8 Complex Fractures of the Proximal Tibia

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8.1 Introduction

Complex fractures of the proximal tibia are difficult to treat due to the comminution and associated injuries, such as meniscal and ligamentous tears, lesions of the peroneal nerve or the popliteal vessels, and severe skin damage. Preoperative planning is essential and the state of the soft tissue marks the time of surgery. These fractures have been associated with high complication rates. Recognizing and managing the soft tissue components of tibial plateau injuries may be the most important aspects of the treatment and ultimate outcome. The goals of treatment are the decompression and preservation of the soft tissue, reconstruction of the articular surfaces, restitution of normal mechanical axis, and early mobilization.

8.2 Classification

Complex tibial plateau fractures are usually described as Schatzker et al. [1] types IV, V, and VI or as a Type C injury when using the AO/Orthopaedic Trauma Association classification [2]. Tibial plateau fractures belong to the segment number 41 of the AO/Orthopaedic Trauma Association classification.

Type C fractures affect both condyles with articular and metaphyseal strokes:

- C-1: simple articular and metaphyseal fracture
- C-2: simple articular and complex metaphyseal fracture
- C-3: complex articular and metaphyseal fracture

Schatzker classification is perhaps the most used today and divides plateau fractures into two groups with three types in each group. The second group consists of high-energy fractures:

- IV fracture of the medial condyle. It is rare but is frequently accompanied by neurovascular injuries, compartment syndrome, and/or ligament lesion. The medial condyle fractures differ from lateral condyle in which more energy is required to produce them.
- V bicondylar fracture without metaphyseal involvement.
- VI fracture of both condyles and metaphyseal.

Schatzker and the AO/OTA systems are based on two-dimensional classification systems. Some fracture patterns are incompletely classified, such as posterior shearing fractures of the tibial plateau. A new classification improves the understanding of more complex fracture patterns. The three-column classification is based on the CT (computed tomography) scan and on the three-dimensional (3-D) reconstruction as a supplement to the Schatzker classification. Three-column classification [3] takes a transverse view and the

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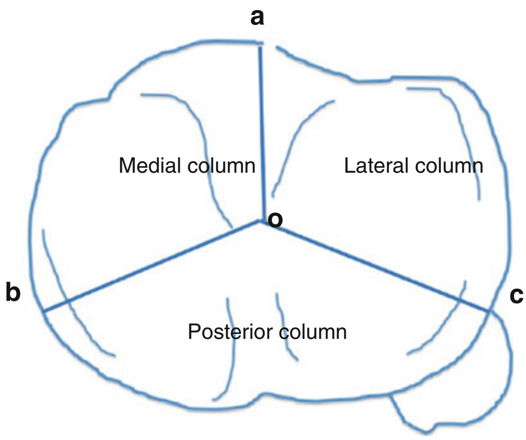

Fig. 8.1 Three-column classification of fractures of the proximal tibia. *Point A* is the anterior tibial tuberosity. *Point O* is the midpoint of the two tibial spines. *Point C* is the most anterior point of the fibular head and *point B* represents the medial–posterior ridge of the tibial plateau. The tibial plateau is divided into three parts which represent the lateral column, medial column, and posterior column, respectively

tibial plateau is divided into three areas, which are defined as the lateral column, the medial column, and the posterior column (Fig. 8.1). The classification can help surgeons for the diagnosis and preoperative planning providing a better approach and fixation methods.

8.3 Clinical Assessment

Patients who have sustained a high-energy injury require a special evaluation, through advanced trauma life support (ATLS) protocols. First treat injuries that are potentially life threatening, and once stabilized, evaluate orthopedic injuries.

The evaluation and documentation of neurological status, vascular status, and soft tissues is essential in these fractures.

