Flexible intramedullary nails for unstable fractures of the tibia in children: a retrospective evaluation of effectiveness

Ahmed Labib Zarad[a,b]

[a]Department of Orthopaedic Surgery, Cairo University, Cairo, Egypt, [b]Department of Orthopaedic and Arthroscopic Center, Royal Commission Hospital, Jubail, Kingdom of Saudi Arabia

Correspondence to Ahmed Labib Zarad, MD, No 73, 22 Street, Cairo, Egypt
Tel: +20 122 212 312; fax: +20 225 166 437; e-mail:labibzarad@hotmail.com

Received 30 October 2014
Accepted 15 September 2014

Egyptian Orthopedic Journal 2014, 49:281–285

Background
Flexible intramedullary nailing is gaining popularity as an effective method for treating long-bone fractures in children.
Patients and methods
We retrospectively reviewed the records and radiographs of 56 unstable fractures of the tibia in 54 children treated between March 2006 and May 2010. Of the 56 fractures, 13 were open. All had been followed up for at least 2 months after removal of the nails.
Results
There were no nonunion cases. The mean time to clinical and radiological union was 10 weeks. Complications included residual angulation of the tibia, leg-length discrepancy, deep infection and failures of fixation. All achieved excellent functional outcome.
Conclusion
Flexible intramedullary fixation is an easy, safe and effective method of management of both open and closed unstable fractures of the tibia in children.

Keywords:
flexible nails, tibia fracture, children

Egypt Orthop J 49:281–285

1110-1148

Introduction

The standard treatment for fractures of the tibia in children is manipulation and casting [1,2]. Surgical stabilization has historically been reserved for fractures associated with polytrauma, neurovascular injury, open injury and following fasciotomy for compartment syndrome.

In the early 1980s, Ligier *et al.* [3] reported the use of flexible intramedullary nails to allow the early stabilization of fractures in children with polytrauma, to facilitate wound care in open fractures and to avoid prolonged immobilization. Stability was achieved by inserting two pretensioned nails from opposite cortices, thereby establishing a three-point fixation. Although this technique was initially intended for fractures of the femur, its use has been extended to other long-bone fractures.

We report our experience and results using flexible titanium nails in the treatment of unstable fractures of the tibia in children.

Patients and methods

We undertook a retrospective review of the notes, theatre records and radiographs of all patients with unstable tibial diaphyseal fractures treated by flexible titanium intramedullary nails at the Royal Commission Hospital, Kingdom of Saudi Arabia, between March 2006 and May 2010. During this period, 54 children (43 boys and 11 girls) with 56 unstable tibial diaphyseal fractures (27 right, 25 left, two bilateral) (Fig. 1a and b) were treated by this method (Fig. 1c and d).

Our indications for the procedure were polytrauma, open fracture, or failure to achieve a satisfactory closed reduction. The mean age on the day of surgery was 12 years (range 4–16). All patients were followed up for at least 2 months after removal of the nail.

We classified each fracture on the basis of the AO classification (Table 1) [4] as well as the mechanism of injury, associated injuries, intraoperative reduction, postoperative immobilization, time to assisted and unassisted weight-bearing, time to union, functional outcome and complications. We also calculated the Injury Severity Score [5] for all children with polytrauma.

Technique

All patients were operated upon under general anaesthesia. The affected limb was cleaned and draped. The appropriate size of nail was determined using an image intensifier. The fracture site and entry point at the level of the metaphysis were marked, taking care to avoid the physis. A 2–3 cm incision was made on either side of the tibia, proximal to the

marked entry point. Under fluoroscopic control, the cortex was broached with a drill of diameter larger than that of the nail to be inserted. Two nails of equal diameter were prebent so that the apex of the bend would lie at the fracture site on opposite cortices. The tips of the nails were bent to 45° to facilitate passage along the opposite cortex and to aid in fracture reduction. The nails were then introduced under fluoroscopic control. The first nail was advanced to the fracture site and the second was introduced from the opposite cortex. The fracture was reduced and the nails advanced into the opposite metaphysis. It was important to leave sufficient nail for subsequent removal. The associated fracture of the fibula was left alone. In three distal third fractures, the surgeons preferred to use retrograde nailing.

