# Intramedullary Nailing Versus Percutaneous Locked Plating of Extra-Articular Proximal Tibial Fractures: Comparison of 56 Cases

*Eric Lindvall, DO,* Roy Sanders, MD,† Thomas DiPasquale, DO,† Dolfi Herscovici, DO,†
George Haidukewych, MD,† and Claude Sagi, MD†*

**Objective:** To compare extra-articular proximal tibial fractures treated with intramedullary nailing (IMN) or percutaneous locked plating (PLP) and assess the ability of each technique to obtain and maintain fracture reduction.

**Design:** Retrospective clinical study.

**Setting:** Level 1 Trauma Center.

**Patients/Participants:** Beginning with the first use of PLP of the proximal tibia at our institution, all skeletally mature patients with surgically treated proximal extra-articular tibial fractures were reviewed. Between August 1999 and June 2004, 29 patients treated with intramedullary nails and 43 patients treated with percutaneous locked plates were identified. Patients with at least 1-year follow-up included 22 IMN and 34 PLP cases, which formed the final study group.

**Main Outcome Measurements:** Final outcomes were assessed for the IMN and the PLP groups by comparing rates of union, malunion, malreduction (defined as >5 degrees angulation in any plane), infection, and removal of implants.

**Results:** The IMN and PLP groups showed similar age and gender demographics. Average length of follow-up was 3.4 years in the IMN group (15–67 months) and 2.7 years in the PLP group (12–66 months). Open fractures made up 55% of the IMN group and 35% of the PLP group. Final union rates (after additional procedures for nonunions after the index procedure) were similar between groups (IMN = 96% and PLP = 97%). Implant removal in the PLP group was 3 times greater than in the IMN group, ($P = 0.390$), whereas an apex anterior (procurvatum) malreduction deformity occurred twice as frequently in the IMN group ($P = 0.103$). Additional surgical techniques (eg, blocking screws) were frequently used during reduction within the IMN group and infrequently used within the PLP group ($P = 0.0002$). Neither technique resulted in a statistically significant loss of final reduction confirming the stability of each construct.

**Conclusions:** Neither IMN or PLP showed a distinct advantage in the treatment of proximal extra-articular tibial fractures. Apex anterior malreduction however was the most prevalent form of malreduction in both groups. Additional surgical reduction techniques were frequently needed with IMN, whereas removal of implants seems to be more commonly needed with PLP.

**Key Words:** extra-articular, proximal tibia, intramedullary nailing, percutaneous locked plating

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## INTRODUCTION

Nonarticular proximal third tibial fractures are often the result of high-energy injuries. Deforming forces created by the extensor mechanism around the knee coupled with significant comminution has made plating the preferred method of treatment. Recent design changes to intramedullary nails (IMNs) and adjunctive fixation techniques have definitely increased the popularity of IMN for the treatment of this fracture. Similarly, the development of percutaneous locked plating (PLP) has allowed surgeons to treat these complex fractures without the need for large incisions or the fear of soft tissue stripping, with subsequent failure due to infection and nonunion. Both IMNs and PLPs are now applied using indirect fracture reduction techniques that require minimal dissection.

More recently, cadaveric studies have compared various plating constructs, intramedullary designs, and intramedullary interlocking screw orientations for these fractures,[1–5] and clinical studies have described the successful use of either IMN or PLP in the treatment of proximal one-third tibial fractures.[6–17] The purpose of this study was to compare these 2 treatment methods and assess the ability of each technique to obtain and maintain fracture reduction and determine union rates, malunion rates, infection rates, need for implant removal, and other possible complications.

## PATIENTS AND METHODS

All extra-articular proximal tibial fractures that were treated with either IMN or PLP dating back to the first use of PLP at our institution (August 1999 to July 2004) were

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From the *Department of Orthopaedics, Community Regional Medical Center, UCSF-Fresno, Fresno, CA; and †Florida Orthopaedic Institute, Tampa, FL.

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Reprints: Eric Lindvall, DO, Department of Orthopaedics, Community Regional Medical Center, UCSF-Fresno, 7th Floor W, 2823 Fresno St, Fresno, CA 93721 (e-mail: elindvall@fresno.ucsf.edu).

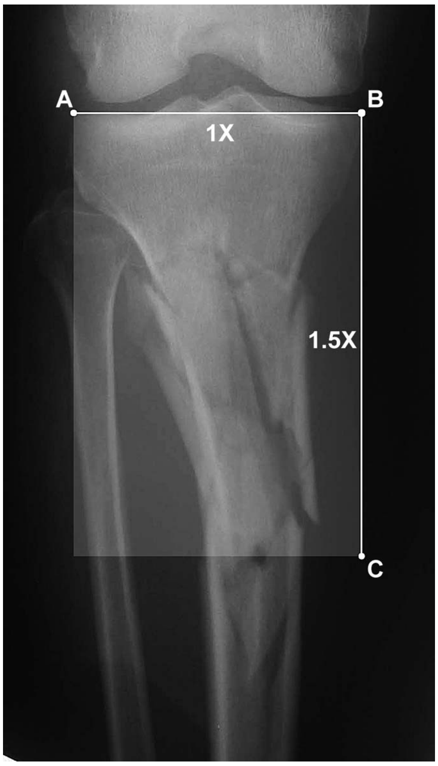

**FIGURE 1.** Definition of the proximal tibia included in the study. The rectangular shaded area represents the required fracture zone. This was defined as the medial-to-lateral joint line width of the proximal tibia as the horizontal line (represented by the line, 1X) and one-and one-half times the M-L width as the vertical line (represented by the line, 1.5X). Any extraarticular fracture in this proximal rectangle was included for review, even if the majority of the fracture was distal to the shaded rectangle.

