Formosan Journal of Musculoskeletal Disorders 1 (2010) 35–40

Contents lists available at ScienceDirect

Formosan Journal of Musculoskeletal Disorders

journal homepage: www.e-fjmd.com

Case Report

Treatment of distal tibial fractures by minimally invasive percutaneous plate osteosynthesis of three different plates: Results and cost-effectiveness analysis

Feng Chen Kao [a,b], Yuan Kun Tu [b,*], Kuo Yao Hsu [c], Chin Hsien Wu [b], Cheng-Yo Yen [b], Ming Chih Chou [a]

[a] *Institute of Medicine of Chung Shan Medical University, Taichung, Taiwan, ROC*
[b] *Department of Orthopaedics, E-Da Hospital/I-Shou University, Kaohsiung, Taiwan, ROC*
[c] *Department of Orthopaedic Surgery, Chang Gung Memorial Hospital, Taoyuan, Taiwan, ROC*

Keywords:
buttress or dynamic compression plates
distal tibial fractures
locking compression plate

A B S T R A C T

Purpose: This study aimed to compare the clinical, radiologic, and cost-effectiveness results between conventional buttress or dynamic compression plates and locking plates for treating displaced distal tibial fractures.

Methods: The conventional plate group included 28 fractures, and the locking compression plate (LCP) group included 24 fractures. Clinical outcomes, radiographic outcomes, and medical costs were compared between the two fixation groups.

Results: Complete union was achieved in all patients. Good or excellent outcomes were achieved in 86% of the conventional plate cases and 79% of the LCP cases ($p = 0.716$). The infection rate was 18% in the conventional plate group and 8% in the LCP group ($p = 0.430$). The malalignment rates in the sagittal plane of the tibia were 7.1% and 8.3% in the conventional plate and LCP groups, respectively. The results showed no significant differences between treatment of distal tibia fractures with conventional plates or LCPs.

Conclusion: The use of conventional plates or LCPs provides a similar outcome in the treatment of distal tibial fractures. However, the LCP is more expensive than the conventional plate. This study showed that the surgical outcome of displaced distal tibial fractures is not affected by the use of LCP.

1. Introduction

The management of displaced distal tibial fractures is a controversial and debatable topic.[1] The classic Arbeitsgemeinschaft für Osteosynthesefragen (AO, Association for the Study of Internal Fixation) technique of open anatomic reduction and internal fixation of distal tibial fractures requires extensive soft-tissue dissection and often leads to subsequent periosteal injury. High rates of complications, including postoperative infection, delayed union, and nonunion, have been reported.[2–6] However, the application of external fixators as the sole method for treating distal tibial fractures can lead to pin tract infections, loosening, and inadequate bone healing.[7,8]

Indirect reduction and biologic percutaneous plating without direct manipulation of the fracture fragments result in good clinical outcomes.[9–12] The main goal of biologic plating techniques is to maintain the soft-tissue attachments and vascularity of the cortical bone fragments,[13,14] thereby theoretically reducing the risk of postoperative infection and

* Corresponding author. Yuan Kun Tu, Department of Orthopedics, E-Da Hospital/I-Shou University, E-Da Road, Jiau-Shu Tsuen, Yan-Chau Shiang, 824 Kaohsiung County, Taiwan, ROC. Tel.: +886 7 6150011x2972; fax: +886 7 6155352.
E-mail address: ed100735@edah.org.tw (Y.K. Tu).

