Outcomes Using Titanium Elastic Nails for Open and Closed Pediatric Tibia Fractures

DEMETRI M. ECONOMEDES, DO; JOSHUA M. ABZUG, MD; EBRAHIM PARYAVI, MD; MARTIN J. HERMAN, MD

abstract
Full article available online at Healio.com/Orthopedics

The authors conducted a retrospective review at their level I trauma center to assess the outcomes of closed vs open pediatric tibial fractures treated with titanium elastic nails. The study group included 38 pediatric patients (median age, 12 years) treated with titanium elastic nails for tibial fractures during a 5-year period. Patient demographics, closed or open injury, Gustilo-Anderson type for open fractures, fracture location, skeletal maturity, time to union, hospital length of stay, number of procedures performed per patient, and complications were recorded. The main outcome measures were time to union and complications. Average follow-up duration was 13 months. Mean time to union was 4 months for closed and 9 months for open fractures ($P<.001$). Average time to union for type IIIA and IIIB fractures was significantly increased (11 and 12 months, respectively; $P=.02$). Delayed union (>6 months postoperatively) occurred in 1 (6%) of 17 closed fractures compared with 11 (52%) of 21 open fractures. The average number of surgical procedures for closed fractures was fewer than for open fractures (2 vs 3 procedures, respectively; $P=.03$). Mean hospital length of stay was shorter for closed than open fractures (3 vs 6 days, respectively; $P=.03$). Two infections occurred in the open fracture group. Closed and open pediatric tibial shaft fractures can be successfully treated with titanium elastic nails. Open fractures treated with titanium elastic nails have a significantly longer time to union, require additional operative procedures, and result in longer hospital stays.

The authors are from the Department of Orthopaedic Surgery (DME, MJH), St. Christopher’s Hospital for Children, Philadelphia, Pennsylvania; and the Department of Orthopaedics (JMA, EP), University of Maryland School of Medicine, Baltimore, Maryland.

The authors have no relevant financial relationships to disclose.

The authors thank Senior Editor and Writer Dori Kelly, MA, for professional manuscript editing and formatting the figures.

Correspondence should be addressed to: Joshua M. Abzug, MD, 1 Texas Station, Ste 300, Timonium, MD 21093 (jabzug@umms.umm.edu).

Received: August 14, 2013; Accepted: December 27, 2013; Posted: July 11, 2014.
doi: 10.3928/01477447-20140626-52
ibial shaft fractures account for 15% of pediatric long-bone fractures and are the second most common cause of posttraumatic pediatric orthopedic hospital admissions. Although most displaced tibial shaft fractures are treated with closed reduction and cast immobilization, use of titanium elastic nails to stabilize displaced length stable fractures has become increasingly popular and has achieved uniformly good results. Ease of insertion, increased patient comfort, and minimal scarring have rendered these implants more appealing than external fixation. The majority of initial published cases managed with titanium elastic nails were closed injuries. However, more recent studies have reported the use of titanium elastic nails to treat open fractures.

Previous studies of pediatric patients with open tibial fractures treated by any means have reported a substantial rate of delayed healing, especially in older children. However, Srivastava et al recently found a longer time to union with titanium elastic nails in a closed fracture group (21.5 weeks) compared with an open fracture group (20.2 weeks). Furthermore, Gordon et al presented a report of the complications associated with titanium elastic nails for pediatric tibial fractures. The authors found delayed healing in 5 patients, 3 of whom had closed injuries.

Over the past several years, the current authors have used titanium elastic nails almost exclusively for surgical stabilization of closed tibial shaft fractures with open physes for failed closed reductions and for open injuries. During this time, the authors have noticed a pattern of delayed healing of open fractures, which is contrary to the findings of the aforementioned recent studies. The purposes of the current study were to review a consecutive series of patients treated with titanium elastic nails and to compare outcomes for closed versus open fractures. The authors’ hypothesis was that children with open fractures treated with titanium elastic nails would achieve satisfactory outcomes but experience longer healing times compared with children with closed injuries. The authors also sought to identify patient and fracture characteristics that were predictive for delayed union or nonunion.

**Materials and Methods**

After institutional review board approval, the authors retrospectively identified all pediatric patients who underwent implantation of titanium elastic nails at the authors’ institution for displaced tibial shaft fractures from 2004 to 2009. Patient demographics, mechanism of injury, associated injuries, hospital length of stay, and fracture status (closed vs open) were recorded. Operative reports from the initial irrigation and debridement procedures were used to grade the open fractures based on Gustilo-Anderson classification. The number of procedures performed and complications, including infections, delayed unions, and nonunions, were determined from hospital and outpatient records. Radiographs were reviewed to determine fracture location and skeletal maturity.

**Radiographic Analysis**

Radiographs were analyzed to determine the fracture location (proximal third, middle third, or distal third), to assess the postoperative alignment, and to follow fracture healing. Radiographic union was defined as bone bridging across 3 of 4 cortices at the fracture site as viewed on orthogonal radiographs. Delayed union was defined as radiographic bony union not occurring by 6 months after definitive treatment. In addition, skeletal maturity was determined based on the degree of ossification of the tibial tubercle, as classified by Ogden et al.

