

Review Article

Minimally Invasive Plate Osteosynthesis in Distal Tibial Fractures: Union Rates and Complications

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Abstract

Background: Distal tibial metaphyseal fractures are difficult to fix because the overlying soft-tissue envelope is thin and poorly vascularised, predisposing open plating to wound breakdown, infection and delayed union. Minimally invasive plate osteosynthesis (MIPO) was developed to restore alignment while preserving periosteal blood supply.

Objective: To synthesise published evidence on MIPO for distal tibial fractures, comparing union, malalignment, and complications against open reduction internal fixation (ORIF) and intramedullary nailing (IMN).

Methods: Narrative review of rationale studies, comparative cohorts, randomised trials, meta-analyses and a Cochrane review.

Findings: MIPO achieves union in roughly 84-96% of reported series, generally by 18-20 weeks, comparable to IMN and ORIF. IMN shortens operative time and lowers wound infection, but carries higher malunion and anterior knee pain rates.

Conclusions: MIPO is a safe, biologically favourable option for selected fractures, with technique choice guided by fracture pattern, soft-tissue status and surgeon experience.

Keywords: Minimally invasive plate osteosynthesis; Distal tibia fracture; Intramedullary nailing; Fracture union; Malunion

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Keywords: minimally invasive plate osteosynthesis; distal tibia fracture; intramedullary nailing; fracture union; malunion

Introduction

Fractures of the distal tibial metaphysis, whether extra-articular or with a simple articular extension, sit at the junction of a thin subcutaneous soft-tissue envelope and a segment with comparatively poor intraosseous blood supply. Traditional open reduction and internal fixation (ORIF) through an extensile approach, while affording direct visualisation and anatomical reduction, has historically been associated with wound dehiscence, deep infection and delayed union in this location, particularly after high-energy or open injury. Minimally invasive plate osteosynthesis (MIPO) was introduced as a

biologically respectful alternative: the fracture is reduced indirectly, and a plate is passed submuscularly or subcutaneously through small proximal and distal incisions, avoiding direct exposure of the fracture haematoma and preserving the surrounding periosteal and soft-tissue vasculature [1].

The biological rationale for MIPO rests on classic work demonstrating that percutaneous plating disrupts the extraosseous blood supply substantially less than traditional open plating in long-bone diaphyseal fractures, supporting more rapid callus formation and fewer bone-grafting requirements [2]. Early clinical series applying percutaneous plating techniques to periarticular tibial fractures with compromised soft tissue reported reliable healing with a low reoperation rate, reinforcing the technique's suitability for the distal tibia specifically [3]. Over the subsequent two decades, MIPO has been progressively refined and compared against both ORIF and intramedullary nailing (IMN), the other principal option for extra-articular and simple distal tibial fracture patterns. This review synthesises the union rates, malalignment and complication data reported for MIPO, and situates these findings relative to ORIF and IMN using comparative cohort studies, randomised trials, systematic reviews, and a Cochrane systematic review of the topic [4].

Technique and Biological Rationale

MIPO for the distal tibia typically uses a precontoured anatomical locking plate inserted through a short incision just proximal to the medial or anterolateral malleolus, tunnelled submuscularly to a second incision near the fracture apex or proximal shaft, with fixation achieved under fluoroscopic control without formally opening the fracture site [1,5]. Locking-plate constructs allow angle-stable fixation even in osteoporotic or comminuted metaphyseal bone, and a "bridging" mode is frequently used across comminuted zones to preserve the fracture haematoma, at the cost of relying more heavily on

secondary bone healing through callus formation [6]. Comparative descriptions of medial versus lateral and anterolateral plate positions, and of posterolateral approaches for specific fracture morphologies, have refined but not fundamentally altered this biological principle [7,8]. Ronga et al. confirmed that locked MIPO constructs remain safe and effective even when the fracture pattern extends close to the plafond, broadening the technique's applicable range [9]. Maffulli and colleagues, in an early series of 20 patients, reported union in all but one case with only minor residual deformity, establishing percutaneous plating as reproducible outside its originating centres [8]. Bahari et al. similarly demonstrated successful transfer to a general trauma unit, reinforcing that MIPO's biological advantages are not confined to specialist practice [10].

Union Rates and Time to Union

Individual MIPO series consistently report high union rates without the need for early secondary intervention. Krackhardt et al. followed 71 patients treated with closed reduction and minimally invasive plating for at least two years and found that 68 (95.8%) achieved healing, with roughly four-fifths showing acceptable axial alignment [11]. Hasenboehler et al. reported union in 27 of 32 patients (84.4%) by nine months using a locking compression plate with MIPO for diaphyseal and distal tibial fractures, noting that prolonged healing occurred specifically in simple fracture patterns fixed in bridging mode [12]. Gupta et al., in a series of 79 patients, documented nonunion in only three cases (96.2% eventual union), all occurring where plates had been applied in bridge mode across comminuted zones [6]. Consistent with these figures, a single-centre prospective comparative study found a radiographic union rate of 96.15% with MIPO versus 85.18% with IMN at six months, despite closely comparable functional ankle scores between groups [13] (Table 1, Figure 1).

