Advantage and limitations of a minimally-invasive approach and early weight bearing in the treatment of tibial shaft fractures with locking plates

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Summary
Objectives: Intramedullary nailing is a common method of treating tibial shaft fractures. However, precise control of reduction at the proximal and distal quarters is difficult to achieve. The purpose of this study was to assess the results of plating using locking screws and the feasibility of a minimally-invasive approach.

Patients/participants: All patients with tibial shaft fracture treated by means of locking plates from January 2004 to October 2006. Thirty-two fractures were treated in 32 patients with a mean age of 43.8 years.

Intervention: Internal fixation with a locking plate and screw construct, using a minimally-invasive or standard approach.

Main outcome measurements: Surgical approach, time to weight bearing, complications and their type, time to bone union, alignment in the frontal and sagittal planes on anteroposterior and lateral radiographs.

Results: The minimally-invasive approach was performed in 28 cases and immediate full weight bearing allowed in 25 cases. At a mean follow-up of 27 months, two patients had died and two patients were lost to follow-up. The mean time to bone union was 9.1 weeks. Four cases had a complicated course: one infection, one compartment syndrome, one hardware breakage and one pseudarthrosis. Six cases ended up with valgus malunion exceeding 5° in the frontal plane, already present at the time of surgery.

Conclusion: Where a minimally-invasive approach can be performed, immediate pain-free weight bearing can be allowed without further displacement at follow-up. The observed rate of
Introduction

Locked intramedullary nailing is the gold standard for treating fractures of the tibial shaft [1]. This technique is known to be difficult when treating fractures that involve either the proximal or the distal quarter of the tibia, although Nork’s work proved that intramedullary nailing is an effective alternative for the treatment of distal tibial fractures [2,3]. In proximal and distal fractures, adequate reduction is difficult to obtain and difficult to maintain with an intramedullary nail, due to metaphyseal widening of the tibia associated with a long lever arm. Therefore, some authors advocate the use of plates in order to treat fractures involving the proximal [4,5] or the distal [6,7] quarters of the tibia. The purpose of this study was to assess the results of plating when treating fractures of the tibial shaft. We report the results of a consecutive retrospective series of fractures of the tibial shaft treated with locking plates mainly through a minimal-invasive approach, and with immediate, full weight bearing allowed in the postoperative course.

Material and methods

The series

This series includes all fractures of the tibial shaft, according to the AO Classification, and treated with a locking plate in a level I academic regional hospital, from March 2004 until October 2006.

We reviewed 32 consecutive fractures retrospectively. There were 32 patients, 14 women and 18 men, with a mean age of 43.8 years (16–90) at the time of surgery. All were closed fractures with the exception of one Gustilo I fracture. According to AO Classification, diaphyseal fractures involved the proximal third in five cases, the mid-third in one case and the distal-third in 26 cases. Among the fractures located in the distal third, eight had an extension down to the tibial plafond, without articular involvement. They were classified as 43C1, according to AO Classification, because of the fracture extending down to the tibial plafond, without displacement at articular level, although the main component of the fracture was located in the diaphysis. The remaining fractures were mainly A Type and were comprised of 21 cases of 42A1, two cases of 42B1 and one case of 42B3.

Surgical technique

The hardware consisted exclusively of anatomical locking plates (LCP, Synthes GmbH, Solothurn, Switzerland) made from titanium alloy. Two types of plates were used: proximal, lateral tibial plates to treat proximal or middle third fractures and distal, medial tibial plates to treat middle third or distal fractures.

Surgery was performed as an emergency procedure in the case of open fracture and all the other cases were operated within 3 days following trauma (median 1 day).

Patient positioning for surgery depended on the fracture type and operating surgeon. Positioning was either performed using a traction table, with the reduction obtained using transcalcanear skeletal traction, or on a standard table, with the reduction obtained using a temporary external fixator (tibiotibial for proximal or middle third fractures, tibio-tibio-tibial for distal fractures) (Fig. 1A and B) or a traction manually applied by the attending surgeon. In the cases where a simple fracture of the distal fibula was associated with the tibial fracture, osteosynthesis of the fibula was performed first. The control of length and rotation of the fibula provided an indirect partial reduction of the tibia with an indication of its appropriate length [8] (Fig. 2A and B). Reduction was obtained using a traction table in seven cases. A standard table was used in 25 cases and reduction obtained using an extemporaneous external fixator in 22 cases and with the help of manually applied traction in three cases.

The “minimal-invasive approach” performed depended on the type of plate being used. A proximal anterolateral approach was performed when using proximal tibial plates and a distal medial paramalleolar approach was performed when using distal tibial plates. Osteosynthesis was performed through a minimal-invasive approach, the plate being slid subcutaneously and outside of the periosteum. The Less Invasive Stabilization System (LISS) instrument was used when inserting a proximal lateral tibial plate, allowing for percutaneous insertion of distal screws. In order to better distribute and absorb strains, it was advocated to use a long construct, with at least five holes beyond the fracture and to leave one hole unfilled between two consecutive screws [9]. All screws were fixed bicortically. According to previously published data, when using this kind of construct, pain-free weight bearing was allowed postoperatively for patients with a Body Mass Index less than 30 [9].

