Tibial Condyle Fractures: Current Concepts of Internal Fixation

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Abstract

Intraarticular Proximal Tibial fractures pose a great challenge, due to its wide variety of complex injury patterns and hence have a varied management protocol. There are various classifications and treatment options described in literature which do not give any guidelines on surgical approach and management. This review article is an attempt to provide a surgical protocol of treatment of these complex challenging fractures keeping in mind the mechanism of injury, understanding of the fracture pattern, surgical approach and column specific reconstruction.

Keywords: Tibial, Condyle.

Introduction

Intraarticular proximal tibia fractures pose a great challenge in terms of its broad spectrum of presentations and management protocols. The correct identification and classification of injury patterns aid the surgeon in providing optimal surgical planning for the injury. Literature describes multiple classifications for various injury patterns based on the position of the limb, the direction of the force, and the fracture patterns based on the combination of the two[1][2]. The fracture lines and zones of comminution help define the surgical approach and fixation techniques. Despite the multiple classifications and approaches for treatment, the primary aim is to restore the native joint alignment. These fractures if inadequately reduced may lead to poor outcomes and ultimately post traumatic osteoarthritis[1][3][4]. The aim of this review article is to look at evidence on planning surgical approaches and current fixation and management techniques for proximal tibia fractures.

Epidemiology

Intraarticular proximal tibia fractures are very common and account for approximately 2% of all adult fractures [5][6]. They have a bimodal age distribution. High velocity injuries in younger individuals and low velocity injury in the older populations as a result of a trivial fall on an osteoporotic bone. These fractures have high morbidity, they are commonly associated with compartment syndrome, vascular and neurological injuries[7][8]. It is also extremely important to identify signs of associated injuries and plan the timing of surgery accordingly.

Surgical Bony Anatomy

The restoration proximal tibial anatomy is of great importance, hence a better understanding of this is very crucial. The articular surface is divided into medial and lateral surfaces divided by an intercondylar eminence. The lateral tibial condyle is more convex as compared to the medial which is concave. The medial condyle is also slightly denser than the lateral. It is because of this convexity and less dense nature of the lateral condyle, there are different types of fractures seen namely split fracture, articular depression and wedge fracture, where as in the medial condyle a high velocity shear force causing a split wedge fracture is seen.[3][9]

The articular surface of the proximal tibia posterior slope is 7 to 9 degree (posterior tibial slope angle-pTSA) (Fig.1a) in lateral view and the medial slope is at a 87 degree varus angle (medial proximal tibial angle- mPTA) (Fig.1b) in the Antero-Posterior (AP) view[2][9]. With the combination of forces, these angles are altered during an intra-articular injury and hence needs to be restored[10].

Common Classifications

1) Schatzker classification

This was first described by Schatzker et al in 1970[11], an Xray based classification (Fig.2) and has been widely used. Type 1-3 are purely of lateral condyle and occur due to low energy trauma and type 4-6 (includes fracture dislocations) occur due to high energy trauma and are associated with ligament instabilities and

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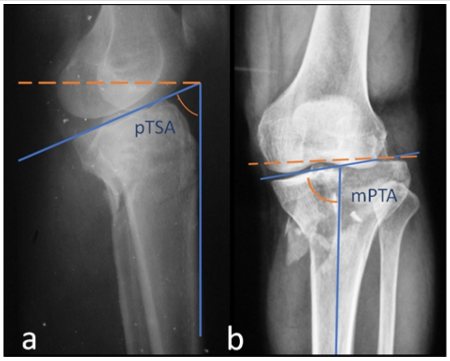


Figure 1: (a) Posterior tibial slope angle (pTSA), defined as the angle created by the tibial plateau and the long axis of the tibia in the sagittal plane. Either medial or lateral pTSA can be measured on sagittal CT slices; (b) Medial proximal tibial angle (mPTA), defined as the angle created by the medial tibial plateau surface and the long axis of the tibia in the coronal plane.

