Tibial Plateau Fractures: Evaluation and Treatment

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Abstract

The goal of tibial plateau fracture management is a stable, well-aligned, congruent joint, with a painless range of motion and function. Minimally displaced stable fractures should be treated with protected mobilization. The treatment of displaced tibial plateau fractures, however, remains controversial. Surgical reduction and stabilization of displaced tibial plateau fractures, when indicated, requires careful evaluation of both the "personality" of the fracture and the soft-tissue envelope. The timing of surgery and the handling of the soft tissue in this region are critical to treatment success. After restoration of a congruent joint surface, bone grafting and buttress plating are usually needed to allow early range of motion and optimize treatment outcome.

J Am Acad Orthop Surg 1995;3:86-94

Tibial plateau fractures result from indirect coronal and/or direct axial compressive forces. Although historically these fractures usually occurred when the bumper of an automobile struck the lateral aspect of a pedestrian's leg, recent series have indicated that tibial plateau fractures are now most commonly the result of falls and motor-vehicle accidents.

Fracture-fragment size, location, and displacement are determined by the magnitude, direction, and location of the generated force, the bone quality, and the degree of knee flexion at the moment of impact. The interplay of varus stress and compression results in medial plateau fractures, while the combination of valgus stress and compression produces lateral fracture patterns. The prevalence of lateral plateau fractures is related to the valgus inclination of the anatomic axis and the usual lateral direction of the applied force.

Patient age and bone quality influence the resultant fracture pattern and associated ligamentous injury (Fig. 1). Young patients with strong, rigid bones typically develop split fractures and have a high rate of ligamentous disruption. With advancing age, the subchondral bone is less able to resist axial loading, and depression or split-depression fractures without ligamentous injury typically develop.

Diagnostic Evaluation

A tibial plateau fracture should be suspected whenever a patient presents with pain and tenderness about the knee after injury. These signs and symptoms may be localized to the fracture or may include the sites of ligamentous attachment. A hemarthrosis is often present. With significant bone or capsule disruption, decompression of the hemarthrosis into the surrounding soft tissue will occur.

One should note the neurovascular status, degree of swelling, and skin condition of the extremity. Popliteal, posterior tibial, and dorsalis pedis pulses must be palpated; if they are absent, Doppler studies should be performed. Although rare, the presence of an associated compartment syndrome must be considered. Presenting signs and symptoms include pain out of proportion to the injury, swelling, pain on passive stretching, pallor, pulselessness, hypesthesia, and motor weakness. Because clinical assessment is not entirely reliable, accurate evaluation may require direct measurement of intracompartmental pressure.

Any open wound must be examined to rule out an open joint injury. If the physician is not sure whether the wound communicates with the joint, at least 50 ml of saline should be injected into the knee away from the wound. Leakage of fluid from

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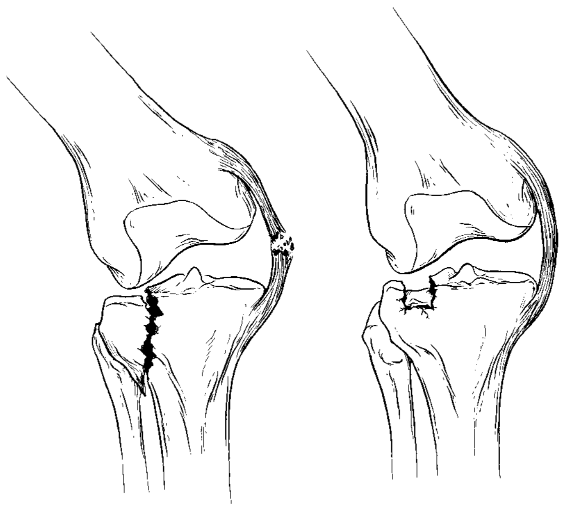

Fig. 1 **Left,** Patients with strong, rigid bone typically develop split fractures and have a high rate of ligamentous disruption. **Right,** With advancing age, the subchondral bone is less able to resist axial loading, and patients typically develop depression or split-depression fractures. As the bone compresses, the force is dissipated, thereby protecting the opposite collateral ligament from injury.

the wound confirms the diagnosis of an open joint.

