Elastic Intramedullary Nailing Versus Open Reduction Internal Fixation of Pediatric Tibial Shaft Fractures

Andrew T. Pennock, MD,† Tracey P. Bastrom, MA,† and Vidyadhar V. Upasani, MD*†*

Background: The optimal fixation strategy for unstable pediatric tibia fractures is unclear with some favoring elastic intramedullary nails (EIN) and others favoring plate and screws [open reduction internal fixation (ORIF)]. The purpose of this study was to compare outcomes and complications of skeletally immature patients undergoing surgical stabilization of the tibia with either EIN or ORIF.
Methods: A retrospective review was performed on all patients undergoing EIN or ORIF of a diaphyseal fracture at a single pediatric level I trauma center between 2010 and 2016. Patients were included if they had open growth plates, no intra-articular or physeal involvement, and radiographic follow-up until union. Patient demographic, injury, radiographic, and surgical data were recorded. Outcome measures included achievement of union, time to healing, residual deformity, complications, need for additional procedures, and return to sport. Statistical analysis was performed with alpha set at $P < 0.05$.
Results: A total of 70 patients met inclusion, 44 underwent EIN and 26 underwent ORIF. There were no significant differences between demographics or injury variables between groups other than ORIF patients having more distal fractures (44% vs. 32%; $P = 0.006$). At a mean follow-up of 1.4 years, 97% of fractures healed and there was no difference in healing rates between groups. The mean time to union was 15 weeks. ORIF patients had a shorter cast duration (7 vs. 10 wk; $P < 0.001$), less angular deformities > 5 degrees (15% vs. 41%; $P = 0.03$), and lower rates of subsequent surgery (35% vs. 91%; $P < 0.001$), but trended toward longer operating room times (69 vs. 59 min; $P = 0.06$), and higher rates of wound complications (23% vs. 9%; $P = 0.10$). Regardless of surgical technique, nearly all patients returned to full activities with no significant deficits.
Conclusions: Surgical stabilization of unstable pediatric tibia fractures with ORIF or EIN constructs lead to predictable healing in the majority of patients. Complications can occur and differ based on surgical approach. ORIF led to more anatomic reductions and lower rates of second surgeries, but trended toward higher rates of wound-related complications and slightly longer operating room times.
Level of Evidence: Level III—therapeutic study.

Key Words: tibia fractures, elastic intramedullary nailing, open reduction internal fixation, pediatric fractures

(*J Pediatr Orthop* 2017;00:000–000)

From the *Department of Orthopaedic Surgery, University of California; and †Department of Orthopedics, Rady Children's Hospital and Health Center, San Diego, CA.
No funding or support was received for this work.
The authors declare no conflicts of interest.
Reprints: Andrew T. Pennock, MD, 7960 Birmingham Drive, 4th Floor, MC 5062, San Diego, CA 92123. E-mail: apennock@rchsd.org.
Copyright © 2017 Wolters Kluwer Health, Inc. All rights reserved.
DOI: 10.1097/BPO.0000000000001065

Tibia fractures are the third most common long bone fracture in children and approximately 12% of trauma-related procedures in a standard pediatric orthopaedic practice will involve the tibia.[1] While conservative management with closed manipulation and cast immobilization has been the mainstay of treatment for minimally displaced, low-energy tibia fractures,[2,3] in certain circumstances, surgical stabilization may be required. Potential surgical indications include: open fractures, "floating knees" (concomitant femur and tibia fracture), patients with compartment syndrome, and unstable fracture patterns that fail closed treatment. The optimal treatment for these relatively uncommon surgical cases is unclear with some favoring elastic intramedullary nails (EIN), and some favoring rigid fixation with plates and/or screws, and others favoring external fixation.[4–7]

At our institution with 10 fellowship-trained pediatric orthopaedic surgeons, there is treatment variety with respect to how these surgical tibia fractures are managed. The purpose of the current study was to assess surgical outcomes and complications of pediatric patients undergoing surgical stabilization of a diaphyseal tibia fracture that were treated with EIN versus those treated with rigid fixation using a plate and/or screws.

