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Tibial plateau fracture: anatomy, diagnosis and management

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Abstract

Tibial plateau fractures are peri-articular knee fractures of the proximal tibia. The presentation is dependent on the mechanism of injury. The tibial plateau is the bony platform of the distal half of the knee joint, and is made up of a medial and lateral condyle separated by the intercondylar eminence.

The presentation of tibial plateau fractures can vary greatly as a result of the bimodal mechanism of injury and patient characteristics. The patient should be assessed for life- and limb-threatening injuries in accordance with British Orthopaedic Association Standards of Trauma guidelines. Imaging is undertaken to understand configuration of the fracture, which is classified by the Schatzker classification. Definitive management of the fracture depends on the severity, ranging from conservative to surgical management. Surgery is required for more severe tibial plateau fractures to restore articular congruity, mechanical alignment, ligamentous stability and to permit early mobilisation.

Medium-term functional outcome after tibial plateau fractures is generally excellent when anatomy and stability is restored. At least half of patients return to their original level of physical activity. Surgical management of tibial plateau fractures is not without complication. Risk factors include postoperative arthritis, bicondylar and comminuted fractures, meniscal removal, instability, malalignment and articular incongruity.

Tibial plateau fractures account for 1% of all fractures, and typically occur either as a fragility fracture or secondary to a high-energy impact. These latter injuries are associated with extensive soft tissue injury, life- and limb-threatening complications and long-term sequelae. While outcomes are generally good, severe injuries are at higher risk of infection and post-traumatic arthritis requiring knee arthroplasty. This article considers the anatomy, diagnosis and evidence-based management strategies for tibial plateau fracture.

Key words: Anatomy; Diagnosis; Management; Tibial plateau fracture

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Introduction

Tibial plateau fractures are peri-articular knee fractures of the proximal tibia. They comprise approximately 8% of all fractures among those aged over 55 years (Rozell et al, 2016). The presentation is dependent on the mechanism of injury and is usually from either very high-energy trauma (typically younger men) or low=energy trauma (typically older women, as a fragility fracture) (Krause et al, 2016). This article considers the anatomy, diagnosis and evidence-based management strategies for tibial plateau fracture.

Important anatomy

The tibial plateau is the bony articular surface of the proximal tibia that forms the distal half of the knee joint. It consists of a medial and lateral condyle separated by the intercondylar eminence. Geometrically, it has a coronal and sagittal slope to allow movement in six degrees of freedom. The lateral condyle is higher as a result of its convex articular surface while the medial condyle is lower as a result of its concave shape (Masouros et al, 2010). In the coronal plane, the difference in height between the two condyles creates a 3° varus slope. In the sagittal plane, the tibial plateau has up to a 9° posterior slope. Surgical reconstruction of this alignment is critical to restore kinematic loading, ligament tension and prevent knee recurvatum.

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The traumatic event resulting in a tibial plateau fracture may also injure the surrounding soft tissue structures, best identified on magnetic resonance imaging. The menisci may be injured in approximately 60–75% of patients (predominantly contusions and peripheral tears, most commonly of the lateral meniscus), while the cruciate ligaments may be injured in 20–50% (most commonly avulsions or partial tears of the anterior cruciate ligament) (Chang et al, 2018). A high index of suspicion for these concurrent soft tissue injuries is required when the tibial plateau is depressed greater than 10 mm.

The neurovascular bundle (popliteal artery and vein and their genicular branches; and the sciatic nerve and its tibial and common fibular branches) passes posterior to the knee. These structures are at risk of injury with high-energy trauma, fracture-dislocations, and significant bony comminution leading to neurological compromise and limb ischaemia (Masouros et al, 2010). Compartment syndrome has a reported incidence of ~10–40% following tibial plateau fracture (Gamulin et al, 2017), with increased risk associated with higher energy trauma, higher comminution, fracture-dislocations, male sex and younger patients (Gamulin et al, 2017; Marchand et al, 2020).

Initial presentation and management

The presentation of tibial plateau fractures can vary greatly because of the bimodal mechanism of injury and patient characteristics. After a systematic assessment and management of life-threatening injuries, the injured limb should be splinted and assessed for neurovascular compromise and open fractures. Soft tissue compartments of the leg should be serially examined for at least 24 hours after the time of injury (British Orthopaedic Association, 2017), and intra-compartment manometry may be used in the obtunded patient. During initial management, most tibial plateau fractures should be splinted in an above-knee cast. Fasciotomies of the four compartments of the leg should be performed when there is suspicion of compartment syndrome, with incisions incorporating open wounds when possible (British Orthopaedic Association, 2016).

