Use of Flexible Intramedullary Nail Fixation in Treating Femur Fractures in Children

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Abstract

We evaluated use of flexible intramedullary nails in the surgical treatment of femoral shaft fractures in 135 children (138 fractures). Mean age was 9.7 years (range, 2-17 years). Mean follow-up was 15.6 months (range, 6.6-53.5 months).

Seventy-two patients were treated with stainless-steel (Ender) nails and 66 with titanium elastic nails. There were 73 midshaft fractures, 48 proximal-third fractures, and 17 distal-third fractures. Fracture patterns were transverse (66), oblique (42), spiral (24), and comminuted (6). There were 16 complications—3 refractures, 2 delayed unions, 3 varus or valgus malalignments, 5 nail-tip irritations, 2 broken interlocking screws (found incidentally on radiographs), and 1 asymptomatic proximal nail migration—for a complication rate of 11.7%.

These results demonstrate that use of flexible intramedullary nails in the treatment of femoral shaft fractures in children is successful regardless of patient age, fracture location, or fracture pattern.

Femoral shaft fractures are among the most common major pediatric injuries treated by orthopedic surgeons.[1] What constitutes appropriate management of femoral shaft fractures in children is a subject of much debate. Treatment ranges from strictly nonsurgical methods (eg, closed reduction with spica casting or traction followed by casting) to surgical stabilization (using intramedullary devices, external fixation, or internal fixation with plate and screws).[1-10] Nonsurgical management has been the standard of care for most children historically. Disadvantages of this treatment include prolonged immobilization and long hospital stay.[1-3] Casting with or without traction is still the preferred treatment for isolated femur fractures in children of preschool age.[1] In adults, intramedullary rods have been the treatment of choice for femoral shaft fractures for the past 20 years. Fixation with rapid mobilization now provides advantages in the pediatric population.

Ideally, fixation of pediatric femur fractures produces an "internal splint" that shares loads, maintains reduction until hard callus formation, and does not endanger the growth areas or blood supply of the femoral head.[4] Results from several studies[1-11] have shown that flexible intramedullary nail (FIN) fixation meets these requirements because it allows rapid mobilization, potentially no risk for osteonecrosis, low risk for physeal injury, and reduced risk for refracture. The FIN functions as an internal splint that at least theoretically holds length and alignment while permitting enough fracture-site motion for callus formation.

Ligier and colleagues[3] were the first to report beneficial use of titanium elastic nails (TENs) in the treatment of femur fractures in children. In their 5-year study of 118 children (123 fractures) ranging in age from 5 to 16 years, they found only 1 case of infection and 13 cases of skin irritation/ulceration from the nail tip near the insertion site. Overall, 1-year follow-up results were excellent—no nonunions, leg-length discrepancies (LLDs), malalignments, disabilities, gait abnormalities, or refractures. Several investigators[5-8] have reported similar outcomes.

Other investigators[2,4,10,11] have attempted to refine the indications and to identify factors that lead to poor outcomes with use of TENs. In a multicenter study of several major pediatric trauma centers, Flynn and colleagues[4] examined early outcome results and complications in 57 children (58 femoral shaft fractures) ranging in age from 4 to 16 years. Over the course of treatment, there were 6 malalignments, 6 LLDs, 4 soft-tissue irritations by nail prominence, 1 refracture after nail removal, and 1 nail backout—for a 32.8% complication rate. These complications did not affect final (1-year follow-up) outcomes (38 excellent, 18 satisfactory, 1 poor). Luhmann and col-

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Am J Orthop. 2009;38(3):E49-E55.

Figure 1. Approximate femoral length: A, distance from tip of greater trochanter to proximal fracture line; B, distance from proximal fracture line to most distal aspect of fracture; C, distance from distal fracture line to intercondylar notch.

leagues[2] reported results of using TENs in 39 children (43 femur fractures) ranging in age from 3 to 9 years. After 1 year, there were 12 (28%) excellent, 26 (60%) satisfactory, and 5 (12%) poor outcomes and 21 (49%) complications: 1 intraoperative, 1 septic arthritis after nail removal, 1 hypertrophic nonunion, 13 cases of pain at nail insertion site, 4 nail-tip erosions through skin, and 1 delayed union. In another large multicenter study (6 major pediatric trauma centers), of 229 school-aged children (230 femur fractures), Flynn and colleagues[11] reported 150 (65%) excellent, 57 (25%) satisfactory, and 23 (10%) poor outcomes and 76 (33%) complications, including 22 malunions and 1 fixation failure. Overall, they found that poor outcomes were 5 times more likely in children who weighed more than 108 pounds, and children younger than 11 had 2.1 times higher odds of better outcomes. Outcome varied by fracture location too—it was poor in 9% of proximal-third and midshaft fractures versus 18% of distal-third fractures.

