Original Article
Clinics in Orthopedic Surgery 2025;17:39-45 • https://doi.org/10.4055/cios24150

Infrapatellar Approach to Intramedullary Nail Fixation of Distal One-Fourth Tibial Fractures

Yong-Cheol Yoon, MD, Hyung Suh Kim, MD*, Hyoung-Keun Oh, MD*

Division of Orthopedic Trauma, Trauma Center, Gachon University College of Medicine, Incheon,
**Department of Orthopedic Surgery, Inje University Ilsan Paik Hospital, Goyang, Korea*

Background: This study aimed to report the radiological outcomes and risk factors for malalignment of fractures in the distal one-fourth of the tibia treated with intramedullary nailing via the infrapatellar approach.

Methods: This study retrospectively analyzed 60 patients (37 men and 23 women; mean age, 45.4 years) who had distal one-fourth tibial fractures and were treated with intramedullary nailing using the infrapatellar approach. These patients were treated between January 2009 and December 2021, with a minimum follow-up of 1 year. Fractures were classified according to the Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association system: 25 were type 42A, 30 were type 42B, and 5 were type 43A. Radiographic outcomes focused on bone union and malalignment, defined as a valgus deviation greater than 5° compared to the unaffected side. Potential risk factors for malalignment, including open fractures (9 cases, 15%), distal tibial extension (20 cases, 33%), and distal fibular fractures (24 cases, 40%), were documented.

Results: Bone union was achieved in all cases, with an average duration of 3.2 months (range, 3–5 months). No cases of postoperative wound infection or neurovascular damage were observed. The average coronal plane malalignment was 2.6° of valgus (range, 0°–9.3°), with significant malalignment (over 5°) occurring in 5 patients (8.3%). Comparison of the malalignment (n = 5) and normal (n = 55) groups showed a statistically significant difference in distal bone fragment length (average, 66.5 mm vs. 77.2 mm; $p = 0.008$) but no significant differences in other variables. A change-point analysis revealed that cases with a primary fracture line < 65 mm showed 4.5° of coronal malalignment, while those with > 65 mm showed 2.3°; the difference was statistically significant ($p = 0.01$).

Conclusions: Intramedullary nailing using the infrapatellar approach for distal one-fourth tibial fractures results in successful bone union with a low incidence of valgus malalignment. However, careful attention is necessary to prevent angular deformities, especially when the distal fragment is short.

Keywords: *Tibial fractures, Intramedullary fixation, Malalignmen, Risk factors*

Distal tibial fractures are prone to accompanying soft tissue damage because of their anatomical characteristics, including a thin periosteum, sparse surrounding soft tissue, and poor blood circulation.[1] Extramedullary plating following open reduction involves exposing the fracture site and detaching the soft tissue, raising concerns about wound complications and infections as well as the risks of delayed union and nonunion.[2] Intramedullary nailing in distal tibial fractures minimizes soft-tissue damage and allows for early weight-bearing, shortening the rehabilitation period. However, owing to the anatomical characteristic

Received April 2, 2024; Revised September 16, 2024;
Accepted October 24, 2024
Correspondence to: Hyoung-Keun Oh, MD
Department of Orthopedic Surgery, Inje University Ilsan Paik Hospital, 170 Juhwa-ro, Ilsanseo-gu, Goyang 10380, Korea
Tel: +82-31-910-7301, Fax: +82-31-910-7967
E-mail: ilsanosd11@gmail.com
Yong-Cheol Yoon and Hyung Suh Kim contributed equally to this work as co-first authors.

