The combined use of titanium elastic intramedullary nails and postoperative skin traction in unstable femoral diaphyseal fractures in children

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Abstract

Background

Paediatric diaphyseal femoral fractures account for less than 2% of all paediatric fractures. Studies suggest that children aged 5–11 years who weigh < 49 kg with femoral diaphyseal fractures may be the best candidates for titanium elastic nails. Elastic flexible nailing has gained wide use because it offers good results with minimal complications in stable femoral diaphyseal fractures. However, the effectiveness of titanium elastic nails for the management of unstable paediatric femoral fractures remains debatable. This study aimed to elicit the effectiveness of titanium elastic nails in unstable paediatric femoral diaphyseal fractures when combined with postoperative immobilisation with skin traction.

Methods

This retrospective review included paediatric patients aged 3–11 years with unstable femoral shaft fractures treated with titanium elastic nails who were admitted to the paediatric orthopaedic department at a tertiary academic hospital between January 2017 and December 2020, and had a minimum follow-up of six months. The unstable fractures were spiral, comminuted, or long oblique fracture patterns.

Results

A total of 67 patients were reviewed, with a mean age of 6 (4–7) years. Fracture union was noted at eight (8–9) weeks. Fifty patients (75%) had excellent overall outcomes according to the Flynn score.

Conclusion

Retrograde titanium elastic nailing may be indicated for the management of unstable paediatric femoral fractures when supplemented by postoperative immobilisation with skin traction in the initial two weeks.

Level of evidence: 4

Keywords: epidemiology, children, unstable, titanium elastic nails, femoral shaft fractures, skin traction

Introduction

The titanium elastic nailing system (TENS) has gained wide use in our institution for paediatric femoral diaphyseal fractures, for both length-stable and length-unstable fractures. According to the literature, the indications for flexible intramedullary nailing for paediatric femoral shaft fractures include age 5–11 years, weight < 50 kg, and length-stable fracture patterns are the best indications as per Ligier et al. and Flynn et al. TENS may be an ideal and effective implant to stabilise many paediatric femoral fractures, avoiding prolonged immobilisation and complications of traction and spica casting.[1-3]

However, there is still a debate in the literature regarding the effectiveness of TENS for unstable fractures. Furthermore, controversies persist in the literature regarding the use of TENS in unstable fractures. According to the criteria of Sink et al., the fractures are designated as unstable (spiral, comminuted or long oblique) or stable (transverse and short oblique). Long oblique fractures are defined as fractures in which the length of the

obliquity is at least twice the size of the diameter of the diaphysis at the fracture site.[4]

Paediatric diaphyseal femur fractures account for less than 2% of all paediatric fractures.[5] Loder et al. stated that falls and motor vehicle collisions account for two-thirds of these injuries, with the incidence of falls being greater in younger children, and motor vehicle collisions being more prevalent in older children.[6] Unlike in adults, femoral shaft fractures in children are commonly isolated injuries.[7] Fifteen per cent of femoral fractures in children younger than two years are due to child abuse.[6,8] Several methods have been introduced to treat paediatric femoral fractures, including spica casting, traction followed by spica casting, internal fixation with a plate, intramedullary nailing, and external fixation.[8] Titanium elastic nails are currently the most popular treatment option for femoral shaft fractures in school-age children and young adolescents.[3] At our institution, a significant number of children presenting with femoral shaft fractures are admitted weekly, with both stable and unstable patterns. In our institutional setting, patients presenting with stable or unstable fracture patterns are managed with TENS and rarely undergo submuscular plating. This study aimed to determine the effectiveness and outcomes of the management of unstable paediatric femoral shaft fractures with titanium elastic nails when combined with postoperative immobilisation with skin traction.

