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Open tibial shaft fracture fixation strategies: intramedullary nailing, external fixation, and plating

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Abstract Tibial shaft fractures are one of the most common orthopaedic injuries. Open tibial shaft fractures are relatively common because of the paucity of soft tissue surrounding the bone. Despite the prevalence of these injuries, the optimal fixation strategy is still a topic of debate. The purpose of this article was to review the current literature on open tibial shaft fracture fixation strategies including intramedullary nailing, external fixation, and plating.

Keywords: trauma, tibia, open fractures, review article, outcomes

1. Introduction

Tibial shaft fractures are one of the most common orthopaedic injuries, accounting for approximately 2% of all adult fractures.[1] They are of particular concern because of their potential to lead to long-term morbidity, extended hospital stays, and significant health care costs. Tibial shaft fractures are often associated with high-energy mechanisms including falls from a height and motor vehicle accidents. However, the literature suggests a bimodal distribution with younger patients presenting after high-energy mechanisms and older populations presenting after lower-energy traumas such as ground level falls.[2] Open tibial shaft fractures are especially difficult because of the added complexity of soft tissue involvement.[3] Appropriate fracture fixation strategies are of paramount importance to decrease the odds of a patient developing malunion, nonunion, infection, or other postoperative complications. In this review, we will evaluate different methods of open tibial shaft fracture fixation strategies including intramedullary nailing, external fixation, and plating.

2. Fixation Strategies: Intramedullary Nailing

Intramedullary nailing (IMN) of tibial shaft fractures is the preferred fixation method for most of the closed and open tibial shaft fractures.[4] This technique has the advantages of preservation of periosteal blood supply, limited soft tissue damage, and the ability to control alignment, rotation, and translation.[4] In the setting of open tibial shaft fractures, immediate IMN after adequate irrigation and debridement has been a successful surgical option for lower-type open tibia fractures[5] (Fig. 1). Kakar et al[6] performed a prospective study evaluating initial aggressive debridement and unreamed IMN immediately after an open tibial shaft injury. The study included 143 patients with Gustilo Type I-IIIb open tibia fractures. Their protocol consisted of debridement with immediate unreamed IMN fixation followed by soft tissue coverage within 14 days. In 89% of patients (127/143), union was achieved without the need for secondary surgeries. Three percent of patients developed a deep infection requiring surgical debridement. They concluded that immediate unreamed IMN of open tibia fractures was an appropriate fixation method if conducted in conjunction with satisfactory debridement. However, they did report that 41% of their patients complained of knee and/or fracture site pain after union. Furthermore, only 13% of their patients were IIIB (19 patients), and no IIIC fractures were included in the study.

The SPRINT trial by Bhandari et al[7] evaluated the differences between reamed and unreamed IMN in both open and closed tibia fractures. There is concern about reaming open fractures because of the risk of disrupting the endosteal blood supply in a bone with an already compromised periosteal blood supply due to the open fracture. The SPRINT investigators included 400 open fractures in their multicenter, blinded, randomized trial. They found no differences in infection or reoperation to achieve union between the unreamed and reamed groups within the open tibial shaft fracture category. They did, however, report that delaying reoperation for nonunion for at least 6 months may decrease the need for reoperation.

Immediate nailing for open tibial shaft fractures was also investigated by the LEAP study group.[8] They found that type IIIA, IIIB, or IIIC open tibia fractures had high overall infection rates and separated the infection rates by fixation technique:

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Figure 1. Open tibia shaft fracture. Initial injury x-ray, clinical photograph, and postoperative x-rays after intramedullary nailing. These are the authors' original photographs and x-rays.

Intramedullary nailing versus external fixation. They found that for patient who needed only simple soft tissue coverage (did not need any flaps), infection rates were lower in intramedullary nailing (30.8%) versus external fixation (40.0%). Similarly, in the cohort who needed complicated soft tissue coverage including a flap, infection rates were also lower for intramedullary nailing (24.4%) versus external fixation (43.8%). The authors concluded that intramedullary nailing may be a more appropriate option than external fixator to decrease the incidence of infection.