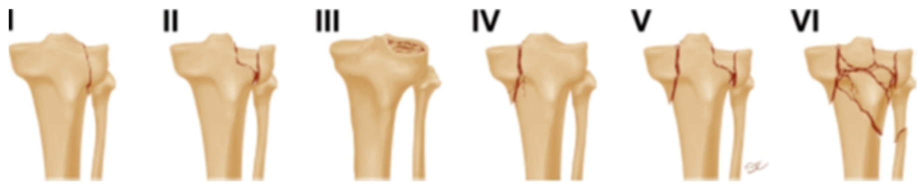


Figure 2: The Type 1 is a pure cleavage fracture, Type II is cleavage combined with depression, Type III Pure central/lateral condyle depression, Type IV Fractures of Medial condyle, Type V Bicondylar fractures, Type VI Tibial plateau fractures with dissociation of the tibial Metaphysis and Diaphysis[8][11].

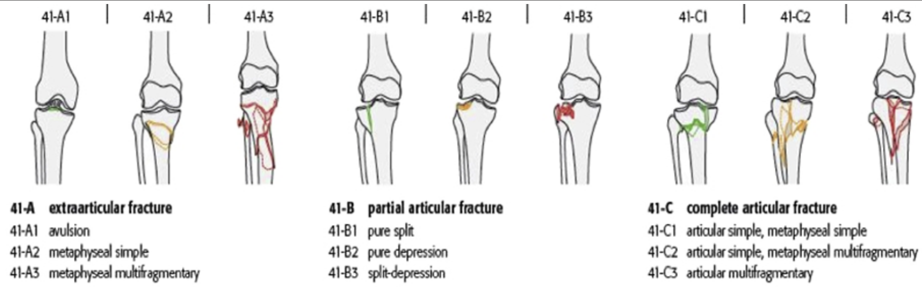


Figure 3: Type A are extraarticular fractures, type B are partial articular and type C are complete articular fractures with 3 subtypes in each type.

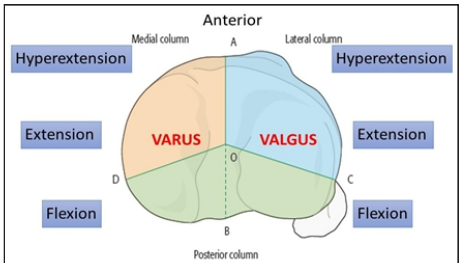


Figure 4: Three-column classification according Luo et al: Classification is made on transverse computed tomographic sections. The knee center (O) is connected with the anterior tuberosity (A), the posterior sulcus of the tibial head (B), the most anterior point of the fibular head (C), and the posterior medial ridge of the proximal tibia (D). The posterior column can be divided into a lateral and medial column indicated by the (OB) line

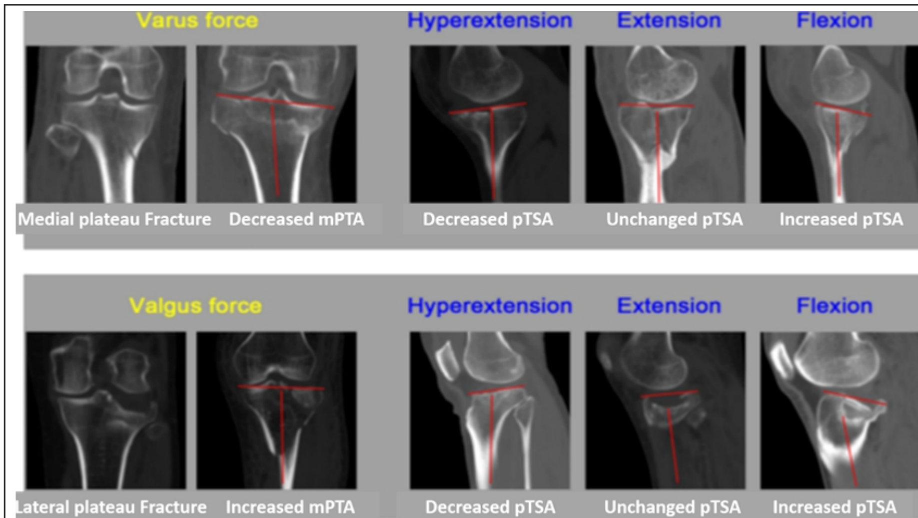


Figure 5: Tibial plateau fracture injury mechanism in 2-Dimensional CT images. mPTA- Medial proximal tibial angle, pTSA- Posterior tibial slope angle[13]

