Surgical Treatment of Extra-articular or Simple Intra-articular Distal Tibial Fractures: MIPO Versus Supercutaneous Plating

XIANFENG HE, MD; JINGWEI ZHANG, MD; MING LI, MD; YIHUI YU, MD; LIMEI ZHU, MD

abstract

Minimally invasive plate osteosynthesis (MIPO) has become a widely accepted technique to treat distal tibial fractures. Recently, the novel application of a locking plate used as an external fixator (supercutaneous plating) was introduced for the management of open fractures and infected nonunions and even as an adjunct in distraction osteogenesis, which is considered another less invasive method. The aim of this study was to compare the results of supercutaneous plating with closed reduction and minimally invasive plating in the treatment of distal tibial fractures. Forty-eight matched patients were divided according to age, sex, Injury Severity Score, and fracture pattern into the MIPO group and the supercutaneous plating group. Minimum follow-up was 12 months (mean, 18.5 months; range, 12-26 months). No patient had nonunion, hardware breakdown, or deep infection. Patients in the supercutaneous plating group had a significantly shorter mean operative time (65.6±13.2 vs 85.9±14.0 minutes; P=.000), hospital stay (7.5±2.0 vs 13.0±4.4 days; P=.000), and union time (15.2±2.4 vs 17.0±2.8 weeks; P=.000). In the MIPO group, 15 (62.5%) patients reported implant impingement or discomfort and there was 1 incidence of stripping of 15.6% at the time of locking screw removal, whereas in the supercutaneous plating group, no patient reported skin irritation, and removal of the supercutaneous plate was easily performed in clinic without anesthesia. Distal tibial fractures may be treated successfully with MIPO or supercutaneous plating. However, the supercutaneous plating technique may represent a superior surgical option because it offers advantages in terms of mean operative time, hospital stay, and union time; skin irritation; and implant removal.

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pen reduction and internal fixation for distal tibial fractures can achieve anatomical reduction but may result in delayed union, nonunion, or soft tissue complications. Minimally invasive plate osteosynthesis (MIPO), which involves insertion of the plate through a limited incision, placement of screws through stab incisions, and using the principles of biologic fixation with indirect reduction techniques to reduce the fracture, is believed to decrease the rates of nonunion and lower soft tissue complications because of the undisrupted local fracture environment and limited skin incisions. As a result, percutaneous plate fixation of distal tibial fractures has gained prevalence as a minimally invasive technique.

A locking plate, such as the less invasive stabilization system (LISS) plate (Synthes, Paoli, Pennsylvania), is advocated as an internal-external fixator given its angular stable screw fixation. These properties make it a good candidate for external plate fixation. Recently, the novel application of a locking plate used as an external fixator was introduced for the management of open fractures and infected nonunions and even as an adjunct in distraction osteogenesis. Analogous to so-called submuscular plating, this technique is called supercutaneous plating. However, to date, the supercutaneous plating technique is still not widely accepted and used.

The purpose of this control-matched study was to compare the MIPO technique with the supercutaneous plating technique in the treatment of distal tibial fractures.

**Materials and Methods**

From January 2010 to January 2012, one hundred fifty-eight cases of distal tibial fracture with or without fibular fractures were enrolled in the study with complete follow-up details. Eligible patients were aged from 18 to 60 years and were diagnosed as having a closed distal tibial AO/OTA classification type 42 fracture with or without fibular fracture. Patients were excluded if they had an open distal tibial fracture, pathologic fracture, multiple fractures or injury, or brain trauma. In addition, patients were excluded if they had existing disorders having an effect on the healing process and function, such as multiple sclerosis, paraplegia or other relevant neurologic disorder, or polytrauma with an Injury Severity Score higher than 16. Among them, 24 patients treated with closed reduction and percutaneous plating were matched to 24 patients treated with closed reduction and supercutaneous plating on the basis of sex, age (±3 years), Injury Severity Score, and fracture pattern (AO classification).