Additional controversy centers on which nail material is superior, titanium or stainless steel. Most recently, Crawford and colleagues[12] found no significant difference between these materials in a study of 92 children. Complication rates were similar—19% (8/42) for children treated with TENs and 12% (6/50) for children treated with stainless-steel (Ender) nails.

In the present study, we evaluated the outcomes of our use of TENs and Ender nails in treating pediatric femoral shaft fractures at Children's Hospital of Wisconsin. We hypothesized that FIN fixation would be an effective treatment for a broad range of pediatric femur fractures, regardless of age, weight, fracture location, or fracture pattern.

Materials and Methods

After our institutional review board approved this study, medical records were searched to identify all children whose femoral shaft fractures had been treated with FINs (TENs or Ender nails) between January 1994 and December 2004 at the Children's Hospital of Wisconsin. Surgeries had been performed by 4 different surgeons. We identified 135 children (138 fractures) for analysis. Children with metabolic bone disease, nonambulatory children, and children with neuromuscular disease (cerebral palsy) were excluded. Mean age at time of injury/surgery was 9.7 years (range, 2.11-16.6 years). There were 99 boys and 36 girls. All patients underwent temporary stabilization of the femur fracture with use of skin traction (120 patients) or skeletal traction (15 patients) while waiting for the appropriate time for definitive operative stabilization.

Inpatient medical records, outpatient clinic notes, and radiographs were reviewed for all patients. Data collected for each patient were demographics, surgery/injury date, diagnosis, surgical procedure (number of FINs used), mechanism of injury, associated injuries, fracture location, fracture pattern, degree of comminution (Winquist grade[13]), nail type, nail size, insertion technique (antegrade, retrograde, both), insertion location (medial, lateral), intraoperative complications, and additional surgical procedures. Postoperative data collected were postoperative immobilization, duration of non–weight-bearing, length of hospital stay, time to nail removal, range of motion (hip, knee, ankle), gait, limb alignment, LLD, signs of irritation at nail insertion site, and major complications (nonunion, delayed union, refracture). LLDs were evaluated clinically; scanograms were performed at the discretion of the treating orthopedist.

Radiographs were evaluated for alignment, amount of nail remaining outside femoral cortex (measured from femoral cortex insertion site to tip of nail), nail shape (C or S), callus formation, nail position, and measurement of fracture location (distance from tip of greater trochanter to proximal fracture, distance from proximal to distal aspect of fracture, and distance from intercondylar notch to distal fracture line, which provide femoral length and fracture location as a percentage of femoral length; Figure 1).

We defined major postoperative complications as nonunion, delayed union, sagittal angulation of more than 20°, coronal angulation of more than 10° (malalignment criteria based on previous studies[2-8]), infection, refracture, nail irritation requiring hardware removal, and nail breakage. Minor postoperative complications were defined as nail irritation that resolved without intervention, asymptomatic nail migration, and any perioperative problem that resolved without surgical intervention or early hardware removal. Final outcome was graded *excellent, satisfactory,* or *poor* based on criteria described by Flynn and colleagues.[4]

Operative Technique

The surgeries were performed with 4 different insertion techniques, according to fracture location and pattern. These techniques applied to both TENs and Ender nails. With the patient supine on a fracture table and under general anesthesia, the extremity was reduced using longitudinal traction applied through a traction boot under fluoroscopic guidance. The surgical technique was similar to what Metaizeau[9] described, with the rod outside the canal with the bone flush (retrograde vs antegrade) determined by fracture location. For proximal and midshaft fractures, nails are usually placed in retrograde fashion; for distal fractures, antegrade fashion. Two retrograde lateral insertion sites were used for diaphyseal fractures in which canal fill was readily achieved. Nail diameter was determined by the operating surgeon but presumably was based on the narrowest intramedullary diameter of the femoral diaphysis (nail diameter should be 40% of the narrowest intramedullary diameter). In the majority of our cases (135 fractures), 2 nails were used. Nail type (titanium or stainless steel) was somewhat based on surgeon preference, with a trend for using TENs in smaller patients and Ender nails in larger patients or in fractures with more comminution and increased likelihood of instability with shortening. Thus, use of eyelet with screw is promised for further stability.

