



Intra-articular fractures of the distal tibia: current concepts of management

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- Results of the treatment of intra-articular fractures of the distal tibia have improved significantly during the last two decades.
- Recognition of the role of soft tissues has led to the development of a staged treatment strategy. At the first stage, joint-bridging external fixation and fibular fixation are performed. This leads to partial reduction of the distal tibial fracture and allows time for the healing of soft tissues and detailed surgical planning.
- Definitive open reduction and internal fixation of the tibial fracture is performed at a second stage, when the condition of the soft tissues is safe. The preferred surgical approach(es) is chosen based on the fracture morphology as determined from standard radiographic views and computed tomography.
- Meticulous atraumatic soft-tissue handling and the use of modern fixation techniques for the metaphyseal component such as minimally invasive plate osteosynthesis further facilitate healing.

Keywords: intra-articular fractures; distal tibia; diagnosis; closed treatment; surgical treatment; outcomes; complications

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Introduction

The treatment of fractures of the distal part of the lower leg (particularly with involvement of the distal tibia articular surface) is challenging for orthopaedic surgeons and often leads to serious complications such as infection, malunion, nonunion and post-traumatic arthritis. The published results are often difficult to compare because of significant heterogeneity of bone and soft-tissue injuries, the small number of patients in reported series, the retrospective nature of many investigations and the absence of a control group in most studies.¹⁻⁵

Despite significant difficulties related to soft-tissue coverage and complex fracture anatomy, there has been an improvement in the results of treatment of these injuries during the last few decades. The purpose of this article is to describe current concepts of management of intra-articular distal tibial fractures with a special emphasis on the avoidance of complications.

Definition

According to the AO/OTA classification,⁶ the term 'distal tibial fracture' includes a heterogeneous group of fractures that involve the distal part of both tibia and fibula. The term 'pilon fracture' was originally introduced by Etienne Destot and indicates the involvement of the weight-bearing surface of the ankle joint which usually results from an axially directed force.³

Mechanisms of injury, epidemiology and concomitant injuries

Distal tibial fractures are usually caused by two possible types of forces: rotational and/or axial loads. Rotational forces (torsion) usually lead to a spiral fracture which may be intra- or extra-articular. These are usually closed, resulting from low energy and the associated soft-tissue injuries are not usually severe. On the other hand, higher energy axial compression forces lead to intra-articular fractures of the distal tibia when the convex talar dome impacts the concave plafond of the distal tibia. The severity of the articular injury depends on the amount of energy applied and the position of foot at the time of impact. With plantarflexion of the foot, most forces are directed to the dorsal (posterior) part of the articular surface and lead to the formation of a relatively large posterior fragment. The opposite situation occurs when the foot is dorsiflexed causing the talar dome to impact on the anterior part of the distal tibial articular surface. If the ankle is in a neutral position, usually total involvement of the articular surface is seen with a Y-type separation of anterior and posterior fragments frequently with central joint impaction (Fig. 1).⁷

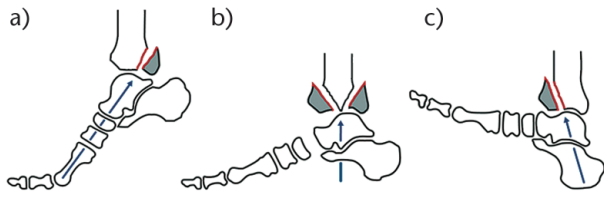


Fig. 1 The role of foot position in the type of distal tibial fracture.

The incidence of distal tibial fractures is 3% to 10% of all tibial fractures or 1% of lower extremity fractures. In 70% to 85% of cases, a fibular fracture is also seen, which occurs in more complex injuries.⁸⁻¹¹

As these fractures are often the result of high-energy trauma, up to 50% of patients may have additional lower extremity injuries, most often ipsilateral calcaneal or tibial fractures. About 6% of patients may also have multiple system injuries.^{1,12,13}

Diagnostic work-up

Clinical examination of the patient with a distal tibial fracture should be performed according to the Advanced Trauma Life Support protocol,¹⁴ as a significant number of patients may have additional injuries.

