Tibial Pilon Fractures

Zlomenina pylonu tibie

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SUMMARY

Tibial pilon fractures are severe injuries to the distal articular surface of the tibia. Such injuries frequently result from high-energy axial impact and are often associated with extended soft tissue injury. Various treatment methods are available, depending not only on the fracture type but mostly on the extent of the soft tissue injury; one of the most frequent procedures is a two-stage surgery: the initial closed reduction of the fracture via primary placement of an ankle joint-spanning external fixator, if possible in conjunction with open reduction and internal fixation of the fractured fibula followed by a secondary procedure after soft tissue recovery by open reduction and internal fixation of the tibial plafond. By now, new types of low-profile and locking plates are available for internal fixation allowing the anatomical reconstruction of the fractured articular surface while sparing the soft tissue. Nonetheless, the treatment of tibial pilon fractures is technically demanding because of their potential for severe complications.

INTRODUCTION

Tibial pilon fractures represent less than 1% of all lower extremity fractures but between 5% and 10% of tibia fractures (30). Fractures of the distal tibia extending into the ankle joint were initially termed „pilon fracture" by Destot in 1911 (10), who compared the distal tibia to a pestle. In 1950, Bonin (3) described the same fracture as a „plafond fracture" because the fracture disrupted the roof of the ankle joint. Although articular surface and metaphyseal area are important factors for outcomes, the soft-tissue component typically presents the rate-limiting step in treatment that often primarily determines outcomes, particularly in open fractures (7).
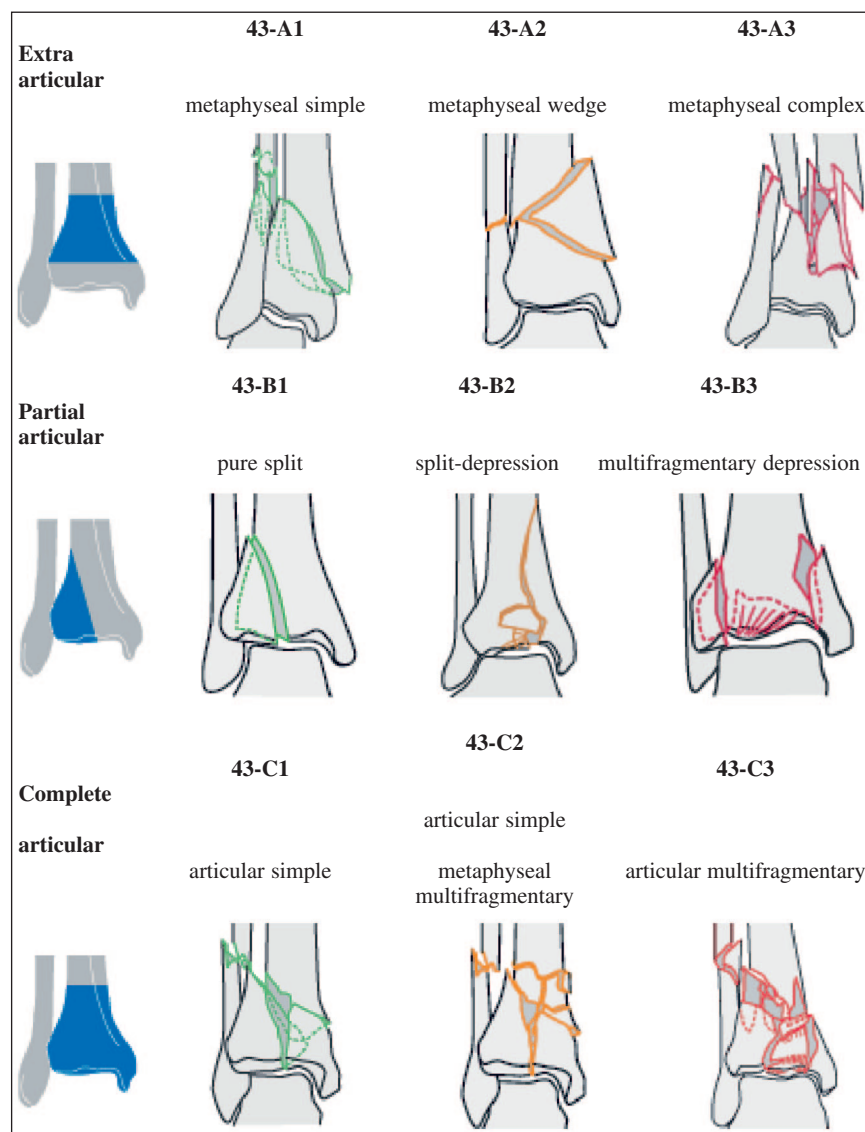
ANATOMY

