Original Article

Clinical and Radiological Outcome of the Locked Plate Osteosynthesis in Distal Metadiaphyseal Tibial Fracture According to the Severity of Comminution: Varus Reduction Would not be Preferable with Lower Clinical Outcomes

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Abstract

Background: The optimal treatment for distal tibial fractures remains a matter of debate. Nonetheless, plate osteosynthesis produces favorable results to intramedullary stabilization in aspects of alignment restoration. **Aim:** The aim of the study was to compare the radiologic and clinical outcomes of distal metadiaphyseal tibial fracture between a simple/wedge fracture (SWF) and a comminuted fracture (CF) using minimally invasive plate osteosynthesis (MIPO). **Patients and Methods:** This retrospective study analyzed patients with SWF or CF of the distal tibial metadiaphysis that was surgically treated with a locking compression plate. Postoperative radiographic assessments and the time to radiologic union were noted. Clinical assessments were evaluated using both the American Orthopedic Foot and Ankle Society (AOFAS) ankle–hindfoot score and the foot function index (FFI). Postoperative complications were documented. **Results:** Seventy-one cases were analyzed over a mean follow-up period of 20.9 months. Thirty-six patients had SWF and 35 patients presented with CF. The mean time to radiologic union, amounts of postoperative coronal angulation, and incidence of malunion showed no statistical differences. Fibular fixation was more applied in the CF group ($P < 0.001$). Moreover, the clinical scores revealed no differences. Nonetheless, in the valgus union group, the AOFAS ankle–hindfoot score was 90.9 compared to 84.1 in the varus union group ($P = 0.042$) and the FFI was 9.2% compared to 20.2% in the varus union group ($P = 0.017$). **Conclusion:** Plate osteosynthesis for SWF or CF of the distal tibial metadiaphysis led to high union rates and good clinical outcomes. There was no significant difference in the radiologic and clinical results according to the presence of fracture comminution. Nonetheless, the valgus union group showed better clinical outcomes than the varus union group. Clinically, it would be preferred to avoid intraoperative varus reduction.

Keywords: *Comminution, distal metadiaphyseal tibial fracture, minimally invasive plate osteosynthesis*

Introduction

The distal tibia has anatomical features of relatively thin soft tissue envelope and poor blood supply.[1] Fractures of distal tibia are often severely comminuted by high-energy damage, and open wounds are accompanied.[2] Due to the frequency of complications including delayed union, nonunion, and wound problems after surgery, it is crucial to select an appropriate treatment strategy. The optimal treatment for distal tibial fractures remains a matter of debate.

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[3] While conservative management may be adequate, surgical treatment remains the mainstay of treatment.[4] It can be considered with intramedullary nailing or plate osteosynthesis for this type of fracture.[5] Minimally invasive plate osteosynthesis (MIPO) with locking plates has shown good results for these patients.[6] Traditionally, plate osteosynthesis produces favorable results to intramedullary stabilization in aspects of alignment restoration.[5,7] Nevertheless, indirect reduction with MIPO makes restoration of anatomical alignment difficult, which often leads to malunion and angular deformities.[8] Although comminuted fractures (CFs) are common, few studies have analyzed the radiologic and clinical results of CFs repaired with MIPO. The purpose of this study was, therefore, to compare the clinical and radiologic outcomes of MIPO according to the presence of comminution in the treatment of distal metadiaphyseal tibial fractures. It was hypothesized that there would be no difference in the clinical and radiologic results of simple/wedge fracture (SWF) and CF.

Materials and Methods

This study was approved by the institutional review board of our institution (IRB File No. 2020-10-035). Our study population included those with distal metadiaphyseal tibial fracture treated with a locking plate at a single center from February 2017 until July 2020. The inclusion criteria were as follows: (1) distal metadiaphyseal tibial fracture AO (Arbeitsgemeinschaft für Osteosynthesefragen) / OTA (Orthopaedic Trauma Association) classification 42A, 42B, 42C, 43A, 43B, 43C1, 43C2)[9]; (2) 18 years of age or older and maturation of physis; and (3) closed fracture or Gustilo–Anderson type I or II open fracture. The exclusion criteria was as follows: (1) pilon fracture (AO/OTA classification 43B3, 43C3); (2) Gustilo–Anderson type III open fracture; and (3) pathologic fracture. (The IRB approval number is KHNMC 2020-10-035, and the date of approval was November-10-2020).

