Contents lists available at ScienceDirect

Annals of Medicine and Surgery

Case Series

Results and complications of minimally invasive medial plate osteosynthesis for distal metaphyseal tibial fractures: A prospective case series from Vietnam

Luong Van Nguyen [a,*], Gioi Nang Nguyen [a], Binh Lam Nguyen [a], Ha Manh Bui [b]

[a] *Institute of Trauma and Orthopaedics, 108 Central Military Hospital, Hanoi, Viet Nam*
[b] *Military Hospital No 4, Viet Nam*

ARTICLE INFO

ABSTRACT

Introduction and importance: The treatment of a fractures in tibial distal metaphyseal remained controversial. The purpose of this study was to assess the results and complications of minimally invasive medial plate osteosynthesis for distal metaphyseal tibial fractures.

Material and method: From April 2014 to December 2019, 70 patients were enrolled in the study who were underwent MIPPO for metaphyseal tibial fractures using a medial distal tibial locking plate in our hospital. Wound healing, alignment, full weight bearing time, function, and complications were recorded.

Results: All wounds primarily healed, just one fibular plating wound was deeply infected. All tibial fractures were solid union without secondary displacement. The average time back to walk without a crutch was 12,5 weeks. The mean AOFAS score was 89 at a mean of 15 months follow-up. There were seven cases of late infection, 14 patients of skin impingement by implants and nine cases of broken screws, who were older than 65 years old. No case was varus, valgus or rotation >5°.

Conclusion: Minimally invasive medial plate osteosynthesis for the distal metaphyseal tibial fracture is safe and effective. This technique decreases the incidence of complications and can help patients to resume their function early. The implant impingement, late wound infections and screw breakage were the quite common complications in old patients but these complications could be simply resolved and did not affect the overall rehabilitation and functions of the patient.

1. Introduction

The treatment of an unstable fractures in metaphyseal distal regions of the tibia remains controversial. Open anatomical reduction and plate osteosynthesis requires extensive soft tissue dissection with consequent periosteal injury. High rates of infective complications and wound dehiscence have been reported [1,2]. With the development of locking nails, distal tibia fractures were treated by indirect reduction in a closed fashion. The goal with this procedure was secondary bone healing with callus formation. Problems such as malunion with rotational and axial malalignment are known disadvantages of this method [1,3].

Minimally invasive percutaneous plate osteosynthesis (MIPPO) is a technique which aims to reduce soft tissue injury and damage to bone vascularity, as well as preserving the osteogenic haematoma of the fracture. MIPPO technique has now become more popular with the development of the locking plate. Through a small skin incision, the plate is inserted subcutaneously along the medial aspect of the tibia and fixed with head locking screws. The better of the pre-contoured distal medial tibial locking plate than other locking plates in the rate of wound complications was reported [4–7].

In Vietnam, minimally invasive medial plate osteosynthesis for distal metaphyseal tibial fractures have been done in few hospitals due to technical and equipment restrictions. Therefore, the number of patients receiving this surgery is negligible, and there are no international reports. Locking plate were made in Eastern country so the shape and size of locking plate may be not suitable for Vietnamese patients. This study aimed to assess the results and complications of minimally invasive plates osteosynthesis for distal metaphyseal tibial fractures using a medial distal tibial locking plate in low-income country like Vietnam.

---

2. Materials and methods

2.1. Study design and subjects

This was a prospective case series study that enrolled adult patients who had minimally invasive medial plate osteosynthesis for distal metaphyseal tibial fractures in our hospital (Level I Institue of Trauma and Orthopaedics, Hanoi, Vietnam) from April 2014 to December 2019. Seventy adult patients (53 males and 17 females) were recruited for the study. The surgeon were authors (L.V.N, B.N.L, G.N.N), who were senior surgeons. The inclusion criteria were distal third 42A-C fracture, 43A, 43C1, 43C2 fractures (AO/ASIF classification), closed fractures, and open fracture grade I, II (Gustilo classification). Patients with proximal and middle third tibial fractures, type 43B, 43C3 of pilon fractures were excluded since a different approach and surgical technique was required. Distal tibia fracture with associated vascular injury, pathological distal tibia fracture, multiple fractures, previous foot, or ankle surgery, patients younger than 18 years were also excluded.