retrospectively reviewed. Institutional review board approval was obtained. For the purpose of our study, the proximal tibia was defined as a region extending from the knee joint distally 1.5 times the medial to lateral joint width (Fig. 1). This correlated roughly to the proximal 30% of the entire tibia. Study inclusion criteria consisted of any skeletally mature patient treated with an IMN or a PLP for a proximal extra-articular tibial fracture with at least 1-year follow-up. Due to the retrospective nature of this study, patients were selected for either technique solely based on the operating surgeons' preference without any randomization. All surgeries were performed by fellowship-trained orthopaedic traumatologists.

Average age was 39.6 years (18–71 years old) with 44 men and 12 women. The mechanism of injury was high energy in 46 patients (20 motor vehicle crashes, 12 pedestrian versus auto, 10 motor cycle crashes, 2 crush injuries, 1 gunshot wound, and 1 boat propeller accident) and low energy in 10 patients (6 falls, 2 assaults, and 2 sporting injuries). Orthopaedic Trauma Association fracture classification was as follows: 41-A2 (9) and 41-A3 (47).

There were 32 closed fractures and 24 with associated open wounds (Gustilo and Anderson type I—6, type II—6, type IIIA—6, type IIIB—5, and type IIIC—1). All open fractures were treated with initial debridement and irrigation and delayed wound closure if gross contamination was present or tissue viability was in question. Temporary external fixation was used before definitive fixation in 3 cases as a result of the initial wound and the operating surgeon's preference. At the time of definitive fixation, open fractures were reduced directly through the traumatic wound when possible, whereas closed fractures were reduced indirectly. For the purposes of this study, an open wound was considered to have become infected if despite surgical debridement and irrigation, it developed signs and symptoms of infection and the patient was placed on antibiotic therapy.[18,19]

Standard methods for the insertion of IMN and application of PLP were used by the authors, who were all trained in these techniques. IMN consisted of a tibial nail with a proximal Herzog curve (Trigen Tibial Nail; Smith and Nephew, Memphis, TN) in 20 patients or a nail with more distal bend (Tibial Nail; Synthes, Paoli, PA) in 9 patients (Fig. 2A–F). The decision to use a particular implant was solely based on surgeon preference. The intramedullary nail entry site was either just medial or lateral to the patellar tendon based on surgeon's preference. Numerous fractures treated with IMN required additional surgical techniques including the use of a femoral distractor, blocking screws (BSs), and percutaneous anterior plating to assist in obtaining fracture reduction (Table 1). All IMNs were locked with $\geq 2$ proximal screws. PLP was performed using the Less Invasive Stabilization System (Synthes) in all 43 PLP cases (Fig. 3A–C). Plate lengths were 5 hole (11), 9 hole (23), or 13 hole (9). PLP cases occasionally required a femoral distractor to assist in reduction (Table 2).

Chart reviews and follow-up examinations were conducted by the authors (fellowship-trained orthopaedic traumatologists). Attempts at confirming time to full weightbearing were unsuccessful as the data was incomplete and patient recollection was unreliable. Union was defined as cortical healing on at least 3 cortices in addition to 2 consecutive follow-up radiographs with no interval alignment or implant changes. Both the immediate postoperative and the final follow-up radiographs were compared for accuracy of reduction and final alignment. Measurements were performed for frontal (valgus and varus) and sagittal (flexion and extension) plane deformities by 2 physicians (an author, E.L., and another orthopaedic surgeon not involved in this study). The measurement technique was according to Freedman and Johnson,[20] and Moore and Harvey.[21] The frontal plane normal value was considered 0 degrees, whereas 8 degrees was subtracted from the sagittal measurement to allow for the normal posterior tilt of the tibia. The averages were recorded and comparisons were then made within and between the IMN and the PLP groups. A malreduction was defined as a deformity of $>5.0$ degrees in any plane. Rotation was assessed clinically.

Statistical analysis was performed both within and among the IMN and PLP groups. Intragroup analysis was assessed for interval fracture alignment changes from the immediate postoperative to the healed radiographic measurements in both frontal and sagittal planes. Intergroup analysis was assessed for differences in demographics and the rate of union, malreduction, malunion, infection, and removal of painful or symptomatic implants.