- Neurological examination focuses on the function of the peroneal nerve, which is the most vulnerable in the medial plateau fractures and high-energy fractures and is stretch on their way around the neck of the fibula. The tibial nerve is located in close proximity to the site of injury and also to be evaluated.
- Vascular examination focuses on the popliteal artery, which can be injured by traction, debuting as a thrombosis, or may be sectioned by posteriorly displaced fracture fragments. If pulses are not palpable, use an echo Doppler. If there is any question of vascular injury, ankle–brachial index is obtained. If less than 0.9 or physical examination (capillary refill, color, and skin temperature) findings suggest vascular injury, CT angiography and vascular surgical consultation should be performed (Fig. 8.2).
- The skin is inspected circumferentially. Contusion, blisters, and swelling are common in high-energy fractures. Open lesions should be excluded. We can inject methylene blue into the joint to assess whether there is communication between the joint and skin lacerations. In our center we photograph any injury to the skin. The Gustilo–Anderson et al. [4] classification and Tscherne and Gotzen [5] classification are used for, respectively, open and closed fractures.

Fig. 8.2 Angio-CT of complex fracture of the proximal tibia with stop in the popliteal artery

The knee stability should be evaluated to rule out ligament disruption although this assessment can be difficult preoperatively owing to difficulty differentiating ligamentous from bony instability.

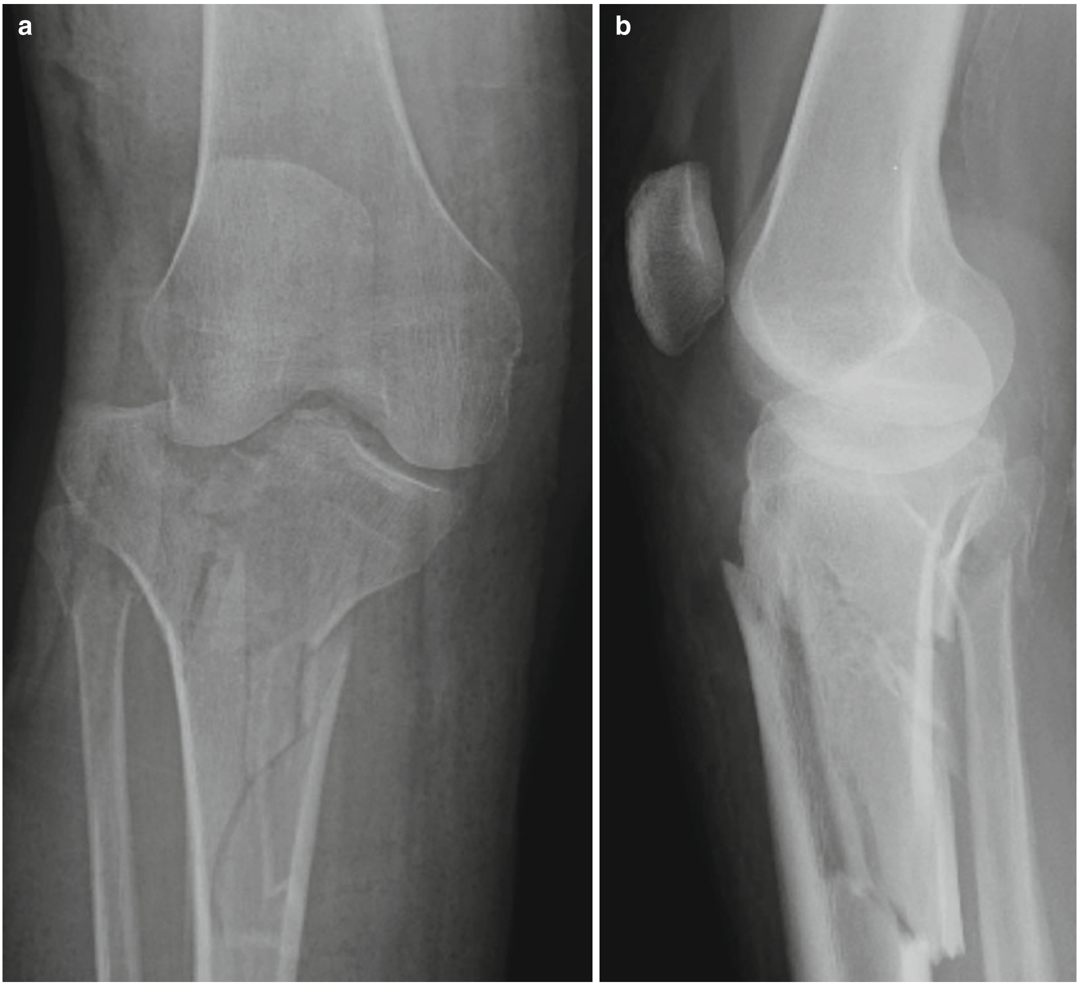

Fig. 8.3 Anteroposterior (**a**) and lateral (**b**) views of a tibial plateau fracture

The examination should be delayed until the time of surgery to prevent the patient's pain and after bone stability. We must also rule out knee dislocation, heightening the importance of a thorough neurovascular examination and the need for preoperative MRI (magnetic resonance imaging).

