Foot and Ankle Surgery 20 (2014) 115–119

Contents lists available at ScienceDirect

Foot and Ankle Surgery

journal homepage: www.elsevier.com/locate/fas

Are locking plates better than non-locking plates for treating distal tibial fractures?☆

Christian Bastias MD[a], Hugo Henríquez MD[a], Manuel Pellegrini MD[a,b], Stefan Rammelt MD, PhD[c], Natalio Cuchacovich MD[a], Leonardo Lagos MD[a,*], Giovanni Carcuro MD[a]

[a] Foot and Ankle Unit, Instituto Traumatológico Teodoro Gebauer, Santiago, Chile
[b] Foot and Ankle Unit, Hospital Clínico Universidad de Chile, Santiago, Chile
[c] Department of Trauma & Reconstructive Surgery, University Hospital Carl Gustav Carus, Dresden, Germany

ARTICLE INFO

Article history:
Received 5 August 2013
Received in revised form 3 December 2013
Accepted 23 December 2013

Keywords:
Distal tibia
Fracture
Locking plate
Mal union
Minimally invasive

ABSTRACT

Background: Locking and non-locking plates has been used for distal tibia fracture osteosynthesis. Sufficient evidence to favor one implant over the other is lacking in the current literature. Our aim is to compare them in terms of fracture healing, alignment, functional outcome, complications.

Methods: Sixty-eight patients operated on using a percutaneous plate were retrospectively reviewed. They were divided into two groups: in group 1 (28 patients) a 4.5 mm narrow conventional dynamic compression plate (DCP) was used. In group 2 (40 patients) a titanium locked compression plate (LCP) was used.

Results: Mean time to union was 16.2 and 15.4 weeks for group 1 and 2, respectively ($p = 0.618$). 11 patients (39.3%) in group 1 and 4 patients (10%) in group 2 showed malalignment ($p = 0.016$). AOFAS scores at follow up were 89 and 88 in groups 1 and 2, respectively. Implant removal was necessary in 9 cases (32.1%) and 4 cases (10%) in group 1 and group 2, respectively ($p = 0.042$). Three patients (10.7%) in group 1 and three patients (7.5%) in group 2 had an infection.

Conclusions: Both plating systems have similar results in terms of time to union, infection, and AOFAS scores. The LCP seems superior with respect to alignment and the need for implant removal.

1. Introduction

Fractures of the distal third of tibia represent about 10% of all tibial fractures and their management is controversial. They predominantly affect young patients and are mainly due to torsional forces or high-energy falls [1,2]. They have to be distinguished from tibial pilon fractures which are a different entity due to articular impaction and/or comminution resulting from axial forces [3,4] and therefore have a different treatment and prognosis [2,5,6]. Opinions vary as to which of the various methods described to treat a distal tibial fracture is the best [4,7–9]. Four recognized methods are external fixation, intramedullary nailing, open reduction and internal fixation with plates, and minimally invasive percutaneous plate osteosynthesis (MIPPO). The latter has recently become more widely accepted due to the fact that it reduces adjacent soft tissue damage, maintains fracture hematoma and preserves bone vascularity, thus providing adequate mechanical stability and fracture biology to allow union [5,6,10–12].

When using this technique, osteosynthesis may be carried out using a variety of anatomical locking plates [12–14] or non-locking plates [11,15–17]. In recent years, several studies have described the advantages of using locking plates such as stability, the low profile, and the ability to lock the screws at a fixed angle [18–21].

Various studies have demonstrated the success of both types of plating systems [11,13,15–19,22]. However, non-locking plates have been associated with a higher rate of complications, stability loss, and osteosynthesis-related soft tissue discomfort [7,9,11,15,16]. On the other hand, locking plates have been associated with improved mechanical stability, higher costs and the need for a longer consolidation period [18,23]. Sufficient evidence to favor one system over the other in the treatment of distal tibial fractures is lacking in the current literature [21].