© 2025 by The Korean Orthopaedic Association
This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (http://creativecommons.org/licenses/by-nc/4.0) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

of the widening medullary cavity distally in the tibia, this method may have weaker fixation strength and difficulties with screw fixation due to the short distal fragments.[3,4] Nevertheless, biomechanical studies have demonstrated that intramedullary nailing can withstand higher loads than locking plates in fractures occurring 3 cm above the tibia plafond, proving its superior stability.[5]

There are 2 main approaches to intramedullary nailing: suprapatellar and infrapatellar.[6,7] Avilucea et al.[8] reported a study of 266 patients with distal tibia fractures in which the infrapatellar approach had a 26.1% risk of malalignment and suprapatellar approach had only a 3.8% risk, highlighting the latter's superiority for alignment correction. However, the suprapatellar approach may risk damaging the patellofemoral joint during insertion, requires additional protection since the nail is inserted through the knee joint, and demands more skilled surgical techniques than the infrapatellar approach. Moreover, a different incision may be necessary for nail removal as the instrument must pass through the knee joint.[9,10]

Complications arising from intramedullary nailing in distal tibial fractures include valgus malalignment due to technical and anatomic reasons and nonunion resulting from insufficient fixation strength.[11,12] However, to the authors' knowledge, the factors causing valgus malalignment are poorly understood, as is the fixation strength of intramedullary nailing in far distal tibia shaft fractures. Therefore, this study aimed to analyze the radiological outcomes of intramedullary nailing via the infrapatellar approach for fractures of the distal one-fourth of the tibia. We hypothesized that shorter distal tibial fragments would be more prone to malalignment and have weaker fixation strength, leading to a higher risk of nonunion.

METHODS

The study design and data collection were approved by the Institutional Review Board of the Human Experimental and Ethics Committee of Inje University, Ilsan Paik Hospital (IRB No. 2023-10-022). Written informed consent was obtained from all individual participants and/or their families.

Patients' Demographic Data

This retrospective study included patients who visited a level I trauma center between January 2009 and December 2021, were diagnosed with distal tibial shaft fractures, and underwent intramedullary nailing through an infrapatellar approach. The study comprised 60 patients (37 men and 23 women; mean age, 45.4 years; range, 18–87 years) who had been followed up for at least 1 year. The average follow-up duration was 28.5 months (range, 12–65 months). The causes of the injuries included traffic accidents (n = 35), falls (n = 22), and direct trauma (n = 3), with 9 instances of open fractures (Gustilo-Anderson classification: I, 5; II, 3; and IIIa, 1).[13] Among the open fractures, 3 cases were initially treated with temporary external fixation before transitioning to internal fixation. In 20 cases (33%), the fractures extended into the distal tibial articular surface. Distal fibular fractures were present in 24 patients (40%), of whom 22 were fixed using plate fixation or intramedullary nailing depending on the fracture comminution and pattern. A retrospective study was conducted involving 35 cases (58%) treated with closed reduction and 25 cases (42%) treated with percutaneous reduction. According to the Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association classification, 25 cases of type 42A, 30 cases of type 42B, and 5 cases of type 43A fractures were present.[14]

Distal tibial fractures were defined as fractures of the tibia in which the midpoint between the proximal and distal fracture lines to the tibial plafond was located at less than one-fourth of the total length of the tibia on an anterolateral view. The inclusion criteria were traumatic fresh fracture, simple articular fracture that could be converted to an extra-articular fracture using lag screw fixation, patient age > 18 years, and normal knee and ankle function prior to the injury.[15] The exclusion criteria were a history of distal tibia fracture, pathological fractures, active malignancies, or infections; fractures with a central length exceeding one-fourth of the total tibial length; a follow-up period < 1 year; other fractures of the same leg that could affect postoperative rehabilitation; preexisting degenerative diseases in the knee or ankle joints; and patients under 18 years old, to reduce bias affecting bone healing.