Methods

The study was conducted at a tertiary academic hospital on paediatric orthopaedic patients between 3 and 11 years of age who were admitted to our institution with sustained femoral diaphyseal fractures, and were subsequently treated with titanium elastic nails from January 2017 to June 2020. Initial injury radiographs were used to classify the fractures according to their location and pattern. The initial injury radiographs were used to classify the fractures according to Sink et al. as unstable (spiral, comminuted or long oblique) and according to their location, fracture pattern and amount of comminution. The inclusion criteria for this study were cases of unstable femoral shaft fractures that were managed with titanium elastic nails and had at least six months of follow-up, irrespective of associated injuries or multiple trauma injuries. Cases managed by other methods (both operative and nonoperative), inadequate follow-up, and incomplete records were excluded. Progression to fracture union was assessed radiologically using Stans et al. criteria.[9] At subsequent follow-ups, radiographic malalignment, leg-length inequality, and any obvious implant-related complications were evaluated and recorded. Most of these patients with femoral diaphyseal fractures were operated on by orthopaedic registrars on the theatre emergency list, which runs daily from 16h00 to 07h00 on weekdays and 24 hours on weekends. All patients were followed until clinical and radiographic union was evident.

Statistical methods

Patients' medical charts and radiographs were assessed for information, including age, weight, sex, fracture pattern, treatment, union, reoperations and complications. Continuous variables, such as weight, were summarised as mean, standard deviation, median, interquartile range (IQR), and minimum and maximum values. Categorical variables (e.g. sex) are summarised using frequency counts and percentage calculations. Fractures were classified as unstable (spiral, comminuted or long oblique). Clinical outcomes were evaluated using the criteria of Flynn et al., who stated that the results of TENS for the treatment of paediatric femoral fractures are based on maximum allowable leg length inequality, malalignment, unresolved pain, and other complications.[3] The percentage of outcomes for each type was calculated using 95% confidence intervals (CIs). The findings from the unstable group were also recorded. The results are presented in tables and graphs according to age and the overall age. Statistical analyses or comparisons of patient subgroups (e.g., age groups) were performed where deemed feasible and clinically relevant. The study data were captured in an Excel spreadsheet and imported into SAS (SAS Institute Inc., Cary, NC, USA), Release 9.4 or higher, for statistical analysis. Statistical tests were two-sided, and p-values ≤ 0.05 were considered significant.

Surgical procedure

All procedures were performed based on principles and techniques as advised by Ligier et al.[2] The procedure was performed under general anaesthesia, supine with or without a traction table, and closed reduction was performed. Alignment was confirmed in the anteroposterior and lateral views using fluoroscopy. All the implants were inserted in a retrograde manner. The entry point was made with an awl, and titanium elastic nails of equal diameter were used. The diameters of the implants were approximately 40% of the narrowest diameter of the diaphysis.

The titanium elastic nails were pre-bent to three times the diameter of the medullary canal. Fracture reduction was performed under fluoroscopic guidance, and the implants were inserted and advanced through the distal fragment using lateral and medial entries to the proximal fragment. Throughout the procedure, implant and fracture positions were evaluated under fluoroscopic guidance. The distal protruding ends of the nails were cut close to the bone, and the wounds were sutured. If the closed reduction technique was unsuccessful, minimal open reduction was performed through a lateral incision. All patients were immobilised on a skin traction postoperatively and kept non-weight bearing for roughly two weeks (median of 14 days). Postoperative radiographs were obtained on the morning after the operation and before discharge at approximately two weeks. On discharge, the patients were allowed partial crutch or walking-frame weight-bearing. Patients were reviewed at four weeks (two weeks post-discharge) postoperatively to assess the insertion site, and at eight weeks to assess alignment and assess for fracture union. Once the fracture union was noted, the patients were followed up at three months and then six months. The weight-bearing status was increased with each visit, depending on the progression of fracture union. The walking aids were discontinued once fracture union was noted, and the patients could tolerate weight-bearing without any support. The removal of the implants at our institution normally takes place at or after six months after the operative day, once radiological and clinical fracture union is noted, which excludes the patients who developed complications that necessitated early implant removal. Clinical assessment for pain and limb length discrepancies was performed at follow-ups. The Picture Archiving and Communications System (PACS) program was used to measure fracture malalignment on both AP and lateral radiographs. Major complications were any complications that led to unplanned operations or led to poor outcomes, whereas any complications that resolved with non-surgical management were considered minor (nail irritation, nail migration, wound site infection). The results were evaluated using the outcome score described by Flynn et al. at the final follow-up,[3] with details of the criteria listed in *Table I*. The radiological assessment of union at the fracture site was assessed using the Stans criteria (details of the criteria are listed in *Table II*).