neurovascular complications. Schatzker et al in their original article, recommended that the primary indication for surgery was joint instability and not the degree of articular depression[11].

2) AO/OTA Classification

The AO/OTA classification (Fig.3) was published in 1996 and has been regularly used in various scientific studies and publications. Number 4 is given for the tibia and 1 is given for the proximal end of the tibia.

3) Luo Classification - Three Column Concept

With use of CT scans and 3-D reconstruction technology, for better understanding of the fracture, Luo et al devised a three Column Concept (TCC) in 2010[12], in which the plateau was divided into medial, lateral and posterior columns (Fig.4) based on the mechanism of injury (MOI) and position of the limb. Later, in 2016 it was updated to 4 columns, the updated TCC (uTCC) with the posterior column further divided into posteromedial and posterolateral. This classification also explained three types of forces acting on the proximal tibia which led to various fracture patterns(Fig.5). The deforming forces act on three axes: [2][13](Fig.5)

- In the sagittal plane - Flexion, Extension and Hyperextension
- In the coronal plane - Varus and Valgus
- In the axial plane (rotational forces) - Internal rotation and External rotation

Luo Classification - uTCC (Updated Three Column Classification)[2]

Zero-Column fracture

In this type of fracture, the outer rim of the condyles are intact, whereas the

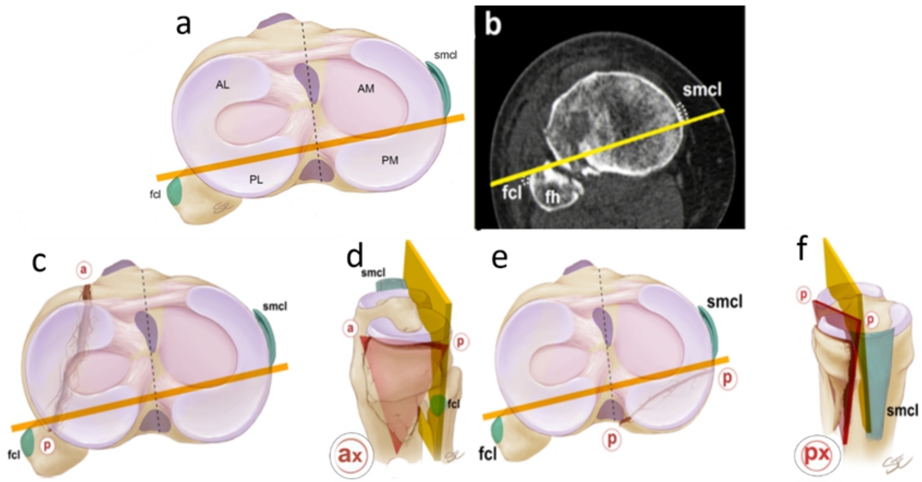


Figure 6: Anatomical topography of a split wedge fracture describing Modified Schatzker Classification[8] a) Axial view of the tibial plateau showing the anatomical quadrants of the tibial plateau. The virtual equator, shown in yellow, divides the tibial plateau into two halves, anterior and posterior hence giving four anatomical quadrants. Anterolateral(AL); anteromedial(AM); posterolateral (PL); posteromedial (PM), b) Axial view of a 2-D CT scan dividing plateau into anterior and posterior, c)The fracture line intersects the rim at two points, one being anterior "a", and the other one posterior to the equator "p". Fibular collateral ligament (fcl); Superficial medial collateral ligament (smcl), d) The lateral view of proximal tibia showing the fracture at the metaphysis exiting anteriorly ax, e) The fracture line bisects the rim twice posteriorly, namely "p" and "p", e)The fracture exiting posteriorly-px in the metaphysis[8]