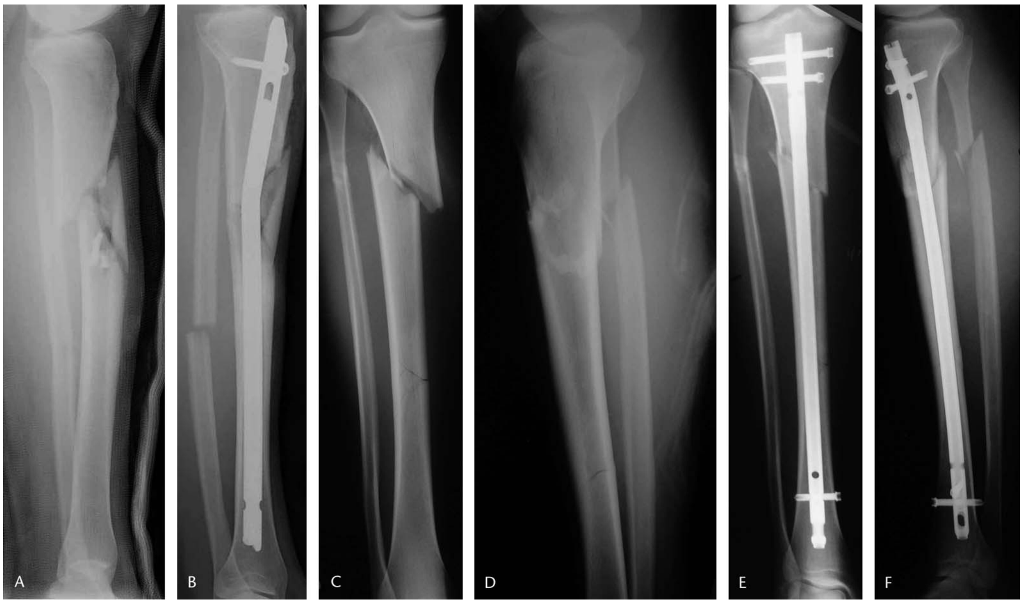

**FIGURE 2.** (A-B) Radiographs demonstrating fixation with an intramedullary nail possessing a more distal bend located at the fracture level; (C-F) radiographs of an intramedullary nail with a more proximal bend. Each type of implant achieved satisfactory alignment.

## RESULTS

Of the original 72 injuries, 7 patients from the IMN group and 9 from the PLP group could not be located for final follow-up, leaving 22 of 29 (76%) in the IMN and 34 of 43 (79%) in the PLP group, respectively (1 patient with bilateral closed fractures who underwent PLP of each fracture had 1 fracture excluded to prevent statistical bias resulting in 34 final PLP cases for statistical analysis. Both fractures in this patient healed without deformity and neither fracture became infected).

Average follow-up for IMN and PLP was 3.4 years (15–67 years) and 2.7 years (12–66 years), respectively. The IMN and PLP groups showed no significant difference with respect to age or gender ($P = 1.000$). Union rates after the index procedure were 77% (17 of 22) in the IMN group and 94% (32 of 34) in the PLP group ($P = 0.10$). Open fractures made up 55% of the IMN group (12 of 22) and 35% of the PLP group (12 of 34) ($P = 0.18$). Infection occurred in 23% (5 of 22) of the IMN and in 24% (8 of 34) of the PLP ($P = 1.0$). Because there was a greater percentage of open fractures in the IMN group, infection was analyzed with respect to open and closed fractures. Four of the 12 open fractures (33%) in the IMN group and 4 of 12 open fractures (33%) in the PLP group became infected. When union rates were analyzed with respect to open and closed fractures, all 32 closed fractures (100%) united after the index procedure, whereas 17 of 24 open fractures (71%) healed after the index procedure ($P = 0.001$). Thus, closed fractures had a significantly higher union rate than open fractures, regardless of the surgical procedure employed (IMN versus PLP).

There were 5 nonunions after the index procedure in the IMN group (23%) and 2 in the PLP group (6%) that required further surgery ($P = 0.10$). All 7 nonunions were in patients who had sustained an open fracture. Final union rates after additional procedures were 96% in the IMN group and 97% in the PLP group. Of the 5 IMN nonunions, 3 were with associated infection and all 5 were open fractures [type I (1), type II (2), and type IIIB (2)]. Two of the IMN nonunions underwent revision plating and 2 underwent exchange IMN with bone grafting. The fifth patient underwent exchange IMN without bone grafting. One fracture had not yet healed, 5 months after his second revision plating, whereas the other 4 achieved union. Of the 2 nonunions in the PLP group, 1 was associated with infection and both were open fractures (1 grade IIIB and 1 grade IIIC). One PLP nonunion underwent revision IMN with bone grafting and achieved union. The other patient underwent amputation for an infected nonunion after a grade 3B open fracture due to contractures, nerve deficits, and distal injuries (Tables 1, 2).

At least 1 additional surgical technique was used to assist in fracture reduction in 13 of 22 (59%) in the IMN group (BSs, 11; femoral distractor, 1; and temporary plating, 1) and in 4 of 34 (12%) in the PLP group (femoral distractor, 4) ($P = 0.0002$). In addition, 12 IMN cases had the standard IMN insertion site altered to a more lateral starting point as described by Buehler et al.[8] There was no statistical difference with respect to incidence of malreduction within the IMN group between those procedures using "additional techniques" and those not using "additional techniques" ($P = 0.67$).

