Intramedullary Nailing of Proximal Quarter Tibial Fractures

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Objective: To report the results of intramedullary nailing of proximal quarter tibial fractures with special emphasis on techniques of reduction.

Design: Retrospective clinical study.

Setting: Level 1 trauma center.

Patients: During a 36-month period, 456 patients with fractures of the tibial shaft (OTA type 42) or proximal tibial metaphysis (OTA type 41A2, 41A3, and 41C2) were treated operatively at a level 1 trauma center. Thirty-five patients with 37 fractures were treated primarily with intramedullary nailing of their proximal quarter tibial fractures and formed the study group. Thirteen fractures (35.1%) were open and 22 fractures (59.5%) had segmental comminution. Three fractures had proximal intraarticular extensions.

Main Outcome Measurements: Alignment and reduction postoperatively and at healing. An angular malreduction was defined as greater than 5 degrees in any plane.

Results: Fractures extended proximally to an average of 17% of the tibial length (range, 4% to 25%). The average distance from the proximal articular surface to the fracture was 67.8 mm (range, 17 mm to 102 mm, not corrected for distance magnification, included for preoperative planning purposes only). Postoperative angulation was satisfactory (average coronal and sagittal plane deformity of less than 1 degree) as was the final angulation. Acceptable alignment was obtained in 34 of 37 fractures (91.9%). Two patients had 5-degree coronal plane deformities (one varus and one valgus), and 1 patient had a 7-degree varus deformity.

Two patients with open fractures with associated bone loss underwent a planned, staged iliac crest autograft procedure postoperatively. Four patients were lost to follow-up. In the remaining 31 patients with 33 fractures, the proximal tibial fractures united without additional procedures. No patient had any change in alignment at final radiographic evaluation. Secondary procedures to obtain union at the distal fracture in segmental injuries included dynamizations (n = 3) and exchange nailing (n = 1). Complications included deep infections in 2 patients that were successfully treated.

Conclusions: Multiple techniques were required to obtain and maintain reduction prior to nailing and included attention to the proper starting point, the use of unicortical plates, and the use of a femoral distractor applied to the tibia. Simple articular fractures and extensions were not a contraindication to intramedullary fixation. The proximal tibial fracture healed despite open manipulations. Short plate fixations to maintain this difficult reduction, either temporary or permanent, were effective.

Key Words: proximal tibia fracture, intramedullary nailing, temporary plate fixation

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INTRODUCTION

Treatment of extraarticular proximal tibial fractures remains problematic. The goals of surgical management include correction and maintenance of sagittal and coronal alignment, restoration of length and rotation, and early functional knee and ankle range of motion. Treatment options include medullary implants, half pin external fixation, hybrid or thin wire external fixation, plate fixations, or combination techniques.[1–12] Ideally, the surgical insult will not produce significant additional injury to already traumatized local soft tissues.

Tibial fracture fixation with an intramedullary device is desirable because this technique allows some load sharing, spares the extraosseous blood supply, avoids an extensive soft-tissue dissection, and is familiar to most surgeons. Intramedullary nailing is particularly advantageous in patients with segmental tibial comminution or tibial fractures with multiple noncontiguous sites of injury. However, medullary nailing of proximal tibial fractures has been associated with significant complications including malalignment, nonunion, and the need for revision fixation. As a result, authors have cautioned against this technique.[9,11,13] Previously reported rates of unacceptable alignment after medullary nailing of proximal third tibial fractures have ranged from 58% to 84%. As a result, various techniques have been recommended to improve nailing proximal tibial fractures including a proximal and lateral starting point,[3,14] use of the semiextended position,[12] blocking screws,[15,16] temporary unicortical plates,[17] and use of newer nail designs with different proximal bends.[18]

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The purpose of this paper is to report the effectiveness of intramedullary nailing of tibial fractures involving the proximal 25% and to review the techniques necessary to successfully accomplish this procedure. We hypothesized that proximal tibial fractures could be effectively treated with intramedullary nailing, that the reduction could be well maintained, and that the complications could be managed effectively.