Table 1: Key comparative studies of MIPO, ORIF and intramedullary nailing (IMN) for distal tibial fractures reviewed here [15,20,22,14,24,23].

Study	Design	N	Comparison	Key outcome
Guo 2010	Prospective RCT	85	IMN vs percutaneous plating	Union in both by 1 year; IMN faster (81.2 vs 97.9 min)
Cheng 2011	Matched cohort	30 (15 pairs)	MIPO vs ORIF	No malunion either group; 1 osteomyelitis in ORIF
Mauffrey 2012	Randomised pilot	24	Locking plate vs IMN	7/12 plate vs 1/12 nail required reoperation
Li 2014	Randomised, prospective	Not stated	IMN vs MIPO vs ORIF	Comparable union; differences concentrated in complications
Polat 2015	Prospective RCT	Not stated	IMN vs MIPO	Comparable function; IMN less radiation/operative time
Costa 2017 (FixDT)	Multicentre RCT	Not stated	Locking plate vs IMN	No significant difference in 6-month disability score

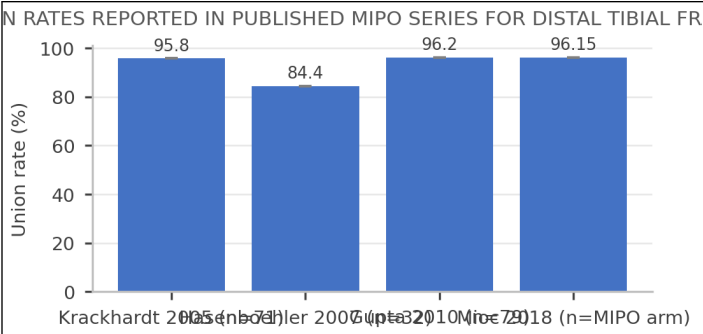


Figure 1: Union rates reported in individual MIPO series for distal tibial fractures: 95.8% at 2 years (n=71) [11], 84.4% at 9 months (n=32) [12], 96.2% (n=79) [6], and 96.15% at 6 months in the MIPO arm of a comparative study [13].

Randomised comparisons reinforce that time to union with MIPO is broadly comparable to IMN, though not necessarily faster. A three-arm randomised trial comparing IMN, MIPO and ORIF for distal tibial shaft fractures found each technique capable of reliable union, with technique-specific differences concentrated in complication rather than union rates [14]. In a prospective randomised trial of 85 patients, both closed

intramedullary nailing and percutaneous locked plating achieved fracture union within one year, though nailing required significantly less operative time (81.2 versus 97.9 minutes) and fluoroscopy exposure [15]. A pooled meta-analysis of five randomised trials totalling 497 patients found that bony healing with MIPO took approximately one week longer on average than with IMN, while rates of malunion, delayed union, nonunion, deep infection and twelve-month functional outcome were statistically comparable between the two techniques [16]. A larger 2024 meta-analysis of 20 randomised trials and 1,528 patients similarly found IMN achieved weight-bearing roughly two to three weeks sooner than plating, without a corresponding difference favouring either technique on union itself [17]. A separate systematic review and meta-analysis reached a concordant conclusion on union, while highlighting substantial heterogeneity that tempers confidence in any single point estimate [18].

Malalignment and Malunion

Malalignment is the complication most consistently disadvantaging non-locked or poorly executed MIPO constructs. A systematic review of 27 studies and 764 cases found that locked plating reduced the odds of both reoperation (odds ratio 0.13) and malalignment (odds ratio 0.10) compared with non-locked plating, while delayed union occurred at a similarly low rate (4-6%) regardless of implant type [19]. This underlines that the "minimally invasive" label alone does not guarantee good alignment; adequate reduction technique and locking-plate hardware are both necessary. Comparative data against IMN are more equivocal: the 2024 meta-analysis found significantly higher rates of malunion and anterior knee pain with IMN, attributing the knee pain to the nail entry portal, while MIPO carried the greater burden of soft-tissue complications discussed below [17]. Earlier matched-pair comparisons similarly

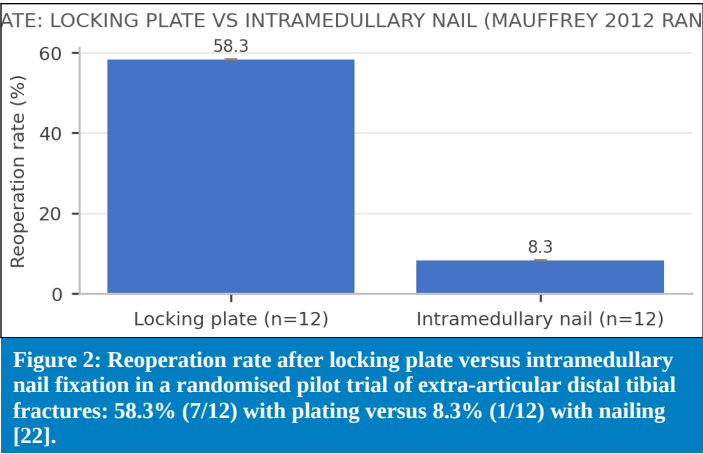
reported no malunion in either MIPO or ORIF groups when reduction was carefully controlled, with only a single deep infection in the open group [20].