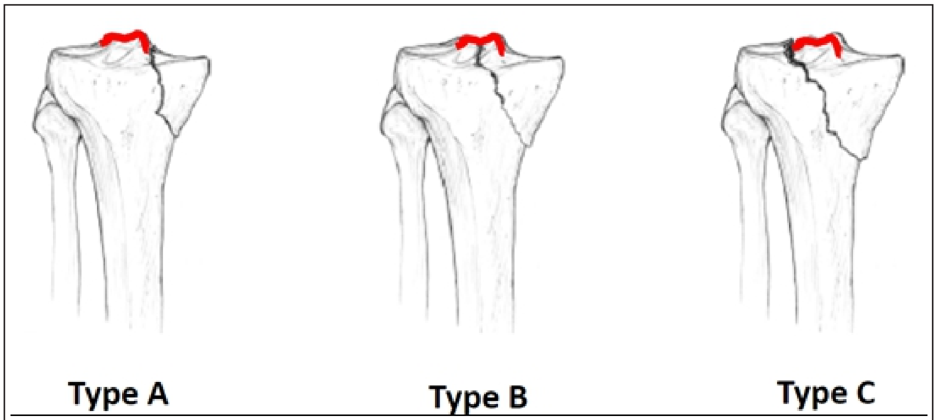


Figure 7: Wahlquist Classification[14] showing the exiting fracture lines A medial to the tibial spine B at the tibial spine and C lateral to the spine

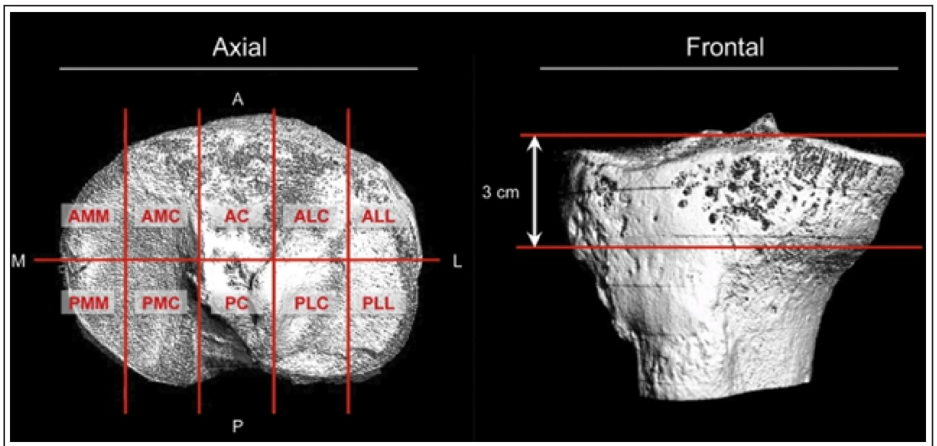


Figure 8: Showing the articular surface of the tibia divided into 10 segments [15]

articulating surfaces are depressed. This type is easily diagnosed on a CT scan.

One-Column fracture

This is further divided into 3 subtypes; lateral, medial and posterior.

Two-Column fracture

There are divided into 3 subtypes; Medial and posterior, Lateral and posterior, Medial and Lateral column fracture.

Three-Column fractures

These are the most complicated type of fracture pattern involving all 3 columns occurring due a combination of all types of forces acting on the knee i.e. varus/ valgus force acting with axial force on the knee in either flexion/ extension/ hyperextension position.

4) Modified Schatzker Classification

In 2018, the original Schatzker classification[11] was modified to a CT based classification. In addition to the 6 principle fracture patterns, a new element A(anterior) and P(posterior) were included. A virtual equator extending laterally from the lateral tubercle of the fibula and medially to the posterior limit of the superficial Medial Collateral ligament is drawn dividing the plateau into anterior and posterior halves (Fig.6a &b)[8]. The fracture line shown at the articular surface always has an exit at the metaphysis denoted by anterior exit-(ax)(Fig.6c&d) and posterior exit (px) (Fig.6e&f). This basic understanding helps in decoding complex fractures and helps in planning surgical steps.

