Minimally invasive plating: a good option for distal tibia fractures with simple or no articular involvement

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Background
Despite great improvements in treatment procedures and implants, management of distal tibia fractures remains challenging.

Objective
The purpose of the present prospective study was to evaluate the use of minimally invasive plating for treating distal tibia fractures with simple or no articular involvement, and to suggest the factors that may improve the results.

Patients and methods
In this prospective, noncontrolled cohort study, 46 patients with distal tibia fractures (excluding AO 43-B3, 43-C3 fractures) were treated with the medial distal tibia anatomical locked plate. Only the results for 40 patients were reported in our study; the remaining six were excluded as they did not complete the follow-up. There were 28 men and 12 women, with a mean age of 37.5 years. According to the AO classification, there were 22 fractures of type A, 13 of type B, and five of type C. Seven fractures were open. The American Orthopedic Foot and Ankle Society (AOFAS) Ankle–Hindfoot Scale was used for functional assessment.

Results
The mean follow-up period was 53.25 ± 9.53 months (range: 36–66 months). All the fractures united with acceptable alignment in a mean time of 17.17 weeks (range: 10–28 weeks). Five (12.5%) patients caught infections – three superficial and two deep. Secondary surgeries were carried out only for debridement or implant removal, but none to achieve union. Six (15%) patients had angular deformities less than or equal to 5°. None of these deformities required a secondary operation for correction. At the end of follow-up, the mean AOFAS score was 90. A total of 32 (80%) patients resumed their preinjury activity and sports and 37 (92.5%) were back to their previous employment.

Conclusion
Minimally invasive plating provides a secure, easily applied good solution for the challenging distal tibia fracture, even with simple articular extension. Surgeon experience and skill, efficient preoperative planning, and well-planned postoperative protocol are important for improving the outcome.

Keywords:
distal tibia fractures, intra-articular, minimally invasive plating

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Introduction

Although many options for treating distal tibia fractures are available, the optimum one remains controversial [1]. The distal tibia has a specific anatomical shape, limited soft tissue envelope especially anteromedially, precarious blood supply, and high energy nature of the injuries in most cases [2]. Experience of the surgical team and the available resources influence implant selection. The options for surgical treatment include external fixation [3], intramedullary nailing [4], open plating [5], and, recently, minimally invasive percutaneous plate osteosynthesis (MIPPO) [6–8].

Traditional plating through open reduction and internal fixation (ORIF) showed good alignment, but with extensive dissection, and additional soft tissue compromise, which may lead to increased rates of wound complications, infections, and union problems [5].

Closed nailing preserves the fracture's hematoma and maintains the integrity of the soft tissue envelope, but it has been accused of technical difficulties, unstable fixation, fracture comminution during nail insertion, and malalignment [5].

The goal of MIPPO is to apply biological stable fixation. The anatomical locked plate is a self-stable construct, needs no contouring, provides both angular

and axial stability through uniform distribution of loads, and needs no screw tightening, which may lead to secondary loss of reduction with nonlocked plates [9,10]. Through indirect reduction and minimal exposure it minimizes the surgical trauma and preserves the fracture hematoma and most of the soft tissue envelope and blood supply of the fracture fragments, with suspected higher rates of union and lower rates of complications [6–8]. Vascular injection studies revealed higher preservation of periosteal circulation with MIPPO in comparison with ORIF [10]. The early results of MIPPO in treating distal tibia fractures have been successful [7,11], but with reported complications such as angular deformities, nonunion, and hardware problems [7,9].

Objective

The present study aimed at evaluating, prospectively, the results of MIPPO using the medial AO distal tibia anatomical locked plate in treating distal tibia fractures with or without simple articular involvement, and at determining important factors for its success in our community.

Patients and methods

Between February 2007 and July 2009, we managed 46 consecutive patients in King Fahad Hospital at Al-Baha, Kingdom of Saudi Arabia, who had distal tibia fractures with extra-articular or simple intra-articular extension. Only the results of 40 patients were reported, as six patients did not complete the follow-up. The study included 28 men and 12 women, with a mean age of 38.1 ± 12.32 years (range: 20–63 years).

