Summary
Intra-articular fractures of the proximal tibia present a wide spectrum of injury patterns with associated soft tissue injury. The last two decades have seen the techniques of management evolve from extensive open reduction and rigid internal fixation to arthroscopy-assisted minimal invasive surgery (MIS) and biologically benign internal fixation. The ultimate aim is to prevent the occurrence of late degenerative arthritis. This could be achieved in selected patients using minimal invasive surgery, which offers the advantages of better visualisation and management of intra-articular soft tissue injuries, confirmation of fracture reduction viewed from the joint surface, faster rehabilitation and fewer wound complications.

Introduction
Tibial plateau fractures present a wide spectrum of injuries with a range of fracture patterns involving varying degrees of joint surface depression and displacement. The tibial articular surface slopes approximately 10° anterior to posterior and the lateral tibial articular surface is higher and dome shaped when compared to the medial surface. The lateral meniscus is broader and covers a larger portion of the lateral tibial plateau than does the medial. The majority of the fractures affect the lateral tibial plateau (55–70%) whilst 10–23% of reported series have isolated medial tibial plateau fractures.1 There is a high incidence of associated intra-articular soft tissue injuries with both. With the increasing use of MRI scans and arthroscopy after acute tibial fractures, meniscal tears are now being reported in 35–91% of fractures and cruciate ligament tears are reported in 15–77% of tibial plateau fractures.2–6 In Schatzker type II fractures, the presence of depression greater than 6 mm and fracture displacement greater than 5 mm is associated with an 83% incidence of lateral meniscal tears.7 The adequacy of fracture reduction and presence of soft tissue injuries relate to the long-term functional outcome and incidence of late arthritis.8–10 Good long-term results have been achieved with open reduction11 but there is a higher risk of imperfect reduction,12 wound complications and stiffness.13 Arthroscopy-assisted minimal invasive surgery has been shown to achieve similar results with fewer wound complications and faster rehabilita-

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Evaluation

History: Understanding the mechanism of injury and the fracture personality is important in planning the management of these fractures. Fractures of the tibial plateau occur with varus or valgus forces coupled with strong axial loading in the range of 1600–8000 lb.\(^\text{18}\) The majority of lateral tibial plateau fractures are secondary to low to medium energy injuries, whilst medial plateau and bicondylar fractures happen with high-energy injuries.

Examination: It is important to assess the soft tissue status, neurovascular injuries and the extensor mechanism. It is important to look for collateral ligament tenderness and gently assess stability. A lot of information is also obtained by examination under anaesthesia prior to surgery and also after fracture stabilisation.

Investigations

In addition to knee radiographs, CT scans and/or MRI scans can offer valuable information about the injuries. The scans provide information about the extent of displacement of any split, the size and location of any depression, rim displacement, tibial spine or tuberosity avulsions, fibular fracture, meniscal tears and ligament injuries.

15° caudal view radiographs or fluoroscopy images are helpful. The axial slices from a CT scan are more helpful in assessing the size of the depressed fragment and planning the placement of screws. Routine MRI scans for Schatzker types I–III are not necessary, as long as the surgeon performs an arthroscopy on all these knees. Midsubstance ACL injuries, even if diagnosed prior to surgery, are treated with rehabilitation and appropriate delayed reconstruction.

Classification

The most widely used system is the Schatzker classification.\(^\text{19}\)

(1) Type I—Lateral split fracture—the bone quality is usually good and these fractures are amenable to percutaneous fixation.
(2) Type II—Lateral split depression fracture— intra-articular soft tissue injuries are common.
(3) Type III—Lateral isolated depressed fracture—usually lower energy.
(4) Type IV—Medial plateau fracture—high-energy injury. Commonly associated with ligamentous and neurovascular injuries.
(5) Type V—Bicondylar fracture—high-energy. Avulsion fractures and neurovascular injuries must be assessed.
(6) Type VI—Bicondylar fracture with metaphyseal diaphyseal dissociation. Soft tissue envelope could be compromised.

Goals of surgery and treatment planning

The non-operative treatment of these fractures is limited to patients who are very poor surgical candidates and those with a very small area of central depression, with less than 5 mm depression, and an intact rim.

The aims of surgical treatment are to obtain anatomical reduction, restore the mechanical axis, achieve stable internal fixation and regain early joint movements.

The role of minimal invasive surgery

Minimal invasive surgery plays a key role in almost all tibial plateau fractures. Arthroscopy-assisted surgery is useful in the most common fracture types I–III. In the high velocity injuries, arthroscopic surgery poses significant risks of fluid extravasation, hence minimal invasive fixation alone with screws and external fixators is favoured.