This case series has been reported in line with the PROCESS 2020 criteria [8]. All patients were informed about the procedure, risks, and advantages of it. Written informed consent was obtained from all patients in our study, which was approved by our Hospital Institutional Ethical Review Board. All patients in the study were asked for their consent, and they agreed to participate in the study. They were notified of their complete right to withdraw from the study at any time without threat or disadvantage.

2.2. Surgical technique

All operations were performed under spinal anesthesia. Tourniquets were used to impede blood flow to the operated limbs. The medial distal tibia locking plate (Intercus company, Germany) were used (Fig. 1). It is made of titanium and anatomically contoured to the distal medial tibia. There is a dense net of threaded screw holes in the distal section (8 holes) to provide a higher anchoring stability. Those threaded holes are angled to allow optimal fixation of the screws in the epiphyseal and metaphyseal area.

Through a small incision over the medial malleolus, sparing the saphenous vein and nerve, the tibial locking plate was inserted extraperiosteally. Fracture fragments were reduced using indirect reduction techniques with pointed forceps. Direct open reduction may be used in difficult cases. Open reduction was performed through a small incision directly to the displaced fracture line or through the wound of an open fracture. The C-arm was used intraoperatively for assessment of fracture reduction and fixation. Fragment position, gap, and longitudinal axis were controlled using fluoroscopy. Fixation of the plate was always done through a small incision with a 3.5 mm mono- or bi-cortical locking screw. Fibula fractures were fixed with open reduction using plate and screws or K-wire osteosynthesis prior to tibial fracture management. All operative steps are presented in Fig. 2.

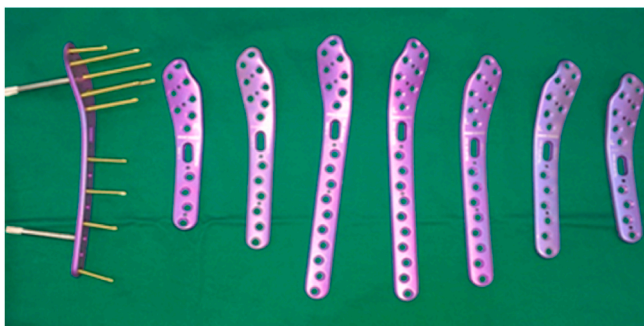Postoperative plaster cast immobilization was not used (see Fig. 2).

Fig. 1. Image of Intercus' medial distal tibial locking plate.

Elevation of the fractured limb to achieve gravity-assisted venous drainage along with active toe and ankle movements were carried out for the initial two weeks. Up to the first follow-up visit at 6 weeks, patients were only allowed to partial weight bearing with crutches. Follow-ups occurred at 6 weeks and at 3, 6, 9, and 12 months postoperative with a clinical and radiological examination (lateral and AP X-ray).

The fracture was considered union when a visible callus bridging of one cortex was present on both lateral and AP X-rays and the patient was fully weight bearing without pain Fig. 3. Healing within the first 6 months was defined as normal, 6–9 months as delayed, and more than 9 months as nonunion. Malunion was defined as the malalignment greater than 5° in any plane. Soft tissue outcome was assessed by history of wound infection, wound dehiscence, plate impingement, and plate removal. American Orthopaedic Foot and Ankle Score (AOFAS), time back to walking without crutch were used to assess the functional outcome.

2.3. Statistical analysis

Descriptive analyses were conducted regarding all patients participating in this study. Continuous variables such as including age, time until surgery, operative time, postoperative inpatient treatment time, AOFAS score, time back to walking without crutch were reported as means and standard deviations.