After surgery, all patients were placed in a short-leg cast and mobilized, non-weight-bearing for 4–6 weeks. Weight-bearing in a walking plaster was permitted when adequate callus was seen at the fracture site. Fractures were considered to be united when tricortical callus was visible on the radiographs and there was no tenderness at the fracture site on clinical examination.

Results

Of the 54 children, the mechanism of injury in 35 (65%) was high-energy trauma and low energy trauma in 19 (35%). There were 13 (23%) open fractures, which were classified according to Gustilo and Anderson [6]. Eight (62%) were grade I, two (15%) were grade II and three (23%) were grade III. The fractures were located in the upper third of the tibia in three (5%), the middle third in 38 (68%) and the lower third in 15 (27%) children. Of the 56 fractures, the fibula was intact in 17 (30%), fractured at a level different to the fracture of the tibia in 15 (27%) but at the same level in 24 (43%). The fracture pattern was spiral in 12 (21%) fractures, oblique in 19 (34%), transverse in four (7%), multifragmentary in 20 (36%) and multifragmentary with bone loss in one (2%). A total of 16 (30%) patients had associated injuries. The mean Injury Severity Score [5] in children with multiple injuries was 13 (range 4–50) (Table 2).

Retrograde nails were inserted (Fig. 2) for fractures of the distal third of the tibia in three (6%) patients. Care was taken to avoid the growth plates. No patient demonstrated evidence of growth arrest after nail insertion.

Table 1 Severity of fractures in our patients, classified using the AO system [4]

AO classification	Number of fractures
A1	12
A2	19
A3	4
B1	9
B2	10
B3	1
C2	1

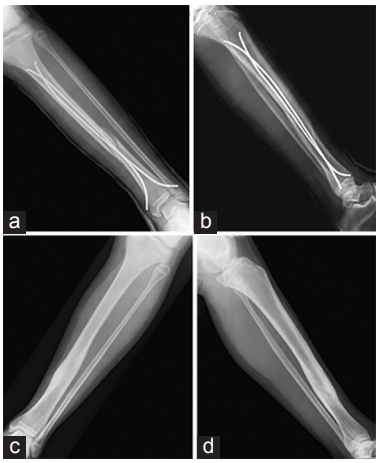
Table 2 Associated injuries in our patients

Type of injury	Number of children
Head injury	9
Ipsilateral femoral fracture	6
Contralateral femoral fracture	1
Ipsilateral humeral fracture	3
Contralateral humeral fracture	1
Ipsilateral forearm fracture	1
Bilateral tibial fractures	2

Figure 1

Radiographs of a 14-year-old boy with tibia fracture: (a, b) preoperative, (c, d) postoperative.

Figure 2



Radiographs of the fractured left tibia of a 13-year-old boy: (a) with retrograde nailing (anteroposterior view), (b) lateral view at 2 weeks postoperatively and (c, d) healed tibia, anteroposterior and lateral view at 6 months after surgery.

There were four patients who had simultaneous fasciotomy and nailing for suspected compartment syndrome.

A 15-year-old boy with a grade I open fracture developed cellulitis following nailing, which settled with antibiotics.

There were two patients, both 13 years of age, with deep infections. Of these, one had a grade II open fracture, whereas the other had a closed fracture that required open reduction after failed conservative management. Both healed uneventfully after debridement and wash-out, with removal of the nails and intravenous antibiotics.

Leg-length discrepancies of 1.5–2 cm following nailing of multifragmentary tibial fractures occurred in two (4%) patients and were treated by epiphysiodesis of the contralateral leg. In two (4%) patients, one with a proximal oblique fracture and the other with a long oblique lower-third fracture of the tibia, there was a need for revision to plate fixation after failed fixation at the 1-week follow-up. The nails could be removed in 52 (96%) children, but the removal failed in two (4%) children as the nail heads were broken.

The mean time to clinical and radiological union was 10 weeks (range 7–18 weeks). The nails were removed between 6 and 9 months after insertion, as a day-case procedure. The mean follow-up duration was 11 months (8–17 months). There was one (2%) patient who had delayed union but required no intervention. Radiographs at final review demonstrated malunion in two patients (Table 3).

In the majority of cases, we noted that the alignment achieved intraoperatively was maintained at the time of the final review. However, two patients with significant comminution had some progression of deformity. No patient had any rotational deformity.