BSs were not used in the PLP group but were used in 50% (11 of 22) of the IMN group. Eight cases had anterior–posterior (A/P) BSs inserted to prevent frontal plane deformity, whereas 4 cases had medial–lateral (M/L) BSs inserted to prevent sagittal plane deformity (1 patient had both A/P and M/L screws inserted). None of the 8 cases with A/P BSs resulted in a valgus deformity and 3 of 4 cases with M/L BSs did have a flexion deformity. Because of the small sample size, no definitive statistical conclusions could be made.

Apex anterior malalignment was the most common deformity in both groups with 36% (8 of 22) malreductions in the IMN group and 15% (5 of 34) malreductions in the PLP

**TABLE 1.** IMN Raw Data

| PT | Sex | Age (yrs) | MOI | Open/ Closed Fractures | Nail Type | Postoperative Deformity | Healed Deformity | Additional Techniques Used | Additional Procedures | Infection | Union | Follow up |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | M | 51 | Ped vs. auto | Closed | Distal bend | No | No | LSP | — | No | Yes | 3 yr 2 mo |
| 2 | M | 38 | Sports | Closed | Distal bend | Yes; flex 10 | Yes, flex 13 | BS (M/L) | — | No | Yes | 3 yr 6 mo |
| 3 | M | 35 | MVA | Open-1 | Distal bend | No | No | BS (A/P) | — | No | Yes | 5 yr 3 mo |
| 4 | F | 24 | Ped vs. auto | Open-2 | Proximal bend | Yes; valgus 10 | Yes*; valgus 16 | LSP | Plated for nonunion 17 mo after index surgery | No | Yes | 2 yr 4 mo |
| 5 | M | 48 | Assaulted | Closed | Proximal bend | No | No | BS (A/P) | — | No | Yes | 4 yr 5 mo |
| 6 | M | 21 | MVA | Open-1 | Proximal bend | No | No | None | — | No | Yes | 5 yr 7 mo |
| 7 | M | 19 | MCA | Open-3B | Proximal bend | Yes; valgus 10, flex 10 | Yes*; valgus 8, flex 10 | LSP; BS (M/L) | I & D; plated for infected nonunion 9 mo after index surgery | Yes | No | 2 yr 5 mo |
| 8 | F | 38 | MVA | Open-2 | Proximal bend | No | No | None | — | No | Yes | 3 yr |
| 9 | M | 18 | MCA | Open-1 | Proximal bend | No | No | None | Exchange IMN W/bone graft for nonunion | No | Yes | 5 yr 6 mo |
| 10 | M | 60 | Fall | Closed | Proximal bend | Yes; flex 12 | Yes; flex 12 | BS (M/L, A/P) | — | No | Yes | 3 yr 10 mo |
| 11 | M | 30 | Crush | Open-3B | Proximal bend | Yes; flex 12 | Yes*; flex 10 | LSP; femoral distractor | I & D; exchange IMN for nonunion 7 mo after index surgery | Yes | Yes | 2 yr 4 mo |
| 12 | F | 32 | Ped vs. auto | Open-2 | Proximal bend | No | No | LSP; BS (A/P) | I & D; exchange IMN W/bone graft for nonunion | Yes | Yes | 3 yr 8 mo |
| 13 | M | 25 | MVA | Closed | Proximal bend | No | No | LSP; BS (A/P) | — | No | Yes | 1 yr 3 mo |
| 14 | M | 46 | Crush | Open-3A | Proximal bend | No | No | LSP | — | No | Yes | 4 yr 2 mo |
| 15 | M | 51 | MCA | Closed | Proximal bend | Yes; flex 12 | Yes; flex 17 | None | I & D; dynamization of IMN | Yes | Yes | 3 yr 4 mo |
| 16 | M | 39 | MVA | Open-3A | Proximal bend | Yes; flex 10 | Yes; flex 10 | BS (A/P) | I & D; ROH | Yes | Yes | 1 yr 8 mo |
| 17 | F | 18 | MCA | Open-3A | Proximal bend | No | No | LSP; PERC. Anterior plating | — | No | Yes | 2 yr 7 mo |
| 18 | M | 51 | MVA | Closed | Proximal bend | Yes; flex 12 | Yes; flex 12 | LSP; BS (A/P) | — | No | Yes | 1 yr 9 mo |
| 19 | M | 22 | MVA | Closed | Distal bend | No | No | LSP; BS (A/P) | — | No | Yes | 4 yr 1 mo |
| 20 | F | 34 | MCA | Open-3A | Distal bend | Yes; flex 16 | Yes; flex 15 | LSP | — | No | Yes | 3 yr 7 mo |
| 21 | M | 57 | Fall | Closed | Distal bend | No | No | None | — | No | Yes | 3 yr 9 mo |
| 22 | M | 44 | Ped vs. auto | Closed | Distal bend | No | No | LSP; BS (M/L) | — | No | Yes | 5 yr 2 mo |

*Measurements just before revision surgery.

