Standard Review Article

OPEN

Extreme nailing and immediate weight bearing constructs in fractures of the distal tibia

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Abstract

Extraarticular fractures of the distal tibia can present as difficult but manageable lower extremity injuries. Historically, these injuries have been fixed in a myriad of ways. Early management with intramedullary nailing had higher complication rates due to the unique anatomical and biomechanical features of the distal tibia. Modern improvements in intramedullary nailing surgical techniques and implant design have significantly decreased complication rates and led to improvement in patient outcomes. Many surgeons protect weight bearing postoperatively, but recent literature suggests that patients may safely weight bear immediately following intramedullary fixation. This article reviews technique and implant design changes that have facilitated immediate safe weight bearing following intramedullary nailing of extraarticular distal tibia fractures.

Keywords: distal tibia fracture, intramedullary nailing, weight bearing

1. Introduction

Extraarticular distal tibial fractures are relatively uncommon, accounting for approximately 15% of tibial fractures and typically occur via a rotational and axial loading mechanism.[1–3] The OTA/AO defines these injuries (43) as a fracture that occurs within 4 cm of the plafond or within the distal tibial square (vertical distance from the plafond equal to the length of the distal epiphysis at its widest portion), and the subcategorized 43A1-3 comprise the extraarticular varieties.[3–5] In the skeletally mature patient, there have been several described ways to manage these injuries, both nonsurgically and surgically. Nonsurgical options include casting and functional brace management. These options have been successful in length stable fracture patterns but delay mobilization and lead to increased adjacent joint stiffness.[6,7] In the modern era surgical management is the standard of care by either open reduction and internal fixation (ORIF) with plating (locked or nonlocked) or antegrade intramedullary nailing (IMN) to support improved fracture alignment, early joint mobility, pain reduction, and to support local soft tissues.[8–12] Plate fixation includes ORIF with nonlocked plates, ORIF with locked plating, or minimally invasive osteosynthesis with locked plating. Several recent meta-analyses and reviews comparing ORIF to IMN point out a large degree of heterogeneity within these study populations due to variations in study design, specific patient and injury characteristics, implant design (locked vs nonlocked plating) and surgical technique (suprapatellar vs infrapatellar nailing) and are therefore unable to suggest a clearly superior modality.[9,11,13–15] Additionally, plates can be used as a reduction aid or adjunctive in combination with intramedullary nailing, in nail-plate constructs (NPC). NPC fixation has been described in complex tibial shaft fractures with extensive bone loss, as well as in proximal and distal metaphyseal fractures with good outcomes and complication rates comparable to those using nail or plate constructs alone.[16–18] Despite the inability to clearly recommend 1 single superior modality, treatment of distal tibial fractures with IMN is the preferred method in many institutions, including the senior author's. Excellent alignment and outcomes are obtainable in these difficult injuries with the additional implant specific benefits offered by intramedullary nail fixation.

1.1. Management with intramedullary nailing

Intramedullary nailing of distal tibial fractures has several proposed benefits compared to ORIF including cost efficacy,[19,20] shorter operating and radiation time,[13,21] and decreased soft tissue disruption leading to more favorable local biology for fracture union and wound-related complications.[6,12–14,21,22] One of the primary benefits of long bone fracture treatment with IMN is the facilitation of immediate weight bearing due to the biomechanical load sharing nature of intramedullary devices.[23] In contrast to IMN of tibial

No sources of funding have been granted for this study.

This study was deemed exempt from Institutional Review Board and Animal Use Committee Review.

Authorship has been granted only to those individuals who have contributed substantially to the research or manuscript.

All authors have read and complied with the ethical approval/informed consent requirements for this study. The manuscript was exempt from any additional ethics requirements as it does not involve research involving human or animal subjects.

Collection: Early Weightbearing Constructs in the Lower Extremity.

The authors have no conflicts of interest to disclose.