5) Wahlquist classification

Marc Wahlquist et al classified the medial tibial condyle fractures based on the fracture line with respect to the tibial spine. Type A (least common of the 3) exiting medial to the spine, Type B (most common) exiting at the tibial spine and Type C lateral to the spine(Fig.24a-c) being clinically the most significant with

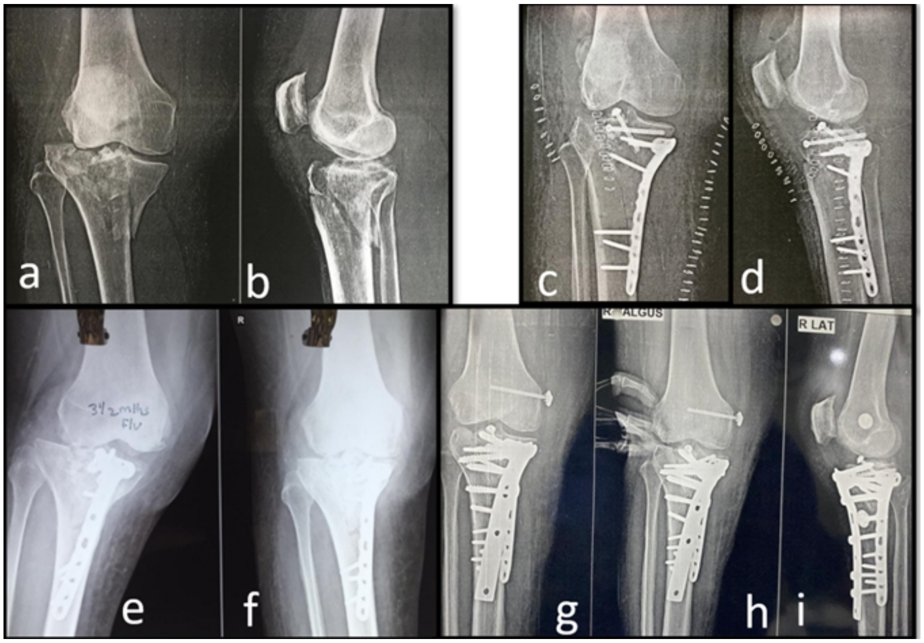


Figure9: Addressing soft tissue injuries in proximal tibial fractures is important for optimum post-operative function. A 48 year old female fell from a scooter a)&b)AP and lateral view proximal tibia injury, c)&d)Posteromedial approach for medial condyle. Lateral incision for lateral meniscal repair fixed with 3.5mm raft plate and cancellous screws, e)three and a half weeks after surgery patient had instability in the knee and frequent loss of balance showing medial opening on valgus stress test, f)varus stress normal, g)&i)Refixation with an additional plate & Reconstruction of the medial collateral ligament done and stability assessed on a stress Xray (h).

67% of the fractures being associated with neurovascular injuries (Fig.7)[14]

6)Ten Segment Classification

Krause et al explained this classification for mapping the intra-articular fracture pattern to get a fracture-based surgical approach. It is a CT scan based classification. In the axial plane a horizontal line divides the entire tibial plateau is divided into Anterior(A) and Posterior(P) columns. In the coronal plane, the plateau was divided into central, medial and lateral sections for fractures extending upto a depth of 3 cm from the plateau. The medial section is further divided into medio-medial (AMM-antero-medio-medial & PMM-postero-medio-medial) and medio-central (AMC-antero-medio-central & PMC-postero-medio-central). The lateral section is divided into latero-lateral(ALL-antero-latero-lateral & PLL-poster-latero-lateral) and latero-central (ALC-antero-latero-central & PLC-postero-latero-central) (Fig.9), central compartment is divided in AC-antero-central and PC- postero-central, hence a 10 Segment Classification [15].