LSP = lateral starting point for nail; F, female; M, male; Ped, pedestrian; BS = blocking screw and direction screw inserted (ie, A/P, anterior to posterior and M/L, medial to lateral); ROH, removal of symptomatic hardware; I & D, irrigation and debridement; open fractures were graded based on the Gustilo classification.

group. The difference between groups was not statistically significant (*P* = 0.103). The apex anterior (procurvatum) deformity was significantly greater (*P* = 0.02) than any other type of malreduction (valgus, varus, or extension). Of the 3 fractures with temporary external fixation, only 1 resulted in a malreduction (IMN group). Apex posterior (recurvatum) deformity occurred twice in the PLP group (0 of 22 IMN and 2 of 34 PLP). There was only 1 varus malreduction in the

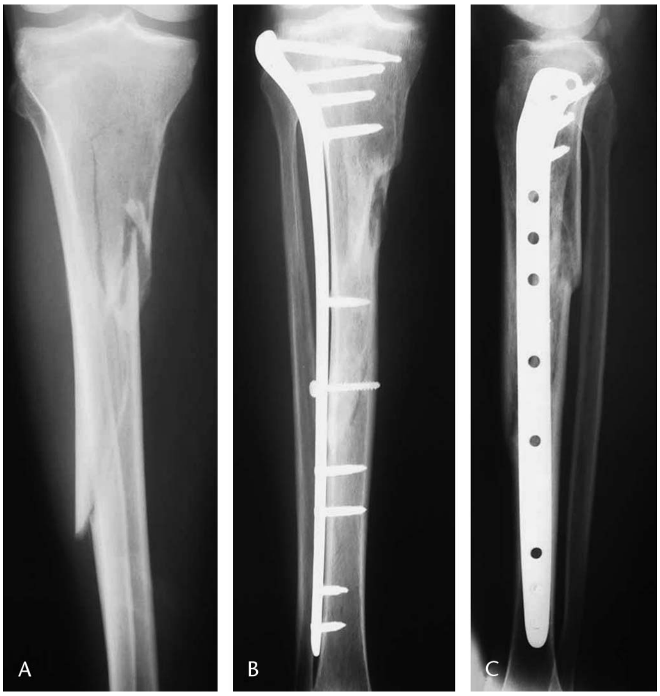

**FIGURE 3.** (A–C) Radiographs demonstrating fixation with a percutaneous locked plate and healed radiographs 7 months post surgery.

series and this occurred in the PLP group (0 of 22 IMN and 1 of 34 PLP). There were 2 valgus reductions, both occurring in the IMN group (2 of 22 IMN and 0 of 34 PLP). Multiplanar malreductions occurred once (5%) in the IMN group (apex anterior and valgus) and once (3%) in the PLP group (apex anterior and varus) ($P$ = 1.0).

Radiographic measurements for frontal and sagittal deformities were recorded as an average of 2 separate measurements. The agreement between physician raters was statistically analyzed using intraclass correlation coefficients and ranged from 0.72 to 0.98 for varus, valgus, flexion, and extension measurements. The overall average intraclass correlation coefficient for immediate postoperative and final follow-up radiographic measurements was 0.84. No rotational deformities were noted.

The interval change from immediate postoperative radiographs to healed radiographs both between and within groups was not statistically significant for frontal or sagittal plane measurements. In the IMN group, statistics revealed a mean difference between postoperative and healed measurements for all IMN cases (22) in each subplane category (varus, valgus, flexion, and extension) as varus = 0.000, valgus = −0.318, flexion = −0.227, and extension = +0.045. Corresponding $P$ values were 1.000, 0.357, 0.436, and 0.329, respectively. The greatest interval changes were noted in 2 IMN cases with a +6 valgus and +5 apex anterior change (both cases had an initial postoperative malreduction). In the PLP group, statistics revealed the mean difference between postoperative and healed measurements for all cases (34) to be varus = +0.235, valgus = −0.029, flexion = −0.382, and extension = +0.059. Corresponding $P$ values were 0.118, 0.744, 0.074, and 0.600, respectively.

Other described conditions such as compartment syndrome, peroneal nerve palsy, and fracture propagation were not encountered as postoperative complications in either group with the exception of 1 case of fracture propagation during intramedullary nail insertion resulting in no alignment changes. Implant removal secondary to discomfort or pain was performed on 1 patient (5%) in the IMN group and 5 patients (15%) in the PLP group ($P$ = 0.39).

## DISCUSSION

Our study data revealed no statistically significant difference in either technique (IMN or PLP) with respect to obtaining fracture reduction or maintaining reduction in treating extra-articular proximal tibial fractures. Loss of initial reduction was not found to be statistically significant in either group. Union and infection rates were similar in each group. Closed fractures had a significantly higher union rate than open fractures, regardless of the surgical procedure employed (IMN versus PLP). All nonunions in either group were associated with open fractures. Implant removal was 3 times greater in the PLP group. This may be the result of the shape of the implant as no other plate was used in this series. Apex anterior deformities were the most common deformity noted when using either device, with a 2-fold greater incidence seen in the IMN group.