The compartment syndrome is a terrible complication, diagnosis and early treatment is essential. We must have a high level of clinical suspicion for compartment syndrome in high-energy plateau fractures, especially types V and VI [6]. Measuring the pressure of the compartments (pressures within 30 mmHg of the diastolic blood pressure) can be useful for diagnosis, but the clinical scene is prevalent (6 Ps: pain out of proportion, pain with passive stretch of muscle groups in the leg, pressure, paresthesias, paralysis, and pulselessness). The management must be urgent through fasciotomies of the four leg compartments.

8.4 Radiological Assessment

Standard preoperative radiographic evaluation includes radiographs and CT.

Most high-energy fractures of the tibial plateau are easy to identify in standard anteroposterior (AP) and lateral views of the knee. The AP projection allows us to classify the fracture. The lateral projections provide a better assessment of coronal fractures (Fig. 8.3).

The CT scan is compelling for the precise diagnosis of tibial plateau fractures. Chan et al. [7] demonstrated that taking CT scans in addition to plain radiographs affected fracture classification, and thus the surgical plan, in >25 % of cases.

Fine-cut (2–2.5 mm) and especially three-dimensional reconstruction allows us to know the fracture and to plan surgery and surgical approaches accurately.

The CT scans were performed after bridging external fixation had been applied; this was much more informative for decision-making. If there is suspicion of vascular injury or compartment syndrome, CT angiography must be performed, which is faster and less invasive and has less radiation than arteriography.

The role of MRI in acute fracture management is controversial. High-energy tibial plateau fractures are often accompanied by ligamentous and meniscal tears. There is scant evidence that its routine use impacts on outcomes. Furthermore, incompatible external fixators often preclude the use of MRI with these injuries. The formal role of MRI in these fractures has yet to be defined [8].

8.5 Treatment

8.5.1 Timing of Treatment

Open fractures with compartment syndrome and vascular injury must be treated immediately. However, patients with multiple injuries, especially those with head, thoracic, or abdominal injuries, must be stabilized provisionally using an external fixator (damage control orthopedics) until the general conditions improve (window of opportunity, 5–10 days after injury). On the other hand, closed fractures with severe damage of soft tissues should not undergo open reduction and internal fixation immediately; in such cases we must do a sequential treatment [9]. This sequential treatment algorithm has evolved from that used for tibial plafond fractures. Egol et al. [10] report low rate (5 %) of deep wound infection in 57 high-energy tibial plateau fractures treated with this protocol.

First, we must stabilize the fracture provisionally by means of an external fixator performing indirect reduction via ligamentotaxis and restoration of limb length. In this way we await resolution of soft tissue injury and relief of pain (Fig. 8.4).

The external fixator spans the knee joint with two femoral pins, proximal to the suprapatellar pouch, and two tibial pins. Tibial pins (5 × 170 mm) must be implanted in the anteromedial surface, nearly perpendicular to the bone surface. Pins must be placed remote from anticipated skin incisions and anticipated implants. Femoral pins (5 × 170 0 200 mm) can be placed anteriorly, laterally, or anterolaterally. Lateral pins avoid loss of knee motion due to scarring of the quadriceps, but the frame is mechanically inferior to that of anterior pins. The stability can improve by stacking the frame. The connector clamps must be placed outside of fracture to allow images of the reduced fracture without interference.

8.5.2 Definitive Treatment

Nonoperative treatment for these high-energy injuries has a role in a medically decompensated patient only. These injuries have poor outcomes with nonoperative treatment [8].

The definitive internal fixation in close fractures should be performed when the soft tissues are improved (normally in 2 or 3 weeks). This can be evaluated by the decrease of inflammation, the perimeter of the leg, and the return of the ability of the skin to wrinkle.

