ORIGINAL STUDY — REVIEW

acta orthopaedica belgica, 2024, 90, 559-565

doi.org/10.52628/90.3.12760

Distal tibial fractures fixation using retrograde tibial intramedullary nail in high-risk patients: a retrospective study

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Distal tibial fractures are common lower-limb injuries and are generally associated with a high risk of postoperative complications, especially in patients with multiple medical comorbidities. This study sought to ascertain the efficacy of retrograde intramedullary tibial nails (RTN) for treating extra-articular distal tibial fractures in high-risk patients. Between January 2019 and December 2021, 13 patients considered at high risk for postoperative complications underwent RTN fixation. Comorbidities in the patient sample included diabetes, renal disease, hypertension, severe osteoporosis, hemorrhagic blisters, long-term smoking, alcoholism and so on. Medical records were retrospectively reviewed to assess treatment data, wound complications, infections, hardware failure, time to bone union, and functional outcomes. The mean preoperative waiting time and operation duration was 7.1 ± 1.7 days and 61.1 ± 7.1 minutes, respectively. The hospital stay time ranged from 10 to 16 days, with a mean of 12.6 ± 1.9 days. All patients were monitored for a mean follow-up time of 17.5 ± 3.3 months. All patients achieved fracture union with an average healing time of 5.0 ± 0.7 months. No implant failure or persistent pain was observed in the surgical site. Two patients had superficial infection, but no further complications resulted from the incision. At the final follow-up, the average AOFAS score was 84.0 ± 7.3 points, with an excellent and good rate of 76.9%. RTN appears to be a reliable treatment option for extra-articular distal tibial fractures in high-risk patients.

Keywords: Extra-articular distal tibial fractures, retrograde intramedullary tibial nail, high-risk, AO/OTA classification, complication.

INTRODUCTION

Distal tibial fractures represent a notable occurrence in clinical practice, constituting approximately 10% of all tibial fractures[1] and 1.5% of all adult fractures[2]. In recent years, the incidence of distal tibial fractures has significantly increased, primarily because of the rising prevalence of high-energy injuries stemming from factors such as traffic accidents and falls from significant heights. The management of distal tibial fractures poses a challenge because of several complicating factors, including limited local soft tissue coverage, heightened skin tension, anatomical ischemia at the fracture site, and adjacency of the distal tibia to the ankle joint[3]. Currently, the two common techniques for addressing extra-articular distal tibial fractures are antegrade tibial intramedullary nails and locking plates. Nevertheless, both modalities have notable limitations. Plate fixation, while widely employed owing to its capacity to achieve a proper degree of reduction and offer sturdy fixation, is unsuitable for patients presenting with serious injuries of soft tissue or open fractures. Even with the adoption of minimally invasive plate osteosynthesis (MIPO), relatively extensive wound exposure and soft tissue dissection are necessary to facilitate fracture reduction. This heightened exposure increases the risk of complications, such as infection, tissue necrosis, delayed union, and nonunion[4]. Although antegrade tibial intramedullary nails offer theoretical advantages such as load-sharing characteristics, minimally invasive application, and reduced soft tissue irritation, their utility is hampered by complications including instability, malalignment of fractures, and postoperative anterior knee pain[5].

RTN has emerged as a novel minimally invasive internal fixation device, conceived by Kuhn et al., specifically tailored for addressing distal tibial fractures[6]. Biomechanical assessments have demonstrated that RTN exhibits biomechanical advantages over the conventional medial distal tibial plate and expertly applied antegrade tibial intramedullary nails concerning fracture fretting and internal fixation stress[7]. Moreover, its clinical application has shown favorable outcomes[8]. Nevertheless, there is relatively limited literature focusing on the application of RTN in high-risk patients with distal tibial fractures. According to the results of intramedullary nail fixation of the fibula have been shown to provide satisfied union rates, excellent functional outcomes, and a low complication profile, comparable with that of open reduction and internal fixation in high-risk patients of fibular fractures[9], we hypothesized that using RTN in high-risk patients with multiple medical comorbidities is a viable alternative for distal tibial fracture fixation.

