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Limited open reduction is better for simple-distal tibial shaft fractures than minimally invasive plate osteosynthesis

Q. Li, B.F. Zeng, C.F. Luo, S. Song, C.Q. Zhang and W.Q. Kong

Department of Orthopaedics,
Shanghai Jiao Tong University Affiliated Sixth People's Hospital, Shanghai, China

Corresponding author: W.Q. Kong
E-mail: congfengluo@126.com

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ABSTRACT. The aim of this study was to compare the effects and indications of minimally invasive plate osteosynthesis (MIPO) and limited open reduction (LOR) for managing distal tibial shaft fractures. A total of 79 cases of distal tibial shaft fractures were treated surgically in our trauma center. The 79 fracture cases were classified into type A, B, and C (C1) according to the Arbeitsgemeinschaft für Osteosynthesefragen (AO) classification, with 28, 32, and 19 cases, respectively. Among the 79 fracture cases, 52 were closed fractures and 27 were open fractures (GUSTILO, I-II). After adequate preparation, 48 cases were treated with LOR and 31 cases were treated with MIPO. All cases were followed up for 12 to 18 months, with an average of 16.4 months. During the follow-up period, 76 fracture cases were healed in the first stage, whereas the 3 cases that developed non-union were treated by changing the fixation device and autografting. For types A, B, and some of C simple fractures (C1), LOR accelerated the fracture healing and lowered the non-union rate. One case suffered from regional soft tissue infection, which was controlled by wound dressing and intravenous antibiotics. Another case that developed local skin necrosis underwent local flap transplant. LOR promoted bone healing and lowered the non-union rate of several simple-distal tibial shaft fractures. Thereafter, the incidence of soft tissue complication was not significantly increased. However, for complex and comminuted fractures, MIPO was the preferred method for correcting bone alignment and protecting soft tissue, leading to functional recovery.

Key words: Distal tibia shaft fracture; Open reduction; MIPO

INTRODUCTION

The introduction of locking compression plate (LCP) (Sommer et al., 2003) led to the worldwide use of minimally invasive plate osteosynthesis (MIPO), which replaced the prior use of limited-contact dynamic compressive plate (DCP) (Oh et al., 2003a). The creation of a small incision without exposing the fracture region is minimally invasive, resulting in less soft tissue damage. Generally, LCPs are used as internal fixators for fracture treatment, which promotes fracture healing. However, the effects of LCP on fracture healing and function recovery need further clinical verification, especially because traditional DCP is still widely applied for simple fractures.

Therefore, selecting a suitable treatment strategy for certain injuries, knowing the correct treatment outcome, and achieving the therapeutic effect of the selected treatment strategy are several of the dilemmas that we currently face.

We determined the optimal therapy for such simple fractures to shorten the healing time and to improve limb function. We compared MIPO and limited open reduction (LOR) for managing distal tibial shaft fractures to find better solutions for treating certain injuries.

MATERIAL AND METHODS

Subjects

A total of 79 cases of distal tibial shaft fractures were surgically treated in our trauma center from February 2008 to June 2008. The gender, age, fracture type, and soft tissue conditions were similar in the two groups. This study was conducted in accordance with the declaration of Helsinki and with approval from the Ethics Committee of Shanghai No. 6 People's Hospital of Jiao Tong University. Written informed consent was obtained from all participants.

Operative technique

The patients were placed in supine position. For the open-direct reduction group, we made a small incision at the lateral side of the crest to expose the fracture line. The soft tissue inside the fracture side was removed for anatomical reduction using the peripheral margin of the fragment as a marker (Figure 1). Reduction forceps were used to maintain the reduction. Two small incisions at the medial side of the crest were made to insert the locking plate (Figure 2). The insertion side of the plate depends on both the fracture type and the local skin condition. A compression screw may also be inserted through the plate. A lag screw was placed vertical to the fracture line outside the plate to compress the fracture side and to maintain initial stability. The locking plate was used as a position plate but not as a bridge plate (Figure 3). Thus, two screw holes near the fracture line were used to strengthen the stability. For the MIPO group, the alignment of the axis was corrected using indirect reduction. Through a small skin incision, the plate was tunneled extraperiostally along the medial aspect of the tibia and fixed with locking head screws. A real bridging plate was used, and the screws on the plate were placed far from the fracture side to protect the local blood supply and to avoid the strength concentration. For most simple fractures, the plate length was approximately three times the fracture length and the screw hole ratio was approximately 0.5.