3. Results

Summary characteristics of the patients enrolled in the study are reported in Table 1. The average age of the patients was 44 years (range: 19–74 years). The study included 70 adult patients (53 male and 17 females). 36 patients had a history of smoking and 14 patients had a history of diabetes mellitus. The average duration of follow-up was 1.9 years (range: 8 months–3.3 years). Fifty-seven cases were high-energy fractures due to road traffic accident or fall from a height, and 13 cases had low-energy trauma. Eleven cases were open fractures. There were 4 cases grade I and 7 cases grade II. Twenty two of the 59 closed fractures got severe soft tissue injury. The fractures were classified by AO/ASIF classification. All fractures were located in the distal third of the tibial shaft and distal tibia (regions 42 and 43 of AO/ASIF classification). Fracture lines usually were in both regions, so we grouped them to 4 groups: 5 cases simple fractures (42A, 43A1); 24 cases wedge fracture (42B, 43A2); 33 cases complex fractures (42C, 43A3); 8 cases completed articular fracture, articular simple (43C1, 43C2). Sixty-three cases involved 59 closed fractures and 4 open fractures were definitive fixed by MIPPO technique using medial distal tibial plates. The mean time from injury until surgery was 5.5 days (range 0–14 days). Seven cases were not suitable for primary osteosynthesis with locking plates, so they were temporarily fixed with bridging external fixators. They were changed by locking the plates with MIPPO technique in the mean of 5 weeks (range 4–6 weeks). In 39 cases, the distal fibular fracture was involved. These fibular fractures were performed ORIF using plates and screws or K-wires prior to tibial plating. Closed reduction achieved tibial anatomical alignment in 58 fractures and open reduction was required in the remaining 12 fractures. Open reduction was performed through a small incision directly to the displaced fracture line or through the wound of an open fracture.

The clinical intervention data are shown in Table 2. No case was added primary bone grafting. Anatomical alignment (varus or valgus angulation <5°, internal or external rotation <5°) was achieved in all cases. The mean operative time was 65 min (range 40–120). The mean postoperative inpatient treatment time was 4.5 days (range: 3–9 of 69 cases), but one case had 35 days inpatient because of the fibular plating wound dehiscence. The average time of full weight bearing was 8.5 weeks post-operation (range: 5–13 weeks). The time back to walk without a crutch ranged from 8 to 18 weeks (average 12.5 weeks). The minimal follow-up time was 8 months, all of the 70 fractures were union.
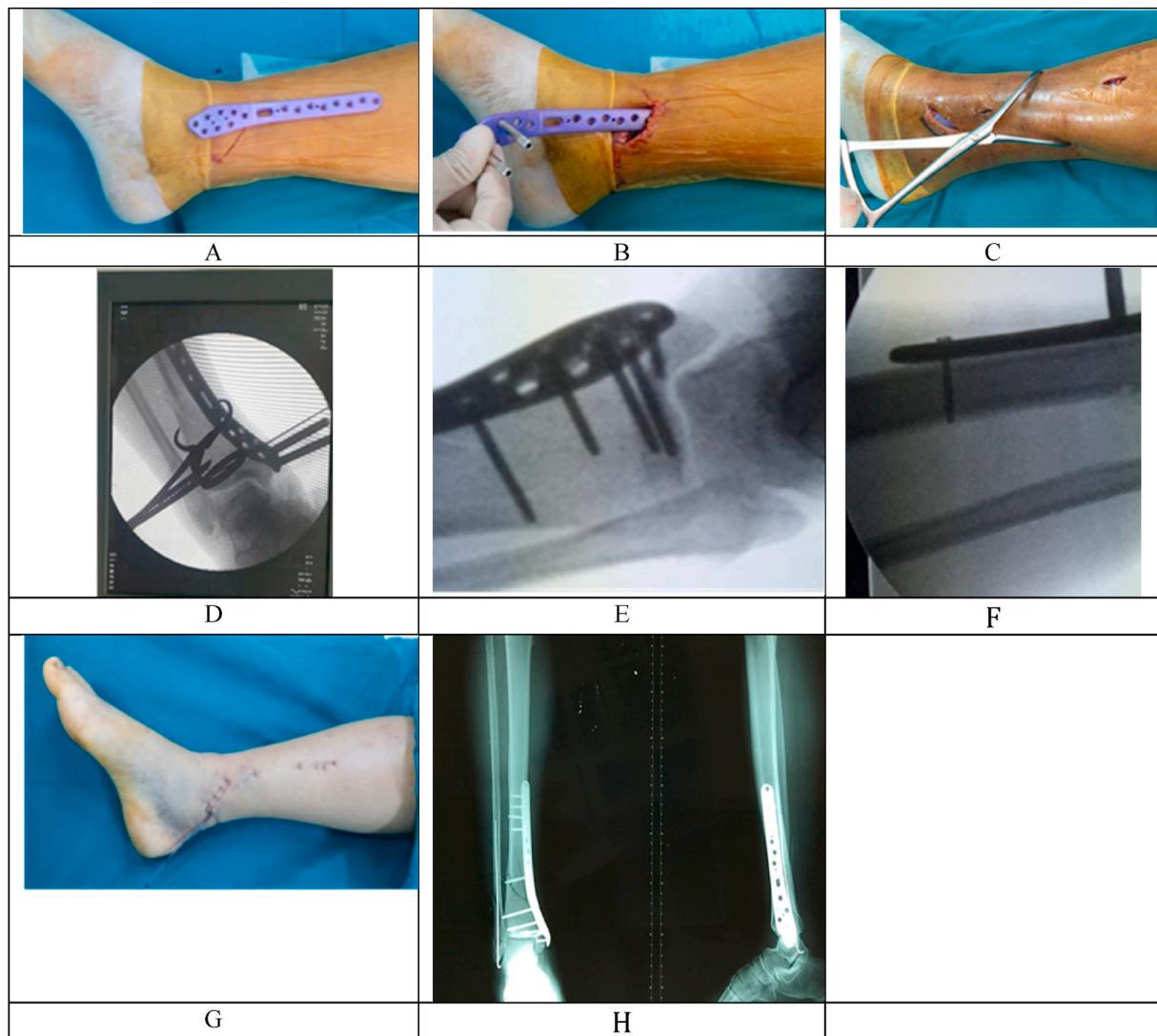
Fig. 2. Steps of minimally invasive medial plate osteosynthesis for distal metaphyseal tibia fracturesNote
A) Skin incision and medial tibial locking plate; B) Insert plate subcutanously; C) Closed reduction of tibia using pointed forcept; D) Using C-arm to check the reduction results; E) Insert screws at the distal tibia and using C-arm to check; F) Insert screws percutanously at the middle third of the tibia; G) Closure of skin incision; H) Post-operative X-rays.

