Tensioned Wire–Assisted Intramedullary Nail Treatment of Proximal Tibia Shaft Fractures: A Technical Trick

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Summary: Proximal tibia shaft fractures are often challenging to manage because of their intrinsic tendency toward valgus and apex anterior deformity. In recent years, intramedullary nailing (IMN) has become more frequently used to treat these injuries, allowing for biologic advantages such as load-sharing, immediate weight-bearing, and avoidance of disruption of periosteal blood supply. Several adjunctive techniques, such as semiextended positioning, blocking screws, and external fixation, have been developed to assist with fracture reduction during IMN. We describe a new adjunctive reduction technique—tensioned wire–assisted IMN—for the treatment of proximal tibia shaft fractures. We have found that tensioned wire assistance facilitates fracture reduction during IMN, does not interfere with intraoperative image intensification, and is compatible with both standard nailing instrumentation and additional adjunctive techniques. We present tensioned wire nailing as a technical trick for anatomic and stable reduction of proximal tibia fractures and compare a cohort of proximal tibia shaft fractures managed with and without tensioned wire assistance.

Key Words: proximal tibia, intramedullary nailing, alignment, tensioned wire–assisted nailing

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INTRODUCTION

Proximal tibia fractures are often the result of high-energy trauma. They account for 5%–11% of all tibia shaft fractures.[1] Although intramedullary nailing (IMN) has become the standard of care for diaphyseal tibia fractures, proximal metaphyseal fractures may be treated in a number of ways, including nailing, plating, and with the use of circular fixators. The advantages afforded by an intramedullary implant, including the ability to load share and spare the periosteal blood supply through avoidance of additional soft tissue dissection, have steadily increased the popularity of IMN in the treatment of these injuries. Recent improvements in nail design and innovations in adjunctive reduction techniques have expanded the indications of IMN to include fractures of the metaphyseal shaft junction of the proximal tibia.

Numerous studies have cited the high rate of malalignment associated with IMN of proximal tibia fractures.[2–5] So much so that some authors were obliged to ask whether these injuries should be nailed at all,[3] and others to conclude that open reduction and plating is the more appropriate treatment option.[4] In response to the historically high rate of malalignment associated with IMN of proximal tibia fractures, several adjunctive reduction techniques have been developed over the years. Semiextended nailing,[6,7] blocking screws,[8–10] and supplemental plating[11–13] are among the most successful techniques developed. A combination of these techniques is often necessary to achieve adequate alignment.

Regardless of the preferred technique, the indirect reduction requisite for insertion of an intramedullary implant may be obtained either by the free leg technique with manual traction and fracture manipulation or by the use of a traction table or distractor. It is the authors' experience and opinion that both the former and latter methods can be imprecise and cumbersome. Using a modification of the fine wire frame described by Jackson et al,[14] we have developed a tensioned wire–assisted approach to IMN of proximal tibia fractures. This simple technique is easy to apply, allows for precise control of reduction, and may be combined with other adjunctive techniques. The distraction frame does not obscure intraoperative imaging. Although Jackson et al[14] described the application of the fine wire frame and concluded that it is exceptionally useful in the treatment of segmental, proximal, and distal tibia fractures, they did not quantify and compare the alignment achieved with the frame with that of a free leg or manual reduction technique.

We report the use of tensioned wire–assisted IMN as a technical trick in achieving anatomic reduction and stability of proximal tibia fractures. To our knowledge, this is the first investigation comparing proximal tibia fractures nailed with and without the use of tensioned wire assistance.