Evaluation criteria

At follow-up, clinical and radiographic data were recorded. To document bony consolidation, bridging callus on three cortices was sought on anteroposterior and lateral views, combined with pain-free full weight bearing. Malunion was defined as a deformation exceeding 5° in frontal, sagittal and transversal plans [6].
Figure 1  Compound proximal tibial fracture. Reduction using temporary external fixation. A. Standard X-ray, anteroposterior and lateral view. B. Peroperative X-ray showing quality of reduction.

Figure 2  Spiral fracture of the leg. Reduction and primary osteosynthesis of the fibula. A. Standard X-ray of the fracture, anteroposterior view. B. Standard X-ray at consolidation. Long construct and spaced screws beyond the fracture line.

Results

The mean follow-up was 27 months, range from 14 to 45 months. At follow-up, two patients representing two fractures, died at respectively 4 days and 4 months after surgery from causes unrelated to the fracture itself (acute myocardial infarct in the first case and complications following a cerebral ischemic attack sustained 43 days postoperatively in the second case). The patient who died at 4 months had documented bone healing on X-ray examination, 10 weeks after surgery. Two other patients had been lost to follow-up after bone healing had been documented, and could not be assessed clinically at follow-up. The results on 28 patients representing 28 fractures could be assessed with clinical and radiological data at follow-up. One patient presented a hardware breakage, needing reoperation.

Among 32 initial cases, a minimal-invasive approach was performed 28 times. Exposure of the fracture site was performed four times. In one case was on an open fracture. The reduction was performed through the wound. In two cases the operating surgeon choose to manage the reduction with no further justification. In the last case open reduction was done because of technical difficulties.

In the postoperative period, weight bearing up to pain threshold was allowed and performed in 25 cases. Weight bearing was forbidden for 6 weeks in four cases,
corresponding to the earliest cases. Partial weight bearing up to 20 kilograms was recommended three times for compound fractures.

Four cases had a complicated evolution. We found: 1 postoperative infection of the operative site, due to meticillin-sensitive Staphylococcus aureus; infection was treated with hardware removal, lavage and antibiotherapy. One compartment syndrome. One non-union, with no sign of infection. One hardware breakage 6 weeks after surgery (Fig. 3).

Radiologically, the mean time to consolidation was 9 weeks (from 6 to 12 weeks). Excluding the patient died 4 days after surgery, 31 cases of tibial shaft fracture were treated with locking plates. Out of these, 29 fractures united (93.5%) without any further intervention to promote bone healing. No malrotation was diagnosed on clinical examination at follow-up. Radiographic examination at consolidation showed a valgus deviation of more than 5° in six cases out of 29 (5 to 12°). Malunion occurred in one proximal tibial shaft fracture and in five distal tibial shaft fractures. Deformations observed at consolidation were already present immediately postoperatively and did not increase despite weight bearing. No cases out of these with minimal-invasive approach, showed postoperative displacement, despite immediate weight bearing. All the four cases united uneventfully. No malunion in the sagittal plan were found at follow-up.

Discussion

The cases of plating osteosynthesis of the tibial shaft reported in this series involved mostly particular indications, namely proximal or distal diaphyseal fractures known to be difficult to treat with the standard nailing technique. Plating was used only once as a first choice, when treating mid-shaft fractures: in one open fracture (choice of the operating surgeon). The experience of treating complex tibial fracture has been reported by Phisitkul et al. [4], and Schutz et al. [10], for the proximal part, and by Refdern et al. [6] and Helfet et al. [7], for the distal part; but in all these cases, the fracture line was metaphyseal-diaphyseal or diaphyseal-metaphyseal. It is, therefore, difficult to compare their results to our series of diaphyseal fractures. Treatment of a few cases of diaphyseal fracture of the tibia using locking plates combined with a minimal-invasive approach was previously published by Hasenboehler et al. [11]. These authors reported a series of 32 cases not exclusively diaphyseal in their location, also comprising distal metaphyseal tibial fractures.

Our series is original, when considering the postoperative rehabilitation regimen in use. Weight bearing up to pain threshold was allowed in 27 cases out of 32 (80%). Weight bearing was allowed because the locking plate system that was used acts as a monobloc construct, ending up in a true internal fixator with three anchorages per screw (two cortices and the plate), as described by Perren [12]. The long constructs, with well-spaced bicortical locking screws that were used, allowed for the spreading and absorption of the strain under application of load (Fig. 2) as stated by Ehlinger et al. [9]. These constructs corresponded to the so-called "bridging effect" of the fracture (Fig. 4). True anatomical reduction, as with nailing, was not necessary, only alignment at the length of the whole bony segment was targeted [12,13].