The distal articular surface of the tibia, which articulates with the talar trochlea, is broader at the front than at the back, showing concave orientation in sagittal and coronary direction. Medially, the articular surface is limited by a strong bone termed medial malleolus, and laterally by a concave indentation or notch, termed incisura fibularis, for the lodgement of the separate fibula. Both malleoli are connected with the lateral articular surfaces of the talus and constitute the joint complex of the ankle joint, which is secured by ligaments. As the most important ligamentary structure of the ankle joint, the position of the fibula is fixed in the incisura fibularis by the distal syndesmosis complex. This complex altogether includes 5 anatomically delimitable structures, from anterior to posterior direction: the anterior tibiofibular ligament, the interosseous tibiofibular ligament, the interosseous membrane of the leg, the posterior tibiofibular ligament, as well as the transverse tibiofibular ligament (15). The anterior tibiofibular ligament, originating from the Chaput tubercle of the anterolateral tibia inserts at the Wagstaffe tubercle of the distal fibula. These ligamentous structures are important for the complex articulation between tibia, fibula and talus. Any disruption leading to instability or incongruency of this area leads to a prearthrotic deformity with consecutive degenerative arthrosis of the ankle joint with loss of function.

MECHANISM OF INJURY

Two distinct, separate mechanisms lead to tibial pilon fractures: Lower energy mechanisms are generally rotational fractures of the distal tibia as a result of falls or sport injuries, particularly of skiing accidents. Higher energy injuries are caused by axial loading in which the talus is driven into the distal tibia. As a result, the distal articular surface implodes, impacting and comminuting the metaphyseal bone. Such injuries are commonly the result of falls from a height or of motor vehicle-related accidents. The tibial articular area most affected by the force is determined by the position of the foot at the moment of impact: Vertical compression force applied to a plantigrade foot leads to central depression. If the force is applied with the foot in dorsiflexion or plantar flexion, the fracture causes anterior or posterior malleolar injuries (32). Associated injuries are varied and usually related to the accident itself.

*Figure 1. AO classification system,
type 43 – distal tibial fractures.*

Extra articular

43-A1 metaphyseal simple **43-A2** metaphyseal wedge **43-A3** metaphyseal complex

Partial articular

43-B1 pure split **43-B2** split-depression **43-B3** multifragmentary depression

Complete articular

43-C1 articular simple **43-C2** articular simple, metaphyseal multifragmentary **43-C3** articular multifragmentary

FRACTURE CLASSIFICATION

Although fracture classifications are typically marked by poor inter- and intraobserver reliability, the classification of fractures can be useful in helping surgeons to understand and communicate fracture patterns and in planning surgical approaches and fixation methods: According to casuistic descriptions, Bonin (3) and Böhler (4) were the first to analyze and classify pilon fractures.

The most well-known system is the Rüedi and Allgöwer classification (29), which is based on comminution and articular displacement and divided into three types: Undisplaced (type 1), displaced-split (type 2), and displaced-comminuted (type 3).

Several other classification systems have been developed sharing the common theme that prognosis is worse for fractures created by higher energy forces (16, 18, 23).

The AO/OTA classification system (22) is a more recently devised system that is primarily used for unifying the multiple classifications in the literature.

Here, distal tibia fractures are divided into three main types (43 A, 43 B, and 43 C) by means of conventional radiography. These three fracture types are further subdivided into three groups, and each group is divided into three subgroups, which finally renders 27 fracture types in all. According to this classification, only type B and C injuries are regarded as tibial pilon fractures because type A fractures are extra-articular fractures (Figure 1).

DIAGNOSIS

Diagnosis is best verified by conventional two-way x-rays of the ankle joint, i.e. from anterior-posterior and lateral direction, as well as by thorough examination of the injured region±also with regard to further concomitant injuries. Full length tibial and fibular orthogonal radiographic views also are suggested for this purpose. Conventional x-ray examination should be followed by computed tomography (CT) providing axial, sagittal, and coronary reconstructions, because CT scans often
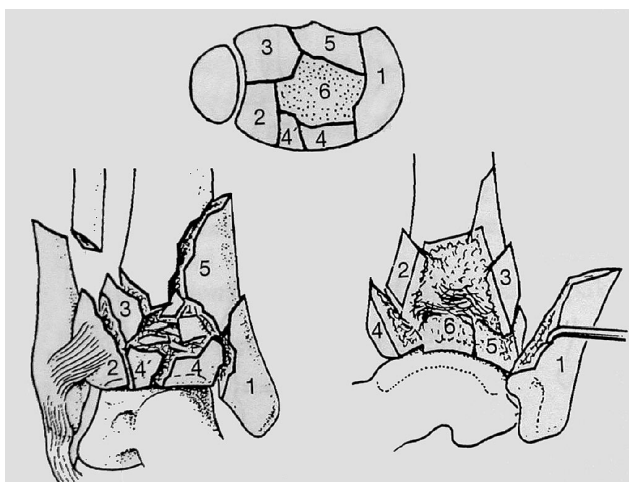
Figure 2. Fracture pattern of tibial plafond fractures.