METHODS

After internal review board approval was obtained, a retrospective review of charts and radiographs of all patients treated surgically at a single level 1 pediatric trauma center with a diaphyseal tibia fracture between 2010 and 2016 was performed. A patient was deemed eligible for inclusion in the study if the following criteria were met: (1) the fracture involved the diaphysis of the tibia with no intra-articular extension or physeal involvement, (2) the distal and proximal tibial growth plates were open, (3) the fracture was treated in an open manner with either plate and/or screws [open reduction internal fixation (ORIF)] or it was treated with EIN, (4) there was clinic follow-up either to radiographic union or to 6 months from the index treatment. Patients with underlying syndromes and metabolic bone disease were excluded from the analysis.

Charts were reviewed for relevant clinical and demographic information. The inciting injury was determined from

Copyright © 2017 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

the medical record and dichotomized based on mechanism. Motor vehicle collisions and pedestrian versus automobile incidents were classified as high-energy mechanisms, whereas mechanical falls and sporting injuries (team sports, biking, skateboarding, etc.) were classified as low-energy mechanisms. Emergency department and hospital records were further reviewed to assess for the presence of co-incident traumatic injuries including head injury, solid organ injuries and other fractures. In addition, any treatment before surgery was documented including an attempt at a closed reduction. Open fractures were graded according to the Gustillo classification.[8]

Prereduction radiographs for each patient were evaluated and classified according to the AO classification system.[9] Injury films were also assessed for tibial comminution, as defined by the presence of >2 fracture fragments. The fractures were classified as to their location within the diaphysis as either being proximal, midshaft, or distal as well as their orientation (short oblique, long oblique, transverse). In addition, the presence of a fibula fracture was documented.

The indications for surgical stabilization included: polytrauma (17%), open fracture (32%), compartment syndrome (7%), inability to obtain reduction (11%), or loss of reduction after closed treatment (32%). For this study, 10 fellowship-trained board-certified pediatric orthopaedic surgeons performed the procedures. The decision to treat the fracture with either plate and/or screws (ORIF) versus EIN was typically multifactorial based on the surgeon's training and comfort with each technique. Regardless of approach, the surgical time was documented, as well as the specific implant utilized, whether or not the fracture site had to be opened, and the total incision length (if recorded in the operative report). For patients treated with EIN where multiple incisions were created (proximal medial, proximal lateral, and possibly the fracture site), the incision length was calculated as the total length of all incisions combined.

Patients were followed with serial clinic visits and radiographs until final healing was obtained (defined as bridging of 3 of 5 cortices) or until 6 months from the index procedure, at which time they were classified as a nonunion. The fracture alignment at final healing was measured. Coronal plane alignment was measured from the anteroposterior radiograph, and the fracture was characterized as having a varus or valgus deformity if the angulation was >5 degrees. Similarly, the sagittal plane alignment was assessed on lateral films and >5 degrees was again used as the cut-off defining a deformity. Fracture shortening was measured as the vertical displacement of the nonopposed fracture ends. A patient was deemed to have adequate final fracture alignment if there was <5 degrees angulation in both the coronal and sagittal planes and <1.0 cm of shortening. Patients with >10 degrees of residual angulation in either plane or >1.0 cm of shortening were considered a major complication.

In addition, patients requiring an additional procedure other than routine removal of implants or complications predisposing to long-term complications (ie, premature physeal closure, refracture, etc.) were classified as major complications. At final healing, the width of the tibia at the fracture site including any implant or fracture callus was measured and compared with the thickness of the surrounding normal tibia. This calculation provided a thickness ratio of the healed bone to see if the patients treated with ORIF or EIN had a more prominent healed fracture site (Fig. 1). Minor complications involved a change in treatment plan such as additional casting or oral antibiotics, but no long-term sequelae or need for surgical intervention. Other variables documented at final follow-up included achievement of union, time to union, duration of immobilization, duration of weight-bearing restriction, and release/return to full activities.

Statistical Methods

Baseline, treatment, and outcome data were compared between the 2 treatment groups (ORIF vs. EIN). Continuous dependent variables were analyzed utilizing analysis of variance techniques and all variables were assessed for normality and homogeneity of variance. Categorical dependent variables were analyzed between groups using χ^2 analysis. Alpha was set at $P<0.05$ to declare significance and SPSS version 12 was utilized to perform the analysis (SPSS Inc., Chicago, IL).

