Minimally invasive locking screw plate fixation of non-articular proximal and distal tibia fractures

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Summary
Intramedullary nailing of proximal and distal quarter tibia fractures is known to be a challenging procedure due to the metaphyseal enlargement, the reduced contact between implant and cortex and fracture comminution. Therefore, some authors suggest preferring the use of plate internal fixation in the management of these challenging fractures. The purpose of this manuscript is to present and describe our technique of minimally invasive locking plate osteosynthesis in the treatment of extra-articular proximal and distal tibia fractures. Osteosynthesis was performed by means of a locking screw plate system which construct characteristics usually allow immediate weight-bearing and early functional mobilization. This minimally invasive surgical procedure advantageously combines the principles of closed fixation with construct stability.

Introduction
Intramedullary nailing is the gold standard treatment option for tibial shaft fractures [1]. However, it is known to be a challenging technique in the treatment of proximal and distal quarter tibia fractures. The long lever arm and metaphyseal enlargement make fracture reduction and nailing technically difficult procedures. Other well-described patterns of difficulties are associated with this technique such as intra-articular extension, hardware failure or epiphysometaphyseal fixation difficulty [2,3]. Therefore, some authors advocate the use of plate osteosynthesis in the management of proximal [4,5] or distal [6,7] quarter tibial fractures.

We will then describe our surgical technique of minimally invasive locking plate osteosynthesis in the treatment of extra-articular tibial end fractures. This technique preserves the fracture haematoma and provides a stable construct which usually allows immediate weight-bearing.

Operative technique

Material
Osteosynthesis was performed using Locking Compression Plate (LCP™) fixation plates (Synthes, Etupes, France)
Minimally invasive osteosynthesis of extra-articular tibia fractures

Figure 1  A: plates having been used: lateral proximal tibial anatomic plate, AP view, right side plate. B: lateral proximal tibial anatomic plate, lateral view, right side plate. C: medial distal tibial anatomic plate, AP view, left side plate. D: medial distal tibial anatomic plate, lateral view, left side plate.

secured with large fragment locking screws made from titanium alloy. Once locked in place, this system provides a monobloc construct which acts as an "internal fixator". Two anatomical configurations are commonly used in this type of minimally invasive surgery, depending on the fracture site: the "anatomical proximal lateral plate" designed for proximal fractures and "the anatomical distal medial plate" designed for distal fractures (Fig. 1). Anatomical plates are usually distributed mentioning they suit 80% of the patients. They are available in left and right versions. The Less Invasive Stabilization System (LISS™) instrumentation is routinely used for proximal plates since it allows easy extraperiosteal plate insertion but also facilitates screw locking. However, there is no LISS instrumentation available for distal plate yet but an aiming device is available to assist in the placement of the most distal locking screws. Proximal plates are secured by means of large fragment screws available in standard version for bone lagged to the plate or in locking version. The medial distal plates are secured by means of large fragment screws supplied in standard or locking configuration, designed to be placed in the upper section and small fragment screws available in standard or locking configuration, to be placed in the lower metaphyseal section. The plate features combination holes for insertion of both standard or locking screws. This distal plate can be used as a conventional dynamic compression plate (DCP™), as a locking plate or as the combination of both types.

Patient positioning

Position the patient supine on an orthopaedic or standard table. Patient positioning on an orthopaedic table is identi-
cal to that used for intramedullary nailing, with transosseous calcaneal traction applied and use of an ankle boot in case of proximal fracture without distal extension. When the patient is positioned on a standard table, an assistant might be instructed to perform limb traction in the axis and rotational control. A cushion may be placed underneath the homolateral buttock in order to prevent limb lateral rotation commonly occurring in distal fractures. Patient positioning is operator-dependent since distal and proximal fractures can be perfectly controlled using both methods. Use of a standard table will most commonly require additional reduction manipulations. A temporary external fixator might also be used for stabilization of fracture reduction during the whole procedure.

