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Review Article

TREATMENT OF DISTAL TIBIA FRACTURE: COMPARISION BETWEEN MINIMALLY INVASIVE PERCUTANEOUS PLATE OSTEOSYNTHESIS AND INTERLOCKING INTRAMEDULLARY NAIL

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ABSTRACT

Distal tibia fractures are complex injuries with a high complication rate. Initial evaluation and work up are significantly important because this is a key step with surgical planning. In this phase, it is important to rule out emergent situations, obtain proper reduction along with staging the procedure, and appropriately respect the soft tissue before definitive surgery. Surgical treatment of distal tibia fractures can be a significant challenge associated with many complications. Surgical treatment of distal tibial fractures includes several options: external fixation, IM nailing, ORIF and minimally-invasive plate osteosynthesis (MIPPO). Each type of fixation has its own advantages and disadvantages. The difficult decision lies in which fixation option will create the most structurally stable environment along with best return of function, keeping in mind minimizing risk of complications. The aim of this article is to discuss and explain the surgical management of distal tibia fractures by minimally invasive percutaneous plate osteosynthesis and interlocking intramedullary nail. This literature will provide a brief overview on the current scenario of these procedures and will compare the efficacy and safety of these two procedures.

Key words: Distal tibia fracture; minimally invasive percutaneous plate osteosynthesis (MIPPO); intramedullary nail (IMN)

INTRODUCTION

Distal tibial fractures are usually the result of combined compressive and shear forces that are usually due to high-energy mechanisms such as falling from heights or motor vehicle accidents. They may also occur from low-energy mechanisms, which are seen in rotational injuries around the ankle [1] and may result in instability of the metaphysis, with or without articular depression, and injury to the soft tissue. The complexity of injury, lack of muscle cover and poor vascularity make these fractures difficult to treat. Distal tibia fractures are inherently difficult injuries of the lower extremity to treat owing to the complexity of the fracture along with the sparse soft tissue envelope. In conjunction with significant osseous injury, the surrounding soft tissue structures often become severely traumatized. Owing to the limited subcutaneous layer surrounding the injury, surgical treatment is often prone to developing complications such as wounds, infections, malunion, and nonunion. The goal of orthopaedic surgeons is to restore the tibial anatomy, to fix the epi-metaphyseal block with the diaphysis and to avoid complications. Many osteosynthesis techniques can be used for these fractures such as; traditional open reduction and internal fixation (ORIF), external fixation with or without limited internal fixation, intramedullary nailing or, more recently, (MIPPO) [2-5]. All of these techniques have advantages and disadvantages and there is no consensus concerning the management of these fractures [2-6]. Currently, the most commonly used method is minimally invasive plate osteosynthesis (MIPPO). External fixators and intramedullary nails (IMN) in the treatment of distal tibia fracture. An intramedullary rod, also known as an intramedullary nail (IM nail) or inter-locking nail or Küntscher nail (without proximal or distal fixation), is a metal rod forced into the medullary cavity of a bone. Intramedullary nails (IMN) have long been used to treat fractures of long bones of the body. Gerald Küntscher is credited with the first use of this device in 1939. Intramedullary nailing not only features favorable mechanical properties but also biological advantages due to the preservation of the vascularity of the fracture site and the integrity of the surrounding soft tissues. Intramedullary nailing allows minimally invasive, symmetric and dynamic fracture fixation, following the principles of biological fracture fixation, and is therefore the treatment of choice in distal tibial fractures. Recently, techniques of closed reduction and minimally invasive percutaneous plate osteosynthesis (MIPPO) with locking compression plate (LCP) has emerged as an alternative treatment option for distal tibia fracture. Locking plate is placed from distal portion percutaneously and screws are placed with small incision in guidance with fluoroscopy. Percutaneous plating preserves the soft tissue envelope and the periosteum, maintains arterial vascularity and therefore minimizes the surgical trauma to the zone of injury [7].

DISCUSSION (MINIMALLY INVASIVE PERCUTANEOUS PLATE OSTEOSYNTHESIS VS INTRAMEDULLARY NAIL)

Indication and contraindication of MIPPO and IMN:

Indication of IMN:

Intramedullary nail is indicated for the majority of closed lower third junction fracture of tibia [8] as well as open fractures with adequate soft tissue cover when fracture is not extending into lower 4cm of tibia from ankle joint [9]. Fixation by medullary nailing is especially indicated in simple transverse or short oblique fractures.