Postoperative immobilization and time to initial protected weight-bearing varied. Types of immobilization were long leg cast, knee immobilizer, and "no immobilization." Choice of immobilization depended primarily on the surgeon.

Statistical Analysis

Nonparametric paired Student *t* test was used to determine statistical significance for the comparison of angulation as measured radiographically on initial postoperative radiograph and on the final radiograph taken before hardware removal ($P<.05$). Comparisons of time to appearance of callus, time to appearance of maximum callus, and time to no fracture line visible were made between patients treated with TENs and patients treated with Ender nails; statistical significance of these comparisons was determined with an unpaired Student *t* test ($P<.05$). The 2 nail groups were also compared with respect to time to initial and full weight-bearing, time to hardware removal, and time to final follow-up ($P<.05$).

Results

The left femur was fractured in 67 patients, the right femur in 70 patients, and both femurs in 3 patients. Mean weight at time of surgery was 81.1 pounds (range, 22-253.5 pounds); 28 patients (21%) weighed more than 110 pounds. Mechanisms of injury were motor vehicle versus pedestrian (48 patients), motor vehicle accident (20), motor vehicle versus bicycle (8), fall (18), sports-related activity (33), all-terrain vehicle accident (5), gunshot wound (2), child abuse (2), being kicked and trampled by a cow (1), and pathologic fracture (nonossifying fibroma, 1). Significant associated multiple additional injuries were documented in 44 patients (33%), including 10 patients with closed head injuries and 24 patients with additional extremity fractures. Fracture characteristics are documented in Table I. Patients (excluding those with closed head injuries and additional lower extremity fractures) walked with assistive devices at a mean of 15 days. By a mean of 8.7 weeks (range, 3-22 weeks), patients walked without assistive devices. Definitive surgical stabilization was performed a mean of 2 days (range, 0-17 days) after hospital admission. Mean postoperative length of hospital stay was 6.2 days (range, 2-48 days) for the entire population and 4.1 days for patients with an isolated femur fracture.

Callus was first noted on follow-up radiograph at a mean of 3.8 weeks (range, 1.1-9.2 weeks). Maximum callus was noted radiographically at a mean of 9.4 weeks (range, 2.4-24 weeks). The first radiograph on which the fracture was no longer visible was taken at a mean of 23.7 weeks from time of injury (range, 5.4-51.9 weeks). In most cases, nails were routinely removed approximately 10 months (range, 4-24.5 months) after injury. Mean time from injury to final follow-up was 15.6 months (range, 6.6-53.5 months). Clinical evaluation revealed full range of motion of the hip, knee, and ankle in all patients at final follow-up. In addition, no patient demonstrated a gait abnormality other than a mild limp.

One hundred thirteen femurs had FINs (Ender nails or TENs) placed in retrograde fashion using distal insertion sites. The distal insertion site was used for stabilization of femoral shaft fractures occurring from the lesser trochanter to approximately the distal metaphyseal–diaphyseal junction. Retrograde nail placement was performed using medial and lateral insertion sites (just proximal to the physis) in 94 cases and using 2 nails through only a lateral site in 19 cases. In 27 distal femoral shaft fractures, an antegrade method of flexible nail insertion was used. In 8 fractures, 1 nail was placed using an antegrade insertion technique and 1 was placed using a retrograde technique through a medial insertion site. One hundred thirty-six fractures had 2 nails implanted, 1 distal fracture had a third nail implanted for additional rotational stability, and 1 fracture had 4 nails implanted. Mean

Table I. Summary of Characteristics of Fractures (N = 138)

Fracture Location (n)	Pattern (n)	Winquist Grade (n)
Proximal (48)	Transverse (66)	I (100)
Subtrochanteric (35)	Oblique (42)	II (20)
Proximal-midshaft (13)	Spiral (24)	III (12)
Midshaft (73)	Comminuted (6)	IV (6)
Distal (17)	—	—
Supracondylar (8)	—	—
Distal-midshaft (9)	—	—