2210-7940/$ – see front matter Copyright © 2010, Taiwan Orthopaedic Association. Published by Elsevier Taiwan LLC. All rights reserved.
doi:10.1016/j.fjmd.2010.10.007

nonunion. Conventional plates such as dynamic compression plates (DCPs) or buttress T plates have been inserted via minimally invasive methods for treating distal tibial fractures, with encouraging results.[10,15–19] Recently, some studies have reported the use of locking plates in treating fractures of the distal tibial shaft and metaphysis. Several studies have reported good clinical outcomes in distal tibial fractures treated with locking compression plates (LCPs) (Synthes, Paoli, PA, USA).[1,20,21] LCPs may provide greater stiffness in some situations. They may also maintain a better periosteal blood flow by minimizing the contact of the plate with bone; however, the implants may be more prominent.[22,23] LCPs are expensive and not covered under the Taiwan National Health Insurance program. It is questionable whether this more expensive implant provides any advantage over the conventional buttress or DCPs for treating distal tibial fractures. Therefore, we evaluated whether there were any clinical, radiologic, and cost-effectiveness differences between the use of conventional plates and LCPs for treating displaced distal tibial fractures.

2. Materials and methods

This study is a retrospective review of the medical records in our teaching hospital. From July 2003 to February 2008, 57 consecutive patients were admitted to the E-Da hospital with distal metaphyseal tibial fractures. The surgical indication was that if the fracture fragments were displaced, surgery was performed by one surgeon. The exclusion criteria were as follows: nondisplaced fracture fragments; AO/Orthopaedic Trauma Association Type B and Type C3 fractures; open Type IIIb and IIIc fractures that required indirect reduction; and conditions in which biologic percutaneous plating could not be performed. Based on the above criteria, 52 consecutive patients (17 women and 35 men; mean age, 48.8 years) were evaluated in this study (Table 1). We evaluated the clinical and radiologic findings of the 52 patients with displaced distal tibial fractures who underwent percutaneous plating with either conventional plates or LCPs. The implant was chosen by the patients themselves because the cost of the LCP was not covered under the National Health Insurance system. The conventional plate group comprised 28 patients with 28 fractures. The LCP group comprised 24 patients with 24 fractures.

Table 1
Patient demographic data.

Characteristic	Conventional plate group (28 patients)	Locking plate group (24 patients)	Total (52 patients)
Men/women	20/8	15/9	35/17
Mean age (y)	48.5 (18–86)	49.2 (20–85)	48.8
AO classification			
A1	2	4	6
A2	4	4	8
A3	9	9	18
C1	3	2	5
C2	10	5	15
Open fracture			
II	9	1	10
IIIA	2	7	9
Proximal 1/3 fibula fracture	3 (10.7%)	3 (12.5%)	
Middle 1/3 fibula fracture	7 (25%)	6 (25%)	
Distal 1/3 fibula fracture	12 (42.9%)	15 (62.5%)	
T plate	15		
DCP	13		

AO = Arbeitsgemeinschaft für Osteosynthesefragen; DCP = dynamic compression plate.

The preoperative radiographs of the 52 patients were retrospectively reviewed, and the fractures were classified according to the AO classification system (Table 1). There were 6 Type A1, 8 Type A2, 18 Type A3, 5 Type C1, and 15 Type C2 fractures. Operations were performed within 24 hours of presentation and within 48 hours after injuries, except in patients with open Type II fractures with a large open wound and Type IIIa fractures. These patients were initially treated with debridement and Hoffman external skeletal fixation; 7–10 days later, they underwent percutaneous plating.

2.1. Operative technique

Patients were placed supine on a radiolucent table, and fluoroscopic guidance was used for optimal diaphyseal–metaphyseal alignment, anatomic reduction of the joint surfaces, and implant fixation. A small rolled surgical towel, acting as a fulcrum, was placed in the concave area posterior to the Achilles tendon region. A 3.0-mm Kirschner wire (K-wire) was placed through the calcaneus at the extension line of the posterior tibial cortex with continuous manual traction. When treating an AO Type C (C1 or C2) fracture, the distal tibial fracture fragments were reduced by indirect reduction with traction and joystick manipulation with a 2.0-mm K-wire. Subsequently, the fracture fragments were stabilized using one or two 4.5-mm cannulated screws.