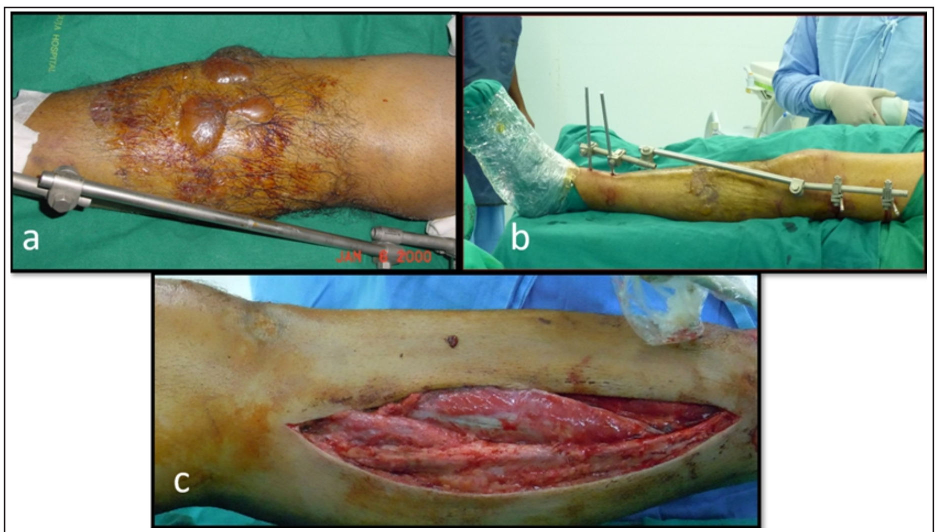


Figure 10: a) tense compartment syndrome, b)joint spanning External fixator, c)fasciotomy done for a tense compartment.

Imaging Modalities

Xray

Imaging is the cornerstone of managing proximal tibia fractures. Anteroposterior (AP) and Lateral (LAT) views generally give a fair idea about the various fracture patterns. But the intra-articular depressed fractures, posterior condyle fractures and the associated soft tissue injuries may be missed or may not be easy to identify on an Xray for upto 13-21% [16].

Computed Tomography Scanning

Literature suggests that the classification of the fracture pattern based on Xray-alone changes in almost 48% of the patients after a CT scan is done.[17] A CT scan with coronal, sagittal & axial cuts and a 3D reconstruction of the intraarticular fracture pattern could explain the mechanism of injury and hence help in pre-planning the approach and fixation for each fracture fragment [18]. A CT-Angiogram may be used to identify the level of vascular injuries in cases of fracture-dislocation(Fig.23b-d).

Magnetic Resonance Imaging

The role of MRI scan is increasingly being used in pre-operative diagnosis of associated soft tissue and ligament injuries especially in fracture-dislocation of knees[7][19]. However, there are no clear guidelines available for the timing and injury pattern requiring this imaging modality.

