Role of elastic stable intramedullary nail in the surgical management of diaphyseal fracture femur in children

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Abstract

Introduction:
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. 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.

Material and method:
The present study consisted of 25 cases with diaphyseal femoral fracture of either sex within age group 5-16 years, admitted in Orthopaedic Department, Guru Nanak Dev Hospital attached to Govt. Medical College, Amritsar and were treated with elastic stable intramedullary nail.

Inclusion criteria:
- Children and adolescent patients from 5 to 16 years with diaphyseal femur fracture.
- Children of both sexes were included in the study.
- Children with only closed diaphyseal femoral were included fractures.
- Patients otherwise fit for surgery were included.

Results:
In our study excellent results were obtained in 72% cases and satisfactory in remaining 28% cases.

Conclusion:
Elastic Stable Intramedullary Nailing (ESIN) is an ideal method for treatment of paediatric femoral fractures as it gives adequate stability with elastic mobility promoting early union at fracture site without loss of reduction.

Keywords: Elastic stable intramedullary nail, Diaphyseal fracture
Introduction

Treatment of pediatric fractures dramatically changed in 1982, when Metaizeau 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 paediatrics 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 are used\(^4,5,6\).

Children managed with traction and spica cast as a treatment modality have 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. However, there is a risk of certain complications, particularly pintract infection and refracture after external fixation or osteonecrosis with solid nails\(^4,5,6,7\).

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\(^8,9,10\).

Patient selection

Inclusion criteria:

- Children and adolescent patients from 5 to 16 years with diaphyseal femur fracture.
- Children of both sexes were included in the study.
- Children with only closed diaphyseal femoral were included fractures.
- Patients otherwise fit for surgery were included.

Exclusion criteria:

- Patients less than 5 years of age and more than 16 years of age.
- Patients unfit for surgery.

Materials and Methods

The present study consisted of 25 cases with diaphyseal femoral fracture of either sex within age group 5-16 years, admitted in Orthopaedic Department, Guru Nanak Dev Hospital, Amritsar and were treated with elastic stable intramedullary nail. The final outcome based on the above observations is done as per Flynn’s criteria (given below)\(^9\).
TENS outcome score

\begin{table}
\centering
\begin{tabular}{|c|c|c|c|}
\hline
\textbf{Variables} & \textbf{Excellent} & \textbf{Satisfactory} & \textbf{Poor} \\
\hline
Limb-length inequality & <1.0 cm & <2.0 cm & >2.0 cm \\
Malalignment & 5° & 10° & >10° \\
Unresolved pain & Absent & Absent & Present \\
Other complications & None & Minor and resolved & Major and lasting morbidity \\
\hline
\end{tabular}
\caption{Results at 24 weeks}
\end{table}

Additional variables included in our study

\begin{table}
\centering
\begin{tabular}{|c|c|c|c|}
\hline
\textbf{Variables} & \textbf{Excellent} & \textbf{Satisfactory} & \textbf{poor} \\
\hline
Range of movements & Full range & Mild restriction & Moderate-severe restriction \\
Time for union & 8-12 weeks & 13-18 weeks & >18 weeks \\
Unsupported weight bearing & 8-12 weeks & 13-18 weeks & >18 weeks \\
\hline
\end{tabular}
\caption{Variables}
\end{table}

\textbf{Results}

The present study consisted of 25 cases with diaphyseal femoral fracture of either sex within age group 5-16 yrs, admitted in orthopaedic department, Guru Nanak Dev Hospital Amritsar and were treated with elastic stable intramedullary nail. The patients were regularly followed and results of treatment with complications, if any were recorded and analysed.

In our study excellent results were obtained in 72% cases and satisfactory in remaining 28% cases.