The fractures were classified into a simple/wedge fracture (SWF) group and a CF group based on the degree of comminution and configuration. Given the major fracture area and the extended configuration, participants were further subclassified according to the AO/OTA classification.[9] The distal medial or lateral locking plate was used depending on the fracture configuration and surgeon preference. At least three locking screws were obtained to fix the proximal diaphysis, while at least five locking screws were purchased in the distal metaphysis. For all open fractures, urgent debridement of contaminated tissue and massive irrigation were performed. Then, definitive fixation and simultaneous wound closure were done. If the fibular fracture was accompanied at the level of distal third or the stability of the ankle mortise was not ensured, combined fibular fixation was performed. Fibular fixation was carried out before tibial fixation to facilitate the restoration of alignment. For the medial plating, on the anterior border of medial malleolus, distal skin incision of 4–5 cm in length was applied. Along the medial surface of tibial shaft, proximal incision of 3–4 cm in length was performed at the level of uppermost three holes. For the lateral plating, on the border of Chaput tubercle at the distal tibia, skin incision was applied. After the blunt dissection with a locking plate from the distal to the proximal window, a supraperiosteal tunnel was prepared. Reduction was achieved indirectly under the control of image intensifier, and bridge plating was performed after a satisfactory reduction was observed [Figure 1].

All patients followed the same rehabilitative protocol postoperatively. A removable splint was applied in both groups for 6 weeks postoperatively; active ankle motion was encouraged after wound stabilization. Tolerable weight load with a crutch was allowed at 6 weeks postoperatively. Then, subsequent progression to full weight load was permitted. Follow-up visits were routinely obtained with radiographic examination at 6 and 12 weeks and at 6 and 12 months postoperatively. At that time, an annual follow-up was recommended.

Radiographic outcomes included the restoration of alignment, time until radiologic union, and complications including malunion and nonunion. To assess alignment, the angle formed by the anatomical axis of the tibia and the line parallel to the ankle mortise (i.e., the medial distal tibial angle) was measured and compared with that of the contralateral side [Figure 2]. Radiologic bone union was defined when the bridging callus was presented in at least three cortices on any two planes. Delayed union was identified as bone union obtained over a period of more than 6 months without secondary intervention. Malunion was identified as an angle >5º. All radiologic assessments were carried out by an orthopedic surgeon. The measurements were recorded as the mean value, which was evaluated twice at 4 weeks interval. An intraclass correlation coefficient (ICC) was evaluated by examining the inter- and intra-observer reliabilities. All records were numbered to one decimal place. Clinical outcomes were assessed using the American Orthopedic Foot and Ankle Society (AOFAS) ankle–hindfoot score[10] and the foot function index (FFI)[11] at the last follow-up.

Kolmogorov–Smirnov and Shapiro–Wilk tests were performed to verify the normal distribution of continuous data. Depending on the results, the independent *t*-test or the Mann–Whitney U-test was applied. The Pearson's Chi-square test or Fisher's exact test was used to analyze categorical data. Interobserver reliability was analyzed with the ICC. The Statistical Package for the Social Sciences (SPSS) for Windows, version 20.0 (IBM Corp., Armonk, NY, USA), was used for all statistical analyses. The level of statistical significance was set at 5% ($P \leq 0.05$).

Results

The study comprised 71 cases (35 male and 36 female) with a mean follow-up of 20.9 ± 8.0 (range, 12–41) months. The mean age was 54.0 ± 15.6 (range, 22.0–90.6) years. Depending on the location of fracture, 46 cases were AO/OTA type 42 and 25 cases were type 43. According to the degree of fracture comminution, there were 36 cases in the SWF group and 35 cases in the CF group. There were seven open fractures, of which five were Gustilo–Anderson type I and two were type II. The patient demographics showed no significant differences between the two groups [Table 1].