Clinical examination includes a thorough, systematic clinical assessment to include peripheral pulses and a careful neurological assessment. Thorough evaluation and documentation of the local soft-tissue condition is critical. Up to 50% of distal tibial fractures are open, but significant soft-tissue injury occurs in closed fractures as well. Local swelling and fracture blisters may develop quickly and will influence the choice and timing of treatment. Compartment syndrome must always be suspected in cases with significant swelling, the appearance of fracture blisters or severe pain not responding to analgesics.^{3,15}

Radiological evaluation includes plain radiographs and CT scanning. In extra-articular fractures, plain radiographs provide sufficient information for surgical planning. With intra-articular fractures, CT is paramount. It has been shown

that in > 80% of cases CT scans provided additional information about the fracture configuration which resulted in a change of the initially planned surgical approach in 64%.¹⁶

Tornetta and Gorup,¹⁶ on the basis of CT investigations of 22 distal tibial fractures, identified six relatively common fracture fragments (Fig. 2a):

- 1) an anterolateral fragment (seen in 58% of cases), which is connected to the fibula by the anterior tibiofibular ligament;
- 2) an anterior fragment (76%);
- 3) a medial malleolar fragment (84%) may still be connected to the anterior or posterior fragment and may include up to 40% of the tibial articular surface;
- 4) a posterior fragment;
- 5) a posterolateral fragment (26%);
- 6) a central fragment (50%) is located in the central articular surface and is not connected to other fragments by ligaments and may comprise up to 20% of articular surface.

Further studies of CT anatomy of distal tibial fractures confirmed the existence of these distinct fragments.¹⁷ With the fracture mapping technique Cole et al¹⁸ revealed the common fracture lines that typically define a Y-shaped fracture pattern with the three most common fragments seen (Fig. 2b): medial, anterolateral and posterolateral. The typical zones of comminution were also described, that involve predominantly the central zone of the plafond and its anterolateral part (Fig. 2c).¹⁸

Classification

According to Müller, the classification of fractures should reflect the severity of injury, the prognosis and possible treatment modalities.¹⁹ In articles dealing with intra-articular distal tibial fractures, the Rüedi and Allgöwer classification and AO/OTA fracture classification are used most often.^{6,20} The AO/OTA fracture classification distinguishes extra-articular (type A), partial articular (type B)

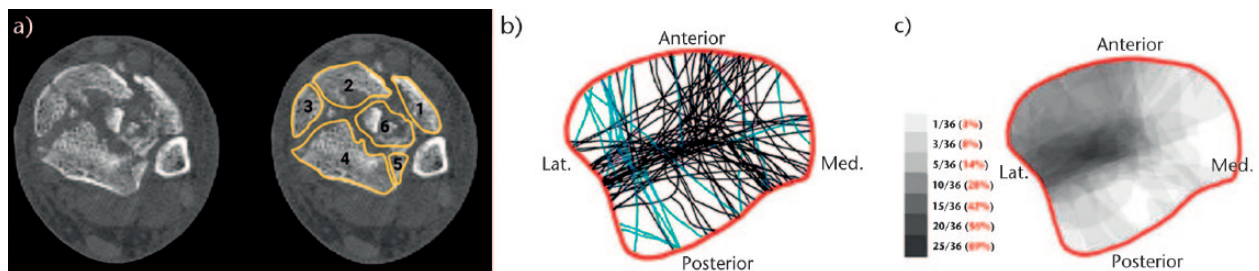


Fig. 2 a) Common articular fracture fragments; b) Common articular fracture lines; c) Common articular impression zones. Panels (b) and (c) reproduced with permission from Cole PA, Mehrle RK, Bhandari M, Zlowodzki M. The pilon map: fracture lines and comminution zones in OTA/AO type 43C3 pilon fractures. *J Orthop Trauma* 2013;27:e152-156.¹⁸