SURGICAL TECHNIQUE

Tensioned wire–assisted nailing was performed as described by Jackson et al,[14] with several noteworthy

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modifications. The original description of the frame involves the use of 4 threaded Ilizarov rods, which were used to connect the 2 half rings. The rings and rods of the Ilizarov fixator resulted in interference with manipulation of the tibia fracture and with the use of screw insertion jigs. We have supplanted the 4 rods with 2 posterior positioned carbon fiber rods, which are connected to modified spatial frame 2/3 rings with transition posts. The fixator components are salvaged from frame removals and are used multiple times with no charge to the patient. The components are available in a set that can be obtained on consignment from one of several implant companies (eg, Smith & Nephew, Synthes). The added cost of implementation is equivalent to the cost of 2 olive wires, each of which is approximately $150. This is comparable to the cost of using a universal distractor, which brings with it the cost of 2 disposable half pins (approximately $110 each). Frame construction begins with the proximal olive wire, which is placed as a reference wire 1 centimeter below the tibial plateau and posterior to the nail entry path (Fig. 1). Next, the distal wire is placed between the subchondral bone and the physeal remnant (Fig. 1). The wires are then each attached to 2/3 rings and tensioned to 110 kg. The rings are in turn connected through transition posts, bars, and bar-to-bar clamps (Fig. 2). The carbon fiber rods are positioned posterior on the rings to avoid interfering with the medial–lateral plane of the tibial shaft. The two 2/3 rings are manipulated on the rod-to-rod clamps to establish the rotational alignment at the beginning of the reduction. Under image intensification, the fracture is reduced using distraction between the rings. Asymmetric lengthening of the bars is used to correct any varus/valgus angulation (Fig. 3). Sagittal plane deformity may be corrected with the use of a surgical towel wrapped around the bars and secured with a towel clamp to deliver an externally applied force as desired (Fig. 2). Retractors may be used to push and pull bone fragments to improve alignment. If necessary, fracture reduction clamps and other percutaneous surgical tools may be used to align complex or segmental fractures. The frame configuration does not hinder the manipulation of the fracture. Once reduction has been achieved, the guide pin is placed into the proximal tibia with the knee flexed over a triangle or using the semiextended approach. Figures 4 and 5.

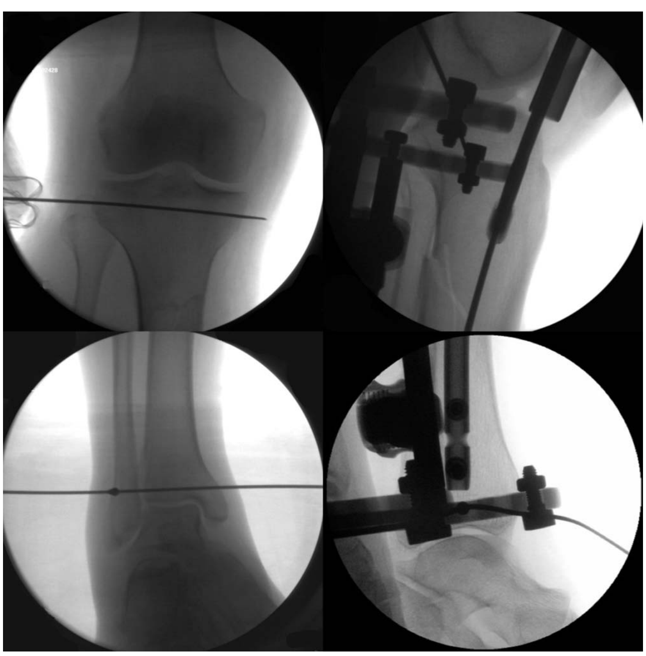

FIGURE 1. (Top) Proximal olive wire placed as a reference wire 1 centimeter below the tibial plateau and posterior to the nail entry path. (Bottom) Distal wire placed between the subchondral bone and the physeal remnant. Note that the olive wires do not interfere with nail insertion.

RESULTS

The strategy outlined in this technical trick was investigated at a single level I trauma center after approval from the institutional review board. All skeletally mature patients with a proximal tibia shaft fracture treated with an intramedullary nail beginning with the first use of tensioned wire–assisted nailing in December 2007 through September 2015 were identified. Demographic data were recorded using a chart review. Inclusion criteria included extra-articular fractures (OTA/AO 41-A and 42C3i) and fractures with a nondisplaced intra-articular component (OTA/AO 41B) that could be successfully treated with percutaneous lag screws. In accordance with Lindvall et al[2] (JOT 2009), the proximal tibia was defined as a region extending from the knee joint distally 1.5 times the medial to lateral plateau width. This method correlates with approximately the proximal 30% of the entire tibia.[2] Exclusion criteria included insufficient radiographic or chart data.

