Staged Management of Tibial Plateau Fractures

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Abstract

Careful and thorough assessment of injury severity, with particular attention paid to identifying high-energy injuries, is critical to achieving optimal outcomes and avoiding complications following tibial plateau fractures. Staged management of tibial plateau fractures refers to the use of temporizing methods of care (often spanning external fixation) in high-energy injuries, as well as delaying definitive fracture surgery until such a time as the risk of soft tissue complications is decreased. This article discusses the principles and techniques of staged management, including the use of less invasive methods for definitive stabilization.

Fractures of the tibial plateau encompass a wide range of severity, from stable nondisplaced fractures with minimal soft tissue injury to highly comminuted unstable fractures with massive soft tissue injury that threaten limb viability.[1] Careful and thorough assessment of severity, with particular attention to identifying high-energy injuries, is critical in achieving optimal outcomes and avoiding complications.[2] Staged management of tibial plateau fractures refers to the use of temporizing methods of care (often spanning external fixation) and delaying definitive fracture surgery until risk of soft tissue and other complications is decreased. Staged management also refers to employing fracture stabilization techniques that are more "friendly" to injured soft tissues.[3]

This article discusses how patient and injury factors, as well as physical and radiographic findings, can be taken into account to identify those tibial plateau fractures best managed with a staged treatment protocol.

Assessment

It is crucial to identify injuries that require staged treatment; failure to apply staged management can results in soft tissue compromise, wound dehiscence, superficial and deep infection, stiffness and poor function, and even loss of limb.[2-8] In some situations, such as a patient with multiple injuries including a degloving soft tissue injury near a comminuted bicondylar tibial plateau fracture, the magnitude of the injury (and the need for staged management) will be self-evident. Occasionally, however, a fracture that appears "straightforward" on radiographs may also warrant staged management because of patient, soft tissue, or biologic factors. A low-energy injury in a patient with compromised physiology (uncontrolled diabetes, smoking, morbid obesity, immunocompromised state, etc) may have a greater risk of complications than a high-energy injury in a healthy patient.[2] Performing acute open reduction internal fixation will increase the risk of soft tissue complications (Figure 1).[3]

History

A focused, yet complete, history and physical examination is the first step in evaluating any patient with a fracture. It is crucial to recognize whether or not the patient was in a situation where a large amount of energy was imparted to the limb. Motor vehicle/motorcycle collisions, falls from heights greater than 10 feet, or being struck by a vehicle while walking are some of the more common high-energy mechanisms.[2] An appropriate history also includes investigation of patient factors (comorbid conditions) that could impact the treatment plan or affect the patient's overall prognosis. Patients with concurrent health problems such as coronary artery disease, emphysema, heavy smoking, or poorly controlled diabetes are at greater risk of suffering a variety of complications.[4] In compromised patients who require surgical intervention, consultations from the appropriate medical services should be expedited.[5]

Physical Examination

Careful examination of soft tissues near the injury site is paramount in determining which injuries require staged management. The entire limb should be viewed circumferentially for evidence of swelling, lacerations, blisters, bruis-

Figure 1. Examples of extensive fracture blisters (left) and wound breakdown with exposed hardware resulting from early definitive care. Courtesy of Dr. J. L. Marsh, Iowa City.

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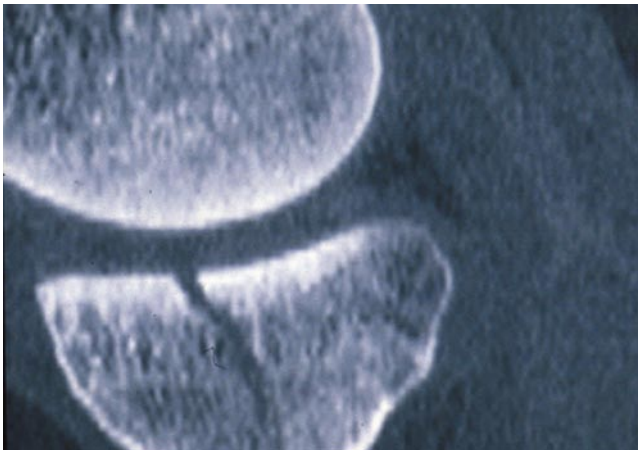

Figure 2. Sagittal CT reconstruction demonstrating a coronal split in the medial tibial plateau. CT demonstrated the location and amount of displacement of this fracture better than did plain radiography. Courtesy of Dr. Dirschl.