METHODS

In this retrospective study, we analyzed consecutive clinical cases, ensuring that written informed consent was obtained from all participants prior to their procedures. All techniques employed during this investigation adhered to the ethical guidelines outlined in the 2013 revision of the Helsinki Declaration and protocols of the Institutional Research Committee. Our study focused on patients diagnosed with extra-articular distal tibial fractures at our Level 1 trauma center between January 2019 and December 2021.

The Inclusion criteria were as follows: (1) Inclusion of OA/OTA 43A closed fractures or Gustilo I, II, or IIIA open fractures with high-risk factors such as uncontrolled diabetes mellitus, hypertension, advanced renal disease, hemorrhagic blisters, poor skin condition, severe osteoporosis, dementia, alcoholism, and long-term smoking[10]. (2) Location of the tibial fracture line between 4 and 11 cm proximal to the plafond. (3) Patients were required to be skeletally mature adults with a minimum 10-month follow-up duration. Patients presenting with Gustilo IIIB and IIIC open fractures, pathological fractures of the tibia, distal intra-articular or proximal intra-articular fractures of the tibia, or a follow-up period of less than 12 months were excluded from the study.

Patients presenting with open fractures underwent immediate debridement, suturing, and calcaneal traction (for Gustilo I fractures) or temporary external fixation (for Gustilo II or IIIA fractures) on the day of admission. In cases of closed fractures, calcaneal traction was initiated after admission. In all patients, the affected leg was elevated and a thorough examination of the affected deep vein was conducted via ultrasound to exclude the presence of thrombosis. Patients were encouraged to engage in ankle pump exercises to mitigate swelling of the affected limb. Surgical intervention was scheduled once the swelling had subsided and there were no discernible contraindications to the procedure.

In cases involving fibular fractures that compromise ankle stability, specifically those occurring within 8 cm above the malleolar fossa, open reduction and fibular plate fixation through a lateral approach was the initial surgery.

The patients underwent either general or epidural anesthesia while lying supine on a fluoroscopic surgical table. A lower-limb traction device was employed to facilitate closed reduction guided by C-arm fluoroscopy. In cases in which closed reduction proved unsuccessful, a small incision was made at the fracture site to assist in the reduction process. Using sharp dissection and separation techniques, a longitudinal incision measuring 2-3 cm was made in the medial malleolus. The insertion point of the guidewire was verified through C-arm fluoroscopy to ensure proper alignment at the midpoint of the medial malleolus in both standard lateral and anteroposterior radiographs. Subsequently, the guide wire was directed parallel to the medial cortex in the anteroposterior radiograph and aligned with the anatomical axis of the distal tibia on the lateral radiograph. Following this, a hole reamer and cannulated awl were employed along the guidewire to create a pathway leading to the medullary canal. Then, the guidewire and awl were adjusted to introduce prosthesis trials into the medullary canal, facilitating the selection of the appropriate length and diameter of the RTN. Once the RTN (Double Medical Technology Inc., Xiamen, China) was assembled on the aiming device, it was inserted into the medullary canal with gentle force and small twisting movements until it was flushed with the cortex of the medial malleolus. C-arm fluoroscopy was used to confirm satisfactory reduction and correct nail positioning. Subsequently, distal and proximal locking screws were introduced through the trocar combination and an end cap was placed at the extremity of the nail.

All patients received a 24-hour course of intravenous antibiotics postoperatively, and active and passive functional exercises were initiated in the postoperative period.

The following parameters were recorded: pre-operative waiting time, operative duration, length of hospital stay, and incidence of complications. To monitor the progress of fracture healing, regular follow-up appointments were scheduled, and monthly postoperative radiographic examinations were performed. Functional outcomes were evaluated using the AOFAS and Ankle Society scores.