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OTA (2022) e180

Received: 5 October 2021 / Accepted: 18 December 2021

Published online 18 July 2022

http://dx.doi.org/10.1097/OI9.0000000000000180

diaphyseal fractures, immediate weight bearing in extraarticular distal tibial metaphyseal fractures is controversial and less commonly employed. The controversy in the AO Type 43A1-3 fractures following treatment with IMN arises from concern for potential displacement resulting in malunion, nonunion, or implant failure that may be associated with early weight bearing. Such complications are a product of both local biomechanical and technical factors, and concern regarding the ability of a locked intramedullary implant to resist the forces associated with immediate weight bearing in a bone with short segment fixation in the capacious distal metaphysis.[9,10,14,18,21,24,25] Recent improvements in implant design and surgical techniques have greatly contributed to decreasing the previously higher reported complication rates with IMN of distal tibia fractures.

Obtaining an initial reduction with acceptable length, alignment, and rotation necessitates a comprehensive understanding of local anatomy and deforming forces about the distal tibia. Techniques to obtain the reduction in distal tibial fractures have improved with surgeon experience and the expansion of previously described techniques to this anatomic location, such as provisional plating [17,18] and the use of Poller (blocking) screws.[6,8,26] In addition to reduction aids and tricks, most IMN systems now facilitate suprapatellar nailing. Compared to nonsemi-extended techniques, suprapatellar nailing has been shown to significantly decrease the rate of malunion in both proximal and distal tibial metaphyseal fractures.[27–29] Compared to infrapatellar nailing of distal tibial fractures, suprapatellar nailing reduced malalignment rates from 20% to 3%.[10,29] Further, arthroscopic and MRI evaluation of the patellofemoral joint show no differences in chondral injury, and the rates of anterior knee pain are no different compared to infrapatellar techniques.[28,30]

From a design standpoint, modern nails are better equipped to resist deforming forces and tolerate the physiological loads required for immediate weight bearing. Early IMN treatment of distal tibial fractures had unacceptably high failure and malunion rates associated with a single uniplanar distal interlocking screw. Interlocking screws now have a larger core diameter and angular stable locking designs which increase the overall axial strength and resistance to coronal angulation.[18,31,32] Modern nails are also equipped with numerous and multiplanar distal interlocking options, which increase construct stiffness and resistance to deformity in distal tibial fractures.[1,33] Recent biomechanical studies demonstrate that the use of at least 2 modern interlocking screws is sufficient to tolerate the forces necessary to facilitate immediate postoperative weight bearing.[33,34] Additional bio-mechanical studies demonstrate that multiple multiplanar distal interlocking screws provide significantly increased construct stiffness in modern nails, rendering any additional lateral column (fibular) support clinically inconsequential in terms of overall bending, torsional, or axial strength.[1,35] When to address the fibula surgically and provide lateral column support in these settings continues to be a point of debate. With these advancements in our understanding, technique, and implant design, IMN management of extraarticular distal tibial fractures continues to become more widely used with excellent results.

1.2. Immediate postoperative weight bearing

Yoon et al[16–18] have demonstrated good outcomes and comparable complication rates using NPC fixation of complex tibial shaft fractures and those with proximal and distal tibial extension allowed to weight bear as tolerated (WBAT) immediately postoperatively. Still, immediate postoperative weight bearing following isolated IMN treatment remains somewhat controversial. Recent studies have provided early compelling evidence that such management is safe with no

Figure 1. Radiographic measurement of the lDTA and aDTA angles for assessing distal tibial alignment.

Figure 2. Initial selected injury films of the right distal tibia fracture. AP (2A) and Lateral (2B) radiograph of the tibia, and a mortise view of the ankle (2C). An axial CT of the distal tibial plafond showing no intraarticular involvement (2D). Arrow indicates fracture extension into distal metaphysis. CT, Computed Tomography.

significant difference in complication rates compared to non-weight bearing protocols.[3,36]