Discussion

For the past two decades, paediatric orthopaedic surgeons have used a variety of methods to minimize the prolonged immobilization necessary after the traditional closed treatment of fractures of the tibia. Although cast immobilization remains the standard treatment for appropriate fractures of the tibia, fixation is particularly beneficial for children who have sustained multiple injuries from high-energy trauma [7], for those with head injuries, open fractures and compartment syndrome and for older children. The ideal device to treat paediatric fractures of the tibia would be a simple load-sharing device, which would maintain alignment, allow mobilization until bridging callus forms and would not cross the physis. It should also be easy to insert and remove after bony union. The development of flexible intramedullary nails, which satisfy most of these criteria, has allowed an increasing number of surgeons to use this type of nail for treating paediatric long-bone fractures. There are several advantages of this technique. Three-point fixation within the medullary canal allows maintenance of both alignment and rotation for most fractures. Flexible intramedullary nails provide fixation that is stable as well as elastic, allowing micromotion at the fracture site when load is applied. This encourages abundant bridging callus formation and facilitates early union [3,8].

Table 3 Complications arising in our patients

Complications	Number of children
Sagittal plane angulation	
>10° recurvatum	1
Coronal plane angulation	
>10° varus	1
Infection	
Superficial	1
Deep	2
Shortening (>1.5 cm)	2
Delayed union	1

The operation is performed through small incisions, away from the fracture site, minimizing the potential for infection. Because there is no reaming of the medullary canal, the endosteal blood supply is not compromised. The technique allows early weight-bearing in a Sarmiento-type [9] cast or functional brace. It is important that both nails are of equal diameter; otherwise, differential loading of opposite cortices may lead to an angular deformity. Nails are generally inserted through two proximal entry points, but can be inserted retrogradely for more distal fractures. When nearing skeletal maturity, nails can be passed through the tip of the medial malleolus, across the physis, in a manner similar to that of the percutaneous technique.

There are few articles in the literature on the management of diaphyseal fractures of the tibia in children with intramedullary fixation [3,10–13]. Barry and Paterson [14] suggested that the marked proximal metaphyseal flare and the triangular cross-section of the tibia pose a challenge in achieving the symmetrically opposed nail configuration required for the technique to work effectively. In the past, this method of fixation was restricted to failure of conservative treatment, fracture of the ipsilateral femur and segmental fractures. O'Brien *et al.* [10] reported 16 fractures of the tibia, fixed internally with intramedullary fixation, which achieved a very good functional outcome. They reported one superficial infection, six coronal and seven sagittal angulations

but no functional compromise. One child had a leg-length discrepancy of over 1.5 cm.

Vrsansky *et al.* [15] reviewed 308 children with fractured long bones fixed with flexible intramedullary nails, of which 36 involved the tibia.

An excellent functional outcome was reported, with all patients mobilizing independently by 3–5 months. Qidawi [13] described a retrospective review of 84 fractures of the tibia treated with intramedullary Kirschner wires with a mean time to union of 9.5 weeks. More recently, Kubiak *et al.* [11] compared flexible nailing with external fixation, as a method of treating fractures of the tibia in children. This was a retrospective review of clinical and radiographical outcomes for 31 children with fractures of the tibia. Of these, 16 had elastic stable intramedullary nailing and 15 had external fixation. In the external fixation group there were eight children (53%) with an open fracture, compared with five (31%) in the elastic stable intramedullary nailing group. The mean time to union was 18 weeks in the external fixation group but only 7 weeks in the nail group. There were seven bony complications in the external fixation group (two delayed unions, three nonunions and two malalignments), whereas there was one bony complication in the nail group. The authors recommended that nailing should be used for the treatment of fractures of the tibia in skeletally immature patients in need of surgical stabilization, including open fractures without segmental bone loss and limited comminution. The reported union at a mean of 7 weeks in the nail group was in contrast to our series in which the mean time to union was 10 weeks. This may be explained by the time to weight-bearing. Kubiak *et al.* [11] allowed immediate partial weight-bearing postoperatively if there was more than 50% bone contact, whereas our patients were non-weight-bearing for a period of 4–6 weeks. In light of our experience, we now permit patients with stable (transverse or short oblique) fracture patterns to partially weight-bear as soon as comfort allows. We also feel that nailing provides adequate stability in all but the most severe comminuted or segmental patterns, assuming that weight-bearing is not allowed until there is evidence of callus.