Arthroscopy—Arthroscopy improves the visualisation of intra-articular soft tissue injuries (Fig. 2). It is synergistic with the C arm in confirming fracture reduction and guiding the placement of screws. Arthroscopy also facilitates fracture reduction, as it is easier to visualise and clear any soft tissue interposed at the fracture gap. Using the tibial guide, a guide wire can be placed at the centre of the depression. It is also technically easier to repair posterior meniscal tears with arthroscopy than using open techniques (Fig. 2).
Fracture reduction—Corkscrew tip guide pins or threaded guide wires through small stab incisions can be used to joystick fracture fragments. Large pointed bone clamps are also useful for fracture reduction. After placing a guide wire at the base of the depressed fragment, the fracture can be elevated with combined fluoroscopy and arthroscopy control.

Fixation—Percutaneous raft screws, antiglide plates and LISS plates can be used to fix the fracture. A bio-cortical interference screw could also be placed in the metaphyseal core to avoid any delayed subsidence of the bone graft.

Preoperative planning
A three-dimensional understanding of the fracture, including the size and amount of depression and orientation of the fracture split, is necessary. The displaced split lateral plateau also produces lateral malalignment.

If the overlying soft tissue envelope is not compromised, surgery is best performed early (24–72 h) to facilitate easier indirect reduction.

The degree of osteopenia and extent of depression will help decide the need for bone grafting or the use of bone graft substitutes. Fixation can usually be achieved by using multiple raft screws ± antiglide plate and for the more complex injuries using the LISS plate.

Surgical technique
Examination under anaesthesia: This is performed before the leg holder is applied in the anaesthetic room and also after the fracture is reduced and fixed.
Theatre set-up: The patient is supine and the affected limb is placed in an arthroscopy leg holder with tourniquet in place. The hip is slightly abducted with the patella facing about 20° externally. This is to enable the C arm to clear the opposite leg when it comes from the ipsilateral side and swings underneath for a true lateral view. If autogenous graft is required then the iliac crest needs to be prepared. The arthroscopy monitor is placed on the contralateral side.

Arthroscopy: Other than the high velocity injuries with significant soft tissue damage, or when there is a severely displaced split, it is preferable to start with a diagnostic arthroscopy.

The use of the powered 4.5 mm synovator blade to clear any clots or haemarthrosis increases the speed of the surgery. The author initially starts with the standard anterolateral and anteromedial portals then subsequently swaps the arthroscope to the anteromedial portal. A further inframeniscal lateral portal could be used to obtain better visualisation. The goldfinger meniscal retractor set (Arthrex, Inc., Florida) may be used.

Soft tissue management: Posterior meniscal tears are easier to repair using the arthroscope with all-inside techniques. The more common anterior third meniscal tears are repaired through mini-open outside-in technique. Anterior cruciate avulsion fracture can also be reduced and fixed arthroscopically using either cannulated screws or a trans-tibial suture technique. MCL injuries are managed in a hinged knee brace.

Fracture reduction:

(a) Type I—Articular gap is reduced using a large pointed reduction forceps placed perpendicular to the fracture line. If there is a step then the fragment is manipulated using a threaded guide wire or cork-screw tip guide pin (Arthrex, Inc., Florida).

![Figure 3](image-url) (a) Case 2—CT images demonstrating depressed segment. (b) Case 2—arthroscopic views before and after reduction. (c) Case 2—after fixation.
(b) Type II—Using the ACL tibial guide, a guide wire is placed just beneath the centre of the depressed fragment. A core reamer is used to take an 8–10 mm core of metaphyseal bone up to 5 mm beneath the fragment. Then this core along with bone graft/bone graft substitutes are gently tapped up using angled bone tamps to elevate the depressed fragment. Both arthroscopy and fluoroscopy help in confirming the reduction. The split fragment is then elevated and reduced as mentioned for Type I (Fig. 3a–c).

(c) Type III—The technique is very similar to that used to elevate the depressed fragment mentioned above.

Fracture fixation: Guide pins for cannulated raft screws are inserted lateral to medial, through stab incisions, perpendicular to the plane of fracture at the subchondral level. The bone tamp is held in position until the guide wires are in place. Multiple cannulated screws are used to achieve fixation in most circumstances. Once bone graft substitute has been packed into the cylindrical tunnel, an angled biocortical interference screw (Arthrex, Inc., Florida) is placed flush on to the tibial cortex to support the graft. To further support the split fracture, an antiglide screw with washer or plate could be used. The LISS plate could be used in more severe split depressed fractures, bicondylar fractures or if there is poor bone quality.