Surgical approach

We describe the minimally invasive technique. The surgical approach is adapted to the fracture site and the selected fixation plate. In the proximal region, a lateral and oblique surgical approach is performed from backward to forward and upward to downward. A 5 cm incision is made starting under the level of the femorotibial joint line. If necessary,
either a fluoroscopic landmark can be made to locate the joint or a pin can be inserted into the joint. In fractures of the distal tibia, two surgical approaches may be used. The first one is a longitudinal incision centred over the medial malleolus, of about 4/5 cm long, performed in the tibial axis. The distal screw insertion is facilitated when using the aiming device but might induce healing complications since it is situated in the plate axis. The second surgical approach is a curved anterolmedial incision centred over the medial malleolus. Screw insertion might be more difficult but healing is safer. Fluoroscopy is used to identify the fracture site using a skin marker for selection of the appropriate plate length and to locate the diaphyseal axis to facilitate plate positioning and prevent excessive use of intraoperative fluoroscopy. It aims at preserving the minimally invasive aspect of this surgery, however it might be necessary to convert in case of irreducible fracture.

Figure 3  Criteria of adequate plate positioning allowing to use the plate as a direct reduction template thus using the anatomical features of this plate design. A: lateral proximal tibia plate: point to be noted: parallelism to the joint line (full-thickness line) of the most proximal epiphyseal screws. B: peroperative images of a distal medial plate: point to be noted: parallelism to the joint line (full-thickness line) of the most distal epiphyseal screws.
Reduction and fixation

In extra-articular fractures, the objective is to restore the anatomical bone axis. Reduction is thus performed at this level. A two-stage procedure is carried out. The reduction is started during the preoperative period and completed manually during the intraoperative phase, under fluoroscopic guidance.

The preoperative phase corresponds to the fluoroscopic control of the reduction under traction. The reduction is performed by applying traction in the axis either on the orthopaedic table as in the intramedullary nailing technique or with help of a surgical assistant when the patient has been placed on a standard table or even by means of a temporary external fixator.

The intraoperative phase corresponds to the supplementary reduction manipulations. As in the intrafocal Kapandji pinning technique, a temporary pinning (Fig. 2) might be performed to reduce a recurvatum/antecurvatum angulation or even a translation. Pinning is performed by means of at least two locking screws and maintained up to complete stabilization of both fragments. The anatomical features of the plate (proximal or distal) acts as a real reduction mold. Actually, the most distal screws of the distal medial plates or the most proximal screws of the proximal lateral plates are designed to be inserted parallel to the joint line. The initial positioning of the plate is assessed under fluoroscopic guidance. A 2 mm diameter pin, inserted through the next to last hole of the distal tibial plates and through the most proximal holes of the proximal plates, should be parallel to the joint line (Fig. 3). The construct is a monobloc system which acts mechanically as an internal fixator and does not require to be in close contact with the bone since there is no need for compressive cortical contact under the plate (friction effect) to achieve primary stability. However, the construct should be parallel to the proximal and distal fragments and should be positioned at a homogeneous distance from the proximal and distal fragment cortex in order to avoid malunion. In such a case, parallel positioning of the screws relative to the joint is not a reliable and sufficient condition to ensure proper positioning of the plate. Despite screw parallel positioning relative to the joint line, screw placement may lead to plate bending thus inducing a faulty axis. The anatomical characteristics of the plate allow bone fragments to be lagged to the plate by means of a standard screw, since the plate acts as a real reduction mold. The bone should be pulled towards the plate and not the contrary. The elasticity and ductility of titanium may lead to plate bending if the plate moves toward the bone thus inducing a valgus deformity.