Fixation of associated fibular fracture was performed in 33 cases (46.5%). Concomitant fibular fixation did not apply in 38 cases: five of an intact fibula, 25 of proximal fibular fracture, and eight of midshaft fracture. Combined fibular fixation was performed more in the CF group ($P < 0.001$). In all cases, bone union was achieved at a mean radiologic union time of 16.8 ± 5.3 (range,

Table 1: Patient demographics and fracture characteristics

	Simple/wedge *n*=36	Comminution *n*=35	*P*
Age, mean±SD, years (range)	49.9±14.1 (22.0-74.3)	55.5±16.1 (26.4-90.6)	0.331[a]
Sex, *n*			0.723[b]
Male	17	18	
Female	19	17	
Follow-up duration, mean±SD, months (range)	20.5±7.6 (12–41)	21.4±8.0 (12–37)	0.682[a]
AO/OTA classification			
42A	19		
42B	11		
42C		16	
43A	5	12	
43B	1	1	
43C		6	
Gustilo-Anderson classification, *n* (%)			
Grade I	2 (5.6)	3 (8.6)	0.260[d]
Grade II	0	2 (5.7)	

[a]Mann-Whitney *U*-test; [b]Pearson's Chi-square test; [c]independent *t*-test; [d]Fisher's exact test. SD=standard deviation

Table 2: Radiographic and clinical outcomes

	Simple/wedge *n*=36	Comminution *n*=35	*P*
Fibular fixation, *n* (%)	8 (22.2%)	25 (71.4%)	<0.001[a]
Anterolateral plating, *n* (%)	0 (0%)	2 (5.7%)	0.239[b]
Radiologic union time (weeks), mean±SD (range)	16.9±6.1 (12-31)	17.1±4.9 (12-26)	0.199[c]
Angulation in the coronal plane, mean±SD (degrees)	1.3±2.7 (−4.2 to 7.1)	1.7±2.4 (−2.9 to 7.6)	0.417[d]
Varus union, *n* (%)	12 (33.3%)	9 (25.7%)	0.585[a]
Clinical outcomes, mean±SD (range)			
AOFAS ankle-hindfoot score	90.3±10.8 (52-100)	88.5±11.9 (52-100)	0.557[c]
FFI (%)	9.0±15.9 (0-68.2)	14.8±22.6 (0-75.9)	0.482[c]
Radiographic complications, *n* (%)			
Malunion	5 (13.9%)	3 (8.6%)	0.710[b]
Nonunion	0	0	
Delayed union	1 (2.9%)	0	1.000[b]
Infection	0	1 (2.9%)	0.493[b]

AOFAS=American Orthopedic Foot and Ankle Society, FFI=foot function index, SD=standard deviation. [a]Pearson's Chi-square test; [b]Fisher's exact test; [c]Mann-Whitney *U*-test; [d]independent *t*-test

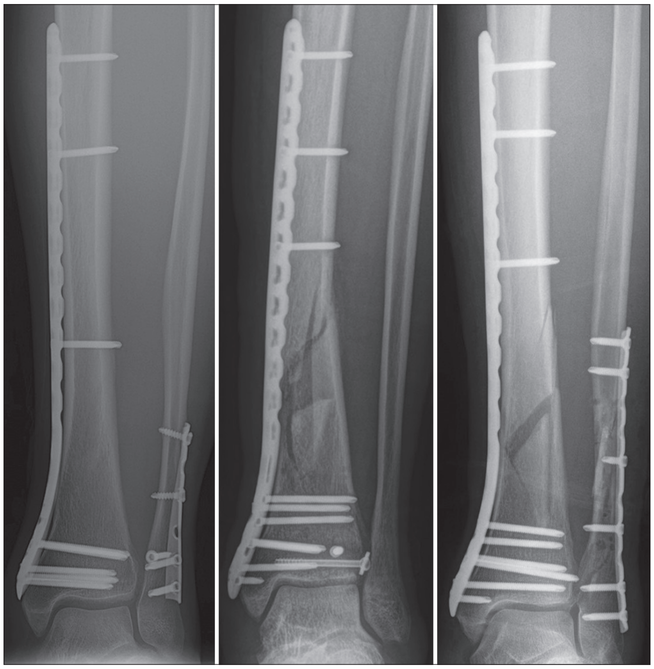

Figure 1: Various constructs of bridge plating according to the fracture configurations

12–31) weeks. The mean coronal plane angular deformity was valgus 1.3° ± 2.6° (range, -5.2° to 7.6°), with no significant difference between the two groups (P = 0.417). The ICC was 0.916 for coronal angular deformity.