Meniscal tears occur in as many as 50% of tibial plateau fractures, and associated ligamentous disruptions occur in as many as 30%. Tenderness and swelling over the medial collateral ligament suggest collateral injury.

Initial radiographs should include anteroposterior, lateral, 15-degree caudal (Fig. 2), and two oblique views. These five radiographs are known as the knee trauma series. One should analyze these films for articular depression, rim widening, shaft extension, and bone avulsions. The amount of condylar depression can be measured from the intact articular surface on a 15-degree caudal or lateral radiograph. Measurements taken from anteroposterior radiographs do not account for the slope of the tibial plateau and do not reflect the true depression.

Varus / valgus stress testing can aid in the identification of associated ligamentous disruption, but should be performed after static radiographic evaluation. Arthrocentesis of tense hemarthrosis followed by intra-articular lidocaine injection may allow a more accurate assessment of possibly injured ligaments. Significant widening of the opposite joint line will not occur with an isolated plateau injury. An increase in the width of the medial or lateral clear space by more than 1 mm (compared with the contralateral limb stressed in the same degree of flexion) is suggestive of a collateral ligament disruption. However, it still may be impossible to separate fracture instability from ligamentous disruption.

Comparison radiographs of the contralateral extremity are used in preoperative planning. Trispiral tomography and computed tomography with sagittal and coronal reconstructions are helpful in evaluating the degree of articular displacement. These studies are also excellent adjuncts to plain radiography in the preoperative planning of lag-screw placement, particularly when contemplating percutaneous fixation (Fig. 3). The role of magnetic resonance imaging is presently unclear; however, it can help detect meniscal and ligamentous injury associated with these fractures.

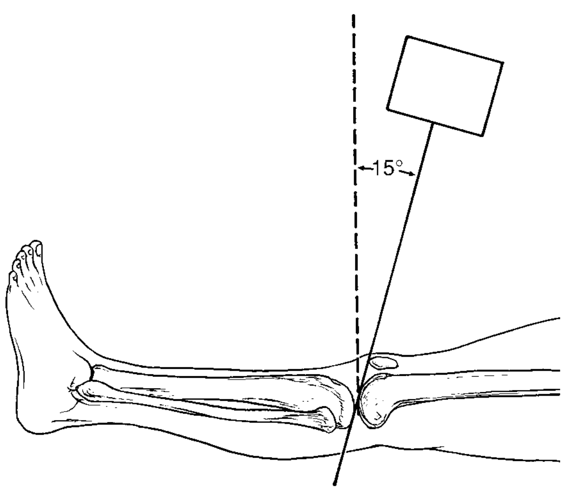

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Fig. 2 Schematic **(A)** and radiograph **(B)** depicting the 15-degree caudal radiographic view. This view takes into account the posterior slope of the tibial plateau and can be used to measure the amount of condylar depression.