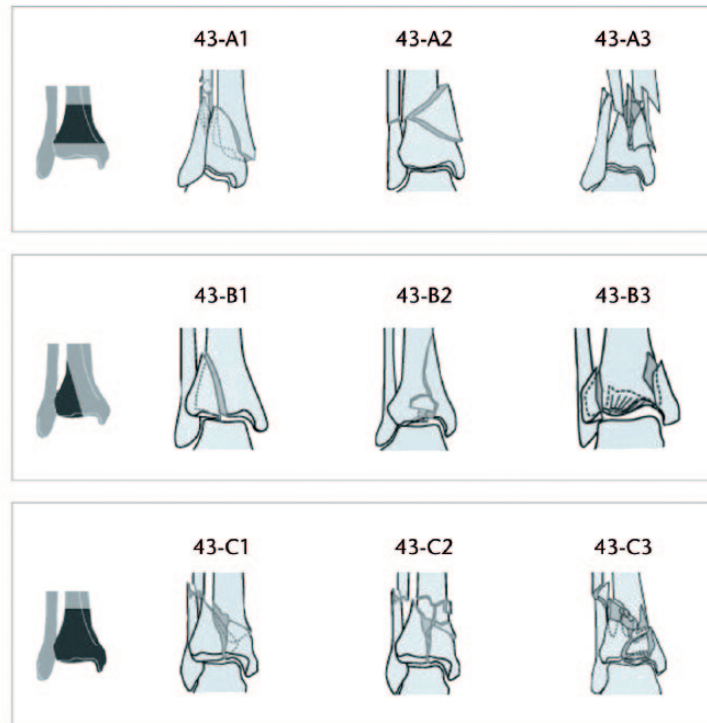


Fig. 3 AO/OTA classification of distal tibial fractures. Adapted with kind permission from AO Foundation, Switzerland. 43-A extra-articular fracture. 43-A1 simple; 43-A2 wedge; 43-A3 complex. 43-B partial articular fracture. 43-B1 pure split; 43-B2 split depression; 43-B3 multifragmentary depression. 43-C complete articular fracture. 43-C1 articular simple, metaphyseal simple; 43-C2 articular simple, metaphyseal multifragmentary; 43-C3 articular multifragmentary.

and complete articular (type C) fractures. All intra-articular fractures (types B and C) can be defined as pilon fractures (Fig. 3).

The condition of the soft tissues plays a key role in the treatment of distal tibial fractures. The safety of a direct approach and open reconstruction of the articular surface early after the injury depends primarily on the condition of the local skin and subcutaneous soft tissues. The most commonly used classification of open fractures is that described by Gustilo and Anderson.²¹ Closed soft-tissue injuries can be classified according to Tschernke and Oestern.²² The AO soft-tissue grading system allows comprehensive description of all soft-tissue injuries in both open and closed fractures.²⁰

Treatment

Conservative management

Conservative management may play a role in the treatment of non-displaced fractures or fractures that can be reduced and remain stable in a cast. Other indications may include patients who are at extremely high risk for anaesthesia or high risk for surgical complications because of the local soft-tissue condition or the patient's refusal of surgical treatment.

After closed reduction, a carefully padded lower-leg plaster cast is applied. Partial weight-bearing on crutches may be started at six to eight weeks in stable, non-displaced fractures. Articular fractures with joint depression should be non-weight-bearing for 12 weeks. One must remember that in multifragmentary intra-articular fractures of the distal tibia (classical pilon fractures), the depressed articular fragments have no soft-tissue attachments and cannot be reduced by indirect closed means (ligamentotaxis) and require direct open reduction.²³

Nonunion is infrequent in conservative treatment with an incidence of about 1.3%. Secondary fracture displacement often complicates cast treatment of distal tibial fractures and may lead to malalignments (most commonly varus) in 15% of cases. Prolonged immobilisation also poses the risks of thrombosis, embolism and post-traumatic joint contractures.^{8,24}

Surgical treatment

Adequate restoration of displaced articular fractures cannot usually be achieved by closed reduction methods so open reduction and internal fixation (ORIF) remains the mainstay of surgical treatment of these injuries. Some authors have advocated external fixation for cases with severe comminution.²⁵⁻²⁷ Other authors have had excellent

results with medullary nailing and interfragmentary screws in selected cases of simple intra-articular fractures.²⁸

The aims of surgical treatment are:

- 1) anatomical restoration of the joint surfaces with correct axial alignment;
- 2) stable internal fixation to allow for early functional treatment;
- 3) careful, atraumatic surgical technique to preserve blood supply to bone and soft tissue.

The classical approach to ORIF of distal tibial fractures was proposed by Rüedi and Allgöwer²⁰ in 1969 and includes these four surgical steps:

- 1) reduction and fixation of the fibula;
- 2) reconstruction of the articular surface of the tibia;
- 3) bone grafting of depressed articular and metaphyseal defects;
- 4) fixation of the metaphysis to the diaphysis with a medial plate.

Reported results of this proposed technique are very good: in 84 pilon fractures, the authors noticed wound complications in 12% and deep infection only in 5% of cases. In total, 73.7% of patients had good functional results four years after the injury. Up to now, this report has been a standard by which all other techniques are compared. However, it must be mentioned that most of the cases were the result of relatively low-energy torsional injuries either from skiing (71%) or a fall.