Under fluoroscopic guidance, two 3- to 4-cm skin incisions were made on the medial side of the tibia at the proximal and distal parts of the estimated position of the plate. After the conventional plates (DCP or T plate) were inserted, two to three 6.5-mm cancellous screws, with or without one 4.5-mm cortical screw, were inserted into the distal tibial fracture fragment, and three 4.5-mm cortical screws were inserted into the proximal tibial fracture fragment (Fig. 1). In the LCP procedure, two or three 4.5-mm locking screws were inserted into the distal tibial fracture fragment, and two 4.5-mm locking screws and one 4.5-mm cortical screw were inserted into the proximal tibial fracture fragment (Fig. 2). If there was a concomitant fracture of the distal one-third of the fibula, open reduction and internal fixation using a conventional or locking reconstruction plate was performed in the same operation.

2.2. Postoperative care

Physical rehabilitation with active motion of the ankle joints was initiated on the second postoperative day and continued until the day of discharge. After discharge, the patients were encouraged to perform straight leg-raising exercises and active ankle motion (extension and flexion). A short leg splint was applied to protect the injured limb for 8 weeks. Partial weight bearing was recommended 8–12

Fig. 1. A 31-year-old man presented with an Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association-Type C2 distal tibial fracture. (A, B) The preoperative radiographs are shown. (C, D) The fracture was treated with minimally invasive percutaneous plating using a buttress T plate; radiographs obtained immediately after the operation are shown. (E, F) The fracture healed 12 months after the operation.

weeks after surgery when evidence of callus bridging was seen on plain radiographs. Full weight bearing was recommended 12 weeks after surgery. Patients were monitored every 4 weeks until the radiographs showed solid continuous callus formation. Anteroposterior and lateral radiographs were obtained at each visit. Solid union was defined as the visualization of cross trabeculations on the anteroposterior and lateral radiographs. Nonunion was defined as the failure of fracture union at the 12-month follow-up visit. Roentgenograms were evaluated for the Johnson angle in the coronal and sagittal planes;[10] the status of union was also checked at each interval. Malalignment was defined as a deviation greater than 10° in the Johnson angle in either the coronal or the sagittal planes.

The ankle scoring system described by Olerud and Molander[24] was used to evaluate patients' outcomes at the 12-month follow-up. The Olerud scoring system included evaluation of pain, range of motion of the ankle joint, walking, climbing stairs, and running. According to the ankle scores, clinical outcomes were categorized as excellent, good, fair, and poor (Table 2). Additional data collected included union times, radiographic parameters, clinical outcomes, and patient demographics. Data were analyzed using the independent-sample t test and Fisher's exact test. $p < 0.05$ was considered significant. The total medical cost for accommodation, blood tests, radiographs, surgery, anesthesia, drugs, techniques, and implants was recorded. Cost-effectiveness analyses of both groups were also performed.

3. Results

All patients received adequate follow-up for at least 12 months. The mean follow-up time was 25.6 months (range, 12–54 months) for the conventional plate group and 31.6 months (range, 12–50 months) for the LCP group. In the conventional plate group, 53.6% of the fractures were Type A