show fracture details that are not obvious on plain radiographs (41). Such new information on important details may change surgical therapy. Topliss et al. (36) conducted a study outlining the anatomic features of 126 consecutive tibial pilon fractures. By means of CT and plain radiographs, 4 to 6 fracture fragments were identified that showed variations in size and number (anterior, posterior, medial, anterolateral, posterolateral and central) (Figure 2 and 4a). Moreover, CT scans allow to evaluate lesions, such as tubercule de Chaput fracture avulsions and syndesmotic disruption, that may have been missed in previous examinations. In a further study (37), CT scans changed the operative plan based on plain radiographs in 64% of patients and additional information was gained in 82% of patients. Moreover, the surgeons subjectively thought that surgery time was decreased and that they had obtained a better understanding of the fracture patterns. These findings are important for planning subsequent treatments. In a two-stage operative protocol, CT scans should be done after obtaining the spanning external fixator because reduction of the fracture with ligamentotaxis allows easier fragment delineation. MRIs are normally not required for the treatment of tibial pilon fractures.

TREATMENT OPTIONS

Several treatment options have been proposed for tibial pilon fractures, including non-operative treatment, open reduction with internal fixation, limited open reduction with external fixation, and closed reduction with external fixation, for example with a hybrid ring fixator. In case of large soft tissue defects, a plastic surgeon should be involved as early as possible.

Non-operative treatment

Surgery is generally indicated for tibial pilon fractures. However, some patients may have contraindications, such as inability to undergo anesthesia for varying reasons, presence of decompensated peripheral

arterial occlusive disease in an advanced stage, or severe chronic venous insufficiency. Good functional results by conservative treatment of pilon fractures with traction and plaster treatment cannot be expected since the joint destruction is not correctable. Even in undisplaced fractures (for example, type 1 injury according to Rüedi and Allgöwer) good functional outcome is rare, obviously due to the required long immobilization period. Nevertheless, conservative treatment may be the first option if a primary or early secondary ankle arthrodesis is planned.
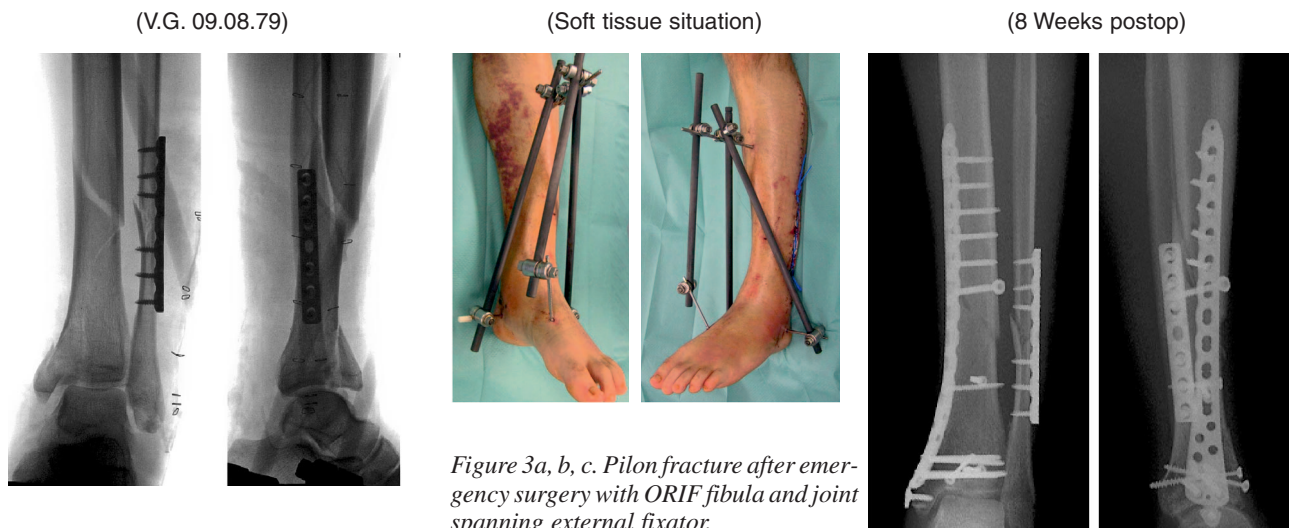
Initial operative treatment

Surgical intervention is indicated in articular displacements measuring more than 2 mm, unacceptable axial alignments, and in open fractures. In 1969, Rüedi and Allgöwer (29) reported first promising clinical results after treating 84 tibial pilon fractures with open reduction and internal fixation (ORIF). Since that time, many surgeons have described a wide variety of treatment options for displaced tibial pilon fractures. Although no consensus exists on the optimal treatment of tibial pilon fractures, most clinicians advocate either open reduction and internal fixation or external fixation with or without limited internal fixation.