Both locking and non-locking plating systems have been used at our institution to treat distal tibial fractures since 2006. Our aim in this study was to compare both forms of fixation in terms of: (1) the time required to achieve bony union, (2) alignment, (3)

☆ This study was revised and approved by the Ethics Committee of our institution.

* Corresponding author at: Instituto Traumatologico Teodoro Gebauer, San Martín 771, Santiago, Chile. Tel.: +56 2 25746150.
E-mail address: leo_lagos@yahoo.com (L. Lagos).

1268-7731/$ – see front matter © 2014 European Foot and Ankle Society. Published by Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.fas.2013.12.004

functional outcome and (4) complications and the need for secondary surgery.

2. Patients and methods

We retrospectively reviewed the clinical data and radiological images of patients in our prospective database who were diagnosed with a fracture of the distal third of the tibia and operated between July 2006 and December 2010. All patients had given informed consent for surgery. The ethics committee of our institution authorized the study and subsequent consent to participate was given by the patients.

The study included all patients treated via minimally invasive percutaneous plate osteosynthesis (MIPPO). Patients were excluded if there was radiographic evidence of articular comminution and/or articular impaction (43 C3 – AO/OTA), and this left a total of 68 patients (35 male, 33 female, mean age 50 years). The two senior surgeons performed all the operations.

Patients were subsequently divided into two groups according to the type of osteosynthesis used. The first group ($n = 28$) comprised patients in which a narrow, large-fragment dynamic compression plate (DCP, Synthes, Bettlach, Switzerland) was used (Fig. 1). In the second group ($n = 40$) a titanium locking compression distal tibial plate (LCP, Synthes, Bettlach, Switzerland) (Fig. 2) was used. A diabetic patient from the LCP group was excluded from the study as she developed a serious early infection that resulted in removal of the plate and treatment with an Ilizarov external fixator.

Both groups were similar with respect to age, gender distribution and fracture patterns according to the AO/OTA classification system (Table 1) [24]. Nine fractures were open (one in the DCP group and eight in the LCP group). Patients received antibiotic treatment as per local protocols. Eight of these were managed initially with external fixation followed by internal fixation within a mean time interval of 9 days (range 2–19 days). A forced torsion of the lower leg was the most commonly identified mechanism of injury in both groups (18 cases in group 1 and 24 cases in group 2).

Surgical technique: After administration of spinal anesthesia, a 3.0 mm Steinmann pin was placed from medial to lateral through the calcaneal tuberosity. Indirect reduction of the fracture was achieved via ligamentotaxis under fluoroscopic guidance using an orthopedic reduction table. Open reduction and internal fixation of an associated fracture of the distal third of the fibula was performed on 15 patients in group 1 and on 27 patients in the group 2 via a posterolateral approach and using a 3.5/4.5 mm non-locking third tube plate (Synthes, Bettlach, Switzerland).