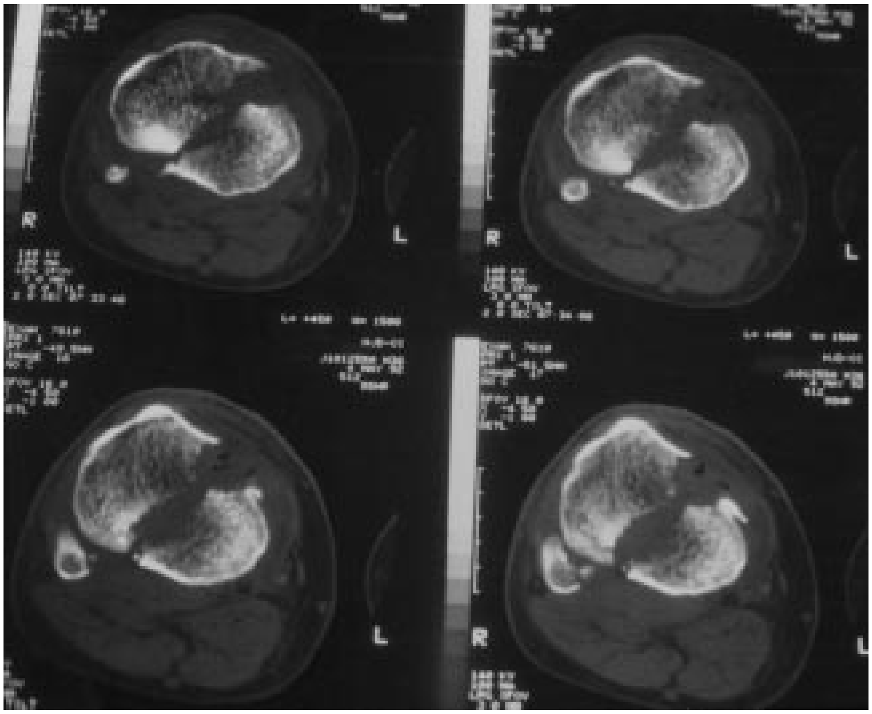


Fig. 3 Computed tomographic scans of a displaced tibial plateau fracture. Such a study is useful in planning lag-screw location and direction, particularly with use of indirect reduction.

Classification

The most widely accepted classification is that proposed by Schatzker[1] (Fig. 4).

Type I is a wedge (split) fracture of the lateral tibial plateau. The split fragment may be displaced laterally and distally. This fracture occurs in younger patients with strong subchondral bone. It carries a high risk of ligamentous disruption, and may be associated with the trapping of a meniscus in the fracture site.

Type II is a split-depression fracture of the lateral plateau. In this fracture, the femoral condyle first splits the condyle and then depresses the medial edge of the remaining plateau.

Type III is a pure central-depression fracture of the lateral plateau without an associated split. It is usually the result of a lower-energy injury in an older patient and carries a low risk of ligamentous damage.

Type IV is a fracture of the medial tibial plateau, usually involving the entire condyle. This fracture is often the result of a high-energy injury and may be associated with a traction lesion of the peroneal nerve.

Type V is a bicondylar fracture, which typically consists of split fractures of both the medial and lateral plateaus without articular depression.

Type VI is a tibial plateau fracture with an associated proximal shaft fracture. This fracture results from a high-energy injury, is often comminuted, and may be associated with popliteal artery disruption. Traction tends to distract the metaphyseal-diaphyseal fracture, rather than producing articular reduction.

Treatment Options

The specific indications for open and closed management of tibial plateau fractures remain controversial.[2,3] Some authors advocate nonoperative treatment for fractures that exhibit up to 1 cm of depression. Others accept only minimal displacement of the articular surface.[2] There is general agreement, however, that varus or valgus instability greater than 10 degrees (compared with the uninvolved knee) of the almost fully extended knee is an indication for operative intervention.[3]

The amount of articular displacement that results in instability is unknown. It is dependent on the fracture location and type and associated ligamentous disruption. Split fractures, in addition to disrupting the articular surface, involve the rim of the tibial plateau, and are therefore likely to be unstable to axial loading. Split-depression fractures are at an even higher risk for instability because of the depressed surface adjacent to the split component. Pure central-depression fractures are usually stable unless the depression involves the entire plateau, because the intact cortical rim provides varus / valgus stability. Plateau fractures that are associated with a tibial shaft fracture are usually not amenable to closed treatment, since traction often causes separation of the shaft component rather than reduction of the articular surface. Open tibial plateau fractures and those associated with a compartment syndrome or vascular insult require emergency surgical care.