Surgical Technique

Patients were anesthetized with general or spinal anesthesia and placed in the supine position. A C-arm was used to take anteroposterior and lateral views of the knee and ankle joint of the unaffected lower leg. Next, a bolster was placed under the posterior side of the hip to position the patella of the affected side in the center. Another bolster was placed under the posterior side of the distal femur to allow 30° of flexion in the knee joint. In cases with distal fibular fractures, fixation of the distal fibula was performed initially. If the fracture extended to the tibial plafond, a lag screw was inserted perpendicular to the fracture line (Fig. 1). The patellar tendon was identified and longitudinally incised and spread apart, and part of the anterior fat pad

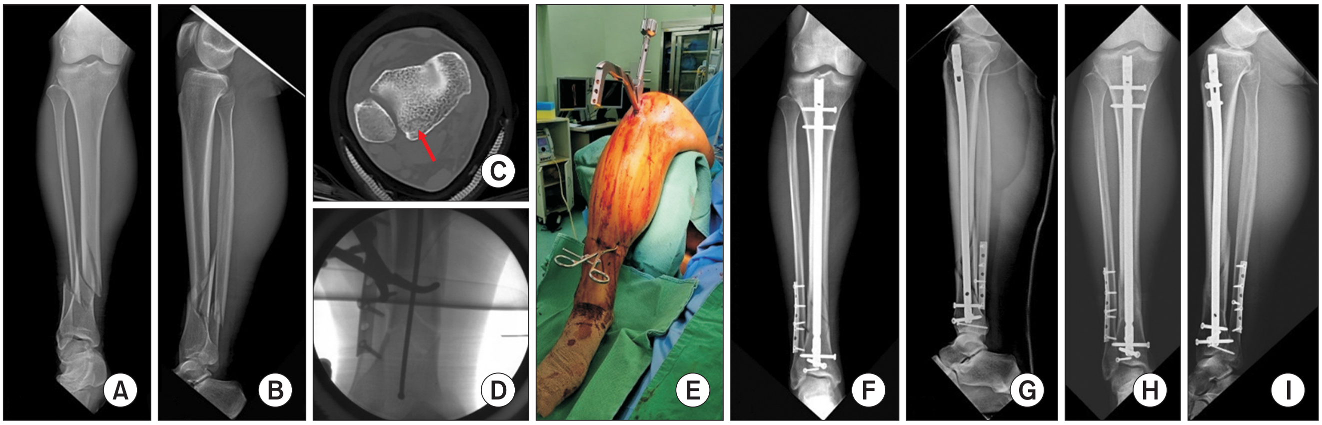

Fig. 1. (A, B) A 31-year-old man had a sports-related injury resulting in a distal tibiofibular fracture classified as AO 42-B2. (C) Computed tomography imaging revealed a posterolateral distal tibia intra-articular fracture (red arrow). (D, E) The fibular fracture was addressed with open reduction and internal fixation using a plate, and percutaneous reduction of the distal tibia oblique fracture was performed using pointed reduction forceps facilitated by an infrapatellar approach and guide pin insertion. (F, G) The intra-articular fracture was subjected to lag screw fixation, and postoperative radiography confirmed the restoration of normal alignment. (H, I) At 4 months postoperative, bone union was achieved without any significant radiological or clinical complications.

