stable intramedullary nailing technique is an ideal method for treatment of pediatric diaphyseal fractures of long bones. It gives elastic mobility promoting rapid union at fracture site and stability which is ideal for early mobilization. It gives lower complication rate, good outcome when compared with other methods of treatment. Is a simple, easy, rapid, reliable and effective method for management of pediatric long bone fractures between the ages of 5 to 16 years, with shorter operative time, lesser blood less, lesser radiation exposure, shorter hospital stay, and reasonable time to bone healing. Because of early weight bearing, rapid healing and minimal disturbance of bone growth. Use of TENS for definitive stabilization of diaphyseal fractures of long bones in children is a reliable, minimally invasive, and physeal-protective treatment method. Our study results provide new evidence that expands the inclusion criteria for this treatment and shows that TENS can be successfully used regardless of fracture location and fracture pattern.

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