MEDICAL SCIENCE MONITOR 25 years

META-ANALYSIS

e-ISSN 1643-3750
© Med Sci Monit, 2019; 25: 7480-7487
DOI: 10.12659/MSM.917311

Received: 2019.05.01
Accepted: 2019.06.17
Published: 2019.10.06

Comparison of 3 Treatment Methods for Distal Tibial Fractures: A Network Meta-Analysis

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

ABCDEF **Zhong-Qin Lin**
ABCE **Hong-Zhen Zhang**
BCDF **Guo-Gang Luo**
BCDF **Jian-Chuan Yao**
BCDF **Hai-Feng Xie**
DE **Xiang Zhang**
ADF **Yi-Zhou Zhu**

Department of Orthopedic Surgery, Wenzhou Hospital of Integrated Traditional Chinese and Western Medicine, Wenzhou, Zhejiang, P.R. China

Corresponding Author: Zhong-Qin Lin, e-mail: wzzxylzq@163.com
Source of support: Self financing

Background: The choice of optimal internal fixation device for distal tibial fractures remains controversial. The purpose of our study was to evaluate the effectiveness and safety of open reduction and internal fixation, minimally invasive percutaneous osteosynthesis, and intramedullary nailing of distal tibial fractures in adults using network meta-analysis of data from clinical trials.

Material/Methods: The studies were abstracted from MEDLINE, EMBASE, CNKI, and the Cochrane Central Register of Controlled Trials. Randomized controlled trials meeting inclusion and exclusion criteria were selected. Statistical analyses were conducted using Stata software, version 13.0 (Stata Corporation, College Station, Texas, USA).

Results: Eleven randomized controlled trials were included. The total number of participants was 710 and the studies were published between 2005 and 2017. There were no significant differences in rates of delayed union, non-union, or malunion among the various treatments (all $p>0.05$). The intramedullary nailing group had a lower incidence of wound complications than did the open reduction and internal fixation group and minimally invasive percutaneous osteosynthesis technique group. The SUCRA probabilities were 28.6% for ORIF, 98.4% for IMN, and 22.9% for MIPPO.

Conclusions: Given the superior results for intramedullary nailing in terms of wound complications, we recommend this procedure for treatment of distal tibial fractures. More RCTs focused on distal tibial fractures are needed to support the current evidence.

MeSH Keywords: **Fracture Fixation • Meta-Analysis • Tibial Fractures**

Full-text PDF: https://www.medscimonit.com/abstract/index/idArt/917311

2131 1 7 44

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

Background

Distal tibial fractures are often caused by high-energy injuries, and may also occur in the context of sprains, falls, or other low-energy traumas [1,2]. Operative treatments that permit early postoperative weight-bearing and rehabilitation have become preferred [2–4]. Surgical treatment also has many complications. Malunion, delayed union, nonunion, and wound infection are the most prevalent complications [5]. There are many methods for treatment of distal tibial fractures, including intramedullary nailing, plate, and external fixation. However, the choice of an appropriate internal fixation in treatment of distal tibial fractures remains controversial [6]. Open reduction and internal fixation (ORIF) provides anatomic reduction and allows early rehabilitation; however, it has shortcomings, including nonunion and wound infection due to extensive soft tissue injury [6,7]. Intramedullary nailing (IMN) is also a common method that avoids soft tissue stripping, allows preservation of the vascular supply, and permits dynamic fracture fixation [8]. Nevertheless, the high rates of malunion and knee pain caused by IMN cannot be ignored [9–11]. With the development of internal fixation techniques, the minimally invasive percutaneous osteosynthesis (MIPPO) technique has recently been proposed [1,12,13]. It had the advantages of simple manipulation, limiting soft tissue stripping and causing less bleeding [8,12,14]. Recently, studies have been carried out comparing various interventions for the treatment of distal tibial fractures using traditional meta-analysis [15-19], but these studies were inconclusive. Compared to traditional meta-analysis, network meta-analysis can be used to compare multiple interventions, even without direct comparisons [20]. Therefore, we conducted a network meta-analysis to assess and rank IMN, ORIF, and MIPPO for treatment of distal tibial fractures. The purpose of our study was to evaluate the effectiveness and safety of open reduction and internal fixation, minimally invasive percutaneous osteosynthesis, and intramedullary nailing of distal tibial fractures in adults using network meta-analysis of data from clinical trials.

Material and Methods

This meta-analysis was performed based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statements [21] and AMSTAR (Assessing the Methodological Quality of Systematic Reviews) guidelines [22].

Study selection

Inclusion criteria were: i) patients were over age 18 years with extra-articular distal tibial fractures located 4–11 cm from the tibial plafond; ii) interventions and comparison included IMM, MIPPO, and ORIF; iii) outcomes included malunion, delayed union, or nonunion and wound complications; iv) the type of research was randomized controlled trial (RCT); and v) minimum follow-up of 12 months. Exclusion criteria were: i) duplicate publications; ii) animal study, study on cadavers, or biomechanical study; iii) pathologic fractures; and iv) non-randomized controlled clinical trials, abstracts, letters, or case reports and reviews.