The mean time to union was 15.3 weeks (range: 12–19 weeks). The healing processes had ensured anatomical alignment without rotation (>5°), shortening (>1 cm), or varus/valgus (>5°) deviation when compared to the other leg. The range movement of ankle of all patients was restored. The mean AOFAS score was 89 at a mean of 15 months follow-up.

3.1. Complications

One case had 35 deep fibular plating wound infection. This was treated by intravenous antibiotic. Seven old patients had late wound infection over three months postoperative. All of them were superficial infection in the medial shin area. All of them were closed tibial fracture. The onset of infection ranged from three to 14 months. Four of them presented as cellulitis. They were treated by oral antibiotics for two weeks. The other three late infection cases presented as subcutaneous abscess or discharging sinus. One out of these cases was occurred after tibial union and two of these cases occurred during healing period of tibial fracture. They needed incision and drainage with removal of implant. The union of tibial fracture and the rehabilitation was not greatly affected by late infection. Nine old patients had broken screws

four to six months postoperative but these patients were not symptomatic and thus refused further surgery. Skin impingement by the implants were occurred in 14 old patients. Malunion or nonunion of tibia was not encountered.

4. Discussion

Fractures in tibial distal metaphyseal often associated with significant soft tissue injury. The key point in the management of this injury was to recognize the importance of the soft tissue component. Failing to appreciate the soft tissue condition would invariably complicate the injury with infection, wound dehiscence or nonunion [9].

Hasenboehler E. et al. [10] have excluded from primary osteosynthesis with locking compress plate (LCP) for all cases who were open fractures, deep abrasion with skin or muscle contusion, crush injury with severe damage to underlying muscle, subcutaneous avulsion, heavy contamination with extensive soft tissue damage ….Temporary fixation was achieved with an external fixator in those cases. Initial plate osteosynthesis or exchange external fixator by locking the plate was only advisable when the soft tissue allowed it, when the 'wrinkle sign' was evident.

Fig. 3. Pre-opertive image and post-operative image.
Note: A) Pre-operative X-rays; B, C) Post-operative X-rays; D,E) 18 months post-operative X-rays. F) 18 months post-operative image of leg.