The significant risk of wound complications after immediate ORIF has led to studies exploring the role played by the timing of surgery and the status of the soft tissue envelope. Immediate ORIF is therefore only accepted in cases when the soft tissues are in good to excellent conditions, like e.g. in osteoporotic low energy fractures or in open fractures in which the traumatic wound requires immediate open reduction followed by a plastic reconstructive measure to cover the bone and implants. Actually, the standard of care for most tibial pilon fractures is a two-staged protocol in which a joint spanning external fixator is placed at the time of admission until the soft tissue injury resolves. If possible open reduction and internal fixation of the fibular fracture is considered as first step in order to achieve an orientational fix point for the ankle joint (11, 24, 34) (Fig 3a-c).

The insertion of the external fixator can be carried out depending on the degree of instability of the fracture. In some cases one Schanz screw insertion antero-medially or strictly medially on the midshaft tibia (high enough not to interfere with the later implanted plate!) may be enough with one Schanz screw or a transversing pin in the os calcis or even the talus body to span the transfixed fracture. In the more unstable cases or if the soft tissue protection requires a stable foot position 2 pins tibial and 2 or more Schanz screws (small diameter) in the fore foot (mostly in the 1st and 5th metatarsal base) in combination with a transversing pin in the calcaneus will give the required stability and correct position of the foot.

Moreover, in case a fracture fragment causes persistent significant skin tension, this tension should be percutaneously reduced at the time of external fixator placement to prevent skin necrosis. Watson (39) showed that transcutaneous oxygen delivery to the skin drops

(V.G. 09.08.79)   (Soft tissue situation)   (8 Weeks postop)

Figure 3a, b, c. Pilon fracture after emergency surgery with ORIF fibula and joint spanning external fixator.

rapidly after injury, remaining at that level in distal tibia fractures from 6 hours to 10 days after injury.

Therefore, after the soft tissue injury and swelling resolve (which may require between 6 and 21 days), the second stage is completed with definitive open reduction and internal fixation of the tibial pilon fracture including the removal of the external fixator.

Having stabilized the patient in this manner a postoperative x-ray control should be taken and a CT-scan with reconstructions should be done to plan the next step. If necessary the patient can safely be transferred to a clinical unit with sufficient experience in such complicated cases.

THE SECOND STEP: DEFINITIVE CARE

Preoperative planning

After the emergency phase is mastered and the patient is awaiting the definitive surgical procedure the plan of the operative steps should be carefully drawn. Since this is a difficult surgical procedure it should be reserved for the most experienced surgeon and a relaxed team at the best time of the day.

The surgical approach has to be chosen depending on the fracture pattern and potential soft tissue problems, the reduction technique steps should be addressed (what can be done indirectly, what has to be done openly?, special reduction forceps necessary?), the methods of temporary fixation denominated (K-wires, cannulated screw system necessary?, ex fix left in place as reduction tool?) and then the fixation principle has to be made clear: intra-articular portion needs anatomic reduction and compression for primary bone healing, the metaphyseal part may need indirect reduction, „no touch"- technique to the bone and bridging for secondary bone healing. Another important question has to be answered before starting surgery: is a bone graft needed? (plan Iliac crest prep). The proper implant has to be selected or even ordered (which plate? correct length available? Which screw holes mounted first, which type of screw where? which

ones important?) and finally soft tissue coverage and wound closure planned (plan A: primary wound closure, when plan A not possible (due to swelling), plan B: implant coverage and temporary artificial skin coverage, plan C: primary or early secondary skin flap procedure).

With such a plan made available to the whole team (doctors and nurses) the procedure can start.
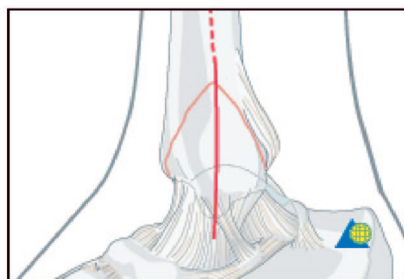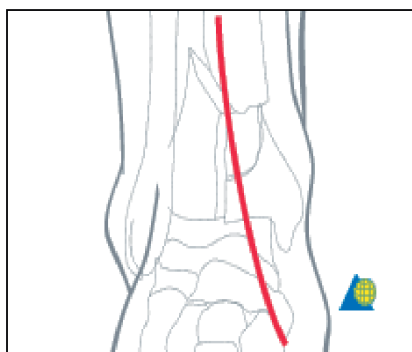
Tourniquet