The new plates have afforded more biological approaches to these fractures. The use of fixed-angle locking plates avoids periosteal dissection. Locking plates can be inserted submuscularly through a limited incision with percutaneously placed locking screws to minimize soft tissue injury. Indications for locking plates are not fully developed; the cost–benefit ratio should be weighed in each case [11].

8.5.2.1 Medial Plateau Fractures

These fractures affect the medial tibial plateau. There is high frequency of soft tissue, ligament, and neurovascular injuries associated with these fractures. Surgical treatment is preferred in most cases through a posteromedial approach. The medial incision started 1 cm posterior to the posteromedial edge of the tibia, and the proximal extension parallel to the pes anserinus tendons

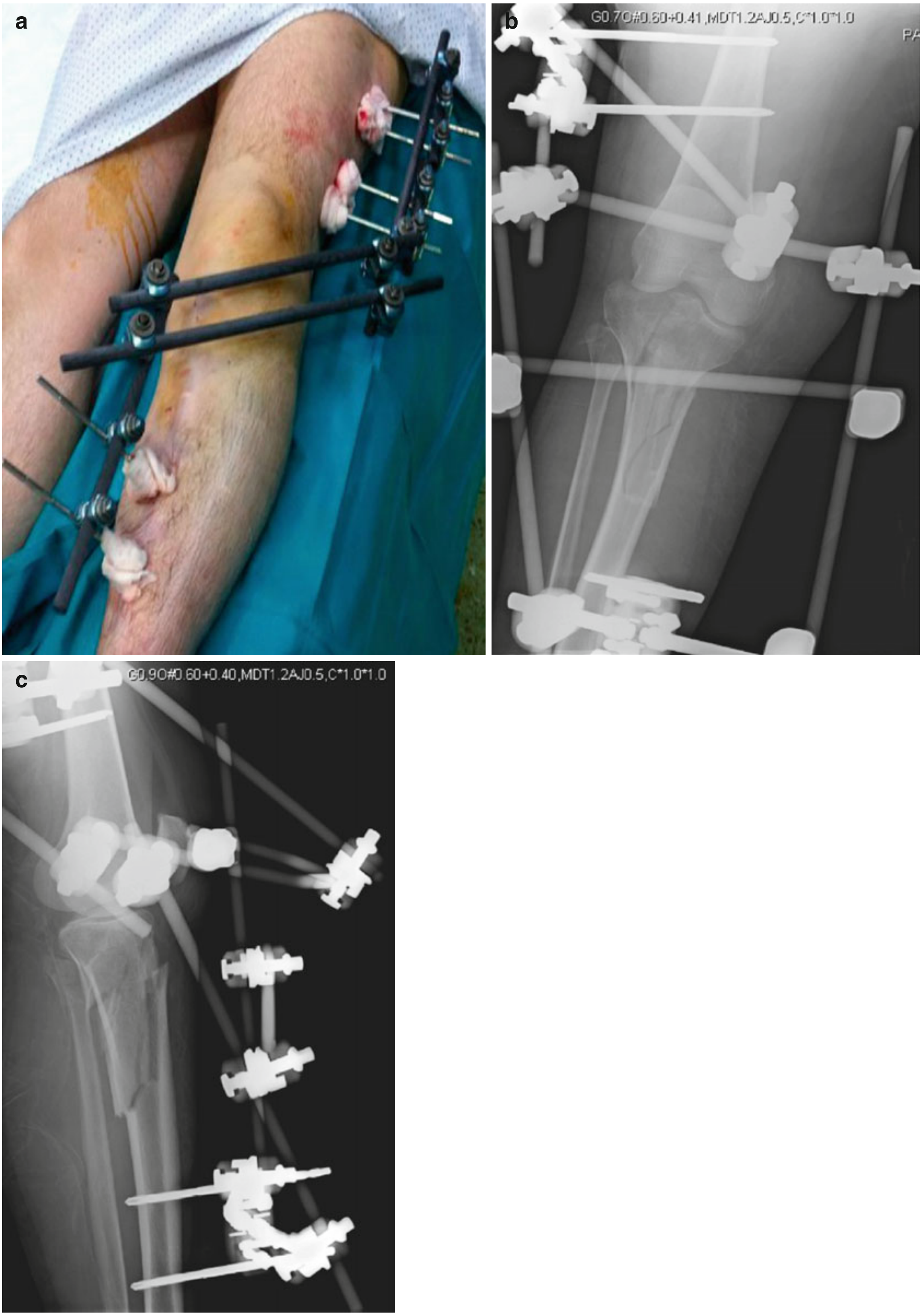

Fig. 8.4 Clinical view of a temporary spanning external fixator (**a**). In (**b**, **c**) indirect reduction via ligamentotaxis and restoration of limb length can be seen

