Definitive Fixation of Tibial Plateau Fractures

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KEYWORDS

• Tibial plateau fracture • Operative management • Internal fixation • Outcomes

KEY POINTS

- Always evaluate mechanism of injury and associated energy.
- Rule out neurovascular injury, and have a low threshold and suspicion for compartment syndrome.
- Be aware of soft tissue condition—implementing a staged protocol with external fixator can allow for a more ideal surgical environment.
- Obtain advanced imaging (CT) before definitive treatment to understand the fracture personality.
- Apply surgical approach and fixation strategy to personality of each fracture.
- Never compromise exposure for cosmesis.
- Multiple surgical approaches, even in a staged fashion, may be necessary.

INTRODUCTION

In regards to operative fixation of tibial plateau fractures, classical Arbeitsgemeinschaft für Osteosynthesefragen (AO) teaching emphasized the importance of anatomic articular restoration and stable fixation to allow for early range of knee motion.[1,2] However, early results, secondary to excessive soft tissue stripping and overly rigid fixation, led to undesirable high nonunion rates and failure.[3] However, the paradigm and strategy in the operative treatment of tibial plateau fractures has evolved dramatically in recent years. Nuances in anatomic approaches, advances in implant technology, and an improved respect and understanding for surgical technique and the surrounding soft tissue envelope have allowed for improved short- and long-term results.[4–6]

Tibial plateau fractures occur in all age groups, but generally have a bimodal distribution within a given population occurring in young adults as a result of high-energy trauma, and in the elderly as a result of low-energy injuries. There is a spectrum of injury, with the severity of each fracture dependent on the mechanism of injury, the associated energy, and the quality of the host bone. However, despite the variety in which these fracture patterns can occur, the goals and principles remain the same: restoration of the articular surface and maintenance of the mechanical axis. However, depending on the specific type of fracture pattern, implementing the proper planning, surgical technique, and management can help to maximize clinical outcomes, while avoiding complications.

This article helps the reader achieve those goals by summarizing the pertinent principles, strategies, and techniques for some of the most commonly presenting tibial plateau fractures. This is achieved via a case-based platform in hopes of providing a more individualized approach that can be readily implemented across a wide audience.

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IMPORTANT CONSIDERATIONS BEFORE SURGERY

Arguably, once appropriately indicated, the most important stage of treating tibial plateau fractures occurs before entering the operating room. Preoperative planning, which includes evaluation and decision for surgery, diagnostic and advanced imaging, along with timing and formulation of a surgical plan not only help to achieve a desired clinical result, but aid the surgeon in execution of the procedure.

Surgical planning begins with the initial evaluation and interview. Assessing the mechanism and energy of the sustained injury along with a thorough medical history can provide a general outline of the underlying fracture pattern, and the fixation and management strategy that may ultimately be required. For example, the injury pattern for a 24-year-old man who presents after a high-energy motorcycle crash differs from that of a 78-year-old woman who sustained a low-energy valgus load to the knee while grocery shopping. Coinciding with obtaining a thorough history is a complete physical examination. Neurovascular assessment, including measuring ankle-brachial indices (ABI), should be performed if there is any suspicion for vascular compromise that could be a hard sign, such as diminished pulses, or a soft sign, such as fracture pattern. Furthermore, initial assessment of the surrounding soft tissue envelope can indicate not only the severity of the fracture, but may also provide an approximate timeline to definitive fixation. Ligamentous assessment, although important in high-energy plateau fracture-dislocations, may be difficult to assess on initial presentation because of pain and swelling.

No matter how thorough a history and physical examination is performed, diagnosis and operative planning cannot start without obtaining appropriate imaging. Anteroposterior (AP), lateral, and oblique views should be initially obtained. Tibial plateau views, directed in line with the anatomic 10-degree slope of the tibia, can also be helpful, although with the advent of more advanced imaging modalities (ie, computed tomography [CT]), it is rarely obtained. Initial diagnosis via plain radiographs, combined with knowing the mechanism and energy of the injury, is of paramount importance because it dictates the next stage in management. For low-energy injuries with relatively simple fracture patterns, immobilization with plaster or a knee immobilizer and an immediate CT should be the next step. However, for higher-energy injuries with associated complex fracture patterns and significant soft tissue damage, the decision to temporarily stabilize with external fixation is made.

Ideally, classification systems should not only have high agreement between observers, but should also provide consistent reliable agreement on treatment and prognosis. However, most classification systems fall short on each of those ideals, and tibial plateau fractures are no different. Most commonly, the Schatzker, the Moore, and the AO/Orthopaedic Trauma Association (OTA) classifications have been used.[3,7,8] Using radiographs alone, Maripuri and colleagues[9] reported moderate agreement between observers, the best agreement exhibited with the Schatzker classification. Adding CT, however, improves observer agreement from moderate to good.[10] If observers are provided with three-dimensional reconstructions, agreement improves to excellent for the Schatzker classification.[11]

The role of CT in regards to operative planning cannot be understated. Close analysis of CT reconstructions in the axial, coronal, and sagittal planes can offer key insight into the degree of injury by revealing entrance and exiting locations of major fracture lines, extent and location of column involvement and articular depression, degree of comminution, and any distal extension into the meta-diaphyseal junction.