Associated Soft tissue injuries

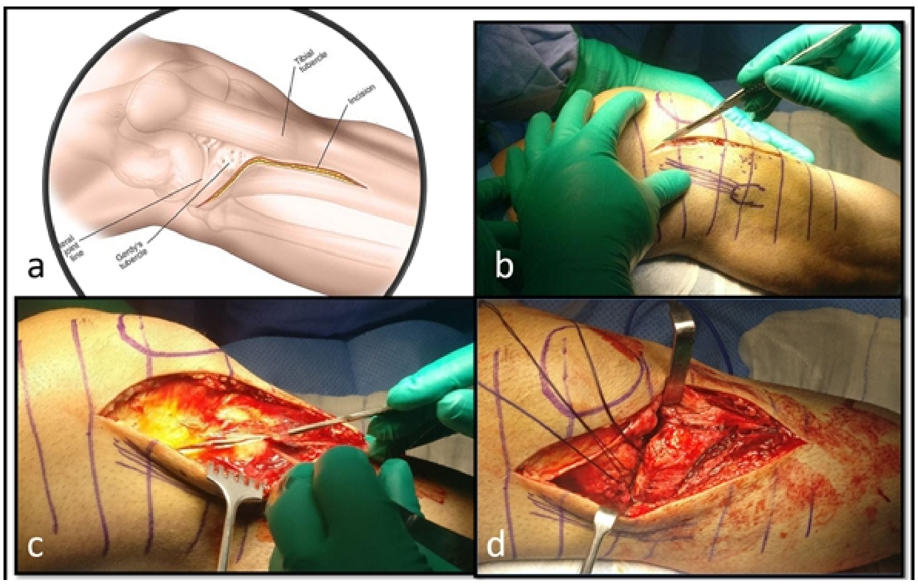


Figure 11: Anterolateral approach a)representation of the skin Incision, b)Skin incision between the fibular head and the tibial tuberosity, c)Splitting the Tensor Fascia, d)Meniscotibial release with meniscal stay sutures.

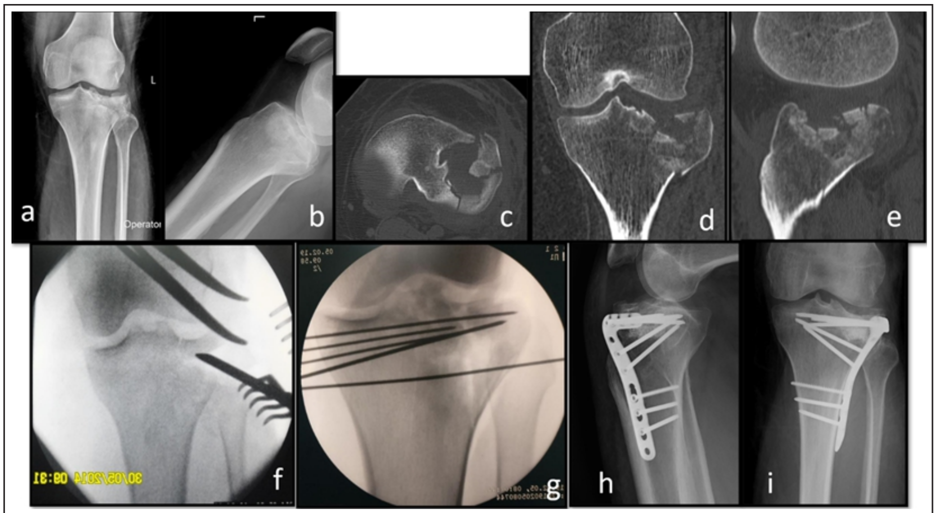


Figure 12: a)&b)Xray views of Lateral condyle depressed fracture, c-e)CT scan views, f)elevating the articular surface, g)fixing with multiple K-wires and exiting from medial condyle/flush on the lateral, h)3.5mm Synthes anterolateral raft plate holding the depression in lateral and i)AP view with bone substitute

The most common soft tissue injuries associated with proximal tibia fractures in descending order of frequency is lateral meniscus(LM) (posterior horn), medial meniscus(MM), the medial collateral ligament(MCL) and the anterior cruciate ligament (ACL) least posterior cruciate ligament (PCL)[20]. According to a study by Holzach et al 2% to 4% tibial plateau fractures are associated with meniscal or ligamentous injuries[21]. Stannard et al reported high rates of soft tissue injuries, 71% of total tibial condyle fractures are associated with atleast one ligament injury and 53% of fractures have multiple ligament injuries[7]. The incidence of cruciate injuries was almost double compared to other soft tissue injuries. They also attributed soft tissue injuries due to high energy trauma (Schatzker IV, V, VI) close to 46% and hence recommended MRI for these high velocity trauma injuries [22]. Rupture of the PCL is rare and usually does not require any fixation[23]. Complications like residual instabilities, loss of motion, poorer functional outcomes may be associated due to the missed soft tissue injuries (Fig.9).