RESULTS

Seventy patients met inclusion criteria for the study. The average age of the patient cohort was 11.5 ± 2.8

FIGURE 1. A and B, Typical healing associated plate fixation of a displaced tibia fracture.

Copyright © 2017 Wolters Kluwer Health, Inc. All rights reserved.

Copyright © 2017 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

years and 74% were male. The EIN group consisted of 44 patients where as the ORIF group consisted of 26 patients. The demographic data (Table 1) revealed no differences between groups with respect to patient age, sex, weight, or body mass index ($P > 0.05$). The injury data also revealed no differences between groups with respect to a high-energy or low-energy mechanisms, whether or not an attempt at closed treatment was performed, or whether or not the fracture was open ($P > 0.05$). While the patients treated with ORIF were more likely to have distal tibial shaft fractures (44% vs. 32%; $P = 0.006$), no other differences were noted between groups with respect to the initial injury radiographs.

Patients undergoing ORIF had a mean surgical time of 69 ± 17 minutes, a mean incision length of 8.3 ± 2.3, were casted on average for 7.0 ± 2 weeks, and were allowed to begin weight-bearing at 6.6 ± 1.5 weeks. The majority of patients in the ORIF group were treated with a plate and screws, however 3 patients (12%) were treated with 2 to 3 lag screws in isolation with no plate. At a mean follow-up of 63 ± 70 weeks, 100% of the fractures had healed with a mean time to healing of 13.2 ± 6.3 weeks. 85% of patients healed in an anatomic position with < 5 degrees of angular deformity and all but 1 patient (96%) healed within 10 degrees. At final radiographic follow-up, the diameter of the fracture site compared with the native tibial diaphysis was 1.2 ± 0.1. Minor complications were observed in 10 patients (38%) and major complications were observed in 3 patients (12%). The minor complications consisted of 4 mild angular deformities (> 5 degrees, but < 10 degrees), 4 cases of minor wound dehiscence requiring local wound care and oral antibiotics, one pressure ulcer, and a case of a tibial stress fracture after plate removal which required a short course of activity modification. The major complications consisted of 2 cases of wound dehiscence requiring one additional surgery in each case consisting of an irrigation and debridement and repeat wound closure followed by a course of antibiotics and a single patient who developed a symptomatic malunion with a 16 degrees procurvatum deformity which required an osteotomy and a rigid locked intramedullary nail. Two patients undergoing EIN developed a postoperative compartment syndrome. Both of these patients had high-energy comminuted tibia fractures associated with motor vehicle accidents with other associated long bone fractures. In both instances the compartment syndromes were diagnosed between 12 and 24 hours after the initial surgical stabilization. Neither of these 2 patients had long-term complications from their injuries or surgical treatment. In total, 27% of patients in the ORIF group elected to have their symptomatic implants removed.

TABLE 1. Patient Demographic, Injury, and Radiographic Data for the Elastic Intramedullary Nail Cohort (EIN) Versus the Plate and/or Screw Cohort (ORIF)

	EIN (N = 44) (%)	ORIF (N = 26) (%)	P
Age (y)	11.9 ± 2.4	10.8 ± 3.4	0.10
Sex (male)	77	69	0.46
Weight (kg)	54 ± 17	46 ± 22	0.15
BMI	22 ± 6	20 ± 5	0.30
High energy	52	42	0.42
Attempted closed treatment	45	54	0.50
Fracture pattern			0.33
Short oblique	73	62	
Long oblique	27	38	
Transverse	0	0	
Comminution	39	42	0.76
Fracture location			**0.006**
Proximal	0	0	
Midshaft	68	35	
Distal	32	65	
Fibula fracture	82	85	0.76
Open fracture	32	27	0.66

BMI indicates body mass index; ORIF, open reduction internal fixation.
Values in bold represent a P-value < 0.05.