In turn, understanding these key components of any tibial plateau fracture helps plan for specific approaches and implant and bone void filler selection. Additionally, for those patterns with increasing levels of articular depression and higher-energy fracture patterns, meniscal injury and/or associated ligamentous injury can be expected.[12–14]

DEFINITIVE FIXATION SHOULD FOLLOW SOFT TISSUE RESOLUTION

Tibial plateau fractures can often present with significant soft tissue injury not amenable to acute, definitive fixation. Ignoring soft tissue quality can lead to high rates of infection and complications, especially during the first 7 days after injury.[15–18] Complications arise from the underlying inflammatory cascade that leads to venous congestion, hypoxia, and subsequent necrosis creating the least ideal operative environment.[19,20]

Drawing from the staged protocol used for pilon fracture management, the same can be applied to tibial plateau fractures to allow for optimum soft tissue status before definitive fixation.[21,22] Egol and colleagues,[22] using spanning external fixation for high-energy proximal tibial fractures, reported low wound complication rates. With minimal soft tissue complications, the group recommended staged fixation for all high-energy fractures of the proximal tibia. Temporary (or in some cases, definitive) external fixation not only provides skeletal stabilization to maintain length, alignment, and rotation, but also allows for easy access for wound and blister management (**Fig. 1**).

Finally, although still controversial, one must be cognizant of pin-site placement in regards to future plate placement. Although classic teaching recommends placement of pin-sites outside of the zone of future plate placement, there is a paucity of literature to suggest if it truly holds an increased infection rate.[23] Recent studies, in an effort to provide objective data to find an answer, reported conflicting results.[24,25] In a small cohort comparison study, Laible and colleagues[24] did not find an increased infection rate in tibial plateau fractures fixed with plates that overlapped with pin-sites. Shah and colleagues[25] found the opposite, finding an increased infection rate with plate, pin-site overlap. However, the authors had a more heterogeneous study cohort, including both tibial plafond and plateau fractures.[25] While we await larger studies for a definitive answer based on objective data, we recommend trying to place pin-sites outside of the zone of fixation. However, that goal should not outweigh achieving stability, length, and alignment.

DEFINITIVE FIXATION: CASE-BASED STRATEGIES AND TECHNIQUES

Goals for definitive fixation for tibial plateau fractures revolve around implementing basic principles to achieve good outcomes (**Box 1**). Certain techniques and strategies can be implemented for specific fracture patterns to achieve desired goals. The following scenarios represent some of the more commonly presenting fracture patterns, from the simple to the complex, with the specific techniques and strategies that can be applied to maximize outcomes.

Box 1
Principles of definitive fixation for tibial plateau fractures

1. Restoration of articular surface, and mechanical axis alignment
   - Do not forget about mechanical alignment
2. Balanced fixation: use appropriate hardware
   - Match fixation strategy to the personality of the fracture pattern
   - Raft subchondral bone either with screws alone or via plate
   - No need to fill every hole with locking screws, use nonlocking where appropriate
   - Buttress plating is your workhorse
3. Always remember to RESPECT THE SOFT TISSUES
   - Only operate when soft tissues are ready (ie, skin wrinkling, minimal blisters)
   - Use percutaneous and minimally invasive when appropriate
   - However, expose as much as needed (never sacrifice to be minimally invasive)

Scenario 1: Simple Split Fractures

For simple split fracture patterns, Koval and colleagues[26] showed that excellent results could be achieved with indirect reduction techniques and percutaneous fixation. This has become a reproducible, reliable technique, but in the correct patient with the correct fracture pattern. Either tibial plateau views or a CT should be obtained to rule out any significant joint depression. If slight joint

Fig. 1. Tibial plateau fractures often present with significant soft tissue injury that requires external stabilization. (*A*) A 37-year-old man with high-energy tibial plateau fracture after motorcycle crash with significant soft tissue injury. (*B*) A 46-year-old man after high-energy fall, with significant blistering with underlying tibial plateau fracture.

depression exists along with the split, percutaneous techniques and methods of elevating the joint line have also been developed.[27,28] However, we prefer to reserve the truly percutaneous and indirect reduction techniques for the pure split fractures. For split-depression fracture patterns, we typically formally open the fracture to visualize and assess and confirm anatomic articular reduction (Scenario 2).

Here we illustrate a 57-year-old woman who was struck by a bicyclist. Radiographs revealed an isolated split tibial plateau fracture (Fig. 2A), which we confirmed to be without depression via tibial plateau view (see Fig. 2B). Patient positioning and setup is the same setup used for all tibial plateau fractures. The patients should be supine on a radiolucent table, with a bump placed under the ischial tuberosity on the ipsilateral side along with fluoroscopic imaging placed on the contralateral side; placing the affected limb on a radiolucent knee triangle also helps to eliminate the uninjured leg, allowing for easily obtained images (see Fig. 2C).