The exclusion criteria included type III open fractures as per Gustilo and Anderson classification, articular comminution (AO B3, C3), pathological fractures, coexisting vascular or neurological lower limb disease, deformity existing before the fracture, and ipsilateral tibia fractures.

According to the AO classification, there were thirteen 43-A1, seven A2, four A3, five B1, four B2, four C1, and three C2 fractures. A total of 33 fractures were closed and seven were open (four type I and three type II as per the Gustilo and Anderson classification).

Detailed preoperative planning was carried out. Each injury was carefully evaluated for the extent of soft tissue injury, fracture pattern, bone comminution, bone loss, and articular extension. Accordingly, implant choice, and the need for fixation of the fibula, bone grafting or plastic reconstruction were determined. Detailed discussion with the patient about his condition, operative procedure, and the postoperative rehabilitation program was conducted, followed by obtaining a written consent from all patients. We preferred early interference, but delayed interference in some cases was due to late patient arrival, excessive swelling, or correction of any associated comorbidities. While waiting for the surgery, immobilization was achieved by using above knee back slab.

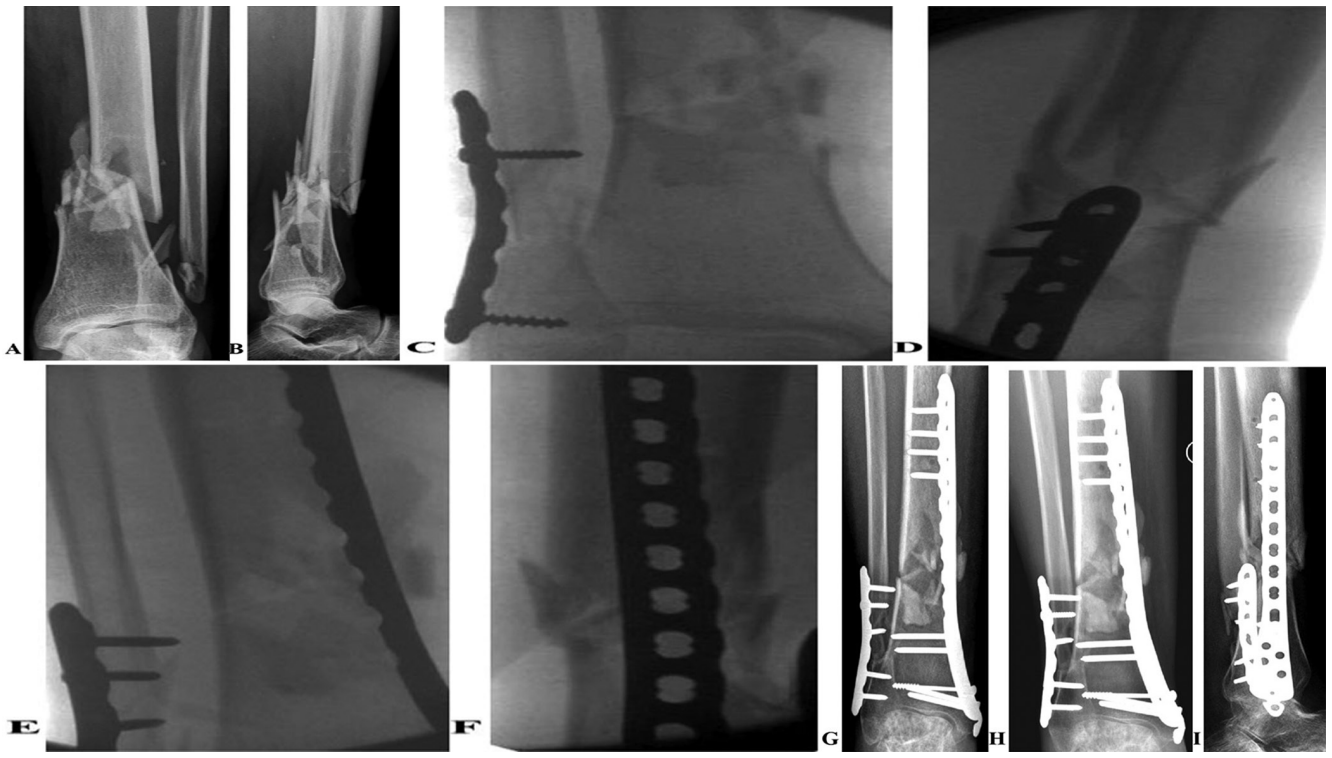
All the patients were treated with medial AO distal tibia anatomical locked plate using the MIPPO technique. We fixed the fibula fracture if it was syndesmotic, displaced infrasyndesmotic, or suprasyndesmotic associated with comminution, impaction, or shortening at the tibia fracture. It was fixed first by using MIPPO, open plating, or intramedullary thick K-wires before tibial fixation in 18/28 (64%) patients. This restored the lateral column and helped in the reduction of the tibia fracture and restoration of its length and alignment (as in the case presented in Fig. 1). Manual traction was used in other cases for reduction (as we did in the case presented in Fig. 2). If the reduction was difficult, a dissector, Schanz screw, or periosteal elevator was used as a joystick to assist in reduction. Cannulated screws and K-wires were used before plating to fix the intra-articular extension of the fracture (as in the case presented in Fig. 3).