Figure 3. Example of a typical configuration for a spanning external fixator crossing the knee joint. Courtesy of Dr. Dirschl.

ing, deformity, angulation, and distal perfusion. The presence of moderate to severe soft tissue swelling, blistering, and/or open wounds is a clear indication to pursue staged management instead of immediate definitive care.[3] Any amount of swelling in the leg should induce the orthopedist to perform a full clinical evaluation for the presence of compartment syndrome. If clinical findings are equivocal, or if the patient is obtunded or sedated, performing compartment pressure measurements can aid in evaluation. A focused neurological examination should be performed to assess both strength and sensibility. Dorsalis pedis and posterior tibial pulses should be palpated, and perfusion of the limb assessed.[2] Since instability of the knee to mediolateral stress is one of the most important surgical indications in managing tibial plateau fractures and one of the most important indicators of prognosis, accurate assessment of mediolateral stability is critical for operative planning and prognosis.[5-8]

Radiography

Any patients with suspected tibial plateau fractures should have anteroposterior (AP) and lateral plain radiographs of the knee on 17-inch radiographic cassettes. In situations where the fracture line propagates to the tibial shaft, full-length AP and lateral radiographs of the tibia should also be obtained. Because of the prevalence, ease, and superior-quality images obtained from computed tomography (CT), this modality has replaced additional plain radiographs during the initial workup.[5] CT scans with axial, coronal, and sagittal reformations facilitate viewing of the articular surface and provide a more thorough evaluation of the fracture pattern (Figure 2). These images allow for better preoperative planning.[9] Although a CT scan can be extremely useful in planning for the definitive fixation of complex intra-articular fractures, the information provided by this modality is less useful when there is gross displacement, angulation, or shortening, as is often the case at the time of initial presentation of the patient.[10] If it is evident that the fracture will require staged treatment, the surgeon should refrain from performing a CT scan until after the length of the extremity has been restored by application of a spanning external fixator.

Spanning External Fixation

The use of an external fixator spanning the knee is the first phase in the staged management of high-energy tibial plateau fractures evolved from techniques used in the management of tibial plafond fractures.[11] Placement of a spanning external fixator allows for immediate fracture stabilization, prevention of further cartilage and soft tissue damage, maintenance of proper alignment, access to wounds for observation and/or treatment, stabilization of a vascular repair, and increased patient comfort.[2]

A variety of external fixation devices can be used to span the knee. Whatever device is used, however, the surgeon must ensure that the external fixator meets the following goals:

- The fixator pins must be inserted outside the zone of injury, defined as the greatest extent of the area in which the skin, soft tissues, or bone are compromised. Periosteal stripping, fracture blisters, open wounds, bruising, and massive swelling are all within the zone of injury.
- The fixator pins must not be inserted in any location that can compromise future incisions or implant positioning. Since tibial plateau fractures are most frequently stabilized with laterally applied plates and screws,[12] locating the tibial pins of the external fixator on the medial side of the tibia distal to where the plate may extend is usually best.
- The external fixator must hold the limb out to length and should also hold the knee in a position of slight valgus and flexion, but neither of these is as important as ensuring that the limb is out to length. Soft tissue compromise in a high-energy injury may dictate that definitive fracture care be delayed for up to 3 weeks. While it is relatively easy to reestablish limb length with an external fixator on the day of injury, it is extremely difficult to do so 3 weeks later—even with open reduction techniques.