Malreductions of >5 degrees in proximal tibial fractures using intramedullary nails is well documented. Published malreduction rates have ranged from 3% to 100%.[7,22] BSs have been reported to decrease the effective canal diameter and aid in appropriate nail placement.[7] The number of clinical cases in the literature of proximal tibial fractures treated with IMN and BSs are limited. Ricci et al[12] reported on the largest clinical series of proximal tibial fractures treated with IMN and BSs. Clinical follow-up in 11 patients revealed only 1 malreduction >5 degrees, which occurred in the sagittal plane, for an overall malreduction rate of 9%. Krettek et al[7] reported on 10 proximal and 11 distal tibial fractures treated with IMN and BSs and reported a similar malreduction rate of 10% for all 21 fractures. Their results were combined and not detailed to the proximal or distal location and simply noted that malreductions >5 degrees were limited to the sagittal plane. Krettek et al[23] also published cadaveric data on "Poller" screws (ie, BSs). Both Ricci et al and Krettek et al supported the clinical effectiveness of BSs; Ricci et al reported no loss of initial reduction, whereas Krettek et al reported <1 degree of average change during healing.[7,12]

Our series had 11 fractures that required the use of BSs—3 used M/L screws, 7 used A/P screws, and 1 case employed both M/L and A/P screws. Although this was a small subset of cases, it seems that the M/L screws were not as well placed as the A/P screws, as 3 of 4 cases using M/L screws still resulted in a sagittal plane malreduction >5 degrees, whereas all 8 cases with A/P screws had correction of any frontal plane deformity.

Anterior cortical plating also has lessened the malreduction rate of IMN.[9] Nork et al,[17] did not use BSs in their recent series but used other additional techniques to achieve accurate reductions before nail insertion. Other additional techniques include a semiextended knee position,[6] use of a transfixation pin distractor,[24] percutaneous clamps,[17]

**TABLE 2.** PLP Raw Data

| PT | Sex | Age (yrs) | MOI | Open/Closed Fractures | Plate Length | Postoperative Deformity | Healed Deformity | Additional Techniques | Additional Procedures | Infection | Union | Follow up |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | F | 47 | MVA | Open-1 | 9 hole | No | No | — | — | No | Yes | 4 yr 2 mo |
| 2 | M | 65 | Assault | Closed | 5 hole | No | No | — | — | No | Yes | 4 yr 7 mo |
| 3 | M | 36 | MVA | Closed | 9 hole | No | No | Femoral distractor | ROH | No | Yes | 2 yr 7 mo |
| 4 | M | 20 | Sports | Closed | 9 hole | No | No | — | I & D | Yes | Yes | 3 yr 10 mo |
| 5 | M | 18 | MVA | Closed | 13 hole | No | No | Femoral distractor | — | No | Yes | 5 yr 2 mo |
| 6 | M | 35 | Ped vs. auto | Open-3A | 9 hole | No | No | — | I & D | Yes | Yes | 1 yr 3 mo |
| 7 | F | 65 | MVA | Closed | 5 hole | No | No | — | I & D | Yes | Yes | 4 yr 5 mo |
| 8 | M | 27 | Ped vs. auto | Open-3B | 9 hole | Yes; varus 8, flex 10 | Yes*; varus 8, flex 12 | — | I & D; BKA for infection | Yes | No | 2 yr 2 mo |
| 9 | M | 55 | Fall | Closed | 9 hole | No | No | — | ROH | No | Yes | 1 yr 3 mo |
| 10 | M | 39 | MVA | Closed | 5 hole | No | No | — | — | No | Yes | 2 yr 10 mo |
| 11 | M | 48 | MCA | Closed | 9 hole | No | No | — | — | No | Yes | 1 yr 4 mo |
| 12 | F | 68 | Ped vs. auto | Closed | 5 hole | No | No | — | I & D; Flap | Yes | Yes | 1 yr 8 mo |
| 13 | F | 28 | Boat propeller | Open-2 | 5 hole | No | No | — | — | No | Yes | 1 yr 7 mo |
| 14 | M | 29 | MCA | Open-3A | 9 hole | No | No | — | — | No | Yes | 2 yr 1 mo |
| 15 | M | 58 | Ped vs. auto | Closed | 13 hole | Yes; flex 12 | Yes; flex 11 | — | — | No | Yes | 1 yr 2 mo |
| 16 | M | 37 | MCA | Closed | 9 hole | Yes; ext 7 | Yes; ext 8 | — | — | No | Yes | 3 yr 7 mo |
| 17 | M | 25 | Ped vs. auto | Open-2 | 5 hole | No | No | — | ROH | No | Yes | 1 yr 6 mo |
| 18 | M | 46 | Ped vs. auto | Closed | 5 hole | No | No | — | — | No | Yes | 1 yr 3 mo |
| 19 | M | 18 | MCA | Open-3B | 9 hole | No | No | — | — | No | Yes | 1 yr 2 mo |
| 20 | M | 60 | MVA | Closed | 13 hole | No | No | — | I & D | Yes | Yes | 1 yr |
| 21 | M | 33 | GS W | Open-1 | 9 hole | No | No | — | I & D | Yes | Yes | 3 yr 11 mo |
| 22 | F | 54 | MVA | Open-3B | 9 hole | No | No | — | — | No | Yes | 1 yr 6 mo |
| 23 | F | 34 | MVA | Closed | 13 hole | No | No | — | — | No | Yes | 1 yr 4 mo |
| 24 | M | 21 | MCA | Open-3C | 9 hole | No | No | — | Revision-IMN w/bone graft for nonunion | No | Yes | 1 yr 8 mo |
| 25 | M | 54 | Fall | Closed | 9 hole | No | No | Femoral distractor | ROH | No | Yes | 2 yr 6 mo |
| 26 | M | 46 | Ped vs auto | Closed | 9 hole | Yes; flex 7 | Yes; flex 7 | — | — | No | Yes | 5 yr 3 mo |
| 27 | M | 71 | Fall | Closed | 9 hole | No | No | — | — | No | Yes | 1 yr 8 mo |
| 28 | M | 42 | MVA | Open-2 | 13 hole | Yes; flex 9 | Yes; flex 10 | — | — | No | Yes | 1 yr 10 mo |
| 29 | M | 30 | MVA | Closed | 5 hole | Yes; ext 10 | Yes; ext 10 | — | — | No | Yes | 1 yr 4 mo |
| 30 | M | 57 | MVA | Closed | 5 hole | No | No | — | ROH | No | Yes | 5 yr 6 mo |
| 31 | M | 48 | Ped vs. auto | Open-1 | 9 hole | No | No | — | I & D | Yes | Yes | 3 yr 9 mo |
| 32 | F | 33 | FALL 17’ | Closed | 13 hole | No | No | Femoral distractor | — |  | Yes | 4 yr 2 mo |
| 33 | M | 29 | MVA | Closed | 9 hole | Yes; Flex 10 | Yes; flex 12 | — | — | No | Yes | 4 yr 5 mo |
| 34 | M | 42 | MVA | Closed | 9 hole | No | No | — | — | No | Yes | 5 yr 2 mo |