In the whole of the series, there was one mechanical failure, with breakage of the plate six weeks postoperatively, weight bearing having been allowed immediately after surgery. This breakage was caused by a fatigue fracture of the hardware, due to imbalance of the strain applied to the plate. Indeed, this was a compound, mid-shaft fracture with a fragmented wedge (4283). The construct obtained in this case was not mechanically satisfactory: a notable gap between the fracture line and the nearest screws on each side of the fracture left a weakness zone at the level of the fracture (Fig. 3). Stoffel et al. [14] have recommended locking screws to be positioned the nearest possible to a compound fracture in order to better stabilize it and
to leave one to two holes unfilled on each side of the fracture, in the case of a simple fracture, to allow the elasticity of the titanium to come into play, made possible with weight bearing. Hasenboehler et al. [11], in a series of 32 leg fractures, observed one mechanical complication with bending of the plate following early weight bearing, in the case of a 42C3 fracture according to AO classification.

The minimal-invasive approach allowed in theory to combine the principles of a stable construct to a closed reduction with conservation of the haematoma. However, we report 1 nonunion in our series (3.6%). Hasenboehler et al. [11] also reported two non-unions out of a series of 32 fractures. Zelle et al. [15] found similar figures in a systematic review of 1125 extra-articular fractures of the distal tibia treated with plating or nailing: a 5.2% nonunion rate when using plates and 5.5% when using nails. The CECOP study [16] that gathers the largest series of intramedullary nailing of the tibia reports 3.2% rate of nonunion. The time to consolidation reported in our series was slightly reduced, when compared to the data known from the literature concerning plating osteosynthesis. The mean time for callus formation was 9 weeks (7 to 12 weeks), according to Redfern et al. [6], in a series of 221 fractures of the distal tibia treated using a minimal-invasive approach, 15 weeks (8 to 24 weeks), according to Phisitkul et al. [4], in a series of 21 distal metaphyseal fractures treated percutaneously, and 12 weeks (6 to 20 weeks), according to Phisitkul et al. [4] in a series of 37 complex proximal epiphysimal fractures. Comparison with other series was difficult, because they consider consolidation as the time of pain-free full weight bearing. Hasenboehler et al. [11] reported 27 patients out of 30 (two lost to follow-up) healed at 9 months (walking with pain free full weight bearing and bony callus). The association we recommend, between weight bearing and a minimal-invasive approach conserving the haematoma might explain the shortening time before the appearance of good quality endosteal callus. In no other series reported was free weight bearing allowed. This might have been of benefit—stimulation of the fracture site owing to the elasticity of the plate. The minimal-invasive approach might play a protective part by preserving the local biology of bone and soft tissues as stated by Helfet et al. [7], Hasenboehler et al. [11], Perren [12], Oh et al. [17].

![Figure 4 Least displaced tibial fracture with distal articular irradiation. A. Standard X-ray, anteroposterior view. B. Standard X-ray, anteroposterior and lateral view after breakage of the plate.](image-url)
The main factor that led us to use locking plates to treat fractures of the tibial shaft was the difficulty in controlling the reduction of the proximal or distal fractures with intramedullary nailing. Radiographic results that we report did not meet our expectations. Our series included six cases (18.8%) with valgus mal-alignment exceeding 5°. In the CECOP study [16], there were 15.1% mal-alignment in the whole series, mostly in valgus, and up to 26.5% at the proximal third and 17.6% at the distal third, the difference being statistically significant. In the proximal third, we found one mal-alignment out of five fractures, and in the distal third, five mal-alignments out of 26 fractures. The essential factors that could be elicited were: lack of experience of the operating surgeon, failure to use the anatomical characteristics of the LCP plates (most epiphyseal screws parallel to the joint line), lack of osteosynthesis of the fibula. According to Egol et al. [6] osteosynthesis of distal fractures of the fibula, when they are simple and associated with a fracture of the distal tibia, should be performed first; because this allows control of the length and the rotation. Osteosynthesis of the fibula also maintains the reduction in the future. The CECOP study [16] also proved statistically the protective effect of the use of a traction table against the occurrence of malunions and the unfavourable effect of fracture comminution. In our series, although not statistically significant, four malunions had been preceded by a temporary reduction using a temporary external fixator.

Osteosynthesis by means of locking plates and a minimal-invasive approach is demanding and requires the mastering of the implant and its biomechanics. Conversely to what was noted by Hasenboehler et al. [11], the bridging effect was a real advantage of this hardware, allowing the treatment of almost all types of fractures. We advocate early weight-bearing within the pain-free range, as long as the construct is mechanically sufficient: the use of titanium alloy, with a long construct and spaced locked screws, and screw placement at a distance from stable fracture lines. This kind of surgery requires preoperative planning.

Conclusion

Radiological results we report led us to be cautious and proved the necessity of rigorous technique. Plating osteosynthesis did not prove superior to nailing in the treatment of tibial shaft fractures, when considering the quality of reduction obtained radiographically with comparable results. However, using this system can allow early weight-bearing within a pain-free range; and in association with minimal-invasive approach, this might be beneficial related to the time to consolidation.

Disclosure of interest


References