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Titanium elastic nailing in pediatric femoral diaphyseal fractures

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Background: The need for operative fixation of pediatric femoral fractures is increasingly being recognised in the present decade. The conventional traction and casting method for management of pediatric femoral fractures is giving way for the operative stabilisation of the fracture.

Methods: Thirty five pediatric patients in age group 6-14 years with diaphyseal femoral fractures were stabilised with two titanium nails. Patients were followed up clinically and radiologically for two years. The final results were evaluated using the criteria of Flynn et al. Technical problems and complications associated with the procedure were also analysed.

Results: Overall results observed were excellent in 25, satisfactory in 8 and poor in 2 patients. Hospital time averaged 12.30 days in the series. All the fractures healed with an average time to union of 9.6 (6-14.4) weeks. Return to school was early with an average of 7.8 weeks. The soft tissue discomfort near the knee produced by the nails ends was the most common problem encountered. Shortening was observed in three cases and restriction of knee flexion in 5 patients. There was no delayed union, infection or refractures. Per operative technical problems included failure of closed reduction in 2 cases and cork screwing of nails in one case.

Conclusion: We believe that with proper operative technique and aftercare TENs may prove to be an ideal implant for pediatric femoral fracture fixation. The most of the complication associated with the procedure are infact features of inexact technique and can be eliminated by strictly adhering to the basic principles and technical aspects.

Key-words: Pediatric; Femur; Titanium elastic nailing

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Introduction

Orthopaedic surgeons have long maintained that all children who have sustained a diaphyseal femur fracture recover well with conservative treatment. The remodelling capacity of the pediatric femur can compensate for less than a perfect reduction. But time and experience of many clinicians have also shown that children with diaphyseal femur fracture do not always recover completely with conservative treatment. Angulation, shortening and malrotation are not always corrected[1].

There is little disagreement regarding the treatment of younger children (usually less than 6 years of age) and these can be treated with immediate spica casting[2]. These young children tolerate the cast well, are easily managed at home and mild to moderate fracture displacement and angulation correct well by growth and remodelling. The cost of care is low and outcome is generally good. Older children (usually older than 16 years of age) show good response with standard locked intramedullary femoral nailing techniques. For children that occupy the middle age group between 6-14 years, there are a wide variety of surgical and nonsurgical treatment options available as early spica casting, traction followed by casting, external fixation, plate fixation, reamed intramedullary rods and flexible intramedullary nails with no clear consensus as to the preferred treatment[3]. A systematic review of the literature provides little evidence to support one method of treatment over another[4].

Over the past two decades the advantages of fixation and rapid mobilization has been increasingly recognised.[5] Health care cost containment and a desire for early discharge from the hospital have become important factors in treatment of femoral shaft fracture. As a result newer techniques have become popular.[6] An ideal fixation device for pediatric femur fracture would be a load sharing internal splint maintaining reduction for a few weeks until callus forms. Most importantly implant should endanger neither the physis nor the blood supply to femoral head[5]. Titanium implants are increasingly being used for elastic stable intramedullary nailing. The material properties of titanium confer advantages for an

implant used to stabilise pediatric femur fractures. Titanium elasticity limits the amount that the nail is permanently deformed during insertion. More importantly elasticity promotes callus formation by limiting stress shielding. Titanium also has excellent biocompatibility[5]. As a result of these management dilemmas, we conducted a prospective study on the use of TENs for the treatment of children with diaphyseal femur fractures

Material and methods

After obtaining approval from our institutional board and informed consent, 35 pediatric patients having femoral diaphyseal fractures were treated with TENs from 2001 to 2005. Patients selected as the subjects of the study were of either sex and in the age group 6-14 years of age. Only cases having closed or grade I and grade II open fractures as determined by Gustilo's classification[7] were included in this study. Cases having sustained multiple system trauma were also included in the study. Children <6 and >14 years of age, femoral metaphyseal fractures, open Grade III femoral diaphyseal fractures, underlying neuromuscular disorder, a metabolic bone disorder, or pathologic fractures were excluded.