*Measurements were just before BKA 25 months after index procedure—this patient never obtained union.

F, female; M, male; I & D, irrigation and debridement; ROH, removal of symptomatic hardware; open fractures were graded based on the Gustilo classification.

temporary Schanz pins for fracture manipulation,[17] and use of a nail with a more proximally placed Herzog curve.[25] Published reports of PLP have documented similar malreductions rates to recent studies of IMN used to treat proximal tibial fractures (Table 3). These reports note that the type of malreduction is more prevalent in the sagittal plane than the coronal plane for both implants. This is consistent with our study findings.

Loss of fixation post surgery was also initially highlighted as a concern following IMN and was reported as high as 20%–25%.[26,27] More recent reports have shown greater stability with adjunctive fixation, nail design changes, and additional interlocking screw configurations. Loss of initial reduction with IMN now is much less frequent and is reported as 0% in multiple studies[7,8,12,17,23,28] (Table 4). PLP data has also confirmed the stability of these implants when treating proximal tibial fractures. The data for PLP, however, is less clear as multiple studies have grouped both intra-articular and extra-articular fractures together. Cole et al,[10] in the largest reported series, noted a 2.6% loss of initial reduction (2 of 77 cases)—1 due to noncompliance from immediate weightbearing and the other involving only the intra-articular joint component of a proximal tibial fracture. Boldin et al[16] similarly reported a loss of the joint reduction in 1 case of 26 fractures for an overall loss of reduction rate of 4%. Other studies on PLP of proximal tibial fractures have reported a 0% loss of reduction[11,13–15] (Table 4).

Union rates for IMN of proximal tibial fractures have ranged from 91% to 100%[7,8,12,17,22,26,28] with similar rates

**TABLE 3.** PLP Studies

| Study/yr | Extra-Articular Proximal Tibial Fractures | Intra-Articular Proximal Tibial Fractures | Malreductions (>5 Degrees) | No. Cases Malreduction With Plane | Loss of Fixation and/or Reduction | Comments |
|---|---|---|---|---|---|---|
| Schutz et al[15] | 10 | 10 | 3 | 2 valgus, 1 varus | 1 | No details regarding malreductions |
| Stannard et al[11] | 10 | 25 | 3–4 | 3 apex anterior; 1 valgus | Unknown | No details regarding combined or single plane malreductions |
| Cole et al[10] | 28 | 49 | 8 | 1 valgus; 6 apex anterior; 1 apex posterior | 2 | 4 had removal of hardware—symptomatic |
| Ricci et al[14] | 18 | 20 | 3–5 | 2 valgus; 2 apex anterior; 1 apex posterior | 1 | No details regarding combined or single plane malreductions; 2 patients with hardware pain |
| Boldin et al[16] | 10 | 16 | 0 | N/A | 1 | 2 had removal of hardware—symptomatic |
| Lindvall et al | 34 | 0 | 7 | 5 apex anterior with 1 varus; 2 apex posterior | 0 | 5 had removal of hardware—symptomatic |

Most common plane of malreduction in these PLP studies was sagittal (apex anterior).
N/A, not available.

reported for PLP.[10,11,13–16] When union rates after the initial fixation were analyzed in our study, the IMN group was 77% and the PLP group was 94% ($P = 0.10$). High union rates consistent with published reports only occurred in our closed fractures (100%) regardless of treatment modality. We believe this difference in union therefore was related to the percentages of open and closed fractures in each group rather than the type of procedure performed.