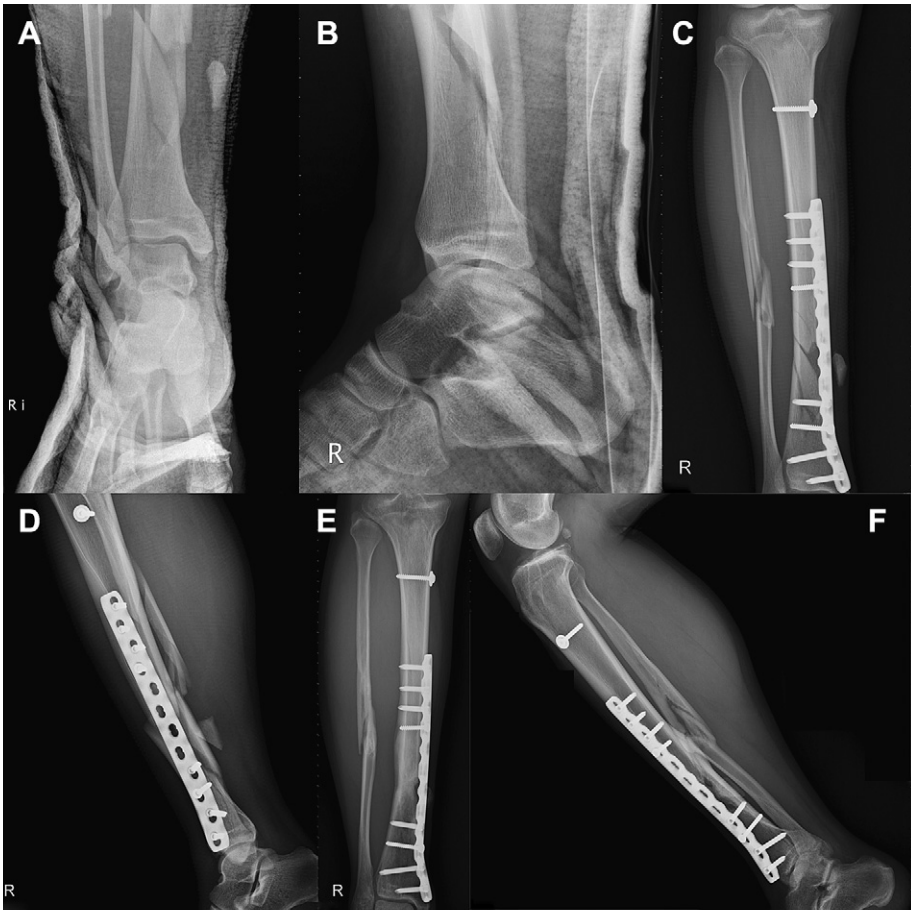

Fig. 2. A 26-year-old man presented with an Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association-Type A3 distal tibial fracture and a middle 1/3 fibular fibular fracture; (A, B) the preoperative radiographs are shown. (C, D) The fracture was treated with minimally invasive percutaneous plating using a locking compression plate; radiographs obtained immediately after the operation are shown. (E, F) Twelve months after the operation, the tibial fracture had healed, whereas the fibular fracture still showed nonunion.

fractures and 46.4% were Type C fractures; in the LCP group, 70.1% of the fractures were Type A fractures and 29.2% were Type C fractures. Open fractures accounted for 39.3% and 33.3% of the fractures in the conventional plate and LCP groups, respectively. Table 2 showed the clinical outcomes. Complete union was achieved in all 52 patients. The overall rate of excellent and good results was 82.7%. The rates of excellent and good results did not differ significantly between the conventional plate and LCP groups. Infection rates were 17.9% and 8.3% in the conventional plate and LCP groups, respectively. The infection rates did not differ significantly between the groups. There was one postoperative infection and one delayed infection in the LCP group and three postoperative infections and two delayed infections in the conventional plate group. Among the seven patients with infection, three had open fractures and four had closed fractures. Patients with infections received surgical debridement and intravenous antibiotics for 2 weeks and underwent surgery to remove the implants after bone union was achieved, with the exception of one patient who had an infection before bone union. After the infection was cured, this patient underwent a second surgery to reapply the LCP implant with bone grafting. Final bone union was achieved 32 weeks after the second surgery.

In the conventional plate group, the average medical cost per case was 31,144 New Taiwan (NT) dollars, and the total cost was 872,032 NT dollars. In the LCP group, the average medical cost per case was 69,144 NT dollars, and the total cost was 1,659,456 NT dollars. The cost-effectiveness was 36,335 NT dollars per good-result case in the conventional plate group and 87,340 NT dollars per good-result case in the LCP group.