There were totally eight cases (11.3%) of malunion, and mean coronal angulation was 4.8 ± 4.1 (range, −5.1 to 7.6). Their mean AOFAS ankle–hindfoot score and FFI score were 82.6 ± 25.1 (range, 32–100) and 21.2% ± 30.6% (range, 0–75.9%), respectively [Table 2].

Forty-eight cases with valgus union showed a mean of 2.6° ± 1.9° (range, 0.2°–7.6°) angulation, and 21 cases with varus union showed a mean of − 1.5° ± 1.2° (range, −4.2° to − 0.2°) angulation. The valgus union group showed better clinical outcome scores: the mean AOFAS ankle–hindfoot scores were 90.9 ± 8.9 (range, 62–100) in valgus union group and 84.1 ± 16.1 (range, 52–100) in varus union group (P = 0.042). The mean FFI scores were 9.2% ± 17.7% (range, 0–75.9%) in valgus union group and 20.2% ± 24.5% (range, 0–68.2%) in varus union group, which showed significant difference (P = 0.017).

Additionally, there was one case of infection in the CF group. Despite proper wound management and antibiotic administration, a skin ulcer developed. Thus, a bipedicled flap was performed to manage the skin ulcer and plate conversion to the lateral side of the tibia.

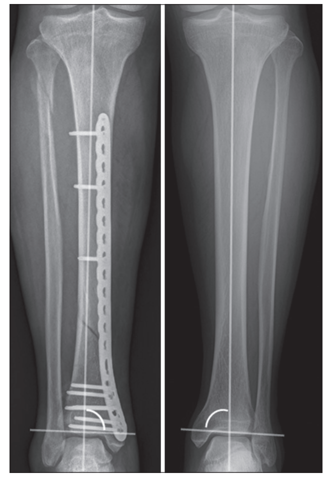

Figure 2: To assess distal tibial alignment in the coronal plane, the angle formed by the anatomical axis of the tibia and the line parallel to the ankle mortise was measured and compared with that of the contralateral side

Discussion

In this study, good radiologic and clinical outcomes were obtained using MIPO for distal metadiaphyseal tibial fracture. A comparison was made by dividing participants into SWF and CF groups, and there was no significant difference in radiologic union time or frequency of malunion; frequency of fibular fixation was significantly higher in the CF group. Those with valgus union showed better clinical outcome scores than those with varus union, regardless of fracture comminution.

Radiologically, the proximal and distal end segments of the tibia are defined as a square and the length of its side has the same length as the widest area of the epiphysis/metaphysis (Heim's system of squares). The diaphysis is the part between the two end segments and is divided into three equal parts.[9] Based on this classification, distal one third diaphyseal tibial fractures (AO/OTA 42) and fractures that extended to the distal end segment (AO/OTA 43) were included in the present study. The SWF and CF groups were categorized according to the degree of comminution. The AO/OTA type 42A and 42B fractures were divided into the SWF group, and 42C fractures were placed in the CF group. Of the type 43A fractures, 43A1 and 43A2 were placed in the SWF group and 43A3 fractures were placed in the CF group. The 43B and 43C types only included simple/partial articular fracture types after excluding the pilon fractures caused by different injury mechanisms and were divided into two groups based on the degree of comminution.