Before reduction, it is important to replicate the tibial plateau view. Replicating the view and eliminating the posterior slope allows for a better assessment of the articular surface and therefore, the reduction obtained. This is another reason why we often obtain a tibial plateau view, because we use it intraoperatively as a comparison to our fluoroscopic images. Following confirmation of reduction, a large pointed reduction clamp can be used to obtain provisional reduction (see Fig. 2D). Care must be taken to avoid undesired pressure on the skin over the anterior aspect of the tibia. Finally, the reduction can be held provisionally with wire fixation, which can subsequently be replaced with partially threaded cannulated screws. Our

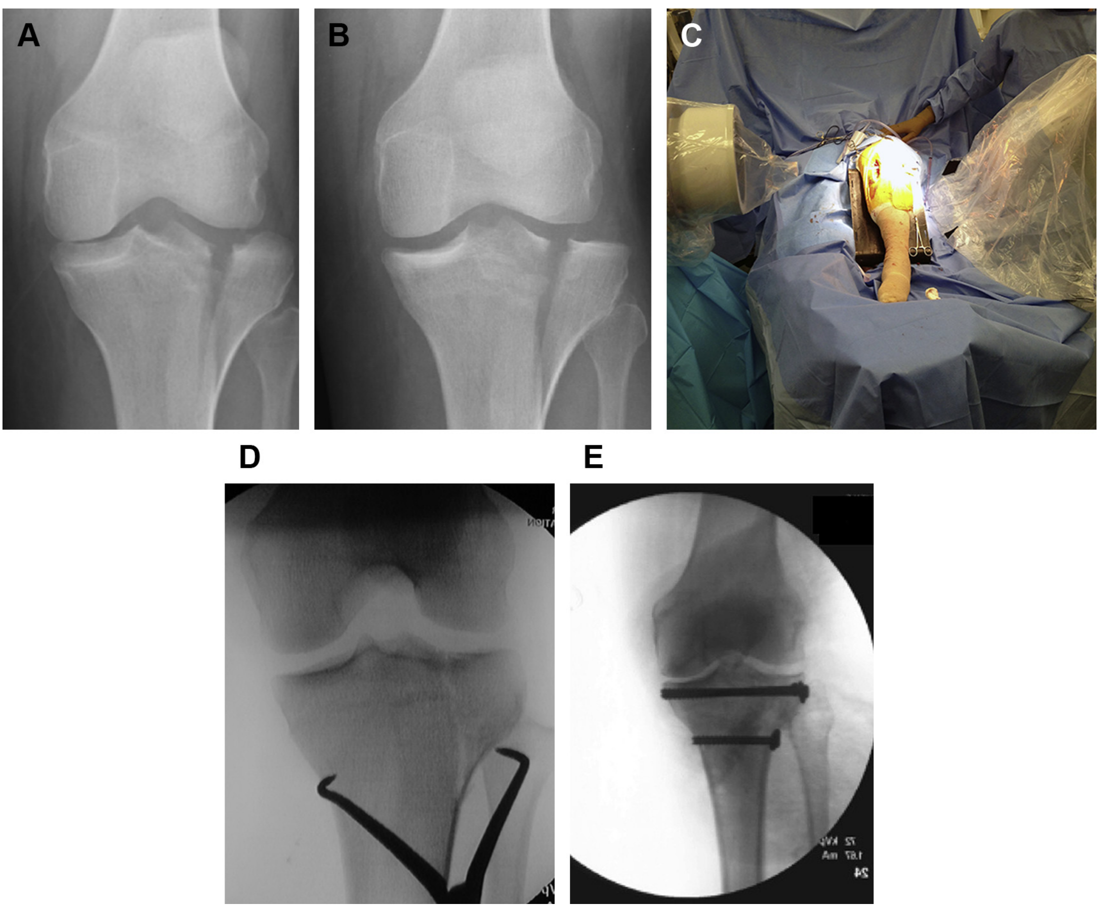

Fig. 2. A 57-year-old woman who was struck by a bicyclist with an (*A*) isolated split tibial plateau fracture, confirmed to be without depression via (*B*) tibial plateau view. (*C*) Patient is positioned supine on a radiolucent table, with a bump placed under the ischial tuberosity on the ipsilateral side on a radiolucent triangle; fluoroscopic imaging comes in from the contralateral side. (*D*) Reduction is obtained with a large pointed reduction clamp on the tibial plateau view and after provisional fixation with wires, (*E*) partially threaded cannulated screws and washers complete definitive fixation.

preference is to place a minimum of two screws along the subchondral surface and a third screw at the distal apex of the fracture (see Fig. 2E). We also use washers to increase the surface area, achieving more compression, and also it is important to sequentially tighten each screw to achieve uniform, symmetric compression across the fracture.

