Does Provisional Plating of Closed Tibia Fractures Have Higher Complication Rates?

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Objectives: To compare infection and nonunion rates after provisional plating (PP) with standard reduction (SR) techniques for closed tibia fractures treated with an intramedullary nail.

Design: Retrospective comparative study.

Setting: Level 1 academic trauma center.

Patients/Participants: Of the 348 closed tibia fractures (Orthopaedic Trauma Association/Arbeitsgemeinschaft für Osteosynthesefragen 42) treated using an intramedullary nail from January 2007 through June 2015, 231 (40 PP and 191 SR) patients met inclusion/exclusion criteria.

Intervention: The patients received either a provisional plate or an SR before intramedullary nail placement.

Main Outcome Measurement: Infection and nonunion.

Results: The PP cohort had a significantly higher proportion of high-energy injury mechanism and a significantly higher proportion of diabetes than the SR cohort. We were unable to demonstrate a difference in rates of infection [PP cohort (1/40, 2.5%) vs. SR cohort (6/191, 3.1%), $P = 1.0$], nonunion [PP cohort (3/40, 7.5%) vs. SR cohort (9/191, 4.7%), $P = 0.44$], or malunion [PP cohort (0/40, 0%) vs. SR cohort (8/191, 4.2%), $P = 0.36$]. Symptomatic implant removal was similar between the 2 groups [PP cohort (4/40, 10%) vs. SR cohort (27/191, 14%), $P = 0.61$].

Conclusion: PP can be used for complex, closed tibia fractures without an increased risk of infection, nonunion, and malunion compared with standard closed reduction techniques.

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INTRODUCTION

Complex tibia fractures including comminuted and segmental fractures are typically high-energy fractures with a wide zone of injury. It can be difficult to obtain and maintain fracture reduction in these fractures, given the instability of the associated extremity. Reduction techniques for complex tibia fractures include percutaneous or open clamping, nail start point adjustment, use of block of blocking screws, concurrent fibular fixation, and use of a femoral distractor or an external fixator.[1–3] Provisional plating (PP) is another useful adjunct to an intramedullary nailing of complex tibia fractures. This technique was originally described using a 3.5-mm dynamic compression plate (DCP) or limited contact dynamic compression plate (LC-DCP) in the setting of open fracture. PP allows for an accurate reduction to be maintained during reaming and placement of an intramedullary nail.[4] This technique is particularly helpful while instrumenting metaphyseal and metadiaphyseal tibia fractures where coronal and sagittal alignments are more difficult to maintain given the larger canal width. Furthermore, PP can be advantageous when surgeons do not have additional assistants available to help maintain the reduction during reaming and instrumentation.

However, the literature is limited about outcomes of the patients who undergo PP for closed tibia fractures. Theoretically, the concern is that patients treated in this manner are at a risk of nonunion or infection, compared with routinely practiced closed or percutaneous reduction techniques. The primary study outcome was to compare infection rates after PP with standard reduction (SR) techniques for closed tibia fractures. Additional study outcomes were nonunion and secondary surgeries between patients receiving PP and patients receiving SR techniques.

PATIENTS AND METHODS

After an institutional review board approval, patients with closed tibia fractures (OTA 42) treated using an intramedullary nail from January 2007 through June 2015 were identified in our prospectively collected orthopedic trauma registry.[5] Patients were excluded if they died during their initial hospital course, had incomplete radiographs, were skeletally immature, sustained a vascular injury, or had less than 6 months of follow-up. During this period, there were 347 closed tibia fractures that underwent intramedullary nailing, with 48 patients receiving PP and 299 patients receiving SR techniques. Twelve patients (1 PP and 11 standard) died during hospitalization, and 1 patient (1 PP) had a vascular injury. This left 46 PP patients and 288 SR patients.

Medical records were reviewed for demographic data including age, sex, comorbidities, and mechanism of injury. All tibia fractures were initially managed with closed reduction and splinting in the emergency department. Operative reports and fluoroscopic images were reviewed to document reduction strategy. SR techniques included closed reduction, percutaneous clamp application, open clamp application, and the use of a femoral distractor or an external fixator. PP was performed based on the surgeon discretion and was primarily used in the setting of comminution, segmental fractures, and/or compromised bone. All PP was performed before reaming. The surgical approach to place the provisional plate was either along the posteromedial edge of the tibia or along the anterolateral edge of the tibia, so there was adequate soft tissue coverage. PP along the anteromedial aspect of the tibia was always avoided. Careful dissection and full-thickness flaps were always maintained in the surgical approach, and additional periosteal stripping was avoided during fracture reduction. The plating consisted of a plate with at least 2 unicortical screws on each side of the fracture (Fig. 1A–C). Postoperative plate retention was based on overall construct stability and was at the discretion of the treating surgeon. Patients were made non–weight bearing for at least 2 weeks for soft tissue rest and wound healing. Weight bearing was then advanced based on additional injuries and fracture characteristics. In general, patients with simple diaphyseal fracture patterns began weight bearing at 1–2 weeks, whereas patients with more complex fractures began weight bearing at 6–12 weeks. Provisional plate retention did not affect surgeon decision to begin earlier weight bearing.