Delayed intramedullary nailing of open tibia fractures after external fixation is a potential strategy for managing these fractures. There is concern that there may be an increased risk of infection due to bacteria within the pin tract sites. Bhandari et al[9] reviewed 22 studies on delayed IMN after external fixator. The literature mostly reported a staged technique where the external fixator was removed for a period of time before the IMN surgery was performed. The stages were separated by a period of between 2 and 224 days. The upper limit of days between procedures is so high because some of the patients included in the cohort are those who were treated with IMN after initial treatment with an external fixator resulted in nonunion, delayed union, or malunion. They found that infection rates averaged 9% and union rates averaged 90%. Furthermore, frames that were on for less than 28 days had an 83% reduction in the rate of infection. Therefore, they recommended that IMN be performed within 14 days of the external fixator removal. However, these data are likely biased in that patients who had a longer duration of external fixator placement and longer interval between interventions likely had worse injuries.

Figure 2. Provisional plating: intraoperative photograph before the plate was removed. This figure is being reprinted from Ref. 10 under the terms of the Creative Commons license (CC-BY).

Provisional plating during IMN procedures has been used to achieve adequate reduction intraoperatively[10] (Fig. 2). Dunbar et al reviewed 31 patients with type III open tibia fracture who underwent provisional plating and IMN. Provisional plating was used when there was limited operative room assistance, when a comminuted fracture included an intercalary segment that needed stabilization, and at the preference and discretion of the operating surgeon. The plate was inserted through the wound, and the plates and screws were removed intraoperatively for all patients after the nail was successfully placed. Four patients developed deep infections (13.3%) and 5 patients developed nonunions (16.7%). The authors concluded that provisional plating is a useful technique for fracture reduction and does not increase the risk of infection or nonunion.

Revak et al[11] described permanent (definitive) reduction plate before IMN where the provisional plate is maintained within the body as compared with provisional plating when it is removed before final closure. In their retrospective study, they reviewed 91 patients with open tibial shaft fractures. Thirty-nine underwent permanent reduction plating in conjunction with IMN and 52 underwent only IMN. Two patients in the plating group developed nonunion compared with 7 patients in the IMN group ($P = 0.29$). Union time was 5.5 months in the plating group and 6.1 months for the IMN group ($P = 0.39$). Finally, 4 patients in the plating group developed infection as compared with 10 patients in the IMN group ($P = 0.38$). Although the sample size was small, the results suggests that for open tibial shaft fractures, permanent reduction plating does not delay time to fracture union or increase the risk of nonunion or infection when compared with fixation with only an IMN.

Intramedullary nailing is a preferred method of fracture fixation for patients with open tibial shaft fractures. Recent data have shown that immediate fixation with IMN is an appropriate surgical option that can improve patient outcomes. Temporary external fixation can be used, but data suggest that patients do better when the second-stage IMN is performed relatively quickly after external fixation removal for optimal fracture union and decreased infection rates. Provisional or permanent reduction plating for IMN fixation can be used to aid in fracture reduction especially in the circumstances when there is an intercalary fracture segment that requires fixation or when there is limited assistance within the operating room.

3. Fixation Strategies: External Fixation

Definitive external fixation remains a viable treatment option for open tibial shaft fractures. In a recent meta-analysis, Alsharef