PATIENTS AND METHODS

During a 36-month period (1997 though 1999, inclusive) 456 skeletally mature patients with fractures of the tibial shaft (OTA type 42) or proximal tibial metaphysis (OTA type 41A2 and A3) were treated operatively at a Level 1 trauma center. Patients were eligible for inclusion if they were skeletally mature, had satisfactory radiographs available for review, demonstrated radiographic evidence of fracture involvement of the proximal quarter (25%) of the tibia, and had a fracture pattern amenable to intramedullary nailing. This included diaphyseal fractures with metaphyseal extension, proximal metaphyseal fractures, and fractures with simple articular extensions. A minimum of 4 cm of anterior tibial cortex was felt to be necessary to allow placement of a tibial nail. However, extension of the fracture proximally at the posterior cortex was not felt to be a contraindication to tibial nailing. Excluded were proximal tibial articular fractures that were characterized by any condylar widening or articular depression because these injury patterns were felt to be more consistent with a tibial plateau fracture as opposed to a proximal tibial fracture with or without articular extension. During this time period, 42 operatively treated fractures involved the proximal 25% of the tibia and met the aforementioned inclusion criteria. Three fractures were treated with unlocked plates and 2 fractures were treated with external fixation. The remaining 35 patients (7.7% of all tibia fractures) with 37 fractures were treated primarily with intramedullary nailing of their proximal quarter tibial fractures and formed the study group. The period of inclusion for this study predated lateral locked proximal tibial plating systems. There were 28 male and 7 female patients, ranging in age from 19 to 73 years (mean 42 years).

Their mechanisms of injury included auto versus pedestrian accidents in 24 patients, motor-vehicle accidents in 7 patients, falls from heights in 2 patients, and motorcycle accidents in 2 patients. The average Injury Severity Score[19] was 13.5 (range, 9–34). These fractures were classified according to their predominant fracture as 41A2 (n = 5), 41A3 (n = 7), 41C2 (n = 3), and 42 (n = 22) using AO/OTA guidelines.[20] Thirteen fractures (35.1%) were open and classified[21] as type I (n = 1), type II (n = 1), type IIIA (n = 7), type IIIB (n = 3), and type IIIC (n = 1). Five patients had a concomitant compartmental syndrome and were treated with 4 compartment fasciotomies at the time of their tibial nailing procedure. Three fractures had proximal intraarticular extensions. Twenty-two fractures (59.5%) had segmental comminution. Of these, 9 (27.0%) had "diaphyseal segmental comminution" characterized by combined proximal and distal tibial fractures with an intact central diaphyseal segment measuring at least 10 cm (Fig. 1A–G).

Biplanar radiographs were obtained on patients until fracture healing occurred. Radiographs were then reviewed jointly by the 2 senior authors and, in cases with discordant evaluations, agreement was reached by consensus. Radiographic measurements included total tibial length, proximal extent of the fracture, fracture classification, and presence of fracture union. Preoperative, postoperative, and final alignment on both the anteroposterior (AP) and lateral radiographs were assessed. An angular malreduction was defined as being 5 degrees or greater in any plane. Fracture union was defined radiographically as bridging cortical bone on at least 2 cortices combined with the ability to bear full weight on the extremity. Nonunion was defined as a failure of progressive radiographic healing over a 3-month period, at a minimum of 6 months from treatment. Delayed union was not defined for the purposes of this study.

Routine antibiotic prophylaxis (intraoperative and postoperative) was used and adjusted depending on the presence of associated open traumatic wounds. Patients followed the same basic postoperative rehabilitation protocol. Patients were initially placed in a splint followed by a removable boot. Patient with extraarticular fractures were restricted to non-weight bearing for 6 weeks followed by progression to activities as tolerated. In patients with articular fracture extensions, the initial period of non-weight bearing was extended to 12 weeks. Early active knee and ankle range-of-motion exercises were encouraged in all patients who were compliant.