**Surgical Technique**

Surgery was performed as soon as possible after presentation if soft tissue conditions permitted. In both groups, the patients were placed in the supine position and administered continuous epidural anesthesia. No tourniquet was used. In the MIPO group, the leg to be operated on was prepared and draped in the usual sterile fashion. If the patient also had a fibular fracture, the posterolateral approach was planned to reduce and stabilize the fracture during supercutaneous plating. If closed functional reduction by manual traction failed, an external frame was prepared and treatment of any fibular fracture was done in the same manner as in the MIPO group. Fractures with articular extension (OTA type 43C) were treated with percutaneous fixation using cannulated screws before supercutaneous plating. If closed functional reduction by manual traction failed, an external frame of the fracture traction table using centrally threaded pins in the calcis was used to reduce and stabilize the fracture during supercutaneous plating (Figure 1). Then a LISS distal femur plate was applied as an external fixator. The position of the LISS external fixator was located on the anteromedial side of the tibia to minimize screw-site problems associated with soft tissue motion. Mechanical stability of the
external fixator increases by placing the plate as close to the bone as possible yet still allowing for some swelling. So the plate was positioned 1 to 2 cm above the skin by temporarily placing a periosteum elevator between the LISS plate and skin. Self-drilling screws strip the near cortex, which might decrease the lifespan of the frame. Therefore, the authors only use locking screws that are predrilled with the appropriate-sized locking drill.

There is little literature describing fixation stability using this new supercutaneous plating technique. Recently, Ma et al. used finite element models of internal plate fixation as well as 2 different external plate fixations for tibial fractures and revealed that axial stiffness and angular stiffness decreased as the offset distance from the bone surface increased. Although unicortical screw fixation has been suggested for standard use of these plates, it seems prudent to option for bicortical fixation when using the plates as an external fixator until biomechanical data for this application provide more insight. Successive holes were drilled over locking drill guides through stab incisions where the overlying soft tissue envelope was intact, and screws were placed. To ensure secure fixation, 4 to 5 screws were placed into both ends of the fractures.

**Intraoperative and Postoperative Care**

All patients underwent surgery in the same hospital by the same group of senior surgeons (all of the authors). In both groups, cefazolin 2 g was used as a prophylactic antibiotic 30 minutes preoperatively and once postoperatively. Patients were encouraged to perform ankle range of motion exercises postoperatively. Partial weight bearing was allowed when radiological evidence of progress toward union was seen, usually at 4 weeks postoperatively. A decision regarding full weight bearing was made on an individual basis, depending on the progression of union. The patients were followed up clinically and radiologically at intervals of 4 weeks until bony union was achieved. They were reviewed at 3, 6, and 12 months and assessed objectively by physical and radiological examination. Fracture healing, delayed union, and nonunion were assessed according to the definition of Im and Tae. The development of a complication was documented at each follow-up visit. The American Orthopaedic Foot and Ankle Society (AOFAS) scoring system was used to evaluate the function of the ankle at 12-month follow-up.

**Statistical Analysis**

Statistical analyses were conducted with SPSS version 13.0 statistical software (SPSS Inc, Chicago, Illinois). Comparison of variables between groups was performed using the paired-samples t test. The frequencies of the data were statistically compared between the groups using Pearson’s chi-square test or Fisher’s exact test. A P value less than .05 was considered significant.

**RESULTS**

Minimum follow-up was 12 months (mean, 18.5 months; range, 12-26 months). Preoperative characteristics of both groups are shown in Table 1. Thirty-five patients had associated fibular fractures and 25 of them had been repaired because of involvement of the ankle joint. Table 2 summarizes the

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**Table 1**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>MIPO Group</th>
<th>Supercutaneous Plating Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age (range), y</td>
<td>36 (20-57)</td>
<td>37 (23-59)</td>
</tr>
<tr>
<td>Male/female, No.</td>
<td>16/8</td>
<td>16/8</td>
</tr>
<tr>
<td>AO fracture classification, No.</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>43-A</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>43-B</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Abbreviation: MIPO, minimally invasive plate osteosynthesis.

**Table 2**

<table>
<thead>
<tr>
<th>Variable</th>
<th>MIPO Group</th>
<th>Supercutaneous Plating Group</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean±SD operative time, min</td>
<td>85.9±14.0</td>
<td>65.6±13.2</td>
<td>.000</td>
</tr>
<tr>
<td>Mean±SD hospital stay, d</td>
<td>13.0±4.4</td>
<td>7.5±2.0</td>
<td>.000</td>
</tr>
<tr>
<td>Mean±SD time to union, wk</td>
<td>17.0±2.8</td>
<td>15.2±2.4</td>
<td>.000</td>
</tr>
<tr>
<td>Complication, No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonunion</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Delayed union</td>
<td>1</td>
<td>0</td>
<td>1.000</td>
</tr>
<tr>
<td>Superficial infection</td>
<td>3</td>
<td>0</td>
<td>.233</td>
</tr>
<tr>
<td>Deep infection</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Implant failure</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Mean±SD AOFAS score</td>
<td>88.9±4.1</td>
<td>90.7±3.8</td>
<td>.070</td>
</tr>
</tbody>
</table>