Scenario 2: Split-Depression Fractures

Split-depression fractures (Schatkzer II) are the most commonly presenting tibial plateau fracture pattern. Here, we prefer a formal open, anterolateral approach for direct assessment and visualization of the extent of the depression along with the joint articular surface.[29] Furthermore, we also recommend performing a formal open approach because of the high incidence of concomitant meniscal injury. Meniscal repair is an essential part of tibial plateau fracture repair and should not be ignored to perform percutaneous joint elevation and fixation. Buttress plating is the most common construct used to provide definitive stability.

Superficially, there are several options available for the initial skin incision and approach. The lazy S, the hockey stick, and a straight longitudinal incision centered over Gerdy tubercle have all been described.[29] Each has their advantages and disadvantages, and use should depend on surgeon familiarity.

Here, a 38-year-old man presented with a split-depression fracture after being struck by a motor vehicle while walking (Fig. 3A, B). CT revealed a more severe injury than led on by radiographs, with noted condylar widening, significant articular depression, and comminution (see Fig. 3C, D). Skin wrinkling was appreciated 5 days after the injury and the patient was taken to the operative room. An anterolateral approach was used. This approach differs from the classic hockey-stick approach because the proximal limb lies more proximal to the joint surface to allow for articular surface visualization. In addition, the distal limb is not as extensile to minimize deeper, soft tissue stripping. More importantly, on deeper dissection, the "L" portion of the approach is careful dissected and lifted from the capsule and bony surface as one, large subcutaneous flap, similar to that of the lateral approach to the calcaneus (see Fig. 3E). The senior author (KAE) prefers this approach because it not only allows for a more facile closure, but also has minimized soft tissue complications in his practice.[30,31]

The flap should be tagged with absorbable suture, which allows for easy retraction and visualization of deeper structures (see Fig. 3F). Following submeniscal arthotomy, the meniscus should be identified and repaired and/or tagged in a vertical fashion, again to allow for retraction and visualization of the articular surface. These same sutures can be later used to stabilize the meniscus to any remaining tissue on the tibial side, or if none remains, can be passed and secured through the K-wire holes. At this juncture, with the fracture exposed, a laminar spreader can be used to book it open and assess the extent of joint depression (see Fig. 3G). After elevating the joint surface, provisional fixation can be placed to hold the split reduction in place. Although a recent biomechanical study has shown decreased rate of loss of reduction by placing drillable bone substitute before fixation, we still prefer to obtain and fluoroscopically confirm our articular reduction with provisional and definitive fixation before void filling.[32] Injectable calcium phosphate remains our void filling substitute of choice because it has been shown to have the highest compressive strength with minimal loss of reduction when compared with autograft, allograft, and calcium sulfate in clinical studies.[33–36]

After visually and fluoroscopically confirming the quality of the reduction, a periarticular, precontoured plate can be applied (see Fig. 3H). Plates larger than 3.5 mm are unnecessary because biomechanical studies have no shown no difference between the two sizes.[37] Furthermore, although it is certainly reasonable to place locking screws underneath the articular surface, if bone stock is adequate, distally, nonlocking fixation may be used. Repair of the meniscus, and appropriate opposition of the thick, subcutaneous flap should be carefully closed, with care paid to the corner of the incision. Following these steps, uneventful healing and good outcomes can be achieved (see Fig. 3I).

Scenario 3: Fracture-Dislocations

Fracture-dislocations of the tibial plateau indicate significant associated energy and warrant special attention. Even before planning definitive fixation, thorough and close monitoring of neurovascular status is required, and often soft tissue injury is more severe than indicated by the underlying bony pathology. Fracture-dislocations should warrant ABIs and frequent vascular examinations, especially with medial plateau fractures (Schatzker 4, Moore 1, Fig. 4A, B) and rim avulsion fractures (Moore 3, Fig. 5A, B), which are associated with at least a 10% incidence of associated neurovascular and/or ligamentous disruption.[38,39]

Schatzker IV and Moore 1 injuries essentially occur when the femoral condyle is driven down