Beebe et al[3] studied a retrospective cohort of 53 adult patients with AO43A fractures treated with IMN allowed to immediately WBAT following surgery. Comparing postoperative and sequential follow up radiographic measures of lateral distal tibial angle (lDTA) and anterior distal tibial angle (aDTA) (Fig. 1) they defined initial alignment outcomes as either excellent, acceptable, or poor based on degree of deviation from accepted norms for lDTA and aDTA.[37] A statistically significant change in alignment was defined as a change greater than 2 degrees between initial and final follow up radiographs.[38] Initial radiographic alignment was deemed excellent in 20.4%, acceptable in 77.8%, and poor in 1.9% with an average change between initial and final alignment of 0.52 ± 1.48 degrees of valgus and 0.48 ± 3.14 degrees of extension. Interestingly, of the 11 patients who had overall significant changes in alignment, 4 had a decline in alignment classification and 7 had an improvement in alignment classification.[3] Seven of their patients went on to nonunion requiring implant removal or revision (*5* infected nonunions), and no patient was revised for implant breakage or failure. Of note, the majority of their patients (92.6%) were treated with 3 distal interlocking screws and over half of the patients had lateral column support (*55.6%*) with either fibular fixation or an intact fibula. They found no difference in initial or final alignment with respect to fibula support. Although there has yet to be a consensus on the effect of fibular support, their results are consistent with recent studies