Infection rates range from 0% to 8%[8,12,17,26] for IMN and 0% to 6% for PLP.[10,11,14–16] Bhandari et al[29] reviewed both plating and IMN of proximal tibial fractures and concluded that there was weak evidence to suggest a decrease in infections with IMN. The analysis, however, did not include PLP. Our study found the infection rates to be higher than that reported in the literature (28% IMN group and 24% PLP group), but similar between groups. Although speculative, this may be attributable to higher injury severity scores, additional comorbidities, or a lower threshold to return to the operating room for irrigation and debridement.

IMN studies of proximal tibial fractures have not routinely reported removal of implants secondary to pain, with only 2 studies including such data, noting 1 screw removed secondary to prominence and pain in 25 cases (4%).[8,12] In contradistinction, however, PLP studies have noted the need for implant removal due to the prominence of the plate and/or irritation of the iliotibial band. Cole et al reported a 5% incidence of hardware removal, whereas Boldin et al noted an 8% incidence.[10,16] Again this is consistent with our findings of greater implant removal in the PLP group.

**TABLE 4.** IMN Studies

| Study/yr | Extra-Articular Proximal Tibial Fractures | Malreductions (>5 Degrees) | No. Cases Malreduction With Plane | Loss of Fixation and/or Reduction | Comments |
|---|---|---|---|---|---|
| Lang et al[26] | 32 | 23 | 16 apex anterior; 13 valgus (6 w/both planes) | 8 | — |
| Freedman and Johnson[20] | 12 | 7 | 5 apex anterior; 4 valgus (2 w/both planes) | Unknown | — |
| Tornetta et al | 30 | 3–7 | 2–4 apex anterior; 3 coronal | Unknown | Only averages and ranges reported; single or multiple plane malreductions not noted |
| Buehler et al[8] | 14 | ≥1 | ≥1 apex anterior; ≥1 valgus (1 w/both planes) | 0 | Only averages and ranges reported |
| Matthews et al[9] | 11 | 3–5 | ≤5 sagittal | Unknown | Only averages and ranges reported |
| Ricci et al[12] | 12 | 1 | 1 valgus | 1 | 4 cases were revision surgery from previous malreductions |
| Nork et al[17] | 30–33 | 3 | 1 varus | 0 | Multiple additional techniques used to obtain reduction in majority of cases; unclear which 3 patients had intra-articular extension |
| Lindvall et al | 22 | 9 | 8 apex anterior; 2 valgus (1 w/both planes) | 2 | Two cases progressed from malreduction by +6 degrees valgus, +5 degrees apex anterior |

Most common plane of malreduction in these IMN studies was sagittal (apex anterior).

Although early weightbearing is inherently obvious in a load-sharing device, such as an IMN, locked plates clearly are different from standard plates in their ability to tolerate axial load. Nonetheless, many surgeons have been hesitant to beginning weightbearing in patients treated with PLP before 12 weeks. The literature does not accurately identify an accepted time until full weightbearing with either method of treatment of proximal tibial fractures. In various studies of extra-articular proximal tibial fractures treated with IMN, full weightbearing has ranged from 0–16 weeks depending on the fracture location, fracture pattern, and surgeon's preference.[7,18,22] Similarly, in extra-articular proximal tibial fractures treated with PLP, full weightbearing has ranged from 6–13 weeks for the same reasons.[10] Studies will often state "… weightbearing advanced as tolerated,"[16] but this does not accurately define when full weightbearing actually occurred and therefore cannot be used to determine if either technique allows for earlier full weightbearing without implant failures. Unfortunately, our study could not document the benefit of either implant in this parameter.

All studies have inherent bias and weaknesses. Ours is no different, with limitations including (1) retrospective design, (2) surgeon selection bias with respect to IMN or PLP, (3) multiple surgeons, and (4) lack of data regarding time to full weightbearing and time of union in each group and the use of 2 different types of IM nails. Some surgeon apprehension toward use of a plate in open fractures may have occurred resulting in more severe injuries treated within the IMN group. Ultimately, a prospective, randomized, clinical trial evaluating these parameters will help more accurately define the advantages and disadvantages of each technique.

## CONCLUSIONS

Our comparison of IMN and PLP for the treatment of extra-articular proximal tibial fractures showed no clear advantage of either technique. We conclude that both forms of treatment (IMN and PLP) provide adequate fracture stability. Additional surgical techniques seem to be needed and should be used to assist in obtaining fracture reduction before nail insertion of these fractures. Closed fractures had a significantly higher union rate than open fractures, regardless of the surgical procedure employed. The need for removal of painful or symptomatic implants may be more prevalent with PLP. Because the most common deformity within each group was an apex anterior deformity, it is recommended that close intraoperative monitoring be performed to avoid this rather prevalent form of malreduction. Additional studies evaluating time to full weightbearing with these 2 forms of fixation may identify a more clear advantage of either device.

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