The author has most commonly used a standard pin-to-bar external fixator to span the knee joint in these injuries. Two 5- or 6-mm half-pins are inserted into the femoral shaft and 2 into the tibial shaft. Self-drilling pins inserted under power are generally used; while this method of insertion is not optimal for an external fixator that will remain in place for an extended period, it provides more than adequate stability for the 2 to

Figure 4. The proximal tibia is tilted in varus relative to the tibial shaft. This is unacceptable alignment and will universally result in early arthrosis. Courtesy of Dr. Dirschl.

3 weeks during which the spanning fixator will be in place. The femoral pins are inserted in the midshaft to be proximal to the suprapatellar pouch. The tibial pins are inserted anteromedial, distal to the level of any anticipated incisions and implants. After insertion, the pins are connected to one another using the connector clamps and fixator bars standard to any external fixation system. The precise configuration of bars and clamps is not critical, but the surgeon should ensure that the frame is stable enough to allow the limb to be moved or lifted, that appropriate length and alignment of the limb are maintained, that there is sufficient clearance between the fixator clamps and bars and the patient's skin, and that there are no metallic clamps directly over the fracture that will obscure bony detail on radiographs. A sample external fixation configuration is shown in Figure 3.

After spanning external fixation, any soft tissue wounds or fracture blisters are appropriately dressed, and the patient is returned to his/her hospital room. While there is no single proven method for dressing fracture blisters, I prefer to treat intact fracture blisters with bulky dry dressings and ruptured fracture blisters with Silvadene cream (used in burn victims). The patient's pain is managed with narcotic analgesics; I avoid the use of regional nerve blocks for pain management in patients with massive soft tissue swelling because the block may mask signs of an evolving compartment syndrome. The injured limb is elevated, and appropriate antibiotic and thromboembolism prophylaxis provided.[13] The patient is strongly encouraged to mobilize, and physical therapy is instituted the day following surgery for toe touch weight bearing ambulation. In the absence of open wounds, patients are allowed to begin bathing/showering 48 hours after fixator application. Many patients with isolated injuries and no serious open wounds can be discharged while awaiting definitive fracture stabilization.

Definitive Stabilization

Timing

While definitive fixation can frequently be carried out within a week of injury, it is not uncommon to wait as long as 3 weeks for resolution of soft tissue issues. As long as limb length and general limb alignment have been maintained in the external fixator, waiting 3 weeks to perform definitive surgery is acceptable.[3,14] While elevation is important, the most important factor is allowing sufficient time for soft tissue swelling to subside.[2] In general, the appearance desired is healthy, well-perfused skin that will develop wrinkles when palpated. In addition to this general criterion, however, particular attention is directed to the areas surrounding the planned surgical incisions and surgical dissection (for example, a medial fracture blister is not a significant barrier to surgery if only lateral incisions and dissection are planned). If, however, fracture blisters are present in the areas where surgical incisions need to be made, the surgeon should wait until there has been re-epithelialization of red (deep) blisters prior to definitive surgery.[2,3,14]

Goals of Definitive Treatment

It has long been taught that anatomic reduction of the articular surface was the most important factor affecting outcome following tibial plateau fractures. Careful review of the literature, however, seems to indicate that the health of the articular cartilage, mediolateral stability of the knee, presence of the menisci, and overall alignment of the tibia are of equal or greater importance.[1,6,8,15,16] All of these factors should be optimized in the care of tibial plateau fractures, but at least one of them (articular cartilage health) is not under the surgeon's control. Current evidence suggests that optimal results are achieved by providing stable fixation and restoring coronal tibial alignment while using soft tissue–friendly surgical techniques.[7] While achieving articular congruity in the management of these fractures is important, the surgeon must recognize that achieving articular reduction "at all costs"—at the expense of the soft tissues, the blood supply to the bone, the stability of the knee, or the integrity of the menisci —is likely to result in suboptimal outcomes.[1,16,17]

In a study of more than 200 patients with lateral plateau fractures followed for over 7 years, Rasmussen noted a 46% incidence of posttraumatic arthritis in patients with greater than 10° of instability to varus valgus testing in full extension.[8] This is compared with the 17% of patients who developed posttraumatic arthritis and did not have mediolateral instability. In a study of 39 patients with tibial plateau fractures and ligamentous injuries, Delamarter and colleagues[6] demonstrated superior results in patients who underwent operative repair of the medial and lateral collateral ligaments in addition to open reduction and internal fixation of the tibial plateau.