**Open Fracture Management**

All patients with open fractures received antibiotics in the emergency department and had tetanus status verified or brought up to date. Emergent irrigation and debridement procedures were performed in all patients before stabilization. Patients received intravenously administered antibiotics initially and until 48 hours after their last operative procedure.

**Surgical Technique**

All patients were brought to the operating room, and general anesthesia was administered. Closed fractures were manipulated to achieve reduction and were opened only when closed manipulation failed.

All open fractures underwent irrigation and debridement on an emergent basis. Type I open fractures underwent irrigation and debridement and were subsequently treated in a similar fashion to closed fractures. Types II and III open fractures underwent more extensive irrigation and debridement. Subsequently, the open fracture wound was used to aid in reduction of the fracture. Once adequate reduction was obtainable, all fractures were stabilized with 2 titanium elastic nails (diameters ranging from 2.5 to 4 mm) placed anterograde starting in the tibial metaphysis. Subsequently, a short-leg walking cast or fracture boot was worn until radiographic union was present.

**Statistical Analyses**

Demographic characteristics of all patients were explored and are reported with percentages for categorical variables and means with standard deviations or medians and interquartile ranges for continuous variables. Bivariate relationships between closed and open fracture and between patient and injury characteristics were assessed by conducting chi-square tests.
and Student t tests for categorical and continuous variables, respectively. Alpha for significance was set at .05, and all P values were 2-tailed.

**RESULTS**

**Demographics**

Forty-five pediatric patients whose tibial fractures were treated with titanium elastic nails were identified. Complete data were available for 38 of the 45 patients (Table 1). Median age at the time of injury was 12 years (range, 4 to 16 years). Seventeen patients had closed injuries and 21 had open fractures, which included 7 Gustilo-Anderson type I fractures, 7 type II fractures, and 7 type III fractures (5 type IIIA and 2 type IIIB). Mean number of procedures performed on patients, including removal of fixation devices (which occurred in all patients), was 2. Mean hospital length of stay after initial injury was 5 days. Patients were followed on a regular basis at 2 weeks, 6 weeks, 3 months, 6 months, and 1 year postoperatively. Patients without union were seen monthly until union was achieved. Mean follow-up duration was 13 months.

**Radiographic Analysis**

Based on injury radiographs, 1 fracture occurred in the proximal third, 18 in the middle third, and 19 in the distal third of the shaft. Mean time to union for all fractures was 7 months. No fracture healed with greater than 10° of angulation or greater than 1 cm of shortening at final follow-up. No significant relationship was observed between delayed union and skeletal maturity (P=.72).

**Complications**

Two wound infections occurred in patients with open fractures: 1 was superficial and resolved with orally administered antibiotics and the other was a subacute osteomyelitis that required a return trip to the operating room for removal of the fixation devices and debridement of the infected bone. One patient in the open fracture cohort incurred fracture through the callous at 3 months postoperatively and was treated with immobilization until union. Two patients developed compartment syndrome before undergoing nail insertion and underwent fasciotomies at the time of nail placement. No patients developed compartment syndrome postoperatively, and no neurovascular injuries occurred during the study period.

**Closed Versus Open Fractures**

Table 2 summarizes the differences in characteristics between closed and open fractures. Seventeen patients comprised the closed fracture cohort, including 6 female and 11 male patients with a mean age of 12 years.
years (range, 4 to 16 years). Eight closed fractures occurred in the middle third of the tibial diaphysis and 9 in the distal third. Mean initial hospital length of stay was 3 days. Each patient underwent placement and removal of the titanium elastic nails. Three (18%) of the 17 patients required open reduction to place the titanium elastic nails during the initial procedure. Mean time to radiographic union was 4 months (range, 2 to 8 months), with only 1 patient in this group experiencing delayed union (at 8 months). No major complications occurred.

Twenty-one patients comprised the open fracture cohort, including 4 female and 17 male patients with a mean age of 12 years (range, 7 to 16 years). One open fracture occurred in the proximal third of the tibial diaphysis, 10 in the middle third, and 10 in the distal third. Mean initial hospital length of stay was 6 days. Patients required a mean of 3 surgical procedures (range, 2 to 10 procedures) consisting of initial irrigation and debridement with fixation, repeat irrigation and debridement as needed, and ultimate removal of fixation devices from all patients. Mean time to radiographic union was 9 months (range, 2 to 12 months), with 11 patients in this group experiencing delayed union. Three (27%) of the 11 patients required return to the operating room for placement of a reamed locked intramedullary nail to achieve union.

Infections

Open fracture site wound infection was identified in 2 (10%) of the 21 open fractures. One patient with a type I open fracture developed cellulitis around the open wound that resolved with a course of orally administered antibiotics. No osteomyelitis was observed in this patient, and the fracture united without additional treatment 11 months after injury.

The other infection occurred in a type II open fracture and was treated with implant removal, debridement of suspected subacute osteomyelitis, and a course of intravenously administered antibiotics at 8 months after injury. Fracture union occurred 21 months after injury after the placement of a reamed locked intramedullary nail.