should be as posterior as possible in order to reduce the posterior fragment. The pes tendons can be retracted or cut and repaired at the end of the procedure. The medial gastrocnemius is dissected from the tibia. A buttress plate is necessary to improve stability after open reduction (Fig. 8.5).

The repair of associated soft tissue injuries is determined on an individual basis. Meniscal injuries should be repaired whenever possible. Osseous avulsion of ligaments can be directly repaired with sutures or screws. Further ligament reconstructions are best delayed until bone healing has occurred and knee range of motion has returned [11].

8.5.2.2 Bicondylar Tibial Plateau Fractures

These fractures affect both lateral and medial tibial plateaus. The preferred treatment of these fractures is open reduction and internal fixation through two approaches: anterolateral and posteromedial. The use of the two-incision approach offers the benefits of direct visualization, reduction, and stabilization of medial and lateral articular and metaphyseal fragments while minimizing extraneous soft tissue dissection and potentially decreasing wound complications and deep sepsis previously reported with a single anterior incision [12, 13].

Anatomical reduction to restore the joint surface and the limb alignment is mandatory. Isolated lateral plating of bicondylar tibial plateau fractures using conventional plates is frequently insufficient in maintaining axial alignment [14]. In a lot of high-energy fractures the medial fragment, which is comminuted or not reducible. Then, the screws from a lateral plate cannot engage this fragment. Therefore, separate medial fixation is required. Bilateral dual plating is usually recommended as the definite fixation for this kind of fracture (Fig. 8.6), but may need an additional plate to fix the posterior column. Three-column fixation is a new fixation concept in treating complex tibial plateau fractures, which is especially useful for multiplanar fractures involving the posterior column [3].

Generally, the medial column is approached first using a posteromedial approach. Care must be taken to avoid screw fixation of unreduced lateral fracture fragments. Lou et al. [15] use the “reversed L-shaped” posterior approach to reduce directly and buttress posterior fragments.

The anterolateral approach is used to reduce and fixate the fracture in the lateral column. We identified the tubercle of Gerdy, tibial crest, patella, and fibular head. A longitudinal curvilinear skin incision is centered on the tubercle of Gerdy extending along the lateral femoral epicondyle and extending distally 1 cm lateral to the tibial crest, expose the iliotibial band and anterior compartment fascia and anterior and posterior retraction to expose the proximal tibia. The arthrotomy is performed through a submeniscal approach pass menisco-capsular sutures. More late we develop fracture line, freeing peripheral rim of the fragment like an open book, and tamping-up of the depressed articular fragment. Then, bone void filling with either allograft or autograft. Our opinion is that synthetic graft is superior. The peripherial rim is reduced (book closed), menisco-capsular sutures through the plate and put screws. Locking plates are commonly used for complex periarticular fractures, but its main use is for fixation in osteoporotic bone. A minimum of four locked screws should be used in the proximal and distal segments.

In complex fractures with severe damage of soft tissues, many authors advise the use of hybrid external fixation [16]. The hybrid construction is made with tensile wires and ring in the proximal tibia and threatened pins in the tibial shaft, all of them through percutaneous insertion. The surface reduction can be checked by arthroscopic view. The hybrid external fixation can be combined with internal fixation through percutaneous cannulated screws. This minimally invasive method provides good result because it does not add damage to the injured soft tissues [17].