\textbf{Age distribution of patients:}

In our study, 25 children with diaphyseal femoral fractures between the age 15-16 years were included. All were fresh cases. The oldest patients in our study was 14 years of age and the youngest being 5 years. 72% of the cases were <10 years of age and 28% were above 10 years age (as shown in Table 1).

\begin{table}
\centering
\begin{tabular}{|c|c|c|}
\hline
\textbf{Age in years} & \textbf{No. of patients} & \textbf{Percentage} \\
\hline
5-8 & 15 & 60.0 \\
9-12 & 7 & 28.0 \\
13-16 & 3 & 12.0 \\
Total & 25 & 100.0 \\
\hline
\end{tabular}
\caption{Age distribution of patients}
\end{table}

\textbf{Time for union:}

Of the 25 cases, 72% of the patients showed radiological union in 8-12 weeks, 24% in 13-18 weeks and 1 patient in 19-24 weeks. No patient had delayed or non union.
Table 2 Time for union

| Time for union | No. of patients | Percentage |
|----------------|-----------------|------------|
| 8-12 weeks     | 18              | 72.0       |
| 13-18 weeks    | 6               | 24.0       |
| 19-24 weeks    | 1               | 4.0        |
| Delayed union  | -               | -          |
| Non union      | -               | -          |
| Total          | 25              | 100.0      |

Complications

In the present study 4 (16%) patients complained of pain at site of nail insertion during initial follow up evaluation. Superficial infection was seen in 1 (4%) case which was controlled by antibiotics. 2 patients developed limb shortening of 1.5 cm. One patient developed varus angulation of 5°. Bursa at tip of nail was noticed in 4 cases.

Table 3 Complications

| Complications                  | No. of patients | Percentage |
|--------------------------------|-----------------|------------|
| Pain                           | 4               | 16.0       |
| Infection                      |                 |            |
| • Superficial                  | 1               | 4.0        |
| • Deep                         |                 |            |
| Inflammatory reaction          |                 |            |
| Delayed union                  |                 |            |
| Non union                      |                 |            |
| Limb lengthening               | 0               | 0          |
| Limb shortening                | 2               | 8.0        |
| Nail back out                  |                 |            |
| Malalignment                   |                 |            |
| • Varus angulation             | 1               | 4.0        |
| • Valgus angulation            |                 |            |
| • Anterior angulation          |                 |            |
| • Posterior angulation         |                 |            |
| • Rotational malalignment      |                 |            |
| Bursa at tip of nail           | 4               | 16.0       |
| Sinking of nail into medullary cavity |           |            |

Results:

In our study, excellent results were obtained in 72% cases, satisfactory results in the remaining 28% cases.

Table 4 Results

| Result          | No. of patients | Percentage |
|-----------------|-----------------|------------|
| Excellent       | 18              | 72.0       |
| Satisfactory    | 7               | 28.0       |
| Poor            | 0               | 0          |
| Total           | 25              | 100.0      |
Pre-operative X-ray

Post-operative X-ray

Complete union
In the present study conducted in GNDH, 25 patients with diaphyseal femur fracture within age group 5-16yrs were treated with elastic stable intramedullary nail. Overall final outcome of surgical management was assessed in accordance with the Flynn’s criteria.

In the our study, 15 patients were between 5-8yrs, 7 between 9-12 years and 3 between 13-16 years of age. Average age in our study was 8.16 yrs. J. N. Ligier et al studied children ranged from 5-16 years with a mean of 10.2 years\(^7\). Rohilla et al had a mean age of 7.6 years in their study of 73 cases.\(^{26}\)

There were 6 (24%) girls and 19 (76%) boys in the present study. The sex incidence is comparable to other studies in the literature. In their study J. N. Ligier et al. out of 118 cases, had 80 (67.7%) boys and 38 girls\(^7\). In the study of
Gamal El-Adl et al. out of 66 patients, there were 48 (72.7%) male and 18 (27.3%) females.\textsuperscript{11}

In the present study RTA was the most common mode of injury accounting for 22 (88%) cases and fall from height accounted for 3 (12%) of the cases. J. M. Flynn et. al, in their study of 234 cases reported 136 (58.1%) following RTAs, 46 (19.6%) following fall due to skidding and remaining 43 (28.8%) as a result of fall from height\textsuperscript{9}.

In our study, transverse fractures accounted for 12 (48%) cases, oblique fractures - 5 (20%), spiral fractures - 6 (24%) and 2 (8%) segmental fractures. In their study J. N. Ligier et al. out of 123 femoral fractures studied 47 (38.2%) were transverse fractures, comminuted fractures - 25 (20.3%), oblique fractures - 7 (23.3%), spiral fractures - 19 (15.4%) and 4 (3.2%) were segmental fractures\textsuperscript{7}.