Our protocol in the management of distal metaphyseal tibial fracture consisted of soft tissue assessment prior to surgery, although MIPPO techniques could have a biological advantage over open reduction and internal fixation (ORIF), especially when dealing with critical soft tissue conditions. In our study, an osteosynthesis operation was performed when the soft tissue conditions at the distal one-third of the leg allowed. In case the soft tissue at the medial aspect of leg was severe damage, another approach and different hardware devices and surgical techniques were chosen. The mean time of 5.5 days (63 patients) and 5 weeks (7 patients were applied temporary external fixator) waiting for plate osteosynthesis was due to soft tissue conditions. In a study of Hazrika, S. et al. [11], there were eight cases of open fractures and 12 cases of closed fractures. The median number of days between admission and definitive fracture fixation was 10 days. In cases unused temporary external fixation, no patient waited more than eight days before definitive treatment. Thirteen patients had temporary fracture stabilization

Table 1
Characteristics of the 70 patients enrolled in the study.

	N or mean (SD)
Age (Years)	44 (14–74)
Sex	
Male	53
Female	17
Mechanical injury	
High-energy fractures	57
Low-energy fractures	13
Fracture type	
Simple fractures (42A, 43A1)	5
Wedge fractures (42B, 43A2)	24
Complex fractures (42C, 43A3)	33
Completed articular fractures, articular simple (43C1, 43C2)	8
Closed fracture	59
Open fracture (Gustilo- Anderson classification)	11
Grade I	4
Grade II	7
Duration from initial injury to operation in days	5.5 (0–14)
Fibula fracture	39
Primary tibial osteosynthesis with locking plates	63
Secondary tibial osteosynthesis with locking plates	7
Fixation of fibula	39
Closed tibial reduction	58
Open tibial reduction	12
The mean operative time (minutes)	65 (40–120)
The mean postoperative inpatient treatment time (days)	4.5 (3–9)

Table 2
Mean clinical and X-rays data after intervention.

	N or mean (SD)
Tibial union	70
Fracture healing time (weeks)	15.3 (12–19)
Delayed union	0
Non union	0
Fibula union	39
Anatomical alignment	
Varus or valgus angulations <5°	70
Internal or external rotation <5°	70
Recurvatum<5°	70
Procurvatum<5°	70
Primary wound healing	70
Wound dehiscence	1
Late wound infection	4
Skin impingement	14
Full weight bearing time (weeks)	8.5 (5–13)
Time to walk without crutch (weeks)	15
Plate bending or breakage	0
Screw breakage	9
AOFAS score (points)	89
Follow-up (months)	
Restriction of foot's dorsiflexion (⁰)	0
Restriction of foot's plantarflexion (⁰)	0
Tibial union	70
Fracture healing time	
Delayed union	0
Non union	0
Fibula union	0
Anatomical malalignment	
Varus or valgus angulations >5°	0
Internal or external rotation >5°	0
Shorten > 1 cm	0

with an external fixator prior to osteosynthesis with LCP. In the report of Hasenboehler E. et al. [10] with 32 patients (24 closed and 8 open fractures), the mean time until surgery was 3.15 days (range 0–13 days).

As reported by Borrelli et al. [12], the risk of disrupting blood supply was increased with the classic approach ORIF in the metaphyseal region of the tibia. Evidence showed that ORIF could often be complicated by infection and wound dehiscence. Previously published infection rates in the management of this injury ranged from 0% to 50%. ORIF had the highest infection rates compared with other methods of treatment [1,9,

13]. Intramedullary nailing techniques had been shown to reduce soft tissue complications, but increase the rate of malunion and nonunion. Fractures in tibial distal metaphyseal were sometimes unsuitable for intramedullary nailing [3,7].

In our series, all fracture stabilization was achieved with a 3.5 mm medial distal tibial locking plate. Osteosynthesis with intramedullary locking nails was not suitable for these fractures. MIPPO technique was an advantageous and feasible alternative for these fractures. Osteosynthesis using a medial distal tibial locking plate could minimize soft tissue compromise and devascularization of the fracture fragments [13,14].

Primary tibial osteosynthesis using MIPPO technique was performed in 63 cases. Fifty-eight closed fractures were performed with closed indirect reduction. A closed tibial fracture, and four grade I open tibial fractures were reduced through the wound or a small incision directly to a displaced fragment. Seven of the 11 open fractures had a bridging external fixator applied prior to definitive treatment due to the wound condition. Open direct reduction was performed during the external fixating operation. When exchanging by locking plates, minimal invasive percutaneous plating was applied firstly, then the external frame was removed. Post osteosynthesis, satisfactory anatomical alignment was observed in all cases (varus or valgus angulation <5°, internal or external rotation <5°).