Contraindication of IMN:

Infection in or near the fracture site is usually a contraindication. Poor condition of the skin over the operative field is a danger that may be over looked. Intramedullary nail is contraindicated in children because the passage of the large nail through the epiphyseal line might disturb the growth of the bone. It is contraindicated in patients in shock and in fractures in which an intramedullary nails not mechanically efficient in immobilizing the fragments.

Indication of MIPPO:

Minimally invasive percutaneous plate osteosynthesis with locking plate is indicated in: Open fracture; Displaced fracture involving tibial palafond; Unstable fracture with 3cm from ankle joint; with or without articular involvement [9], particularly when skin envelop is good and patient can afford.

Contraindications of MIPPO:

Situations that would not be optimal with use of MIPO include soft tissue defects or compromise of the medial ankle or distal leg, fractures in which severe comminution of the distal tibia and plafond are involved, or vascular compromise or injury to the surrounding area.

Advantage of IMN:

1. Preservation of the soft tissue, remaining blood supply.
2. Fracture hematoma is preserved in IMN, which is vital and essential for fracture healing; hence it yields high union rate.
3. Being intramedullary, it acts as a load-sharing implant, so early weight bearing can be started as against plating and full weight bearing can be started after union of fracture.
4. Advantage of controlled impaction over nailing during surgery.
5. Two screws proximal and two to three screws in distal fragments give better rotational stability.
6. Shorter operative time, less soft tissue dissection, less blood loss and hence reduced rate of infection.
7. Reaming itself give advantage of internal bone graft at fracture site at the time of reaming, in communited fracture

Disadvantage of IMN:

1. IM nailing was associated with significantly more malunion.

2. A higher incidence of knee pain.
3. Higher incidence of delayed union and nonunion with intramedullary fixation
4. It is also possible that reamed intramedullary nailing results in delayed healing when compared to plates because of damage to the medullary blood supply when an IM technique is employed.
5. Secondary procedure more after intramedullary fixation
6. Fractures of the distal tibia stabilized with an IM nail have a biomechanical disadvantage compared with those stabilized with plate fixation [10]
7. In more distal fractures, an IM nail provides less intrinsic stability as a result of reduced bone-to-implant contact when cortical contact distal to the fracture site is poor; a higher proportion of the mechanical load is borne by the nail and is transmitted to the distal screws. The result is inferior load sharing between the distal screws and the distal bone, resulting in reduced stability of the construct and four point bending of the distal screws, which may lead to failure
8. Intramedullary nailing is associated with low risk of infection but the technique is associated with complications like malunion, fat embolism, compartment syndrome and anterior knee pain [11, 12]

Advantage of MIPPO:

1. It minimizes soft tissue compromise and devascularization of the fracture fragments.
2. Minimizes extraosseous blood supply than open plating
3. Minimally invasive plating techniques offer biologic advantages, especially for comminuted fractures of the tibia in which maintenance of the vascular supply to small fracture fragments is important
4. In more distal fractures, direct exposure and plating are used to achieve reduction, which might be difficult to achieve with a nail alone
5. In fractures with a simple articular split, direct exposure aids in reduction and allows placement of small fragment screws to achieve reduction of the articular surface
6. Fracture patterns with a propensity for malalignment may warrant stronger consideration of plate fixation due to the previously mentioned biomechanical problems associated with IM nailing.
7. Locking compression plating (LCP) provides an angular stability for fixation. Locked screws prevent the plate from pressing the bone, preserving periosteal blood supply. This system stimulates callus formation due to flexible elastic fixation. The anatomic shape of the plate prevents malalignment of the fracture and provides a better axial and angular weight distribution [13]

Disadvantage of MIPPO:

1. Minimally invasive plating is the potential for increased hardware prominence and irritation
2. simple fracture patterns are prone to delayed healing and nonunion when compression cannot be achieved across the main fracture line [14]
3. The minimally invasive approach limits the use of direct reduction techniques,which may make it more

difficult to obtain optimal alignment and compression in patients with simple fracture patterns [14, 15]

4. there are some concerns on the use of MIPO in distal tibial fractures, including delayed union, malunion, skin impingement and saphenous nerve and vein injury [16, 17]

SURGICAL TECHNIQUE OF MIPPO:

For minimally invasive plate osteosynthesis of distal, tibial fractures the patient is placed supine on a radiolucent table, a support cushion is placed beneath the ipsilateral buttock and a pneumatic tourniquet is applied to the proximal thigh. The ipsilateral iliac crest and the entire lower limb are prepared and draped in the usual sterile fashion. After exsanguinating the limb, the tourniquet is inflated to 300 mmHg.Initial attention is directed to the fracture lines which extend into the tibia1 plafond. Articular fragments are anatomically reduced either by percutaneous means, utilizing fluoroscopy and pointed reduction forceps or via a small anterior incision, arthrotomy, and direct open reduction. Once an articular reduction has been achieved, the articular fragments are stabilized with 3.5 mm lag screws.The appropriate length of the semi-tubular plate is determined by placing a plate along the anterior aspect of the leg and adjusting it so that under fluoroscopy the distal end of the plate is at the level of the tibial plafond and the proximal end extends at least three screw holes beyond the proximal limit of the tibia1 shaft fracture. The plate is then flattened along its entire length and the distal end bent to match the contour of the distal tibia (approximately 25 degrees medial angulation and 20 degrees external rotation). A 2-3 cm incision is made along the anteromedial aspect of the tibia, proximal to the fracture and distally at the level of the medial malleolus. Typically, a subcutaneous tunnel is created between the two incisions and along the medial aspect of the tibia by blunt dissection using a large Kelly clamp. On occasion this is unnecessary and the plate can be advanced directly beneath the soft tissues without making a tunnel. The position of the plate is adjusted under fluoroscopy in both the coronal and sagittal planes so that it lies along the medial aspect of the tibia. 4.5 mm cortex screws are placed at each end of the plate through the two incisions and in the mid-portion via small percutaneous stab incisions. The distal metaphyseal articular fragment can be indirectly reduced to the proximal shaft in this way. Lag screws are then placed across the fracture planes to maintain the reduction, to provide inter-fragmentary compression, and to increase the stability of the construct. Permanent radiographs are taken in the operating room to assess the overall alignment of the limb and ensure proper placement of the implants. The surgical incisions are irrigated and closed. Sterile dressings are applied and the limb is immobilized in a well-padded posterior and U-splint with the ankle maintained in the neutral position. Hemovac drains, if in place, can be removed when drainage is less than 20 cc/eight hours, generally within the first 24-48 hours. All patients receive 48 hrs.' of preoperative prophylactic antibiotics. Post-operatively, the limb is maintained in the elevated position while the patient is in bed and ambulation training is begun on the first post-operative day in the form of toe-touch weight-bearing (TTWB, 20 lbs.') with crutches. On post-operative day number two, gentle exercises for the ankle are begun. The sutures were removed at l0-14 days after surgery. Radiographs, including anteroposterior, lateral and mortise views of the distal tibia and fibula are taken at two weeks, six weeks and three months post-operatively to assess healing and alignment. Progression to partial weight-bearing (PWB) depended upon their clinical and radiographic evaluation, but in general most patients advance to PWB by six weeks.

SURGICAL TECHNIQUE OF IMN:

General considerations:

A number of A-type fractures of the distal tibia can be treated with intramedullary nailing. The nail design determines the number, location, and orientation of distal interlocking screws. There must be enough screws appropriately distributed in the short distal tibial segment to provide sufficient stability. Minimum of 2 and preferably 3 well distributed distal interlocking screws are recommended. Fractures that are too distal (within 1 or 2 cm of the articular surface) may not be adequately stabilized with an intramedullary nail. Distal tibial fractures must be reduced correctly by the surgeon before the nail is driven home, and the reduction confirmed with the image intensifier. Some type C fractures with undisplaced articular extensions can be treated with intramedullary nailing. The undisplaced fracture lines must first be fixed with lag screws. An occasional type C distal tibia fracture, with simple displaced articular extension, might be reduced, stabilized with lag screws, and treated similarly with an intramedullary nail. Caution: Be certain, that adequate stability is achieved. Plate fixation of an associated fibular fracture is recommended for additional stability when intramedullary nailing is used for distal tibia fractures.

Reduction:

Preliminary remark:

Nail insertion does not reduce a distal tibia fracture the way it does for diaphyseal fractures. There is no cortical bone contact in the distal segment. Accurate provisional reduction of distal fractures is essential. It must be maintained during nail insertion and distal locking. A variety of provisional reduction methods is possible. The choice depends on personal preference and experience. The following reduction techniques are often well suited for intramedullary fixation of distal tibia fractures.

Manual traction:

The distal femur is supported by a leg rest. Manual traction is applied to the foot, to restore length, and to correct angulation and rotation. Manual support must be maintained as the nail is inserted, typically with back pressure against the nail. For very distal fractures, use of a traction pin in the calcaneus, talus, or distal tibia may be required to apply manual traction.