A variety of methods can be considered for management of distal metadiaphyseal tibial fractures, including conservative treatment, external fixation, intramedullary nailing, and plate osteosynthesis. Of these, intramedullary nailing and plate osteosynthesis primarily have been considered the definitive treatments.[12] Many studies comparing the two treatments and their advantages and disadvantages have been described.[5,7,13-17] Intramedullary nailing would be considered the optimal treatment for tibial diaphyseal fracture. However, it is difficult to manage fractures involving a distal metaphysis due to the difficulty of adequate reduction and rigid fixation that can result from metaphyseal widening and the presence of a long lever arm. Thus, many studies have advocated for plate osteosynthesis to treat fractures involving the tibial metaphysis. Moreover, plate osteosynthesis has evolved and is more widely used due to the technological advances of locking plates and the availability of minimally invasive techniques.[18,19]

Various studies have reported on radiologic union time. Most studies that used plate osteosynthesis with a locking plate showed satisfactory union in about 17–24 weeks.[14,20] In this study, radiologic union was confirmed at a mean of 16.8 weeks, which was not different from the findings of previous studies. One delayed union case was examined 1 month after the scheduled follow-up at 6 months, which can be considered a characteristic of the retrospective study.

The malunion rate of this study was similar to the previous reports. Several studies that investigated the issue of malunion after locked plate osteosynthesis have shown an incidence of 0–18%.[14,16,20-22] There were no significant differences in the incidence of malunion between the two groups, which is thought to be more helpful in tibial reduction since fibular fixation was performed more frequently in the CF group. The criteria for malunion of tibial shaft fractures are different for each report, but an alignment of 5° or more is generally accepted. However, these criteria have not been adequately validated with well-designed studies, and the results of long-term follow-up are still lacking. Some previous authors had reported that small angular deformities of the tibia are significantly related to functional loss,[23] but opposite results were presented in later reports. Merchant and Dietz reported the clinical and radiographic outcomes were not affected by the amounts of angulation in long-term follow-ups.[24] Theriault *et al.*[25] have reported that malrotation of the tibia over 10° has no significant intermediate-term functional impact. In the present study, there was no difference in clinical outcomes between the groups even when assessed with a validated scale. In addition, it did not lead to secondary procedures including corrective osteotomy.

Controversy exists regarding combined fibular fixation in the treatment of distal tibial fractures. The absence of a fibula fracture is related to increased risk of nonunion and malunion of tibial fractures.[26] It could be suggested by weight transmission through the intact fibula rather than the injured tibia, which prevent cyclical loadings on the tibia, which is essential for fracture healing. Egol *et al.*[27] have reported that concomitant fibular fixation in distal tibial fractures is associated with immediate restoration of postoperative alignment and decreased malunion at follow-up. Likewise, Williams *et al.*[28] suggest that fibular fixation in tibia diaphyseal fractures may increase the risk of nonunion. Nevertheless, fibula carries approximately 16% of the static load during weight bearing[29] and has meaningful roles of mortise stability. Thus, the adequacy of fibular fixation is still debated. In this study, fibular fixation was performed more frequently in the CF group, which may have affected alignment restoration. In addition, there was no significant difference in union time between the two groups, thus it is difficult to clarify the association of tibial union suppression and fibular fixation.

With regards to varus or valgus alignment, it is known that varus malalignment of the tibia could alter the biomechanics of ankle joint and lead to degenerative changes. In patients with varus ankle osteoarthritis, it is expected that the applied compressive force will be changed by valgus correction by supramalleolar osteotomy. In this regard, it could be explained that the case with varus alignment showed a worse clinical outcome than that of valgus in this study. However, meaningful comparative analysis will be possible with more cases with malalignment exceeding the normal range.

There are some limitations in the present study. It has a retrospective nature and methodological limitations. Further study would be needed in a larger population with a prospective design. More precise radiographic assessment tools such as computed tomography were not applied for alignment evaluation. Nevertheless, this is the first study to compare and analyze the results of different statuses of fracture comminution using a clinically validated scale. The reliability and validity of the FFI have been demonstrated, and a significant correlation with 36-Item Short Form Survey (SF-36) has been reported.[30] Clinically, regardless of the comminution, MIPO for distal tibial metadiaphyseal fracture shows good outcomes and may lead to malalignment, but has little effect on the clinical courses.

Conclusions

The locked plate osteosynthesis for SWF or CF of the distal tibial metadiaphysis led to high union rates and good clinical outcomes. There was no significant difference in radiologic and clinical results according to the presence of fracture comminution. Nonetheless, the valgus union group showed better clinical outcomes than the varus union group. Clinically, it would be preferred to avoid intraoperative varus reduction.

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Conflicts of interest

There are no conflicts of interest.

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