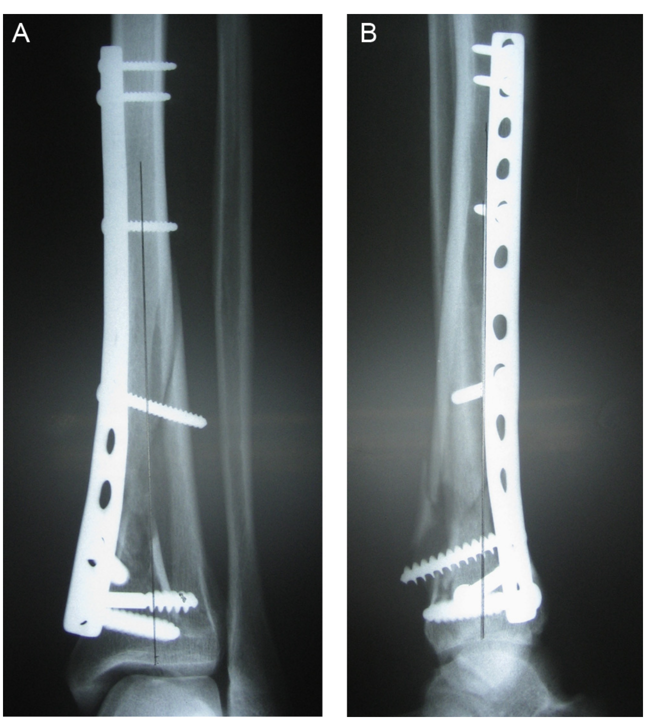

Fig. 1. (A and B) A comminuted distal tibial fracture in a 55 year old man. This patient was treated with a non-locking plate DCP. Anteroposterior and lateral radiographs showing the correct alignment obtained with a DCP.

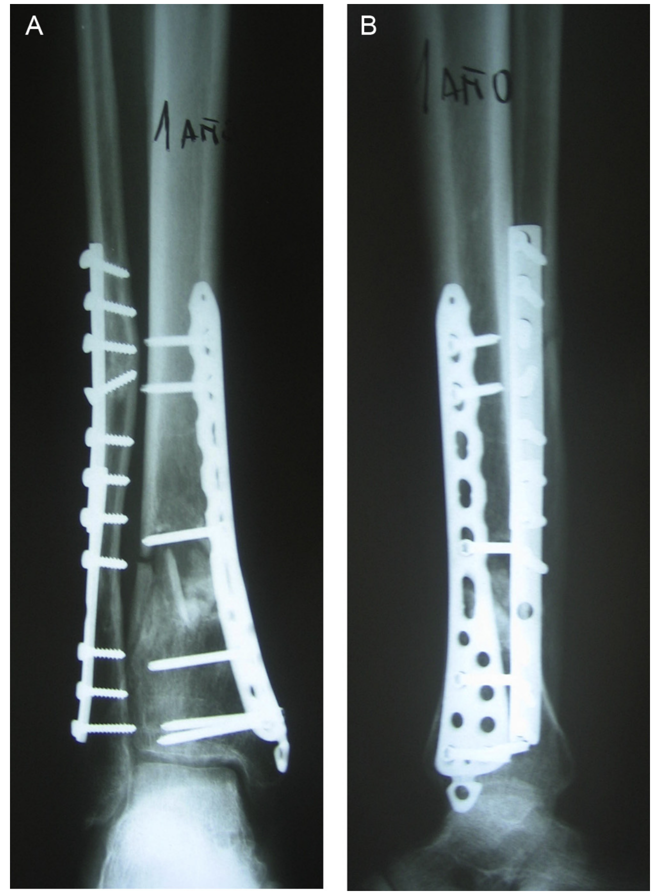

Fig. 2. (A and B) Distal tibial fracture with metaphyseal comminution treated with a locking plate (LCP).

Table 1
Patient characteristics.

	DCP	LCP
Number of patients	28	40
Age (range)	50 (22–77)	50 (21–75)
Male/female	16/12	19/21
Fibular fracture	17	21
AO/OTA Type 42 A1	1	1
AO/OTA Type 42 B1	6	4
AO/OTA Type 42 C1	1	1
AO/OTA Type 43 A1	6	8
AO/OTA Type 43 A2	1	4
AO/OTA Type 43 A3	8	8
AO/OTA Type 43 B1	0	7
AO/OTA Type 43 B2	0	7
AO/OTA Type 43 C1	3	0
AO/OTA Type 43 C2	2	0

Percutaneous fixation was subsequently achieved using a non-locking DCP (Fig. 1) with 4.5 cortical screws proximal to the fracture and 6.5 cancellous screws distal to the fracture; or a locking LCP (Fig. 2) with 3.5 non-locking and locking screws (these last distal to the fracture), depending on the preference of the senior surgeon. All non-locking plates were molded during surgery. All patients were discharged with a short lower leg splint and non-weight bearing on two crutches until the first follow-up visit at three weeks after surgery.

At this time sutures were removed and rehabilitation was started. Partial weight bearing was allowed between 6 and 8 weeks following surgery, provided absence of pain during physical examination and radiological evidence of bone healing. Further clinical and radiological follow-up visits were performed after 2, 3, 4, 5, and 12 months.