Literature search

We searched MEDLINE, EMBASE, CNKI, and the Cochrane Central Register of Controlled Trials (up to September 30, 2018). The specific retrieval strategy is displayed in Supplementary List [Supplemantary/raw data available from the corresponding author on request]. To assure our study was based on up-to-date results, we further updated the literature search on April 30, 2019.

Data extraction

Two authors extracted data from the studies that met the inclusion criteria. The collected data included patient age, publication year, sample size, first author, country, follow-up time, operative method, fracture types, wound types, and complications. The pre-defined outcome measures of interest were primary postoperative complications (i.e., malunion, delayed union or nonunion and wound complications). Two researchers evaluated the methodological quality of the included studies using the Cochrane Collaboration's tool. Disagreement between 2 authors was resolved by the third author.

Statistical analysis

Statistical analysis was performed using Stata statistical software (Version 13.0, Stata Corporation, College Station, Texas, USA). For dichotomous variables, relative risk (RR) with 95% confidence intervals (95% CI) was calculated. We used the Z-test to assess the overall effect size [23]. Heterogeneity was evaluated using chi-square test and the I^2 statistic. A fixed-effects model was used ($I^2<50\%$); otherwise, a random-effects model was used [24,25]. $P<0.05$ was considered statistically significant. A network meta-analysis was designed to simultaneously pool direct and indirect outcomes [26]. We used the inconsistency test to detect whether there was inconsistency between direct and indirect evidence. The specific statistical method was as described by Chaimani et al. [26]. Funnel plots were used to detect the existence of small-study effects [27]. We calculated surface under the cumulative ranking curve (SUCRA) probabilities to rank the 3 treatment methods for treating distal tibial fractures. Higher SUCRA values mean better results for the treatment method [28].

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

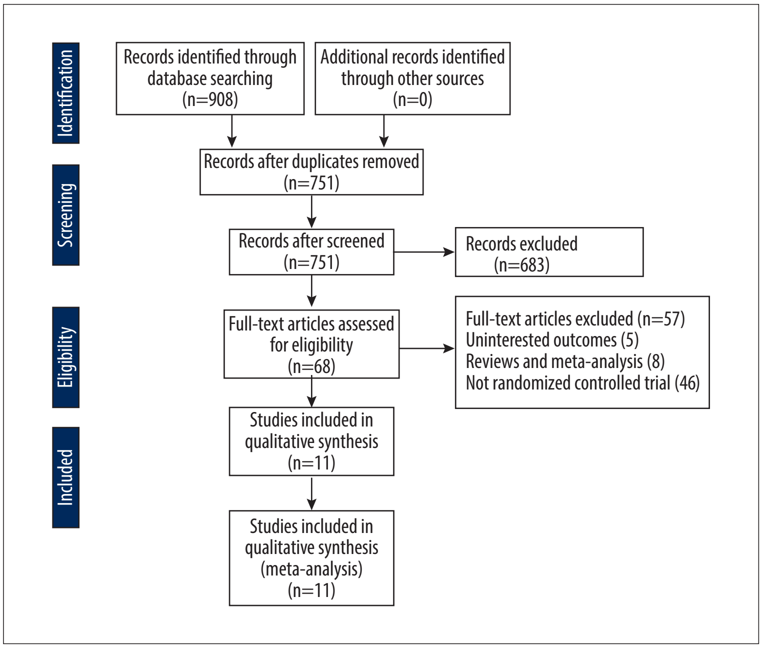

Figure 1. Flow diagram of article selection for inclusion.

Results

Baseline characteristics and risk of bias of included studies

A total of 908 potential studies were identified by the search method; 157 duplicate studies were eliminated, 683 studies were eliminated by reading titles and abstracts, and 68 studies were screened for relevance according to full text. Finally, 11 studies with 710 participants were included [7,12,29–37]. Three types of internal fixations, including IMN, MIPPO, and ORIF, were used in these 11 trials. The process of selecting appropriate studies is shown in Figure 1. The baseline characteristics are shown in Table 1. The risk of bias summary of the selected articles is shown in Figure 2. All studies were published between 2005 and 2017.

Evidence network

The evidence network is demonstrated in Figure 3. Connecting lines show direct comparison between 2 connected interventions, and 2 interventions without a connection can be compared indirectly through network meta-analysis. The width of lines represents the number of included studies. The size of nodes corresponds to the overall sample size of each intervention. This study included 3 internal fixations (ORIF, IMN, and MIPPO).

Small-study effect and inconsistency test

This network meta-analysis was composed of 1 triangular loop (the IMN-ORIF-MIPO loop). There was an inconsistency factor (IF) of 1.26 (95% CI: 0 to 3.68). The 95% CI of IF reached zero, indicating that no statistical inconsistency existed (Figure 4). The funnel plot was roughly symmetrical, demonstrating that no small-study effect existed in our network meta-analysis (Figure 5).