Postoperative management

Pain relief is achieved through a femoral nerve block and intra-articular infiltration of local anaesthetic agent. In most situations, the author uses continuous passive mobilisation over the first 48 h and the patients mobilise non-weight bearing with a hinged knee brace for the first 6 weeks. If there was more posterior depression or comminution, flexion is restricted to 90° but it is important to regain full extension as soon as possible. After 6 weeks the patients commence progressive weight bearing and should aim to achieve full flexion.

Results

ARIF

There are no prospective randomised studies comparing open versus arthroscopic techniques for management of tibial plateau fractures. Fowble\(^\text{12}\) retrospectively compared the two techniques for local compression and split compression fractures. The results were superior in the ARIF group with better anatomical reduction. There was also a significant reduction in hospital stay (5.36 vs. 10.27 days).

There are many reports of ARIF providing anatomical reduction without long-term loss of fixation and excellent results at follow-up.\(^\text{6,16-17}\) Young patients with sporting injuries have also been reported to have 92% good to excellent results with ARIF.\(^\text{16}\) Eighty-four per cent of these patients returned to full sporting activity. Cassard\(^\text{15}\) performed a clinical and radiological assessment of 19 tibial plateau fractures treated arthroscopy assisted with an average follow-up of 32.7 months. The average knee society score was 94.1 for the knee and 94.7 for function.
no secondary bony depression. They also noticed 8 meniscal injuries at arthroscopy.

The lesions at injury (cartilage, menisci and ligaments) and the late condition (articular incongruity, axial abnormality and instability of the knee) influenced the functional score and the importance of late arthritis. Instability is a major cause of unacceptable results in tibial plateau fractures. MRI scans have shown an 80% incidence of meniscal tears and 40% complete ligament tears even in undisplaced tibial plateau fractures and in displaced fractures 91% meniscal tears and 77% complete ligament disruptions. Similarly arthroscopy for tibial plateau fractures has shown 57% meniscal injuries and 25% ACL injuries in 98 knees. Bennett reported 20% meniscal injuries and 10% ACL tears and found these commonly associated with Types II and IV injuries. Van Glabbeek found 35% meniscal lesions in 20 arthroscopies.

**MIS fixation**

Limited internal fixation with percutaneous screws has been found to be effective in the fixation of tibial plateau fractures, with no reports of late subsidence. Simpson and Keating compared 13 tibial plateau fractures treated with open reduction and bone grafting with a similar group of well matched fractures treated with minimal internal fixation and injectable calcium phosphate bone cement. They found more favourable anatomical results in the MIS group at 1-year follow-up. A biomechanical comparison of various fixation methods for Type II fractures shows that 3.5 mm raft screws with an antiglide plate provided superior longitudinal and depression stiffness than the conventional large fragment buttress plates.

The LISS plating system provides a minimally invasive fixed angle construct and Cole reports 89 tibial plateau fractures treated using this system achieving 97% stable fixation. This allows minimal invasive management of complex bicondylar tibial plateau fractures allowing early range of knee motion with favourable clinical results.

**Bone graft substitutes**

Biomechanical comparative studies have shown that bone graft substitutes can prevent fracture subsidence better than autograft. The treatment of centrally depressed tibia plateau fractures with calcium phosphate cement provides equivalent or better stability than conventional open reduction and internal fixation in pure depression tibial plateau fractures and provides the option of faster rehabilitation and earlier weight bearing.

**Complications**

Very few complications have been reported that are specific to arthroscopy-assisted minimal invasive surgery. There is a risk of fluid extravasation and compartment syndrome during arthroscopy, hence it is important to use gravity inflow and good outflow. This is more of a risk in the high velocity injuries. Cassard reported one case of septic arthritis.

**Summary**

Arthroscopy is a useful aid in the management of lower energy tibial plateau fractures. Meniscal tears and ligament injuries are commonly associated with tibial plateau fractures and the use of MRI scans and arthroscopy has increased their diagnosis. Understanding the fracture anatomy is a prerequisite to minimal invasive techniques. Theatre set-up is important when using both arthroscopy and fluoroscopy during surgery. Gravity inflow with adequate outflow is important during arthroscopy. The placement of a guide wire under the depressed fragment is performed with arthroscopy assistance whilst elevation of the depressed fragment is more fluoroscopy assisted, the arthroscope confirming the reduction.

Screw placement has to be perpendicular to the fracture plane and both axial images of CT scans and the arthroscope aid during this step. Multiple percutaneous screws offer good fixation and depression stiffness.

**Learning points:**

1. Examination includes assessment under anaesthesia before and after fracture fixation
2. Displacement of the split greater than 5 mm is highly associated with lateral meniscal tears
3. During arthroscopy, use gravity inflow only to avoid extravasation of fluid and use an outflow cannula
4. Preoperative planning using axial images essential for correct screw placement

**References**