Closed Management

Protected mobilization in a hinged cast brace should be used for minimally displaced, stable tibial plateau fractures. Isometric quadriceps exercises and progressive passive, active-assisted, and active range-of-motion exercises are

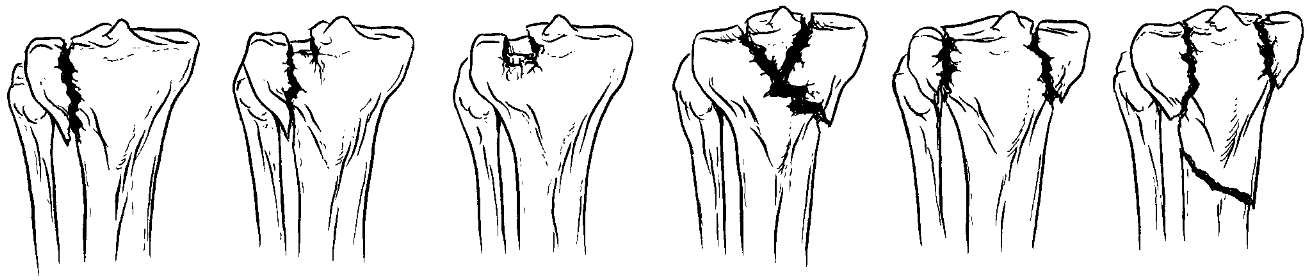


Fig. 4 The Schatzker classification of tibial plateau fractures. Type I is a wedge (split) fracture of the lateral tibial plateau. Type II is a split-depression fracture of the lateral plateau. Type III is a pure central-depression fracture of the lateral plateau without an associated split. Type IV is a fracture of the medial tibial plateau, usually involving the entire condyle. Type V is a bicondylar fracture, which typically consists of split fractures of both the medial and lateral plateaus without articular depression. Type VI is a tibial plateau fracture with an associated proximal shaft fracture.

allowed. Partial weight-bearing is recommended for 8 to 12 weeks, with full weight-bearing thereafter as tolerated. Unrestricted activities, including running, are generally not allowed before 4 to 6 months.

Surgical Management

One should understand the exact nature of the fracture before attempting any form of surgical intervention. Preoperative planning is essential for more complex injuries as it forces the surgeon to understand the "personality" of the fracture and mentally prepare an operative strategy. Radiographs of the contralateral extremity serve as templates. Traction radiographs often allow better visualization of individual fragments. All aspects of the reduction and fixation should be carefully planned to avoid technical pitfalls. The surgeon must also ensure that all needed equipment is available.

The timing of surgery is dependent on the soft-tissue conditions. Early postinjury swelling represents fracture hematoma. Within 8 to 12 hours, the soft tissues become edematous. Definitive surgery should be delayed to allow the swelling to subside and local skin conditions to improve. In high-energy tibial plateau fractures, particularly those resulting from an anterior blow to the leg, it may take 3 to 8 days for the soft tissues to normalize. Earlier operative intervention with incisions through compromised soft tissues is inadvisable and may result in a higher incidence of wound complications.

As an alternative to full-scale open reduction, recent publications have advocated the use of indirect methods to achieve a limited open reduction.[4,5] As proposed by Mast et al,[4] this is a more "biologic" approach, which preserves soft-tissue vascularity while still allowing adequate bone stabilization, early motion, and functional recovery.

As part of these more limited approaches, fluoroscopy is used to assess articular congruence rather than direct joint visualization. This approach is most useful in the treatment of split fractures (Schatzker types I, IV, and V). It is less sensitive in the assessment of depressed fragments. Radiographic visualization of a split-fracture fragment can be quite good on the image intensifier, but depressed fragments are often buried within the remaining plateau, creating a confluence of shadows. Image intensification will not detect associated meniscal injury but can be used to evaluate ligamentous injury with stress testing.