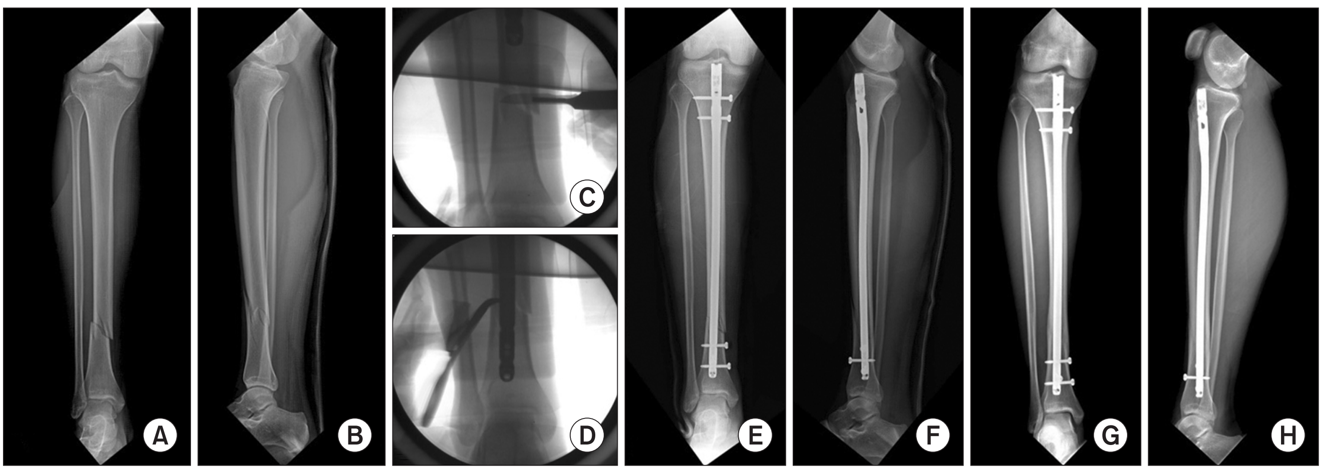

Fig. 2. (A, B) An 18-year-old man presented with a distal tibia fracture (AO 42-A2) following a sports injury. (C, D) The distal fragment, which was laterally translated, was percutaneously reduced using a Kelly clamp. (E, F) Postoperative radiography showed that the lateral distal tibia angle was comparable to that of the healthy side, indicating the restoration of normal alignment. (G, H) At 3 months postoperative, the patient achieved bone union without any significant radiological or clinical complications.

was removed. Using a C-arm fluoroscope, the medial aspect of the lateral tibial plateau was identified, and an entry point was created using an awl to insert the intramedullary nail. After the nail passed through the proximal tibia, the knee joint was maximally flexed to advance the nail. To maintain alignment during insertion, the distal fragment was atraumatically reduced. If the alignment or rotation was unsatisfactory, percutaneous reduction techniques using reduction forceps, Kelly clamps, joystick maneuver, or blocking screws were actively employed (Figs. 1 and 2). After the nail was inserted close to the tibial plafond, as many interlocking screws as possible were inserted to enhance fixation in the distal fragment. In osteoporotic patients, an Angular Stability Locking System (ASLS) was used to increase fixation strength. Postoperative alignment and rotation were confirmed by comparison with the initial images of the unaffected knee and ankle joint. All surgeries were performed by a single operator, an orthopedic trauma specialist with over 15 years of experience performing fracture surgeries (HSK). The intramedullary nails used in these procedures were the Expert tibial nail (Depuy-Synthes) or T2 nail (Stryker).

Patients began knee and ankle joint movements 2–3 days postoperatively. Depending on the stability of the internal fixation, partial weight-bearing walking was initiated using a walker or crutches. After discharge, the patient was followed up with regular monthly outpatient visits. Radiographic images were used to assess bone union, and weight-bearing was increased in accordance with callus formation.

Evaluation

Bone union was defined as the formation of a bony callus involving more than three-fourths of the cortical bone at the fracture site on both anteroposterior and lateral radiographic images during follow-up visits. Clinically, the absence of pain or abnormal gait during weight-bearing walking indicated bone union.[16] Nonunion was defined as the absence of complete bone union at the fracture site on plain radiographs taken more than 6 months postoperatively or a lack of progression in bone union during 3 months of follow-up accompanied by clinical symptoms such as pain at the fracture site or an abnormal gait.[17] On whole-leg standing radiography for leg alignment studies, the anatomical lateral distal tibial angle was measured in the coronal plane and compared to that of the unaffected side.[18] A difference of more than 5° was considered malalignment.[4]

Statistical Analysis

Patients were divided into 2 groups based on the presence or absence of malalignment to analyze potential contributing risk factors. Statistical analysis was conducted using IBM SPSS 25.0 software (IBM Corp.). All continuous variables were tested for normality using the Kolmogorov-Smirnov test. Normally distributed variables are expressed as means and standard deviations, while non-normally distributed variables are shown as medians and ranges. Categorical variables are expressed as frequencies and percentages. The collected data were analyzed using Student t-test, Pearson's chi-squared test, and Fisher's exact test for intergroup comparisons, with $p < 0.05$ considered statistically significant.