The ages of children ranged from 6-14 years with average age being 11.26 years. There were 28 boys and 7 girls who had sustained 20 right sided and 15 left sided fractures. The most common mechanism of injury was that of a pedestrian being involved in a motor vehicle accident (40%). Twenty eight fractures were in the middle third followed by proximal one-third (7) of the femoral shaft, and the most common fracture pattern was transverse fracture (15). Comminution was present in 8 cases. Associated injuries were present in 15 patients, 6 had head injury and 5 had fracture of other long bones.

TENs available in standard length of 440 mm, were used. The diameter of the nail (range 2.0 mm - 4.0 mm) to be used was determined on the basis of the size of medullary canal of the femur of the particular patient.

To determine the size of the titanium nails to be used, femoral diaphyseal internal diameter was measured on both antero-posterior and lateral roentgenograms and was divided by 2 and 0.5 mm was subtracted from that calculation for the eventual nail diameter as determined by Kasser and Beaty[8].

$$\text{Nail size} = \frac{\text{Internal diameter}}{2} - 0.5\ \text{mm}$$

Operative technique: Under general anaesthesia, the patient was placed on the fracture table and the image intensifier was used to localise the placement of skin incisions 2.5 cm above the distal femoral physis by viewing the distal femur in both anteroposterior and lateral planes. After soft tissue dissection, distal femoral metaphysis was exposed and opened using an awl at a point 2.5 cm proximal to distal femoral physis. The drill was then inclined so that it made an angle of 10 degrees with distal metaphyseal cortex for easy passage of the nail through the dense metaphyseal bone.

The titanium elastic nails were selected for the particular patient depending on the size of the medullary canal and contoured with a long gentle bend such that the apex of the convexity tends to lie at the level of the fracture. The nail tip was also bent to facilitate placement and also to allow the nail to bounce off the opposite cortex at the time of insertion. This also facilitated the spreading of the nail ends in proximal femoral metaphysis.

When this nail reached the fracture site, the fracture was reduced by manipulation and traction under image intensifier control. Once the fracture site was reduced the nail was pushed into proximal fragment. Then the medial incision was given and the second nail was inserted in a similar retrograde manner.

The two nails were then driven into the proximal end of the femur. The tip of the nail that entered from the lateral femoral cortex came to rest just distal to trochanteric apophysis. The opposite nail was made to lie at the same level but pointing towards the calcar region of femoral neck. Distally the nail was cut so that 1 cm of nail remains outside the cortex. The extraosseous portion of the nail was bent slightly away from the bone for easy removal after fracture union. Too much bending was avoided to prevent the formation of painful bursa over nail ends.

In the postoperative period patients were followed up initially at monthly intervals for first six months and then at three monthly intervals till the completion of one year after operation. At each visit patients were clinically and radiologically evaluated. The final results were evaluated using the criteria of Flynn et al[5].

Results

Median duration of surgery was 63 (50-70) minutes and the median hospital stay was 12.3 (8-36) days. The patients returned to school early with an average of 7.8 weeks. All the fractures healed with an average time to union 9.6 (6-14.4) weeks. Partial weight bearing with crutches was started at 4-

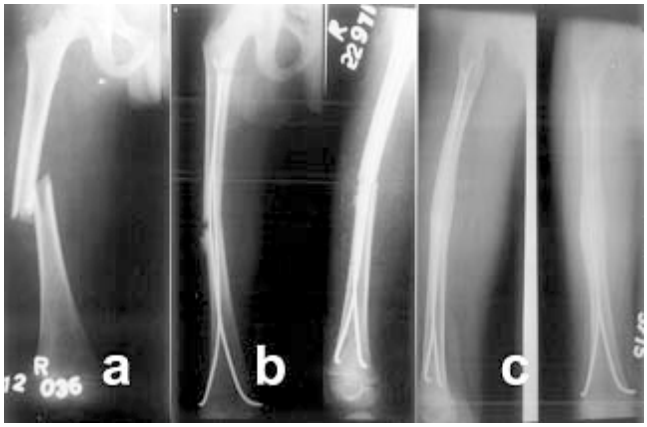

Fig.1. (a) ***A preoperative radiograph of a 13-year-old child with mid diaphyseal femoral fracture.*** **(b)** ***immediate postoperative anteroposterior and lateral views showing good reduction.*** **(c)** ***follow up X-rays after 1 year of TEN fixation shows good alignment and consolidation. Patient had excellent functional results.***