Table 3 shows the radiographic findings. The union rate was 100%, and the mean union times were 26.9 and 24.6 weeks in the conventional plate and LCP groups, respectively. The mean union times did not differ significantly between both groups. The loss of correction measured on the basis of the Johnson angle also did not differ significantly between the two treatment groups. The malalignment rates in the sagittal plane of the tibia were 7.1% and 8.3% in the conventional plate and LCP groups, respectively.

Table 4 shows that the infection rate did not differ significantly when considering the factors of plate type,

Table 2
Clinical outcomes.

	Conventional plate group (28 patients)	Locking plate group (24 patients)	Total (52 patients)	p
Ankle scoring system*	87.9	87.0	87.5	0.526†
Excellent	11	7	18	
Good	13	12	25	
Fair	4	5	8	
Excellent/good results	24 (85.7%)	19 (79.2%)	43 (82.7%)	0.716‡
Complications				
Infection	5 (17.9%)	2 (8.3%)	7 (13.5%)	0.430‡

Excellent: above 92 units; Good: between 86 and 92 units; Fair: between 64 and 86 units; Poor: below 65 units.
* Ankle scoring system described by Olerud and Molander in 1984.[24]
† Independent-samples t test.
‡ Fisher's exact test.

existence of open fracture, or surgery for fracture of the distal one-third of the fibula.

4. Discussion

A good functional outcome after surgical treatment of displaced distal tibial fractures entails the restoration of mechanical stability and resumption of former activities.[7] The rate of complete fracture healing of distal tibial fractures ranges from 80% to 100%.[1,7,20,21,25–28] In our study, complete union was achieved in all patients.

Gao et al[20] treated 32 extraarticular distal tibial metaphyseal fractures with LCPs. On the basis of the American Orthopedic Foot and Ankle Society ankle score, an average score of 87.3 points was reported. Our patients had an average score of 87.5 points, and the overall success rate was 82.7%. Nonetheless, the conventional plate and LCP groups were similar with regard to the functions measured in the present study. In the LCP group, the success rate was 79.2%; in the conventional plate group, it was 85.7%. There was no significant difference between the two groups.

We compared the changes in the Johnson angle from the postoperative status up to the time of fracture healing and found no significant difference between the conventional plate and LCP groups. In our study, conventional plates and LCPs showed similar abilities to retain the fracture fragments in the distal tibia.

There was no significant difference in the infection rate between the conventional plate and LCP groups in our study. A total of 5 of the 28 patients (17.9%) in the conventional plate group and 2 of the 24 patients (8.3%) in the LCP group developed infections. The overall infection rate (13.5%) in our study was higher than previously reported infection rates (0–4.4%).[1,7,20,21,25–28] Our results showed that plating on the medial side of the distal tibia had a higher incidence of infections. Because the distal tibia is covered only by a thin layer of soft tissue, the operative treatment of distal tibial fractures often involves complications,[7] especially when the stabilizing plate is placed at the medial side of the distal tibia. In the present study, the 4.5-mm cortical screws, 6.5-mm cancellous screws, and the plate, which was not anatomically contoured, were too prominent to be placed on the medial side of the distal tibia. Another reason for the higher infection rate in our study may be that some high-energy metaphyseal fractures (open Type II or III) had soft-tissue problems related directly to the injury itself.

The study results revealed that the cost-effectiveness was 36,335 NT dollars per good-result case in the conventional plate group and 87,340 NT dollars per good-result case in the LCP group. The cost was higher in the LCP group, but the result was the same. Thus, the analysis did not support the higher cost of the LCP.

There were some limitations in our study. Because the cases were not randomly selected, there may have been a selection bias. While the conventional plate group contained more C2 distal tibial fractures than the LCP group, it did not have a higher rate of implant loosening. The results were similar between the two groups. Our study had some weak points. We did not reveal the length of the distal fracture fragments and the severity of comminuted

Table 3
Radiologic results of surgery.