Patients were routinely followed up at 2, 6 weeks, 3, 6 months, and 1 year postoperatively. At the final follow-up, additional surgical procedures and any complications were recorded including infection, implant removal, and nonunion. Immediate postoperative radiographs were assessed for malalignment > 5 degrees in the coronal and sagittal planes. Radiographs at the final follow-up were assessed for malunion >5 degrees in the coronal or sagittal plane. Union was defined as healing on at least 3 cortices on orthogonal radiographs without pain at the fracture site during full weight bearing.[6] Radiographic union was assessed by 2 orthopedic trauma fellows (J.H. and M.G.) who were not involved in the patients' care.

Statistical Analysis

The Pearson χ^2 test and Fisher exact test were used for the categorical variables between the PP and control groups including sex, tobacco use, infection, nonunions, etc. A 2-tailed Student t test was used for continuous variables. A P value less than 0.05 was considered to be significant.

RESULTS

During this period, 104 patients (6 PP and 98 standard) had insufficient follow-up. This left 40 patients in our PP cohort and 191 patients in our standard cohort. Mean patient age, sex, and tobacco usage was similar between the PP and SR cohorts (see **Table**, **Supplemental Digital Content 1**, http://links.lww.com/BOT/A989, Patient demographics). There were significantly more patients with diabetes in the PP group (13%, 4/40) as compared to the SR group (3%, 6/191) ($P = 0.02$). Mean follow-up was not statistically different between the 2 groups. Pedestrian versus automobile was the most common mechanism of injury in the PP group, and ground-level fall and pedestrian versus auto were the most common mechanisms of injury in the SR group (see **Table**, **Supplemental Digital Content 2**, http://links.lww.com/BOT/A990, Mechanism of Injury). When the mechanisms of injury were grouped into high energy (motor vehicle crash, motorcycle crash, pedestrian vs. auto, crush, fall from height, etc) and low energy (ground-level fall, sport, assault, etc), there was a significantly higher proportion of high-energy

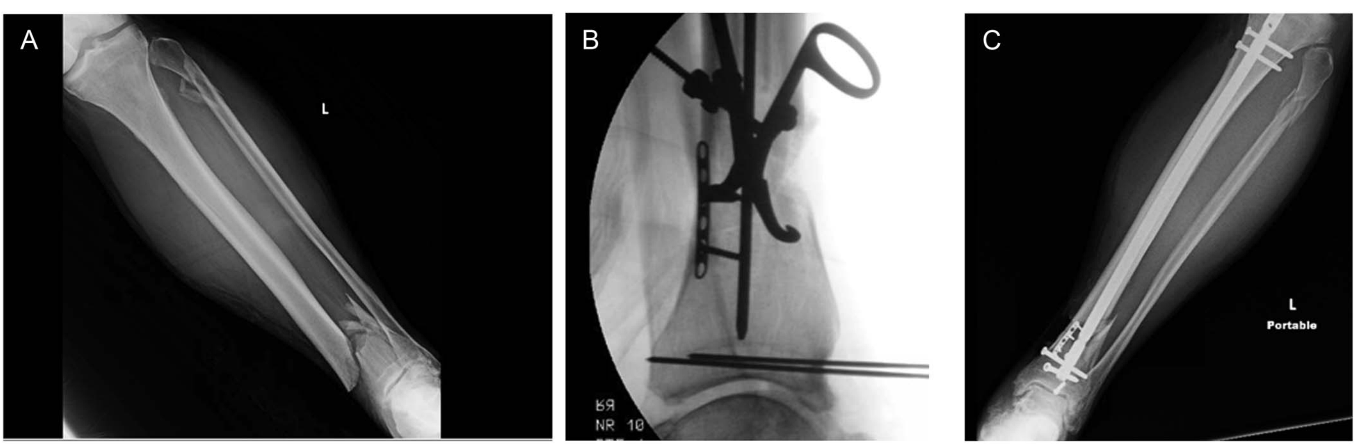

FIGURE 1. A, Forty-two-year-old man with closed comminuted distal tibia fracture. B, Open reduction and PP with a 2.0-mm plate and 2.4-mm screws along the posterior medial aspect of the distal tibia. C, Final anteroposterior radiograph with retained provisional plate and intramedullary nail.

mechanisms treated in the PP group (88%, 35/40) as compared to the SR group (63%, 120/191) (*P* = 0.003).