Additionally, a change-point analysis was conducted to examine the variation in valgus values based on distal fragment length.[19] This method involves comparing intergroup differences at various threshold values to identify the most statistically significant threshold. Specifically, various threshold values for the distal fragment length (range, 50–80 mm at 1-mm intervals) were set. At each threshold value, the data were divided into those below and those above the threshold value. An independent sample t-test was then conducted for the intergroup valgus values at each threshold value. This test assesses whether the mean intergroup difference is statistically significant. The p-values were compared at each threshold to identify the threshold with the lowest value.

RESULTS

In all cases treated with the infrapatellar approach to intramedullary nailing, bone union was achieved without nonunion or hardware loosening at a mean bone healing time of 3.2 months (range, 3–5 months). No postoperative complications such as wound infections, neurovascular damage, or arthritis in the ankle joint were observed. The average ratio of the distal fragment was 20.5%, less than the distal one-fourth of the tibia, while the average distal fragment length was 7.7 cm (range, 5.8–11.5 cm). The average valgus angle in the coronal plane was 2.6° (range, 0°–9.3°).

Malalignment greater than 5° occurred in 5 of 60 patients (8.3%), all of whom presented with valgus deformity (Table 1). The average angle of malalignment was 6.4° (range, 5.2°–9.3°), while the average distal fragment length in the malalignment group was 66.5 mm (range, 61.6–77.2 mm). Comparison of the malalignment and normal groups revealed no statistically significant differences in age, sex, fracture type, open fracture, intra-articular involvement, or the number of distal interlocking screws. However, mean distal fragment length and ratio differed significantly: 66.5 mm (18.7%) in the malalignment group versus 77.2 mm (20.6%) in the normal group ($p = 0.008$ and $p = 0.049$, respectively). A change-point analysis performed to analyze the variation in valgus values with distal fragment length found that at a fracture length of 65 mm, the intergroup difference in valgus values was most significant. Using 65 mm as a threshold, the valgus in the coronal plane was 4.5° for lengths < 65 mm and 2.3° for lengths > 65 mm, indicating that shorter distal fragment lengths were statistically significantly associated with greater valgus tilting ($p = 0.01$).

Among the 24 cases with distal fibular fractures, 10 (42%) were simple fractures and 14 (58%) were comminuted fractures. In 22 of these cases, fixation was performed using plate fixation or intramedullary nailing. Malalignment based on the presence or method of fixation of the fibular fracture did not differ between them; however, a higher incidence of malalignment in the distal tibia was noted in cases with comminuted fibular fractures, but this was not statistically significant ($p = 0.2$).

Table 1. Comparative Analysis of Distal Tibial Fracture Outcomes: Malalignment vs. Normal Alignment

Variable	Malalignment (n = 5)	Normal alignment (n = 55)	*p*-value
LDTA (affected side, °)	80.7 (79.4–82.2)	89.3 (84.2–94.3)	-
LDTA (unaffected side, °)	87.2 (84.6–89.9)	89.7 (84.2–94.4)	-
LDTA difference (°)	6.4 (5.2–9.3)	2.3 (0–4.9)	< 0.001
Age (yr)	56.2 (32–79)	44.5 (20–87)	0.218
Sex (male : female)	4 : 1	33 : 22	0.387
Open fracture	1 (20)	8 (14.5)	0.740
Articular extension (%)	1 (20)	8 (14.5)	0.740
Tibia fracture pattern (simple : wedge)	2 : 3	25 : 30	0.811
Percutaneous additional reduction	2 (40)	23 (41.8)	0.941
Number of distal locking screws	3 (2–4)	3 (2–4)	0.663
Length of the distal fragment (mm)	66.5 (61.6–77.4)	77.2 (58.3–115.1)	0.008
Whole tibia length (mm)	356.1 (342.4–366.1)	374.4 (316.0–430.1)	0.087
Fragment length proportion of whole tibia length (%)	18.7 (16.9–21.1)	20.6 (15.5–26.8)	0.049

Values are presented as median (range) or number (%). LDTA difference, age, and other demographic variables were considered non-normally distributed due to the small sample size of the malalignment group (n = 5).
LDTA: lateral distal tibia angle.
The *p*-values were calculated using the Mann-Whitney *U*-test.