Patients undergoing EIN had a mean surgical time of 58 ± 18 minutes, a mean combined incision length of 7.8 ± 3.0 cm, were casted on average for 10.5 ± 4.1 weeks, and were allowed to begin weight-bearing at 8.5 ± 3.0 weeks. At a mean follow-up, 80 ± 65 weeks, all but 2 patients (96%) had healed their fracture with a mean time to healing of 16.2 ± 6.5 weeks. In total, 59% of patients healed in an anatomic position with < 5 degrees of angular deformity and 86% healed within 10 degrees. At final radiographic follow-up, the diameter of the fracture site compared with the native tibial diaphysis was 1.2 ± 0.2. Minor complications were observed in 12 patients (27%) and major complications were observed in 8 patients (18%). The minor complications consisted of 10 mild angular deformities (> 5 degrees, but < 10 degrees) and 2 cases of minor wound dehiscence requiring local wound care and oral antibiotics. The major complications included 2 cases of postoperative compartment syndrome, 2 cases of wound dehiscence requiring an additional surgery in each case consisting of an irrigation and debridement and repeat wound closure followed by a course of antibiotics, 2 sympotmatic malunions requiring additional surgery (1 malunion repair and 1 ostectomy), and 2 nonunions. A total of 84% of patients in the EIN group elected to or were advised to have their symptomatic implants removed.

When comparing the ORIF group to the EIN group, the ORIF group mobilized approximately 3.5 weeks faster ($P < 0.001$), began weight-bearing 2 weeks faster ($P = 0.002$), and had a trend toward faster healing by 3 weeks ($P = 0.08$). The ORIF group was more likely to heal with < 5 degrees of residual deformity ($P < 0.03$) and was less likely to require an additional procedure ($P < 0.001$). With respect to other complications and returning to activities, there were no statistically significant differences between treatment groups (Table 2).

DISCUSSION

The introduction of intramedullary nails revolutionized fracture care in the years following World War II enabling early patient mobilization and weight-bearing.[10] While multiple long bones are amenable to rigid intramedullary nailing, a contraindication to this technique in the tibia is a patient with

Copyright © 2017 Wolters Kluwer Health, Inc. All rights reserved.

Copyright © 2017 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

TABLE 2. Outcome Data and Complications for the Elastic Intramedullary Nail Cohort (EIN) Versus the Plate and/or Screw Cohort (ORIF)

	EIN (N = 44) (%)	ORIF (N = 26) (%)	P
Follow-up (wk)	80 ± 65	74 ± 67	0.31
Surgical time (min)	59 ± 18	69 ± 22	0.06
Total incision(s) length (cm)	7.8 ± 3.0	8.3 ± 2.3	0.54
Achieved union	95	100	0.27
Time to union (wk)	16.2 ± 6.5	13.2 ± 6.3	0.08
Cast duration (wk)	10.5 ± 4.1	7.0 ± 2.1	**< 0.001**
Weight-bearing restrictions (wk)	8.5 ± 3.0	6.6 ± 1.5	**< 0.001**
Mean maximum angular deformity (deg.)	4.6 ± 4.0	3.1 ± 3.8	0.13
Healed tibia width ratio	1.2 ± 0.2	1.2 ± 1.4	0.36
Healing with < 5 degrees deformity	59	85	**0.03**
Healing with < 10 degrees deformity	86	96	0.19
Minor complication	27	38	0.33
Major complication	18	12	0.46
Removal of implants	84	27	< 0.001
Other additional surgeries	12	16	0.89
Released to full activities	95	96	0.64

BMI indicates body mass index; ORIF, open reduction internal fixation.
Values in bold represent a P-value < 0.05.

open physes with substantial growth remaining. For these instances, flexible intramedullary nails have been developed which spare the physis and can be inserted distant from the fracture site allowing the fracture site to not have to be opened in most circumstances. Multiple studies have now shown good outcomes with this technique for unstable tibia fractures in the pediatric population.[11–15]

There are several drawbacks to flexible intramedullary nails compared with rigid locked intramedullary nails, including the lack of construct rigidity which allows potential loss of reduction, a short period of immobilization is frequently required, and weight-bearing is typically delayed for 4 to 6 weeks. Gordon and colleagues reported on 60 pediatric diaphyseal tibia fractures treated with titanium elastic nails and reported an 11% (5 patients) rate of delayed healing. Three of these patients healed with prolonged casting or observation and 2 required revision surgery with a fibular osteotomy or exchange to a reamed rigid nail.[15] For these reasons as well as others, some surgeons continue to favor open reduction and internal fixation with plates and/or screws in this population.[16–18] The superficial nature of the tibia enables an easy approach and an anatomic reduction can be achieved with fracture compression using lag screws or a dynamic compression plate. A concern with this technique, however, is that the lack of soft tissue overlying the diaphysis of the tibia as well as any periosteal dissection that may be required to obtain an anatomic reduction may delay fracture healing and predispose to wound-related complications such as dehiscence and infection. To date, no head-to-head study has compared the results of EIN to plate and/or screw fixation of diaphyseal tibia fractures in patients with open growth plates.