Comparison of complication rates

Nonunion was reported in 6 included trials [7,12,29,32,33,35]. No significant differences were found in the incidences of nonunion of IMN, ORIF, and MIPO for treating distal tibial fracture (ORIF: RR=0.89; 95% CI, 0.32–2.46; P=0.820; MIPPO: RR=0.93; 95% CI, 0.28–3.07; P=0.902; Figure 6A). The SUCRA probabilities were 55.1% for ORIF, 43.2% for IMN, and 51.7% for MIPPO (Figure 7A). Delayed union was reported in 7 trials [12,29,31–33,35,37]. No significant differences were found in the incidences of delayed union of IMN, ORIF, and MIPPO (ORIF: RR=1.34; 95% CI, 0.4–3.87; P=0.594; MIPPO: RR=0.72; 95% CI, 0.35–1.72; P=0.377; Figure 6B). The SUCRA probabilities were 20% for ORIF, 44.6% for IMN, and 85.4% for MIPPO (Figure 7B). Infection was reported in all 11 included RCTs [7,12,29–37]. There was a significant difference between IMN and MIPPO in terms of infection rate. No significant differences were found in the incidences of infection of ORIF and MIPPO (ORIF: RR=2.56; 95% CI, 0.96–6.18; P=0.06; MIPPO: RR=2.73; 95% CI, 1.34–5.56; P=0.006; Figure 6C). The SUCRA probabilities were 28.6% for ORIF, 98.4% for IMN, and 22.9% for MIPPO (Figure 7C). Malunion was reported in 9 trials [7,12,29,32–37]. No significant differences were found in the incidences of malunion of IMN, ORIF, and MIPPO (ORIF: RR=0.58; 95% CI, 0.29–1.13; P=0.11; MIPPO: RR=0.7; 95% CI, 0.39–1.25; P=0.23; Figure 6D). The SUCRA probabilities were 80.8% for ORIF, 8.7% for IMN, and 60.56% for MIPPO (Figure 7D).

Table 1. Characteristics of the included studies.

Study	Design	Country	Internal fixation	Age (year) I	Age (year) C	Number of patients I	Number of patients C	Follow-up time (month)	AO classification	Wound type
Daolagupu 2017	RCT	UK	IMN *vs.* MIPPO	35.19	39.09	21	21	12	43A1, A2, A3	Closed
Fang 2016	RCT	China	IMN *vs.* MIPPO	35	38.6	28	28	29.4	42A, B, C	Closed, type I, II
Guo 2010	RCT	China	IMN *vs.* MIPPO	44.2	44.4	44	41	12	43-A	Closed, Gustilo I
Li 2014	RCT	China	IMN *vs.* MIPPO	44	43	46	46	14.6	42-A	Closed or Gustilo I, II
Polat 2015	RCT	Turkey	IMN *vs.* MIPPO	34	36.4	10	15	23.8	42A1, A2, A3	Closed
Wani 2017	RCT	India	IMN *vs.* MIPPO	36.4	38.4	30	30	12	42-A	Closed
Im 2005	RCT	Korea	IMN *vs.* ORIF	42	40	34	30	24	43-A, C	Closed or Gustilo I
Valier 2011	RCT	US	IMN *vs.* ORIF	38.1	38.5	56	48	19.9	42A, B, C	Closed or Gustilo I, II, III
Mauffrey 2012	RCT	UK	IMN *vs.* ORIF	50	33	12	12	12	43-A	Closed, Gustilo I
Zou 2013	RCT	China	MIPPO *vs.* ORIF	46.5	46	52	42	15	42A, B, C	Closed
Kim 2017	RCT	Korea	MIPPO *vs.* ORIF	51.2	51.9	32	32	12	42A1, A2, or 43 A1	Closed or Gustilo I, II,

RCT – randomized clinical trial; MIPPO – minimally invasive plate osteosynthesis; IMN – intramedullary nail; ORIF – open reduction and internal fixation; AO – Arbeitsgemeinschaft für Osteosynthesefragen (association for questions of osteosynthesis), I – intervention; C – comparison.

Discussion

The optimal treatment for distal tibial fracture remains controversial. The ORIF, IMN, and MIPO techniques are the 3 main treatment methods used. Recently, some studies have compared various interventions using traditional meta-analysis [15–19]. To the best of our knowledge, all studies focused on the comparison between 2 treatments [15–19], and most studies included retrospective trials [16–19]. By contrast, our study only included RCTs, and we carried out a network meta-analysis, comparing multiple treatments even if there was no direct comparison.

This is the first network meta-analysis to compare 3 interventions for distal tibial fracture. We aimed to rank MIPPO, ORIF, and IMN in terms of their associated complication rates. Although we found no significant difference among the 3 internal fixations in terms of malunion according to the RR values, the SUCRA value of IMN was substantially lower than that of MIPPO and ORIF. Some studies reported that, compared with plate fixation, IMN had a higher incidence of malunion [7,9,35]. This may be partially explained by technical and implant problems such as quality of surgical reduction, distal fracture fragments, and inadequate distal locking. Anatomical reconstruction and stable fixation are effective measures to decrease the rate of malunion of distal tibial fractures. Plates obtain better alignment and compression than does IMN [7]. In terms of biomechanics, plates have better bending and torsional resistant capabilities than does intramedullary fixation. Because the medullary cavity of the tibial metaphysis is spacious, even if reamed intramedullary nails and the medullary cavity do not match exactly, the lack of adequate distal locking screws often leads to loss of reduction [38]. With improvements of IMN design and development of adjunctive techniques such as angle-stable and multi-directional distal screws and block screws, reduction and fixation effects have become more effective. Lateral displacement and angulation deformities can be corrected with blocking screws [39–41].