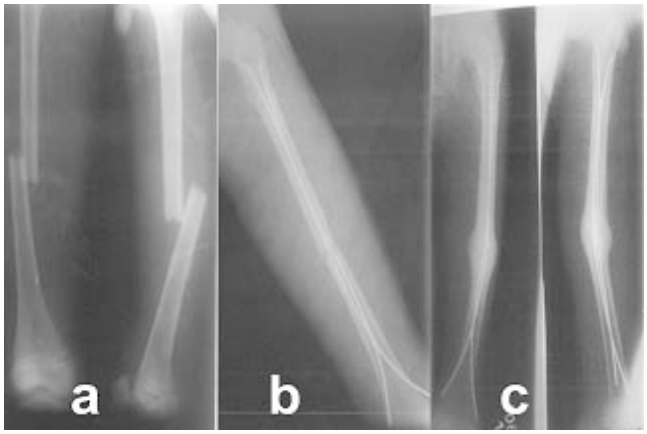

Fig. 2. (a) ***A preoperative radiograph of a 12-year-old child with transverse mid diaphyseal femoral fracture.*** **(b)** ***immediate postoperative X-ray showing good alignment, but the nails are thin and have apex of the curvature distal to the fracture site.*** **(c)** ***follow up X-rays at six months showing varus tilt of 10° and anterior tilt of 15°.***

8 weeks with an average of 4.56 weeks. External callus was visible on roentgenograms when partial weight bearing was started. Full weight bearing was started at 7-12 weeks in the series depending on the clinical and roentgenographic progress of fracture union with an average time of 8.3 weeks. The results as evaluated using the criteria as suggested by Flynn et al[5] were 25 excellent, 8 satisfactory and 2 poor (Fig.1a-c).

The most common problem encountered in the present series was skin irritation due to distal nail ends which occurred in 5 cases. It disappeared in all these cases after nails removal following union. Skin ulceration was seen in one of these cases and was taken care of after nail trimming under anaesthesia. Malalignment was seen at the fracture site in 3 cases. One of these three cases had varus tilt of 10° and posterior bowing of 10°, another case had varus tilt of 10° and anterior tilt of 15° (Fig.2a-c) and third one had varus of 16°.

Shortening was seen in three cases. Both the patients who had biplanar malalignment at the fracture site, also had shortening and third one had comminuted fracture and weight 62 kg. Shortening was 12 mm in two cases and 15mm in third one. No case of limb lengthening was seen. Range of motion at the knee was full i.e. 0-140° in 85.6% of the cases. Five cases had limitation in last 20° of knee flexion because of discomfort near the knee due to nail ends. Analysis of these cases showed that in three cases nails were cut too long and excessively bent at the ends; and in two cases insertion site were too high. This limitation in knee flexion improved when nails were removed after fracture union. Migration of the nails was not seen with titanium nailing. No soft tissue infection or osteomyelitis, physeal growth arrest or over growth was seen in the series.

Per operative technical difficulties encountered were difficulties in closed reduction requiring open reduction in two cases and cork screwing of one nail over other in one case. The nails were routinely removed at about 1 year after fracture fixation. No complications were associated with the nail removal procedure and no refractures were observed after nails removal.

Discussion

Femoral shaft fracture in the pediatric patients have traditionally been treated nonoperatively with either early spica cast or a period of traction followed by application of hip spica cast until the time of fracture union. This is the accepted standard of care for the young children but complications such as malunion, joint stiffness and delay in functional recovery are common in older children if managed in this manner[9]. Moreover, conservative treatment results in prolonged hospitalization causing more burden on the hospital and financial losses to the family with parents attending their children in the hospital. Recent studies have also increased awareness of the psychosocial and economic effects of spica casting on children and their families[5,10,11].