All surgeries were performed by experienced orthopaedic traumatologists. Because of the retrospective nature of this review, fractures were selected for either nailing technique based solely on the treating surgeon's preference. The use of adjunctive reduction techniques such as blocking screws, supplementary plating, and semiextended positioning was also at the discretion of the attending surgeon.

The anatomic alignment of each tibia was measured on anteroposterior and lateral radiographs obtained during the immediate postoperative period (the same day as surgery). The anatomic axis, as defined by Paley (*Principles of Deformity*…2002),[15] was used to measure deformity in the coronal and sagittal plane. The main outcome measurement was malalignment, defined as greater than 5 degrees of angulation in the coronal or sagittal plane. Statistical analysis was completed using Pearson χ^2 test and Student t test. $P < 0.05$ was considered statistically significant.

Patients were divided into 2 groups: those treated with tensioned wire–assisted nailing and those treated with manual reduction (conventional) nailing. Seventy-seven patients with proximal tibia fractures treated with IMN met the inclusion criteria. The distribution of fractures according to OTA/AO fracture classification is illustrated in **Supplemental Digital Content 1** (see **Table**, http://links.lww.com/JOT/A1). Forty-two (54.5%) patients underwent tensioned wire–assisted IMN, whereas the remaining 35 (45.5%) underwent conventional

FIGURE 2. Tensioned wire frame attached to the tibia. Note that the leg may be in full extension and that the bars are placed posterior on the rings so that the lateral–medial access plane to the tibia is not blocked by the frame. A towel is wrapped around the rods and secured with a clamp to support the mid tibia from apex posterior deformity.

IMN with manual reduction. The manual reduction and tensioned wire–assisted groups were equally matched with respect to age and sex demographics (see **Table**, **Supplemental Digital Content 2**, http://links.lww.com/JOT/A611). Open fractures requiring irrigation and debridement comprised 26% of the tensioned wire–assisted group and 40% of the conventional group, and this was not statistically significantly different between the 2 groups.

As illustrated in **Supplemental Digital Content 3** (see **Table**, http://links.lww.com/JOT/A612), primary angular malalignment occurred in 10 (28.6%) patients who underwent conventional IMN insertion and in 3 (7.1%) who underwent tensioned wire–assisted IMN insertion. The proximal tibia fractures treated with tensioned wire–assisted nailing had a significantly lower rate of postoperative malalignment than the group treated with manual reduction IMN (P = 0.0124). Adjuvant reduction techniques, consisting of blocking screws and/or open reduction and temporary plate fixation, were used in 18 of the 42 tensioned wire nailing cases and 10 of the 35 conventional nailing cases. Open reduction and supplemental plating was used in 2 of the 18 tensioned wire nailing cases and 4 of the 10 conventional nailing cases. As shown in **Supplemental Digital Content 4** (see **Table**, http://links.lww.com/JOT/A613), there was no statistically significant difference in the rate of utilization of adjuvant reduction techniques, consisting of blocking screws and/or supplemental plates. Surgeons who applied the tensioned wire–assisted technique did use the semiextended position more frequently than those who used manual reduction (P = 0.0005). Semiextended nailing was performed by a suprapatellar approach in all but 2 cases, in which nailing was performed through a lateral parapatellar arthrotomy. All conventional nailing was