At final follow-up, at least one year after surgery, written consent to participate in the study was obtained and functional results were evaluated with the AOFAS Ankle/Hindfoot score [25]. The average post-operative follow-up was 45 months (range 12–79 months).

The presence of a bone bridge in at least one cortex in either the AP and/or lateral radiographs in addition to pain-free full weight bearing was the criterion for bony union. According to the criteria of Borg et al. [15], the normal time to bone union was set at 6 months, delayed union was considered between 6 and 9 months, and non-union was diagnosed after 9 months.

Malalignment, according to Hasenboehler's criteria, was defined as a deviation from the normal axis greater than 5° in both the sagittal and coronal plane, or a shortening greater than 1 cm [24,27].

The criteria for implant removal was defined as local pain and/or skin irritation related to plates and screws.

To determine the significance of intergroup differences regarding alignment, implant removal and infection rate, the Fisher's exact test was used. To assess the consolidation timeframe and functional outcome scores differences, the *T* test was used. Statistical difference was set at $p < 0.05$ and all statistical analyses were reviewed by an independent statistician.

3. Results

The average time to bony consolidation was 16.2 weeks (range 10–24) in the DCP group and 15.4 weeks (range 10–32) in the LCP group. With the numbers available there was no statistically significant difference in the average time to union between the two groups ($p = 0.618$). One patient in the LCP group (2.5%) presented with delayed union, taking 32 weeks to consolidate. Initially, this case had been an open fracture treated primarily with external fixation and with definite surgery carried out 4 days after the injury. One patient in the DCP group (3.5%) presented with delayed union, taking 32 weeks to achieve consolidation. This patient presented with a significant degree of metaphyseal comminution due to a high-energy injury.

11 patients (39%) in the DCP group and four patients (10%) in the LCP group, healed with some grade of malalignment (Table 2).

Table 2
Alignment at follow-up.

	DCP	LCP
Varus (>5°)	2	0
Valgus (>5°/>10°)	3/0	3
Antecurvatum (>5°)	4	0
Recurvatum (>5°)	2	1
Total	11/8	4

Table 3
Postoperative complications.

Group	Complications				
	Infection		Implant removal		Amputation
	Superficial	Deep	Total	Partial	
DCP	2	1	7	2	0
LCP	2	1	4	0	1

The difference between the two groups was statistically significant ($p = 0.016$). No shortening of >1 cm was observed in either group. During the observation period, no need for secondary corrective surgery was seen in any of the patients.

The final mean AOFAS ankle/hindfoot score was 89 points (range 58–100) in the DCP group and 88 points (range 25–100) in the LCP group. The difference between the two groups was not statistically significant ($p = 0.635$).

Three patients (10.7%) in the DCP group suffered postoperative infections (Table 3). There were two cases of superficial infection of the fibular wound that were successfully treated with local wound care and oral antibiotics for 14 days. One case of deep infection required surgical debridement and flap coverage. Three patients (7.5%) from the LCP group had infections. Like in the DCP group, there were two cases of superficial infection that responded to oral antibiotics and one case of early deep infection in a diabetic patient resulting in wound dehiscence. The latter patient had the plate removed on 20 weeks post surgery after antibiotic treatment and surgical debridement had failed. The fracture was treated with an Ilizarov frame but infection persisted and below knee amputation was required after 10 months. With the numbers available, there was no statistically significant difference with respect to infection rates between the two groups ($p = 0.688$).

Nine patients (32.1%) in the DCP group experienced local discomfort, requiring total implant removal in seven cases (Fig. 3) and partial implant removal in two cases (one proximal screw and one distal screw). Four patients (10%) from the LCP group required secondary surgery to remove the medial implants due to local discomfort. The need of implant removal was significantly lower in the LCP group than in the DCP group ($p = 0.042$).