As shown by Gupta, R.K. et al. [1], pre-contouring was required for all locking plates to approximately match the contour of the distal tibia in all 80 fractures. Even so, 20 pre-contoured distal medial tibial LCPS were required extra correction of the contour. We did not bend the plate to correct the plate contour in our patient group. It was not mandatory for the plates to be contoured as there was no necessity to ensure an exact fit to the bony contour. Mechanically, a locked construct did not require a friction fit of the plate against the bone [5,13–15]. Intercus's medial distal tibia locking plate has a suitable contour for the medial metaphyseal tibia, so we could correct the fracture's alignment by using a reduction screw through and based on the plate. However, skin impingement by the implants was occurred in 14 cases in our series, who were old patients with short stature or had previous ankle trauma.

It was usually difficult to achieve compression of the gap's fracture with percutaneous plate osteosynthesis technique [5,9]. In our study, the locking plate was used as a bridging construct across the fracture and it preserved the periosteal circulation. Eight of the 70 cases had articular fractures. In these cases, the platform of the tibia had been reduced and temporarily fixed with K-wires before MIPPO technique was performed.

The appropriate length of the plate was chosen to allow at least three locked screws to be placed proximal to the fracture. We applied at least two bi-cortical locked screws and one mono-cortical screw per proximal tibial fragment. Minimal amounts of three locked screws were applied at the distal tibial fragment. No case with broken plate was noted in our study but nine patients had broken screws about four to six months postoperative. These patients were old patients without symptomatic and thus refused further surgery. Gautier E. and Sommer C [5]. recommended at least two screws per main fragment with purchase of at least three cortices for simple fractures and at least two screws per main fragment with purchase of at least 4 cortices for comminuted fractures. One case with plate bending of more than 18° was observed in the study of Hasenboehler E. et al. [10], but mobilization with partial weight bearing of 32 patients started on the mean of 2.75 days (range 1–12) postoperatively. Bahari S. et al. [1] met one case of hard-ware failure of 42 distal tibial locking plates. One of the proximal screws was broken but the overall alignment and angulation was maintained.

In our series, all of the 70 fractures were anatomical alignment, union without rotation (>5°) or shortening (>1 cm), or varus/valgus (>5°) deviation. The mean time back to walk without a crutch was 12.5 weeks postoperatively (range: 8–18). The mean time of fracture healing was 15.3 weeks, without bone grafting. Gupta R.K. et al. [1] performed primary bone grafting in five cases to fill up the gap at the fracture site and secondary bone grafting in three cases of delayed union and nonunion.

We found that distal tibial locked plating allowed early active range of ankle movement and without immobilization postoperative. Sixty-seven patients were estimated at more than one year postoperative. The mean AOFAS score was 89 at a mean of 15 months follow-up. It was the same with Bahari's series [1].

Wound infection was of concerns when operated with locking plates. Average rate of infection in literature was 5–15%. In Guo's series, the rate of wound complications in LCP group was 14.6%. In our research, one case had deep fibular plating wound infection, this was treated by daily dressing and two weeks of intravenous antibiotics There were some articles about minimally invasive medial plate osteosynthesis for distal metaphyseal tibial fractures. However, few studies reported detailly about complications, especially the late wound infection. Lau [16] reported late infection rate of 15%, all of them were superficial infection in the medial shin area and occurred 2–12 months post-operative. In our series, seven patients had late wound infection over three months postoperative. All of them were older than 65 years old. The onset of infection ranged from three to 14 months. Four of them presented as cellulitis. They were treated by oral antibiotics for two weeks. The other three late infection cases presented as subcutaneous abscess. One out of these cases was occurred after tibial union and two of these cases occurred during healing period of tibial fracture. They needed incision and drainage with removal of implant after tibial union. They all responded well. We agreed with Lau [16] that once abscess was formed, surgical incision and drainage were needed together with intravenous antibiotics for the acute phase. The wound was then managed by daily dressing until it granulates. Removal of the implant in an acute situation was rarely required. The decision should be based on the clinical response of the initial management and the stage of bone healing. In our experience, the union of tibial fracture and the rehabilitation was not greatly affected by late infection.