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

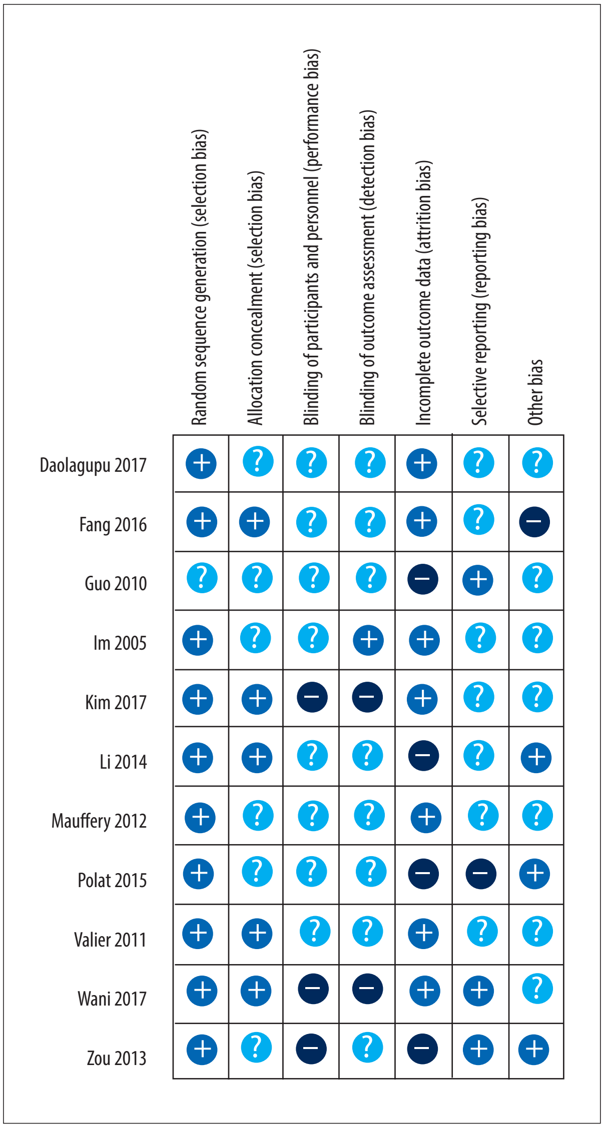

Figure 2. Forest plot showing risk of bias summary.

Intramedullary nailing has the advantages of being minimally invasive, causing less bleeding, and preserving the integrity of the vascular supply. Yu et al. reported that the major reason for delayed union or nonunion was insufficient blood supply due to soft tissue injury influencing fracture healing [18]. Anatomically, the distal tibia has less blood supply. Therefore, healing of lower 1/3 fractures is slow and prone to delayed union or nonunion. Mohamed et al. reported shorter operation times and faster fracture healing times in reamed IMN compared with MIPPO [42]. Intramedullary nailing has elastic fixation that promotes fracture healing, whereas plate fixation has absolute stability. However, Vallier et al. reported that there was no significant difference between IMN and locking plates in terms of nonunion rate, and IMN had a high rate of malalignment [35]. Other studies found similar effects between IMN and plates [29,37]. Our results are consistent with these.

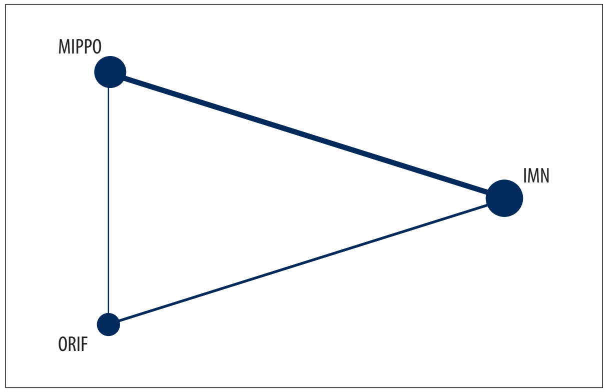

Figure 3. The evidence network for trials enrolled in this network meta-analysis. ORIF – open reduction and internal fixation; MIPPO – minimally invasive percutaneous osteosynthesis technique; IMN – intramedullary nailing.