Figure 5. This split-depressed fracture of the tibial plateau was managed with limited incisions and percutaneous screw stabilization. Courtesy of Dr. Dirschl.

Figure 6. Dual-plate stabilization of a bicondylar tibial plateau fracture in a patient who had a previous tibial shaft fracture. This procedure was performed through a single midline incision. Courtesy of Dr. Dirschl.

The surface of the normal uninjured tibial plateau is in approximately 3° of varus alignment to the longitudinal axis of the tibial shaft. Stabilization and healing of the fracture in a position that restores alignment has proven to be an important factor affecting the rate of arthrosis and patient outcomes. In a study of 131 tibial plateau fractures, Honkonen and coauthor[7] noted a declining relationship between outcome and varus angulation. Up to 5° of valgus angulation seemed to be tolerated, but outcomes declined when valgus angulation was greater. Particularly in bicondylar fractures, surgeons must remember the importance of restoring this alignment and obtain full-length images to evaluate alignment and avoid creating a varus or valgus malunion (Figure 4).

Techniques

Management of the external fixator at the time of definitive surgery. There are possibly as many ways to manage the external fixator as there are surgeons undertaking this care. Among the described methods have been removal of the frame and pins prior to prepping and draping the patient, removing and autoclaving the fixator bars and reassembling the frame after draping the patient, and wrapping the fixator in a combination of towels and a plastic adhesive surgical barrier.[2,3,14]

My preferred technique is to leave the spanning external fixator in place until after definitive internal fixation of the fracture has been completed. Use chlorhexidine solution and isopropyl alcohol to scrub the patient's limb and external fixator. The entire limb and fixator are then prepped with a povidone iodine solution and surgical drapes applied. If necessary, the external fixator is adjusted to fine tune the length and alignment of the limb, and then the definitive fracture surgery is carried out according to the preoperative plan. After fracture fixation is completed, the external fixator is removed and the knee assessed for varus-valgus stability. Pin sites are not closed and are dressed with gauze dressings; after 48 hours, pin sites are left open to air.

Limited open reduction and internal fixation. Limited open reduction and internal fixation refers to the technique of utilizing small incisions, indirect reduction via reduction aids (clamps, probes, etc), and intraoperative imaging to provide limited screw stabilization of fracture fragments. This technique limits the insult to soft tissues and devascularization of osseous fragments. Cannulated or standard screws can be inserted after articular fragments are teased into place with small instruments inserted through 1- to 2-cm incisions. Fracture alignment and screw placement are verified with fluoroscopic imaging. Although this technique does not, by itself, provide sufficient stability in high-energy tibial plateau fractures, it can serve as a useful adjunct to either plating or external fixation techniques.[16] In the presence of articular depression, a small incision is made distal to the joint line, fluoroscopic guidance is used to position elevators or tamps beneath the depressed fragments, and the depressed fragments are then tamped into place. The resulting defect can then be filled with bone graft or bone graft substitutes, and percutaneous screws can be inserted (Figure 5).[15] Small incisions also allow for probes or reduction forceps to manipulate fracture fragments and provide provisional reduction. Under fluoroscopic guidance, cannulated screws can be inserted to stabilize fracture fragments. Screws can also be positioned in parallel in a raft formation just under the subchondral bone to support the articular reduction.[18]

Dual plating. This technique for bicondylar factures was originally performed through a single anterior incision, with subperiosteal dissection of the proximal tibia on both medial and lateral sides (Figure 6). This massive soft tissue stripping led to devascularization of bone and high rates of infection. Infection rates markedly decreased and outcomes

Figure 7. Example of a posteromedial antiglide or buttress plate used to stabilize a posteromedial fracture fragment. The patient had a tibial nail inserted 5 years previously for a tibial shaft fracture. Courtesy of Dr. Dirschl.