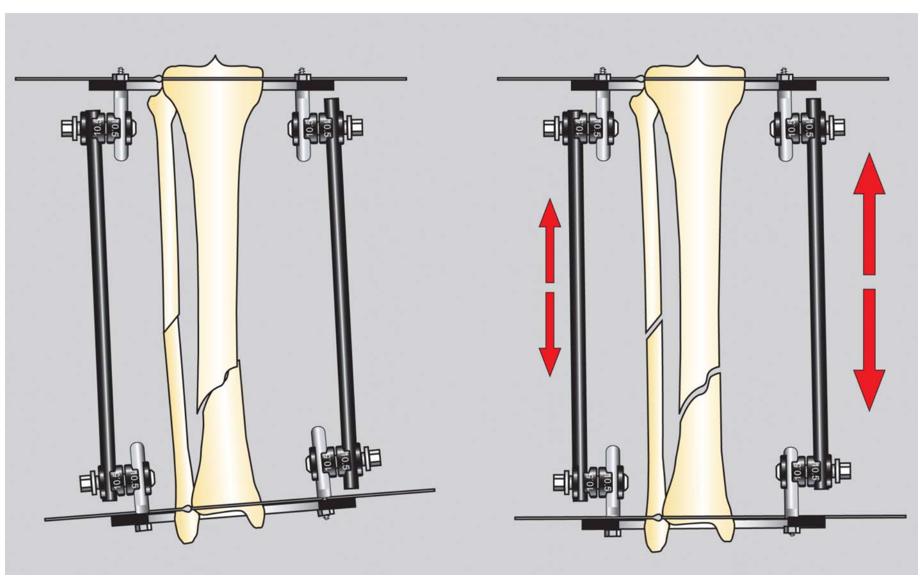

FIGURE 3. The fracture is reduced by distraction of the medial and lateral rods. The rods are lengthened asymmetrically as needed to reduce the varus or valgus alignment. The fracture is slightly over-distracted to facilitate the alignment.

FIGURE 4. A, Anteroposterior and (B) lateral preoperative radiographs of a grade II open, complex proximal tibia fracture (OTA/AO 42C.1) managed with tensioned wire–assisted IMN.

performed through a patellar tendon split. There was a trend toward a lower rate of coronal and sagittal malalignment in the semiextended position versus conventional positioning; however, these trends did not reach statistical significance (coronal: 8.2% vs. 17.9%, $P = 0.2028$; sagittal: 4.1% vs. 10.7%, $P = 0.2559$).

Valgus malalignment occurred in 2 (4.8%) patients treated with tensioned wire–assisted nailing and in 7 (20.0%) patients treated without tensioned wire assistance (see **Table, Supplemental Digital Content 3**, http://links.lww.com/JOT/A612). Apex anterior deformity occurred in 2 (4.8%) patients in the tensioned wire group and 3 in the manual reduction group. Accordingly, the incidence of malalignment between the 2 groups was statistically significantly different in the coronal plane ($P = 0.0382$), and not different in the sagittal plane ($P = 0.4994$).

DISCUSSION

Relatively recent advances in implant design and improvements in adjunctive reduction techniques have made IMN a popular and successful option in the treatment of proximal tibia fractures.[6,9,13,16,17] In contrast to fractures isolated to the tibial diaphysis, an intramedullary implant cannot achieve an interference fit in the wide metaphysis of the proximal tibia.[18] The surgeon cannot rely on the implant to reduce the fracture in the proximal tibia where the bone diameter is far wider than the diameter of the intramedullary nail. Rotational, angular, and length alignment may be lost during the process of limb manipulation (to obtain imaging), reaming, nail insertion, and placement of interlocking screws using manual distraction. Manual distraction requires constant attention by a member of the surgical team and can be irregular. These anatomic and technical considerations account for the historically high rates of malalignment reported with IMN of proximal tibia fractures.[3–5]

To improve the reduction of proximal tibia fractures, Jackson et al[14] introduced the idea of a "fine wire frame" as an adjunct to IMN of tibia fractures more than 10 years ago. The use of 1.8-mm tensioned wires reduces bone destruction associated with using 5-mm pins and allows tensioned wires to be placed in the bone adjacent to the subchondral joint surface, improving the ability to nail periarticular fractures. They concluded that the technique is indispensable in the