8.5.2.3 Special Situations

The management of open fractures and high-energy fractures in the tibial plateau with associated compartment syndrome represents a challenge. In both cases, emergency surgery is required. Irrigation, debridement, and appropriate antibiotic or fasciotomy opening the four com-

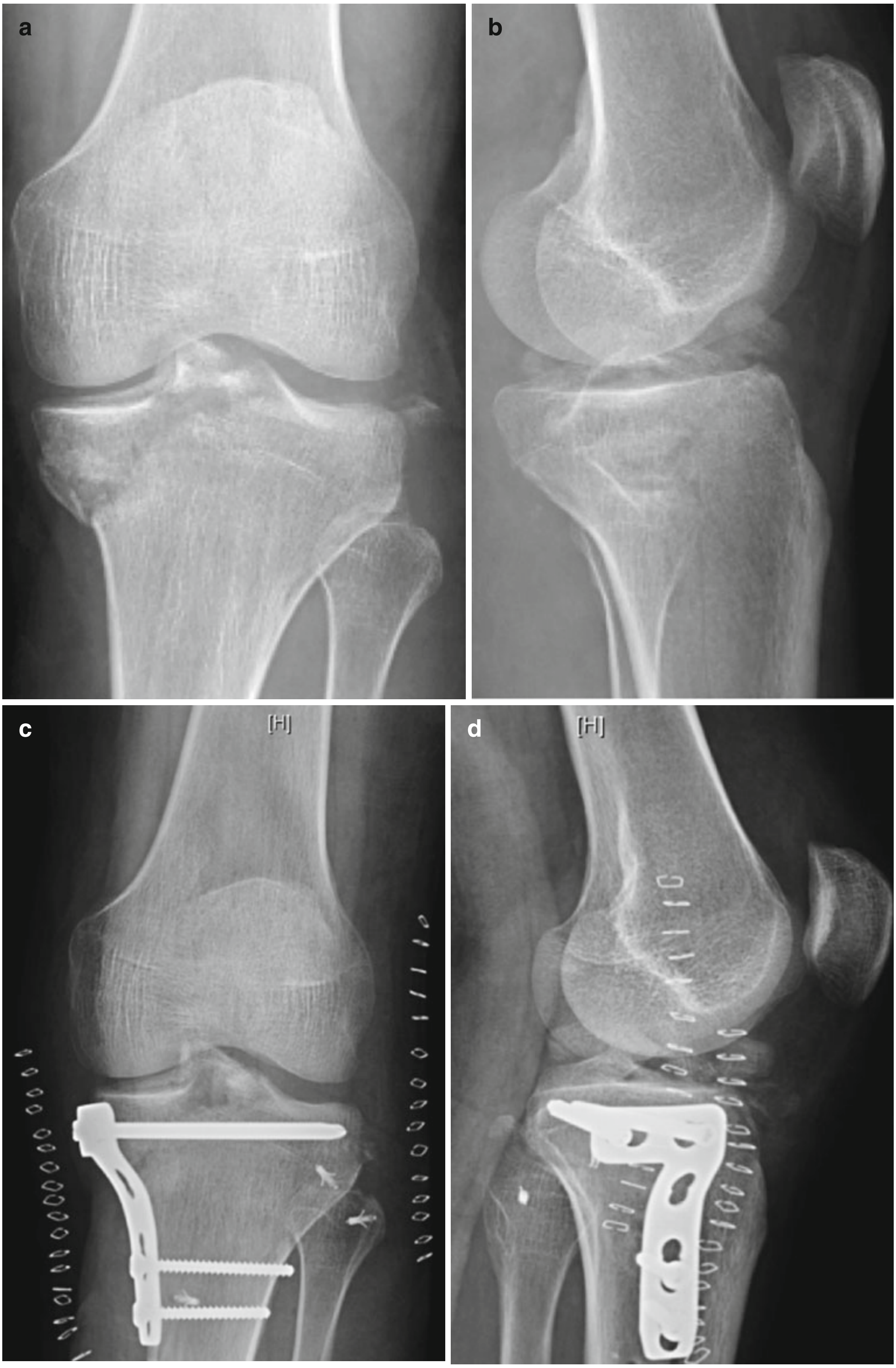

Fig. 8.5 Medial column fracture: anteroposterior (**a**) and lateral (**b**) views. The same fracture with medial osteosynthesis with a plate and lateral avulsion repaired, (**c**, **d**), respectively