DISCUSSION

This study found that malalignment occurred in 8.3% of cases treated with the infrapatellar approach, significantly lower than the 24.9% reported in a meta-analysis of distal tibial fractures.[3] This reduction in malalignment is attributed to preoperative imaging of the unaffected tibia with a C-arm, comparison of alignment using postoperative images, and active efforts to correct alignment during surgery. Additionally, bone union was achieved in all cases without complications such as soft-tissue necrosis, likely owing to the sufficient stability provided by the interlocking screws of the intramedullary nail and the meticulous surgical technique that preserved the soft tissues.

Despite these efforts, some cases of valgus deformity were still observed. Reducing shorter distal fragments posed a challenge due to the increased space within the medullary canal, which made it difficult to achieve and maintain precise alignment during surgery. The maximum valgus deviation observed in our study was 9.3°. This measurement was taken from postoperative x-rays, although the surgeon had judged the reduction to be neutral or acceptable during surgery. Based on our experience, valgus deformities of less than 10° do not significantly impact bone union or walking ability and typically present only mild symptoms for the patient. Consequently, we managed the 5 cases of malalignment conservatively, and all patients healed well without major complaints.[20,21]

The study identified distal fragment length as the sole factor contributing to malalignment. Shorter distal fragments are more prone to valgus deformity, particularly when the length is < 65 mm, necessitating extra caution. Valgus deformity can induce abnormal stress on the joints, potentially leading to long-term issues like arthritis.[22] Not only does the fracture itself cause pain, but the deformity can create pressure on the surrounding tissues, leading to discomfort and a reduced range of motion in the ankle as well as complicating and prolonging the patient's rehabilitation.[23] Therefore, attention and active correction of valgus deformity in distal tibia fractures are crucial. The study noted that as the distal fragment shortens, the space in the distal tibia widens, making a thin nail more prone to malalignment compared to a plate that can fix a relatively wider area. To prevent malalignment, percutaneous reduction techniques were actively used in this study. In 25 cases (42%), reduction forceps, the joystick maneuver, blocking screws, and K-wires were employed.

Distal tibial fractures, which often result from high-energy injuries, are challenging to treat with an extensive incision for plate fixation because of the thin soft-tissue coverage.[1)] While intramedullary nailing in such fractures preserves the soft tissues, concerns about malalignment arise, especially when nailing is performed in the wide metaphyseal area.[11,14)] Recent advancements in interlocking nail design and the development of ASLS have made it easier to achieve fixation near the tibial plafond.[24,25)] Studies have shown that the fixation strength of intramedullary nails is sufficient for bone union, even in distal tibial fractures involving the joint surface. In this study, 20 cases involved fractures that extended to the distal tibial articular surface, but joint surface fixation was achieved using lag screw fixation before conversion to an extra-articular type.[15)] To ensure adequate fixation in the distal fragment, 53 cases (88%) used 3 or more interlocking screws, while 7 cases used the ASLS. This approach is supported by the cadaveric study by Gorczyca et al.,[26)] which demonstrated that 2 distal interlocking screws are adequate to achieve fixation.

The suprapatellar approach results in less malalignment because it allows for stable nailing with the patient's leg in a semi-extended position.[7)] In contrast, the infrapatellar approach requires flexing the knee joint, making reduction control more challenging.[6)] However, the suprapatellar approach, involving insertion through the knee joint, risks damage to the quadriceps tendon and intra-articular structures and requires a new incision for implant removal.[27)] Trocar insertion can be difficult in patients with a narrow patellofemoral space, leading to a steep learning curve. Infrapatellar nailing, familiar to surgeons and less damaging to the knee joint, can yield good results with active efforts to correct alignment, as seen in this study.