In our study, 7 (28%) had fracture in the proximal 1/3 rd region, 17 (68%) in the middle 1/3 rd and 1 (4%) in the distal 1/3 rd. In Hanumantharaya et al. et study , out of 20 cases 25% were proximal 1/3 rd, 65% were in the middle 1/3 rd and 10% were in the distal 1/3 rd region of femur.\textsuperscript{12} In J. N. Ligier et al study among 123 femoral shaft fractures, 42 (34%) fractures were in the proximal 1/3 rd, 45 (36.5) in the middle 1/3 rd and 36 (29%) were in the distal 1/3 rd.\textsuperscript{7}

In the present study, 18 (72%) cases were operated within 2 days, 5 (20%) cases within 3-5 days and 2 (8%) cases were operated after 5 days. Out of these two, one patient reported to our hospital after 5 days of injury and was operated on 7 th day. The other patient was operated on 8 th day of injury due to delay in surgical fitness because of head injury. Gamal el al operated 56.1% of cases between 3-4 days after injury, 21.2% cases between 3 -4 days and 22.7% cases after 7 days\textsuperscript{11}.

In the present study, duration of surgery was < 30 mins in 2 (8%) cases, 30-60 mins in 17 (68%) cases, 61-90 mins in 6 (24%) cases . average duration of surgery was 48.6 mins. Surgery time >60 minutes was mostly due to difficulty in reduction in segmental and long spiral fractures.

In Hanumantharaya et al study, average duration of surgery was 82 mins\textsuperscript{12}. In Heybeli et al study (2004), average duration of surgery was 55 mins\textsuperscript{62} and in Bar-On et al study (1997) it was 74 mins\textsuperscript{13}.

The duration of stay in the hospital was <7 days in 19 (76%) cases and 8-12 days in the remaining 6 (24%) cases. The average duration of stay in hospital was 6.5 days. The mean hospital stay was 12 days in Kalenderer O et al study\textsuperscript{14}. Average hospitalization time was 11.4 days in the study conducted by Mann DC et al\textsuperscript{15}. 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\textsuperscript{16}. 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. 6.5 days. The reduced hospital stay in our series is because of proper selection of patients, stable fixation and less incidence of complications.

In our study union was achieved in 18 (72%) cases in less than 12 weeks, in 6 (24%) cases within 13-18 weeks and >18 weeks in 1 case. Average time of union was 10.9 weeks. Oh C.W et al\textsuperscript{28} reported average time for union as 10.5 weeks. 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\textsuperscript{17}. 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 was started in <12 weeks for 18 (72%) of the patients, between 13 and 18 weeks in 5 (20%) and at 20 weeks in 2 (8%) patient. The average time of full weight bearing was 11.6 weeks. The average time of full weight bearing in Flynn et al (2002) study was 8.5 weeks.

19 (76%) patients had full range of hip and knee motion in the present study and 6 (24%) 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. In our study, 4 (16%) 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. Superficial infection was seen in 1 (4%) 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 nails.

Leg length discrepancy is the most common sequela after femoral shaft fractures in children and adolescents. No patient in our study had major limb length discrepancy (i.e. > ± 2 cm). only 2 patients had shortening of 1.5 cm. Beaty et al. reported, two patients had overgrowth of more than 2.5 cm necessitating epiphysiodysis, after conservative treatment. Ozturkman Y et al observed mean leg lengthening of 7 mm in 4 (5%) patients and mean shortening of 6 mm in 2 (2.5%) children. Cramer KE, et al noted average limb lengthening of 7 mm (range 1-19 mm) in their study. Clinically significant limb discrepancy (> 2 cm) did not occur in any patient in their study. John Ferguson et al. noted more than 2 cm shortening in 4 children after spica treatment of pediatric femoral shaft fracture. In the present study, limb lengthening of more than 10 mm was present in 2 (10%) cases. Comparing to limb length discrepancy in conservative methods, limb length discrepancy in our study was within the acceptable limits.