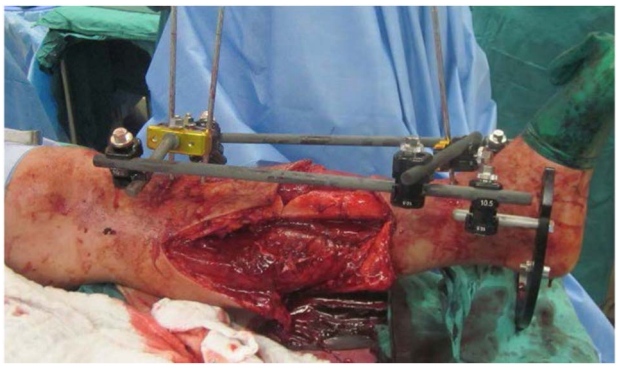

Figure 3. Clinical photographs of a uniplanar external fixator. This figure is being reprinted from Ref. 15 under the terms of the Creative Commons license (CC-BY).

et al[12] compared differences in outcomes between external fixation and intramedullary nailing in the treatment of open tibial shaft fractures. They included 12 randomized controlled trials encompassing 1090 patients in the analysis. The found that external fixation had a higher rate of superficial infection, pin track infection, and malunion when compared with IMN. They did not find any differences in deep infection, nonunion, delayed union, or implant/hardware failure. The authors concluded that IMN is a more favorable treatment option versus external fixation for optimal patient outcomes.

Another meta-analysis by Al-Hourani et al[13] investigated the outcome differences between fixation techniques including unreamed intramedullary nailing, reamed intramedullary nailing, and plate fixation, multiplanar and uniplanar external fixation. The primary outcome measure was unplanned reoperation defined as an unplanned repeat debridement, removal/exchange of implants for deep infection, unplanned intervention for established nonunion, malunion, malalignment, or for implant removal/exchange because of compromised construct stability. Eighteen studies comprising 1764 patients were ultimately included in the meta-analysis. They found that external fixation showed a higher risk of unplanned reoperation compared with unreamed nailing. However, this difference was not statistically significant. In Gustilo Type III open fractures, there was a significant difference with external fixation having higher reoperation rates compared with nailing ($P = 0.05$). The authors concluded that intramedullary nailing reduced the risk of unplanned reoperation when compared with external fixation.

Meltsios et al[14] performed a retrospective study on severe tibial shaft fractures treated with unilateral external fixator as the primary and definitive treatment (Fig. 3). Two hundred twenty-three patients were included: 26 with severe soft tissue injuries, 30 with impending compartment syndrome, 139 with Gustilo Type III open fractures, and 28 with multiple other injuries. Mean time to fracture union in the open fracture group was 25 weeks (range 17–32 weeks, median 28 weeks). Among the 223 patients, there were 18 nonunions, 21 delayed unions, 4 malunions, 58 pin site infections, and 3 osteomyelitis cases. The authors concluded that because of advances in external fixator technology and application methods, external fixators should be considered as a treatment option for severe tibial shaft fractures, especially those with significant soft tissue injury or impending compartment syndrome.

Henley et al[16] prospectively evaluated the outcomes of patients with open tibial shaft fractures treated with unilateral external fixation versus unreamed intramedullary nailing. The group

Figure 4. Clinical photographs of a ring external fixator. This figure is being reprinted from Ref. 15 under the terms of the Creative Commons license (CC-BY).

treated with IMN had significantly less malalignment versus the external fixator group (8% vs. 31%). IMN also had fewer infections and fewer subsequent procedures. Henley et al concluded that unreamed IMN are the preferred treatment options versus external fixators for the best outcomes.

Ring fixators are another type of external fixation treatment option (Fig. 4). Similar to uniplanar external fixators, ring fixators have the advantage over IMN in that the hardware is applied away from the fracture site. This theoretically decreases the risk of deep infection because there is not a metal surface at the location of the fracture and open wound for the formation of bacterial biofilm. The ring fixators are also advantageous compared with the uniplanar fixators because it has improved fracture stability because of its multiplanar nature. Furthermore, the ring fixator allows for correction of deformity and the ability to apply compression or