Although some surgeons prefer not to use a tourniquet and there are instances in which a tourniquet should not be used (marginal soft tissue perfusion), we find its use advantageous to truly evaluate articular reductions with best visualization. Thus, before incision, an Esmarch bandage can be used to exsanguinate the limb. Then, a high thigh tourniquet is inflated to 300 mm HG, which is enough pressure and which can be left inflated for up to 2 hours without any adverse effects. Regardless of the surgical technique used, the patient should be administered a single shot antibiotic coverage intravenously, we usually apply a broad spectrum 2nd generation cephalosporin like Cefazolin 1g, with induction of anaesthesia before the start of surgery.

SURGICAL APPROACH

The surgical approach remains a potential challenge in adequate fracture and articular surface exposure. A further challenge is avoiding structures at risk: tibial pilon fractures can be surgically approached through a medial or anteromedial incision or through a central to anterolateral approach. Between the initial lateral incision for fixation of the fibula and the approach to the tibia the incision lines have to be kept at least 6 to 7 cm apart to preserve vascularity and to prevent soft tissue ischemia and secondary wound breakdown.

Anteromedial approach

This approach is the standard incision for ORIF. The incision initially runs in a straight line in lateral direc-
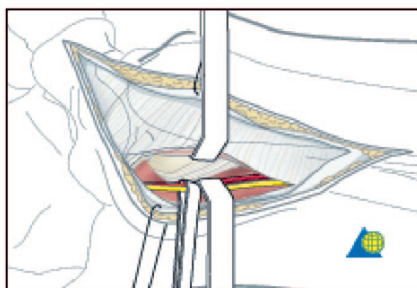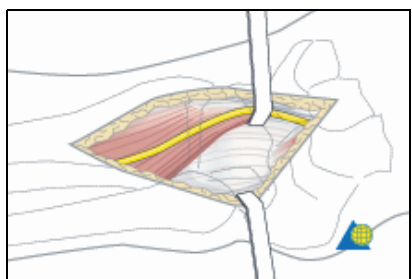
a|b
c|d

Figure 4a. **Anteromedial approach.** *The anteromedial approach is useful in many type 43B and C fractures, particularly if the medial malleolus is involved.*

Figure 4b. **Anterolateral approach.** *The anterolateral approach is useful in the majority of complete articular (type 43C) tibial pilon fractures, anterior, and anterolateral partial articular (type 43B) pilon fractures, and some extraarticular distal tibia fractures.*

Figure 4c. **Medial approach.** *A direct medial approach is usually used for vertical medial split fractures with associated articular impaction (43–B2 fractures).*

Figure 4d. **Posteromedial approach.** *The posteromedial exposure allows direct reduction of posterior and medial fracture fragments.*

tion to the tibial crest, curving medially over the ankle joint in the direction of the tip of the medial malleolus (Fig 4a).

Anterolateral approach

This incision is an extensile anterolateral approach to the ankle allowing exposure of the entire anterior aspect of the distal tibia and particularly the Chaput fragment: The incision starts 5 mm in proximal direction to the Chaput tubercle, heading distally towards the middle between the shafts of the third and fourth metatarsals (Fig 4b).

Medial approach

In some rare cases a direct medial approach can be used. This is used for medial split fractures or if soft tissue problems do not permit a more anterior approach (Fig 4c).

Posteromedial approach

Only occasionally this dorsal approach will be useful for reduction of posteromedial fragments (Fig 4d).

Results of the combined anteromedial /anterolateral approach with the standard lateral fibular incision are generally well accepted in the two-stage procedure. In 2007, Chen et al. (6) reported their experience with a two-incision approach. By means of a two-staged delayed ORIF technique, a medial or lateral approach was used for definitive ORIF. This series reported a wound complication rate of only 8% compared with other published rates up to 20%.

INTERNAL FIXATION

Fibula

Approximately 90% of type C pilon fractures have a fractured fibula (2). Rüedi and Allgöwer (29) stressed the importance of anatomic reduction and osteosynthesis of the fibula to reduce the attached anterolateral Chaput fragment or the posterolateral Volkmann fragment for joint reconstruction. The standard implant for osteosynthesis of the fibula is a 5 or 6 hole one-third tubular plate, which can be applied either on the lateral aspect or on the posterior crest of the fibula in an anti-glide position. A complex fracture may warrant the stronger LCP or LCDCP measuring 3.5 mm. Correct length, rotation, and axis are essential. In the rare situation of severe lateral soft tissue damage, an intramedullary pin, inserted from the tip, may be a useful option, but the pin does not control rotation. Although the majority of the publications suggest that osteosynthesis of the fibula is beneficial, some authors fear that fixation of the fibula may contribute to delayed union or non-union of the tibia and the requirement of secondary procedures.