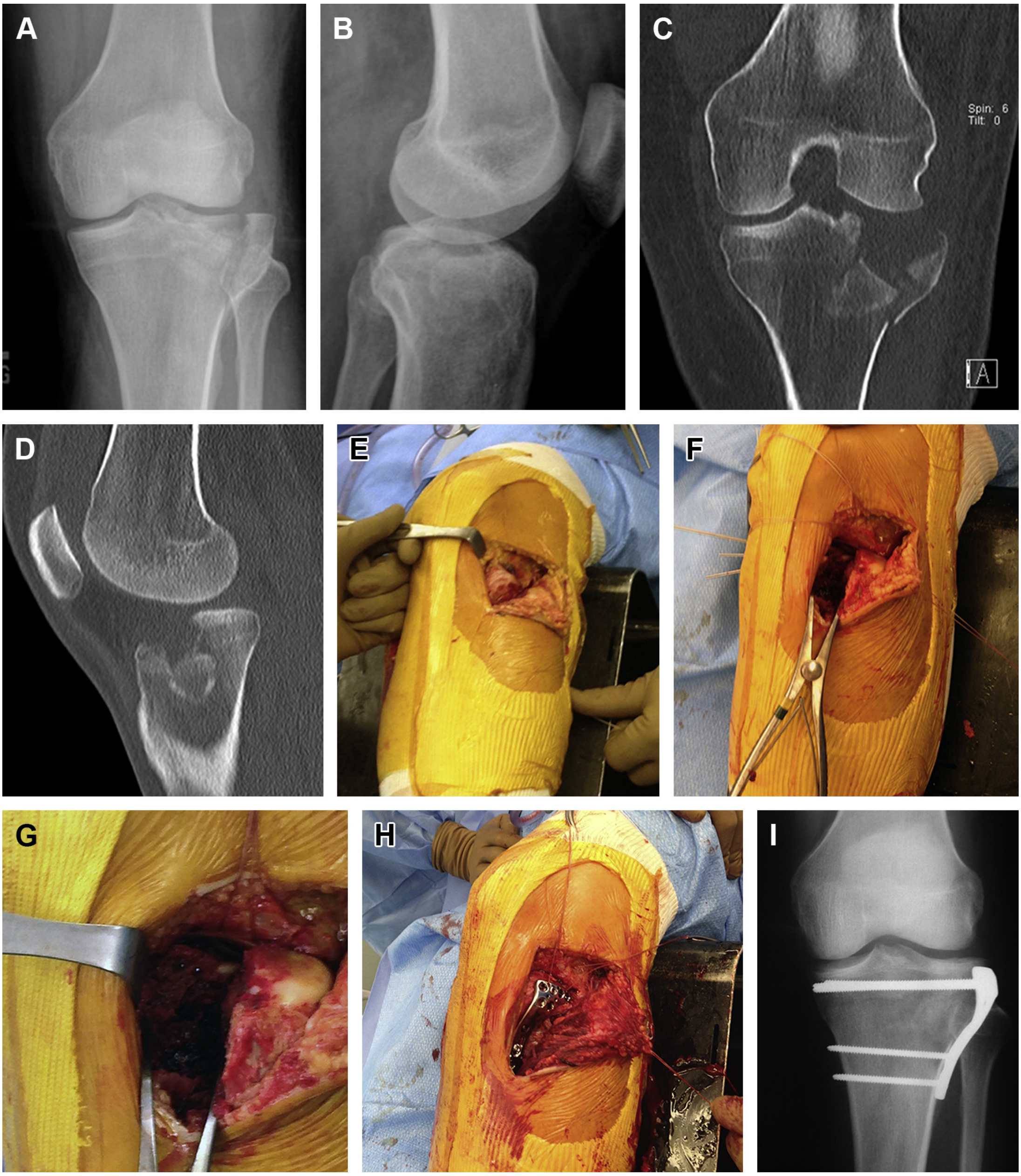

Fig. 3. (*A, B*) AP and lateral radiographs can mask a more severe degree of widening and depression that can be appreciated on CT (*C, D*). The senior author prefers a modified "L" incision and approach similar to the thick flap created for calcaneus fractures (*E*). Tagging the flap along with the meniscus allows for good visualization of the articular surface and fracture (*F*), which can be opened with a laminar spreader for proper assessment (*G*). Hardware placement before void filling is preferred to ensure and confirm anatomic reduction without the complication of excess substance (*H*). With appropriate meniscal repair, and closure, desired fracture healing and joint line restoration can be achieved (*I*).

into the tibia, effectively fracturing and shearing off the medial plateau. Here, a 44-year-old man fell off of a ladder, sustaining a fracture-dislocation (see Fig. 4A, B). Grossly unstable, with associated soft tissue swelling, there should be a low threshold to obtain temporary stabilization (see Fig. 4C, D). Definitive fixation for this injury pattern can be applied in a step-wise process: interfragmentary screws between the condyles followed by buttress plating (see Fig. 4E, F). Surgical approach is dictated by plane of the fracture pattern. For medial plateau fractures in the coronal plane, a standard medial