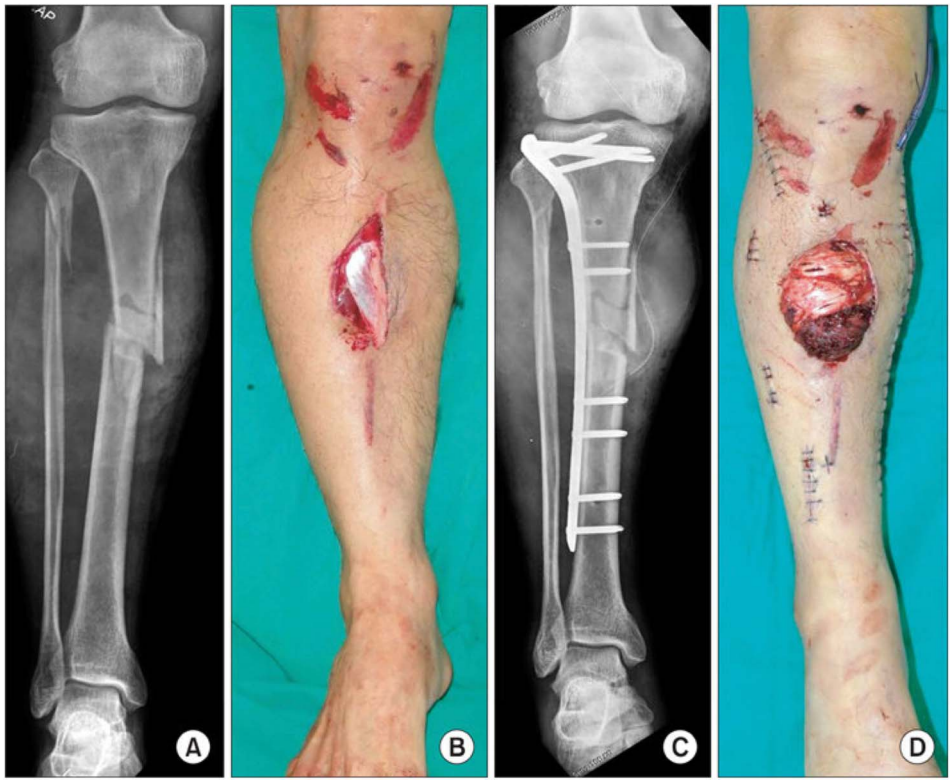

Figure 5. A and B, Initial injury x-ray and clinical photograph of a 53-year-old male patient who sustained an open proximal tibial fracture. C and D, Postoperative x-ray and clinical photograph after minimally invasive plate osteosynthesis and rotational gastrocnemius muscle flap. This figure is being reprinted from Ref. 23 under the terms of the Creative Commons license (CC-BY).

distraction at the fracture site. The FIXIT Study by the Major Extremity Trauma Research Consortium (METRIC) is a randomized clinical trial comparing the treatment of open tibial shaft fractures treated with modern external ring fixator versus internal fixation (IMN or plate).[17] The study included 127 patients treated with ring fixation and 133 patients treated with internal fixation. The primary outcome was a major limb complication within 365 days after randomization including amputation, infection, a soft tissue problem, nonunion, malunion, or a loss of reduction/implant failure. They found that the probability of at least 1 major limb complication was higher for the external fixation group (62.1%) versus internal fixation group (43.7%). There were no significant differences in the probability of deep infection, amputation, nonunion, soft tissue problems, malunion, or fracture healing between the 2 groups. The authors argued that these results favor the use of internal fixation for open tibial shaft fractures versus ring external fixation.

Hutson et al[18] studied 45 open tibia fractures, many sustained from military blast injuries. All patients were treated definitively with ring external fixators. All fractures healed with less than 5 degrees of malalignment. The average time to union with frame removal was 221 days. The authors concluded that treatment of severe open wartime tibial fractures with placement of a ring external fixator can result in a high rate of fracture union and low rate of unwanted complications.

Dickson et al[19] evaluated the outcomes of 22 patients with open tibial fractures treated with circular external fixators. They found that all cases achieved fracture union, and there was a low rate of deep infection (4.5%). They advocated for using ring external fixators in many severe, open tibial shaft fractures.