Not surprisingly, the results of the current study reveal that both techniques (EIN and ORIF) provide good outcomes with high union rates and high levels of return to activities and sport (Figs. 1, 2). A little more surprising was the differential advantages and disadvantages of each technique that were observed. Patients treated with ORIF healed, mobilized, and began walking slightly faster (2 to 4 wk) than patients treated with EIN. Even though the fracture site had to be opened in all cases treated with ORIF, we hypothesize that the fractures healed slightly faster because an anatomic reduction was obtained with compression across the fracture site. In our experience, most pediatric tibia fractures have short oblique, long oblique, or comminuted fracture configurations which are amenable to lag screw fixation. In fact, 3 patients (12%) of our fractures treated in our ORIF cohort were treated with screws alone and no plate, minimizing the incision length, periosteal stripping, and implant prominence.

Another advantage of ORIF was that the fractures healed in a more anatomic position. A greater proportion of patients in the EIN group had a residual deformity > 5 degrees compared with the ORIF group (41% vs. 15%; $P < 0.05$). The exact clinical significance and long-term implications of these mild angular deformities is currently unknown. Interestingly, the one case in the ORIF group that developed a symptomatic malunion was rigidly fixed

FIGURE 2. A and B, Typical healing associated with elastic nail fixation of a displaced tibia fracture.

Copyright © 2017 Wolters Kluwer Health, Inc. All rights reserved.

Copyright © 2017 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

in the misaligned position at the time of surgery. Otherwise, there were no cases of lost reduction. In the EIN group on the other hand, many patients were noted to have minor loss of reduction in the fracture healing process, and 5 patients (14%) had significant loss of reduction that resulted in an angular deformity of > 10 degrees. To date, 3 of these patients are asymptomatic from their deformity, 1 has elected to have a malunion repair over a rigid locked intramedullary nail, and 1 patient remains symptomatic and has been offered a revision surgery, but is holding off on surgery for now (Fig. 3). Future studies will be necessary to determine which patients and which fracture patterns are best suitable for EIN.

The results of the current study suggest that a potential disadvantage of plate fixation is a higher incidence of wound-related complications. In the ORIF group, 15% of patients required oral antibiotics and another 8% required at least one additional surgical debridement and intravenous antibiotics compared with the EIN group which averaged 5% and 5%, respectively. These findings are not totally surprising given the fact that 100% of the fracture sites were opened in the ORIF group compared with only 48% (of which 32% were traumatic open fractures and 16% had to be opened to reduce the fracture and pass the nails) in the EIN group. Despite the relatively high wound-related complications in this series, this has also been observed in other series involving high energy tibia fractures with a high percentage of open and comminuted fractures.[15,18,19] Fortunately, none of the wound-related complications resulted in significant long-term morbidity with no cases of chronic osteomyelitis, no amputations, and no coverage procedures being necessary. This is likely due to the youth (all under 16 y of age) and health (no smokers or diabetics) of the study population, but certainly this may become a concern with larger series.

The need for a second procedure was higher in the EIN group compared with the ORIF group. This finding likely stems from our institutional bias where nails are routinely removed 6 to 12 months after the index procedure where as plates and screws are typically left in place unless they are significantly symptomatic. Another possible explanation for this difference is that elastic nails are frequently placed slightly prominent to facilitate future implant removal. This superficial placement puts these implants at greater risk of being symptomatic compared with low profile plates that are placed immediately adjacent to the tibial cortex. Regardless of the exact reason for this difference, these second procedures add substantial costs, require additional resources, and impart

