International Journal of Orthopaedics Sciences

ISSN: 2395-1958
IJOS 2016; 2(4): 31-35

www.orthopaper.com
Received: 07-08-2016
Accepted: 08-09-2016

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A prospective study of surgical management of diaphyseal fractures of femur & tibia in children aged between 5 to 16 years using elastic stable intra medullary nailing

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DOI: http://dx.doi.org/10.22271/ortho.2016.v2.i4.007

Abstract
Introduction: Elastic stable intramedullary nailing for the treatment of pediatric femur & tibia diaphyseal fractures was introduced by pr´evot and colleagues in 1979. The technique offers several advantages, including better reduction, dynamic axial stabilization, shorter hospitalization with early rehabilitation and low rate of complications.
Methods: 30 children between ages 5 to 16 years admitted to the department of Orthopedics at Sapthagiri institute of medical science and research center, Bangalore with diaphyseal fractures of femur & tibia during the period from November 2014 to February 2016 are selected.
Results: Our series consisted of 30 patients, 18 femur & 12 tibia. 24 male and only 6 female. Most common fracture pattern of femur & tibia was spiral. 23 fractures healed within an average duration of 10 to 12 weeks following surgery. There was superficial infection in 1 case, 2 cases had lld <2cm & 1 tibia case had nail backing out proximally which was treated with second surgery for implant removal after complete union of fracture.2 cases had varus angulation & 1 case had valgus angulation. All patients had full range of knee and ankle motion in the present study and 4 (13.33%) patients had mild restriction in knee flexion at 12 weeks.
Conclusion: based on our experience and results, we conclude that elastic stable intramedullary nailing technique is an ideal method for treatment of pediatric femur & tibial diaphyseal fractures.

Keywords: Diaphyseal femur & tibia, elastic stable intramedullary nailing, titanium elastic nailing system

Introduction
Treatment of paediatric fractures dramatically changed in 1982, when Métaizeau and the team from Nancy, France, developed the technique of flexible stable intramedullary pinning (FSIMP) using titanium pins [1, 2]. In the last two decades there was an increased interest in the operative treatment of paediatric fractures, although debate persisted over its indications [3].
Femoral shaft fractures account for 1.6% of all paediatric injuries. In children 5 years or younger, early closed reduction and application of spica cast is an ideal treatment for most diaphyseal fracture. In skeletally mature adolescents, use of antegrade solid intramedullary rod has become standard treatment. But, the best treatment for children between five to sixteen years of age is still debated. Compared with younger children, patients in this intermediate age group have high risk of shortening and malunion when conservative measures used [4].
Children managed with traction and spica cast as a treatment modality has to undergo various adverse physical, social, psychological and financial consequences, of prolonged immobilization. Various other modalities include external fixation, plates and screws, use of solid antegrade intramedullary nail are available. However, the risk of certain complications, particularly pintract infection and refractures after external fixation or osteonecrosis with solid nails [5, 6].
In the past seven years fixation with flexible intramedullary nails have become popular technique, for stabilizing femoral fracture in school aged children [6, 7]. ESIN fixation system is a simple, effective and minimally invasive technique. It gives stable fixation with rapid healing and prompt return of child to normal activity. This study was intended to assess the results following treatment of fracture shaft of femur by flexible intra medullary nail or elastic stable intramedullary technique [8].

Elastic stable intramedullary nailing of long bone fractures in the skeletally immature has gained widespread popularity because of its clinical effectiveness and low risk of complications. Many studies have supported the use of this technique in the femur, citing advantages that include closed insertion, preservation of the fracture hematoma, and a physeal-sparing entry point [9, 10]. The purpose of this study was to present our results following fixation of unstable femur shaft fractures with ESIN.

Methodology

All children and adolescent patients between 5-16 years of age with diaphyseal fractures of femur & tibia admitted at SIMS & RC, Bangalore - meeting the inclusion and the exclusion criteria (as given below) during the study period were the subjects for the study.

Inclusion criteria

- Children and adolescent patients from 5 to 16 year with diaphyseal femur & tibia fracture.
- children of both the sexes are included in the study
- children with closed diaphyseal fractures of femur
- Patient fit for surgery

Exclusion criteria

- Patients less than 5 years of age and more than 16 years of age.
- Patients unfit for surgery
- segmental fractures
- Patients not willing for surgery
- Patients medically unfit for surgery

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 & ankle joints to assess the extent of fracture comminution, the geometry and the dimensions of the fracture.

On admission to ward, a detailed history was taken, relating to the age, sex, and occupation, mode of injury, past and associated medical illness. Routine investigations were done for all patients. Patients were operated as early as possible once the general condition of the patient was stable and patient was fit for surgery.

After prior informed consent, a pre-operative anaesthetic evaluation is done. Pre-op planning of fixation is made.