Results

A total of 67 patients with femoral diaphyseal fractures who met the inclusion criteria were reviewed during the study period. Radiographic union was achieved in all patients who were included in the study. This study included 55 males (81%) and 12 females (19%). Falls from a height were a common mode of injury, followed

Table I: Flynn scoring system[3]

	Excellent result	Satisfactory result	Poor result
Malalignment (°)	< 5	6–10	> 10
Leg length inequality (cm)	< 1	1–2	> 2
Pain	None	None	Present
Complications	None	Minor and resolved	Major complication

Table II: Radiological criteria – Stans et al. grading for callus formation[9]

Grade 0	No identifiable fracture healing
Grade 1	Primary bone healing with little or no periosteal new bone formation
Grade 2	Periosteal new bone formation on two sides of the femur
Grade 3	Periosteal new bone formation on three or four sides of the femur

Table III: Clinical characteristics of patients with femoral diaphyseal fracture

Characteristics	n (%)
Mechanism of injury	
Fell while playing	21 (31)
Gate injury	13 (19)
Fell from a height	11 (16)
Fell off a tree	8 (12)
PVA	6 (9)
Fell off a swing	2 (3)
MVA	2 (3)
Fall off the bed	1 (2)
Fell of a couch	1 (2)
Fell off bicycle	1 (2)
Fell off jungle gym	1 (2)
Side of injury	
Right femur	38 (57)
Left femur	29 (43)
Location of Injury	
Middle third	51 (76)
Proximal third	12 (18)
Distal third	4 (6)
Fracture patterns	
Long oblique	21 (31)
Spiral	17 (25)
Comminuted	13 (19)
Long oblique & comminuted	10 (15)
Spiral & comminuted	6 (9)

by gate injuries, falls from trees, and motor vehicle accidents. With regard to the affected side, 38 patients (57%) presented with right-sided fractures, and 29 (43%) had left-sided fractures. No case of bilateral femoral involvement was observed. Regarding the location affected, most fractures were in the middle third of the shaft (76%, 51 cases), followed by the proximal third fractures (18%, 12), and 6% involved the lower third. Regarding the fracture pattern, spiral fractures were seen in 17 cases (25%), long oblique fractures were seen in 21 cases (31%), six (9%) had spiral with comminution, and 13 cases (19%) presented with comminution (details of the results are listed in *Table III*).

The median patient age was 6 (4–7) years (range 2–12 years). Their median weight at presentation was 19.3 (15.5–24.3) kg, ranging from 10.5–45 kg. The median duration from admission to surgery was two (2–4) days. The period of immobilisation after surgery ranged from 7–20 days, with a median of 14 (12–15) days. The median duration from surgery to implant removal was eight (7–9) months, ranging from 1–17 months. The duration to union was a median (IQR) of 9 (8–9), with no significant difference between males and females concerning duration to union. Children with comminuted fractures were significantly older and heavier ($p < 0.05$) than those with spiral or long oblique fractures. In this study, 24 complications were identified. The most prevalent issues included proximal migration, pain, and skin tenting, each accounting for 17%. Notably, three patients required unplanned surgery due to major complications. Among them, 4% experienced complications related to protruding implants, prompting early

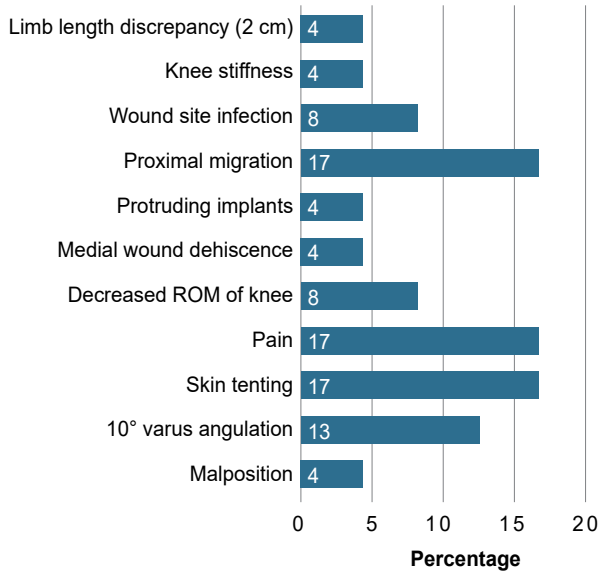

Figure 1. Percentage distribution of complications (n = 24)