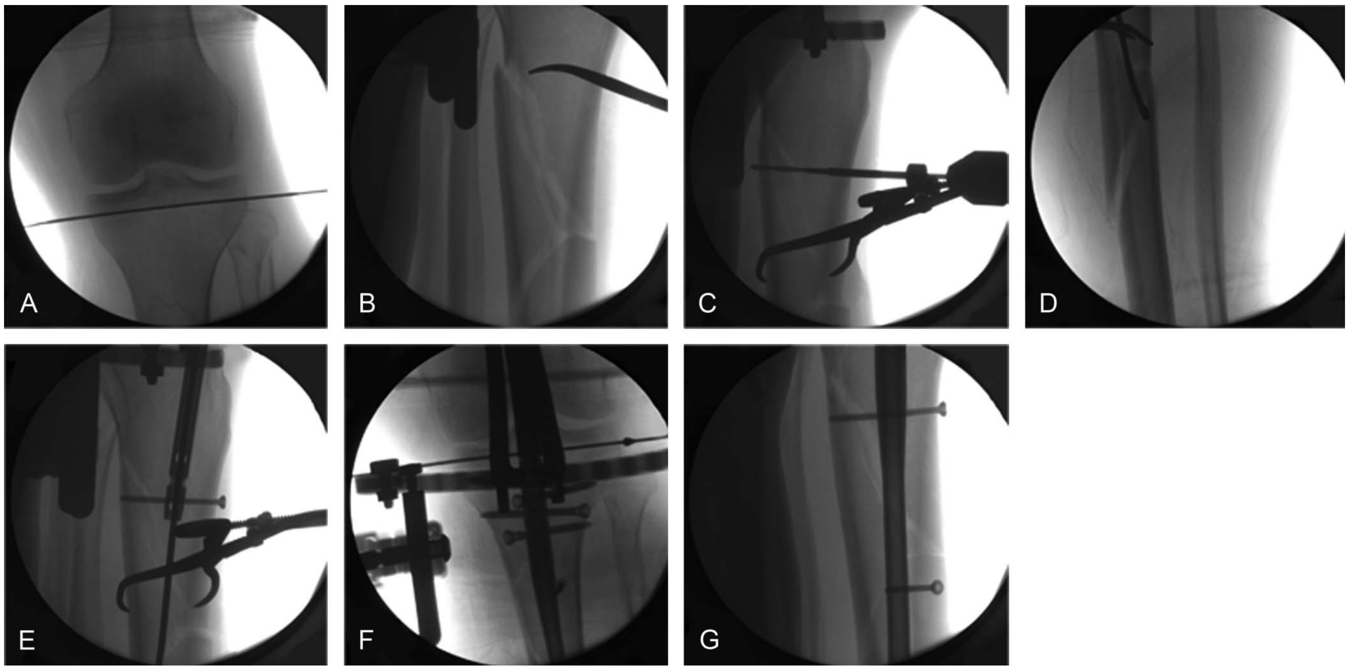

FIGURE 5. A, A 1.8-mm olive wire is placed in the proximal tibia, tensioned, and attached to the proximal 2/3 ring. B, The tensioned wire frame is used to apply distraction between the proximal tibia, posterior spiral wedge fragment, and distal tibia for the duration of the reduction and fixation. C, A Weber clamp is applied percutaneously to reduce the proximal spike of the posterior spiral wedge fragment. A 3.5-mm cortical screw is placed as a combination lag-blocking screw. D, The curved guide wire is passed into the distal tibia. E, The intramedullary nail is inserted across the fracture, which is held to length by the tensioned wire external fixator. F, Insertion of the proximal locking screws is unencumbered by the presence of the frame. Note the arcing of the 3.5-mm lag-blocking screw. G, A second lag screw is placed distally in the posterior spiral wedge fragment, allowing Weber clamp removal.