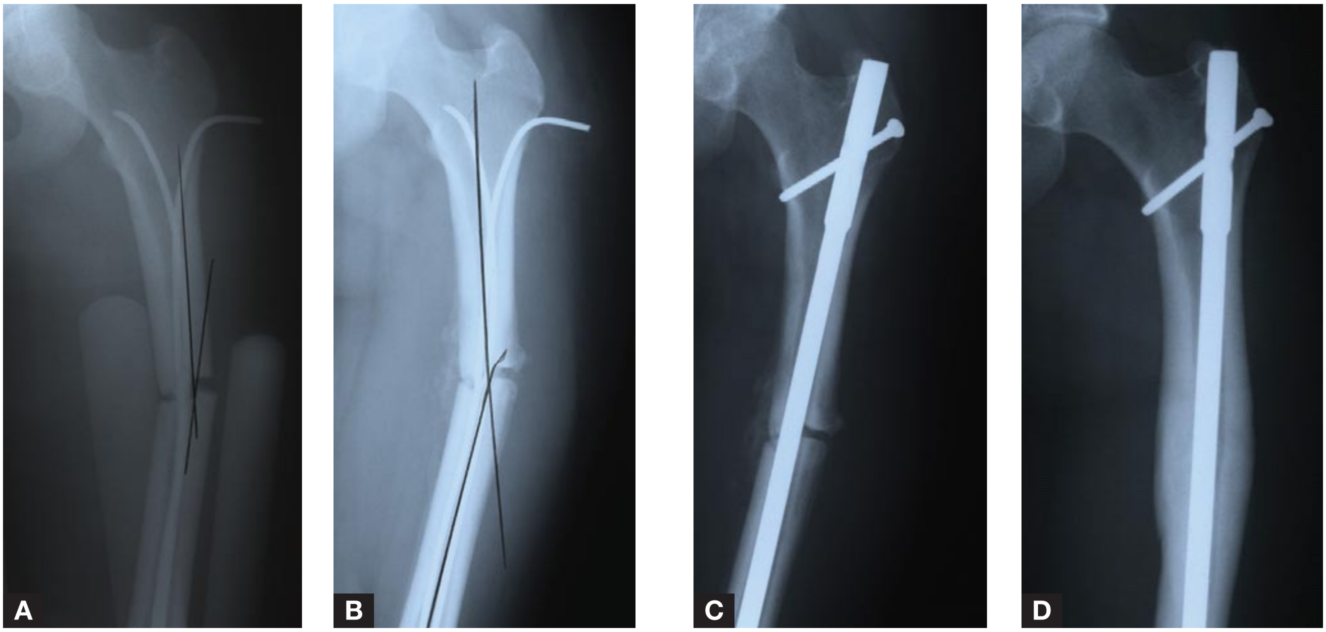

Figure 2. A 14-year-old girl sustained a midshaft transverse femoral shaft fracture in a motor vehicle accident. Despite stabilization with titanium elastic nails, the fracture did not unite; after the nails were replaced with a rigid intramedullary nail, the fracture healed without incident. (A) Radiograph 4 weeks after stabilization. (B) Radiograph a few months after surgery (4-mm gap at fracture site and some varus angulation remain). (C) Initial radiograph after nail exchange. (D) Radiograph shows complete fracture healing.

amount of nail remaining outside the femur was 22.6 mm (SD, 0.98 mm).

Nail diameter was theoretically chosen on the basis of 40% of the narrowest intracortical diameter but was ultimately determined by the treating surgeon. Forty-eight fractures were stabilized with 3.5-mm nails, 39 with 4.0-mm nails, 24 with 3.0-mm nails, 16 with 4.5-mm nails, 1 with 2.0-mm nails, 1 with a 3.0-mm nail and a 3.5-mm nail, and 1 with a 3.5-mm nail and a 4.0-mm nail. Seventy-two fractures were stabilized with Ender nails, and 66 were stabilized with TENs. Of the 72 Ender-nail stabilizations, 36 (50%) used interlocking screws (35 of these used 2 screws; 1 used 1 screw).