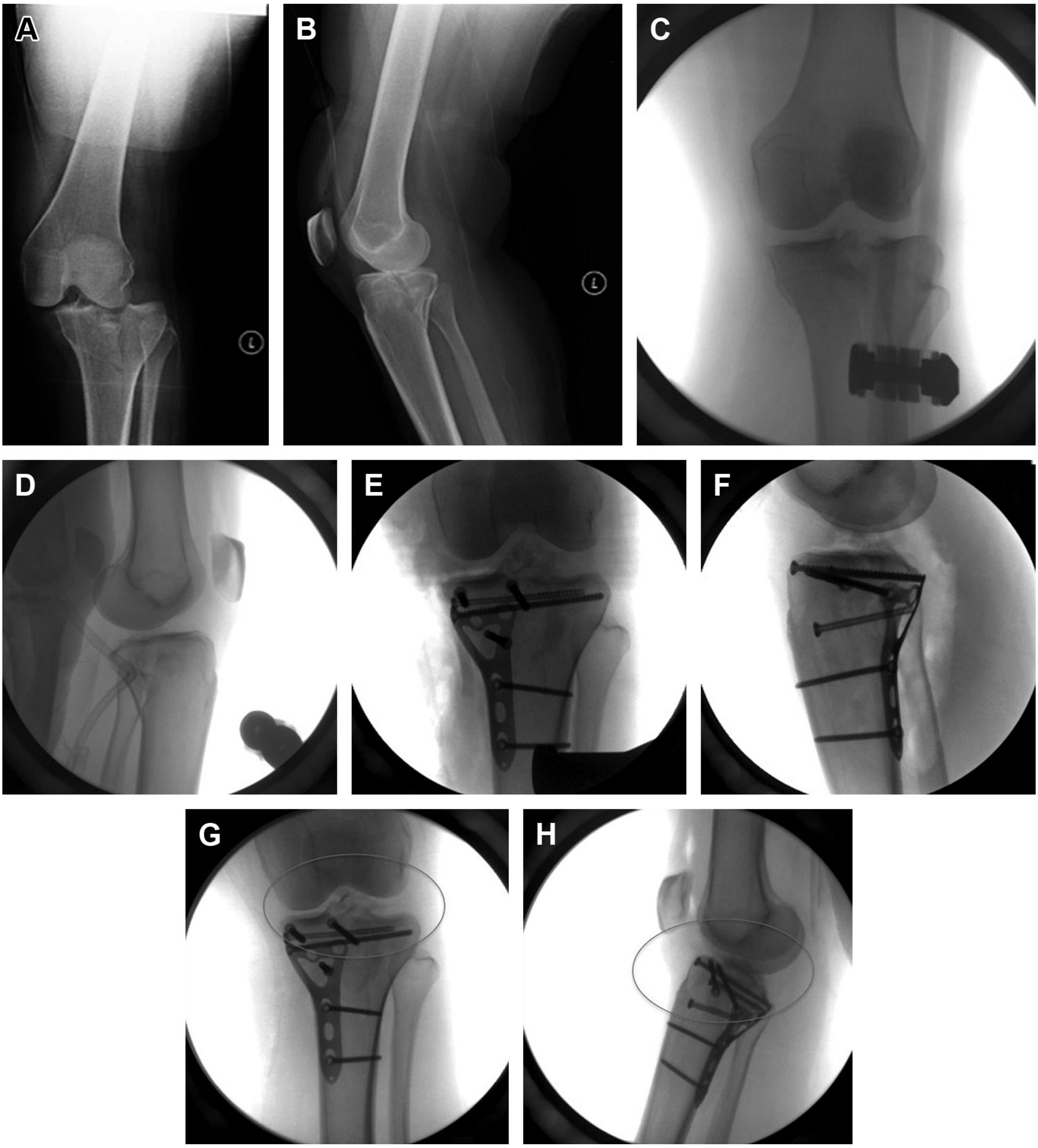

Fig. 4. Fracture-dislocations of the tibial plateau (*A, B*) are high-energy fractures commonly associated with neurovascular or ligamentous instability. There should be a low threshold to place an external fixator for gross instability (*C, D*). Fixation strategies should start with interfragmentary fixation between the condyles followed by buttress plating (*E, F*). Finally, before leaving the operating room, the affected limb should be stressed to assess for any ligamentous injury (*circles*), which is common (*G, H*).

approach can be used. However, for Moore 1 fractures where the fracture line is in the sagittal plane, creating a posteromedial fragment, the posteromedial approach working between the medial head of the gastrocnemius and the semimembranosus may offer an easier point of access for placing the buttress plate (see Fig. 4E, F).[40] Finally, an intraoperative ligamentous examination should be performed because it is not uncommon that ligamentous reconstruction is required (and if so, it is typically fixed in a staged fashion) (see Fig. 4G, H).

Rim avulsion fractures (Moore 3) also carry a higher rate of associated neurovascular injury. This 67-year-old woman was a pedestrian struck who presented with concomitant peroneal nerve palsy (see Fig. 5A–D). A standard, anterolateral approach, as described previously, can be used to provide definitive fixation (see Fig. 5E, F).

Fig. 5. (*A, B*) Rim avulsion (Moore 3) fractures are also associated with an increased incidence of neurovascular injury. (*C, D*) Often, these fracture patterns are without obvious joint line depression and although a high-energy fracture pattern, a standard, anterolateral approach can be used to provide definitive fixation (*E, F*).