Some authors have achieved the same results in patients with low-energy fractures, but in high-energy fractures the number of complications appeared to be much higher. Bourne et al²⁹ (1983) found 13% rate of deep infections in their series of 42 high-energy distal tibia fractures. Dillin and Slabaugh³⁰ reported a 55% incidence of wound complications and Teeny and Wiss³¹ reported a 37% incidence in their series.

It became obvious that this high number of wound complications was related to poor local soft-tissue conditions at the time of surgery. At the end of the 1990s, a staged protocol for the treatment of distal tibial fractures was proposed by several authors.³²⁻³⁴ The first stage included fixation of the fibula and application of an external fixator medially. Definitive distal tibial fixation was performed only after the resolution of soft-tissue oedema, usually seven to 14 days (or more) after the injury. Sirkin et al,³² in a series of 48 type 43-C distal tibial fractures (19 were open), reported three cases of deep infection (6.25%). In a subgroup with closed fractures, there was just one case of infection (1/29, 3.4%). Similar results were obtained by other authors using a staged approach

and currently this two-staged treatment strategy has become universally accepted.³⁵⁻³⁷

A temporary, joint-bridging external fixator is recommended for alignment and stabilisation of the bone as well as stabilisation of the soft tissue until the soft-tissue condition is conducive for surgical intervention. This is indicated by resolution of any fracture blisters and appearance of wrinkling of the skin.

There are two main configurations of external fixator for temporary joint-bridging ankle fixation. A unilateral, medial fixator may be used after initial fibular fixation and consists of two Schanz-pins in the proximal antero-medial tibia and a Schanz pin in the medial calcaneal tuberosity and another pin in the first metatarsal bone distally to help maintain the foot in a plantigrade position. In some cases, when lateral support is not provided by fixation of the fibula, a medially placed external fixator may be insufficient to prevent valgus displacement and lateralisation. In these cases, a centrally threaded Steinmann pin is inserted through the calcaneal tuberosity and secured to two half pins in the tibia. The forefoot may be stabilised and positioned with smaller diameter pins. This construct provides equal distribution of traction forces to both medial and lateral sides (Fig. 4).^{24,38}

Surgical approaches

Surgical approach(es) for the treatment of distal tibial fractures must provide good access to the injured bone for reduction and fixation and at the same time be safe enough to avoid complications primarily related to poor vascularity of the injured soft tissues in the region. A number of approaches are used for this purpose (Fig. 5). They may be divided into two groups: 1) anterior (medial, anteromedial, anterior, anterolateral and lateral); and 2) posterior (posteromedial and posterolateral). Every surgical approach for the distal tibia has its own advantages and disadvantages that are well described.^{3,7,20,36,39}

For practical reasons the subdivision of distal tibia into three basic columns is very helpful⁴⁰ (Fig. 6). The medial column is the continuation of the medial side of tibia shaft and includes the medial part of articular surface and the medial malleolus. The lateral column is the prolongation of the anterolateral side of tibia shaft and contains the anterolateral part of the articular surface of the plafond, the Tillaux-Chaput tubercle and the incisure for the fibula. The posterior column is the continuation of posterior surface of the tibia and ends in the posterior malleolus. The surgical approach to the pilon fracture should be chosen according to the location of the articular injury (involved column) and appropriate mechanical fixation needed for stability.⁴⁰

Historically, the extensile anteromedial approach (Fig. 5b) was the most commonly used for the reconstruction

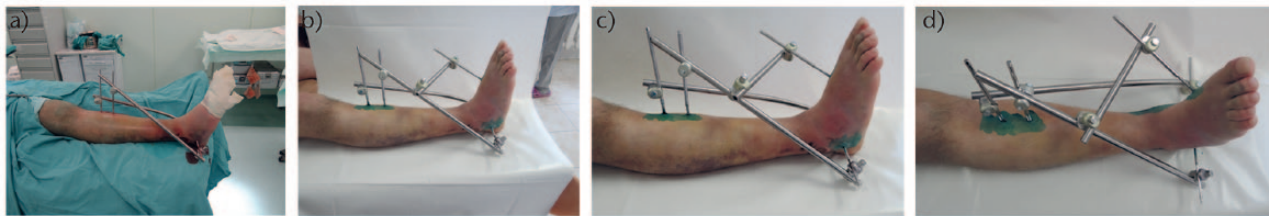


Fig. 4 Temporary external fixation frame with transcalcaneal pin.