Abbreviations: AOFAS, American Orthopaedic Foot and Ankle Society; MIPO, minimally invasive plate osteosynthesis; SD, standard deviation.
follow-up data for both groups. The authors found no difference in mean AOFAS score between the 2 groups (supercutaneous plating group, 90.7±3.8; MIPO group, 88.9±4.1 [P=.070]) (Figures 2-5). However, mean operative time and hospital stay time were significantly shorter in the supercutaneous plating group (65.6±13.2 vs 85.9±14.0 minutes [P<.05] and 7.5±2.0 vs 13.0±4.4 days, [P<.05], respectively). Compared with the MIPO group, fracture union occurred faster in the supercutaneous plating group (17.0±2.8 vs 15.2±2.4 weeks, respectively [P<.05]). One case (AO type A1) in the MIPO group had a delayed union at 28 weeks. All fracture unions in both groups occurred without additional surgery. There were more wound problems in the MIPO group, although the difference was not statistically significant. All 3 cases of infection were superficial and resolved with oral antibiotics.

A total of 22 (91.7%) patients in the MIPO group wanted to have the implant removed. Several factors contributed to the decision for removal, principally prominence of the plate and pain (15 patients; 62.5%). Other reasons included aesthetics, insurance, and compensation. Mean time to removal was 16.5 months (range 12-22 months) in the MIPO group. Of the 167 self-tapping locking screws of the locking compression plate, 26 (14 patients) were removed with some difficulty because of stripping of the hexa-
In the supercutaneous plating group, patients were allowed to walk with full weight bearing for 4 weeks before the plate was removed. All patients in the supercutaneous plating group underwent uneventful plate removal in clinic without anesthesia (Figures 6-7). Transient effusion from the screw site occurred in 1 patient (1 screw) in the supercutaneous plating group, which was controlled with daily cleaning with povidone iodine.

**Discussion**

The treatment of distal tibial fractures can be challenging because of limited soft tissue, the subcutaneous location of the bone, and poor vascularity. Minimally invasive plate osteosynthesis, which reduces iatrogenic soft tissue injury and damage to bone vascularity and preserves the osteogenic fracture hematoma, has gained popularity for the management of distal tibial fractures. \(^9\)\(^{12}\) Recently, several reports have described the use of locking plates as external fixators for the treatment of infectious nonunion and open fractures. \(^13\)\(^{16}\) This technique (supercutaneous plating) proved to be versatile, low profile, and well tolerated by patients.

With a thin layer of skin and subcutaneous tissue over the anteromedial surface of the bone, the LISS plate was placed at the anteromedial side of the tibia to minimize screw-site problems associated with soft tissue motion in the current study. Owing to its morphology matched to the contour of the anteromedial side of the tibia and its stronger biomechanics, the LISS-distal femur plate was applied. The supercutaneous plating technique with closed reduction is another less invasive method. To the best of the current authors’ knowledge, no previous study has been performed to compare these 2 methods.

Delayed union and nonunions are important issues in the clinical treatment of tibial fractures. Despite the theoretic advantages associated with minimally invasive plating, several studies have reported the rate of delayed union or nonunion for distal tibial fractures with the MIPO technique to be 5% to 17%. \(^17\)\(^{18}\) In the current study, there were no nonunions, malunions, or hardware failures, and all patients achieved satisfactory or excellent results in both groups, except one patient (AO type A1) in the MIPO group who had a delayed union. Although minimally invasive plating techniques offer biologic advantages, especially for comminuted fractures of the tibia in which maintenance of the vascular supply to small fracture fragments is important, the concept of rigid fixation and direct healing should not be totally ignored.

The minimally invasive approach limits the use of direct reduction techniques, which may make it more difficult to obtain optimal alignment and compression in patients with simple fracture patterns. \(^17\)\(^{18}\) Therefore, simple fracture patterns are prone to delayed healing and nonunion when compression cannot be achieved across the main fracture line, even with the MIPO technique. \(^18\) In the current authors’ opinion, if percutaneous plating or supercutaneous plating is planned for a simple fracture, a compression osteosynthesis with percutaneous interfragmentary lag screws and neutralization plate should be performed.