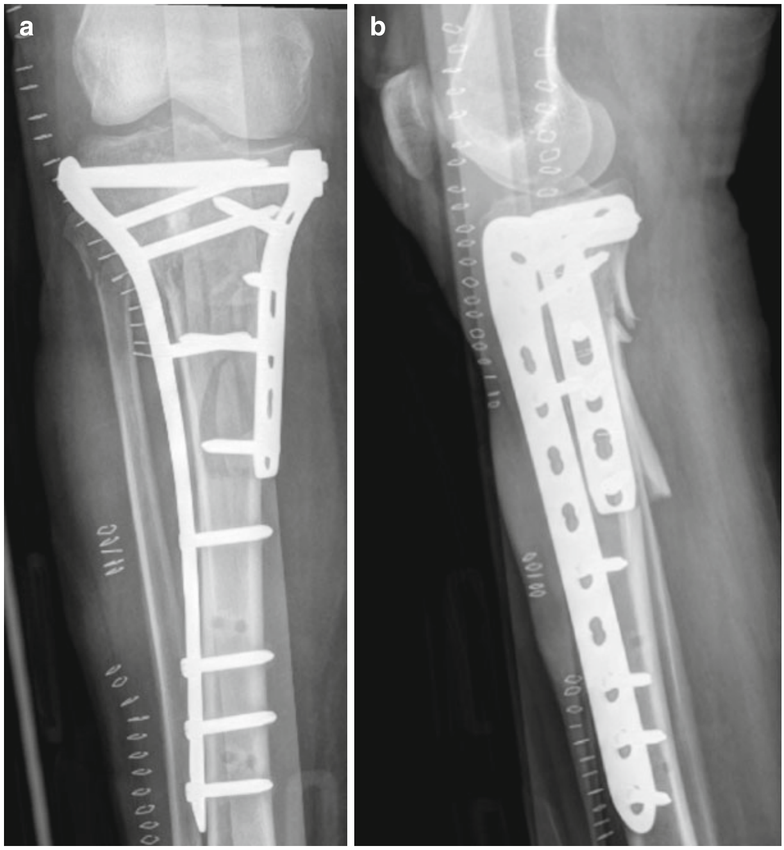

Fig. 8.6 Lateral and medial osteosynthesis plates for Schatzker VI fracture: AP view (**a**) and lateral view (**b**)

partments of the leg is mandatory, respectively. A sequential treatment will be more prudent. This, however, presents an opportunity to carry out early internal fixation. In level 1 trauma center with plastic surgeons, the open fractures can be treated with immediate fixation and early soft tissue coverage [9].

In fractures with suspected injury of the popliteal artery, an angio-CT must be performed. Arterial injury must be repaired immediately; but we must first stabilize the fracture with an external fixator. The artery can be repaired with a bypass using vein graft or prosthesis. It is very important to perform fasciotomy opening the four compartments of the leg after repair.

The repair of associated soft tissue injuries is determined on an individual basis. Meniscal injuries should be repaired whenever possible. Osseous avulsion of ligaments can be directly repaired with sutures or screws. Further ligament reconstructions are best delayed until bone healing has occurred, knee range of motion has returned [11], and hardware has been removed.

8.6 Postoperative Treatment

The patients with closed fractures received intravenous antibiotics for a period of 24–48 h after the surgery. When the fixation is stable, the main goal is to emphasize early motion to avoid stiffness. We use a hinged knee brace only if there is subtle instability. During the first week the patient can do passive motion and then begin on active range of knee motion and isometric quadriceps strengthening. The patient is kept non-weight bearing until 6–12 weeks. During this time, the patient must walk with the help of crutches. Thereafter, weight bearing is advanced based on radiographic evidence of fracture healing.

Conclusions

Complex fractures of the proximal tibia are associated with soft tissue and neurovascular injuries. Appropriate clinical assessment, diagnostic imaging, and management of the soft tissue are the most important aspects. The sequential treatment algorithm with temporary external fixation allows the recovery of soft tissue and improvement of the results. Definitive treatment is aimed at reconstruction of the articular surfaces and restitution of normal mechanical axis. The use of the two-incision approach decreases wound complications and deep sepsis. Minimally invasive techniques and anatomically contoured plates have afforded more biological approaches to these fractures. Bilateral dual plating is usually recommended as the definite fixation for this kind of fracture but may need an additional plate to fix the posterior column.

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