If the distal fragment of the tibial fracture was displaced medially, the plate was inserted from distal to proximal and vice versa. Compared with the other side, alignment, limb length, and rotation were assessed and adjusted before fixing the plate. It was reassessed after the plate was secured by one screw to the proximal and distal fragments. If satisfactory, the remaining screws were applied.

Postoperatively, the limb was maintained in the elevated position and immobilized by using a removable below knee back slab for 2 weeks. Smooth active range of motion (ROM) exercised for the ankle and nonweight bearing ambulation were allowed in the first postoperative day. Toe-touch weight-bearing was allowed at 4 weeks and progressed gradually to full weight-bearing according to clinical and radiographic evaluation.

The patients were followed up every 2 weeks till they reached full weight-bearing, every 3 months till end of the first year, and then every 6 months till end of the follow-up period. On every visit, the patients were assessed clinically, functionally, and radiographically for gait, deformity, ankle ROM, infection, leg-length discrepancy, union, need for secondary procedures,

Figure 1

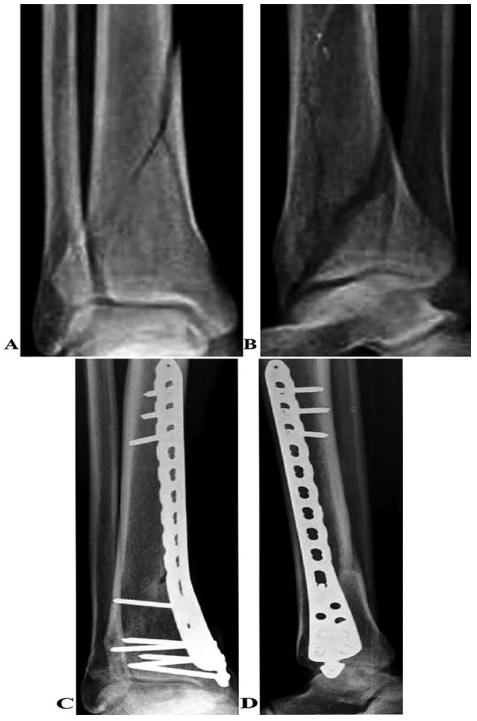


(a, b) Type 43-A3 fracture. (c–f) Restoration of the lateral column reduced the tibia fracture and restored length and alignment. (g–i) Fast healing of the tibia fracture.

complications, and return to original job, preinjury daily activity, and sports. The American Orthopedic Foot and Ankle Society (AOFAS) Ankle–Hindfoot Scale [12] was used for the assessment at the final evaluation.

Superficial infection was defined as persistent drainage for at least 2 days [13]. Late skin infection was defined as one that occurred at least 2 months after complete wound healing [14]. Union was defined as the presence of bridging callus in three of the four cortices as seen on anteroposterior and lateral radiographs, delayed union was defined as the ongoing process of union but not completed after 6 months, and nonunion was defined as the failure of union after 9 months with no radiographic progression in the last 3 months [5]. Malunion was defined as the incongruity of the articular surface of more than 2 mm, angular malalignment greater than 5° in any plane, or more than 15° rotation difference [5,14,15]. Limb length discrepancy greater than 1 cm was considered as shortening [5,14].