4. Discussion

Fractures of the distal third of the tibia account for approximately 3–10% of all tibial fractures and can be difficult to treat. Several factors must be taken into account when performing surgery such as the fracture anatomy, soft tissue damage and comorbidities like diabetes mellitus [4,6,10,11,26,27]. In these scenarios, percutaneous plating has become increasingly popular as it minimizes further soft tissue injury [5,10]. Both locking [13,14,19,22,28] and non-locking Plates [7,9,11,15,16] may be used for fixation. A recent survey by Anglen and colleagues found four studies that compared the use of locking plates with non locking

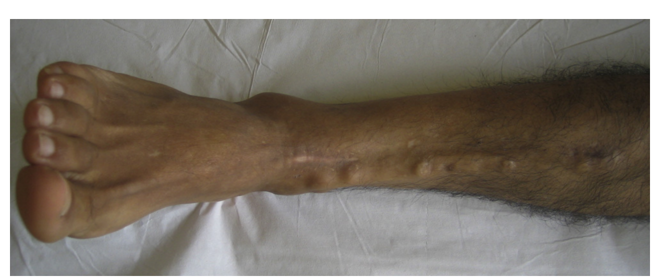

Fig. 3. Visible protruding screws in a patient after treatment with a DCP. The patient required implant removal after fracture healing (same patient as in Fig. 1).

plates and stated that there were no statistically significant differences between them with respect to patient oriented outcomes, adverse events and complications [21]. Unfortunately, no one of these studies included patients with distal tibial fractures and, to the best of our knowledge, the one by Ozkaya and colleagues was published at a later time [24]. We therefore compared both forms of fixation in terms of: (1) the time required to achieve bony union, (2) alignment, (3) functional outcome, and (4) complications and the need for secondary surgery.

In our study, time to union was similar in both groups, being only insignificantly longer in the DCP group when compared to the LCP group (16.2 vs. 15.4 weeks; $p = 0.618$). This contrasts with the retrospective study by Ozkaya et al. [24] comparing locking and non-locking plates in 43 patients. The authors reported that the timeframe to achieve bony union was 3 weeks longer (18 vs. 15 weeks) in the LCP group.

The union rates of 100% in both groups of our study compare favorably with those published in other series. Hasenboehler et al. performed a study in 32 patients treated with LCP, providing a 1-year follow-up [18]. Twenty-seven patients (84%) achieved consolidation after 9 months and two cases were re-operated due to non-union. The authors stated that using locking plates as a bridge in simple fracture patterns has disadvantages when it comes to fracture healing. On the other hand, Borg et al. used a titanium DCP and reported 17 cases (81%) of consolidation before 6 months, two cases of delayed union and two cases of non-union, one of which required further surgery [15]. Helfet reported no cases of delayed or non-union in 20 patients treated with a stainless steel DCP, with an average time to union of 10.7 weeks [7].

We believe that the choice of screws for osteosynthesis is of vital importance when using locking plates. Collinge et al. used a hybrid approach: conventional screws for reduction and angular stabilization to fix the plate [22]. We used only two locking screws in the distal fragment and non-locking screws in the proximal fragment. This hybrid approach combines the advantages of locking screws providing angular stability and non-locking screws providing friction and compression of the plate to the bone. This may explain the similar consolidation times in the two groups.

No cases of non-union were found in our series, despite having eight open fractures. However, there were two cases of delayed union, one in a patient with an open fracture and the other in a patient who sustained a high-energy injury with significant metaphyseal comminution.

There is some controversy regarding the acceptable level of malalignment. Using Hasenboehler's criteria, we considered varus or valgus $>5^\circ$, ante or recurvatum $>5^\circ$ and shortening greater than 1 cm to indicate significant malalignment [24,27]. When applying these criteria, 39% of patients in the DCP group and 10% of patients in the LCP group healed with some malalignment. Helfet et al. considered $<5^\circ$ varus, $<10^\circ$ valgus and $<10^\circ$ ante or recurvatum acceptable [7]. Using these criteria in 20 patients treated with DCP in his study, four had malalignment (25%), two had varus $>5^\circ$ and two had recurvatum $>5^\circ$; however, no additional surgery was required. When applying Helfet's criteria for malunion, our results are comparable.