RESULTS

Of the 13 patients identified, 8 were male and 5 were female, ranging in age from 16 to 85 years (mean age: 52.6 ± 19.4 years). The etiology of the injuries included traffic accidents (5 patients), falls from heights (3 patients), sprains (3 patients), and crush injuries (2 patients). The AO/OTA classification identified 6 patients with 43A1 fractures, 5 with 43A2 fractures, and 2 with 43A3 fractures. Three of the 13 patients had open fractures (2 Gustilo II and 1 Gustilo IIIA), while 9 patients had multiple injuries, including traumatic brain injury (1), hemopneumothorax (1), rib fractures (1), contralateral calcaneal fracture (1), ipsilateral fibular fractures (8), ipsilateral femoral fracture (1), distal radius fracture (1), patellar fracture (1), and tibial fracture (1). Table I displayed the detailed clinical parameters of the patients.

The mean preoperative waiting time and operation duration was 7.1 ± 1.7 days (range: 5~10 days) and 61.1 ± 7.1 minutes (range: 52~75 minutes), respectively. The hospital stay time ranged from 10 to 16 days, with a mean of 12.6 ± 1.9 days. All the patients were monitored for a mean follow-up time of 17.5 ± 3.3 months (range: 11~18 months) after surgery. All patients achieved hard fracture union, with an average healing time of 5.0 ± 0.7 months (range: 4.0~6.0 months). No implant failure or persistent pain was observed in the surgical site. Two patients had superficial infection, but no further complications resulted from the incision. The final follow-up AOFAS score was 84.0 ± 7.3 points (range: 69-93 points), with an excellent and good rate of 76.9%. The patient outcomes are shown in Table II, and typical cases are shown in Figure 1 (Case 2), Figure 2 (Case 5), and Figure 3 (Case 10).

DISCUSSION

Distal tibial fractures are usually high-energy injuries that are accompanied by extensive soft tissue damage. The presence of marginal soft tissue and vascular supply in this area undoubtedly increases the difficulty of treatment and the risk of postoperative complications[11]. Presently, surgical intervention is the primary approach for managing distal tibial fractures, with plate fixation and antegrade tibial intramedullary nailing being the most common methods, and there is no substantial discrepancy in overall effectiveness between these two modalities[12]. Plate fixation imposes greater demands on soft tissue conditions and is unsuitable for patients with severe soft tissue injuries, peripheral vascular diseases, or diabetes affecting the surgical site. Moreover, it has

Table I. — Baseline characteristics of the high-risk patients

No.	Gender	Age (years)	Location	BMI	Causes Of Injury	Type of fractures	Fractures classification (AO/OTA/Gustilo)	High risk factors	Multiple injuries
1	Male	63	Right	19	Traffic accident	Closed fracture	43A1	Osteoporosis, HTN, DM	TBI, Ipsilateral fibular fracture
2	Female	85	Right	16	Sprain	Closed fracture	43A2	Osteoporosis, DM	-
3	Male	43	Right	22	Traffic accident	Closed fracture	43A1	Long term smoking, Postoperative MI	Ipsilateral fibular fracture
4	Male	52	Right	25	Fall from height	Closed fracture	43A2	Chronic renal insufficiency, HTN, DM	Rib fractures, Hemopneumothorax
5	Female	55	Left	18	Sprain	Closed fracture	43A1	Hemorrhagic blisters, Ischemic stroke	Ipsilateral fibular fracture
6	Male	57	Right	32	Fall from height	Open fracture	Gustilo II 43A2	Alcoholism, Long term smoking, COPD	-
7	Female	36	Right	24	Traffic accident	Closed fracture	43A1	Hemorrhagic blisters, Soft tissue contusion	Ipsilateral fibular fracture
8	Male	54	Left	23	Crushes	Closed fracture	43A2	Uremia, Moderate anemia	Contralateral calcaneal fracture
9	Male	58	Right	25	Fall from height	Closed fracture	43A1	Schizophrenia, CAD	Ipsilateral fibular fracture
10	Male	16	Left	26	Traffic accident	Open fracture	Gustilo II 43A3	Hemorrhagic blisters, Soft tissue contusion	Ipsilateral femoral and fibular fractures
11	Male	45	Right	24	Crushes	Closed fracture	43A2	Alcoholism, DM	-
12	Female	59	Left	26	Traffic accident	Open fracture	Gustilo IIIA 43A3	Osteoporosis, HTN, Hyperlipidemia	Ipsilateral fibular fracture
13	Female	62	Left	20	Sprain	Closed fracture	43A1	Osteoporosis, COPD	Ipsilateral fibular fracture

BMI, body mass index; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; DM, diabetes mellitus; HTN, hypertension; MI, myocardial infarction; TBI, Traumatic brain injuries (Cerebral concussion).