Tibia

In complex cases with several articular fragments and considerable metaphyseal impaction, the medial application of an external joint-bridging distraction device like the spanning fixator may be helpful to achieve a preliminary indirect reduction of length and axis. Alternatively, a transverse Schanz screw through the talus or calcaneus may help the reduction maneuver if the span-

- **Restoration of dorso-lateral frame of the facet**
  - „Triangel of Volkmann"
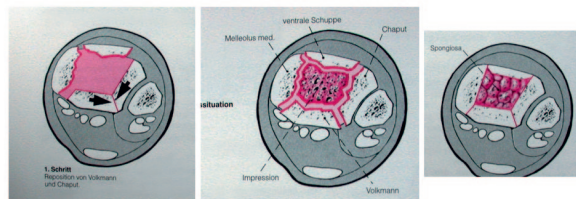 - „Tubercule de Chaput"

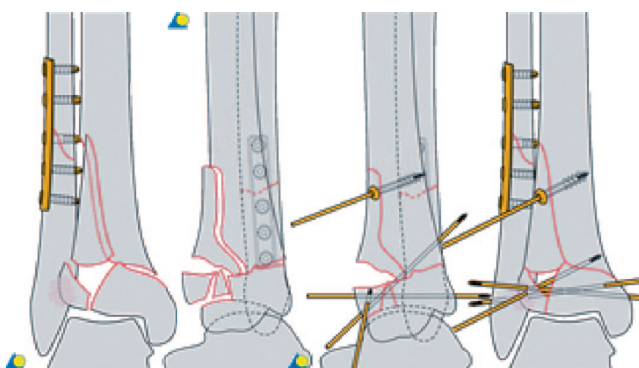*Figure 5. Reconstruction of tibial plafond.*

Figure 6. Reconstruction of tibial plafond Temporary fixation with passing K-Wires

ning fixateur cannot be used for this procedure. The tibial articular bloc is reduced by a combination of direct and indirect techniques. Anterior and medial fragments may be retracted by a pointed hook or a small bone spreader for a better view into the joint. This procedure brings the central and posterior fragments, often a key to reduction (Fig 5).

All articular fragments are lined up one after the other using the talus as a mold to restore anatomical congruence. Once aligned, the fragments are held in position by a pointed forceps or preliminary K-wires. Another key fragment, the anterolateral edge of the tibia, must be perfectly aligned. The preliminary reduction must be checked by x-ray or image intensifier before definitive stabilization is started (Fig 6).

In all cases with articular impaction and or metaphyseal bone defect, the latter has to be filled up, preferably with an autologous graft or bone substitute. Sometimes in cases of complete destruction of the articular cartilage a tricortical bone block serves as replacement of the articular surface. The type of plates for definitive reconstruction has been dramatically altered in recent years by several new advances: minimally invasive surgery, anatomic plate designs, locking plates, and screw technology (Fig 7a, b).

In suited cases in the metaphyseal area the plate can be inserted as a Minimally-Invasive Plate Osteosynthesis (MIPO technique) which reduces the interference of the surgical incision with the blood supply to bone and the adjacent soft tissue structures (Fig 8 a-e).

Figure 7a. LCP medial distal tibia plate 3,5.

Figure 7b. AO-LCP (locking compression plate) LCP antero lateral distal tibia plate 3,5, for anterolateral placement.
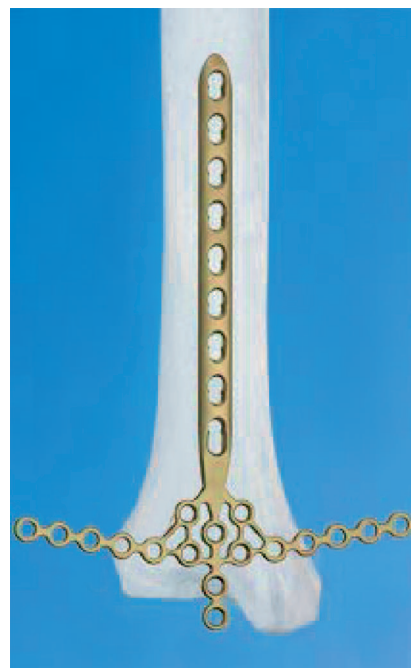

Figure 7c. LCP pilon plate 3,5.

Figure 8a. Skin drawing for exact planning of incisions.

Figure 8b. Percutaneous insertion of plate.

Figure 8c. Distal locking of inserted plate.

Figure 8d. Skin incisions for percutaneous plate fixation.