Figure 2



(a, b) 43-C1 fracture. (c, d) Fixation of the articular fragments through the plate with good healing.

Statistical analyses

Statistical analyses were performed in SPSS (version 19; SPSS Inc., Chicago, Illinois, USA). Quantitative variables were expressed as mean ± SD and compared using the Student *t*-test. Categorical values were expressed as a percentage and compared using the χ^2-test. *P* value less than 0.05 was considered significant.

Results

The mean follow-up period was 53.25 ± 9.53 months (range: 36–66 months). The mean time between trauma and surgery (time to operating room (OR)) was 62.5 ± 51.29 h (range: 5–168 h). The mean operative time was 72 ± 27.64 min (range: 40–120 min). The mean hospital stay was 4.67 ± 1.95 days (range: 3–11 days). The mean time to full weight-bearing was 11.50 ± 2.25 weeks (range: 8–16 weeks).

The wounds healed smoothly without problems in 35 (87.5%) patients, whereas five (12.5%) caught infections — three early superficial and two late deep infections — after fracture union. The superficial infections were treated successfully with wound care and antibiotics. The deep infections were treated with implant removal, wound debridement, and antibiotics.

All fractures united without secondary procedures to achieve union. The mean time to radiological union was 17.17 ± 4.24 weeks (range: 10–28 weeks). Delayed union, from 26 to 28 weeks, was encountered in two cases with type II open fractures. Six (15%) patients had angular deformities less than or equal to 5° – three varus, one valgus, and two anterior bowing. No patient had rotational malalignment, recurvatum deformity, or implant failure. Limb length discrepancy less than or equal to 1 cm and limping was found in three (7.5%) patients, but only one of them had shoes adjustment done. Two (5%) patients had 10° and another one had less than or equal to 25° reduced ankle ROM. He was a 63-year-old man, not cooperative with the rehabilitation program, and was phobic that movement will lead to refracture, despite reassurance and the help from a psychiatrist.

A total of 37 (92.5%) patients could return to their original job in a mean time of 5.36 ± 2.73 months and three (7.5%) lost their job or retired. The first patient retired because his job required him to stand for long hours, which led to foot and leg swelling; he was 57 years old. The second patient was a manual worker and could not maintain his job. The third patient retired because of a cause not related to the tibia fracture.

In total, 32 (80%) patients were back to their preinjury daily activity and sports, whereas eight patients did not — four (10%) of them because of complications such as limping, or reduced ankle ROM, and the other four (10%) because of fear of practicing sports with implants.

Five (12.5%) patients asked for implant removal because of skin irritation. In another two (5%), the implants were removed because of deep infection. Thus, all the seven secondary surgeries were performed for implant removal. The mean AOFAS score was 90 ± 6.09 (range: 70–100) at the end of follow-up. Table 1 presents the overall results.

Figure 3

(a, b) 43-B2 fracture. (c, d) percutaneous compression (PC) fixation by using screws and K-wires was carried out to restore the intra-articular fragments before plating.

Discussion

Controversy still exists about the surgical merits of the different lines for treating distal tibia fractures; decision making may be difficult, and no best treatment has been determined [1,15]. The minimal soft tissue envelope recommends the choice of reduction techniques and implants that will further compromise the already poor blood supply. MIPPO carried great hope for improving the results with its biological and mechanical advantages. The plate acts as an internal

Table 1 Overall results

Variables	Percentage of patients
Union	100
Angular deformities >5°	0
Leg-length discrepancy >1 cm	0
Limp	7.5
Decreased range of motion of ankle >20°	2.5
Return to preinjury daily activities and sports	80
Return to previous job	92.5
Deep infection	5
Implant removal	17.5

fixator that carries the biomechanical properties of both internal and external fixation. The distal end of the plate allows placement of multiple locking screws in a small bone zone, providing better stability [16]. This can be achieved through a small distal incision with minimal soft tissue disruption especially if the plate is inserted from proximal to distal.

A study by Mahajan [17] reported that the results of operative treatment are dependent on the severity of the initial injury, the reduction quality, and the fixation stability. In our opinion, the long-term results depend on many factors related to the patient, injury, and the surgeon. The patient factors include his age, bone quality, activity level, job, and associated comorbidities. The injury factors include its mechanism, severity, degree of soft tissue compromise, and degree of bone comminution, or loss. The surgeon factors include his experience in managing distal tibia fractures, efficient preoperative planning, implant choice, surgical technique, and the postoperative rehabilitation protocol.