Table II. — Hospitalization and follow-up data of the high risk patients

No.	Preoperative waiting time (days)	Operation time (minutes)	Hospital stay (days)	Average follow up period (months)	Time to bone union (months)	AOFAS score at final follow up	Complications
1	6	60	11	12	5	83	-
2	5	53	13	13	6	69	Superficial
3	5	65	12	11	5	86	infection
4	6	55	10	15	6	90	-
5	6	70	10	18	5	92	-
6	9	60	12	14	4	88	-
7	9	75	13	12	4	87	-
8	6	58	13	11	6	79	-
9	7	68	11	18	5	85	-
10	9	57	13	13	4	88	-
11	8	52	14	15	5	93	Superficial
12	10	56	16	14	5	72	infection
13	6	66	10	14	5	80	-

Figure 1 — A 85-year-old female with a extra-articular distal tibial fracture received an operation with RNT fixation (Case 2)— a-d: Preoperative radiography. e, f: X-ray at 5 days after the operation. g, h: X-ray at 2 months after the operation. i-l: Radiography at 6 months after the operation. The fracture was union.

a higher risk of complications related to wound healing and postoperative wound infections[13]. Antegrade intramedullary nailing not only brings favorable mechanical properties but also offers biological advantages by preserving vascularity at the fracture site and the integrity of surrounding soft tissues, thus earning it the gold standard for treating tibial shaft fractures. When applied to distal tibial fractures, antegrade intramedullary nailing can yield improved function, reduced infection risk, and an acceptable range of motion[14]. Nevertheless, owing to the gradual expansion of the distal tibial medullary cavity and its distinctive anatomical structure, intramedullary nails may not fit snugly in the medullary canal, predisposing the fracture to poor reduction and instability, which can lead to malalignment, malunion, and delayed union[15].

In the late 1990s, Hofmann et al.[16] introduced the concept of RTN, which was subsequently designed and implemented in clinical practice by Kuhn et al[6]. Recent biomechanical studies have highlighted RTN as an innovative surgical alternative for managing distal tibial fractures, demonstrating its potential superiority over plating techniques[17]. Moreover, their clinical application has yielded promising results. In a study involving nine patients with distal tibial fractures, RTN achieved an impressive 100% excellent-to-good rate in AOFAS scores[8]. However, to our knowledge, relatively little information exists regarding the effectiveness of RTN in high-risk patients. In this study, high-risk patients are associated with one or several of diabetes mellitus, renal disease, hypertension, advanced age with osteoporosis, hemorrhagic blisters, neuropathy, long-term smoking, alcoholism and we showed that, in those patients with extra-articular distal tibial fractures, the RTN fixation appeared to lead to a low infection complication rate and satisfactory functional and radiological outcomes. Based on the findings of previous research and our own investigations, we