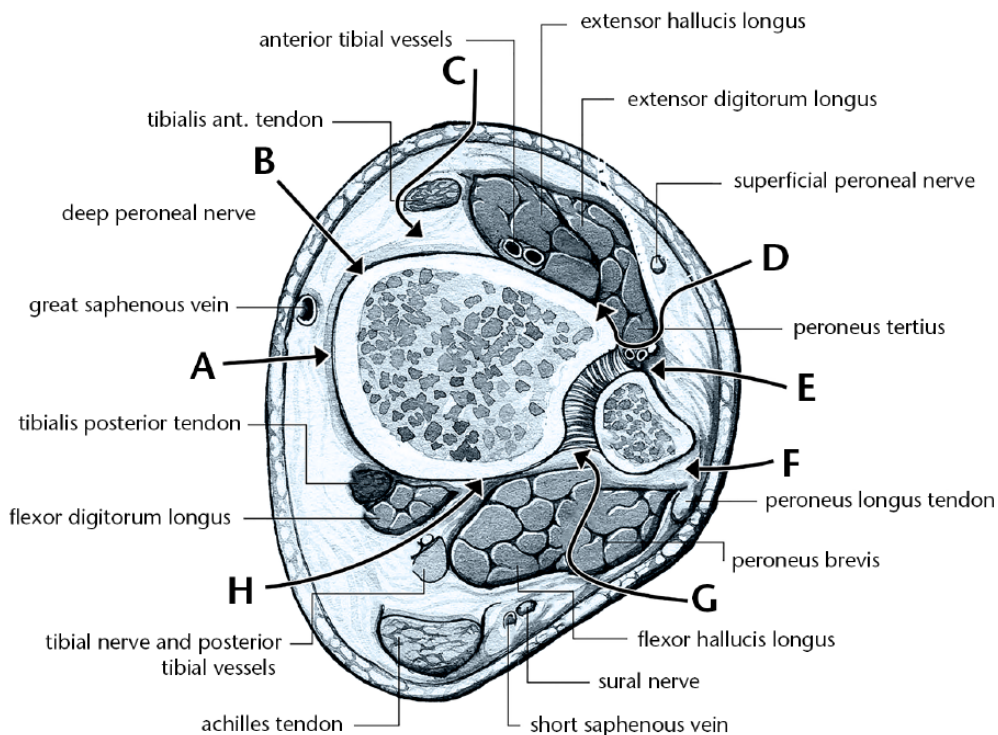


Fig. 5 Schematic drawing of surgical approaches to distal tibia: a) medial approach; b) anteromedial approach; c) anterior approach; d) anterolateral approach (for tibia and fibula); e) lateral approach (for fibula only); f) posterolateral approach; g) posteromedial approach; h) posteromedial approach.

of pilon fractures.²⁰ It provides an excellent view of the medial column and anterior part of the plafond, but the possibilities for the restoration and fixation of lateral column and Tillaux-Chaput tubercle are somewhat limited.

The anterolateral approach allows direct visualisation of the lateral column and anterior part of the joint, but does not provide access to the medial column (Fig. 5d). When a lateral column fracture is associated with a fibular fracture, the reduction and fixation of both can frequently be achieved through a single anterolateral approach. Soft tissues on this side of the joint are less vulnerable compared with the medial side.^{3,36}

Other anterior approaches to the distal tibia (medial, anterior and lateral) may be used if fracture anatomy

dictates this, but are not so popular.^{40,41} For the fractures with involvement of both medial and lateral columns the extensile anterior approach was described.⁴²

All anterior approaches rely on the assumption that the posterolateral fragment is anatomically reduced to the tibia by reduction and fixation of the fibula. Once this posterolateral fragment is reduced it becomes the ‘stable and constant fragment’ to which and around which the adjacent fragments are reduced and fixed. The reduction of the fracture is performed from posterior to anterior.

In approximately 20% of cases the posterior fragment remains dislocated (displaced) and needs direct reduction. For this reason, posterolateral or posteromedial approaches may be used. After reduction of the posterior