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

Some degree of angular deformity is frequent after femoral shaft fractures in children, but this usually remodels after growth. In our study, 1 (4%) patient presented with varus angulation of 5 degrees. J.M.Flynn et al. reported 10 (4.3%) cases of minor angulation out of 234 fractures treated with titanium elastic nails. 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. The varus malalignment that occurred in our study is 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. Herndon WA, et al. noticed anterior angulation ranging from 8° to 35° in patients treated with traction and spica casting. 96.8% of the patients had an average anterior or posterior angulation of 8° in Heinrich SD, et al study. 16 out of 143 nails were removed due to protrusion, skin irritation and discomfort by Simonovsky et al.

In the present study, the final outcome was excellent in 18 (72%) cases, satisfactory in 7 (28%) cases and there were no poor outcome cases. 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. Heybeli et al. (2004) observed excellent results in 25 (71.4%) cases, satisfactory in 9 (25.7%) cases and poor in 1 (2.9%) case. Moroz et al. (2006) found excellent results in 150 (65%) cases, satisfactory in 57 (25%) cases and poor in 23 (10%) cases.

Conclusion

Based on our experience and results we conclude:

- Elastic Stable Intramedullary Nailing (ESIN) is an ideal method for treatment of
paediatric femoral fractures as it gives adequate stability with elastic mobility promoting early union at fracture site without loss of reduction.

- It is simple, easy, rapid and effective method for management of paediatric femoral fractures with shorter operative time, lesser blood loss and shorter hospital stay.
- ESIN is a reliable, minimally invasive and physeal-protective definitive treatment modality for diaphyseal fracture femur in children.
- It acts as biocompatible internal splint which provide adequate stability with minimal risk of infection.
- It helps in reducing the chances of malunion as loss of fracture reduction is not observed in our study.
- Early mobilisation of knee and hip can be initiated because of no immobilization of hip and joint as is compulsarily required in conservative treatment.
- Early weight bearing can be resorted to in all patients treated by ESIN without any fear of loss of reduction at the very first radiological sign of callus formation.
- The development of ESIN has put an end to misplaced fear of surgical treatment in paediatric femoral fractures vis-à-vis conservative method is not associated with any bone growth disturbance, any bone damage or weakening, due to physeoprotective surgical technique and elasticity of construct.