Figure 1. A 14-year-old male with distal tibia shaft fracture, AO type B2 with fibular fracture treated using open reduction, and long locking compression plate fixation for both the tibia and the fibula. We achieved excellent anatomic reduction, which was maintained until the locking plate was inserted. Fibular reduction and fixation also helped restore the length of the limb. The fracture healed within 3 months, and the limb functioned quite well.

Figure 2. Skin incision for the limited open-reduction approach. One small intermediate incision was made for reduction and the two other incisions were for plate insertion.

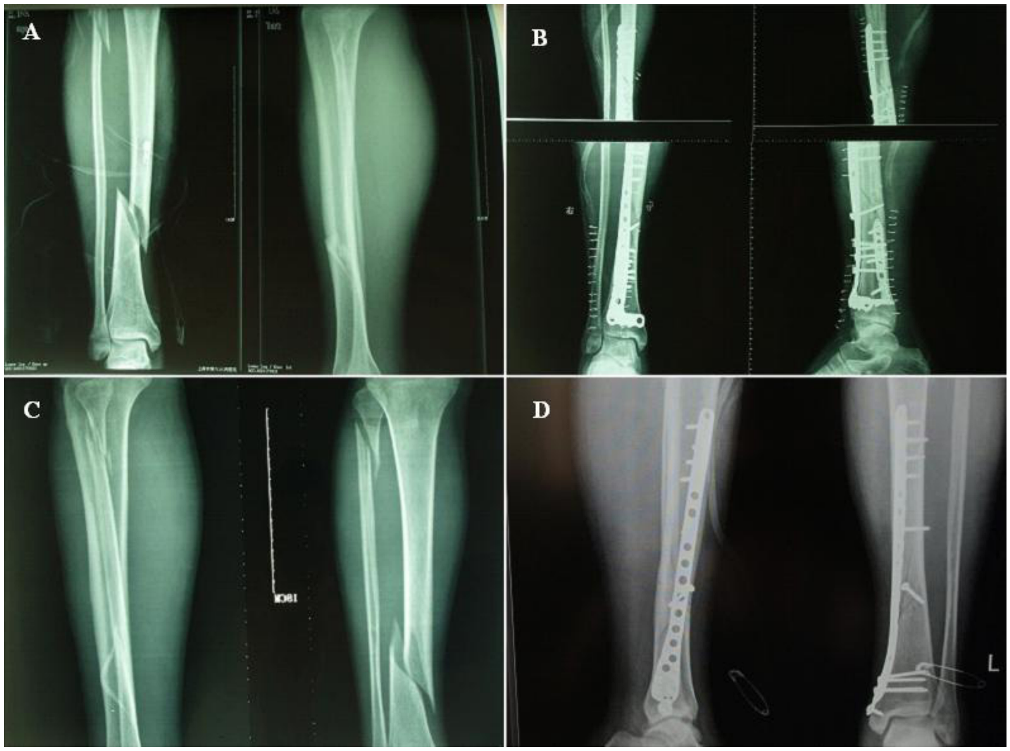

Figure 3. A. and **B.** A 26-year-old male with distal tibia shaft fracture and proximal fibular fracture, AO type A1 treated with open reduction, and long locking compression plate (LCP) fixation for tibia. After reduction, a lag screw was initially applied to maintain the anatomic relation and to achieve interfragmentary compression. Then, the long LCP was inserted. **C.** and **D.** A 38-year-old male with distal tibia shaft fracture and proximal fibular fracture combined with posterior malleolar fractures (PMF), AO type A1 (for distal tibia shaft) treated via open reduction, and long LCP fixation for tibia. After plate reduction and insertion, a lag screw was applied through the plate and two screws were used near fracture line. The plate was inserted lateral to avoid a medial skin problem. The PMF was treated using another plate through the posterior approach.

Post-operative treatment

We recommended immediate ankle and knee joint exercise after the operation. Partial weight bearing (5 to 10 kg) continued until the X-ray showed callus formation. Full weight bearing was continued until clinical healing of the fracture for both groups. At 6 weeks and at 3, 6, 9, and 12 months after surgery, the patients were followed up through clinical and radiological examinations (lateral and posteroanterior X-ray or XR) by an experienced trauma surgeon. The classic definitions of non-union and delayed union were strictly observed. Healing within the first 6 months was considered normal, more than 9 months was considered delayed, and more than 12 months was considered non-union. We performed routine XR examinations for fracture healing and monitoring, and the patients were followed up for functional recovery. For cases suspected as non-union, additional computed tomography (CT) reconstruction was performed to confirm the diagnosis before repeat operations. The fracture was considered healed when visible callus bridging of one cortex was present on both the lateral and the posteroanterior XR, and when the patient was capable of full-weight bearing without pain. A repeat operation was performed in cases of non-union.