During the past few decades some form of internal fixation as plate fixation, rigid intramedullary nailing, Ender nailing, titanium nailing has been advocated but the controversy regarding the ideal implant to treat pediatric femoral fractures still exists[8]. The ideal device for the treatment of most femoral

fractures in children would be a simple, load sharing internal splint that allows mobilization and maintenance of alignment and extremity length until bridging callus forms. TENs offer these features[12]. Mazda et al treated 34 femoral shaft fractures with TENs. They observed that elastic properties of titanium provide a very good stability and it is a safe surgical treatment for immature femoral shaft fractures[13].

In the present series all the fractures united within 4 months of fixation with TENs with no nonunion or delayed union. The time when the patient had no pain at the fracture site on full weight bearing without support and roentgenographically the fracture had united was considered the union time. The patients belonging to the age group <10 years and those who had a transverse fracture pattern had a shorter union time. Oh et al observed that all 31 fractures in his series healed within 12 weeks (mean 10.5 weeks) without delayed union[14]. Buechsenchuetz et al reported that in 42 patients treated with ESIN all fractures healed at a mean of 88 days from injury[10]. Houshian et al reported median union time of 7 (5-9) weeks[15].

Partial and full weight bearing in the present series averaged 4.56 weeks and 8.3 weeks respectively. These are comparable to as reported in the literature[5,13,14]. In patients with comminuted fractures, head injuries and with associated injuries affecting the mobility of patients with crutches partial weight bearing was delayed. Oh et al used Ender nails and observed weight bearing without assistive devices at an average of 9.7 weeks (6-16 weeks)[14]. Flynn et al and Mazda et al observed walking without assistive devices at an average of 8.5 weeks and 9.5 weeks respectively in patients using TENs[5,13]. Houshian et al reported partial weight bearing as early as 3 weeks and full weight bearing after 6-8 weeks[15]. Early mobilization have all the benefits like shorter hospital stay; economical; less school days loss; psychological advantages; and less joint stiffness and muscle atrophy.

Hospitalization times have considerably decreased with titanium elastic nailing. Average hospitalization time was 12.30 days in the present series. Herndon et al showed that the hospital stay in the nonsurgical group averaged 28 days and in the surgical group averaged 17 days which was significant[16]. Reeves et al in a comparative study have shown that the mean hospital stay in the non-operative group was 29 days while in the operative group it was only 15 days[17]. The decreased hospitalization time has resulted in the decrease in the hospital bed occupancy, early return of patients to their home environment. And, it is also a cost effective treatment modality, as the parents can get back to their work earlier. Return to school averaged 6.8 weeks in the present series causing less disturbance in the continuation of studies of the patients. In the series of 15 children observed by Griesberg et al school absence averaged 120 days for patients in the casts while for ESIN group it was only 29 days[18]. Flynn et al reported that compared with children treated with traction and cast, those treated with TENs had shorter hospitalization, walked with support sooner, walked independently sooner, and returned to school earlier. These differences were significant ($p<0.0001$)[12].

Angulation in both anteroposterior and varus/valgus planes was seen in two cases. One case in whom two different diameter nails had to be used, had posterior bowing of 10° and varus tilt of 10°. TENs achieve axial and rotatory stability through so called “3-point support” and inner bracing. Nails of different thickness with the same pre-bending have a different “restoring force”, which pushes the proximal fragment into a varus or valgus position. To avoid such a complication in principle, two nails of same thickness and similarly pre-bended should always be used.[19] Another who had transverse fracture showed varus tilt of 10° and anterior angulation of 15° on fracture union. Retrospective analysis of this case showed that too thin nails were used in this case and contouring of the nails was not proper. Apex of the curvature was distal to the fracture site (Fig. 2a-c). We agree with Schmittenbecher et al that too thin nails in lower extremity can cause unacceptable problems, even in transverse fractures[20]. It is recommended that the apex of the curvature should be at the level of the fracture and nails diameter be related to correspond to between one third and 40% of the narrowest medullary space diameter[19]. These malalignments may require correction followed by additional plaster stabilization, replacement of the nails or additional stabilization by traction or external fixator till callus forms. A cautious approach is required for unstable fracture pattern and obese children. Comminuted unstable fractures have a tendency to angulate despite correct contouring of nails, a period of traction or brace may be necessary. There is no definite advice available in the literature whether elastic nails are strong enough to stabilize the fractures in heavier children[21]. These two factors were responsible for varus angulation of 16 degree in the third case. A brief period of bed rest or use of a femoral brace after the operation may be required[21].