Open tibial plateau fractures should be photographed and dressed with sterile saline gauze before splinting. While macroscopic debris should be removed from the wound, low-pressure saline irrigation should be performed at the time of surgery. Prophylactic intravenous antibiotics and protection against tetanus should be administered followed by immediate referral to a specialist centre for combined orthopaedic and plastic surgery input (British Orthopaedic Association, 2017). Open fractures may require a temporary spanning knee external fixator. This enables ligamentotaxis (distraction of the fracture using tension) to maximise the value of computed tomography imaging and facilitate safe transfer of the patient to a tertiary centre.

Regardless of whether the tibial plateau fracture is an open or closed injury, the neurovascular status of the limb needs to be routinely assessed. Sensation to the dorsum of the foot and the ability to dorsiflex the ankle indicates peroneal nerve function; sensation to the sole of the foot, and the ability to plantarflex the ankle and flex the toes indicates tibial nerve function (Berkson and Virkus, 2006). Dorsalis pedis and posterior tibial artery pulses should be palpated and marked. Ankle-brachial indices should be obtained if there is any question of a vascular injury, and a result of <0.9 or concerning clinical signs should prompt urgent angiography. Once the patient is stabilised, a thorough history and examination should be undertaken to understand the mechanism of injury and underlying comorbidities. Pain relief should be adjusted based on the severity of the pain, complexity of the fracture and age of the patient following standard escalations in pain management options (National Institute for Health and Care Excellence, 2016).

Low-energy trauma is typically associated with fractures in the lower density bone of the lateral plateau (Berkson and Virkus, 2006), although this pattern is less predictable in patients with osteoporosis (Krause et al, 2016). High energy trauma with a valgus impact may also result in isolated lateral plateau fractures (Berkson and Virkus, 2006). These are associated with injury to menisci and structures in the posterolateral corner, resulting in significant mechanical instability (Berkson and Virkus, 2006). It is difficult to assess the stability of the knee in the acute setting as a result of pain and haemarthrosis. Stability should therefore be routinely assessed before surgical fixation when the patient is under

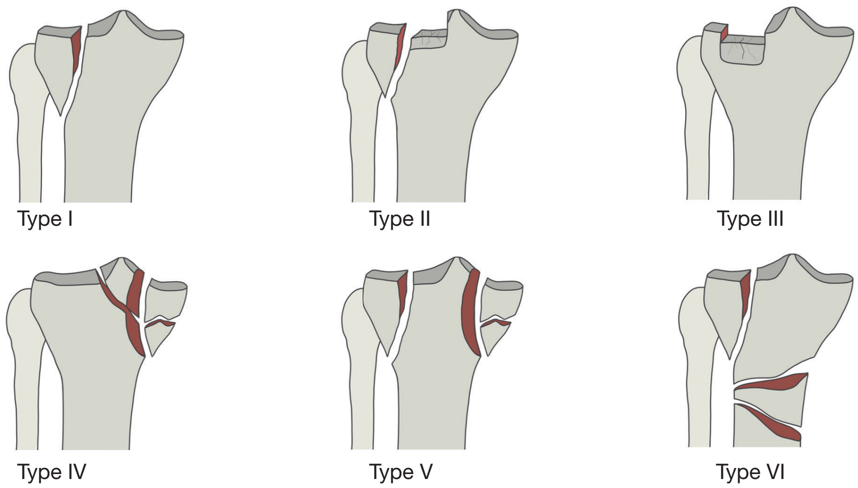

Figure 1. Schematic illustration of the Schatzker classification of tibial plateau fractures.

anaesthesia. More than a 10° increase in varus or valgus alignment in comparison to a normal contralateral knee is indicative of mediolateral instability from collateral ligament injury (Dirschl and Dawson, 2004), while anterior or posterior translations of the tibia on the femur are indicative of cruciate ligament injury.