When surgery is performed on a standard table, intraoperative reduction may be achieved by means of a temporary external fixator thus obviating the need for an assistant to apply traction in the axis. The external fixator could be a monoplane tibiotibial device in proximal fractures or a tibio-calcaneal triangular frame construct in distal fractures. The bone screws are inserted into the proximal and distal fragments, two bone screws being placed in each fragment when a tibiotibial device has been selected. A calcaneal transfixing screw and two tibial transfixing screws are placed in case of triangular frame construct. The absence of any articular fracture line enhances bone screw anchorage. Titanium bone screws should be positioned anteriorly to facilitate plate placement (proximal or distal). This temporary fixation helps restore length and rotation and maintains reduction during osteosynthesis. The cable of the electrocautery knife is used as a plumb line (Fig. 4). In spiral or long-oblique fractures, a sharp Weber forceps may be used to complete and maintain reduction (Fig. 5). The associated use of these technical tricks is possible.

Placement of this locking screw plate should follow rigorously the operating instructions. The aiming device and torque screwdriver should be used systematically as above mentioned [8].

The osteosynthesis requirements

In our current practice, immediate postoperative weight bearing of these fractures is allowed as far as possible. Some osteosynthesis requirements should be observed.

1) Extra-articular aspect of the fracture.
2) Minimally invasive surgery with haematoma preservation called biological osteosynthesis [9].
3) The construct should feature at least five plate holes placed underneath a proximal tibial fracture or above a distal tibial fracture. Each locking screw should alternate with an empty hole in order to provide a better stress distribution and absorption (that is three locking screws and two empty holes out of the five holes situated beyond the fracture site) (Fig. 6).
4) Since the lower limb is subjected to compressive stress, at least three locking screws should be inserted into the proximal or distal metaphyseal section.
5) Bicortical screws should be systematically inserted to enhance the construct stability and reduce the pullout effects.
6) Locking screws should be placed close to a complex fracture site and at a distance from a simple stable fracture, taking advantage of the elasticity of titanium.

Discussion

Our technique combines the principles of closed fixation and preservation of the fracture haematoma with achieving a stable construct. This biological osteosynthesis method, like intramedullary nailing, preserves the periosteum, the fracture haematoma and the surrounding soft tissue integrity [9–13].

Fixation was performed using a locking compression plate system (LCP™, Synthes). Locking screws enable the plate to act mechanically as an internal fixator and do not rely on the bone/plate friction effect to achieve primary stability thus preserving the surrounding periosteal blood supply and reducing bone resorption under the plate [10]. The triple screw anchorage and the monobloc aspect of the construct enhance stability and improve the pullout strength [10–12]. Like Dougherty et al. [14], we advocate routine use of bicortical screws. These authors have demonstrated the higher mechanical strength of bicortical locking screws in a complex proximal tibial fracture pattern in fresh osteoporotic bones. The higher titanium biocompatibility improves bone anchorage. Locking screw placement is adapted to the frac-
Figure 6  Example of left distal tibio-fibular fracture treated using a classic assembly allowing in our experience weight-bearing resumption up to the pain threshold. A: AP and lateral view of the same example. B: postoperative X-ray: points to be noted: the long spanning of this assembly (at least five holes in proximal direction beyond the fracture line) with special distribution of the locking screws (alternating unused holes and locking screws) and still visible traces of the external fixator pin tracks which allowed temporary peroperative reduction.

ture type. It should be close to the fracture site in complex fracture patterns and at a distance from the fracture site in simple fracture patterns [15]. This construct and the technique used for locking screw placement take advantage of the titanium material elasticity which promotes bone healing. It is adapted to each fracture pattern, providing rigidity to complex fractures and allowing for dynamization in simple fracture patterns. Simple fracture line patterns require
a minimal bone-to-plate contact to avoid stress concentration on the plate around the fracture site which could lead to a stress fracture.

This minimally invasive surgical technique is in favour of the patient. This construct allows weight bearing when possible, improves the healing time and reduces decubitus complications [16]. The use of locked screwing ensures early joint mobilization for fast and high-quality functional recovery.