Our results differ from those of others authors, in that we found significantly more malalignment in the DCP group compared to the LCP group [7,9]. In our opinion this difference is related to the implant, because no problems were observed in relation to the reduction technique, with a good post-operative result in DCP and LCP groups, and no differences in the rehabilitation protocol neither in time to consolidation in both groups; but the DCP group malalignment became present during the follow-up. Having fewer holes than locking plates in the distal segment, non-locking plates provide less stability, potentially leading to loss of reduction and malalignment. In addition, appropriate molding of the non-locking plate is not always an easy process and requires some experience. Non-locking plates are not fixed angle devices and thus are more prone to loosening through toggling of screws, which have a reduced pullout strength.

The clinical consequences of slight malalignment still remain unclear. Several studies have described no pain and normal clinical function with angulation exceeding 10° [29,30]. In contrast, cadaveric studies have shown that in the presence of malalignment (10° and 15° of angular deformities) there is up to a 40% decrease in the contact area in the ankle joint [31]. On this basis, we strongly believe that small angular variations may result in joint overload and eventual osteoarthritis; hence stricter criteria should be recommended. No patient in our series required additional surgery to correct axes. However, it would be interesting to evaluate the presence of osteoarthritis in the long term, and its correlation with malalignment.

Functional evaluation at a mean of 45 months follow-up measured with the AOFAS score revealed no difference between the DCP and LCP groups (88 vs. 89). This could be explained in part by the generally good functional results obtained with minimally invasive techniques. For functional rehabilitation, the type of implant may not be as important as the technique used to fix it in place. However, a prospective randomized study should be conducted to address this hypothesis. The overall scores compare favorably with that from previous studies [22].

Postoperative infection was seen in 6 of 68 patients (8.8%). This rate is higher than that reported previously for tibial fractures using a percutaneous technique, although the number of cases requiring surgical revision was the same [32]. With the numbers available, it is impossible to say whether the one or the other type of implant favored infection. The most serious complication encountered in a LCP patient (uncontrolled infection eventually requiring below knee amputation) may have been related to a poorly controlled diabetes mellitus, leading to delayed wound healing and constituting an independent risk factor for infection. Alternative treatment options may be required for this subset of patients [6].

Patient discomfort relating to the plate has been described for both DCP and LCP [13,15,17,18]. Some authors argue that the higher profile of DCP results in a substantial incidence of subcutaneous discomfort, often requiring removal [15]. In our study, a DCP had to be removed more than twice as much as a LCP.

There are several limitations to our study. First, as this is a retrospective study, definite conclusions cannot be drawn. There was no randomization and no specific matching of groups. Consequently, a selection bias might have been introduced by the senior surgeons' preferences with regard to the type of implant to be used. Second, each group had a relatively small number of patients, making statistical analysis difficult. Nevertheless, most of the published studies have lower patient numbers and less follow-up than ours [9,24]. Furthermore, with the exception of one study there has been no direct comparison of the two treatment options [24]. Third, we have used the AOFAS score to quantify the functional outcome [25]. It has been shown recently that the AOFAS rating systems are neither reliable nor valid [33]. This fact has not been evident when planning the present study. Using the AOFAS score provides at least some comparison with other studies on that topic because it used to be the most frequently used clinical scoring system over the last decade. Fourth, the follow-up was relatively short. Posttraumatic osteoarthritis from residual malunion might develop over the long term at the ankle and/or knee joints. Over the short term, no corrective surgery or salvage procedures were needed (Fig. 4).