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References

1. Metaizeau JP. Osteosynthesis in children : techniques and indications (in French) ChirPédialtr1983; 69 : 495-511.
2. Metaizeau JP. Ostéosynthèse chez l’ Enfant :Embrochage Centro MédulaireElastique Stable. Sauramps Med Dif - fusion Vigot, Montpellier, 1988, pp 61-102.
3. Beatty JH, Austin SM, Warner WC. Interlocking intramedullary nailing of femoral shaft fractures in adolescents: preliminary results and complications. J PediatrOrthop1994; 14 : 178-183.
4. Scheri SA, Miller L, Lively N, Russinof S, Sullivan M, Tornetta P III et al. Accidental and nonaccidental femur fractures in children. ClinOrthop and Rel Research 2000; 376:96-105.
5. Momberger N, Stevens P, Smith J, Santora S, Scott S and Anderson J. Intramedullary nailing of femoral fractures in adolescents. J PediatrOrthop 2000; 20:482-484.
6. Lee SS, Mahar AT and Newton PO. Ender nail fixation of pediatric femur fractures. A biomechanical analysis. J PediatrOrthop 2001; 21: 442-445.
7. Ligier JN, Metaizeau JP, Prevot J and Lascombes P. Elastic stable intramedullary nailing of femur fracture in children. J Bone & Joint Surg (Br) 1988; 70B: 74-7.
8. Carey TP, Galpin RD. Flexible intramedullary nail fixation of pediatric femoral fractures. ClinOrthop 1996; 332:110–118.
9. Flynn JM, Hresko T, Reynolds RA, Blasier RD, Davidson R, Kasser J. Titanium elastic nails for pediatric femur fractures— a multicenter study of early results with analysis of complications. J PediatrOrthop 2001; 21(1):4–8
10. Metaizeau J. Stable elastic intramedulary nailing of fractures of the femur in children. J Bone Joint Surg Br 2004; 86:954–957.
11. Gamal El-Adl, Mohamed F. Mostafa, Mohamed A. Khalil, Ahmed Enan. Titanium elastic nail fixation for paediatric femoral and tibial fractures. ActaOrthopBelg 2009; 75: 512-520
12. Hanumantharaya GH and Kamala GR. A Clinical Study of Flexible Intramedullary Nailing in Management of Diaphyseal Fractures of Femur in Children and Adolescents (6-16 years of age).ISSN 2015; 3 (9): 198-207.
13. Bar-on E, Sagiv S and Porat S. External fixation or flexible intramedullary nailing for femoral shaft fractures in children. J Bone Joint Surg (Br) 1997; 79-B: 975-8.
14. Kalenderer O, Agus H and Sanli C. Open reduction and intramedullary fixation through minimal incision with ender nails in femoral fractures of children aged 6 to 16 years. ActaOrthopTraumatolTurc 2002; 36(4):303-9.
15. Mann shaft fractures in adolescents. J PediatrOrthop 1986; 6(6): 651-5.
16. Gross RH, Davidson R, Sullivan JA, Peeples RE and Hufft R. Cast brace management of the femoral shaft fracture in children and young adults. J PediatrOrthop 1983; 3 (5) : 572-582.
17. Aksoy C, Caolar O, Yazyoy M and Surat A. Pediatric femoral fractures A comparison of compression plate fixation and flexible intramedullary nail fixation. J Bone & Joint Surg (Br) 2003; 85-B (3): 263
18. Beaty JH, Austin SM, Warner WC. Interlocking intramedullary nailing of femoral shaft fractures in adolescents preliminary results and complications. J PediatrOrthop 1994; 14 (135): 178-183.
19. Ozturkman Y, Dogrul C, Balioglu MB and Karli M. Intramedullary stabilization of pediatric diaphyseal femur fracture with elastic ender nails. ActaOrthopTraumatolTurc 2002; 36 (3) : 220-7
20. Cramer KE, Tornetta P, Spero CR, Alter S, Miraliakbar H, Teeffey J. Ender rod fixation of femoral shaft fracture in children. ClinOrthop and Rel Research 2000; 376: 119-123.
21. Ferguson J, and Nicol RO. Entry spica treatment of pediatric femoral shaft fractures. J PediatrOrthop 2000; 20: 189-92.
22. Herndon WA, Mahnken RF, Yngve DA and Sullivan JA. Management of femoral shaft fractures in the adolescent. J PediatrOrthop 1989, 9(1): 29-32.
23. Heinrich SD, Drvaric DM, Darr K, MacEven GD. The operative stabilization of pediatric diaphyseal femur fractures with flexible intramedullary nails. A prospective analysis. J PediatrOrthop 1994; 14: 501-7.
24. Heybeli M, Muratli HH, Celebi L. The results of intramedullary fixation with titanium elastic nails in children with femoral fractures. ActaOrthopTraumatolTurc 2004; 38(3): 178-87.
25. Moroz LA, Launay F, Kocher MS, Newton PO, Frick SL, Sponseller PD, Flynn JM. Titanium elastic nailing of fractures of the femur in children Predictors of complications and poor outcome. J Bone Joint Surg 2006; 88-B(10).
26. Lohiya R, Bacchal V, Khan U, Kumar D, Vijayvargia V, Sankhala SS, Bhargava R, Jindal N. Flexible intramedullary nailing in paediatric femoral fractures. A report of 73 cases. Journal of Orthopaedic Surgery and Research 2011; 6:64.
27. Simanovsky N, Tair MA, Simanovsky N, Porat S. Removal of flexinail titanium nails in children. J PediatrOrthop. 2006 26(2); 188-92.
28. AS Oh chang-wug, Park Byung-chul, Kim Poong-Tack, Kyung Hee-Soo, Kim-Sung-jung, IhnJoo-chul. Retrograde flexible intramedullary nailing in children’s femoral fracture. International Orthopaedics 2002. 26(1):52-5.