Imaging

Non-weight-bearing plain radiographs of the knee in the anterior–posterior and lateral views should be obtained for all patients with suspected tibial plateau fractures. These assist with the initial diagnosis, classification of the fracture pattern (Figure 1) and give an indication about the forces involved. However, radiographs may be misleading – particularly in the assessment of patients with osteoporosis, those with fractures in the coronal plane or those with concomitant soft tissue injuries (Dirschl and Dawson, 2004; Kfuri and Schatzker, 2018). Therefore, computed tomography imaging (including three-dimensional reconstruction) is recommended before surgery to determine:

1. The principal plane of the fracture (typically sagittal or coronal)
2. The affected segments (delineated by the lateral and medial plateaus and a horizontal equator between the attachments of the fibular and superficial medial collateral ligaments)
3. The exit point of the fracture distally.

These characteristics determine the surgical approach and placement of hardware (Kfuri and Schatzker, 2018). In addition, magnetic resonance imaging can further determine the need for ligamentous or meniscal repair; this is usually performed in the days and weeks after the initial bony fixation (Berkson and Virkus, 2006; Kfuri and Schatzker, 2018).

Radiographic classification of tibial plateau fractures

The majority of tibial plateau fractures are isolated fractures to the lateral tibial plateau, usually secondary to a valgus-producing force. Medial tibial plateau fractures are a result of a varus-producing force. They are less common, perhaps as the medial plateau is of a higher bone density and anatomically lower than the lateral side. An axial compressive force causes bicondylar fractures, while a combination of these forces at high energy results in more comminution and soft tissue trauma.

The Schatzker classification (Figure 1) is commonly used to describe tibial plateau fractures. It defines the bony injury by the presence of a sagittal split, a depressed articular segment, the presence or absence of a medial plateau fracture, and whether the tibial plateau is attached to the tibial shaft (Schatzker, 1974; Zura et al, 2007). Type II fractures (a sagittal split in the lateral plateau with depression of the joint line) are most associated with soft tissue injuries, most commonly to the lateral meniscus and posterolateral corner structures.

Schatzker type III fractures (a pure depression of the joint line in the lateral plateau) are typically seen in older patients, resulting from a valgus force causing the femoral condyle to impact into osteoporotic bone. Schatzker type IV fractures (a medial plateau split from the articular surface which exits out of the medial metaphysis) typically require more energy to occur. They can be associated with knee dislocation and concomitant soft tissue injury, as the femur can translate anteriorly along the displaced medial tibial condyle. Schatzker type VI fractures (complex plateau fractures with a transverse subcondylar fracture) are also high energy injuries which result in a dissociation of the metaphysis from the diaphysis. Type IV–VI fractures are most frequently associated with vascular injury and compartment syndrome, thus a high index of suspicion is required when these injuries are noted on radiography (Marchand et al, 2020). The Schatzker classification is summarised in Table 1.

Classification of tibial plateau fractures is useful for surgical planning: to plan the placement of fixation plates, to recognise comminution and consider external fixation. Approximately 10% of tibial plateau fractures do not fit the Schatzker classification – particularly high-energy injuries with fracture lines in the coronal plane and compression or avulsion fractures to the plateau rim (Molenaars et al, 2015). Such fractures, along with complex, multiplanar fractures, may be better appreciated with the use of three-dimensional computed tomography imaging. This can better identify the principal fracture plane(s) and subdivide areas of instability with the use of an anatomical equator (Kfuri and Schatzker, 2018).

Management of tibial plateau fractures

Conservative management

Conservative management may be suitable for non-displaced Schatzker type I fractures, non-ambulatory patients, those with low functional demands or patients with existing severe osteoarthritis for whom delayed complex joint replacement arthroplasty is preferred over immediate open reduction and internal fixation. This entails a hinged knee brace, physiotherapy, restricted weight-bearing status and staged increases in range of motion (Mthethwa and Chikate, 2018). For non-compliant patients, a long leg cast may be more appropriate than a brace, although frequent skin checks are required to check for skin breakdown (Rozell et al, 2016).

Surgical management

Surgery for tibial plateau fractures is required to restore articular congruity, mechanical alignment and ligamentous stability, and to permit early mobilisation (Mthethwa and Chikate, 2018). The indications for surgical fixation of a tibial plateau fracture are summarised in Table 2. The anterolateral surgical approach is used for most tibial plateau fractures. It requires a curvilinear incision over Gerdy's tubercle and lateral to the patellar tendon.