Traction table:

The patient is positioned supine on the fracture table. The contralateral uninjured leg is placed on a leg holder. Place a traction pin or wire in the distal tibia, talus, or calcaneus. The more proximal the fixation point, the easier it is to control the distal tibial segment. However, the pin must not obstruct the nail. Reduction will be achieved by first pulling in line with the tibial shaft axis. Once the fragments are distracted, angulation and rotation are corrected and the nail can be passed across the fracture. Depending upon soft-tissue integrity, traction may increase angular deformity, and need to be released partially. Reduction should be controlled under image intensification. Rotation must be confirmed by physical exam. If closed reduction is unsuccessful, a reduction clamp may be added percutaneously or with a small incision.

Mobile reduction frame:

An option to apply traction intraoperatively without traction table; is the use of a mobile reduction frame. Traction is applied over a Steinmann pin inserted through the calcaneus.

Joystick:

Angulation of the distal fragment can be controlled with a percutaneous pin (joystick). Place the pin outside the path of the nail.

Percutaneous pointed reduction clamp:

Simple oblique or spiral fractures can be reduced with a percutaneous reduction clamp, and held during passage of the nail. It is sometimes necessary to leave the clamp in place until distal locking has been completed.

Fibular fracture reduction:

Preliminary reduction and fixation of an associated distal fibula fracture will often help by indirectly reducing the distal tibial fracture via ligamentotaxis.

Open reduction:

In the event of delayed treatment, or if a cortical bone fragment is stuck in the canal, open reduction of the tibia may be required.

Poller screws:

The use of Poller screws, placed outside the nail, is described later in the nailing procedure. The entry point is on the anterior edge of the tibial plateau, missing the menisci, and centered over the medullary canal on the AP view.

Opening the cortex:

Different instruments are available for opening the cortex. A cannulated drill or cannulated cutting instrument can be inserted over a guide wire or pin. Alternatively, a curved entry site awl may be used, according to the surgeon’s preference. Initial placement of a guide pin allows radiographic confirmation before entering the bone.

Insertion of centering pin:

For cannulated cutter insert a 4 mm centering pin (Steinmann pin). Pass the pin distally, angled 15° in the sagittal plane to the axis of the tibial shaft, into the proximal aspect of the medullary canal. In the coronal plane, the pin is inserted in line with the axis of the tibia shaft. Verify placement under image intensification.

Opening the medullary canal with a cutter:

Insert a cannulated cutter over the centering pin. Manually advance the cutter rotating it to remove a core of cancellous bone until the canal is entered. Use the protection sleeve in order to prevent damage of the patellar tendon.

Alternative: Opening of the medullary canal with an awl

Press the sharp tip of the awl into the cortex at the entry site, aim posteriorly, and advance it, turning the awl back and forth. Stay posterior to the anterior cortex, and in the midline aiming down the medullary canal on the AP view. Gradually rotate the awl to align it with the center of the canal on the lateral view. The shaft of the awl should finish parallel to the anterior cortex of the tibia.

Insertion of guide wire:

Principle:

The fracture must be reduced before the guide wire is placed across it.

Hand reamer (optional):

Pass a small hand reamer through the entry site if necessary to advance the guide wire through dense bone of the proximal metaphysis. Protect the patellar tendon with a retractor.

Ball-tip guide wire:

Once the proximal metaphysis is breached, a ball-tip guide wire is passed down the medullary canal, and as deeply as possible into the distal metaphysis. It is important to ensure the fracture has been accurately reduced at the time of passage of the guide-wire through the fracture, and that the guide-wire ends up as near to the centre of the distal articular tibial segment as possible.

Fluoroscopic control:

Use fluoroscopy to check that the guide wire is positioned above the centre of the ankle joint. It is very important with distal fractures to confirm the correction of the angular deformity in the lateral, and AP views before moving on to the next step.

Determination of nail length and diameter:

Determination of nail length:

For distal tibial fractures, it is essential that the nail be placed as deeply as possible. It thus must be long enough, by nail selection, or with some nail systems by adding a proximal extension. However, the nail must not protrude proximally. The length of the intact opposite tibia may be used as a helpful guide. If comminution is present, make sure that length has been restored accurately before measurement.

Use of a radiographic ruler:

Nail length can be determined intraoperatively, preferably by using a radiographic ruler. With the fracture reduced, measure the required nail length from the center of the distal tibia to the planned nail entry point. Caution: Such measurement may result in a nail that is too short.