Of the 72 patients in the Ender group, 53 were males, and 19 were females. At time of surgery, their mean age was 11.1 years (range, 6-16 years), and their mean weight was 95.9 pounds (range, 44.1-253.5 pounds). Of the 66 patients in the TEN group, 49 were males, and 17 were females. At time of surgery, their mean age was 8 years (range, 2.9-14.5 years), and their mean weight was 62.8 pounds (range, 22-130.1 pounds). Fractures stabilized with TENs began healing significantly sooner than fractures stabilized with Ender nails; mean time to maximum callus was 7.8 weeks for TENs and 10.4 weeks for Ender nails ($P = .008$), and mean time to no radiographically visible fracture was 21 weeks for TENs and 25.6 weeks for Ender nails ($P = .025$). In addition, mean time to full weight-bearing was significantly ($P = .009$) shorter for the TEN group (7.4 weeks) than for the Ender group (9.7 weeks); likewise, mean time to nail removal was significantly ($P < .0001$) shorter for the TEN group (36 weeks) than for the Ender group (47.5 weeks).

Sixteen intraoperative difficulties were recorded. All were corrected during surgery and had no impact on final outcome. In 4 cases, initial nail size was incorrect, and, during placement of the first nail, the surgeon had difficulty getting past the fracture site; the nail was removed and exchanged without difficulty. In 5 cases, the surgeon had difficulty maintaining reduction; after surgery, a long leg cast was placed on the patient to maintain reduction. In 2 cases, a significant amount of blood (~400 mL) was lost; after surgery, the patient was transfused with 2 units of packed red blood cells because of a symptomatic (tachycardia) drop in hematocrit. In 4 cases, the distal end of the nail penetrated the opposite cortex (subsequently noted on follow-up radiograph) but did not result in any symptoms or loss of reduction or require hardware revision. Last, in 1 case, the islet broke during insertion of an Ender nail, but it was not exchanged and did not lead to any complications during the postoperative course.

There were 16 postoperative complications—5 major and 11 minor (Table II). The major complications were delayed unions (2 cases) and refractures after hardware removal (3 cases). One patient with delayed union was an 11-year-old boy who weighed 132.3 pounds and had a right transverse midshaft femur fracture treated with two 4.0-mm Ender nails and a long leg cast. As the fracture had not shown any evidence of healing by 3 months after surgery, the Ender nails were exchanged for a rigid intramedullary nail. The patient then healed without complication. The other patient with delayed union was a 14-year-old girl who weighed 121 pounds and had a left transverse proximal femoral shaft fracture treated with

Table II. Complications

Intraoperative Complications (n)	Postoperative Complications (n)	Leg-Length Discrepancy (n)
Difficulty/loss of reduction (5)	Nonunion/delayed union (2)	<1 cm (6)
Rods exchanged/improper size selection (4)	Refracture (3)	1 cm (11)
Penetration of proximal/distal cortex (4)	Nail-tip irritation (5)	<2 cm (4)
Broken needle eye of Ender rod (1)	Malalignment (3)	>2 cm (3)
Blood loss (2)	Broken screw (2)	—
	Asymptomatic nail migration (1)	—
	Infection (0)	—
Total = 16	**Total = 16**	**Total = 24**

Table III. Outcome Scoring, as Established by Flynn et al[4]

	All Outcomes		
	Excellent	**Satisfactory**	**Poor**
	115	14	9
Stainless-steel nail (Ender)	57	9	6
Titanium elastic nail (TEN)	58	5	3
	Satisfactory Outcomes		
	Ender	**TEN**	**Total**
1- to 2-cm leg-length discrepancy	3	1	4
Soft-tissue irritation by hardware	5	3	8
5°-10° of varus/valgus malalignment	1	1	2
Total	**9**	**5**	**14**
	Poor Outcomes		
	Ender	**TEN**	**Total**
Nonunion	—	1	1
Delayed union	1	—	1
Refracture	2	1	3
>10° varus/valgus malalignment	—	1	1
Leg-length discrepancy >2 cm	3	—	3
Total	**6**	**3**	**9**

two 3.0-mm TENs. One month after surgery, there was a 4-mm gap at the fracture site, no signs of healing or callus formation, and 20° varus malalignment that had not been present immediately after surgery. This patient also underwent exchange nailing with a rigid intramedullary rod and then healed without incident (Figures 2A–2D). In all 3 cases of refracture after hardware removal, the patients were more than 1 year past initial injury and were involved in significant trauma (eg, soapbox derby crash, fall from a height). These patients were all treated with FINs and then healed without incident.