management of segmental fractures and those located in the proximal and distal third of the tibia. Although the technique was used in 30 patients and they noted that operative time was not increased in comparison to the free leg technique, the authors did not mention postoperative alignment. This study compares malalignment rates between proximal tibia fractures treated with tensioned wire–assisted IMN and those nailed using the manual traction technique. We observed a significantly lower rate of malalignment among patients in the tensioned wire group. Although this is confounded by the observation that more patients in the tensioned wire group underwent semiextended nailing, a closer look at the data reveals that the plane of deformity improved by semiextended nailing is the sagittal plane. The principal form of malalignment encountered postoperatively was valgus (7 of 35 in the manual group vs. 2 of 42 in the tensioned wire group), whereas the difference in the incidence of apex anterior deformity was much less prominent (3 of 35 in the manual group vs. 2 of 42 in the tensioned wire group). The incidence of malalignment was statistically significantly different in the coronal plane ($P = 0.0382$), but not in the sagittal plane ($P = 0.4994$). A review of recent studies reveals that the semiextended position functions primarily to minimize sagittal malalignment in proximal third tibia fractures, specifically apex anterior angulation caused by the extensor mechanism pull on the proximal tibia.[6,17,19–24] Tornetta and Collins[6] noted that the technique functions to "eliminate the extension force of the quadriceps on the proximal fragment, which otherwise would have tended to cause anterior angulation at the fracture site." Of the 25 patients with proximal tibia fractures treated in the semiextended position, the authors reported none with more than 5 degrees of apex anterior angulation but 3 with greater than 5 degrees of angulation in the coronal plane. There is evidence that the semiextended position can improve coronal plane alignment and distal third tibia fractures, likely because of decreased manipulation of the extremity required in this position.[25] To date, no evidence is available on the impact on the semiextended position on coronal plane alignment for proximal third tibia fractures treated with IMN. It is possible that the semiextended positioning used in most of our tension wire–assisted cases is responsible for some of the improvement in coronal plane alignment. However, we believe that tensioned wire assistance is invaluable in establishing correct coronal plane reduction and at least partially responsible for the improved alignment observed in those patients. The use of additional techniques such as blocking screws and supplemental plates was not statistically different between the 2 groups.

We have adopted this technique at our institution—a busy level I trauma center—and have been impressed by the ease of application and the facilitation in fracture reduction (see **Figure**, **Supplemental Digital Content 5**, http://links.lww.com/JOT/A614). After the fracture is reduced to length and the rotation of the fracture aligned with the fixator, tensioned wire–assisted IMN offers several advantages over manual reduction. It allows for precise, step-wise fracture reduction under (limited) image intensification. Once the reduction is locked in, the frame resists any malalignment that may otherwise occur during limb manipulation, successive reaming, nail insertion, and placement of locking screws. It obviates the need for an assistant to manually hold the reduction in place during each successive step. As a result, the surgeon's/assistant's hands are out of the field of radiation. The tensioned wire frame also allows adjustment of shortening and distraction at the fracture site. During the initial reduction, the fracture can be slightly over-distracted to facilitate reduction. During nail insertion, the fixator can be used to compress the fracture to prevent gapping at the fracture site, which is associated with delayed union.[26]

We have not encountered any intraoperative complications related specifically to the use of the tensioned wire fixator–assisted nailing technique. As espoused by Jackson et al, operative times are not significantly prolonged. Comparison of case times was not possible in our study because numerous patients within both groups were polytrauma patients, and surgical times are extended by the educational process of a teaching program. The technique is minimally invasive, and each of the two 1.8-mm olive wires requires only a small skin incision and creates a small diameter pin tract in the bone. This is in contrast to the larger cortical defects and skin incisions created by the application of a distractor with 5-mm pins. The tensioned wire construct allows for more efficient distraction as force is applied through the proximal and distal tibia and not through the ankle or hind foot joints (as with manual traction or other distractors). Fluoroscopy time is likely minimized because the surgeon does not need to constantly check the reduction once the fracture is reduced and the frame construct is locked in place.

This study is limited by its retrospective nature and the lack of long-term clinical outcome data, as well as confounders of limb positioning techniques and heterogeneity in reduction sequence. Having long-term data would allow us to comment on union rates, alignment at fracture healing, and any complications unique to the technique. Controlling for limb positioning and reduction strategy would also allow us to draw stronger conclusions of the effect of the technique on fracture alignment. Despite our limitations, however, our study shows that performing IMN of proximal tibia fractures in a semiextended position with our tension wire–assisted technique improves coronal alignment versus conventional technique. This technique is simple to apply and greatly facilitates IMN of proximal tibia fractures.

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