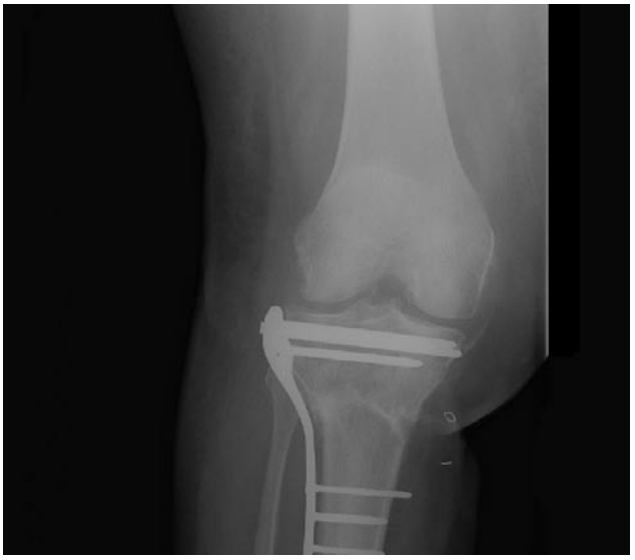

Figure 8. Stabilization of a bicondylar tibial plateau fracture with a lateral locking plate; this procedure was done through a limited-incision approach. Courtesy of Dr. Dirschl.

greatly improved when the single anterior incision was replaced by separate medial and lateral incisions, limiting periosteal stripping and soft tissue damage.[3,19] The advent of periarticular locking plates contoured to fit the lateral tibial surface has greatly decreased the need for a separate plate on the medial side in most bicondylar fractures.[14,20,21]

The posteromedial plateau fragment is approached through an incision along the palpable posterior border of the medial tibial metaphysis. This location is distal to the joint line and between the medial collateral ligament and the medial head of the gastrocnemius. The deep fascia overlying the medial head of the gastrocnemius muscle is incised posterior to the pes anserinus tendons. The pes tendons are retracted anteriorly while the medial gastrocnemius muscle is elevated to reveal the posteromedial proximal tibia. Articular reduction is done indirectly by reducing the metaphyseal spike of the fracture fragment; reduction of the articular surface can be confirmed using fluoroscopy. A plate is positioned over the fragment on the posterior metaphysis and screws are inserted from distal to proximal to provide buttress fixation of the fracture fragment (Figure 7).

The lateral plateau fracture is approached through a hockey stick incision over the anterolateral proximal tibia from just proximal to the joint line extending distally 1 cm lateral to the tibial spine as far distally as necessary for plate fixation. Dissection is carried down to the iliotibial (IT) band, which is split in line with its fibers over the fracture. For intra-articular exposure, a horizontal inframeniscal incision is made, allowing the lateral meniscus to be elevated and the articular surface examined. A provisional reduction is obtained, and a precontoured plate is positioned on the lateral side of the tibia and secured with screws. In cases of metaphyseal comminution, care should be taken to choose a plate long enough to bridge the injury and obtain stable fixation (Figure 8).

Locked plates/fixed-angle devices. The advent of locked-plating techniques has increased stability of complex tibial plateau fractures by allowing the creation of multiple fixed-angle devices that support the entire proximal tibial articular surface. This allows for bicondylar fractures to be effectively stabilized from the lateral side (Figure 8).[20,21] In the presence of severe comminution or a coronal split of the medial condyle, the fixed angle of the locking screws may not be able to achieve adequate fixation medially. In this situation, an additional medial plate should be used.[2]

The surgical approach for a lateral locking plate is the same as the limited lateral approach for standard plating. I usually lay the selected plate on the patient's skin and use fluoroscopic images to confirm appropriate plate length and position. With the plate on the skin, its outline is marked with a surgical marker. The appropriate skin incision will then be an oblique incision that passes through the center of the proximal aspect of the plate outline. After exposure of the bone, and release of the origin of the anterior compartment musculature, the plate can be slid submuscularly along the lateral surface of the tibia. The proximal incision can then be used to insert screws into the proximal fragment, and small stab incisions can be used to insert screws into the distal aspect of the plate (Figure 8).