Regarding factors influencing malalignment, the presence and degree of associated fibular fractures did not impact malalignment. This is because the 2 nonoperatively managed fibular fractures were simple fractures with minimal displacement, while most of the associated fibular fractures were anatomically reduced and stably fixed surgically. Similarly, open fractures and distal tibial articular extension were not significantly contributing to malalignment. Open fractures, present in 15% of cases, were likely mitigated by early soft-tissue management and stable fixation, while fractures extending into the articular surface did not lead to malalignment, potentially due to the successful use of lag screws and careful reduction techniques. Thus, none of these factors demonstrated a significant impact on malalignment in distal tibial fractures.

This study has several limitations. Firstly, it has a relatively small sample size and focuses exclusively on distal tibial fractures, without including a control group. Additionally, patient compliance was not considered, which may affect the generalizability of our findings. The retrospective design and relatively short follow-up period also limit our ability to assess long-term clinical outcomes, such as infection, joint motion limitations, or complications beyond 1 year postoperatively. While favorable radiological outcomes were observed, the lack of detailed clinical outcome evaluation is a significant limitation. The absence of clinical data hinders a comprehensive understanding of patient recovery and the potential long-term effects of valgus malalignment. Future prospective, multicenter studies are needed to explore the relationship between radiological findings and clinical outcomes, as well as to provide a more robust evaluation of this surgical method.

In distal tibial fractures involving the distal one-fourth of the tibia, performing intramedullary nailing using the infrapatellar approach with active correction of malalignment resulted in an 8.3% incidence of valgus malunion. Bone union was achieved in all cases without complications. However, as the fracture location becomes more distal, particularly when the length is ≤ 65 mm, the frequency of malalignment increases, indicating a need for careful attention to angular deformities.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ORCID

Yong-Cheol Yoon https://orcid.org/0000-0003-4137-0764
Hyung Suh Kim https://orcid.org/0000-0003-4979-0122
Hyoung-Keun Oh https://orcid.org/0000-0001-5388-7096

REFERENCES

1. Bedi A, Le TT, Karunakar MA. Surgical treatment of nonarticular distal tibia fractures. J Am Acad Orthop Surg. 2006;14(7):406-16.

2. Zelle BA, Bhandari M, Espiritu M, Koval KJ, Zlowodzki M; Evidence-Based Orthopaedic Trauma Working Group. Treatment of distal tibia fractures without articular involvement: a systematic review of 1125 fractures. J Orthop Trauma. 2006;20(1):76-9.

3. Kwok CS, Crossman PT, Loizou CL. Plate versus nail for distal tibial fractures: a systematic review and meta-analysis. J Orthop Trauma. 2014;28(9):542-8.

4. Janssen KW, Biert J, van Kampen A. Treatment of distal tibial fractures: plate versus nail: a retrospective outcome analysis of matched pairs of patients. Int Orthop. 2007;31(5):709-14.

5. Hoenig M, Gao F, Kinder J, Zhang LQ, Collinge C, Merk BR. Extra-articular distal tibia fractures: a mechanical evaluation of 4 different treatment methods. J Orthop Trauma. 2010;24(1):30-5.

6. Lu Y, Wang G, Hu B, et al. Comparison of suprapatellar versus infrapatellar approaches of intramedullary nailing for distal tibia fractures. J Orthop Surg Res. 2020;15(1):422.

7. Yang CY, Tay ST, Kuo LT. Suprapatellar vs infrapatellar approaches for intramedullary nailing of distal tibial fractures: a systematic review and meta-analysis. J Orthop Traumatol. 2023;24(1):14.

8. Avilucea FR, Triantafillou K, Whiting PS, Perez EA, Mir HR. Suprapatellar intramedullary nail technique lowers rate of malalignment of distal tibia fractures. J Orthop Trauma. 2016;30(10):557-60.