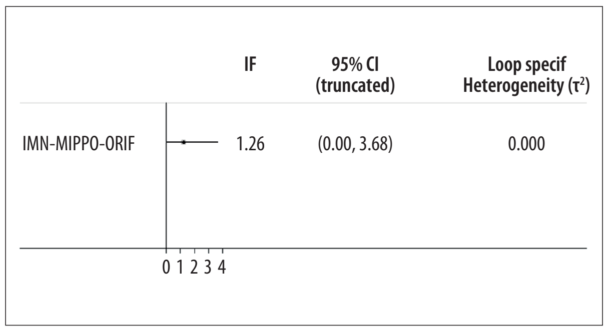

Figure 4. Inconsistency test for direct and indirect comparisons. ORIF – open reduction and internal fixation; MIPPO – minimally invasive percutaneous osteosynthesis technique; IMN – intramedullary nailing.

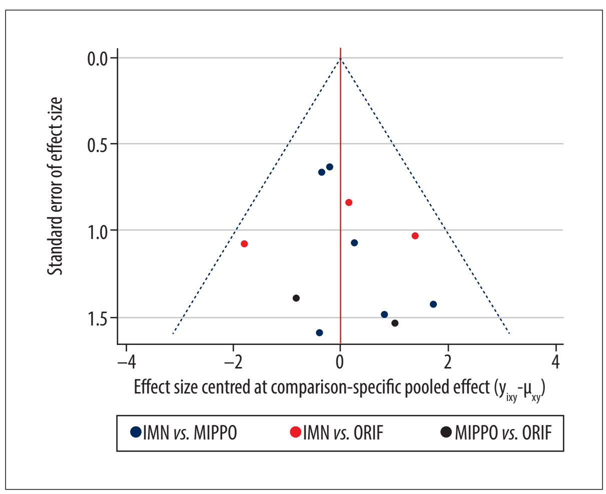

Figure 5. Funnel plots assessment of publication bias of all included studies. ORIF – open reduction and internal fixation; MIPPO – minimally invasive percutaneous osteosynthesis technique; IMN – intramedullary nailing.