Tibia fracture location was not evenly distributed between the 2 groups with PP having a higher percentage of proximal tibia and segmental tibia fractures, and SR having a higher percentage of middle and distal tibia fractures (Table 1). The 2 study groups had similar rates of associated fibula fracture. In addition, there was no difference in the rate of fibula fixation between the PP and SR groups. We were unable to detect a difference in compartment syndrome rates between the 2 groups (Table 1).

The 2.7-mm LCDC plate (60%, 24/40) was the most common plate used in the PP group followed by the 3.5-mm LCDC plate (27.5%, 11/40), 1/3 tubular plate (7.5%, 3/40), and 2.0-mm plate (5%, 2/40). The plate was removed after completion of intramedullary nail and interlock screw placement in half of patients (50%, 20/40). Closed reduction with manual manipulation was the most common reduction maneuver in the SR cohort (42%, 80/191) (see **Table**, **Supplemental Digital Content 3**, http://links.lww.com/BOT/A991, Tibia fracture reduction methods). None of the patients treated with PP had postoperative malalignment >5 degrees in any plane on immediate postoperative radiographs. Eight patients (8/191, 4.2%) in the SR group had malalignment on immediate postoperative radiographs: 2 patients had sagittal plane deformity between 5 and 10 degrees, 5 patients had coronal plane deformity between 5 and 10 degrees, and 1 patient had both coronal and sagittal plane deformities between 5 and 10 degrees.

We were unable to detect a difference in postoperative infection between the PP cohort (1/40, 2.5%) and the standard cohort (6/191, 3.1%) (*P* = 1.0). When comparing patients with high-energy injury, the infection rates between groups remained similar (PP 1/35, 2.8% vs. SR 4/120, 3.3%) (*P* = 1.0). The average time to union was similar between the PP group (mean 7 months, range 3–16 months) and SR group (mean 8 months, range 3–28 months) (*P* = 0.51). We were unable to detect a difference in nonunion rate between the PP cohort (3/40, 7.5%) and the standard cohort (9/191, 4.7%) (*P* = 0.44). When comparing patients with high-energy injury, the nonunion rates between groups remained similar (PP 3/35, 8.6% vs. SR 8/120, 6.7%) (*P* = 0.71). There were 7 patients in the SR group who developed a delayed union between 6 and 12 months postoperatively and did not return for follow-up. Of the 3 patients who developed a nonunion in the PP group, 1 patient with segmental tibia fracture had the provisional plate removed during the initial operation, and the 2 other patients (one proximal fracture and one segmental fracture) retained the provisional plate. Malunion rates were similar between the PP (0/40, 0%) and standard groups (8/191, 4.2%) (*P* = 0.36). Finally, implant removal was similar between the PP (4/40, 10%) and standard groups (27/191, 14%) (*P* = 0.61). In comparing the distribution of complications to fracture location, segmental fractures had significantly more nonunions (*P* < 0.001) and cases of compartment syndrome (*P* = 0.012) than the other fracture locations (Table 2).

TABLE 1. Fracture Characteristics

	PP		SR		*P*
Fibula fracture	90% (36/40)		90% (172/191)		1.0
Fracture location					<0.001
Proximal	32.5% (13/40)		7% (13/191)		
	A-type	B-type	A-type	B-type	
	6	7	9	4	
Middle	27.5% (11/40)		34% (65/191)		
	A-type	B-type	A-type	B-type	
	6	5	37	28	
Distal	22.5% (9/40)		56% (107/191)		
	A-type	B-type	A-type	B-type	
	5	4	72	35	
Segmental	17.5% (7/40)		3% (6/191)		
Compartment syndrome	7.5% (3/40)		4.2% (8/191)		0.42

DISCUSSION

The goals of surgical treatment in complex tibia fractures include correction of coronal and sagittal plane deformities and restoring length and rotation while limiting local soft tissue trauma. An intramedullary implant is ideal because it is a load-sharing implant that spares the periosteal blood supply and avoids soft tissue disruption. However, obtaining and maintaining an adequate reduction for fractures with extensive comminution or segmentation can be challenging. Useful reduction techniques include altering nail start point, placing blocking screws, stabilizing an ipsilateral fibula fracture, using a femoral distractor or an external fixator, and applying a provisional plate.