Arthroscopy is another effective, less invasive method of assessing fracture reduction.[6,7] Some investigators have advocated arthroscopic evaluation of even minimally displaced split fractures, since theoretically the meniscus may become trapped in the fracture line. Although sensitive for the evaluation of central depression and intra-articular pathologic changes, arthroscopy does not adequately assess the rim or the metaphyseal alignment. Arthroscopy is most useful in the treatment of central-depression fractures (Schatzker type III); it is not as helpful in more complex fractures. Furthermore, a potential danger of arthroscopic evaluation of tibial plateau fractures is compartment syndrome secondary to fluid extravasation. Therefore, surgeons attempting this technique should avoid high-pressure inflow and evaluate the compartments frequently during surgery.

Surgical Technique

Limited Open Reduction

The patient is positioned supine on a radiolucent operating table, and the ipsilateral anterior iliac crest is prepared for a possible graft. If arthroscopy is to be used, one may wish to flex the end of the table. The use of a tourniquet is optional.

In pure split fractures (Schatzker types I, IV, and V), where the fragment is displaced only medially or laterally, a tenaculum clamp can be used to achieve fracture reduction (Fig. 5, A). If the split fragment is also depressed, reduction can be accomplished using ligamentotaxis with the aid of a femoral distractor placed on the same side as the fracture (Fig. 5, B). Ligamentotaxis requires intact soft-tissue attachments to allow distraction of the remainder of the tibia, thus reducing the depressed condyle.

Bone grafting is not needed in pure split fractures, as reduction can be maintained using compression alone. In fact, a bone graft may actually prevent accurate interdigitation of the fracture fragments, precluding anatomic reduction. Once reduced, the fracture can be stabilized with the use of either screws or buttress plates, depending on patient age and bone quality.

In fractures with central depression (Schatzker type III), the metaphyseal cortex can be fenestrated, and the depressed fragment can be elevated *en masse* from below with the use of a bone tamp (Fig. 6). Elevation of depressed fracture fragments creates a metaphyseal defect, which should be filled with a spacer to prevent articular collapse. Cancellous iliac bone grafts have been used for this purpose because cancellous bone can be compacted into the shape of the defect, offers structural support, rapidly revascularizes, and has osteoinductive and osteoconductive properties. Corticocancellous blocks can be used when greater structural support is required. One disadvantage of the use of an iliac-crest bone graft is that it may add considerable morbidity to the procedure. Recent reports have supported the use of allografts and synthetic bone substitutes as effective spacers in the treatment of tibial plateau fractures. Once grafted, percutaneously placed 6.5- or 7.0-mm cancellous lag screws can be inserted parallel to the joint surface immediately below the graft to act as a supporting beam.

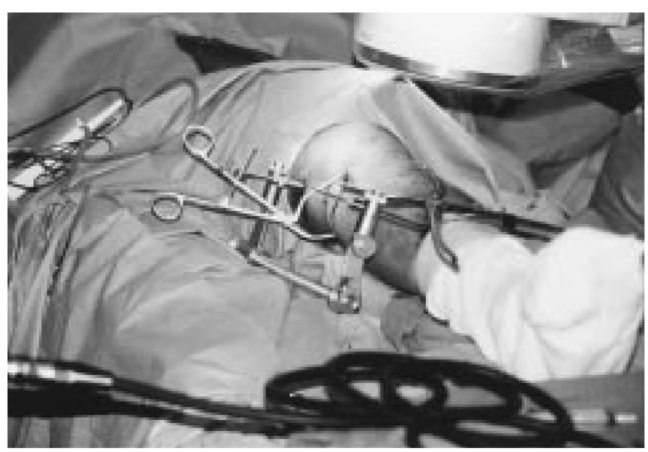
Open Reduction

Open reduction should be considered for the treatment of split-depression (Schatzker type II) fractures and those with metaphyseal-diaphyseal dissociation (Schatzker type VI fractures). This approach offers the best chance for an anatomic joint reduction with axial alignment and stable fixation, thus allowing an early functional range-of-motion program.