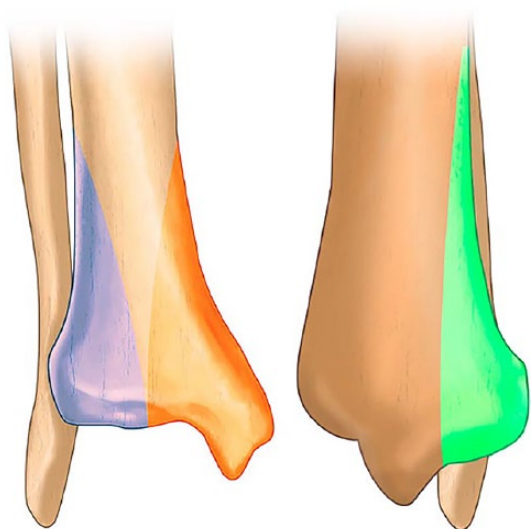


Fig. 6 Medial (orange), lateral (blue) and posterior (green) columns of the distal tibia. Reproduced with permission from Assal M, Ray A, Stern R. Strategies and surgical approaches in open reduction internal fixation of pilon fractures. *J Orthop Trauma* 2015;29:69-79.⁴⁰

fragment the fracture is 'converted' to a stable type B (partial articular) fracture and one may now proceed with anterior fixation having a stable posterior fragment.^{3,7}

The posteromedial approach (Fig. 5h) may be used for fractures with a large posteromedial fragment. The neurovascular bundle should be retracted anteromedially or posterolaterally. This approach does not provide good access for the posterior fractures that extend laterally.⁴⁰

The posterolateral approach (Fig. 5g) between flexor hallucis longus and peroneal muscles provides access to the lateral and posterior aspect of the tibia, posterior column and plafond. A large posterolateral fragment can be mobilised on its ligamentous hinge and rotated to allow direct reduction of the articular fragments. Visualisation of the joint is difficult from this approach but anatomical reduction of the posterior fracture line (an accurate cortical read) will indirectly indicate articular reduction. More medial fragments are difficult to address through this approach. Simultaneous fixation of the fibula is possible through the same skin incision when the peroneal muscles are retracted medially.⁴⁰

When planning surgical approaches, one has to remember that the skin bridge between the two incisions (if used) should be wide enough to maintain the blood supply of the soft tissues. It was empirically postulated that for safe skin blood supply the width of the bridge should be at least 7 cm. The use of more limited approaches (minimally invasive osteosynthesis or minimally invasive plate osteosynthesis (MIPO)) or the delay of surgery until the soft tissues have recovered enough may allow the

width of the skin bridge to be reduced to 5 cm to 6 cm safely with low complication rates.⁴³

Pros and cons of fibular fixation

In most cases of pilon fractures, the reduction and fixation of the fibula is an important part of the first stage of treatment. Correct reduction of the fibula with restoration of length, rotation and axial alignment not only provides a reference for reconstruction of the distal tibia, but may also facilitate partial reduction of the anterolateral and/or posterolateral fragments as a result of the usually intact syndesmotomic ligaments (ligamentotaxis). Correct reduction of the fibula prevents valgus malalignment of the distal tibia.^{20,23}

On the other hand, the need for accurate fibula fixation is controversial in cases where restoration of the length of a highly comminuted tibia fracture may be impossible to achieve or when external fixation is used for definitive treatment of the fracture.^{33,44}

In cases of a simple fibular fracture with varus deformation of the tibia, a one-third tubular plate that functions as a tension-band plate is effective for fixation. In comminuted fractures of the fibula or valgus angulation of the distal tibia, more rigid implants are preferred. In transverse fractures, intramedullary fixation may be considered as a less invasive method of fracture fixation.²³

Reduction of fracture - distraction

Besides the correct choice of surgical exposure, distraction (either with an external fixator or a femoral distractor) provides great help in facilitating surgical reduction. It is possible to use unilateral (uniplanar) distraction with Schanz-pins or bilateral distraction with threaded Steinmann pins. This last one is extremely useful when the fibula is not fixed or stabilised.

It is important to keep in mind that placement of a pin through the calcaneus (in the tuberosity, posterior to the tibia plane) will cause dorsal extension of the ankle and may hinder the joint visualisation from an anterior approach. However, placement of a Schanz pin in the talar neck can be used to provide plantar flexion of the foot and provide better visualisation of the anterior joint.^{3,37}

Reduction of the posterolateral fragment

As mentioned earlier, the posterolateral fragment is a 'key fragment' for the reconstruction of the distal tibia articular surface. It may be reduced spontaneously by fixation of the fibula relying on ligamentotaxis, but in approximately 20% of cases, direct reduction is needed which may be achieved by different methods. These include use of a 'joystick-pin' placed through an anterior approach directly into the anterior cancellous surface of the fragment or the