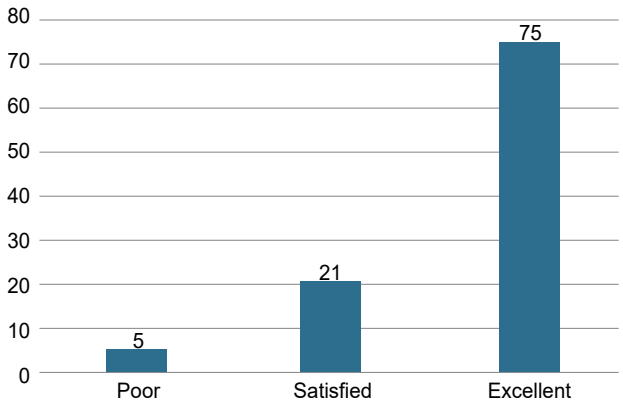

Figure 2. Outcome scores of patients with femoral diaphyseal fracture based on Flynn criteria[3]

removal. Additionally, three patients encountered early knee stiffness, leading to premature implant removal (*Figure 1*).

Figure 2 shows the functional outcomes using the Flynn criteria. In this study, the overall outcome was excellent in 50 patients (75%), satisfactory in 14 patients (21%), and poor in three patients (5%), based on the Flynn outcome score.[3]

Discussion

While the efficacy of TENS in unstable femoral diaphyseal fractures in children remains a topic of debate, some authors caution against its use because of potential complications and a high reoperation rate.[4,10] In the current study, we observed an impressive 75% outcome based on the Flynn outcome score. Numerous studies have reported positive outcomes for length-unstable femoral shaft fractures treated using TENS.[11-13] Li et al. conducted a retrospective study comparing flexible elastic nailing and submuscular plating for proximal femur fractures, revealing a 48% overall complication rate in the flexible elastic nailing group compared to 14% in the submuscular plating group.[14]

Contrary to the recommendations of Sink et al., who reported a 40% reoperation rate in length-unstable femoral fractures treated with TENS, our study reported a significantly lower reoperation rate of 5%.[4] Additionally, Narayanan et al.'s findings on fracture comminution did not align with our results, as in the cases with varus or valgus angulation.[10] While Moroz et al. reported a minor angulation rate of 4.3% in femoral fractures treated with TENS, our study similarly indicated a low rate of complications, with only 4% of the patients experiencing limb length discrepancies.[1] Flynn et al. and Staheli also reported the concept of overgrowth in femoral shaft fractures, supporting our observations.[15,16]

The most common minor complications in our study were pain (17%) and implant prominence (4%), consistent with existing literature.[4,10,11] Importantly, patients experiencing pain associated with prominent implants reported mild symptoms, and elective implant removal led to complete resolution. In terms of infections, 4% of our patients developed superficial wound site infections, which were successfully managed with dressings and oral antibiotics. Radiological assessment using the Stans et al. score[9] demonstrated 100% union, which is consistent with the findings of Flynn et al. and Sink et al.[3,17]

In our review, patients who presented with pain associated with prominent implants reported mild pain that did not require premature implant removal. Furthermore, all patients who presented with pain and implant prominence had complete resolution of symptoms following elective removal of implants. Flynn et al. reported that 16.8% of the patients with pain at the insertion site were treated with TENS.[3] Sink et al. reported that TENS yielded acceptable rates of minor complications regardless of the fracture pattern.[17]