Table 1. Schatzker classification of tibial plateau fractures

Schatzker classification	Description
I	Pure split of the lateral plateau
II	Type I and depression of the remaining lateral plateau
III	Central depression of the lateral plateau with no split
IV	Wedge fracture of the medial plateau A. Depression fracture of the medial plateau B. Both can be combined with fracturing of the tibial spine
V	Fracturing of both the lateral plateau and medial plateau with the metaphysis maintaining contact with the diaphysis May be associated with fracturing of the intercondylar eminence
VI	Dissociation of the metaphysis from the diaphysis with a varying degree of communication between the condyles and the articular surface

From Schatzker (1974)

Elevating the tibialis anterior muscle gives access to the proximal aspect of the lateral tibia (Figure 2). Complex tibial plateau fractures may require a posteromedial approach alone or in combination with the anterolateral approach. A longitudinal incision down the posteromedial tibia is required before the space between the hamstring tendons (pes anserinus) and the medial head of the gastrocnemius is developed for access to the bone.

Simple, low-energy injuries of the lateral tibial plateau, without significant soft tissue damage or neurovascular compromise, can be managed definitively with single-stage open reduction and internal fixation. This is typically performed when swelling has settled (and the skin is wrinkling) via an anterolateral approach. The joint can be reduced under direct vision through a sub-meniscal arthrotomy (Buckley et al, 2019).

For displaced Schatzker type I fractures in patients with high functional demands and good bone quality, open reduction and internal fixation using only screws is adequate for fixation and permits early mobilisation. Type II and III fractures are managed in a similar fashion: split fractures are reduced (for type II fractures), the depressed segment of the lateral plateau is elevated, and the resulting metaphyseal void is filled with a bone substitute before the construct is typically held with a fixed-angle pre-contoured plate (Figure 3) (Mthethwa and Chikate, 2018). In osteoporotic bone, locking plates are preferred as they sit proud of the tibial shaft, and do not compress the periosteal blood supply (Berkson and Virkus, 2006). Schatzker type IV fractures involve the medial plateau and, when minimally

Table 2. Indications for fixation of tibial plateau fractures
Lateral plateau fracture with: >3 mm articular step-off, >5 mm condylar widening, or varus or valgus instability
Displaced medial plateau fracture
Bicondylar fracture
Neurovascular compromise
Open fracture

From Mthethwa and Chikate (2018)