Scenario 4: Complex, Bifocal Fractures, Addressing Comminution, Metadiaphyseal/ Intra-articular Extension, and Segmental Injuries

For more complex, higher-energy tibial plateau fractures, several more principles must be considered.

- Be patient and wait for the soft tissues. Most of these fractures require temporary stabilization with an external fixator.
- Obtain CT after achieving length with external fixator.
- Leave the external fixator on, because it can serve as a valuable distractor to help maintain length (Fig. 6) and if an ex-fix is not on, have a femoral distractor ready and have a low threshold for use (Fig. 7).
- Do not hesitate to release compartments if compartment syndrome is suspected; have a low threshold for fasciotomies.

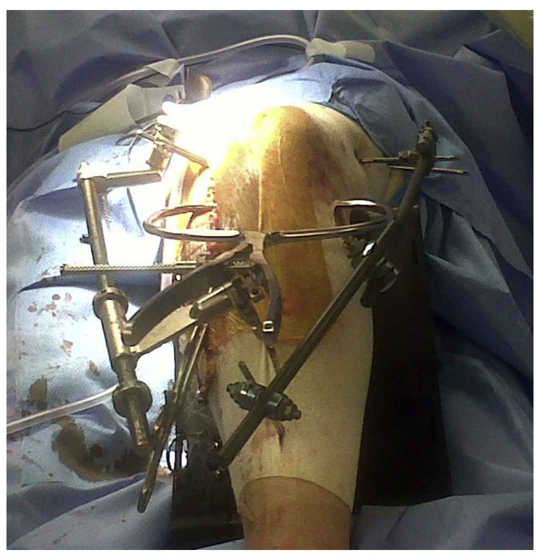

Fig. 6. For higher-energy fractures that are temporarily spanned, leaving the external fixator on during definitive fixation can offer an additional distraction tool that can be incredibly helpful.

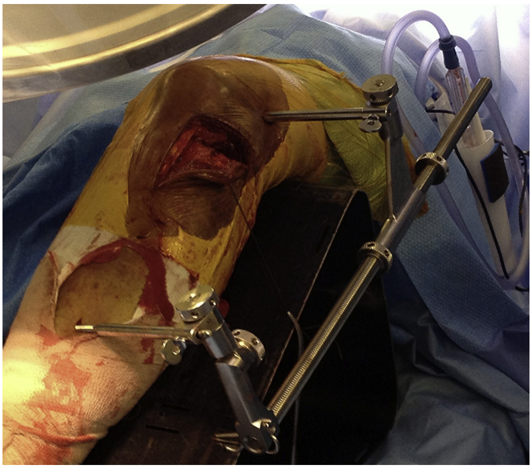

Fig. 7. A femoral distractor should always be available, and to obtain additional visualization, there should be a low threshold to place it.

- Multiple surgical approaches may be required.
- Do not be afraid to stage operations (ie, medial then lateral, or vice versa).
- For long, bifocal injuries that extend far distal or present as segmental injuries, additional fixation may be required to achieve desired level of stability.

In our first case example, a 22-year-old woman was ejected out of her motor vehicle. Her left lower extremity presented with obvious swelling and deformity with a tense calf. Initial radiographs revealed a comminuted tibial plateau fracture where the femur has driven itself into the proximal tibia (**Fig. 8**A, B). With increasing concern for compartment syndrome, the patient was taken to the operating room for compartment releases and stabilization with a spanning knee fixator, which achieved reduction, allowing for

Fig. 8. High-energy tibial plateau fractures can present with severe levels of comminution, especially those that experience severe axial load of the femur into the proximal tibia (*A, B*). These fractures often require temporary stabilization with external fixation (*C, D*) and a CT should be obtained after ex-fix (*E–G*). With severe fracture patterns, staging each column is also acceptable, by starting with the easier side (*H, I*), allowing for the soft tissues to recover, and return to complete fixation (*J, K*).