Delayed Unions

A total of 12 delayed unions occurred, including 3 that required further surgical intervention with placement of a reamed locked intramedullary nail to achieve fracture healing (Figures 1-4). One (6%) of 17 patients in the closed fracture group experienced delayed union, compared with 11 (52%) of 21 patients in the open fracture group (P<.001). An increased risk of delayed union was present for all open fractures compared with closed fractures regardless of the severity of the open fracture. Of the delayed unions present in the open fracture group, 4 occurred in 7 type I open fractures, 2 in 7 type II open fractures, and 5 in 7 type III open fractures (Table 3). The authors found a significantly greater time to union for type III A and B fractures (11 and 12
months, respectively) compared with other types ($P=.022$).

Based on location within the tibial diaphysis, 1 delayed union occurred in the 1 proximal third fracture, 5 in the 18 middle third fractures, and 6 in the 19 distal third fractures. When assessing delayed union based on fracture location and accounting for the presence or absence of an open fracture, no significant difference was observed in the rate of delayed union ($P=.74$).

**DISCUSSION**

Tibial shaft fractures in children usually can be managed by immobilization alone. However, unstable fractures require further intervention if acceptable alignment parameters are to be obtained after union. Traditional stabilization has included external fixation, but fixators can be cumbersome, can lead to pin tract infections, and are associated with bone re-fracture after removal.\(^6\),\(^13\),\(^14\) Subsequently, titanium elastic nails have been used to treat tibial shaft fractures because of the associated minimal scarring, ease of implementation, and low infection rates.

Initial reports of the use of titanium elastic nails to treat tibial shaft fractures mainly focused on closed fractures, with excellent outcomes reported.\(^6\),\(^7\) More recently, authors have reported the success of titanium elastic nails in the treatment of open fractures.\(^3\),\(^4\)

Historically, open tibial shaft fractures have been shown to have delayed union times when compared with those of closed fractures, especially in older children.\(^8\)–\(^10\) However, recent reports of the use of titanium elastic nails to treat open fractures showed a shorter time to union\(^4\) and fewer delayed unions compared with closed fractures.\(^3\) Srivastava et al\(^4\) reported that union occurred at an average of 20.2 weeks in an open fracture group treated with titanium elastic nails compared with 21.5 weeks in a closed fracture group. Gordon et al\(^3\) presented a report of 5 cases of delayed union after use of titanium elastic nails in 51 patients younger than 17 years, 3 of which occurred in the closed fracture group and 2 in the open fracture group.

The current study shows more delayed unions in the open fracture group compared with the closed fracture group (52% vs 6%, respectively) and a longer overall time to union in the open fracture group (9.2 vs 4.2 months, respectively). Three of the patients with delayed union in the open fracture group required additional operative procedures, including placement of a reamed locked intramedullary nail to achieve union, compared with none in the closed fracture group. Srivastava et al\(^4\) also found a higher number of delayed unions in the open fracture group compared with the closed fracture group (44% vs 25%, respectively), similar to the current authors’ findings but with a higher rate present in the closed fracture group.

Further analysis of the authors’ data showed that there was a higher complication rate in the open fracture group. Two patients had infections; 1 required a return to the operating room for removal of the fixation device and debridement and 1 incurred refracture through the callous and was treated with immobilization. No major complications occurred in the closed fracture cohort. Furthermore, patients with open fractures have longer hospital stays (6 vs 3 days, respectively) and require more surgical procedures (3 vs 2 procedures, respectively) than do patients with closed fractures.

Limitations of the current study include its retrospective nature and lack of a control group treated with either external fixation or immobilization alone. However, many patients do not tolerate external fixation well, and there is a known associated risk of pin tract infections. Furthermore, treatment of unstable fractures with immobilization alone is suboptimal in that final union could have unacceptable parameters. Because of the retrospective nature of this review, the authors were not able to control for intraoperative decision making, such as the exact amount of debridement performed, selection of nail size, reduction technique, and amount of periosteal stripping. However, these factors would be dif-

---

**Table 3**

<table>
<thead>
<tr>
<th>Type of Open Injury</th>
<th>No. of Patients</th>
<th>Average Time to Union, mo</th>
<th>No. of Delayed Unions at ≥6 mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>7</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>II</td>
<td>7</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>IIIA</td>
<td>5</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>IIIB</td>
<td>2</td>
<td>12</td>
<td>5</td>
</tr>
</tbody>
</table>

**Figure 4:** Post-revision anteroposterior (A) and lateral (B) radiographic views showing revision of fixation to a standard locked intramedullary nail, which ultimately resulted in union.
difficult to control for, even in a prospective randomized trial.

**Conclusion**

Fixation of both closed and open pediatric tibial shaft fractures with titanium elastic nails is effective in maintaining alignment and achieving union. Time to healing is significantly longer for open fractures than for closed fractures. In addition, a higher rate of complications, including delayed union and infection, is associated with the use of titanium elastic nails for open fractures compared with closed fractures. Despite these longer times to union and higher complication rates, the authors believe that the use of titanium elastic nails to treat open tibial fractures in pediatric patients is safe and effective.

**References**