EXTERNAL FIXATION

Because of the high rate of often unforgiving complications associated with open reduction and internal fixation of tibial pilon fractures, studies have supported different external fixator systems (for instance, hybrid fixation, or Illizarov ring fixator) as an alternative treatment option (27, 28, 41). Watson et al. (39) immediately stabilized all tibial pilon fractures by applying a calcaneal traction. Then, patients with grade 0 and 1 soft tissue injuries underwent open reduction and internal fixation with contemporary techniques and low profile implants. All patients with an open fracture underwent definitive treatment with limited open reduction and stabilization by means of small wire circular external fixators. After an average of 4.9 years postoperatively, patients with open plating had a significantly higher rate of non-union, malunion, and severe wound complications compared with patients who had received external fixation for type c fracture patterns. The technique reported by McDonald et al. (21) involved indirect reduction, stabilized by an Ilizarov ring fixator from the tibial diaphysis to the epiphysis but not crossing the tibial-talar


Figure 8e. Percutaneous osteosynthesis of antero-medial plate location.

joint. Therefore, immediate postoperative ankle motion was possible. The authors reported no deep infection and good functional recovery. The authors concluded that the technique of Ilizarov external fixation represents an

Figure 9a. A 50 year old male patient with a high energy, 2 degree open, tibial pilon fracture: Preoperative axial CT with an anterolateral, medial, posterior and a central multiple fragmented bone piece.

Figure 9b. Result 1 year postoperatively; antero-medial approach, open reduction and fixation with LCP, additional one single screw for fixation of central bone fragment from anterior to posterior.

a | b
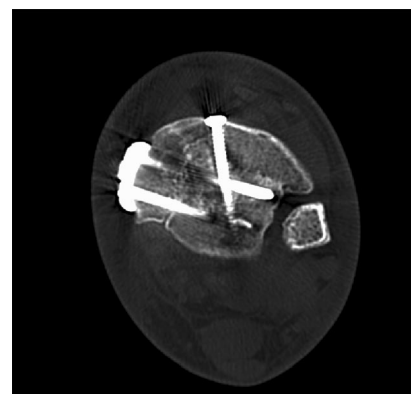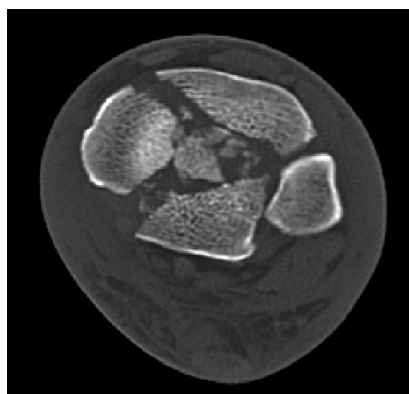
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Figure 9c. CT with coronar reconstruction, tibial pilon fracture preoperatively.

Figure 9d. CT with coronary reconstruction, result 1 year postoperatively, with nearly anatomical reduction of the central fragment.
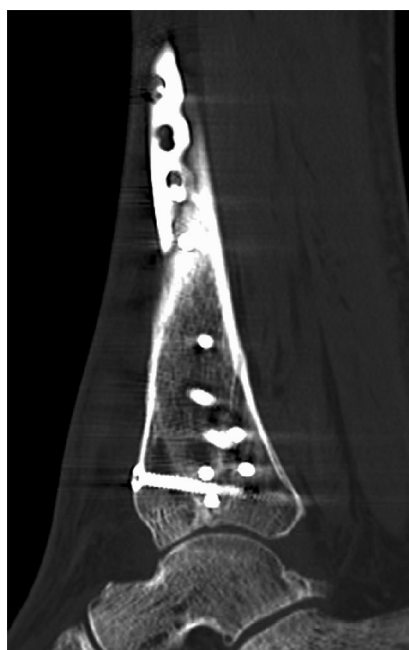

e | f

Figure 9e. CT with sagittal reconstruction, tibial pilon fracture preoperatively.

Figure 9f. CT with sagittal reconstruction, result 1 year postoperatively, with nearly anatomical reduction of the central fragment.

effective treatment option for all patients with tibial pilon fractures. However, for patients with a type 3 fracture according to Rüedi, increased frame time, initial bone grafting, and increased time without weight bearing are indicated. When using an external fixator for the definitive treatment of tibial pilon fractures, benefits include a decreased incidence of wound and bone infection. However, this benefit must be weighted against the risk of pin tract infections resulting in septic arthritis (19). Moreover, metaphyseal nonunions are not uncommon, and joint reduction may not be possible with limited incisions. Despite these drawbacks, many authors feel that

Figure 9g. Postoperative radiographic, treatment with LCP (AO-locking compression plate).

Figure 9h. Postoperative radiographic, treatment with LCP (AO-locking compression plate).

Figure 9i. Radiographic result 2 years postoperatively, the male patient still works as a truck driver.

external fixation is the safest treatment option in very severe fractures (14, 17, 18, 39).