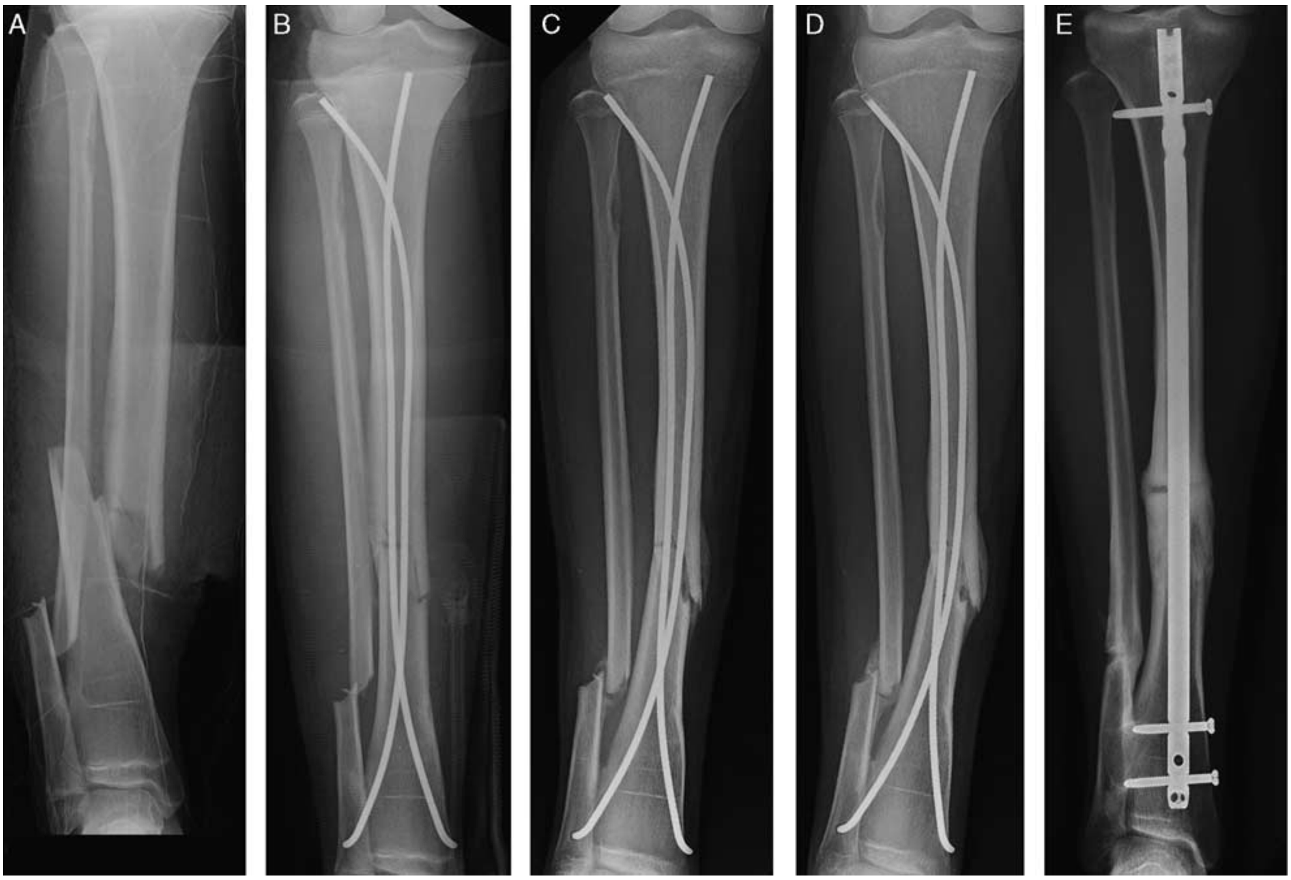

FIGURE 3. A, A 14-year-old male with an open tibia fracture from a motor vehicle accident. B, Initial postoperative radiograph after the fracture was fixed with elastic nails. C, Early loss of reduction seen at 6 weeks. D, Progressive loss over reduction observed at 4 months. E, Revised tibia with a rigid intramedullary nail.

Copyright © 2017 Wolters Kluwer Health, Inc. All rights reserved.

Copyright © 2017 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

added patient risk to the treatment of these fractures. We believe this should be considered when selecting the optimal treatment approach for a surgical tibia fracture. In addition, patients and their families should be counseled accordingly.