Guide-wire measurement:

First insert the guide wire (I) across the reduced fracture to its maximal depth. Place a second guide wire (II), of equal length, at the entry portal and measure the difference in length between the two wires. This difference represents the proper nail length.

Determination of nail diameter:

Choose a nail that is big enough to provide adequate fixation and that can be inserted through the tibial isthmus without excessive reaming. The nail should be strong enough to securely hold adequate distal locking screws. Typically, this requires a nail diameter of 9 -10 mm or larger. This will depend upon the chosen nailing system. Usually, reaming is necessary to increase the diameter of the tibial isthmus sufficiently for easy insertion of an appropriately sized nail. The distal shaft may not require reaming. However, the dense distal epiphyseal bone usually must be reamed to where the tip of the nail will lie. Ream the canal to a minimal diameter (reamer size) of at least 0.5 -1 mm greater than that of the selected nail. The nail should fit easily through the tibial isthmus.

Reaming:

Protecting the soft-tissues:

Insert the flexible reamer over the guide wire. Use a sleeve or other soft tissue protector.

Reaming technique:

Reaming is undertaken in sequential steps by increments of 0.5 mm. Do not force the reamer! Frequently retract the reamer partially to clear debris from the medullary canal. The purpose of reaming is primarily to increase the diameter of the tibial canal isthmus sufficiently for easy insertion of a large enough nail. Distal to the isthmus, canal preparation may not require reaming. However, the dense epiphyseal bone usually must be reamed to where the tip of the nail will lie. Ream the canal to a minimal diameter (reamer size) of at least one millimeter greater than that of the selected nail. This will depend upon the chosen nailing system. Usually, a 9 -10 mm or larger should be chosen.

Pitfall - Heat necrosis by overaggressive reaming:

Overaggressive reaming should be avoided because it may cause heat necrosis of the femoral canal. This applies especially for narrow midshaft canals (9 mm or less in diameter)

Pitfall - Rapid thrusting/systemic fat embolization:

Care should be taken to use sharp reamers, to advance the reamers slowly, and to allow sufficient time between reaming steps in order for the intramedullary pressure to normalize. Rapid thrusting of the reamer may worsen the intramedullary pressure increase that is observed during nailing. This image demonstrates fat extrusion in a human cadaver specimen with a window in the proximal section. This may cause pulmonary embolization of medullary fat, which in turn may lead to pulmonary dysfunction (lower image in the enlarged view shows an example of fat embolization through the right atrium).

Special situation: conversion from an external fixator to an intramedullary nail:

If an external fixator has been left in place to maintain reduction, the tibial Schanz screws may need to be partially withdrawn to allow the guide wire, the reamers, and later the nail, to pass through.

Nail insertion:

Preparing nail insertion:

If necessary, replace the ball-tip guide wire with one that can be removed through the inserted nail. (This technique is described for a cannulated nail system.)

Insertion of the cannulated nail:

Achieving and maintaining an accurate provisional reduction is essential for successful alignment of distal tibial fractures. Do not lose the reduction during nail insertion. To prevent distraction or displacement of the fracture, it may be necessary to provide counter-pressure or manual support. The nail should advance easily over the guide wire, by hand or with gentle hammer strokes. Make sure the nail is properly aimed down the tibia. Remove it and ream to a larger diameter if the nail is still hard to insert. The tip of the nail should be placed deeply in the center of the distal tibia, usually to the level of the physeal scar. Confirm this position with AP and lateral image intensifier views

Pearl – use of Poller screws:

Blocking screws (Poller screws) can be placed in the distal fragment to guide the nail and correct fracture deformity. These screws are placed from anterior to posterior to correct coronal plane deformities, and from medial to lateral to correct sagittal plane deformities. They can be left for stability or removed after nail insertion. For a valgus deformity, a proximal Poller screw should be placed more laterally, and/or a distal Poller screw should be placed more medially. Conversely, for a varus deformity, a proximal Poller screw should be placed more medially and a distal Poller screw should be placed more laterally. Alternatively, two screws can be placed (medially and laterally) to effectively centralize the nail in the distal fragment. Blocking screws may be preplanned, or used to correct intraoperative displacement. In the latter, the nail is withdrawn, and the principal blocking screw is placed to keep the nail from following its initial path, and redirect it towards the center of the distal fragment. Then, manually reduce the fracture and advance the nail past the blocking screw.

Pitfall – Undisplaced intraarticular fracture:

Sometimes, a distal tibia fracture that appears to be extra articular may have an undisplaced extension into the ankle joint. This is typically in the sagittal plane. Displacement may occur as the nail is driven into the distal fragment. It is wise to have a very low threshold for inserting percutaneous “protection screws” just above the level of the joint if such a fracture is suspected or develops.