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

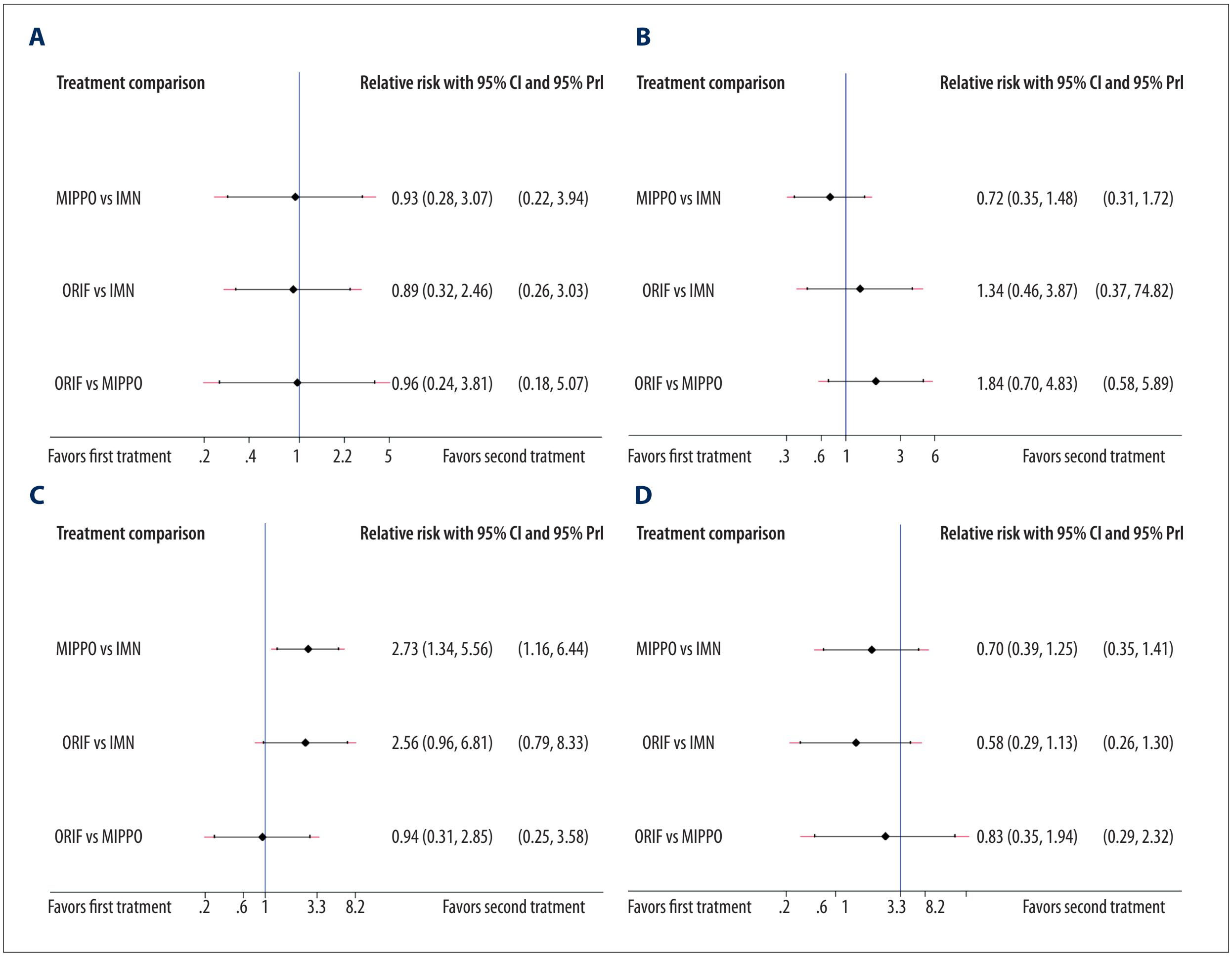

Figure 6. Forest plot showing treatments compared with each other in nonunion rate (**A**), delayed union rate (**B**), malunion (**C**), and wound infection (**D**). ORIF – open reduction and internal fixation; MIPPO – minimally invasive percutaneous osteosynthesis technique; IMN – intramedullary nailing.

We found no significant difference among the 3 types of internal fixation in terms of delayed union or nonunion according to RR values. However, the SUCRA value of IMN was lower than one or both of the other treatment methods. The poor reduction, excessive fracture gap, and reaming the medullary cavity temporarily injury the nutrient artery of bone, which can contribute to slower healing than with plates [2].

Wound complications, especially deep infection, are key factors affecting fracture healing and increasing medical costs. Many factors influence wound infections, including open fractures, surgical technique, and the conditions of the soft tissue. Soft tissue injury increases the wound infection rate. Plate fixation requires greater exposure and wider soft tissue dissection, possibly increasing the risk of infection. Such problems can be avoided using IMN, which is a minimally invasive method. Nevertheless, some studies reported that with the development of biologic techniques, plate fixation provides stable fixation and a low rate of infection for distal tibial fractures [34,43,44]. In the present study, ORIF and MIPPO had higher rates of infection than did IMM fixation, and no significant difference was found in the incidences of infection of ORIF and MIPPO. We could not carry out subgroup analysis stratified by wound type because the results were not reported separately by wound type. Therefore, this result should be interpreted with caution.

There were several strengths in this network meta-analysis. First, it is the first network meta-analysis to assess and compare 3 interventions for distal tibial fracture. Second, all included studies were RCTs, reducing selection bias and increasing the reliability of the results. Third, we used SUCRA values to detect subtle differences among the 3 interventions. Finally, inconsistency testing showed no substantial inconsistency. Nevertheless, this meta-analysis has potential limitations. First, only 11 studies were included in this study, to compare 3 treatments for distal tibial fracture; the number of cases was small, and the quality of the included studies was not high, which