9. Wang C, Chen E, Ye C, Pan Z. Suprapatellar versus infrapatellar approach for tibia intramedullary nailing: a meta-analysis. Int J Surg. 2018;51:133-9.

10. Bleeker NJ, Reininga IH, van de Wall BJ, et al. Difference in pain, complication rates, and clinical outcomes after suprapatellar versus infrapatellar nailing for tibia fractures?: a systematic review of 1447 patients. J Orthop Trauma. 2021;35(8):391-400.

11. Brinkmann E, DiSilvio F, Tripp M, Bernstein M, Summers H, Lack WD. Distal nail target and alignment of distal tibia fractures. J Orthop Trauma. 2019;33(3):137-42.

12. Richmond J, Colleran K, Borens O, Kloen P, Helfet DL. Nonunions of the distal tibia treated by reamed intramedullary nailing. J Orthop Trauma. 2004;18(9):603-10.

13. Kim PH, Leopold SS. In brief: Gustilo-Anderson classification. Clin Orthop Relat Res. 2012;470(11):3270-4.

14. Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF. Fracture and dislocation classification compendium-2018. J Orthop Trauma. 2018;32 Suppl 1:S1-170.

15. Nork SE, Schwartz AK, Agel J, Holt SK, Schrick JL, Winquist RA. Intramedullary nailing of distal metaphyseal tibial fractures. J Bone Joint Surg Am. 2005;87(6):1213-21.

16. Garabano G, Jaime A, Alamino LP, Taleb JP, Rodriguez J, Pesciallo CA. Does the distal nail position impact the rates of misalignment and bone union in distal tibial fractures? Eur J Orthop Surg Traumatol. 2023;33(8):3365-71.

17. Megas P. Classification of non-union. Injury. 2005;36 Suppl 4:S30-7.

18. Appusamy VS, Ramachandran K, Kumbakrishnakumar AM. Radiological parameters determining outcome in pilon fractures treated by minimally invasive plate osteosynthesis. Int J Res Orthop. 2019;5:490-7.

19. Taylor WA. Change-point analysis: a powerful new tool for detecting changes [Internet]. Taylor Enterprises; 2000 [cited 2024 Dec 1]. Available from: https://variation.com/wp-content/uploads/change-point-analyzer/change-point-analysis-a-powerful-new-tool-for-detecting-changes.pdf

20. Milner SA, Davis TR, Muir KR, Greenwood DC, Doherty M. Long-term outcome after tibial shaft fracture: is malunion important? J Bone Joint Surg Am. 2002;84(6):971-80.

21. Obremskey WT, Cutrera N, Kidd CM; Southeastern Fracture Consortium. A prospective multi-center study of intramedullary nailing vs casting of stable tibial shaft fractures. J Orthop Traumatol. 2017;18(1):69-76.

22. Joveniaux P, Ohl X, Harisboure A, et al. Distal tibia fractures: management and complications of 101 cases. Int Orthop. 2010;34(4):583-8.

23. Newman SD, Mauffrey CP, Krikler S. Distal metadiaphyseal tibial fractures. Injury. 2011;42(10):975-84.

24. Hontzsch D, Schaser KD, Hofmann GO, et al. Evaluation of the effectiveness of the angular stable locking system in patients with distal tibial fractures treated with intramedullary nailing: a multicenter randomized controlled trial. J Bone Joint Surg Am. 2014;96(22):1889-97.

25. Agres AN, Alves SA, Hontzsch D, et al. Improved weight bearing during gait at 6 weeks post-surgery with an angle stable locking system after distal tibial fracture. Gait Posture. 2024;107:169-76.

26. Gorczyca JT, McKale J, Pugh K, Pienkowski D. Modified tibial nails for treating distal tibia fractures. J Orthop Trauma. 2002;16(1):18-22.

27. Franke J, Hohendorff B, Alt V, Thormann U, Schnettler R. Suprapatellar nailing of tibial fractures: indications and technique. Injury. 2016;47(2):495-501.