Infection and Wound Complications

Soft-tissue-sparing fixation was intended to reduce infection, and most series bear this out relative to historical open plating, though wound problems have not been eliminated. Lau et al. reported an average time to full weight-bearing of 9.4 weeks and to union of 18.7 weeks after MIPO in 48 patients, but documented a 15% late infection rate (7 of 48) and implant removal in 52% of patients, principally for skin irritation from a prominent subcutaneous plate [21]. Randomised comparisons directly implicate implant choice in this risk profile: in a pilot trial randomising 24 patients to locking plate or IMN, seven of twelve plate patients required further surgery compared with only one of twelve nail patients, a striking eight-fold difference driven substantially by wound-related and hardware complications (Figure 2) [22]. The larger meta-analytic literature corroborates this direction of effect: pooled data from five randomised trials found wound complications occurred more frequently with MIPO than IMN, even as deep infection rates did not differ significantly [16], and the 2024 meta-analysis similarly found a markedly reduced risk of wound infection with IMN [17] (Table 2). Nonetheless, deep infection with MIPO remains uncommon in most series, and the Cochrane review concluded existing randomised evidence, while very-low certainty, showed no clinically important difference in function or pain between IMN and plating overall [4].

Table 2: Key complication and malalignment findings relevant to fixation choice [19,21,16,17].		
Source	Focus	Key finding
Khalsa 2014	Locked vs non-locked plating (27 studies, 764 cases)	Locked plating reduces reoperation (OR 0.13) and malalignment (OR 0.10)

Source	Focus	Key finding
Lau 2008	MIPO wound complications (n=48)	15% late infection; implant removal in 52%, mainly for skin irritation
Goh 2018	Meta-analysis, 5 RCTs, 497 patients	MIPO wound complications more frequent; healing ~1 week longer; malunion/infection comparable
Li 2024	Meta-analysis, 20 RCTs, 1528 patients	IMN markedly reduces wound infection risk; higher malunion and anterior knee pain with IMN



Functional Outcomes

Functional recovery after MIPO appears broadly equivalent to alternative fixation methods once union is achieved. The three-arm randomised comparison of IMN, MIPO and ORIF found no clinically meaningful differences in ankle function scores across techniques [14], and the single-centre comparative study similarly found Olerud-Molander ankle scores of 74.23 with MIPO versus 75.55 with IMN at six months, a difference the authors judged clinically negligible [13]. The FixDT trial, the largest randomised comparison of locking-plate fixation against IMN for displaced distal tibial fractures, found no significant difference in patient-reported disability at six months, reinforcing that surgeon familiarity and fracture-specific factors, rather than uniform implant superiority, should guide selection [23]. A randomised comparison targeting extra-articular tibial fractures likewise found comparable functional outcomes

between IMN and MIPO, despite differences in radiation exposure and operative time favouring nailing [24]. Earlier work by Vallier and colleagues similarly found functional recovery did not differ substantially by implant choice, with complication profile rather than function distinguishing the two approaches [25].

Discussion

Across three decades of published experience, MIPO for distal tibial fractures has matured from a biologically motivated concept, grounded in blood-supply-preservation data from long-bone fracture models [2], into a well-characterised clinical technique with union rates in the 84-96% range and functional outcomes statistically indistinguishable from ORIF or IMN in most comparative studies [14,13,24]. Its principal advantage over ORIF is soft-tissue preservation and consequently fewer major wound complications in high-risk metaphyseal fractures [3,26]; its principal disadvantage relative to IMN is a persistently higher burden of minor wound problems, implant prominence, and reoperation for hardware-related issues [22,16], counterbalanced by IMN's higher rates of malunion and anterior knee pain [17]. Locked-plate constructs and careful indirect reduction technique substantially mitigate the malalignment risk historically associated with percutaneous plating [19]. Overall, the Cochrane-level evidence remains of low-to-very-low certainty due to modest trial sizes [4], leaving fracture pattern, soft-tissue condition, and surgeon experience as the principal determinants of technique selection rather than a single evidence-based hierarchy.

Conclusion

MIPO is a safe and effective fixation strategy for distal tibial fractures, achieving union rates comparable to ORIF and IMN while reducing the soft-tissue disruption responsible for historically high wound-complication rates after open plating. IMN offers shorter operative time,

less radiation exposure, and lower infection rates but at the cost of higher malunion and anterior knee pain, while MIPO's principal residual risks are wound-related complications and implant prominence, both attenuated by locked-plate technique and meticulous indirect reduction. Given the low-to-very-low certainty of existing randomised evidence, further adequately powered trials directly comparing contemporary MIPO constructs with IMN, stratified by fracture morphology and soft-tissue grade, are needed to refine technique selection.

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