SURGICAL TECHNIQUE AND TECHNIQUES OF REDUCTION

Eight different orthopedic trauma surgeons, each with fellowship training, performed these operative procedures. Patients were positioned supine on a radiolucent table. A fracture table was not used for these fractures at the choice of the surgeons and the institution. Preoperative intravenous antibiotic prophylaxis was administered. Open fractures were treated with an appropriate debridement and irrigation prior to definitive fixation. All tibial fractures were treated with a reamed intramedullary nailing system (Zimmer, Warsaw, IN) that optimizes proximal tibial fracture reduction and fixation. This nail allows for placement of up to 4 proximal interlocking screws through the proximal 4.5 cm of the nail. The 4 interlocking screws include 2 placed from medial to lateral and 2 placed obliquely. In addition, the proximal Herzog bend was felt to minimize any of the potential nail wedge effect in these proximal fractures.[5] The choice of implant was solely at the discretion of the operating surgeon, but in-hospital nail availability was also a factor.

A tourniquet usually was placed but was not used during reaming and nailing. A patellar tendon splitting approach was used in 28 fractures and a lateral parapatellar tendon approach was used in the remaining 9 fractures. The knee was then flexed past 90 degrees to assess the behavior of the proximal tibial fracture. If there was a significant flexion deformity at the fracture, additional methods for maintenance of reduction

FIGURE 1. A and B, Anteroposterior (AP) and lateral views of a 28-year-old male with a Type IIIA open tibial injury after being struck by a motor vehicle. Note the bifocal fracture, the proximal tibio-fibular disruption, and the fibular head fracture as seen on the lateral view. C, Intraoperative fluoroscopic views showing that multiple supplemental reduction tools were necessary to maintain reduction including application of a pointed reduction clamp, placement of a medial femoral distractor, and the use of a proximal and lateral nail insertional starting point. Additionally, a temporary unicortical plate was used for the diaphyseal component of the fracture. D and E, Initial AP and lateral postoperative radiographs demonstrating the alignment, reduction, and nail position with multiple interlocking bolts. On the lateral view, the diaphyseal lucencies are the result of a temporary unicortical plate used in that location. F and G, Radiographs 4 months after injury, demonstrating healing of the proximal metaphyseal fracture despite open reduction in this location.

were performed. The starting point for the nail was, based on the AP radiograph, located proximally and laterally[14] in line with the medial aspect of the lateral intercondylar eminence. A cannulated drill was used to establish the starting point to allow for accurate placement on the AP view and for placement parallel to the anterior tibial cortex on the lateral view.

In 8 of 37 fractures (21.6%), the fracture was successfully reduced and stabilized without supplementary reduction techniques as assessed after flexing the knee intraoperatively to confirm the fracture behavior. While these 8 patients had displaced fractures, their alignments could be obtained and maintained with external manual manipulations only. In the remaining 29 fractures, multiple adjunctive methods of reduction were used, frequently with several methods required for fracture reduction maintenance in the same extremity. A medially placed femoral distractor placed proximally and distally on the tibia was used as a primary reduction aid in 25 of 37 fractures (67.6%) to help maintain length and alignment during the procedure. It should be noted that the proximal Schanz pin of the medial femoral distractor can be placed in a location that mimics the effects of blocking screws. Supplemental unicortical plating was used in 13 fractures (35.1%) to assist with obtaining and maintaining reduction of the proximal fracture deformity. In 3 of these cases, the plates were temporary reduction aids and were removed at the conclusion of the procedure. In the remaining 10 cases, the plates were left in situ (Fig. 2A and B). The decision to remove or leave in the plate was determined by the