This minimally invasive surgical technique requires rigour and technical skill and the learning curve is unavoidable. Surgeons should be aware of the associated reduction technical tricks. This technique is only indicated in extra-articular fractures or in simple non-displaced fracture patterns. However, minimally invasive surgery should not be the sole aim. Achieving a good quality reduction at the level of the bone segment should be the objective for anatomical axis restoration. The most adapted surgical approach should be performed to achieve reduction using a temporary forceps or to manage an irreducible fracture due to incarcerated muscles or tendons, particularly the posterior tibial tendon.

This surgical procedure is performed through closed reduction thus inducing the risk of intraoperative fluoroscopic radiation exposure. Skin landmarks identifying the fracture site will help reduce the exposure duration. The absence of a large aggressive surgical approach decreases blood loss and immediate postoperative pain induced by an extensive approach.

The construct pattern that we advocate allows immediate postoperative weight bearing up to the threshold of pain. It aims at providing early autonomy, good quality functional recovery and limited decubitus complications. The literature does not report this type of postoperative protocol. In two previous publications, we reported our experience regarding femoral fractures around implants managed with locking screw plates and immediate postoperative weight bearing up to the threshold of pain [16,17]. Let us remind that the plate construct experiences flexion in extra-osseous situations whereas the intramedullary nail experiences axial compression. Therefore, repeated dynamic solicitation could induce a fatigue failure of the construct, especially in case of inappropriate fixation with locking screws placed close to one another thus inducing stress concentration.

The recent data from the experimental literature provide more details about the mechanical requirements of the most adapted construct. According to Ahmad et al. [18], the construct should be placed close to the bone despite the internal fixation mechanical features of the device. After an experimental study performed on Sawbone®, they conclude that a bone/implant distance lower than 2 mm will provide a better compressive and torsional strength. A bone/implant distance greater than 5 mm leads to a major plastic distortion. The LCP plates contain combination holes that allow a LCP internal fixation configuration, a DCP compression plating configuration, or the combination of both. In a recent study conducted by Stoeffel et al. [19], these three techniques were compared in the management of distal femoral supra- and intercondylar fractures. The ‘‘internal fixation’’ configuration provides a better rigidity in axial compression with reduced plastic distortion while the ‘‘compression DCP’’ configuration demonstrates a better torsional strength, therefore the authors advocate the use of a combined configuration. Bottlang et al. [20] advocate the use of a standard screw at the end of the plate in case of fracture with poor bone quality, in order to reduce stress and prevent any stress fracture of the underlying bone. This type of construct improves the bending strength without compromising the compressive and torsional strengths.

The operative technique of the locking screw plate biological osteosynthesis in the management of extra-articular proximal and distal tibia fractures, as described above, is part of our current practice. However, these fractures are rare and our experience is based on about 60 cases (from January 2004 to December 2008), the great majority of which involved distal tibia fractures. Satisfactory results were achieved in terms of functional recovery, return to previous levels of autonomy, complication and healing rates. According to the radiographic outcomes, this procedure should be rigorously performed to achieve a satisfactory reduction and a stable fixation. Axis deviations over 5° were observed but very few were greater than 10°, the fault-tolerance threshold determined by the 2009 Sofcot symposium for distal tibia fracture in which we had participated. It seems important to perform fixation of distal fibular fractures associated with distal tibial fractures in order to provide good length and rotational control thus improving the reduction quality. Immediate weight bearing was allowed, usually offering a real functional gain with no major complications.

Conclusion

Minimally invasive osteosynthesis of proximal and distal tibia fractures by means of a locking screw plate fixation is a reliable but demanding technique. It combines the advantages of closed fixation with achieving a stable construct. This procedure specific requirement must be thoroughly respected to achieve a stable fixation as well as a good reduction quality. Weight bearing, when allowed, facilitates functional recovery and promotes good quality consolidation.

Conflict of interest statement

ME and PA: limited intervention: consultancy services for Synthes.
FB: none.

References