Results

Table 1: Age distribution of patients studied

Age in years	Number of patients	%
5-8	16	53.3
9-12	7	23.3
13-16	7	23.3
Total	30	100.0

Table 2: Mode of Injury of patients studied

Mode of injury	Number of patients	%
RTA	18	60.0
Self fall	10	33.3
Fall from height	2	6.66
Total	30	100.0

Table 3: Pattern of fracture

Pattern of fracture	Number of patients	%
Transverse	11	36.6
Oblique	9	30.0
Spiral	10	33.3
Segmental	0	0.0
Comminuted	0	0.0
Total	30	100.0

Table 4: Level of fracture

Level of fracture	Number of patients	%
1. Proximal 1/3rd	13	43.3
2. MIDDLE 1/3rd	17	56.6
3. DISTAL 1/3rd	0	0.0
Total	30	100.0

Table 5: Duration of surgery in minutes

Duration of surgery (min)	Number of patients	%
<30	5	16.6
30-60	16	53.3
61-90	7	23.3
91-120	2	6.7
Total	30	100.0

Table 6: Post-operative Immobilization

Post-op immobilization	Number of patients	%
6 weeks	24	80.0
9 weeks	6	20.0
Total	30	100.0

Table 7: Time for union

Time for union	Number of patients	%
< / = 12 weeks	23	76.6
>12 – 18 weeks	5	16.6
>18 – 24 weeks	2	6.6
Total	30	100.0

Table 8: Outcome

Outcome	Number of patients (n=30)	%
Excellent	20	66.67
Satisfactory	10	33.34
Poor	0	0.0

Age incidence: In the present study 16(53.3%) of the patients were 5-8 years, 7 (23.3%)were 9 to 12 years and 7(23.3%) were 13 to 16 years age group with the average age being 9.03 years.

Sex incidence: There were 6(20%) girls and 24 (80%) boys in the present study. The sex incidence is comparable to other studies in the literature.

Mode of Injury: In the present study RTA was the most common mode of injury accounting for 18 (60.0%) cases, self fall accounted for 10 (33.3%) cases and fall from height accounted for 2 (6.66%) of the cases.

Pattern of Facture: In our study, transverse fractures accounted for 11(36.6%) cases, oblique fractures - 9(30.0%), spiral fractures – 10(33.3%) and there were no segmental fractures

Level of Fracture: Fractures involving the middle 1/3rd accounted for 15 (50%) cases, proximal 1/3rd – 10(33.3%) and there are 5(16.66) distal 1/3rd fractures in our study.

Time interval between trauma and surgery: In the present series, 16 (53.3%) patients underwent surgery within 2 days after trauma, 8(26.6%) in 3 – 4 days, 4(13.3%) in 5 – 7 days and 2(6.6%) patients after 7 days.

Duration of surgery in minutes : In the present study, duration of surgery was < 30 mins in 5(16.6%) case, 30-60 mins in 16 (53.3%) cases, 61-90 mins in another 7 (23.3%) cases and 91-120 mins in 2 (6.7%) of the cases.

Post-operative immobilization/mobilization: In our study, 24 (80%) cases were immobilized (long legslab with a pelvic band for femur fracture postoperatively for 2 weeks and such immobilization was for 4 weeks in rest of the 6 (20%) of the cases with associated injuries.
The period of immobilization was followed by active hip and knee / knee and ankle mobilization with non-weight crutch walking. The advantage of the present study was early mobilization of the patients.

Duration of stay in the hospital: The duration of stay in the hospital ≤ 7 days for 21 (70%) patients, 8-10 days for 3 (10%), 11-15 days for 4 (13.3%) and 2 (6.6%) patients stayed for more than 15 days with associated injuries. The average duration of hospital stay in the present study is 6.6 days.

Time for union: In our study union was achieved in <3 months in 23 (76.6%) of the patients and 3 – 4.5 months in 5 (16.6%) and 4.5- 6 months in 2(6.6%). Average time to union was 10.2 weeks.

Time of full weight bearing: In the present study, unsupported full weight bearing walking was started in <12 weeks for 23 (76.6%) of the patients, between 12 and 18 weeks in 5 (16.6%) and at 20 weeks in 2 (6.6%) patient. The average time of full weight bearing was 12.06 weeks.

Pain at the site of nail insertion: In the present study, 4(13.3%) 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.

Infection: Superficial infection was seen in 1(3.3%) case in our study which was controlled by antibiotics.

Range of motion: All patients had full range of hip and ankle motion in the present study and 4 (13.33%) patients had mild restriction in knee flexion at 12 weeks, but normal range of knee flexion was achieved at 6 months.

Limb length discrepancy: This is the most common sequele after femoral shaft fractures in children and adolescents. 2(6.66%) patients had lengthening (femur – 1.2cm). No patient in our study had major limb length discrepancy (i.e. > ± 2cm).

Malalignment: Some degree of angular deformity is frequent after femoral shaft fracturesin children, but this usually remodels after growth.

Varus/valgus malalignment: 2 (6.7%) patients presented with varus(8^0 and 6^0) angulation, 1(3.3%) patient presented with valgus(6^0) angulation.