Ours and others studies [18] preferred early interference, as it allows easy reduction because of effective ligamentotaxis. In addition, early bony stabilization may limit further soft tissue damage, decrease the risk of bacterial spread, improve the blood flow and venous return, and reduce post-traumatic edema, pain, and stiffness. But delayed interference may be advocated in case of gross swelling, skin injury, and fracture blisters. In this study, the mean time between trauma and surgery was 62.5 versus 4.45 days in a study by Shrestha *et al.* [15].

Our results are in agreement with that of a study by Gupta *et al.* [14], who did not fix the fibular fractures proximal to the syndesmosis when the tibia fracture was simple. But, with impaction, comminution, shortening of the tibia, the fibula should be fixed first to maintain the lateral column of the ankle, which helps in the reduction of the tibia fracture and prevents later collapse. This collapse may cause shortening and limping. We fixed 18 of 28 fractured fibulas. Three (7.5%) of our patients got less than 1 cm limb length discrepancy with a limp, whereas a study by Ronga *et al.* [2] reported limping in 8/19 (42%) patients.

As 4 weeks represent enough period for fracture consolidation, we allowed partial weight-bearing at that time versus 5.6 weeks in a study by Bahari *et al.* [16] and 5.6 versus 6 weeks in a study by Leonard *et al.* [18]. We progressed it to full weight-bearing on individual basis according to the progress of healing and the patient's weight. The mean time to full weight-bearing was 11.5 weeks in our study versus 11.3 weeks in a study by Bahari *et al.* [16], and 10 weeks in a study by Leonard *et al.* [18]. Following this protocol, we did not get any implant-related problems or fixation failure.

In their study, Ronga *et al.* [2] reported 9/21 (43%) patients who caught infections — six minor and three deep. In our study, five (12.5%) patients caught infections — three superficial and two late deep — after bone healing. These did not affect the final results except the need for another surgery for implant removal in the two cases with deep infections. A study by Collinge *et al.* [19] considered the liberal use of temporizing external fixation and timing reconstructions to be the main barriers against infection. Whereas, our and a study by Ronga *et al.* [2] considered that stable fixation, soft tissue protection, and preservation of the blood supply to the bone fragments with the use of MIPPO represent good barriers against infection. We used external fixation, and timing reconstructions were required if the soft tissues around the fracture site were devitalized.

High nonunion rates and increased need for secondary surgeries were reported with ORIF [3,4], whereas MIPPO showed better results [7,9,11]. The union rates with MIPPO were reported to be 100% in a study by Helfet *et al.* [7] and in our study; it was 97% in a study by Zelle *et al.* [1] and 90% in that of Hazarika *et al.* [13]. The mean duration for radiological union was reported to be 18.5 weeks (range: 14–28 weeks) in as study by Shrestha *et al.* [15], 20.7 weeks (range: 16–28 weeks) in open and 17.96 weeks (range: 10–36 weeks) in closed fractures in a study by Aksekili *et al.* [20], and 17.17 weeks (range: 10–28 weeks) in our study. Fixation loss and implant failure may be related to early uncontrolled weight-bearing, infection, and nonunion. Fixation loss was reported in a study by Collinge *et al.* [19] to be 7%. Implant failure was reported to be 2.4% by Bahari *et al.* [16], 5% by Hazarika *et al.* [13], and 5.5% by Ahmad *et al.* [21]. In our study, no fixation loss or implant failure was encountered. This may be attributed to the absence of the predisposing factors for implant failure or fixation loss. The two cases of deep infections in our study occurred after bone healing.

The need for bone grafting should be carefully evaluated in each patient. We considered it unusual that, in their study, Collinge *et al.* [19] reported the need for secondary procedures to achieve union in 35% of their patients. Our study and others [4] considered that delayed or nonunion, and the need for secondary surgeries to achieve union, are correlated with the extent of soft tissue injury, bone comminution, or loss. In our study, no secondary procedures were required to achieve union, but two cases with type II open

fractures required 26 and 28 weeks, respectively, to achieve union.