The 11 minor complications were nail-tip irritations (5 cases, did not become infected, resolved without intervention or early hardware removal), varus or valgus malalignments of more than 15° during the month after surgery (3 cases, treated with cast wedging and manual reduction, healed without additional complication or malalignment), broken interlocking screws incidentally found in patients treated with Ender nails (2 cases, asymptomatic, did not require intervention), and proximally migrated antegrade nail found during follow-up examination (1 case, asymptomatic, nail palpable proximally).

Eighteen patients had LLDs of 1 cm or more on clinical measurement (anterior superior iliac spine to medial malleolus). On follow-up scanograms, 7 patients had LLDs of more than 1 cm. Titanium nail outcome scores (Flynn and colleagues[4]) were used to grade the 138 results: 115 were excellent, 14 satisfactory, and 9 poor (Table III). Of the 72 Ender group results, 57 were excellent, 9 satisfactory, and 6 poor; of the 66 TEN group results, 58 were excellent, 5 satisfactory, and 3 poor.

Discussion

Traditionally, management of femoral shaft fractures has been based on age. The classic treatment algorithm consists of spica casting in children younger than 5 years; early skeletal traction followed by casting, FINs, external fixation, or compression plating in children 6 to 11; and locked rigid intramedullary rod, external fixation, compression plate, or FINs in children 12 and older.[1,2,4,5,8] With the growing popularity and success of FINs for femoral shaft fractures in children, several authors[2-12] have offered criteria for FIN use based on age, weight, and fracture location. The most common FIN recommendation is for transverse midshaft femoral diaphyseal fractures in skeletally immature children older than 6.[1]

In the present study, we evaluated the outcomes of TEN and Ender-nail treatment for pediatric femoral shaft fractures at Children's Hospital of Wisconsin. Our goal was to provide evidence that, regardless of patient age, weight, fracture location, and fracture pattern, appropriate use of FINs can have successful outcomes.

Results from several studies have demonstrated the successful use of FINs for the definitive treatment/stabilization of femoral shaft fractures in children. As mentioned, Ligier and colleagues[3] wrote one of the earliest reports on the outcomes of TEN use in 118 children (mean age, 10 years) with 123 femur fractures. There was a variety of fracture patterns: transverse (63, including 16 with comminution), spiral (28, including 9 with a large butterfly fragment), and oblique (22). There was also a variety of fracture locations: proximal (42), midshaft (35), distal (36), and pertrochanteric (6). Overall, 1-year follow-up results were excellent—no nonunions, LLDs, malalignments, disabilities, gait abnormalities, or refractures. The authors found only 1 case of infection and 13 cases of skin irritation/ulceration from the nail tip near the insertion site. These results closely resemble those of our treatment population and success, as we also treated a large variety of fracture patterns and locations. In our study, results were excellent for 83% of fractures (115/138).

Carey and Galpin[5] reported on 25 children (mean age, 8.5 years; range, 5.9-10.9 years) with 27 femoral shaft fractures treated with Ender and titanium FINs. Most of the fractures were mid-third transverse or short oblique. Although there were no major postoperative complications, and outcomes were successful overall, the fracture pattern and location in these cases are inherently stable, and the authors used only an antegrade insertion technique (our study, on the other hand, demonstrated the diverse use of FINs in fracture stabilization).

Bar-On and colleagues[6] examined 19 children (mean age, 9.3 years; range, 6.9-13.2 years) with 20 femur fractures, 10 treated with FINs and 10 treated with external fixation. They found no major complications in the FIN group at 14-month follow-up (but reported 1 case of quadriceps wasting of 1 cm, which did not affect functional motion).

Flynn and colleagues[7] reported outcomes for 48 children (mean age, 10.2 years; range, 6-16 years) with 49 fractures treated with TENs. Their complication rate (12%) and our complication rate (21%) were similar and showed that most patients in these studies had successful outcomes. Flynn and colleagues found no angulation, malalignment, or LLD of more than 1 cm but reported 8 cases of nail-tip irritation near the insertion site (2 led to wound breakdown and early hardware removal), 1 refracture caused by premature (6.5-week) nail removal, and 1 case of nail bending after a fall (corrected by closed reduction, which led to delayed union, which was treated with external fixation).