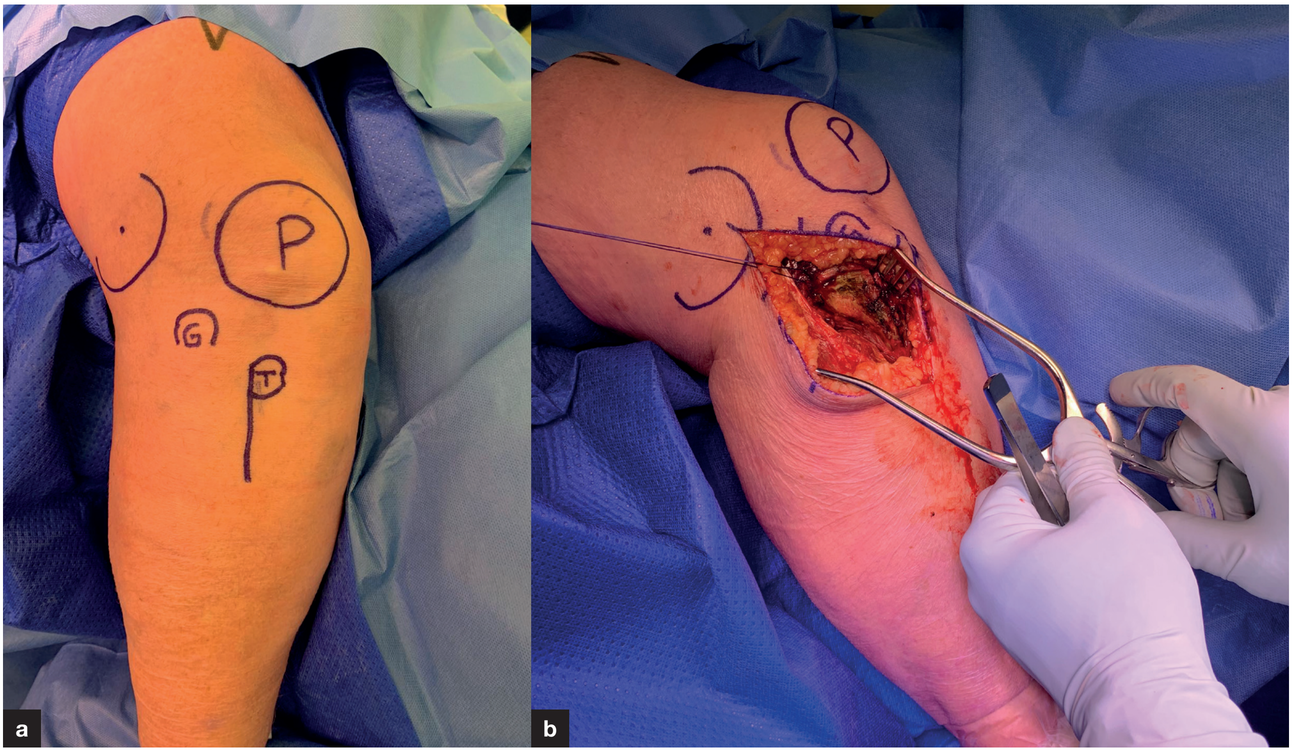

Figure 2. a. Surface anatomy and (b) anterolateral surgical approach for Schatzker type II tibial plateau fracture. G=Gerdy's tubercle; P = patella; T = tibial tubercle with line below along tibial crest.

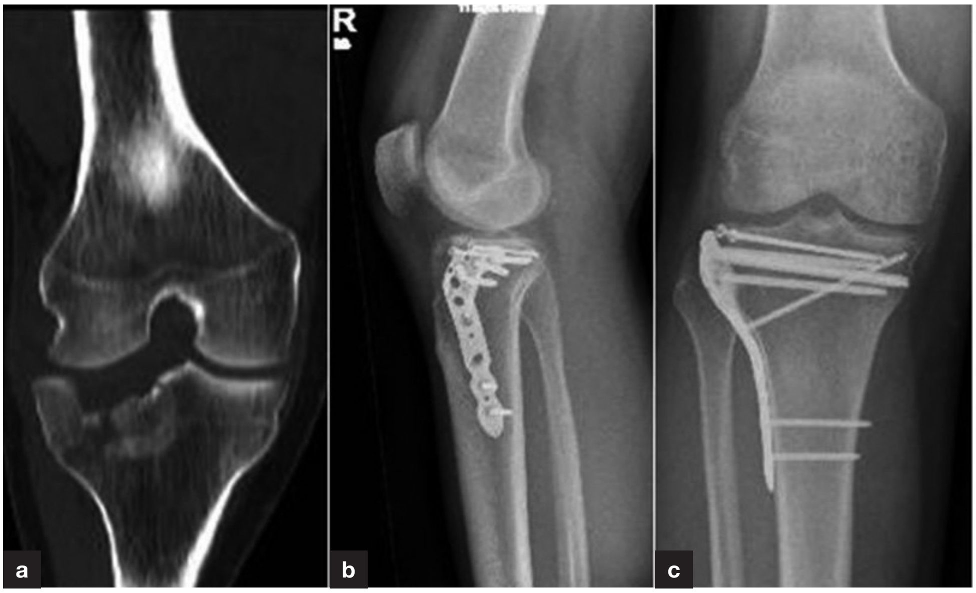

Figure 3. a. Preoperative anterior–posterior radiograph and (b) postoperative lateral and (c) anterior–posterior radiographs following open reduction and internal fixation of a Schatzker type III tibial plateau fracture using a pre-contoured fixed-angle locking plate and subchondral raft screws.

displaced, can be safely fixed using a single, laterally placed locking plate. However, those fractures with displacement, comminution or a posterior fragment require a separate posteromedial approach and plating (Berkson and Virkus, 2006).

High impact bicondylar injuries, as seen in Schatzker type V and VI fractures, often require a multi-stage, damage control approach as a result of the associated soft tissue injuries or neurovascular compromise. A temporary spanning external fixation may be emergently applied to obtain stability, ensuring pain relief and reduction of the fracture via ligamentotaxis, before the limb is scanned using computed tomography. Definitive surgical fixation is delayed until the soft tissue envelope is healthy enough to withstand incisional trauma (Zura et al, 2007). This may include bicondylar plating as well as a posteriorly placed buttress plate for fractures in the coronal plane.