Statistical analysis

We applied the chi-squared test of a 4-fold table using the statistical software (SAS 8.10) to compare clinical data. $P < 0.05$ was considered to be statistically significant.

RESULTS

Basic data

The 79 cases of distal tibial shaft fractures with a mean age of 47 years (range = 18-69 years) were operated in our trauma center, among which 43 cases were males and the other 36 cases were females. According to the Arbeitsgemeinschaft für Osteosynthesefragen (AO) classification, all cases were classified into type A, B, and C (C1), with 28, 32, and 19 cases, respectively. Of the total 79 cases, 52 were closed fractures and 27 were open fractures (GUSTILO, I-II).

All cases were randomized into two groups. The first group (48 cases) was treated with LOR, and the second group (31 cases) was treated with MIPO. The subtype distribution in the LOR group (48 cases) was as follows: 17 were type A (A1 = 8, A2 = 6, and A3 = 3), 19 were type B (B1 = 9, B2 = 6, and B3 = 4), and 12 were type C1. In the MIPO group (31 cases), 11 were type A (A1 = 5, A2 = 4, and A3 = 2), 13 were type B (B1 = 6, B2 = 3, and B3 = 4), and 7 were type C1.

Among all 79 cases, 75 also had fibular fractures. Up to 70 of the fibular fractures were in the middle and distal segments, and were operated by plate or nail, whereas the other 5 were in the proximal part and were treated conservatively. Up to 5 cases had posterior malleolar fractures (PMF), which were fixed by plate or cannulated screw.

Operation effect

All cases were followed up for 12 to 18 months, with an average of 16.4 months. The post-operative XR images are shown in Figures 1 and 3. For most type A and type B cases, as well as some type C simple fractures (C1), LOR accelerated the fracture healing and lowered the non-union rate (Table 1). At 4 and 6 months post-operation, the healing rates of the open-reduction group were 39/48 and 46/48, respectively, whereas those of the MIPO group were 17/31 and 23/31, respectively. This result indicates that the open-reduction group had higher healing rates during the early stage compared with the MIPO group. The χ^2 values at 4 and at 6 months after the operation were 6.37 and 6.14, respectively ($P < 0.05$). One case of non-union that underwent MIPO was re-operated using open reduction 1 year after the initial operation. The fracture finally healed 6 months after the second operation.

For soft tissue conditions, one case from the open-reduction group suffered from regional soft tissue infection, which was controlled by wound dressing and intravenous antibiotics. Another case, which suffered from skin necrosis, underwent local flap transplant, suffered from skin necrosis. However, no significant difference in the occurrence of soft tissue problems was observed between the two groups (Table 1; $\chi^2 = 0.17$ between the two groups).

Other post-operative functions and complications were similar between the two groups.

Table 1. Clinic results of treating simple-distal tibia fracture with MIPO or LOR.

	Healing time (healing rate pro-operation)		Non-union rate[a]	Soft tissue problem[b]
	4 months	6 months		
MIPO	54.84%	74.19%	9.68%[φ]	2%
LOR	81.25%*	95.83%[#]	0%	3%

MIPO = minimally invasive plate osteosynthesis; LOR = limited open reduction. [a]The standard for non-union includes clinical symptoms, signs and typical X-rays. Sometimes a 3-D CT scan is necessary. [b]Soft tissue problem including infection, flap necrosis, local sinus tract, and exudates. *$\chi^2 = 6.37$; P < 0.0 5 *vs* MIPO; [#]$\chi^2 = 6.14$; P < 0.05 *vs* MIPO. [Φ]$\chi^2 = 2.54$, P < 0.05.

DISCUSSION

Traditional dynamic plates achieve the first-stage healing of fractures through absolute stable fixation (Horn et al., 2011). This method was once the standard for plate osteosynthesis in the early 1960s and 1970s (Rüedi and Murphy, 2001). However, the method was recently challenged by minimally invasive biological osteosynthesis because of the introduction of locking plates (Perren, 2002). Complications, such as malunion fractures that results from rotational and axial malalignment, are known disadvantages of this approach. According to Hasenboehler (2007), the non-union rate of diaphyseal and distal tibial fractures by MIPO is approximately 9.37% (3/32), which is quite similar to our data (3/31). Given that LCP is very popular for orthopedic trauma (Bhandari et al., 2001; Brown et al., 2001; Skoog et al., 2001; Egol et al., 2004; Ruedi et al., 2007), traditional DCP is also applied in many cases. Generally, the application of these techniques depends on fracture stabilization and type: either absolute or relative stabilization. In our study, prolonged healing was observed in simple-fracture patterns when a bridge-plating technique was used. Therefore, an absolute stable osteosynthesis is important in fracture management (Hasenboehler et al., 2007).