Postoperative Care

In the acute postinjury period, it is important that peripheral nerve blocks not be used for postoperative analgesia, as the block could mask signs and symptoms of postoperative compartment syndrome. At the time of delayed definitive fracture stabilization, however, the status of the patient's soft tissues and the amount of surgical dissection and intervention planned by the surgeon will result in a more variable risk of postoperative compartmental syndrome. The author's current

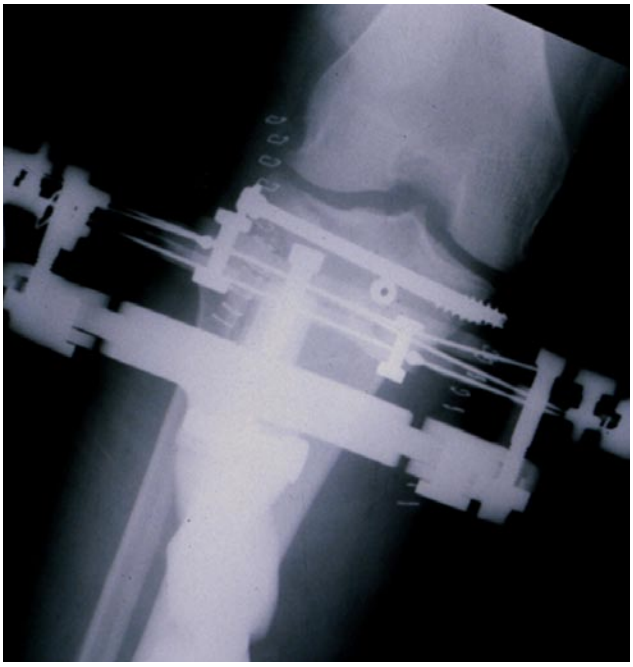

Figure 9: Example of hybrid external fixation with limited open internal fixation for a bicondylar tibial plateau fracture. Courtesy of Dr. Dirschl.

practice is to delay definitive fracture surgery until the soft tissue swelling has subsided enough that the skin wrinkles and to use minimally invasive plating techniques whenever possible. In the absence of a peripheral nerve block, I generally use a morphine or hydromorphone patient-controlled anesthesia machine for 1 to 2 days after surgery. By postoperative day 2, patients are transitioned from intravenous to oral pain control. Given the concerns with inhibition of bone healing, nonsteroidal anti-inflammatory medications should be avoided in the first 6 weeks following surgery.

By the time of definitive fixation, all open wounds and/or fracture blisters will be clean, closed, or covered. As such, perioperative antibiotic usage for delayed fracture surgery should be the same as for clean, elective orthopedic procedures.[13] A first-generation cephalosporin begun within an hour prior to surgical incision and continuing for 24 hours is the regimen routinely employed. The surgical dressing is left in place for 48 hours and the incision is left open to the air. Patients are allowed to shower and/or wash their leg at this time. Sutures are removed after approximately 2 weeks.

One of the main benefits of operative intervention in tibial plateau fractures is the ability to prevent stiffness and retain range of motion of the knee.[2,16,22] Patients who were in a knee-spanning external fixator prior to definitive treatment are already at risk for loss of motion of the knee. It is therefore beneficial to begin passive and active range of motion immediately after definitive fracture fixation surgery. If there was no major damage to the extensor mechanism, physical therapy will start on postoperative day 1. Weight bearing and activity restrictions should be tailored for each patient individually, taking into account the fracture pattern, the stabilization used, the presence of other extremity injuries, and the patient's ability to mobilize safely. In general, toe-touch weight bearing is observed on the fractured limb for 6 to 8 weeks after surgery.

Author's Disclosure Statement

Dr. Dirschl reports he has receives grant/research support from EBI Medical Systems and is a consultant to Stryker. Dr. Del Gaizo reports no actual or potential conflicts in relation to this article.

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This paper will be judged for the Resident Writer's Award.