There are several limitations to the current study mostly stemming from its study design. Clearly, a randomized clinical trial would allow better conclusions to be drawn, but performing a study of this nature would be challenging and expensive to perform for a relatively rare surgical procedure. Given the retrospective nature of the study design, we focused our outcomes primarily on radiographic measures and complications. While patient derived outcome scores were not obtained, nearly all patients were cleared for full sporting activities and officially released from our clinics with no additional follow-up necessary. Finally, given our study design, we cannot account for surgeon bias as to why each of the treatment approaches was selected. While nearly all demographic, injury, and preoperative radiographic factors were statistically similar, the ORIF group tended to have more distal fractures, revealing at least some element of selection and surgeon bias.

In conclusion, there is little data in the orthopaedic literature to guide surgeon's treatment of tibia fractures in the pediatric population. The results of the current study reveal that both flexible intramedullary nailing and open reduction internal fixation with plates and/or screws yields high union rates and return to activity. Patients treated with plates and/or screws tend to heal and mobilize a few weeks faster, have slightly more anatomic reductions at final healing, and are less likely to require implant removal. These potential advantages must be balanced with the potential increased risk of wound-related complications associated with opening the fracture site. Overall, regardless of treatment approach, complication rates were around 16%. Patients and families should be informed of the pros and cons of each treatment approach.

REFERENCES

1. Ward WT, Rihn JA. The impact of trauma in an urban pediatric orthopaedic practice. *J Bone Joint Surg Am*. 2006;88:2759–2764.
2. Shannak AO. Tibial fractures in children: follow-up study. *J Pediatr Orthop*. 1988;8:306–310.
3. Thompson GH, Wilber JH, Marcus RE. Internal fixation of fractures in children and adolescents. A comparative analysis. *Clin Orthop Relat Res*. 1984;188:10–20.
4. Robertson P, Karol LA, Rab GT. Open fractures of the tibia and femur in children. *J Pediatr Orthop*. 1996;16:621–626.
5. Gordon JE, O'Donnell JC. Tibia fractures: what should be fixed? *J Pediatr Orthop*. 2012;32(suppl 1):S52–S61.
6. Bohn WW, Durbin RA. Ipsilateral fractures of the femur and tibia in children and adolescents. *J Bone Joint Surg Am*. 1991;73:429–439.
7. Letts M, Vincent N, Gouw G. The "floating knee" in children. *J Bone Joint Surg Br*. 1986;68:442–446.
8. 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;58:453–458.
9. Muller ME, Nazarian S, Koch P. *The Comprehensive Classification of Fractures of Long Bones*. New York, NY: Springer-Verlag; 1990.
10. Duan X, Al-Qwbani M, Zeng Y, et al. Intramedullary nailing for tibial shaft fractures in adults. *Cochrane Database Syst Rev*. 2012;1:CD008241.
11. Kc KM, Acharya P, Sigdel A. Titanium elastic nailing system (TENS) for tibia fractures in children: functional outcomes and complications. *JNMA J Nepal Med Assoc*. 2016;55:55–60.
12. Heo J, Oh CW, Park KH, et al. Elastic nailing of tibia shaft fractures in young children up to 10 years of age. *Injury*. 2016;47:832–836.
13. Sankar WN, Jones KJ, David Horn B, et al. Titanium elastic nails for pediatric tibial shaft fractures. *J Child Orthop*. 2007;1:281–286.
14. Karaman I, Halici M, Kafadar IH, et al. Mid-term results of the elastic intramedullary nailing in paediatric long bone shaft fractures: a prospective study of 102 cases. *J Pediatr Orthop B*. 2014;23:212–220.
15. Gordon JE, Gregush RV, Schoenecker PL, et al. Complications after titanium elastic nailing of pediatric tibial fractures. *J Pediatr Orthop*. 2007;27:442–446.
16. Head J, Lewis TR, Puffinbarger W, et al. Plating of open pediatric tibia fractures. *J Okla State Med Assoc*. 2014;107:382–383.
17. Clifford RP, Beauchamp CG, Kellam JF, et al. Plate fixation of open fractures of the tibia. *J Bone Joint Surg Br*. 1988;70:644–648.
18. Masquijo JJ. Percutaneous plating of distal tibial fractures in children and adolescents. *J Pediatr Orthop B*. 2014;23:207–211.
19. Pandya NK. Flexible intramedullary nailing of unstable and/or open tibia shaft fractures in the pediatric population. *J Pediatr Orthop*. 2016;36(suppl 1):S19–S23.

Copyright © 2017 Wolters Kluwer Health, Inc. All rights reserved.

Copyright © 2017 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.