Based on our results, we suggest that both locking (LCP) and non-locking (DCP) plating systems are suitable for stabilizing distal

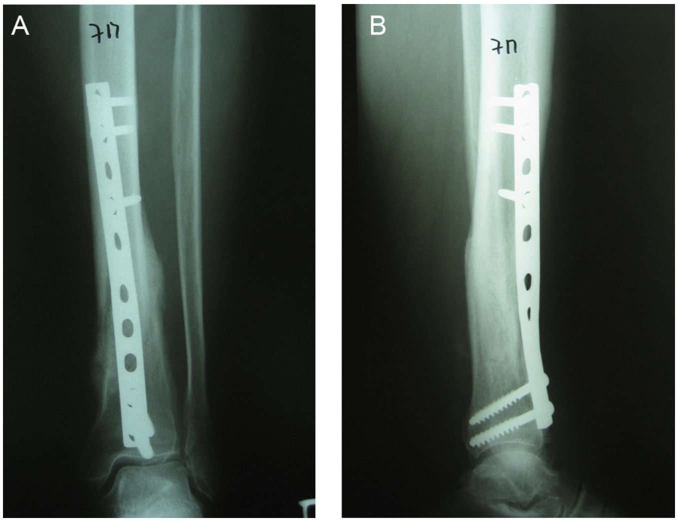

Fig. 4. (A and B) Patient treated with a DCP seven months post surgery. Significant recurvatum and valgus can be seen. However, the patient is asymptomatic at that time.

tibial fractures without intra-articular comminution using a percutaneous technique. We found no statistically significant differences regarding the time to union or functional outcome using the AOFAS score. However, in our study, the use of locking plates resulted in a significantly lower incidence of malalignment and less need of implant removal. Further research is required to determine if and what degree of malalignment has detrimental consequences for the adjacent joints.

Conflicts of interest

No conflicts of interest or funding source are involved in this study.