FIGURE 2. A and B, Anteroposterior and lateral views of a 40-year-old patient who underwent unicortical plating for reduction prior to placement of the medullary implant. Following intramedullary nailing, the unicortical screws were replaced with bicortical screws to improve the stability of the construct. Healing progressed uneventfully as demonstrated in the final radiographs obtained 18 months following the injury.

operating surgeon and no consistencies could be identified. Plate placement was along the anterior tibial cortex in 9 fractures and posteromedially in 4. These were 3.5-mm dynamic compression (DC) or limited contact dynamic compression (LCDC) plates (Synthes, Paoli, PA) with multiple unicortical screws placed strategically to avoid interference with reamers and the medullary implant. Other supplementary reduction techniques included temporary percutaneous clamp fixations (n = 7) and percutaneous manipulation with Schanz pins (n = 4). Lag screw fixations were used to augment the medullary implant in an additional 3 patients. These additional techniques of reduction (total of 52 in 29 tibiae) usually were continued during the entire nailing procedure to ensure the surgical goal of maintaining the reduction during reaming and nail passage. Blocking screws were not used at the preference of the operating surgeon in any cases in this series.

RESULTS

Extraarticular fractures extended proximally to an average of 17% of the tibial length (range, 4% to 25%). The average distance from the proximal articular surface to the fracture was 67.8 mm (range, 17 mm to 102 mm, not corrected for distance magnification, included for preoperative planning purposes only). Postoperative angulation was satisfactory (average coronal and sagittal plane deformity of less than 1 degree) as was the final angulation (average coronal and sagittal plane deformity of less than 1 degree). Acceptable alignment was obtained in 34 of 37 fractures (91.9%). Two patients had 5-degree coronal plane deformities (1 varus and 1 valgus), and 1 patient had a 7-degree varus deformity.

Four patients with 4 fractures were lost to follow-up in the first 6 months and were excluded from further analysis. The remaining 31 patients with 33 fractures were followed until fracture healing or the establishment of a tibial nonunion. Average follow-up was 18.9 months (range, 6–55 months), with less than 1-year follow-up in 8 patients with 9 fractures. Two patients with open fractures and associated bone loss underwent a staged iliac crest autograft procedure at an average of 7 weeks postoperatively. In all 33 injuries, the proximal tibial fracture united. Secondary procedures to obtain union at the distal fracture in segmental injuries included dynamizations (n = 3) and early exchange nailing at 3 months (n = 1). Despite these procedures, 2 nonunions developed at the distal fracture site. Successful union was accomplished after exchange nailings in these 2 patients. None of the 31 patients (with 33 fractures) that were followed through fracture union had any change in alignment at final radiographic evaluation.

Complications included deep infections in 2 patients, both of whom had open fractures (one Type IIIA and one Type IIIB). Neither of these patients had undergone temporary or permanent unicortical plate stabilization. Both of these infections were delayed in presentation (greater than 6 weeks from surgical stabilization). One patient presented with erythema at a distal interlocking screw site and was successfully treated with suppressive antibiotics followed by nail removal after fracture healing. The other patient presented with purulence at the site of the previous open fracture. Multiple local debridements (n = 3) were necessary to treat his infection. Union was ultimately obtained.

DISCUSSION

The primary goals of this manuscript were to report the effectiveness and reduction techniques of intramedullary nailing for the stabilization of tibial fractures involving the proximal quarter. Despite the high rates of radiographic and clinical success of intramedullary nailing of both open and closed tibial diaphyseal fractures,[22–30] medullary nailing of proximal fractures has been problematic.[3,14,18] The results of this paper, however, suggest that satisfactory radiographic alignment and union rates can be achieved, but strict attention to obtaining a reduction prior to nail insertion and interlocking is required. The success of the reduction techniques described further demonstrates that satisfactory nailing can be accomplished with the use of several reduction methods, all of which appear to have utility in achieving the primary goal of fracture reduction prior to nail insertion.