Several studies involving flexible intramedullary nailing of the tibia in adults are documented [16–18]. Wiss *et al.* [16] reported that 48 of 52 fractures of the tibia healed at a mean of 17 weeks. Three patients developed angular malformation greater than 7° and five had shortening greater than 1.2 cm, but no functional restriction was noted. Hasenhuttl [19] reviewed 235 cases and reported good healing in 93% of closed fractures and 66% of open fractures. The nonunion rate was 4.4%, as was the rate of deep infection with osteomyelitis. Two reports [8,16] of intramedullary nailing for grade II to grade III open fractures in adults documented deep infection rates of one in 38 patients and none in 20, respectively.

We have reviewed 56 fractures of the tibia in 54 children, fixed with flexible intramedullary nails. The mean time to radiological union was 10 weeks. There were two deep infections and two angular deformities, which did not compromise function. There were no cases of nail erosion through the skin, and all the wounds healed uneventfully. Two patients developed shortening of the affected leg of no more than 1.5–2 cm following multifragmentary fractures. All patients were able to start protected weight-bearing by 4–6 weeks, and all but two (who had open fractures and other associated injuries) were able to fully weight-bear independently after 6 weeks.

Conclusion

Flexible intramedullary nailing is a relatively simple and effective way to stabilize open and closed fractures of the tibia in children with few complications, allowing early mobilization and excellent functional outcome.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

References

1 Shannak AO. Tibial fractures in children: follow up study. J Pediatr Orthop 1988; 8:306–310.

2 Thompson GH, Wilber JH, Marcus RE. Internal fixation of fractures in children and adolescents: a comparative analysis. Clin Orthop 1984; 188:10–20.

3 Ligier JN, Metaizeau JP, Prevot J. Closed flexible medullary nailing in pediatric traumatology. Chir Pediatr 1983; 24:383–385.

4 Müller ME, Nazarian S, Koch P. *The comprehensive classification of fractures of long bones*. Heidelberg-Berlin, Germany: Springer-Verlag; 1990.

5 Baker SP, O'Neill B, Haddon WJr, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 1974; 141:187–196.

6 Gustilo RB, Anderson JT Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. J Bone Joint Surg Am 1976; 58-A:453–458.

7 Tolo VT. External skeletal fixation in children's fractures. J Paediatr Orthop 1983; 3:435–442.

8 Pankovich AM, Tarabishy IE, Yelda S. Flexible intramedullary nailing of tibial shaft fractures. Clin Orthop 1981; 160:185–195.

9 Sarmiento A. A functional below-the-knee cast for tibial fractures. J Bone Joint Surg Am 1967; 49-A:855–875.

10 O'Brien T, Weisman DS, Ronchetti P, Piller CP, Maloney M. Flexible titanium nailing for the treatment of the unstable paediatric tibial fracture. J Pediatr Orthop 2004; 24:601–609.

11 Kubiak EN, Egol KA, Scher D, *et al.* Operative treatment of tibial fractures in children: are elastic stable intramedullary nails an improvement over external fixation?. J Bone Joint Surg Am 2005; 87-A:1761–1768.

12 Huber RI, Keller HW, Huber PM, Rehm KE. Flexible intramedullary nailing as fracture treatment in children. J Pediatr Orthop 1996; 16: 602–605.

13 Qidawi SA. Intramedullary Kirschner wiring for tibia fractures in children. J Pediatr Orthop 2001; 21:294–297.

14 Barry M, Paterson JM. Flexible intramedullary nails for fractures in children. J Bone Joint Surg Br 2004; 86-B:947–953.

15 Vrsansky P, Bourdelat D, Al Faour A. Flexible stable intramedullary pinning technique in the treatment of paediatric fractures. J Pediatr Orthop 2000; 20:23–27.

16 Wiss D, Segal D, Gumbs VL, Salter D. Flexible nailing of tibial shaft fractures. J Trauma 1986; 62:1106–1112.

17 Gad HF, Abul Kheir IH, Booz MK. Closed nailing of tibial shaft fractures. Injury 1990; 21:217–219.

18 Flynn JM, Hresko T, Reynolds RA, *et al*. Titanium elastic nails for paediatric femur fractures: a multi-centre study of early results with analysis of complications. J Pediatr Orthop 2001; 21:4–8.

19 Hasenhuttl K. The treatment of unstable fractures of the tibia with flexible medullary wires: a review of two hundred and thirty-five fractures. J Bone Joint Surg Am 1981; 63-A:921–931.