Adequate alignment after distal tibia fractures was a challenge with different lines of treatment, and was greatly affected by surgeon's learning curve [1]. Alignment problems were low with ORIF, high (7–35%) with nailing [4], and were recognized as a potential pitfall for MIPPO [2,9,11]. A study by Ronga *et al.* [2] reported angular deformities of less than or equal to 7° in 21% of the patients; half of them had deformities in two planes. In agreement with a study by Leonard *et al.* [18], we were convinced that MIPPO using a medial plate was effective at restoring and maintaining alignment, as we achieved satisfactory reduction in all cases. There were three patients with less than or equal to 5° varus deformity; one had 5° valgus deformity, two had 5° anterior bowing, and no one had rotational malalignment. None of them needed a secondary operation for correction.

Restriction in ankle motion was reported in a study by Ronga *et al.* [2] to be greater than 20° in 5/21 (24%) patients. In our study, four (10%) patients had less than or equal to 10° reduced range of ankle motion; another one had less than or equal to 25° reduced range of ankle motion, mainly in dorsiflexion because he was 63 years old, not cooperative with the rehabilitation program, and phobic about refracture.

In their study, Collinge *et al.* [19] nominated secondary surgeries to be the only variable that influenced functional outcomes. They reported a mean AOFAS score of 83. Similar to the results obtained in a study by Bahari *et al.* [16], the mean AOFAS score in our study was 90 (70–100) at the end of follow-up. We could not determine any specific factor affecting the outcome, and all the seven secondary surgeries were performed for implant removal because of skin irritation or infection. In agreement with the results obtained in respective studies by Bahari *et al.* [16] and Gupta *et al.* [14], we removed the implants routinely.

The return to preinjury job and its possible timing were the main questions asked by any patient with an injury. The advancement of the treatment techniques mostly aimed at minimal surgical interference to allow fast rehabilitation and early return to the original job. In addition, the problem of work compensation for the insurance companies and the governments were much more with traditional lines of treatment. MIPPO, in general, and specifically in distal tibia fractures, worked well to fasten the rehabilitation time and to help most of the patients to return early and effectively to their original jobs. In a study by Bahari *et al.* [16] 95% of the included patients were back to work within 6 months of injury. In our study, 37 (92.5%) patients could return to their original job in a mean time of 5.36 ± 2.73 months. Two of them were due to the tibia fracture, but, the third one was not.

Conflicting results about resuming the preinjury sporting or leisure activities were reported in several studies, ranging from 89% in a study by Bahari *et al.* [16] to 16% by Ronga *et al.* [2]. In our study, 32 (80%) patients resumed preinjury daily activities and sports, whereas eight (20%) patients could not. Three of these last eight patients were those who lost their jobs. As MIPPO adds minimal surgical trauma to the already traumatized zone, the effect of the injury and the postoperative rehabilitation protocol remain the main determinants for the return to the level of preinjury daily activity and sports. Preoperative discussion with the patient to clarify his or her role in the rehabilitation program is important in resuming the preinjury level of daily activities and sports in a short time.

We believe the following factors and recommendations may help in improving the results in dealing with the challenging distal tibia fractures:

(1) Surgeon skill, learning curve, and experience in MIPPO and strict adherence to its technical, mechanical, and biological principles are keys to better outcomes.
(2) High recognition of the soft tissue envelope and the effect of surgical trauma in increasing its compromise, especially the devascularization of the fracture fragments, should be taken into consideration.
(3) Efficient preoperative planning to determine the interacting patient and injury factors help the surgeon in choosing the proper implant and surgical technique suitable for a specific patient with a certain injury.
(4) Well-planned postoperative management and rehabilitation protocol and efficient participation of the patient remain highly important for success.

We recommend the following:

(1) These cases should be managed by the most experienced surgeon in the team.
(2) Early interference is preferable, except with severe swelling.
(3) Proximal to distal plate insertion should be carried out if the fracture configuration permits.
(4) Primary fixation of suprasyndesmotic fractures of the fibula should be done, if there is impaction, comminution, or shortening in the tibia fracture.

Conclusion

This prospective study showed that MIPPO provides a secure, easily applied solution for the challenging distal tibia fracture even with simple articular extension. Surgeon experience and skill, efficient preoperative planning, well-planned postoperative protocol, and patient cooperation are important for improving the outcome.