LOR increased the healing rate of several simple-distal tibial shaft fractures and decreased the non-union rate. Thus, we conformed to the AO principle: anatomic reduction and rigid fixation, which cause first-stage fracture healing. We also used a locking plate as a "protection" plate to achieve this goal. The fracture side was compressed with a lag screw inside or outside the plate. Thus, compression accelerates fracture healing, and the plate protects the screw from bending, shearing, and rotational forces. Therefore, two screw holes near the fracture line should be routinely used. At 4 and 6 months post-operation, the open-reduction group had higher healing rates (81.25 and 95.83%, respectively) than the MIPO group (54.84 and 74.19%, respectively). Therefore, we can compress the fracture side to its maximum for this kind of simple fracture. We can clear the soft tissue (such as muscle and tendon) and hematomas impacted in the fracture side through a local incision, which also helps fracture healing.

The classic open approach with plates is related to local septic complications and bone healing problems (Ozkaya et al., 2009; Collinge and Protzman, 2010). In our limited open approach, the soft tissue complication was not significantly increased ($\chi^2 = 0.17$ between the two groups). Soft tissue complication did not cause the malalignment. Adequate reduction should be ensured for fractures treated using MIPO to prevent serious complications such as delayed union or non-union. In this study, these complications developed in a typical case. Achieving a sufficient anatomic relationship is always the key factor in managing simple fractures.

MIPO (Collinge and Sanders, 2000; Khoury et al., 2002; Oh et al., 2003b; Perren et al., 2003; Borg et al., 2004; Toms et al., 2004) has now become increasingly popular with the development of LCP. In MIPO with LCP, the plate was tunneled extraperiostally along the medial aspect of the tibia through a small skin incision and then fixed with locking head screws. If percutaneous plating with MIPO is to be implemented for a simple fracture, compression osteosynthesis with percutaneous interfragmentary lag screws and neutralization plate should be performed. However, this additional procedure is difficult to execute because of soft tissue inside, inadequate traction, and so on. This procedure also requires indirect reduction. In most cases, malrotation still occurs, which impedes fracture healing. In cases where MIPO is impossible, formal open reduction and internal fixation, such as our LOR, is the method of choice. However, if only bridge plating is performed, surgeons must remember to inform the patient of a possible delay in rehabilitation (Hasenboehler et al., 2007). For complex and comminuted fractures, MIPO is the preferred method of choice for correcting the alignment to improve function recovery. With this method, the blood supply in the fracture site and in the soft tissues is protected. Using LCP as an internal fixator could also prevent infections. We should also pay attention to associated distal tibial shaft fractures, which have a high rate of misdiagnosis (Wu et al., 2008). Tibial diaphyseal fractures are often associated with PMFs. The incidence is very high, especially in spiral distal tibial shaft fractures. Previous studies reported an incidence rate of 9.7% (Hou et al., 2009). In our study, we also encountered such cases. In some cases, we failed to recognize its occurrence until our last confirmation with C-arm.

Intramedullary (IM) nailing is generally used to treat tibial shaft fractures. However, with the development of surgery, IM can now be used to treat distal tibial fractures (Pobłocki et al., 2011). A biomechanical test showed that the stiffness of the reamed nail is significantly higher than that of the locked plate (Hoegel et al., 2012). However, the rates of infection, nonunion, and secondary procedures were similar for the two aforementioned methods. Aside from knee and ankle pain (Vallier et al., 2012), IM nailing is also associated with greater malalignment compared to locking plate (Vallier et al., 2011). MIPO is associated with more malalignment than open reduction for simple-distal tibial fractures.

In conclusion, compared with MIPO, LOR promotes bone healing of certain simple-distal tibial shaft fractures and lowers the non-union rate, which minimizes the occurrence of soft tissue problems.

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REFERENCES

Bhandari M, Guyatt GH, Swiontkowski MF and Schemitsch EH (2001). Treatment of open fractures of the shaft of the tibia. *J. Bone Joint Surg. Br.* 83: 62-68.

Borg T, Larsson S and Lindsjo U (2004). Percutaneous plating of distal tibial fractures. Preliminary results in 21 patients. *Injury* 35: 608-614.

Brown OL, Dirschl DR and Obremskey WT (2001). Incidence of hardware-related pain and its effect on functional outcomes after open reduction and internal fixation of ankle fractures. *J. Orthop. Trauma* 15: 271-274.