Malunion is an uncommon complication after LCP. Rate of malunion in literature varies from 0 to 5% [16,17]. Delayed union and nonunion had been reported to be 5–16%, that required a reoperation [4]. Implant failure had been reported to be 2–6%. Plate bending or breakage was often associated with malalignment, delayed or nonunion rate [16,17]. In our research, malunion or nonunion of tibia were not encountered. Nine patients had broken screws four to six months postoperative but these patients were not symptomatic and thus refused further surgery and the tibial alignment was maintained.

Hardware prominence and pain due to impingement of the implant on the skin was common. Gao [18] suggested locking plates had to gain adequate fixation and a perfect match between the plate and the distal part of the tibia, which in turn may further reduce tension in the soft tissue. Skin impingement by the implants was occurred in 14 cases in our series, who were old patients with short stature or previous ankle trauma. In Vietnam, all locking plate were made in Eastern country so the shape and size of locking plate was not suitable with distal tibial anatomy. We advised to use more suitable locking plate for Vietnamese patients, for preventing skin impingement, especially in patients who had short stature or previous ankle trauma.

The great saphenous vein and nerve injury could be occurred, so it was careful to identify during surgery and apply adequate drill sleeve placement. No case of saphenous nerve or vein injury was occurred in our series.

Our study had some limitations. The number of patients with open fracture was small and their follow-up was long. Further research should be based on the larger sample size and longer follow-up time.

5. Conclusion

We found that osteosynthesis of the distal metaphyseal tibial fracture using a medial distal tibial locking plate with MIPPO technique was safe and effective. This technique could help patients to resume their function early. The mean AOFAS score was 89 at a mean of 15 months follow-up. Our research showed that late wound infections were the

quite common complications in old patients but it could be simply resolved. In our experience, removal of the implant in an acute situation was rarely required; the union of tibial fracture and the rehabilitation was not greatly affected by late infection. We advised to use more suitable anatomy locking plate for Vietnamese patients, for preventing skin impingement, especially in patients who had short stature or previous ankle trauma.

Consent

Written informed consent was obtained from the patient for publication of this case series and accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal on request.

Author statement

L.V.N designed and conceptualized the study.
L.V.N, B.N.L, G.N.N, H.M.B conducted the data analysis, interpreted the results, and prepared the manuscript. All authors contributed to a critical revision of the manuscript regarding important intellectual content and read and approved the final manuscript.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Registration of research studies

Name of the registry: Research Registry.
Unique Identifying number or registration ID: researchregistry7138.
Hyperlink to our specific registration https://www.researchregistry. com/browse-the-registry#home/registrationdetails/6138d7 e4b565ed001e20e52e/.

Availability of data and materials

The data used to support the findings of this study are available from the corresponding author upon request.

Guarantor

Dr. Luong Van Nguyen
luongnv108@gmail.com.

Declaration of competing interest

The authors declare that they have no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amsu.2021.102886.

References

[1] S. Bahari, B. Lenehan, H. Khan, J.P. McElwain, Minimally invasive percutaneous plate fixation of distal tibia fractures, Acta Orthop. Belg. 73 (5) (2007) 635–640. PubMed PMID: 18019921.

[2] W. Cheng, Y. Li, W. Manyi, Comparison study of two surgical options for distal tibia fracture-minimally invasive plate osteosynthesis vs. open reduction and internal fixation, Int. Orthop. 35 (5) (2011) 737–742, https://doi.org/10.1007/s00264-010-1052-2. PubMed PMID: 20517695; PubMed Central PMCID: PMC3080491.

[3] A.K. Bhat, S.K. Rao, K. Bhaskaranand, Mechanical failure in intramedullary interlocking nails, J. Orthop. Surg. 14 (2) (2006) 138–141, https://doi.org/10.1177/230949900601400206. PubMed PMID: 16914776.

[4] C.A. Collinge, R.W. Sanders, Percutaneous plating in the lower extremity, J. Am. Acad. Orthop. Surg. 8 (4) (2000) 211–216, https://doi.org/10.5435/00124635-200007000-00001. PubMed PMID: 10951109.

[5] E. Gautier, C. Sommer, Guidelines for the clinical application of the LCP, Injury 34 (Suppl 2) (2003) B63–B76, https://doi.org/10.1016/j.injury.2003.09.026. PubMed PMID: 14580987.

[6] E.N. Kubiak, E. Fulkerson, E. Strauss, K.A. Egol, The evolution of locked plates, J. Bone Jt. Surg. Am. Vol. 88 (Suppl 4) (2006) 189–200, https://doi.org/10.2106/JBJS.F.00703. PubMed PMID: 17142448.