Difficulty with medullary nailing of proximal tibial fractures has been largely attributed to the voluminous anatomy in the proximal tibial relative to a medullary implant and the proximity of the knee joint to the fracture, potentially amplifying the bending moment of the short proximal segment. As a result, intramedullary nailing of proximal third tibial fractures has been associated with an increased risk of coronal and sagittal plane malalignment when compared

to diaphyseal injuries,[3,8,12,14,16,18] with early reports of malalignment exceeding 50%.[3,9] In response to these difficulties, a number of modifications of standard nailing techniques have been introduced and used with some success.[8,12,14,16] In this series of patients the primary reduction methods used included placement of a medial femoral distractor, unicortical plating, and attention to the starting point for nail insertion. The use of a variety of these reduction techniques, either singly or in combination, emphasizes that no single method was applicable in all instances. Finally, although other reduction methods such as the placement of blocking screws[16] have been shown to be effective in proximal third tibial fractures, they were not used in this series primarily because of surgeon comfort and the satisfactory results obtained using the methods previously described.

Nail design parameters and the location of the nail insertion site may influence the success of nailing these proximal fractures. In addition to assisting with the coronal and sagittal plane reductions, the proper insertion site and angle decreases the associated nail insertional bursting strains.[3,9,14,18,31,32] Similarly, the location and angulation of the proximal bend may affect nail insertion and nail stability. Henley et al[18] investigated the biomechanical effects of nail design and fracture site cortical reduction on stiffness after fixation of proximal tibial fractures associated with intramedullary nailing. They demonstrated the wedge effect of the nail on the distal segment with subsequent posterior translation, supporting the use of a nail with a proximal bend.[18] Additionally, proximal interlocking using oblique screw orientation has demonstrated increased construct stability compared to transverse locking.[33] In this series, insertional strains were minimized and stability was maximized by accurately placing the nail starting point and by using a nail with a proximal bend and multiple oblique interlocking bolts.

Given the need for multiple techniques to successfully place a medullary implant down a reduced proximal tibial fracture, alternative methods such as open reduction or minimally invasive plating may become more attractive. However, from a biomechanical standpoint, intramedullary nails have been shown to tolerate higher loads when compared to even locking plate constructs in proximal tibial fractures.[34] Further, proximal quarter tibial shaft fractures are frequently associated with a noncontiguous, more distal ipsilateral tibial fracture. These bifocal injuries, especially those that produce a long central diaphyseal tibial segment, may prove to be difficult to manage with a single plate, even the longer lateral locking implants. In these patterns, intramedullary nailing becomes more desirable given the ability of the implant to span the multiple fractures combined with the ability to successfully manage any subsequent complications including nonunion at either location.

Limitations in this study include a small number of patients, multiple surgeons, and the routine inaccuracy of nonstandardized radiographic measurements. Radiographic measurements were not performed by an unblinded observer given the straightforward nature of the radiographic parameters. Because the major emphasis of this review was on the successful surgical management of these injuries, functional outcomes were not obtained. Finally, this is a retrospective review of prospectively obtained data and, hence, has a low level of scientific validity. However, the major emphasis of this review is that proximal tibial fractures can be nailed, especially if the reductions can be obtained prior to and maintained during nailing. A number of techniques should be available to the surgeon and may be required to accomplish tibial nailing in these difficult injury patterns.

CONCLUSIONS

Intramedullary nailing is a safe and effective technique for the treatment of extremely proximal tibial fractures. Alignment can be well maintained despite the short segment of the proximal tibia. However, numerous modifications to the usual technique were required in the majority of instances and included a nail starting path parallel to the anterior cortex of the tibia and in line with the medial aspect of the intercondylar eminence and a medial femoral distractor to control coronal plane alignment. Short plate fixations to maintain this difficult reduction, either temporary or permanent, were effective and not associated with complications. Simple articular fractures and extensions are not a contraindication to intramedullary fixation. The proximal tibial fracture healed despite open manipulations.

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