Originally described by Dunbar et al,[4] the provisional plate technique was used in type III open proximal third tibia fractures to help maintain the fracture reduction during reaming and nail placement. More recently, several other studies included PP of both open and closed tibia fractures; however, the patient numbers in these studies were relatively small.[7–9] It could be argued that PP in open type III tibia fractures makes sense, as plating uses exposed bony surfaces where periosteal stripping has already occurred. However, using a provisional plate for a closed tibia fracture may be considered counterintuitive, unnecessary, and too high a risk for some surgeons.

There are several theoretical concerns for applying a provisional plate to a closed tibia fracture. First, the application of the plate requires soft tissue stripping of a traumatized area, and this could place the fracture at a greater risk of nonunion. Further stripping of the periosteum near the fracture could be harmful for a reamed intramedullary nail because the fracture healing relies

TABLE 2. Complications Based on Tibia Fracture Location

	Proximal	Middle	Distal	Segmental	*P*
Nonunion	4	1	3	4	<0.001
Infection	1	2	3	1	0.264
Compartment syndrome	1	4	3	3	0.012

significantly on periosteal blood flow for healing. Second, violating the closed fracture space releases the fracture hematoma that contains growth factors that could play a role in fracture healing. Although a theoretical risk, the loss of the fracture hematoma impairing fracture healing has not been substantiated in the literature, and its clinical relevance is unknown. Third, placing an incision near the traumatized zone of injury could place the patient at a greater risk for postoperative infection. Finally, if the provisional plate is left on the tibia after placing the nail, the plate could stiffen the overall construct and limit fracture motion. With the goal of secondary bone healing in a tibia stabilized with an intramedullary nail, limited fragmentary motion could lead to nonunion.

The authors realized these theoretical concerns and were careful to respect the soft tissue envelope in the zone of injury. All incisions were located over the anterolateral leg or posteromedial leg to avoid high-risk incisions directly over the bone in the traumatized zone. In this study, the treating surgeons were careful not to strip additional periosteum during plate application. Sharp drill bits and drilling under constant saline irrigation were commonly performed to minimize bony thermal necrosis. Finally, placing a plate with unicortical 2.7- or 3.5-mm screws was not felt to be too stiff in these complex tibia fractures. Overall construct rigidity was considered after nail interlock screws were placed, and the provisional plate was removed at the surgeon's discretion. Provisional plates that were used in the diaphysis were generally removed, and provisional plates that were used in the metaphysis were generally retained. An additional benefit of PP compared with SR techniques is potentially fewer tibial malunions. In our study, we report fewer malunions in the PP group, but this failed to reach statistical significance with the numbers in our series.

Postoperative infection was a primary concern with performing PP in closed tibia fractures. The rate of infection for closed tibia fractures is relatively low, ranging from 1% to 4%.[10–13] However, making incisions near the zone of injury for provisional plate placement certainly raises concerns about increasing the possibility of postoperative infection. Our overall infection rate was comparable with rates previously published in other series. Based on our available numbers, we were unable to detect a difference in infection rates between the provisional plate and SR groups. It was also interesting that the provisional plate group had a similar infection rate as the SR group, despite the plate group having significantly more patients with diabetes. We attribute our low infection rate to the meticulous soft tissue handling during provisional plate application.

Tibial nonunion after performing PP in closed fractures was another possible complication. As previously mentioned, the loss of the closed fracture hematoma, the periosteal stripping that can happen with plate application, and the additional rigidity of a retained provisional plate could all increase the nonunion rate. Tibial nonunion after closed fracture ranges from 2.4% to 10%.[10,11,13] Our nonunion rate for injuries that received a provisional plate was slightly higher than the SR group, but this failed to reach statistical significance. Although this increased nonunion rate could be a result of the provisional plate, the authors believe that the more likely reason is that the provisional plate group was composed of patients with higher energy injuries as demonstrated by the higher percentage of high-energy mechanism and the higher percentage of segmental tibia fractures. Also, the provisional plate group had more patients with compartment syndrome, which has been associated with higher rates of tibial nonunion.[14] Overall, we were unable to demonstrate a difference in tibial nonunion for patients who PP as compared to SR techniques.