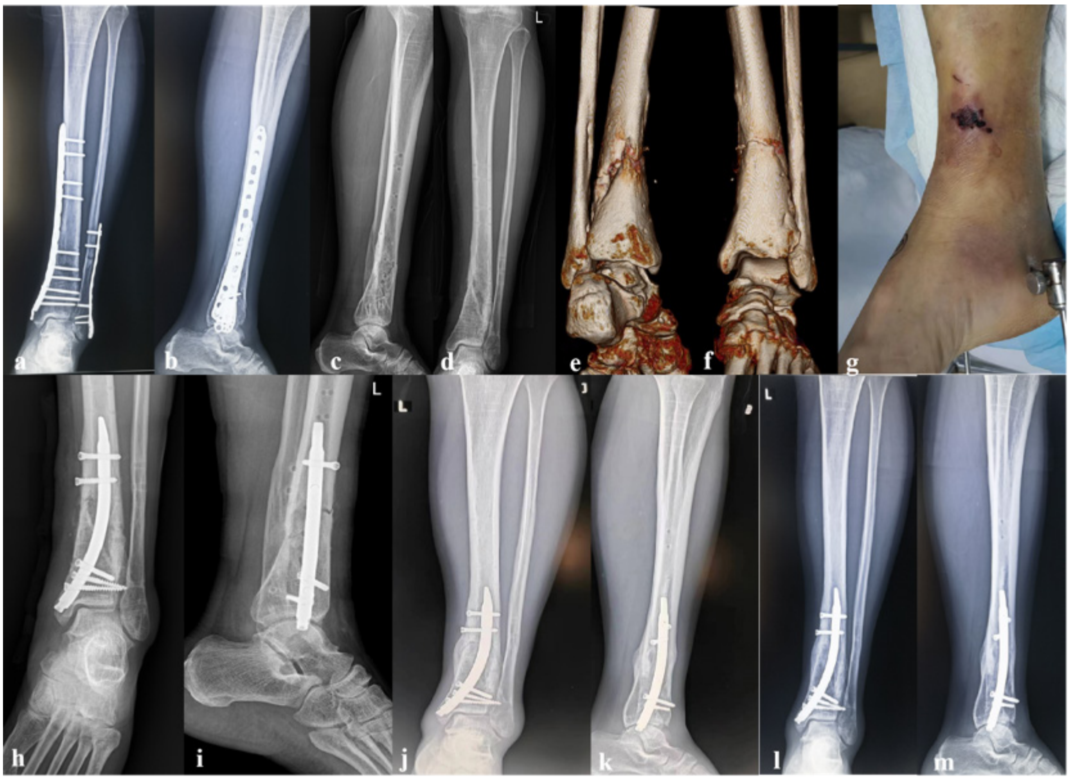

Figure 2 — A 55-year-old female with ischemic stroke and refracture of distal tibial received RNT fixation (Case 5) — a, b: One year ago, the patient with a distal tibial and fibular fracture received an operation with plates and srcews fixation. c, d: X-ray after the remove of the internal fixation. e, f: The patient sprained and suffered distal tibial refracture. g: Poor soft tissue with hemorrhagic blisters. h, i: X-ray at 3 days after the operation. j, k: X-ray at 2 months after the operation. l,m: Radiography at 5 months after the operation. The fracture was union.