[7] R.V. Cantu, K.J. Koval, The use of locking plates in fracture care, J. Am. Acad. Orthop. Surg. 14 (3) (2006) 183–190, https://doi.org/10.5435/00124635-200603000-00009. PubMed PMID: 16520369.

[8] R.A. Agha, C. Sohrabi, G. Mathew, T. Franchi, A. Kerwan, N. O'Neill, et al., The PROCESS 2020 guideline: updating consensus preferred reporting of CasESeries in surgery (PROCESS) guidelines, Epub 2020/11/16, Int. J. Surg. 84 (2020) 231–235, https://doi.org/10.1016/j.ijsu.2020.11.005. PubMed PMID: 33189880.

[9] D.L. Helfet, P.Y. Shonnard, D. Levine, J. Borrelli Jr., Minimally invasive plate osteosynthesis of distal fractures of the tibia, PubMed PMID: 10897286, Injury 28 (Suppl 1) (1997) A42–A47, https://doi.org/10.1016/s0020-1383(97)90114-5. discussion A7-8.

[10] E. Hasenboehler, D. Rikli, R. Babst, Locking compression plate with minimally invasive plate osteosynthesis in diaphyseal and distal tibial fracture: a retrospective study of 32 patients, Injury 38 (3) (2007) 365–370, https://doi.org/10.1016/j.injury.2006.10.024. PubMed PMID: 17241634.

[11] S. Hazarika, J. Chakravarthy, J. Cooper, Minimally invasive locking plate osteosynthesis for fractures of the distal tibia–results in 20 patients, Injury 37 (9) (2006) 877–887, https://doi.org/10.1016/j.injury.2006.06.002. PubMed PMID: 16895727.

[12] J. Borrelli Jr., W. Prickett, E. Song, D. Becker, W. Ricci, Extraosseous blood supply of the tibia and the effects of different plating techniques: a human cadaveric study, J. Orthop. Trauma 16 (10) (2002) 691–695, https://doi.org/10.1097/00005131-200211000-00002. PubMed PMID: 12439191.

[13] S.V. Paluvadi, H. Lal, D. Mittal, K. Vidyarthi, Management of fractures of the distal third tibia by minimally invasive plate osteosynthesis - a prospective series of 50 patients, Journal of clinical orthopaedics and trauma 5 (3) (2014) 129–136, https://doi.org/10.1016/j.jcot.2014.07.010. PubMed PMID: 25983486; PubMed Central PMCID: PMC4223765.

[14] K.A. Egol, E.N. Kubiak, E. Fulkerson, F.J. Kummer, K.J. Koval, Biomechanics of locked plates and screws, J. Orthop. Trauma 18 (8) (2004) 488–493, https://doi.org/10.1097/00005131-200409000-00003. PubMed PMID: 15475843.

[15] T.C. Lai, J.J. Fleming, Minimally invasive plate osteosynthesis for distal tibia fractures, Clin. Podiatr. Med. Surg. 35 (2) (2018) 223–232, https://doi.org/10.1016/j.cpm.2017.12.005. PubMed PMID: 29482791.

[16] T.W. Lau, F. Leung, C.F. Chan, S.P. Chow, Wound complication of minimally invasive plate osteosynthesis in distal tibia fractures, Epub 2007/06/19, Int. Orthop. 32 (5) (2008) 697–703, https://doi.org/10.1007/s00264-007-0384-z. PubMed PMID: 17572892; PubMed Central PMCID: PMCPMC2551726.

[17] J.J. Guo, N. Tang, H.L. Yang, T.S. Tang, A prospective, randomised trial comparing closed intramedullary nailing with percutaneous plating in the treatment of distal metaphyseal fractures of the tibia, Epub 2010/07/03, The Journal of bone and joint surgery British 92 (7) (2010) 984–988, https://doi.org/10.1302/0301-620X.92B7.22959. PubMed PMID: 20595119.

[18] D. Gao, B. Jia, J. Zheng, [Case-control study on minimally invasive percutaneous anatomic plate osteosynthesis for the treatment of distal tibia fracture], Zhong Guo Gu Shang 25 (3) (2012) 194–197. Epub 2012/06/21. PubMed PMID: 22712366.