OUTCOME

An exemplary case shows our management and the result (Figure 9a-j).

The clinical outcome can be correlated to the type of fracture, and poor outcomes increase with severity of the injury (5, 31, 34). In general, the worse the initial soft tissue injury, the poorer is the overall function, regardless of the initial fracture pattern: Rommens et al. (27) found a significant relationship between fracture type and soft tissue injury: Patients without soft tissue lesions showed good to excellent subjective results in 86% and good to excellent objective results in 75%. Patients with severe soft tissue damage had good or excellent subjective results in 56% and good to excellent objective results only in 48%. How efficacious an operative – at best- an anatomical reconstruction of the articular surface may be on the outcome has not yet been scientifically verified. Wyrsch et al. (40) found that the mean ankle score was better for patients treated with external fixation than for those treated with open reduction and internal fixation despite the fact that the latter patients had better reduction. DeCoster et al. (9) found no difference with respect to outcome between patients who had better reduction compared with those who had poorer reduction. Etter and Ganz (12) noted that even perfect reductions were not always followed by excellent outcomes. Crutchfield et al. (8) thought that the severity of
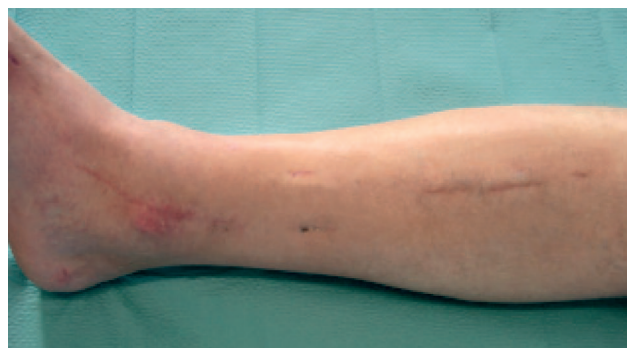

Figure 9j. Medial approach to the tibia with small incisions proximally for screw fixation of locking plate.

the articular injury was the major determinant of outcome. In two studies that used the same technique to assess the quality of the reduction after treatment, Patterson and Cole (24) found that 14% of the 21 ankles in their study showed fair reduction, whereas Marsh et al. (20) found that 30% of 49 ankles showed fair or poor reduction. Despite the difference in the quality of the reduction, 9% of the ankles in the former study required ankle arthrodesis in contrast to only 3% in the latter study. Chen et al. (7) showed in a retrospective study with open reduction and plating that the long-term outcome was affected by fracture patterns, fibular length restoration, quality of reduction, and severity of soft tissue injury. The worst outcome was detected in the group of type 3 fractures according to the Rüedi and Allgöwer classifi-

cation as well as in the group of open injuries. Additional surgery of the fibula showed better results in comparison with untreated fibula fractures. The findings of all these studies indicate that our current level of clinical research is insufficient to show that more accurate reductions consistently lead to better outcomes or even to a lower risk of posttraumatic osteoarthritis since the amount of cartilage damage still cannot be quantified. On the other hand, Pollak et al. (26) showed in a retrospective cohort analysis of 80 tibial pilon fractures treated at two different centers that external fixation with or without limited internal fixation were significantly related to poorer functional results compared to ORIF. Moreover, 5 out of 80 patients underwent late amputation, each of the 5 patients had sustained AO type C fractures, and four out of five fractures were open fractures. All amputations were conducted in patients who had been treated with external fixation with or without limited internal fixation.

Return to work

Pollak et al. (26) reported that only 57% of the patients who had been employed at the time of injury were working at the time of follow-up. Sands et al. (33) reported similar results in his series. Teeny and Wiss (35) reported a 37% rate of good to excellent results after the treatment of Rüedi Type 1 and 2 fractures with open reduction and internal fixation compared with a rate of only 13% after the treatment of type 3 fractures. Therefore, 50% of their 58 patients had poor clinical results. Conversely, all of their patients with poor fracture reduction had a poor clinical result.

Complications

Numerous complications are associated with the open operative treatment of tibial pilon fractures. The literature reports on different complication rates for superficial or deep wound infection, delayed union or malunion, osteitis, late arthrodesis, or below knee amputation. The most common complication of this high energy injury is posttraumatic arthritis, which can occur in up to 50% of patients. Other complications include reflex sympathetic dystrophy, varus angulation, metal erosion and others making additional surgical procedures necessary (7, 8, 9, 12, 20, 25, 26, 30, 33). Although it is quite likely that the recent improvements in implant designs and the better understanding of the importance of proper handling of the soft tissue envelope may reduce the fracture healing problems. The destruction of articular cartilage can still not be treated adequately, not even the amount of this damage can be measured objectively.

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