References

[1] Mast J, Jakob R, Ganz R. Planning and reduction technique in fracture surgery. Berlin, Heidelberg, New York: Springer; 1989. p. 60–70.
[2] Ovadia DN, Beals RK. Fractures of the tibial plafond. J Bone Joint Surg Am 1986;68-A:51–543.
[3] Rüedi T, Allgöwer M. Fractures of the lower end of the tibia into the ankle joint. Injury 1969;1:92–9.
[4] Robinson CM, McLauchlan GJ, McLean JP, Court-Brown CM. Distal metaphyseal fractures of the tibia with minimal involvement of the ankle. J Bone Joint Surg Br 1995;77-B:7–781.
[5] Pellegrini M, Cuchacovich N, Lagos L, Henríquez H, Carcuro G, Bastías G. Minimal invasive alternatives in the treatment of distal articular tibial fractures. Fuss Sprungg 2012;10(1):37–45.
[6] Rammelt S, Endres T, Grass R, Zwipp H. The role of external fixation in acute ankle trauma. Foot Ankle Clin 2004;9(3):455–74.
[7] Helfet DL, Shonnard PY, Levine D, Borrelli Jr J. Minimally invasive plate osteosynthesis of distal fractures of the tibia. Injury 1997;28(Suppl. 1):A42–7.
[8] Müller ME, Nazarian S, Koch P, Schatzker J. The comprehensive classification of fractures of long bones. Berlin, Heidelberg, New York: Springer; 1990.
[9] Redfern DJ, Syed SU, Davies SJM. Fractures of the distal tibia: minimally invasive plate osteosynthesis. Injury 2004;35:615–20.
[10] Farouk O, Krettek C, Miclau T, Schandelmaier P, Guy P, Tscherne H. Minimally invasive plate osteosynthesis and vascularity: preliminary results of a cadaveric injection study. Injury 1999;30:8–591.
[11] Khoury A, Liebergall M, London E, Mosheiff R. Percutaneous plating of distal tibial fractures. Foot Ankle Int 2002;23(9):818–24.
[12] Panchbhavi V. Minimally invasive stabilization of pilon fractures. Tech Foot Ankle Surg 2005;4:240–8.
[13] Gao H, Zhang CQ, Luo CF, Zhou ZB, Zeng BF. Fractures of the distal tibia treated with polyaxial locking plating. Clin Orthop Relat Res 2009;467(3):831–7.
[14] Ronga M, Longo UG, Maffulli N. Minimally invasive locked plating of distal tibia fractures is safe and effective. Clin Orthop Relat Res 2010;468(4):975–82.
[15] Borg T, Larsson S, Lindsjö U. Minimally-invasive plating of distal tibia fractures: preliminary results in 21 patients. Injury 2004;35(6):608–14.
[16] Francois J, Vandeputte G, Verheyden F, Nelen G. Percutaneous plate fixation of fractures of the distal tibia. Acta Orthop Belg 2004;70(2):148–54.
[17] Maffulli N, Toms A, McMurtie A, Oliva F. Percutaneous plating of distal tibia fractures. Int Orthop 2004;28:159–62.
[18] Hasenboehler E, Rikli D, Babst R. Locking compression plate with minimally invasive plate osteosynthesis in diaphyseal and distal tibial fracture: a retrospective study of 32 patients. Injury 2007;38:365–70.
[19] Hazarika S, Chakravarthy J, Cooper J. Minimally invasive locking plate osteosynthesis for fractures of the distal tibia: results in 20 patients. Injury 2007;37:877–87.
[20] Wagner M. General principles for the clinical use of the LCP. Injury 2003;34(Suppl. 2):B31–42.
[21] Anglen J, Kyle RF, Marsh JL, Virkus WW, Watters 3rd WC, Keith MW, et al. Locking plates for extremity fractures. JAAOS 2009;17(7):465–72.
[22] Collinge C, Protzman R. Outcomes of minimally invasive plate osteosynthesis for metaphyseal distal tibia fractures. J Orthop Trauma 2010;24(1):24–9.
[23] Marsh JL, Slongo TF, Agel J, Broderick JS, Creevey W, DeCoster TA, et al. Fracture and Dislocation Classification Compendium – 2007: Orthopaedic Trauma Association Classification, Database and Outcomes Committee. J Orthop Trauma 2007;21(Suppl. 10):S1–33.
[24] Ozkaya U, Parmaksizoglu A, Gul M, Sokucu S, Kabukcuoglu Y. Minimally invasive treatment of distal tibial fractures with locking and non-locking Plates. Foot Ankle Int 2009;30(12):1161–7.
[25] Kitaoka H, Alexander I, Adelaar R, Nunley JA, Myerson MS, Sanders M. Clinical rating systems for the ankle, hindfoot, midfoot, hallux and lesser toes. Foot Ankle Int 1994;15:349–53.
[26] Newman S, Mauffrey C, Krikler S. Distal metadiaphyseal tibial fractures. Injury 2010;41:693–702.
[27] Vallier HA, Le TT, Bedi A. Radiographic and clinical comparisons of distal tibia shaft fractures (4 to 11 cm proximal to the plafond): plating versus intramedullary nailing. J Orthop Trauma 2008;22(5):307–11.
[28] Pallister I, Iorworth A. Indirect reduction using a simple quadrilateral frame in the application of distal tibial LCP—technical tips. Injury 2005;36:1138–42.
[29] Kristensen KD, Klaer T, Blicher J. No arthrosis of the ankle 20 years after malaligned tibial-shaft fracture. Acta Othop Scand 1989;60(2):9–208.
[30] Merchant TC, Dietz FR. Long-term follow-up after fractures of the tibial and fibular shafts. J Bone Joint Surg Am 1989;71(4):599–606.
[31] Tarr RR, Rescnick CT, Wagner KS, Sarmiento A. Changes in tibiotalar joint contact areas following experimentally induced tibial angular deformities. Clin Orthop Relt Res 1985;199:72–80.
[32] Lau TW, Leung F, Chan CF, Chou SP. Wound complication of minimally invasive plate osteosynthesis in distal tibia fractures. Int Orthop 2007;32(5):697–703.
[33] Pinsker E, Daniels TR. AOFAS position statement regarding the future of the AOFAS Clinical Rating Systems. Foot Ankle Int 2011;32:841–2.