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Conflicts of interest

There are no conflicts of interest.

References

1 Zelle BA, Bhandari M, Espiritu M, Koval KJ, Zlowodzki M. Evidence-Based Orthopaedic Trauma Working Group. Treatment of distal tibia fractures without articular involvement: a systematic review of 1125 fractures. J Orthop Trauma 2006; 20:76–79.

2 Ronga M, Longo UG, Maffulli N. Minimally invasive locked plating of distal tibia fractures is safe and effective. Clin Orthop Relat Res 2010; 468:975–982.

3 Court-Brown CM, Walker C, Garg A, McQueen MM. Half-ring external fixation in the management of tibial plafond fractures. J Orthop Trauma 1999; 13:200–206.

4 Nork SE, Schwartz AK, Agel J, Holt SK, Schrick JL, Winquist RA. Intramedullary nailing of distal metaphyseal tibial fractures. J Bone Joint Surg Am 2005; 87:1213–1221.

5 Janssen KW, Biert J, van Kampen A. Treatment of distal tibial fractures: plate versus nail: a retrospective outcome analysis of matched pairs of patients. Int Orthop 2007; 31:709–714.

6 Collinge C, Sanders R, DiPasquale T. Treatment of complex tibial periarticular fractures using percutaneous techniques. Clin Orthop Relat Res 2000; 375:69–77.

7 Helfet DL, Shonnard PY, Levine D, Borrelli J Jr. Minimally invasive plate osteosynthesis of distal fractures of the tibia. Injury 1997; 28S1:A42–A47.

8 Perren SM. 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 2002; 84:1093–1110.

9 Maffulli N, Toms AD, McMurtie A, Oliva F. Percutaneous plating of distal tibial fractures. Int Orthop 2004; 28:159–162.

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; 28:A7–A12.

11 *K*rackhardt T, Dilger J, Flesch *I*, Höntzsch D, Eingartner C, Weise K. Fractures of the distal tibia treated with closed reduction and minimally invasive plating. Arch Orthop Trauma Surg 2005; 125:87–94.

12 Kitaoka HB, Alexander IJ, Adelaar RS, Nunley JA, Myerson MS, Sanders M. Clinical rating systems for the ankle–hindfoot, midfoot, hallux, and lesser toes. Foot Ankle Int 1994; 15:349–353.

13 Hazarika S, Chakravarthy J, Cooper J. Minimally invasive locking plate osteosynthesis for fractures of the distal tibia — results in 20 patients. Injury 2006; 37:877–887.

14 Gupta RK, Rohilla RK, Sangwan K, Singh V, Walia S. Locking plate fixation in distal metaphyseal tibial fractures: series of 79 patients. Int Orthop 2010; 34:1285–1290.

15 Shrestha D, Acharya BM, Shrestha PM. Minimally invasive plate osteosynthesis with locking compression plate for distal diametaphyseal tibia fracture. Kathmandu Univ Med J 2011; 9:62–68.

16 Bahari S, Lenehan B, Khan H, McElwain JP. Minimally invasive percutaneous plate fixation of distal tibia fractures. Acta Orthop Belg 2007; 73:635–640.

17 Mahajan N. Minimally invasive techniques in distal tibial fractures. JK Sci 2008; 10:78–80.

18 Leonard M, Magill P, Khayyat G. Minimally-invasive treatment of high velocity intra-articular fractures of the distal tibia. Int Orthop 2009; 33:1149–1153.

19 Collinge C, Kuper M, Larson K, Protzman R. Minimally invasive plating of high-energy metaphyseal distal tibia fractures. J Orthop Trauma 2007; 21:355–361.

20 Aksekili MA, Celik I, Arslan AK, Kalkan T, Uğurlu M. The results of minimally invasive percutaneous plate osteosynthesis (MIPPO) in distal and diaphyseal tibial fractures. Acta Orthop Traumatol Turc 2012; 46:161–167.

21 Ahmad MA, Sivaraman A, Zia A, Rai A, Patel AD. Percutaneous locking plates for fractures of the distal tibia: our experience and a review of the literature. J Trauma Acute Care Surg 2012; 72:E81–E87.