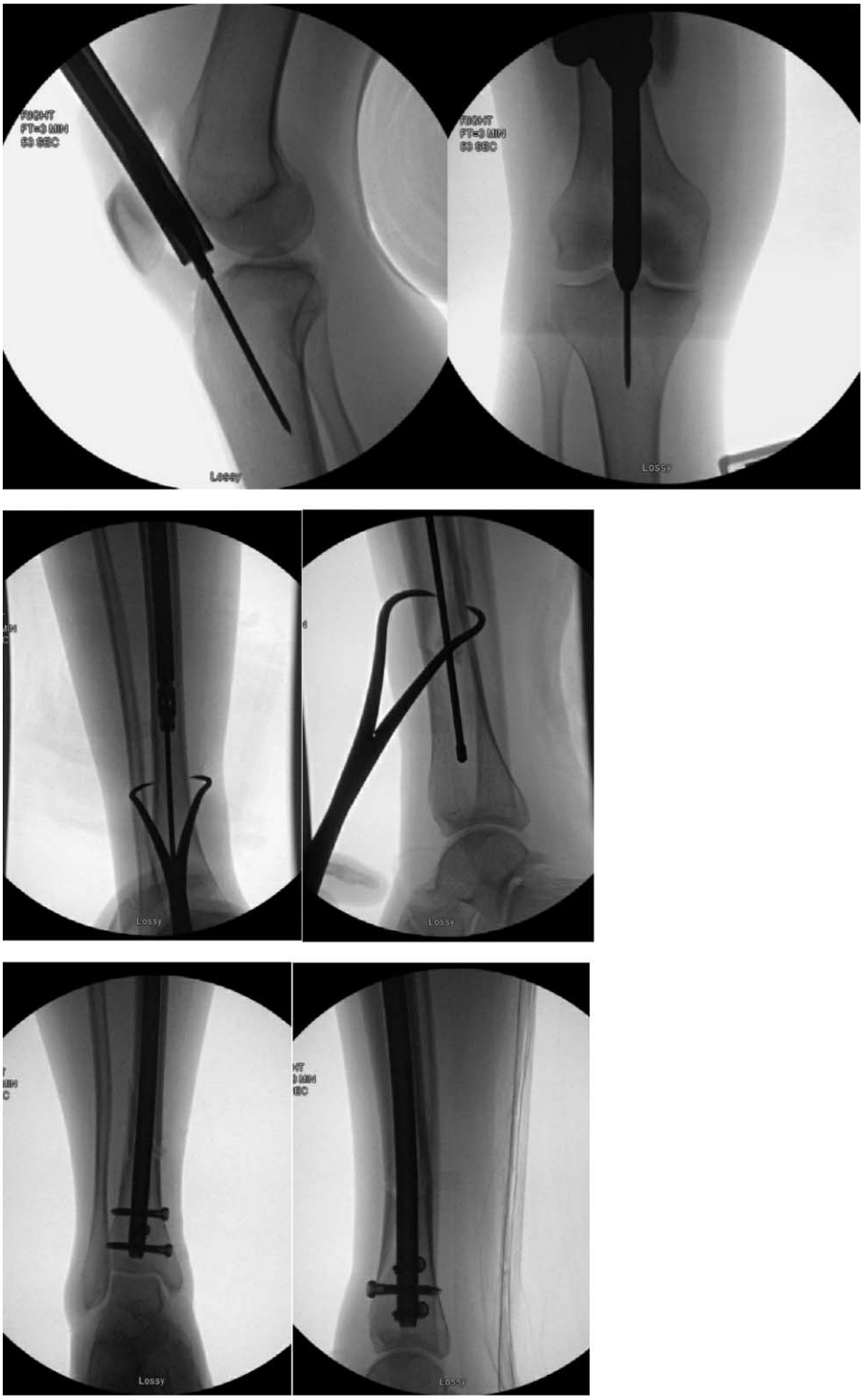

Figure 3. Intraoperative imaging showing suprapatellar entry position in semi-extended tibia nailing and reduction technique with percutaneous clamp.

showing minimal additional angular support is obtained with fibula fixation when using modern IMNs with at least 2 angle stable distal interlocking screws.[1,33,35,39,40] To date, there are no studies designed that investigate the role an intact lateral column has on stability in distal tibial fractures treated with IMN *in patients allowed to WBAT immediately* after surgery.

Weng et al[36] desi gned a prospective cohort study of consecutive extraarticular distal tibial fractures allowed to immediately WBAT in a walking boot compared to historical controls managed postoperatively with nonweight bearing for 28 days. In their prospective cohort of 167 fractures compared to historical controls they found no difference in secondary

Figure 4. AP and Lateral Tib/Fib radiographs at 16 months postoperatively showing progression to full radiographic union and unchanged fracture alignment.

displacement during average follow up of 18.5 months. In both groups about half of the fractures (54% in prospective cohort) had fibula fixation or an intact fibula and all had 3 or 4 distal interlocking screws – neither of which was shown to have an impact on overall changes in alignment. Compared to the study by Beebe et al,[3] in this study patients were only allowed to fully weight bear while in the walking boot until they were pain free, an average of 1.2 ± 0.6 months in the prospective group compared to 2.1 ± 1.2 months in the historical group. Interestingly, their experimental cohort experienced an increase in the rate of radiographic healing (3.5 ± 1.2 months vs 4.9 ± 1.3 months, $P = .023$) and a lower overall rate of nonunion (2.4% vs 7.1%, $P = .027$) in the closed fractures. This interesting finding is supported further in a study of IMN treated tibial shaft fractures showing that patients who initiated full weight bearing earlier (2.6 weeks vs 7.4 weeks) had faster time to full healing and less delayed or nonunion.[41] There were no differences between the groups in soft tissue related complications or infection, but this study excluded open fractures.

1.3. Case example

The patient is a 28-year-old female involved in a high-speed motor vehicle accident resulting in a closed right spiral fracture of the distal tibia (Fig. 2) and an ipsilateral midshaft clavicle fracture managed nonoperatively. On the day of trauma, her orthopaedic injuries were managed with early definitive care with an intramedullary nail via the suprapatellar approach (Fig. 3).

She was allowed to weightbear as tolerated after the procedure. Postoperative alignment was excellent as demonstrated by the lDTA and aDTA. She went onto uneventful radiographic and clinical fracture union by 16 weeks and her final images at 16 months show no significant change in overall alignment (Fig. 4).

2. Conclusion

Both modernization of surgical techniques and intramedullary implants over the past decade have helped resolve shortcomings that previously limited excellent outcomes with the use of intramedullary nailing in distal tibial fractures. As the use of IMN in these injuries becomes more widespread, early postoperative weight bearing protocols may be lagging at many centers. Increasing biomechanical and clinical evidence suggest that immediate postoperative WBAT can be safe and effective in these circumstances, without an increase in overall complications. In addition to the benefits described above—patient convenience, the risk of venous thromboembolism, and the effect on muscle atrophy as well as joint stiffness associated with immobility may all benefit from immediate WBAT. Additional high-quality studies will help to support these findings in the current evidence-based medical environment.