In our study, 5% of patients developed superficial wound site infections, and they were treated with dressings and oral antibiotics, and the infections resolved. Flynn et al. reported that 1.7% of cases (4 out of 234) had a superficial infection at the nail insertion site. Radiological union was assessed using the Stans et al. criteria (*Table II*); 100% radiological union was achieved, and fractures united at an average of 8 (8–9) weeks. These findings are comparable to those reported by Flynn et al. and Sink et al.[3,4] Four patients presented with skin tenting due to prominent implants, and two patients presented with wound site infection; they were treated with dressings and oral antibiotics. Four patients experienced proximal implant migration. Allen et al. reported that TENS provides superior results to plating due to decreased operative time, estimated blood loss, and cost at both the index operation and hardware removal.[18]

Some authors have recommended additional postoperative immobilisation with a single-leg walking spica cast, hip-knee-ankle-foot orthosis (HKAFO), or knee immobiliser to increase stability and reduce complications following treatment with TENS in children with unstable femoral fractures.[10,19,20] In our review, the postoperative immobilisation period was roughly two weeks to allow callus formation. Immobilisation also avoids any deforming force at the fracture site till the callus is formed, after which children are referred to physiotherapy for mobilisation and knee range of motion programmes, and quadriceps and hamstring strengthening exercises. The modality for immobilisation was skin traction and weight, and no backslab or circular cast was applied. None of the children was mobilised immediately postoperatively. Li et al. stated that no postoperative immobilisation is necessary for patients treated with submuscular plating, and toe-touch weight-bearing can be initiated immediately postoperatively.[21] Notably, three cases (17%) in our study experienced proximal migration, a point of divergence from Bar-On et al.'s report of one case.[22] Moroz et al. suggested a nonsignificant association between poor outcomes and fractures in the distal third, which was not mirrored in our findings.[1] Our study is not without limitations, as this was a retrospective study. Limitations include the exclusion of certain unstable patterns, and challenges related to poor record-keeping and note-writing in the hospital files, across theatres, ward rounds, and outpatient departments, which hindered comprehensive data collection on patient complications.

Conclusion and recommendations

Our study concludes that titanium elastic intramedullary nails can be a viable option for treating unstable paediatric femoral diaphyseal fractures, yielding favourable long-term results. Retrograde TENS, when supplemented with postoperative immobilisation using skin traction for the initial two weeks, demonstrated positive outcomes in managing length-unstable paediatric femur fractures.

We recommend further investigations on a larger scale or as a multicentre study involving paediatric patients with femoral shaft fractures with extended follow-up periods. A comparative study between stable and unstable femoral shaft fractures would be beneficial, as would research directly comparing the outcomes of titanium elastic intramedullary nailing and submuscular plating in unstable femoral shaft fractures.

Ethics statement

The authors declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010.

Before commencing the study, ethical approval was obtained from the institutional ethical Review Board of the Sefako Makgatho University Research Ethical Committee (SMUREC/M/272/2020: PG). All procedures were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. This was a retrospective study, therefore, informed written consent was not obtained from the patients.

Declaration

The authors declare authorship of this article and that they have followed sound scientific research practice. This research is original and does not transgress plagiarism policies.

Author contributions

BS: data capture, literature review, study design, first draft preparation, manuscript preparation and manuscript revision
ZMK: study design, literature review, and first data preparation
MP: data collection, data capture, and first draft preparation
RD: data capture, data analysis, and design of testing setup
SKB: study conceptualisation and first draft preparation
PAR: study conceptualisation, data analysis, first data preparation, manuscript preparation, and manuscript revision