Other complications: Bursa over tip of the nail was noticed in 3 case in our study; Implant removal is done in all the 3 cases.

Assesment of Outcome
In the present study, the final outcome was excellent in 20 (66.66%) cases, satisfactory in10 (33.33%) cases and there were no poor outcome cases based on FLYNN CRITERION.
TENS outcome score (Flynn *et al*) [19]

Discussion
The treatment of closed femoral shaft fractures in children has traditionally been traction and casting but children in the 5-15 year age group experienced a change in trend. Prolonged immobilization, short hospitalization of the child, concerns of the parents, risk of joint stiffness and delayed functional recovery have all prompted orthopaedicians to advocate for intramedullary nailing in form of ender's nail or titanium nails. The ideal implant should be simple, load sharing, and allow mobilization as well as maintain length until a callus forms.
Ender nails are stainless steel implants that proved to be inadequate for adult femoral and tibial fractures but may be effective for paediatric fractures although they may be not elastic enough as their modulus of elasticity is higher than titanium nails.
TENs are more elastic, thus limiting the amount of permanent deformation during nail insertion;
They promote healing by limiting stress shielding in addition to their biocompatibility without metal sensitivity reactions [11-15].
The principle of Ender nail fixation is canal filling with the nails, while TENs work by balancing
The forces between the two opposing flexible implants. To achieve this balance, the nail diameter
Should be 40% of the narrowest canal diameter or more; the nails should assume a double-C construct. They should have similar smooth curve and same level entry points [14, 16].
The development of the TENs fixation method has put an end to criticism of the surgical treatment of paediatric long bone fractures, as it avoids any growth disturbance by preserving the epiphyseal growth plate, it avoids bone damage or weakening through the elasticity of the construct, which provides a load sharing, biocompatible internal splint, and finally it entails a minimal risk of bone infection. The low incidence of complications reported in this study especially for malunion and limb-length discrepancy may be related to exclusion of extreme
Proximal and distal femoral fractures, meticulous adhesion to all technical requirements of the technique, and the use of postoperative immobilization in cases with concern about stability.
In our opinion, the exact value of TENs fixation of extreme proximal or distal femoral fractures
Should be evaluated on a large scale. The low incidence of complications reported in this study especially for malunion and limb-length discrepancy may be related to exclusion of extreme
Proximal and distal femoral fractures, meticulous adhesion to all technical requirements of the technique, and the use of postoperative immobilization in cases with concern about stability.
In our study union was achieved in <3 months in 23 (76.6%) of the patients and 3 – 4.5 months in 5 (16.6%) and 4.5- 6 months in 2(6.6%). Average time to union was 10.2 weeks.
Oh C.W *et al* reported average time for union as 10.5 weeks [17].
Aksoy C, *et al* compared the results of compression plate fixation and flexible intramedulalry 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 [18].

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 23 (76.6%) of the patients, between 12 and 18 weeks in 5 (16.6%) and at 20 weeks in 2 (6.6%) patient.

The average time of full weight bearing was 12.06 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 [19].

Limb length discrepancy:

This is the most common sequele after femoral shaft fractures in children and adolescents. 2(6.66%) patients 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 [20].

Ozturkman Y. *et al* observed mean leg lengthening of 7mm in 4 (5%) patients and mean shortening of 6mm in 2 (2.5%) children [21].

Cramer KE, *et al* noted average limb lengthening of 7mm (range 1-19mm) in their study. Clinically significant limb discrepancy (>2cm) did not occur in any patient in their study [22]

Wudbhav N. Sankar in their study of 19 tibial shaft fractures reported no leg length discrepancy [23]

John Ferguson *et al* noted more than 2cm shortening in 4 children after spica treatment of pediatric femoral shaft fracture. In the present study, limb length discrepancy of more than 10mm was present in 2 (10%) cases [24].

Comparing to limb length discrepancy in conservative methods, limblength discrepancy in our study was within the acceptable limits

In the present study, the final outcome was excellent in 20 (66.66%) cases, satisfactory in10 (33.33%) cases and there were no poor outcome cases.

Gamal El Adl *et al*. in their study of 66 children with 48 femoral and 25 tibial shaft fractures reported (75.8%) excellent, 24.2% satisfactory and no poor results [23].

J.M. Flynn *et al*. treated 234 femoral shaft fractures and the outcome was excellent in 150(65%) cases, satisfactory in 57 (25%) cases and poor in 23 (10%) of the cases [25].

Wudbhav N. Sankar in their study of 19 tibial shaft fractures reported 12 (63.15%) excellent, 6 (31.57%) satisfactory and 1 (5.26%) poor results [19]

K C Saikia *et al*. in their study of 22 children with femoral diaphyseal fractures reported 13 (59%) excellent, 6 (27.2%) satisfactory and 3(13.6%) poor results [26]

Conclusion

Use of ESINs for definitive stabilization of femoral and tibial shaft fractures 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 ESINs can be successfully used regardless of fracture location and fracture pattern.

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