Leg length discrepancy was seen only in cases who had angulation at the fracture sites. Based on the guidelines laid down by Kasser and Beaty for shortening only two cases

had clinically significant shortening.[8] Several more years of followup will be necessary before the precise final difference in the lower extremity lengths of each patients can be determined. We recommend adhering to biomechanical principles of elastic stable intramedullary nailing to avoid limb length discrepancy.

Skin irritation due to nail ends was the most common problem encountered in the series. For many years, outward bending of the nail to facilitate retrieval was recommended, but this can cause anything from irritation to skin necrosis and infection and therefore should be avoided.[19] Five (14.2%) cases had discomfort of the soft tissues due to nail ends near the knee and one of these cases developed skin ulceration due to nail impingement. These cases also had restriction of knee motion. Review of these cases showed in three cases nails were left too long and excessively bent; and in two cases insertion sites were too high. Insertion points that are too diaphyseal lead to severe muscle irritation. Moreover, during insertion and more so during removal of nail, the musculature is further damaged. Nails that are left too long in the distal femur, the iliotibial tract can be blocked, thus inhibiting knee flexion[19]. This problem resolved in all our patients once the nails were removed and patient with skin ulceration required trimming under anaesthesia. These were our initial operated cases and in subsequent cases we selected proper insertional sites and the nails were advanced so that they lie against the supracondylar flare of the femur with a small portion of nail left outside. The nails ends were cut straight rather than bending them to avoid symptoms at the insertion site. We had good results then. Fortunately none of these patients developed deeper infection.

Ligier et al observed 13 cases of skin ulceration or local inflammatory reaction due to nail protrusion out of 123 cases. Three of these required reintroduction of the nail while in the remaining 10 the nails were trimmed off under anaesthesia[22]. New instrumentation allowing nail removal when only a few mm of the nail is extraosseus may solve this problem.

Migration of the nails was not seen in the present series, this is probably because TEN technique requires balancing the forces of two opposing flexible implants and titanium nails do not tend to migrate. On the contrary, Ender nails which work on the principle of stacking the medullary canal tend to migrate. Two cases of proximal migration were observed by Karaoglu et al in the series of 31 femoral fractures stabilised with Ender nails[22,23].

No cases of infection were seen in the present series. The titanium elastic nailing requires only small incisions and the operative time is also less. Hence, infection is not a problem with this procedure. Similar results, regarding infection were observed by Herndon et al[16].

Per operative technical difficulties in three cases were also analysed. Soft tissue interposition was the cause of failure of closed reduction in two cases requiring open reduction. These cases were operated on 12th and 16th day post injury and had other associated injuries. We recommend proper traction / splintage if operative procedure is likely to be delayed. Excessive rotation of nail during difficult negotiation of the fracture site leads to wounding of the nail around the other. This "cork screw phenomenon" must be detected using image intensifer and avoided at all costs. Once the phenomenon has been detected, the nail in question must be removed during the same operation and replaced by correctly placed one[19].

Nails were removed as an out patient procedure under anaesthesia after one year of the fracture fixation, without any complication during or after the procedure. Theoretically it is possible to remove nails 3 months after surgery and in literature nails have been removed as early as 6 weeks[15]. There are always chances of refracture with early removals and delayed nail removal may be the factor responsible for no refracture in the present series.

In conclusion, titanium elastic nailing has considerably decreased the hospitalisation time resulting in early return of the patients to their home environment, thus cutting the cost of treatment and have psychosocial advantages. TEN technique, through the principle of two opposing balancing forces gives enough stability at the fracture site to allow early ambulation. It also allows a biological environment that enhances both the rate of fracture healing and quantity of callus formation. It may be considered to be a physiological method of treatment and it may prove to be the ideal implant to treat many pediatric femoral fractures. The technique is relatively simple, minimally invasive and healing occurs in an extremely natural way with a mass of callus. Most of the complication associated with it are infact features of inexact technique and can be eliminated by strictly adhering to the basic principles and technical aspects.

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