Building on the increasing popularity of FINs in the treatment of femoral shaft fractures in children, several authors[2,4,10,11] have attempted to refine the indications for their use by examining complications and factors that may contribute to poor outcomes. Luhmann and colleagues[2] found a complication rate of 49% (21/43 femoral shaft fractures) in 39 children (mean age, 6 years; range, 3.75-9.33 years) treated with TENs. There were 21 complications: 1 intraoperative complication, 2 major complications (septic arthritis after nail removal, hypertrophic nonunion), 13 cases of nail irritation/pain at the insertion site, 4 nails eroded through the skin, and 1 delayed union. Of the 43 outcomes, 12 were excellent, 26 satisfactory, and 5 poor. Fracture characteristics were similar to those in our study, but our complication rate was lower (12%), and found more complications related to nail-tip prominence.

Flynn and colleagues[4] reported 39 excellent results, 18 satisfactory results, and 1 poor result in a large multicenter study of children (mean age, 9.5 years; range, 4-16 years) with 58 femoral shaft fractures definitively treated with TENs. There were 42 midshaft, 7 distal, 9 proximal, and 9 comminuted fractures. The authors reported 19 postoperative complications: 7 malalignments, 6 LLDs, 4 soft-tissue irritations caused by prominent nail tips at the insertion site, 1 refracture, and 1 nail migration (backout). Although our complication rate was lower, we encountered many of the same issues. Again, Flynn and colleagues examined only fractures stabilized with TENs, whereas we used both TENs and Ender nails. Of our 66 TEN outcomes, however, 58 were excellent, 5 were satisfactory, and 3 were poor.

In a larger multicenter study, Flynn and colleagues[11] described factors associated with poor outcomes in 229 children (230 fractures) treated with TENs. Children who were heavier (>108 pounds) were 5 times more likely to have poor outcomes when treated with TENs, and children younger than 11 had 2.1 times higher odds of better outcomes. Children with distal femur fractures were more likely to have poor outcomes. There were 76 major or minor complications. One hundred fifty patients had excellent results, 57 had satisfactory results, and 23 had poor results (3 in proximal fractures, 14 in midshaft fractures, 6 in distal fractures). In contrast, we obtained excellent results with FINs regardless of age (41 patients older than 11, only 5 complications) and weight (28 patients weighing more than 108 pounds, only 7 complications).

Most recently, Crawford and colleagues[12] compared use of TENs in 42 children with use of Ender nails in 50 children to determine if one nail type is superior to the other. They found no significant between-groups differences in rates of major complications (TEN, 8/42; Ender, 6/50) or minor complications (TEN, 1/42; Ender, 2/50). Their results, which suggest that there is no significant clinical difference between these stabilization materials, are contrary to our results. We demonstrated significantly faster healing (callus formation) and faster return to full weight-bearing in patients treated with TENs than in patients treated with Ender nails. However, our Ender group was older than our TEN group (mean ages, 11.1 and 8 years, respectively) and weighed almost twice as much as our TEN group (43 kg and 28 kg, respectively). Further study is needed to determine the impact of these results and to determine whether selection bias may have played a role in these outcomes.

LLD was not a major problem in our patients. We encountered 17 cases of 1 cm or less, 4 cases of less than 2 cm, and 3 cases of more than 2 cm measured clinically and confirmed by scanograms. Although recognition of LLDs is important, data and long-term follow-up are so far insufficient for determining what permanent clinical impact they may have, if any.

Conclusions

Use of FINs for definitive stabilization of femoral shaft fractures in children is a reliable, minimally invasive, and physeal-protective treatment method. Our study results provide new evidence that expands the inclusion criteria for this treatment and shows that FINs can be successfully used regardless of age, weight, fracture location, and fracture pattern. There is a significant learning curve; this treatment should not be used only occasionally. Further investigation may provide additional evidence that appropriate nail selection (TEN or Ender) based on fracture and patient characteristics may improve outcomes.

Authors' Disclosure Statement

The authors report no actual or potential conflict of interest in relation to this article.

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This paper will be judged for the Resident Writer's Award.