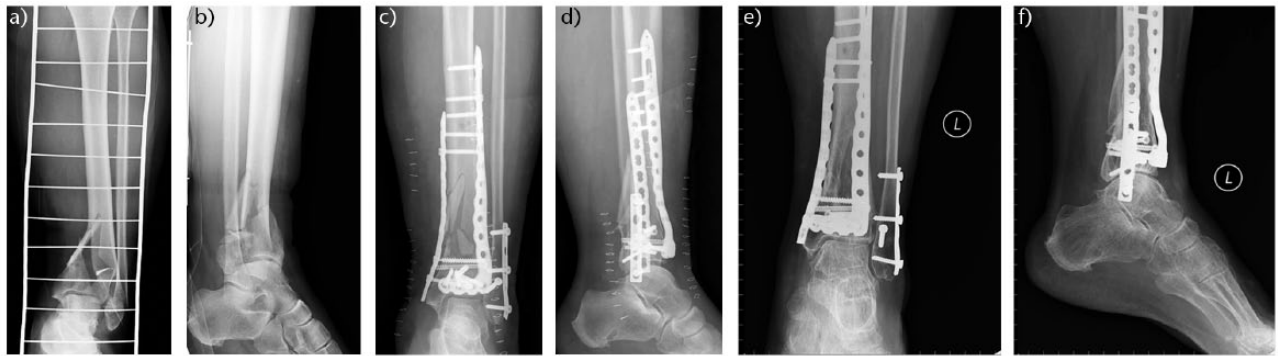


Fig. 7 a, b) Patient S, a 67-year-old woman who fell down from the stairs. c, d) Comminuted distal tibial and fibular fractures, treated initially with external fixation and fibular fixation. Definitive fixation on day 14 - posteromedial and anterolateral approaches for joint reconstruction, percutaneous plate positioning. e, f) Follow-up two years after the surgery.

use of a bone hook or pointed reduction clamp through the syndesmosis or a large pointed reduction clamp placed directly against the posterolateral surface of the fragment through a separate posterior stab incision. Reduction through a separate posterolateral or posteromedial approach may be the most accurate, but requires separate procedures and special patient positioning (prone or lateral decubitus).^{7,36}

Restoration of the depressed zone and bone grafting

Axial displacement of the talus into the distal tibia causes impaction of the articular fragments and underlying cancellous bone that results in a bony defect after reduction of articular fragments. Autologous bone grafting is recommended as a standard procedure for filling these voids and supporting the articular fragments.²⁰ In some cases, introduction of locked plates and bone substitutes has reduced the need for autologous bone grafting.^{41,45}

Fixation to the diaphysis

After the reconstruction of the articular surface is completed, the joint block must now be reduced and fixed to the tibial shaft to restore length, rotation and axial alignment. The use of minimally invasive plate fixation at this stage may allow the surgeon to limit the length of the surgical incision and maximise the preservation of blood supply to the metaphyseal bone and soft tissues. Axial alignment is easily assessed with intraoperative radiograph controls but torsion is best assessed clinically.^{2,5,46}

Fixation of the restored joint block to the diaphysis is usually accomplished with low-profile 3.5(2.7)-mm plates. Use of locking plates has advantages primarily in osteoporotic bone and comminuted, short peri-articular segments, common in pilon fractures. Medial plate positioning

was preferred historically,²⁰ but biomechanical testing showed no differences in stiffness in compression and torsion between anterolateral and medial locking plate constructs.⁴⁷ The choice between medial or anterolateral plates should be determined mainly by the soft-tissue condition and failure mode of the fracture configuration (Figs 7 and 8).

Wound closure

Excessive tension of skin during the wound closure should be avoided. If this is impossible, a vacuum assisted closure-therapy device can be applied temporarily on the open wound with subsequent secondary closure a few days later. If the wound edges still cannot be approximated, the use of skin grafts or local or even free vascularised flaps should be considered.^{15,24}

Results of ORIF

ORIF remains the procedure of choice for treating intra-articular fractures of the distal tibia. Reported results have improved during the last decades due to a better understanding of the role of soft tissues in these fractures. The range of wound complications varies from 3% to 14%, with deep infection in the range of 2% to 4.8% and for nonunions 0% to 9%.^{5,35,36,39,41}

Intramedullary nailing

Results of medullary nailing of pilon fractures (43-C1 and 43-C2) are described in only one article with only a small number of cases. After closed reduction of the articular fractures and independent screw fixation under radiological control, the reconstructed joint block was fixed to the shaft with the nail. In 23 patients, the authors reported one nonunion, two deep infections and no malalignments.²⁸