References

1. Attal R, Maestri V, Doshi HK, et al. The influence of distal locking on the need for fibular plating in intramedullary nailing of distal metaphyseal tibiofibular fractures. *Bone Joint J* 2014; 96-B:385–389.
2. Tyllianakis M, Megas P, Giannikas D, et al. Interlocking intramedullary nailing in distal tibial fractures. *Orthopedics* 2000; 23:805–808.
3. Beebe MJ, Morwood M, Serrano R, et al. Extreme nailing: is it safe to allow immediate weightbearing after intramedullary nail fixation of extra-articular distal tibial fractures (OTA/AO 43-A). *J Orthop Trauma* 2019; 33:392–396.
4. 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 (Suppl 10):S1–S133.
5. Meinberg EG, Agel J, Roberts CS, et al. Fracture and dislocation classification compendium-2018. *J Orthop Trauma* 2018; 32 (Suppl 1): S1–S170.
6. Bedi A, Le TT, Karunakar MA. Surgical treatment of nonarticular distal tibia fractures. *J Am Acad Orthop Surg* 2006; 14:406–416.
7. Sarmiento A, Latta LL. 450 closed fractures of the distal third of the tibia treated with a functional brace. *Clin Orthop Relat Res* 2004; 261–271.
8. Casstevens C, Le T, Archdeacon MT, et al. Management of extra-articular fractures of the distal tibia: intramedullary nailing versus plate fixation. *J Am Acad Orthop Surg* 2012; 20:675–683.
9. Kwok CS, Crossman PT, Loizou CL. Plate versus nail for distal tibial fractures: a systematic review and meta-analysis. *J Orthop Trauma* 2014; 28:542–548.