External fixation remains a potential surgical option for treatment of patients with severe soft tissue injury after open tibial shaft fractures. Uniplanar external fixators have worse outcomes, leading to higher rates of malunion. However, circular external fixators show more promising outcomes, likely because of their multiplanar stability.

4. Fixation Strategies: Plating

Plating, or plate osteosynthesis, is an uncommon fixation technique for open tibial shaft fractures. Avilucea et al[20] reviewed open reduction internal fixation (ORIF) with plates versus IMN in patients with open distal tibial shaft fractures. They reviewed 180 IMN and 36 ORIF cases. They found that the ORIF patients had a higher rate of nonunion (25%) compared with the IMN patients (10.6%). In addition, the ORIF patients had 2.52 greater odds of developing any complication compared with the IMN patients ($P = 0.04$). The authors concluded that plate osteosynthesis for open distal tibial shaft fractures led to higher rates of nonunion and overall complications when compared with IMN in this cohort.

Galal[21] performed a randomized controlled trial comparing minimally invasive plate osteosynthesis with reamed IMN in treating open tibial shaft fractures. A total of 60 patients were included and randomized into one of the 2 groups. They found no significant difference in regards to infection or nonunion between the groups. However, they did find that time to fracture union was shorter is the IMN group versus the plating group (17 weeks vs. 20 weeks). The authors proposed minimally invasive plate osteosynthesis can be considered a valid treatment alternative to IMN for open tibial shaft fractures.

Bach et al[22] performed a prospective study of 59 patients with Type II or III open tibia shaft fractures treated with either plate osteosynthesis or definitive external fixation. They found that patients treated with plates had a significantly higher rate of osteomyelitis (19% vs. 3%). They also found a higher rate of wound infection (35% vs. 13%) and a high rate of plate fixation failure (12%). However, because this was an older study, it predated the use of the minimally invasive plate osteosynthesis that is available today.

Kim et al[23] reviewed 34 patients with open proximal tibial fractures treated by minimally invasive plate osteosynthesis (Fig. 5). They had an infection rate of 26.7%. Alignment was less than 5 degrees in all but 2 patients. Primary union was achieved by 24/30 patients. The authors propose plate osteosynthesis as a treatment option for these types of open fractures.

Plating for open tibial shaft fractures remains an uncommon fracture fixation technique. There are a few studies proposing noninferiority to IMN. However, these studies include a small sample size and are mostly retrospective. Minimally invasive plating techniques have improved recently with the ability to apply the hardware with less soft tissue disruption. However, more studies are needed to determine the efficacy of using this treatment method.

5. Conclusion

The best definitive surgical fixation strategy for open tibial shaft fractures remains controversial. However, through a thorough review of current literature, we are able to make more informed choices when deciding how to treat patients. Intramedullary nailing remains the preferred treatment option for many surgeons. This fixation technique has improved over time to include interlocking screws that provide additional rotational control. In most studies, this is the surgical option that provides the best outcomes including high fracture union rates, low infection rates, and low reoperation rates. However, external fixators remain a viable option for open tibial shaft fractures, as well. In general, uniplanar external fixators have fallen out of favor because of their increased incidence of malunion and pin site infections. Circular external fixators can provide additional stability because of their multiplanar design. They can be a reliable treatment option for patients with severe soft tissue injury or the polytrauma patient. Finally, plate osteosynthesis is an uncommon alternative to the aforementioned choices. This technique had improved over the years, now allowing minimally invasive and percutaneous application. However, the current literature does not demonstrate superiority when compared with IMN or circular external fixator. Plating may be an option for very distal or proximal tibia fractures either by itself or with a nail; however, this remains an area of continued investigation. Further studies, especially prospective, randomized controlled trials will continue to elucidate optimal fixation strategies for open tibial shaft fractures.

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