The operative procedure should be performed under image intensification on a radiolucent operating table. Fracture reduction can be facilitated with ligamentotaxis performed with use of a femoral distractor. The distractor should be placed on the ipsilateral side of the tibial plateau fracture, with one pin in the femoral condyle and the other in the middle to distal portion of the tibia, well away from the anticipated distal end of the implant. In type VI fractures, bilateral femoral distractors may be required.

The plateau should be approached through a midline incision in anticipation of the possible need for future reconstructive surgery. A full-thickness skin flap including the underlying subcutaneous tissue is raised on the side of the injury, usually the lateral plateau, but should not be raised

A



B

Fig. 5 Techniques of treating split fractures. **A,** A split tibial plateau fracture reduced with a large tenaculum clamp. **B,** Use of the femoral distractor and percutaneous tenaculum clamps to achieve fracture reduction.

Fig. 6 Use of a percutaneously placed bone tamp to elevate a depressed articular fragment.

any farther than necessary to visualize the fracture. The other flap is lifted only if open reduction of that condyle is required. The crural fascia over the tibia and the iliotibial band are then split vertically and retracted. A horizontal arthrotomy is made through the coronary ligament just below the meniscus, with care taken to preserve the meniscus and sufficient ligament on the tibia for later repair. With tibiofemoral distraction and proximal retraction of the meniscus, the surgeon should have an unobstructed view of the knee joint. The joint should be examined for evidence of pathologic changes in the meniscus, since tears have been reported in as many as 50% of tibial plateau fractures. Lesions that are not appropriate for repair should be excised. Peripheral tears should be repaired by suturing just before closure.

If joint visualization is not adequate, extending the incision, including partial sectioning of the iliotibial band, may be all that is required. If the view is still inadequate, Z-plasty of the patellar tendon should be considered. This is usually needed only in type VI fractures and is performed by longitudinally dividing the patellar tendon, leaving half of the tendon attached to the tibial tubercle and the other half attached to the distal patella. The tendon can be repaired using nonabsorbable suture and can be protected with a tension band placed either through or superior to the patella and through the proximal tibia. Before performing Z-plasty of the patellar tendon, however, one must first ascertain that a fracture of the tibial tubercle does not exist. If it does, the fractured tubercle should be lifted to create the necessary visualization. It may be fixed back with screws or wire at the conclusion of the procedure.

Schatzker Type II Fractures

In Schatzker type II fractures, the split fracture line should first be identified. Exposure of the depressed articular fragment is accomplished by opening up the metaphysis like a book at the split fracture line and hinging the peripheral fragments outward, preserving their soft-tissue attachment. Depressed articular fragments should be elevated from below *en masse* as large cancellous blocks in order to prevent articular surface fragmentation. This can be achieved by using a bone tamp or elevator, working through the split component. At this point, the surgeon has two choices: (1) bone grafting of the metaphyseal defect, followed by reduction and provisional stabilization of the split component; or (2) reduction and provisional stabilization of the split fragment, followed by bone grafting. The latter approach requires that the graft be inserted through a separate metaphyseal window.

Definitive stabilization is performed using 6.5- or 7.0-mm cancellous lag screws inserted parallel to the joint, followed by metaphyseal buttress plating. The choice of plates is dependent on the degree of cortical comminution, and may be as simple as a washer (one-hole plate), two-hole plate (oriented either horizontally as a double washer or vertically as an antiglide plate), a T or L buttress plate, or a Burri plate. The Burri plate, precontoured to the lateral tibial plateau, is thin proximally with multiple round holes for placement of cancellous screws and has standard self-compressing holes distally for placement of cortical screws. The surgeon should select the plate that offers stable fixation yet minimizes bulk to prevent complications with wound closure. If a large plate is selected, the cancellous lag screws should be inserted through its proximal holes.

Schatzker Type VI Fractures

Most Schatzker type VI fractures can be reduced and stabilized without creating large medial and lateral soft-tissue flaps. The medial plateau fragment is usually large and extra-articular, and can be used as a building block on which to attach the lateral fragments and shaft. When the intra-articular fracture component extends into the medial plateau, however, reduction and stabilization of this fragment may require a medial exposure.