10. Vallier HA, Cureton BA, Patterson BM. Randomized, prospective comparison of plate versus intramedullary nail fixation for distal tibia shaft fractures. *J Orthop Trauma* 2011; 25:736–741.
11. Vallier HA. Current evidence: plate versus intramedullary nail for fixation of distal tibia fractures in 2016. *J Orthop Trauma* 2016; 30 (Suppl 4):S2–S6.
12. Newman SD, Mauffrey CP, Krikler S. Distal metadiaphyseal tibial fractures. *Injury* 2011; 42:975–984.
13. Guo C, Ma J, Ma X, et al. Comparing intramedullary nailing and plate fixation for treating distal tibail fractures: a meta-analysis of randomized controlled trials. *Int J Surg* 2018; 53:5–11.
14. Iqbal HJ, Pidikiti P. Treatment of distal tibia metaphyseal fractures; plating versus intramedullary nailing: a systematic review of recent evidence. *Foot Ankle Surg* 2013; 19:143–147.
15. Zelle BA, Bhandari M, Espiritu M, et al. Treatment of distal tibia fractures without articular involvement: a systematic review of 1125 fractures. *J Orthop Trauma* 2006; 20:76–79.
16. 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.
17. Yoon RS, Gage MJ, Donegan DJ, et al. Intramedullary nailing and adjunct permanent plate fixation in complex tibia fractures. *J Orthop Trauma* 2015; 29:e277–e279.
18. Yoon RS, Liporace FA. Intramedullary nail and plate combination fixation for complex distal tibia fractures: when and how? *J Orthop Trauma* 2016; 30 (Suppl 4):S17–S21.
19. Maredza M, Petrou S, Dritsaki M, et al. Infographic: economic justification for intramedullary nail fixation over locking plate fixation for extra-articular distal tibial fractures. *Bone Joint J* 2018; 100-B:622–623.
20. Maredza M, Petrou S, Dritsaki M, et al. A comparison of the cost-effectiveness of intramedullary nail fixation and locking plate fixation in the treatment of adult patients with an extra-articular fracture of the distal tibia: economic evaluation based on the FixDT trial. *Bone Joint J* 2018; 100-B:624–633.
21. Im GI, Tae SK. Distal metaphyseal fractures of tibia: a prospective randomized trial of closed reduction and intramedullary nail versus open reduction and plate and screws fixation. *J Trauma* 2005; 59:1219–1223. discussion 1223.
22. Avilucea FR, Sathiyakumar V, Greenberg SE, et al. Open distal tibial shaft fractures: a retrospective comparison of medial plate versus nail fixation. *Eur J Trauma Emerg Surg* 2016; 42:101–106.
23. Bong MR, Kummer FJ, Koval KJ, et al. Intramedullary nailing of the lower extremity: biomechanics and biology. *J Am Acad Orthop Surg* 2007; 15:97–106.
24. Vallier HA, Le TT, Bedi A. Radiographic and clinical comparisons of distal tibia shaft fractures (4 to 11 cm proximal to the plafond): plating versus intramedullary nailing. *J Orthop Trauma* 2008; 22:307–311.
25. Gorczyca JT, McKale J, Pugh K, et al. Modified tibial nails for treating distal tibia fractures. *J Orthop Trauma* 2002; 16:18–22.
26. Krettek C, Miclau T, Schandelmaier P, et al. The mechanical effect of blocking screws ("Poller screws") in stabilizing tibia fractures with short proximal or distal fragments after insertion of small-diameter intramedullary nails. *J Orthop Trauma* 1999; 13:550–553.
27. Metcalf KB, Du JY, Lapite IO, et al. Comparison of infrapatellar and suprapatellar approaches for intramedullary nail fixation of tibia fractures. *J Orthop Trauma* 2021; 35:e45–e50.
28. Sanders RW, DiPasquale TG, Jordan CJ, et al. Semiextended intramedullary nailing of the tibia using a suprapatellar approach: radiographic results and clinical outcomes at a minimum of 12 months follow-up. *J Orthop Trauma* 2014; 28:245–255.
29. Avilucea FR, Triantafillou K, Whiting PS, et al. Suprapatellar intramedullary nail technique lowers rate of malalignment of distal tibia fractures. *J Orthop Trauma* 2016; 30:557–560.
30. Leliveld MS, Verhofstad MHJ, Van Bodegraven E, et al. Anterior knee pain and functional outcome following different surgical techniques for tibial nailing: a systematic review. *Eur J T rauma Emerg Surg* 2021; 47:763–772.
31. Horn J, Linke B, Höntzsch D, et al. Angle stable interlocking screws improve construct stability of intramedullary nailing of distal tibia fractures: a biomechanical study. *Injury* 2009; 40:767–771.
32. Gueorguiev B, Wähnert D, Albrecht D, et al. Effect on dynamic mechanical stability and interfragmentary movement of angle-stable locking of intramedullary nails in unstable distal tibia fractures: a biomechanical study. *J Trauma* 2011; 70:358–365.
33. Chan DS, Nayak AN, Blaisdell G, et al. Effect of distal interlocking screw number and position after intramedullary nailing of distal tibial fractures: a biomechanical study simulating immediate weight-bearing. *J Orthop Trauma* 2015; 29:98–104.
34. Agathangelidis F, Petsatodis G, Kirkos J, et al. Distal locking screws for intramedullary nailing of tibial fractures. *Orthopedics* 2016; 39:e253–e258.
35. Morin PM, Reindl R, Harvey EJ, et al. Fibular fixation as an adjuvant to tibial intramedullary nailing in the treatment of combined distal third tibia and fibula fractures: a biomechanical investigation. *Can J Surg* 2008; 51:45–50.
36. Weng S, Bi C, Gu S, et al. Immediate weightbearing after intramedullary fixation of extra-articular distal tibial fractures reduces the nonunion rate compared with traditional weight-bearing protocol: a cohort study. *Int J Surg* 2020; 76:132–135.
37. Paley D. Principles of Deformity Correction. 2002;Springer, Heidelberg, Germany:1–18.
38. Barg A, Amendola RL, Henninger HB, et al. Influence of ankle position and radiographic projection angle on measurement of supramalleolar alignment on the anteroposterior and hindfoot alignment views. *Foot Ankle Int* 2015; 36:1352–1361.
39. De Giacomo AF, Tornetta P3rd. Alignment after intramedullary nailing of distal tibia fractures without fibula fixation. *J Orthop Trauma* 2016; 30:561–567.
40. Taylor BC, Hartley BR, Formaini N, et al. Necessity for fibular fixation associated with distal tibia fractures. *Injury* 2015; 46:2438–2442.
41. Houben IB, Raaben M, Van Basten Batenburg M, et al. Delay in weight bearing in surgically treated tibial shaft fractures is associated with impaired healing: a cohort analysis of 166 tibial fractures. *Eur J Orthop Surg Traumatol* 2018; 28:1429–1436.