The majority of patients with tibial plateau fractures will have associated ligamentous or meniscal injuries identifiable on magnetic resonance imaging, but most of these injuries do not lead to long-term functional limitation. Therefore, operative treatment is reserved for those with instability after bony fixation (Warner et al, 2018). The medial collateral ligament can be repaired or reconstructed at first presentation if there is persistent and significant valgus instability on physical examination after open reduction and internal fixation. A torn lateral meniscus is easily accessed and repaired via a submeniscal arthrotomy after the anterolateral approach (Buckley et al, 2019). The management of significant varus and rotatory instability – indicating injury to structures in the posterolateral corner including the lateral collateral ligament, popliteus and biceps femoris tendon – is complex and typically addressed in a second operation (Levy et al, 2011). Similarly, cruciate ligament injuries should be addressed after bony healing to reduce the incidence of arthrofibrosis (Kfuri and Schatzker, 2018).

Postoperative protocols vary from surgeon to surgeon, with some opting for immediate touch weight-bearing or even full weight-bearing (Mthethwa and Chikate, 2018). In the setting of high-energy trauma, some surgeons prescribe non-weight-bearing for up to 6 weeks (Zura et al, 2007). Early passive range of motion is essential to minimise the risk of stiffness and may include routine use of a continuous passive motion machine (Mthethwa and Chikate, 2018).

Outcomes and complications

Medium-term functional outcome after tibial plateau fractures is generally excellent when anatomy and stability is restored. At least half of patients who were participating in a recreational sport before their injury can envisage returning to it, although the chance is reduced in those

Key points

- The presentation of tibial plateau fractures is dependent on the mechanism of injury. These usually occur as a result of either very high-energy trauma (typically younger men) or low-energy trauma (typically older women, as a fragility fracture).
- During the initial management, life- and limb-threatening injuries should be excluded. Soft tissue compartments of the leg should be examined fastidiously for at least the first 24 hours after the injury, with particular attention paid to the neurovascular status of the distal limb.
- The Schatzker classification should be consulted to classify tibial plateau fractures with the use of three-dimensional computed tomography imaging for complex, multiplanar fractures.
- The surgical fixation of a tibial plateau fracture is dependent on the severity of the fracture and requires surgical planning. The medium-term functional outcome after tibial plateau fractures is generally excellent when anatomy and stability is restored.
- Involvement of the multidisciplinary team is imperative to optimise the patient's recovery.

with higher-energy fracture patterns or open fractures, and male patients (Kugelman et al, 2017). At 5 years postoperatively, approximately one-third of patients may develop post-traumatic arthritis. Risk factors include bicondylar and comminuted fractures, whether the meniscus was removed (rather than repaired), residual instability, malalignment >5° from normal, and inadequate reduction (Barei et al, 2006; Rademakers et al, 2007; Wasserstein et al, 2014).

Approximately 6% of patients who undergo surgery for tibial plateau fractures have deep surgical site infection (Norris et al, 2019). This is more common in smokers, people who are obese, those with open fractures and those for whom fasciotomy was required to treat concurrent compartment syndrome (Dinçel et al, 2018).

Other complications after tibial plateau fractures include contractures and stiffness secondary to arthrofibrosis, septic arthritis, and persistent neurovascular injury from the index injury or as a result of surgery.

Conclusions

Tibial plateau fractures typically occur either as a fragility fracture or secondary to a high energy impact. The latter are associated with extensive soft tissue injury, life- and limb-threatening complications and long-term sequelae. Plain radiography and computed tomography are necessary for diagnosis and surgical planning, while magnetic resonance imaging can identify ligamentous and meniscal injury which contributes to knee instability. Initial management can include temporary external fixation, while definitive surgery – to restore joint congruity, limb alignment and knee stability – most commonly involves open reduction and fixation with fixed-angle plates with meniscal repair if necessary; and a further procedure to repair ligaments. While outcomes are generally good, patients with severe injuries are at higher risk of infection and post-traumatic arthritis requiring knee arthroplasty.

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Conflicts of interest

The authors declare no conflicts of interest.

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Curriculum checklist

This article addresses the following requirements from the general internal medicine training curriculum:

- Managing an acute specialty-related take
- Managing medical problems in patients in other specialties and special cases
- Managing a multidisciplinary team including effective discharge planning.

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