In the current study, there were more wound problems (superficial infections) in the MIPO group, although the difference was not statistically significant. Even in those patients who received MIPO surgery, the incidence of wound complications was as high as 15%. \(^19\) A minimal incision cannot ensure minimal invasion because surgeons who are unfamiliar with the MIPO technique may repeatedly insert and pull out the plate, which will induce a dead space and increase infection risk or delayed union. By contrast, the supercutaneous plating technique can almost be regarded as noninvasive because there are only stab incisions for screw insertion and no incision for plate insertion. Also, compared with the MIPO technique, there is no percutaneous tunnel for supercutaneous plating, resulting in more protection of the bone blood supply and less invasion of the soft tissues, which may be the reason for the shorter time to bone union in the supercutaneous plating group.

Another drawback of minimally invasive plating is the potential for increased hardware prominence and irritation. Although low-profile and anatomically contoured plates have been developed in an attempt to address this issue, several retrospective series have reported high rates of hardware prominence and irritation. \(^19\)\(^{20}\) In a retrospective study, Cheng et al\(^20\) compared MIPO with conventional open reduction and internal fixation and demonstrated a significantly higher incidence of
hardware irritation among patients treated with MIPO (9 of 28 vs 2 of 30; P=.008). Another retrospective study reported an incidence of hardware irritation as high as 52%, with 29% of patients undergoing hardware removal because of irritation. Similar to these reports, as many as 62.5% of patients in the current study have removed the hardware due to plate prominence and pain. The authors had some difficulty removing the locking screws in 14 patients in the MIPO group because of stripping of the hexagonal recess and threads of the head of the locking screw. Cole et al described cold welding at the interface of 4 of 11 locking screws in one LISS, all of which were fixed to the diaphyseal segment. An incidence of stripping of 8.6% at the time of removal of 279 locking screws, which was much higher than that in the removal of conventional screws, has also been reported. Thus, in practice, the difficulty of the removal of locking screws can be a serious problem. However, in the supercutaneous plating group, removal of the supercutaneous plate was easily performed in clinic without anesthesia. The authors encountered no difficulty during the removal of the supercutaneous plates.

Although a high number of pin-tract complications have been reported in traditional external fixation, in the current study there was only 1 screw with secretions in the supercutaneous plating group, which was controlled with daily cleaning with povidone iodine. This low incidence of pin-tract complications may be related to the titanium alloy device of the screws.

Also, compared with traditional external fixation, supercutaneous plating is not only biomechanically superior, providing better resistance to bending and torsion, but it overcomes the shortcomings of traditional external fixation. External fixator frames are often bulky and cumbersome for patients. When used on the legs, patients typically encounter problems with sleeping and wearing clothes, and the contralateral limb is impeded when walking. Supercutaneous plating is able to construct a low-profile frame close to the skin and can be concealed under clothing, making it more acceptable to patients. In addition, supercutaneous plating used as a definitive external fixator does not need to cross the joint, so early functional exercise is possible.

A greater number of days in the hospital imposes higher health care costs and economic burdens to society. In the current study, patients in the supercutaneous plating group had a significantly shorter operative time and length of hospital stay compared with those in the MIPO group (P<.05), which would result in reduced health care costs. In the authors’ experience, emergency supercutaneous plating surgery could provide the definitive treatment even in severe soft tissue–damaged patients. Nevertheless, the authors are cautious when using the MIPO technique to deal with these severe fractures associated with poor soft tissue status. Surgeons should be aware that wound infection or necrosis is the most common postoperative complication of distal tibial fracture.

Although early intervention is advantageous, it is desirable to delay surgery in the presence of gross local swelling until the subsidence of swelling and the appearance of the wrinkle sign to ensure good local skin condition prior to MIPO. In fact, delaying surgery is the main reason for the longer length of hospital stay in the MIPO group in the current study.

The control-matched design of this study has certain limitations. Selection bias was not avoided because the surgeons decided which operative treatment to perform. Some of the bias was eliminated by matching the patients. To maintain a sufficient number of patients, matching considered only sex, age, AO classification, and Injury Severity Score.

**CONCLUSION**

Although this study is limited by the number of patients and the retrospective design, its results suggest that both MIPO and supercutaneous plating can achieve satisfactory functional outcomes in patients with distal tibial fractures. The supercutaneous plating technique may be considered a better surgical option because it offers advantages in terms...
Feature Article

of mean operative time, hospital stay, and union time; skin irritation; and implant removal. The authors have adopted supercutaneous plating as their preferred method of treating these fractures.

REFERENCES


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