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

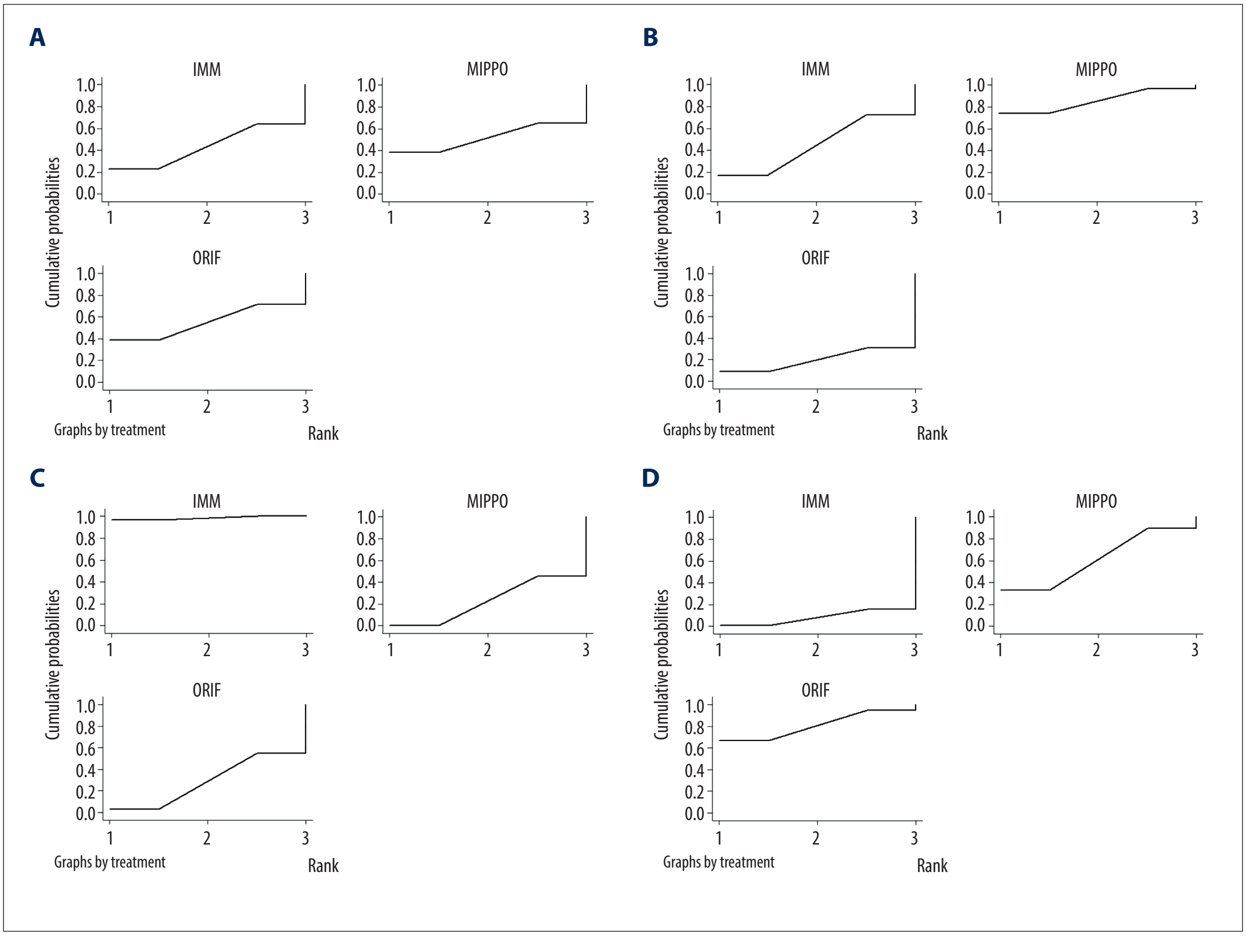

Figure 7. Surface under the cumulative ranking curve for nonunion rate (**A**), delayed union rate (**B**), malunion (**C**), wound infection (**D**). ORIF – open reduction and internal fixation; MIPPO – minimally invasive percutaneous osteosynthesis technique; IMN – intramedullary nailing.

may have influenced the results. Second, we only focused on primary complications; we did not compare other outcomes like operative time, patient satisfaction, anterior knee pain, and fixation failure because these were not always reported or were reported in various ways. Third, because of substantial differences in postoperative X-ray images and operative incisions, the term "blinding of outcome assessment" was assessed as "high risk" for all 11 studies.

Conclusion

We demonstrated that IMN has lower risk of wound complications than does ORIF and MIPPO. There were no significant differences in the incidences of delayed union, nonunion, or malunion among the 3 treatments. Given the better results of intramedullary nailing in terms of wound complications, we recommend intramedullary nailing for treatment of distal tibial fractures. More RCTs focusing on distal tibial fractures are needed to support the current evidence.

Conflict of interest

None.

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

References:

1. Mahmood A, Kumar G: Review of the treatment of distal tibia metaphyseal fractures; Plating versus intramedullary nailing: A systematic review of recent evidence. Foot Ankle Surg, 2014; 20: 151
2. Vallier HA: Current evidence: Plate versus intramedullary nail for fixation of distal tibia fractures in 2016. J Orthop Trauma, 2016; 30(Suppl. 4): S2–6.
3. Bedi A, Le TT, Karunakar MA: Surgical treatment of nonarticular distal tibia fractures. J Am Acad Orthop Surg, 2006; 14: 406–16
4. Gao H, Zhang CQ, Luo CF et al: Fractures of the distal tibia treated with polyaxial locking plating. Clin Orthop Relat Res, 2009; 467: 831–37
5. Cebesoy O: Distal tibial fractures and minimal invasive techniques. Injury, 2007; 38: 255
6. Joveniaux P, Ohl X, Harisboure A et al: Distal tibia fractures: Management and complications of 101 cases. Int Orthop, 2010; 34: 583–88
7. 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: 1219–23; discussion 1223
8. Newman SD, Mauffrey CP, Krikler S: Distal metadiaphyseal tibial fractures. Injury, 2011; 42: 975–84
9. Mosheiff R, Safran O, Segal D, Liebergall M: The unreamed tibial nail in the treatment of distal metaphyseal fractures. Injury, 1999; 30: 83–90
10. Court-Brown CM, Gustilo T, Shaw AD: Knee pain after intramedullary tibial nailing: Its incidence, etiology, and outcome. J Orthop Trauma, 1997; 11: 103–5
11. Obremskey WT, Medina M: Comparison of intramedullary nailing of distal third tibial shaft fractures: Before and after traumatologists. Orthopedics, 2004; 27: 1180–84
12. Zou J, Zhang W, Zhang CQ: Comparison of minimally invasive percutaneous plate osteosynthesis with open reduction and internal fixation for treatment of extra-articular distal tibia fractures. Injury, 2013; 44: 1102–6
13. Ronga M, Longo UG, Maffulli N: Minimally invasive locked plating of distal tibia fractures is safe and effective. Clin Orthop Relat Res, 2010; 468: 975–82
14. Hazarika S, Chakravarthy J, Cooper J: Minimally invasive locking plate osteosynthesis for fractures of the distal tibia – results in 20 patients. Injury, 2006; 37: 877–87
15. 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
16. Kwok CS, Crossman PT, Loizou CL: Plate versus nail for distal tibial fractures: A systematic review and meta-analysis. J Orthop Trauma, 2014; 28: 542–48
17. Li A, Wei Z, Ding H et al: Minimally invasive percutaneous plates versus conventional fixation techniques for distal tibial fractures: A meta-analysis. Int J Surg, (London, England), 2017; 38: 52–60
18. Yu J, Li L, Wang T et al: Intramedullary nail versus plate treatments for distal tibial fractures: A meta-analysis. Int J Surg (London, England), 2015; 16: 60–68
19. Li B, Yang Y, Jiang LS: Plate fixation versus intramedullary nailing for displaced extra-articular distal tibia fractures: A system review. Eur J Orthop Surg Traumatol, 2015; 25: 53–63
20. Caldwell DM, Ades AE, Higgins JP: Simultaneous comparison of multiple treatments: combining direct and indirect evidence. BMJ,2005; 331: 897–900
21. Moher D, Liberati A, Tetzlaff J, Altman DG: Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. J Clin Epidemiol, 2009; 62: 1006–12
22. Shea BJ, Reeves BC, Wells G et al: AMSTAR 2: A critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. BMJ, 2017; 358: j4008
23. Chen H, Manning AK, Dupuis J: A method of moments estimator for random effect multivariate meta-analysis. Biometrics, 2012; 68: 1278–84
24. Peters JL, Sutton AJ, Jones DR et al: Comparison of two methods to detect publication bias in meta-analysis. JAMA, 2006; 295: 676–80
25. Zintzaras E, Ioannidis JP: Heterogeneity testing in meta-analysis of genome searches. Genet Epidemiol, 2005; 28: 123–37
26. Chaimani A, Higgins JP, Mavridis D et al: Graphical tools for network meta-analysis in STATA. PLoS One, 2013; 8: e76654
27. Egger M, Davey Smith G, Schneider M, Minder C: Bias in meta-analysis detected by a simple, graphical test. BMJ, 1997; 315: 629–34
28. Salanti G, Ades AE, Ioannidis JP: Graphical methods and numerical summaries for presenting results from multiple-treatment meta-analysis: An overview and tutorial. J Clin Epidemiol, 2011; 64: 163–71
29. Fang JH, Wu YS, Guo XS, Sun LJ: Comparison of 3 minimally invasive methods for distal tibia fractures. Orthopedics, 2016; 39: e627–33
30. Guo JJ, Tang N, Yang HL, Tang TS: A prospective, randomised trial comparing closed intramedullary nailing with percutaneous plating in the treatment of distal metaphyseal fractures of the tibia. J Bone Joint Surg Br, 2010; 92: 984–88
31. Kim JW, Kim HU, Oh CW et al: A prospective randomized study on operative treatment for simple distal tibial fractures-minimally invasive plate osteosynthesis versus minimal open reduction and internal fixation. J Orthop Trauma, 2018; 32: e19–24
32. Li Y, Jiang X, Guo Q et al: Treatment of distal tibial shaft fractures by three different surgical methods: A randomized, prospective study. Int Orthop, 2014; 38: 1261–67
33. Mauffrey C, McGuinness K, Parsons N et al: A randomised pilot trial of "locking plate" fixation versus intramedullary nailing for extra-articular fractures of the distal tibia. J Bone Joint Surg Br, 2012; 94: 704–8
34. Polat A, Kose O, Canbora K et al: Intramedullary nailing versus minimally invasive plate osteosynthesis for distal extra-articular tibial fractures: A prospective randomized clinical trial. J Orthop Sci, 2015; 20: 695–701
35. 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: 736–41
36. Wani IH, Ul Gani N, Yaseen M et al: Operative management of distal tibial extra-articular fractures – intramedullary nail versus minimally invasive percutaneous plate osteosynthesis. Ortop Traumatol Rehabil, 2017; 19: 537–41
37. Daolagupu AK, Mudgal A, Agarwala V, Dutta KK: A comparative study of intramedullary interlocking nailing and minimally invasive plate osteosynthesis in extra articular distal tibial fractures. Indian J Orthop, 2017; 51: 292–98
38. Bong MR, Kummer FJ, Koval KJ, Egol KA: Intramedullary nailing of the lower extremity: Biomechanics and biology. J Am Acad Orthop Surg, 2007; 15: 97–106
39. Hontzsch D, Blauth M, Attal R: [Angle-stable fixation of intramedullary nails using the Angular Stable Locking System(R) (ASLS).] Oper Orthop Traumatol, 2011; 23: 387–96 [in German]
40. Krettek C, Stephan C, Schandelmaier P et al: The use of Poller screws as blocking screws in stabilising tibial fractures treated with small diameter intramedullary nails. J Bone Joint Surg Br, 1999; 81: 963–68
41. 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: 550–53
42. Ali M, Othman AMA, Yahya M, Al-Zahrani AW: Plate or nail for distal tibia fractures: Is there a clear answer? European Orthopaedics and Traumatology, 2015; 6: 91–97
43. Oh CW, Kyung HS, Park IH et al: Distal tibia metaphyseal fractures treated by percutaneous plate osteosynthesis. Clin Orthop Relat Res, 2003; (408): 286–91
44. Krackhardt T, Dilger J, Flesch I et al: Fractures of the distal tibia treated with closed reduction and minimally invasive plating. Arch Orthop Trauma Surg, 2005; 125: 87–94

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]