Collinge C and Protzman R (2010). Outcomes of minimally invasive plate osteosynthesis for metaphyseal distal tibia fractures. *J. Orthop. Trauma* 24: 24-29.

Collinge CA and Sanders RW (2000). Percutaneous plating in the lower extremity. *J. Am. Acad. Orthop. Surg.* 8: 211-216.

Egol KA, Kubiak EN, Fulkerson E, Kummer FJ, et al. (2004). Biomechanics of locked plates and screws. *J. Orthop. Trauma* 18: 488-493.

Hasenboehler E, Rikli D and Babst R (2007). Locking compression plate with minimally invasive plate osteosynthesis in diaphyseal and distal tibial fracture: a retrospective study of 32 patients. *Injury* 38: 365-370.

Hoegel FW, Hoffmann S, Weninger P, Buhren V, et al. (2012). Biomechanical comparison of locked plate osteosynthesis, reamed and unreamed nailing in conventional interlocking technique, and unreamed angle stable nailing in distal tibia fractures. *J. Trauma Acute Care Surg.* 73: 933-938.

Horn C, Dobele S, Vester H, Schaffler A, et al. (2011). Combination of interfragmentary screws and locking plates in distal meta-diaphyseal fractures of the tibia: a retrospective, single-centre pilot study. *Injury* 42: 1031-1037.

Hou Z, Zhang Q, Zhang Y, Li S, et al. (2009). A occult and regular combination injury: the posterior malleolar fracture associated with spiral tibial shaft fracture. *J. Trauma* 66: 1385-1390.

Khoury A, Liebergall M, London E and Mosheiff R (2002). Percutaneous plating of distal tibial fractures. *Foot Ankle Int.* 23: 818-824.

Oh CW, Kyung HS, Park IH, Kim PT, et al. (2003a). Distal tibia metaphyseal fractures treated by percutaneous plate osteosynthesis. *Clin. Orthop. Relat. Res*. 286-291.

Oh CW, Park BC, Kyung HS, Kim SJ, et al. (2003b). Percutaneous plating for unstable tibial fractures. *J. Orthop. Sci.* 8: 166-169.

Ozkaya U, Parmaksizoglu AS, Gul M, Sokucu S, et al. (2009). Minimally invasive treatment of distal tibial fractures with locking and non-locking plates. *Foot Ankle Int.* 30: 1161-1167.

Perren SM (2002). Evolution of the internal fixation of long bone fractures. The scientific basis of biological internal fixation: choosing a new balance between stability and biology. *J. Bone Joint Surg. Br.* 84: 1093-1110.

Perren SM, Perren T and Schneider E (2003). Are the terms “biology” and “osteosynthesis” contradictory? *Ther. Umsch.* 60: 713-721.

Poblocki K, Domaradzki M, Gawdzik J, Prochacki P, et al. (2011). Complications after intramedullary nailing of the tibia. *Chir. Narzadow. Ruchu. Ortop. Pol.* 76: 274-277.

Rüedi TP and Murphy WM (2001). AO Principles of Fracture Management.Thieme Medical Publishers, New York, 253-257.

Rüedi TP, Buckley RE and Moran CG (2007). AO Principles of Fracture Management. 2nd edn. Thieme Medical Publishers, New York, 175-253.

Skoog A, Soderqvist A, Tornkvist H and Ponzer S (2001). One-year outcome after tibial shaft fractures: results of a prospective fracture registry. *J. Orthop. Trauma* 15: 210-215.

Sommer C, Gautier E, Muller M, Helfet DL, et al. (2003). First clinical results of the Locking Compression Plate (LCP). *Injury* 34 (Suppl 2): B43-B54.

Toms AD, McMurtie A and Maffulli N (2004). Percutaneous plating of the distal tibia. *J. Foot Ankle Surg.* 43: 199-203.

Vallier HA, Cureton BA and Patterson BM (2011). Randomized, prospective comparison of plate versus intramedullary nail fixation for distal tibia shaft fractures. *J. Orthop. Trauma* 25: 736-741.

Vallier HA, Cureton BA and Patterson BM (2012). Factors influencing functional outcomes after distal tibia shaft fractures. *J. Orthop. Trauma* 26: 178-183.

Wu HT, Hou ZY, Zhang Q, Zhao HT, et al. (2008). Clinical epidemiological analysis of adult spiral tibial shaft fracture associated with ipsilateral posterior malleolar fracture. *Zhonghua Yi Xue Za Zhi* 88: 2166-2170.