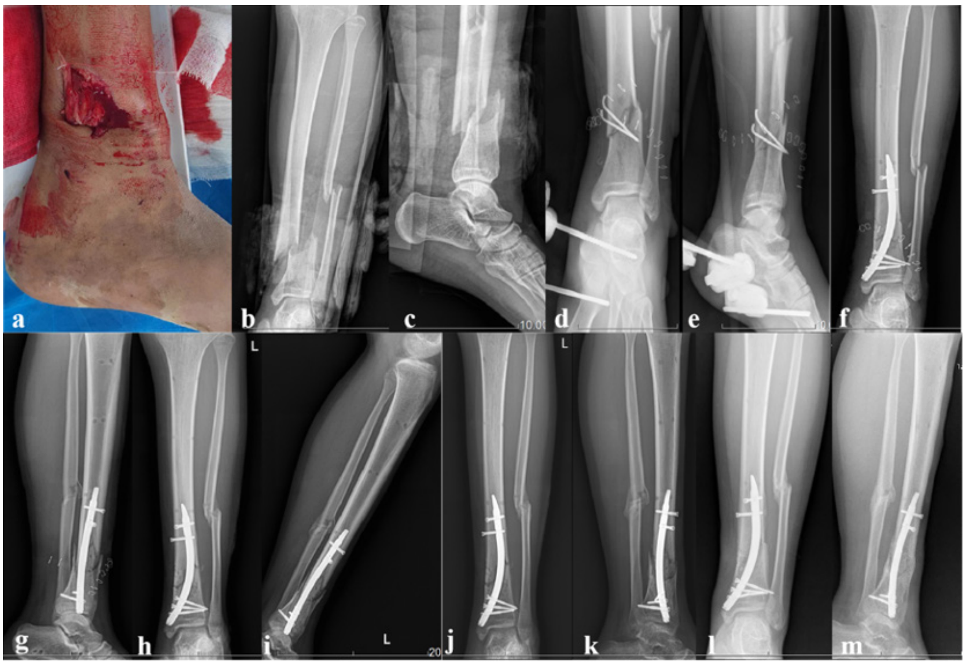

Figure 3 — A 16-year-old male with a Gustilo II open fracture received RNT fixation (Case 10) – a-c: Preoperative appearance and radiography. d, e: Debridement and first external fixation were performed on the day of admission. f, g: X-ray at 2 days after the operation. h, i: X-ray at one months after the operation. j, k: X-ray at 3 months after the operation. l, m: Radiography at 4 months after the operation. The fracture was union.

assert that RTN presents unique advantages. First, the distal curved configuration of the RTN aligns more harmoniously with the distal tibial morphology. Biomechanically, RTN exhibits superior resistance to rotation and axial stability compared to antegrade tibial intramedullary nails and plates. The successful achievement of fracture healing without distal tibial valgus deformity in all RTN patients underscores the commendable stability of this technique. Second, RTN simplifies fracture reduction and fixation, offering greater convenience with a high accuracy in its locking nail aiming device, thereby reducing the operation time and radiation exposure. Third, the limited length of the RTN ensures that the nail does not traverse the isthmus of the tibial shaft, resulting in reduced influence on the bone marrow cavity. This feature can reduce the risk of fat embolism, particularly in patients with concurrent lung injuries or multiple trauma. Finally, RTN employs the medial ankle as the entry point, effectively averting anterior knee pain. Postoperative AOFAS results confirmed its minimal impact on the ankle joint.

As a recent technology, several considerations merit attention when using RTN for distal tibial fractures. (1) RTN's limited length of the RTN renders it unsuitable for patients with middle and lower tibial fractures. (2) The medial malleolus serves as the insertion point for RTN, making it unsuitable for children, adolescents with epiphyses, or individuals with skin infections or ulcerations at the medial malleolus. (3) Particular care should be exercised to protect the triangular ligament and medial malleolus during RTN insertion to prevent ligament tearing or medial malleolus fracture. (4) Owing to the wide medullary cavity of the distal tibia, there is a heightened risk of fracture displacement during RTN insertion. Therefore, we recommend the application of a lower-limb traction device throughout the surgery to maintain fracture stability, with adjunctive blocking screw techniques employed when deemed necessary.

CONCLUSION

RNT is a viable alternative for treating extra-articular distal tibial fractures in high-risk patients with multiple comorbidities. It is a minimally invasive and relatively simple procedure, with a low incidence of complications. Nonetheless, this study has certain limitations. (1) Retrospective Study Design: This study adopted a retrospective design, potentially introducing selection bias into the research methodology. (2) Limited Sample Size and Short Follow-Up Duration: The study's sample size was relatively small and the follow-up period was short. Future investigations should address these limitations by conducting large-scale prospective comparative studies to confirm the aforementioned findings.

Funds: This research was funded by General Program of PLA Nanjing Military Area Command, grant number 15ZD029.

Conflict of Interest: The authors declare that there were no commercial or financial relationships that could be considered potential conflicts of interest at the time the research was conducted.

Informed Consent: Written Informed consent was obtained from all patients.

Ethics Approval: This study was approved by the School of Medicine, Xiamen University Ethics Committee [Approval No. 2022-0015].

Authors'Contribution: JW and YX wrote the manuscript, analyzed and interpreted the patient data. JZ was responsible for acquisition of data, and analyzed and interpreted the patient data. HL, DL, and WX were responsible for designing the study, and the analysis and interpretation of the data.
All authors have read and approved the final manuscript.

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