	Conventional plate group (28 patients)	Locking plate group (24 patients)	p (independent-samples t test)
Union time (wk)	26.9 (14–49)	24.6 (14–40)	0.918
Coronal angle*			
Postoperative	92.0 (86–98)	91.6 (84–99)	
Final	92.0 (84–99)	92.0 (86–99)	
Loss of correction	0 (−5 to 4)	−0.2 (−5 to 6)	0.15
Sagittal angle*			
Postoperative	80.8 (68–87)	83.3 (73–93)	
Final	81.5 (65–93)	82.6 (74–94)	
Loss of correction	−0.8 (−11 to 8)	0.79 (−5 to 7)	0.07
Malalignment in the coronal plane	0	0	
Malalignment in the sagittal plane	2 (7.1%)	2 (8.3%)	0.634†

* Johnson angle.[18]
† Fisher's exact test.

Table 4
Infection under different situations.

	Infection, *n* (%)	No infection	*p* (Fisher's exact test)
T plate	3 (20)	12	0.572 (T plate vs DCP)
DCP	2 (15.4)	11	0.280 (T plate vs LCP)
LCP	2 (8.3)	22	0.441 (DCP vs LCP)
Open fracture	3 (15.8)	16	0.697
Close fracture	4 (12.1)	29	
Surgery for distal 1/3 malleolar	5 (18.5)	22	0.422
No surgery for distal 1/3 malleolar	2 (8)	23	

DCP = dynamic compression plate; LCP = locking compression plate.

fractures. If the distal fragments were too short or too small, the large plates used in our study could not achieve adequate fixations. In addition, we combined articular C type and extraarticular A type distal tibial fractures in this study. These different conditions may have led to different results; further studies may be required to clarify this issue.

In summary, minimally invasive percutaneous plating with either conventional plates or LCPs provides a similar outcome in the treatment of distal tibial fractures. However, LCP is more expensive than the conventional plate. The findings of this study did not reveal any clinical advantages of LCP that would justify its higher cost.