After articular reconstruction, Schatzker type VI fractures require shaft stabilization. This can be accomplished, depending on fracture configuration, with use of (1) a single plate, (2) double plates, (3) one plate and a contralateral external fixator, or (4) a thin wire fixator.

When plates are used, the fracture pattern determines implant choice (Fig. 7). If the fracture line exiting the cortex opposite the plate is transverse, a single plate will suffice. Oblique fracture lines exiting the cortex opposite the plate require the use of an additional small antiglide plate or external fixator to neutralize shear forces and prevent varus or valgus displacement, depending on the plate location. If a second plate is needed, a thin semitubular or one-third tubular plate should be inserted with minimal dissection.

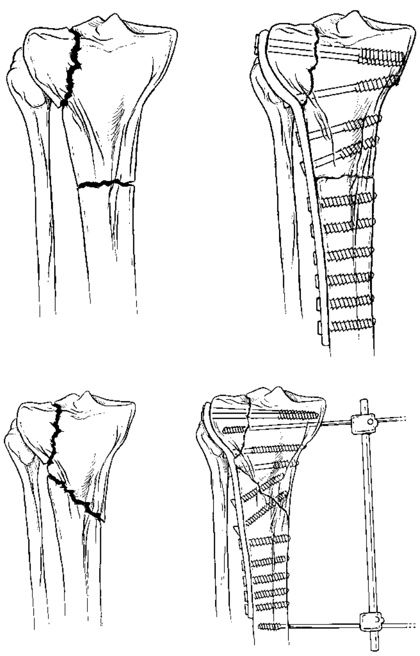


Fig. 7 The need for adjunctive fixation of Schatzker type VI fractures is determined by the fracture pattern. **Top,** If the fracture line exiting the cortex opposite the plate is transverse, a single plate will suffice. **Bottom,** Oblique fracture lines exiting the cortex opposite the plate require the use of an additional small antiglide plate or an external fixator to neutralize shear forces.

To avoid creating a stress riser, one should take care that the two plates do not end at the same level.

If the shaft component is extremely proximal, a thin wire fixator should be considered. For this type of treatment, the articular surface should still be reconstructed with lag screws. The thin wires should be placed 10 mm below the joint surface so that they cannot penetrate the synovial recess, which overhangs the plateau. If the recess is penetrated, a low-grade pin-track infection can contaminate the entire knee.

Wound closure is performed over suction drains. If the wound cannot be closed without tension, it is preferable to leave the incision partially open and covered with a sterile dressing, with delayed primary closure at 48 hours.

Postoperative Care

Postoperatively, the knee should be protected in a hinged knee brace, and a program of continuous passive motion should be initiated. If stable fracture fixation cannot be achieved, early motion can be instituted in conjunction with skeletal traction. Physical therapy consists of passive, active, and active-assisted range-of-motion exercises and touch-down weight-bearing. Patients with polytrauma and multiple fractures are treated according to the limitations produced by their concomitant injuries. Progressive weight-bearing is dependent on fracture healing. When adjunctive external fixation is used, the frame may be removed after 6 to 8 weeks. Similarly, in patients with thin-wire circular fixators, dynamization and / or progressive weight-bearing may be started at 6 to 8 weeks, progressing to full activity at 3 to 4 months.

Ligamentous Injury

The significance of associated ligamentous disruption and the need for repair remain controversial.[8,9] Although as many as 30% of tibial plateau fractures have associated ligamentous injuries, it is not known which, if any, will result in postoperative instability. Proponents of operative treatment of ligamentous disruptions argue that the collateral ligaments are essential for maximal joint function, but there is less enthusiasm for acute operative treatment of associated cruciate disruptions. Proponents of nonoperative treatment of associated ligamentous disruptions argue that collateral ligament repair requires additional soft-tissue dissection and that no significant collateral instability was found in large series of tibial plateau fractures treated without collateral ligamentous repair. In addition, there is overwhelming evidence that isolated medial collateral ligament injuries heal satisfactorily without surgical repair.