There are several limitations to this study including its retrospective design and inclusion of multiple treating surgeons. The greatest limitation of our current series was that the minimum follow-up in this study was 6 months. We felt that this follow-up period was adequate to identify one of our primary outcome measures of infection, as this is similar to the criteria set forward by the Centers for Disease Control for postoperative infections related to the actual procedure. In addition, although we present the largest series of closed tibia fractures treated with provisional plate fixation, our PP cohort was relatively small and may have limited our ability to demonstrate a difference in complications, if one truly existed. After performing a post hoc power analysis using our nonunion rates for PP and SR in closed tibia fractures, we determined that 641 PP patients and 3077 SR patients would be required for a power of 0.8 (assuming $\alpha = 0.05$). A post hoc power analysis using our infection rates required 10,613 PP patients and 50,942 SR patients for a power of 0.8 (assuming $\alpha = 0.05$). To reach these enrollment numbers would be challenging and require significant funding. Finally, we did not report on any patient-reported functional outcomes data, which may have been helpful in demonstrating return of overall patient function.

In conclusion, PP can be a useful adjunct for obtaining and maintaining reduction during intramedullary nailing of tibia fractures. The authors do not advocate for the routine use of PP in closed tibia fractures; rather, their recommendation is that this technique be reserved for complex tibia fractures. PP is particularly helpful for fractures that have cortical reads that allow for accurate reduction so that the surgeon can restore length, alignment, and rotation. Surgeons should avoid PP techniques in the setting of comminuted fractures with unreliable cortical reads. Careful incision planning and meticulous soft tissue handling are key to successful plate application and minimizing complications. In this setting, the study suggests that PP can be used for complex, closed tibia fractures without an increased risk of infection, nonunion, and malunion compared with standard closed reduction techniques.

REFERENCES

1. Krettek C, Stephan C, Schandelmaier P, et al. The use of Poller screws as blocking screws in stabilising tibial fractures treated with small diameter intramedullary nails. *J Bone Joint Surg Br.* 1999;81:963–968.
2. Henley MB, Chapman JR, Agel J, et al. Treatment of type II, IIIA, and IIIB open fractures of the tibial shaft: a prospective comparison of unreamed interlocking intramedullary nails and half-pin external fixators. *J Orthop Trauma.* 1998;12:1–7.

3. Weber TG, Harrington RM, Henley MB, et al. The role of fibular fixation in combined fractures of the tibia and fibula: a biomechanical investigation. *J Orthop Trauma.* 1997;11:206–211.
4. Dunbar RP, Nork SE, Barei DP, et al. Provisional plating of Type III open tibia fractures prior to intramedullary nailing. *J Orthop Trauma.* 2005;19:412–414.
5. Marsh JL, Slongo TF, Agel J, et al. Fracture and dislocation classification compendium—2007: Orthopaedic Trauma Association classification, database and outcomes committee. *J Orthop Trauma.* 2007;21(10 suppl):S1–S133.
6. Donohue D, Sanders D, Serrano-Riera R, et al. Ketorolac administered in the recovery room for acute pain management does not affect healing rates of femoral and tibial fractures. *J Orthop Trauma.* 2016;30:479–482.
7. Yoon RS, Bible J, Marcus MS, et al. Outcomes following combined intramedullary nail and plate fixation for complex tibia fractures: a multi-centre study. *Injury*. 2015;46:1097–1101.
8. Nork SE, Barei DP, Schildhauer TA, et al. Intramedullary nailing of proximal quarter tibial fractures. *J Orthop Trauma.* 2006;20:523–528.
9. Kubiak EN, Camuso MR, Barei DP, et al. Operative treatment of ipsilateral noncontiguous unicondylar tibial plateau and shaft fractures: combining plates and nails. *J Orthop Trauma.* 2008;22:560–565.
10. Tornetta, P. Study to Prospectively Evaluate Reamed Intramedullary Nails in Patients With Tibial Fractures Investigators; Bhandari M, Guyatt G, Tornetta P, et al. Randomized trial of reamed and unreamed intramedullary nailing of tibial shaft fractures. *J Bone Joint Surg Am.* 2008;90:2567–2578.
11. Blachut PA, O'Brien PJ, Meek RN, et al. Interlocking intramedullary nailing with and without reaming for the treatment of closed fractures of the tibial shaft. A prospective, randomized study. *J Bone Joint Surg.* 1997;79:640–646.
12. Finkemeier CG, Schmidt AH, Kyle RF, et al. A prospective, randomized study of intramedullary nails inserted with and without reaming for the treatment of open and closed fractures of the tibial shaft. *J Orthop Trauma.* 2000;14:187–193.
13. Xia L, Zhou J, Zhang Y, et al. A meta-analysis of reamed versus unreamed intramedullary nailing for the treatment of closed tibial fractures. *Orthopedics*. 2014;37:e332–e338.
14. Blair JA, Stoops TK, Doarn MC, et al. Infection and non-union following fasciotomy for compartment syndrome associated with tibia fractures: a matched cohort comparison. *J Orthop Trauma.* 2016;30:392–396.