References

1. S. Hazarika, J. Chakravarthy, J. Cooper, Minimally invasive locking plate osteosynthesis for fractures of the distal tibia—results in 20 patients, Injury 37 (2006) 877–887.
2. W.D. Fisher, D.L. Hambledon, Problems and pitfalls of compression fixation of long bone fractures: a review of results and complications, Injury 10 (1978) 99–107.
3. M.A. McFerran, S.W. Smith, H.J. Boulas, H.S. Schwartz, Complications encountered in the treatment of pilon fractures, J Orthop Trauma 6 (1992) 273–285.
4. S. Olerud, G. Karlstrom, Tibial fractures treated by AO compression osteosynthesis. Experiences from a five year material, Arch Orthop Scand Suppl 1 (1972) 1–104.
5. T. Ruedi, M. Allgower, Fractures of the lower end of the tibia into the ankle joint: results 9 years after open reduction and internal fixation, Injury 5 (1973) 130–134.
6 T. Ruedi, M. Allgower, The operative treatment of intra-articular fractures of the lower end of the tibia, Clin Orthop 138 (1979) 105–110.
7. T. Krackhardt, J. Dilger, I. Flesch, D. Höntzsch, C. Eingartner, K. Weise, Fractures of the distal tibia treated with closed reduction and minimally invasive plating, Arch Orthop Trauma Surg 125 (2005) 87–94.
8. T.A. Russell, Fractures of the tibia and fibula. in: C.A. Rockwood, D.P. Green, R.W. Buckolz (Eds.), Fractures in Adults, 4th ed. Lippincott, Philadelphia, PA, 1996, pp. 2139–2157.
9. M. Leunig, R. Hertel, K.A. Siebenrock, F.T. Ballmer, J.W. Mast, R. Ganz, The evolution of indirect reduction techniques for the treatment of fractures, Clin Orthop 375 (2000) 7–14.
10. C.W. Oh, H.S. Kyung, I.H. Park, P.T. Kim, J.C. Ihn, Distal tibia metaphyseal fractures treated by percutaneous plate osteosynthesis, Clin Orthop 408 (2003) 286–291.
11. S.M. Perren, 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 (2002) 1093–1110.
12. D.A. Wiss, What's new in orthopaedic trauma, J Bone Joint Surg Am 83 (2001) 1762–1772.
13. O. Farouk, C. Krettek, T. Miclau, P. Schandelmaier, H. Tscherne, Effects of percutaneous and conventional plating techniques on the blood supply to the femur, Arch Orthop Trauma Surg 117 (1998) 438–441.
14. O. Farouk, C. Krettek, T. Miclau, P. Schandelmaier, P. Guy, H. Tscherne, Minimally invasive plate osteosynthesis: does percutaneous plating disrupt femoral blood supply less than the traditional technique? J Orthop Trauma 13 (1999) 401–406.
15 T. Borg, S. Larsson, U. Lindsjo, Percutaneous plating of distal tibia fractures. Preliminary results in 21 patients, Injury 35 (2004) 608–614.
16. C.A. Collinge, R.W. Sandeers, Percutaneous plating in the lower extremity, J Am Acad Orthop Surg 8 (2000) 211–216.
17. A. Khoury, M. Liebergall, E. London, R. Mosheiff, Percutaneous plating of distal tibial fractures, Foot Ankle Int 23 (2002) 818–824.
18. C.W. Oh, B.C. Park, H.S. Kyung, S.J. Kim, H.S. Kim, S.M. Lee, J.C. Ihn, Percutaneous plating for unstable tibial fractures, J Orthop Sci 8 (2003) 166–169.
19. A.D. Toms, A. McMurtie, N. Maffulli, Percutaneous plating of the distal tibia, J Foot Ankle Surg 43 (2004) 199–203.
20. H. Gao, C.Q. Zhang, C.F. Luo, Z.B. Zhou, B.F. Zeng, Fracture of the distal tibia treated with polyaxial locking plating, Clin Orthop Relat Res 467 (2009) 831–837.
21 E. Hasenboehler, D. Rikli, R. Babst, Locking compression plate with minimally invasive plate osteosynthesis in diaphyseal and distal tibial fracture: a retrospective study of 32 patients, Injury 38 (2007) 365–370.
22. K.A. Egol, E.N. Kubiak, E. Fulkerson, F.J. Kummer, K.J. Koval, Biomechanics of locked plates and screws, J Orthop Trauma 18 (2004) 488–493.
23 M.J. Kaab, A. Frenk, A. Schmeling, K. Schaser, M. Schütz, N.P. Haas, Locked internal fixator: sensitivity of screw/plate stability to the correct insertion angle of the screw, J Orthop Trauma 18 (2004) 483–487.
24. C. Olerud, H. Molander, A scoring scale for symptom evaluation after ankle fractures, Arch Orthop Trauma Surg 103 (1984) 190–194.
25. C. Collinge, M. Kuper, K. Larson, R. Protzman, Minimally invasive plating of high-energy metaphyseal distal tibia fractures, J Orthop Trauma 21 (2007) 355–361.
26. D.L. Helfet, P.Y. Shonnard, D. Levine, J. Borrelli Jr., Minimally invasive plate osteosynthesis of distal fractures of the tibia, Injury 28 (Suppl 1) (1997) A42–A48.
27. D.J. Redfern, S.U. Syed, S.J.M. Davies, Fractures of the distal tibia: minimally invasive plate osteosynthesis, Injury 35 (2004) 615–620.
28. H.A. Vallier, T.T. Le, A. Bedi, Radiographic and clinical comparisons of distal tibia shaft fracture (4 to 11 cm proximal to the plafond): plating versus intramedullary nailing, J Orthop Trauma 22 (2008) 307–311.