Avulsion fractures involving the intercondylar eminence should be stabilized. Reattachment of the cruciate ligaments with their attached bone allows early full range of motion.

Open Fractures

At the time of initial irrigation and debridement, limited internal fixation of the articular surface (Fig. 8) may be performed to prevent articular malunion if infection or associated injuries preclude further surgery before fracture healing occurs. If additional stability is required, temporary external fixation can be placed across the knee. Alternatively, a definitive thin-wire external fixator may be applied. Cast treatment or

Fig. 8 Limited internal fixation of an open tibial plateau fracture with adjunctive external fixation placed across the knee.

traction may complicate the postoperative care of an extremity that has an extensive soft-tissue injury.

Complications

Infection following tibial plateau fracture occurs in as many as 12% of cases and may be related to either the initial fracture status or the surgical intervention. Skin slough, a risk factor for later infection, is a particular concern in the proximal tibial region because of poor soft-tissue coverage. The major predisposing factors for skin slough are poor surgical timing, improper soft-tissue handling, and the use of bicondylar implants (medial and lateral plates).

Loss of fixation may be prevented by proper preoperative planning. Stabilization of tibial plateau fractures with lag screws alone should be attempted only in patients with good bone quality and noncomminuted fractures. Fractures with metaphyseal-diaphyseal dissociation and all fractures in osteopenic bone require buttress-plate fixation. Bone grafting should be performed in all depressed fractures.

Posttraumatic arthrosis may occur as a result of cartilage damage from the initial injury or can be related to residual joint incongruity. Meniscal preservation is important to prevent excessive load-bearing by the underlying plateau. Some loss of joint motion may occur secondary to periarticular soft-tissue injury and can be compounded by prolonged immobilization. Rarer complications include popliteal artery laceration, peroneal neuropathy (following either surgery or casting), avascular necrosis, malunion, nonunion, and compartment syndrome.

Results

Most authors agree that minimally displaced tibial plateau fractures do well with nonoperative treatment, and most report 90% good to excellent results. It is difficult to evaluate the results of treatment of displaced tibial plateau fractures since no universally accepted classification scheme, surgical indications, or follow-up grading system exists. In addition, a patient may have a good clinical result despite abnormal radiologic findings because the lateral meniscus bears almost the entire load carried by the lateral plateau.[10] Conversely, patients may complain of pain suggestive of degenerative joint disease without significant radiologic changes.

Schatzker et al[1] reported a series of 70 tibial plateau fractures with an average follow-up of 28 months. Those fractures treated with open reduction and internal fixation, elevation of the plateau *en masse,* bone grafting, and early motion had an 89% rate of acceptable results. Savoie et al[8] reported satisfactory results in 87% of 52 operatively treated tibial plateau fractures at an average follow-up of 24 months. Porter[11] reported 96% acceptable results in fractures with less than 10 mm of depression that were treated with an early range-of-motion program, but only 47% acceptable results in fractures with more than 10 mm of depression that were treated with early motion; 80% of the latter fractures had acceptable results with open reduction, internal fixation, and bone grafting. Jennings[7] treated 21 tibial plateau fractures with arthroscopically assisted reduction; 85% had a good result at 1- to 5-year follow-up. Lansinger et al,[12] using clinical instability of the nearly extended knee joint as the main indication for surgical treatment, reported 90% good to excellent results in 102 patients followed up for an average of 20 years.

Summary

The specific indications for open and closed management of tibial plateau fractures remain controversial. Minimally displaced stable fractures should be treated with protected mobilization. Surgical reduction and stabilization of displaced tibial plateau fractures, when indicated, requires careful evaluation of both the fracture and the soft-tissue envelope. The timing of surgery and the handling of the soft tissue in the region are critical to success. After restoration of a congruent joint surface, bone grafting and buttress plating are usually needed to allow early range of motion and optimize treatment outcome.

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