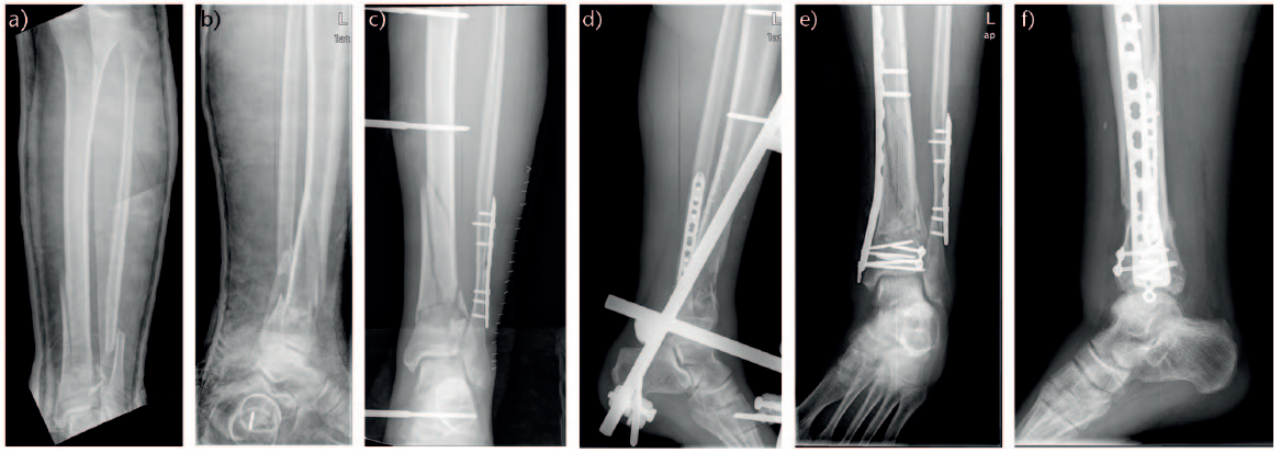


Fig. 8 Patient D, 46-years-old. a, b) Skiing injury. c, d) Initial fibular fixation and external fixation on the medial side. e, f) Definitive fixation on day 12 - small anterolateral approach for reduction and fixation of anterolateral fragment and minimally invasive plate osteosynthesis of the tibia with pre-contoured medial plate.

External fixation as definitive treatment

In cases of severe soft-tissue injuries with anticipated prolonged healing time, external fixation may be considered as a definitive treatment option. This treatment option is also widespread in countries with limited resources and high risks with open surgery.

The use of bridging external fixation has been shown to be accompanied by a high level of long-term complications, including nonunion in about 7% and malunion in up to 13.5%. Some authors have postulated that the use of bridging external fixation as a definitive treatment is one of the predictive factors of poor result.^{12,48}

Thin-wire fixation as hybrid fixation or Ilizarov frame fixation have some advantages over joint-bridging fixation. They may be applied, in selected cases, in combination with limited open or closed internal fixation directly in the acute setting as a one-stage treatment without waiting time for the soft-tissue insult to resolve. Wound complications are less frequent, but pin-track infection becomes the main problem and occurs in up to 37% of cases. The rate of malunion is lower than in joint-bridging fixation and reaches 5.7%. Another issue is the occurrence of axial deformity within the first weeks after frame removal that may be attributed to an injudicious estimate of fracture healing.⁴⁹

Functional results and prognosis

Despite advancements in the treatment of intra-articular distal tibial fractures, about 25% to 50% of surgically treated patients develop signs of post-traumatic arthritis within several years of the injury. Patients with intra-articular distal tibial fractures have significantly lower

Short Form-36 physical function and role scores⁵⁰ compared with the general age-matched population.^{51,52}

The treatment of intra-articular distal tibial fractures (pilon fractures) remains challenging for orthopaedic surgeons. Complex fracture anatomy and delicate soft tissues in the region make surgical treatment risky and complicated. As in other articular fractures, anatomical reconstruction of the joint surface, stable fixation of the articular fragments as well as respect for the soft tissues with early functional aftercare are needed to maximise good results.

Staged treatment of these injuries allows soft tissues to recover from the initial injury and makes subsequent surgical treatment safer. Other improvements are associated with precise pre-operative diagnostics (CT) and careful planning of surgical approaches according to the fracture morphology. Atraumatic soft-tissue handling and the use of modern fixation techniques for the metaphyseal component (MIPO) further facilitate healing. Last, but not least, improvements in implant design (low-profile locking plates) also play a significant role in the treatment of these severe fractures.

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