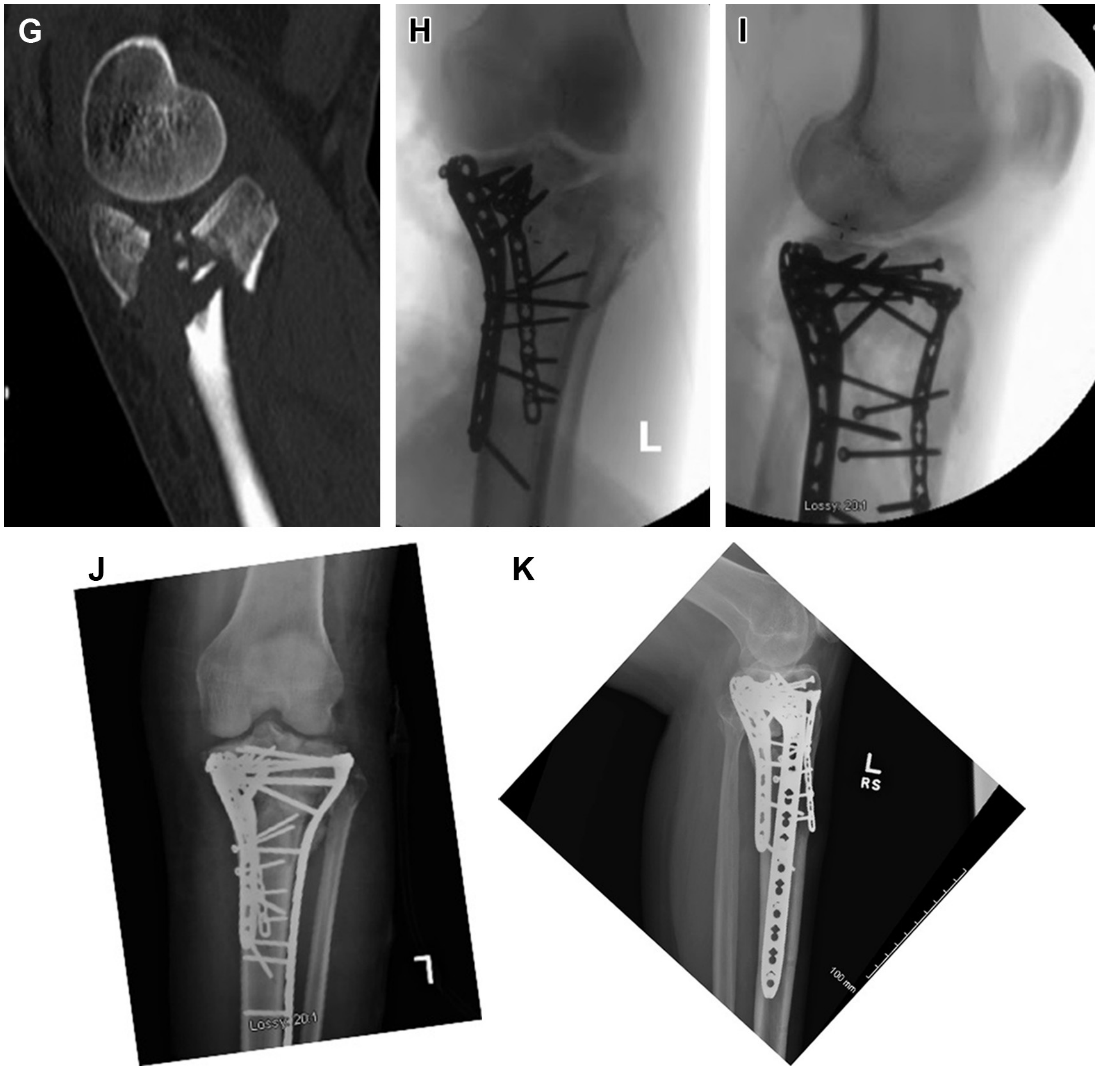

Fig. 8. (*continued*)

temporarily restored length (see Fig. 8C, D). Obtaining a CT after restoring length, one can better appreciate and understand the nature of the fracture (see Fig. 8E–G).

Analyzing the CT, the medial side appears to be in larger, more reconstructable fragments, and thus was fixed first (see Fig. 8H, I). Because of the severity of the injury and the time required to reconstruct only the medial side, the fasciotomies were closed and a negative pressure wound dressing applied. The patient's soft tissue status was closely monitored and when skin wrinkling was seen, the patient was brought to complete reconstruction of the lateral side (see Fig. 8J, K).

In our next case, distal extension with a long area of metadiaphyseal comminution presented a more difficult challenge. This type of bifocal injury often requires additional fixation to achieve appropriate stability. This 67-year-old woman after motor vehicle accident presented with a tibial plateau fracture with distal metadiaphyseal extension and significant comminution. Despite plate application via minimally invasive percutaneous plate osteosynthesis (MIPPO) technique to protect the soft tissues, the length of the fracture comminution still remained unstable (Fig. 9A–C). Dual plating provided a more stable construct for this long segment of comminuted bone (see Fig. 9D, E).

Fig. 9. Plateau fractures that present with long, distal extension of metadiaphyseal comminution offer a unique challenge. These bifocal injuries often remain unstable even following initial plate fixation (*A–C*), and at times require additional plating to achieve desired stability (*D, E*).

SUMMARY

Tibial plateau fracture presents in a wide range of fracture patterns, associated injuries, and soft tissue concerns. General principles along with a step-wise approach can be applied to every fracture and anatomic reduction and restoration of the mechanical axis. Definitive fixation should match the nature of each fracture pattern with the goals of always respecting the soft tissues. There should be a low threshold to apply a staged treatment protocol with a temporary external fixator in order for the soft tissues to optimize. CT scans offer detailed information about the fracture pattern, and in higher-energy fractures, should be obtained after restoring length and stability. Understanding the nature of the injury and applying the appropriate fixation to achieve ideal reduction and stability can be achieved, even in the most complex fracture patterns, with a desired clinical result.

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