Proximal and distal nail locking:

Proximal locking:

Because the fracture is distal to the isthmus of the tibia, which is the narrowest part of the medullary canal, a single proximal static locked screw is sufficient unless there are concerns about the quality of the bone.

Distal locking:

It is important to maintain accurate reduction of the distal segment while distal locking is carried out. The number and position of distal locking screws is determined by the individual locking configuration of the nail and by the fracture morphology. Insert the greatest number of screws distal to the fracture as possible. Screws may injure local vessels and nerves. Bluntly dissect to the bone surface before drilling to reduce this risk. Occasionally, the most proximal of the distal locking screws can help reduce or fix a more proximal extension of the fracture pattern as shown in the illustration.

CONCLUSION

Evidence suggests that both IM nailing and plating are appropriate treatments as IM nailing shows lower rate of delayed wound healing and superficial infection while plating avoids malunion and knee pain. Large, rigorous RCTs are required for determining the optimal treatment because of the modest sample sizes and the heterogeneity among the studies' designs. The choice of treatments should be based on the surgeon's expertise, the clinical circumstances, and especially the patient's injury pattern.

REFRENCES

1. Thordarson, D.B., *Complications after treatment of tibial pilon fractures: prevention and management strategies.* J Am Acad Orthop Surg, 2000. 8(4): p. 253-65.
2. Blauth, M., et al., *Surgical options for the treatment of severe tibial pilon fractures: a study of three techniques.* J Orthop Trauma, 2001. 15(3): p. 153-60.
3. Leonard, M., P. Magill, and G. Khayyat, *Minimally-invasive treatment of high velocity intra-articular fractures of the distal tibia.* Int Orthop, 2009. 33(4): p. 1149-53.
4. Pugh, K.J., et al., *Tibial pilon fractures: a comparison of treatment methods.* J Trauma, 1999. 47(5): p. 937-41.
5. Zelle, B.A., et al., *Treatment of distal tibia fractures without articular involvement: a systematic review of 1125 fractures.* J Orthop Trauma, 2006. 20(1): p. 76-9.
6. Pollak, A.N., et al., *Outcomes after treatment of high-energy tibial plafond fractures.* J Bone Joint Surg Am, 2003. 85-a(10): p. 1893-900.
7. Maffulli, N., et al., *Percutaneous plating of distal tibial fractures.* Int Orthop, 2004. 28(3): p. 159-62.
8. Gorczyca, J.T., et al., *Modified tibial nails for treating distal tibia fractures.* J Orthop Trauma, 2002. 16(1): p. 18-22.
9. Francois, J., et al., *Percutaneous plate fixation of fractures of the distal tibia.* Acta Orthop Belg, 2004. 70(2): p. 148-54.
10. Bong, M.R., et al., *Intramedullary nailing of the lower extremity: biomechanics and biology.* J Am Acad Orthop Surg, 2007. 15(2): p. 97-106.
11. Kessler, S.B., et al., *The effects of reaming and intramedullary nailing on fracture healing.* Clin Orthop Relat Res, 1986(212): p. 18-25.
12. Chapman, M.W., *The role of intramedullary fixation in open fractures.* Clin Orthop Relat Res, 1986(212): p. 26-34.
13. Aksekili, M.A., et al., *The results of minimally invasive percutaneous plate osteosynthesis (MIPPO) in distal and diaphyseal tibial fractures.* Acta Orthop Traumatol Turc, 2012. 46(3): p. 161-7.

14. Hasenboehler, E., D. Rikli, and R. Babst, *Locking compression plate with minimally invasive plate osteosynthesis in diaphyseal and distal tibial fracture: a retrospective study of 32 patients.* Injury, 2007. 38(3): p. 365-70.
15. Hazarika, S., J. Chakravarthy, and J. Cooper, *Minimally invasive locking plate osteosynthesis for fractures of the distal tibia--results in 20 patients.* Injury, 2006. 37(9): p. 877-87.
16. Cheng, W., Y. Li, and W. Manyi, *Comparison study of two surgical options for distal tibia fracture-minimally invasive plate osteosynthesis vs. open reduction and internal fixation.* Int Orthop, 2011. 35(5): p. 737-42.
17. Khoury, A., et al., *Percutaneous plating of distal tibial fractures.* Foot Ankle Int, 2002. 23(9): p. 818-24.