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References

1. Moroz LA, Launay F, Kocher MS, et al. Titanium elastic nailing of fractures of the femur in children: Predictors of complications and poor outcome. J Bone Joint Surg Br. 2006 Oct 1;88(10):1361-66.
2. Ligier JN, Metaizeau JP, Prevot J, Lascombes P. Elastic stable intramedullary nailing of femoral shaft fractures in children. J Bone Joint Surg Br. 1988 Jan 1;70(1):74-77.
3. Flynn JM, Hresko T, Reynolds RAK, et al. Titanium elastic nails for pediatric femur fractures: A multicenter study of early results with analysis of complications. J Pediatr Orthop. 2001 Jan 1;21(1):4-8.
4. Sink EL, Gralla J, Repine M. Complications of pediatric femur fractures treated with titanium elastic nails: A comparison of fracture types. J Pediatr Orthop. 2005 Sep 1;25(5):577-80.
5. Kocher MS, Sink EL, Blasier RD, et al. Treatment of pediatric diaphyseal femur fractures. J Am Acad Orthop Surg. 2009 Nov 1;17(11):718-25.
6. Loder RT, O'Donnell PW, Feinberg JR. Epidemiology and mechanisms of femur fractures in children. J Pediatr Orthop. 2006 Sep 1;26(5):561-66.
7. Hunter JB. Femoral shaft fractures in children. Injury. 2005. Feb 1;36:A86-93.
8. Luo Y, Wang L, Zhao LH, et al. Elastic stable titanium flexible intramedullary nails versus plates in treating low-grade comminuted femur shaft fractures in children. Orthop Surg. 2019 Aug;11(4):664-70.
9. Stans AA, Morrissy RT, Renwick SE. Femoral shaft fracture treatment in patients aged 6 to 16 years. J Pediatr Orthop. 1999 Mar 1;19(2):222-28.
10. Narayanan UG, Hyman JE, Wainwright AM, et al. Complications of elastic stable intramedullary nail fixation of pediatric femoral fractures, and how to avoid them. J Pediatr Orthop. 2004 Jul 1;24(4):363-69.
11. Soni JF, Schelle G, Valenza W, et al. Unstable femoral fractures treated with titanium elastic intramedullary nails, in children. Rev Bras Ortop. (English Edition). 2012 Sep 1;47(5):575-80.
12. Siddiqui AA, Abousamra O, Compton E, et al. Titanium elastic nails are a safe and effective treatment for length unstable pediatric femur fractures. J Pediatr Orthop. 2020 Aug 7;40(7):e560-65.
13. Mutimer J, Hammett RD, Eldridge JD. Assessing leg length discrepancy following elastic stable intramedullary nailing for paediatric femoral diaphyseal fractures. Arch Orthop Trauma Surg. 2007 Jul; 127:325-30.
14. Li Y, Heyworth BE, Glotzbecker M, et al. Comparison of titanium elastic nail and plate fixation of pediatric subtrochanteric femur fractures. J Pediatr Orthop. 2013 Apr 1;33(3):232-38.
15. Staheli LT. Femoral and tibial growth following femoral shaft fracture in childhood. Clin Orthop Relat Res (1976–2007). 1967 Nov 1;55:159-64.
16. Flynn JM, Luedtke L, Ganley TJ, Pill SG. Titanium elastic nails for pediatric femur fractures: lessons from the learning curve. American journal of orthopedics (Belle Mead, NJ). 2002 Feb 1;31(2):71-74.
17. Sink EL, Faro F, Polousky J, et al. Decreased complications of pediatric femur fractures with a change in management. J Pediatr Orthop. 2010 Oct 1;30(7):633-37.
18. Allen JD, Murr K, Albitar F, et al. Titanium elastic nailing has superior value to plate fixation of midshaft femur fractures in children 5 to 11 years. J Pediatr Orthop. 2018 Mar 1;38(3):e111-77.
19. Porter SE, Booker GR, Parsell DE, et al. Biomechanical analysis comparing titanium elastic nails with locked plating in two simulated pediatric femur fracture models. J Pediatr Orthop. 2012 Sep 1;32(6):587-93.
20. Luhmann SJ, Schootman M, Schoenecker PL, et al. Complications of titanium elastic nails for pediatric femoral shaft fractures. J Pediatr Orthop. 2003 Jul 1;23(4):443-47.
21. Li Y, Hedequist DJ. Submuscular plating of pediatric femur fracture. J Am Acad Orthop Surg. 2012 Sep 1;20(9):596-603.
22. Bar-On E, Sagiv S, Porat S. External fixation or flexible intramedullary nailing for femoral shaft fractures in children. J Bone Joint Surg Br. 1997 Nov;79-B(6):975-78.