There is no general consensus on the long-term functional outcomes of untreated ligament injuries. Warner et al concluded that MRI to diagnose soft tissue injuries and addressing these injuries did not alter the final outcome whether done in a single sitting or at staged intervals[19].

Treatment options

The tibial plateau plays a major role during weight bearing and has a good protection with thick articular cartilages and menisci protective cover. The intra-articular involvement in these fractures and the associated soft tissue injuries make the treatment plan challenging for any surgeon. There is no consensus on the degree of acceptable articular step-off. Even after surgical intervention patients have had residual joint pain, stiffness and knee instability associated with poor outcome.

Indication for the surgery -

Open fractures

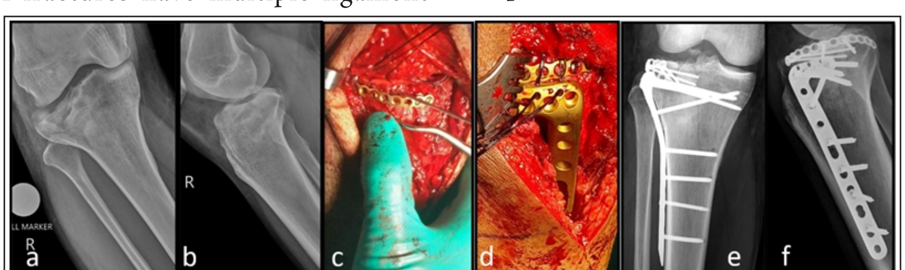


Figure 13: Shows a rim plate fixation for a proximal tibia fracture with fixation by jail screw technique. a)&b)Pre-operative AP view & lateral view, c)Intra-operative view of rim plate placement, d)meniscal stay sutures being passed through the plate, e)&f)Post-operative AP and lateral view of combination of rim plate and 3.5mm AO Synthes raft plate holding the joint depression.

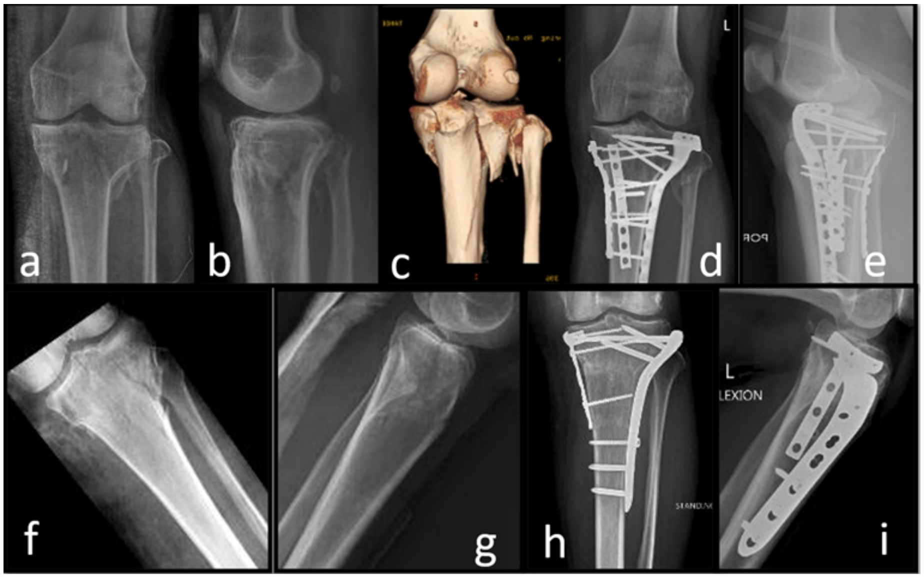


Figure 14: Bicondylar tibial plateau fracture with undisplaced medial condyle. Case 1- (a to e); a)&b)AP and lateral Xrays, c)3-D CT scan, d)&e)post-operative fixation with 3.5mm lateral raft plate and low profile medial and posteromedial plate as support. Case 2- (f to i); f)&g) AP and lateral Xrays, h)&i)post-operative fixation with lateral plate and a low-profile medial plate.

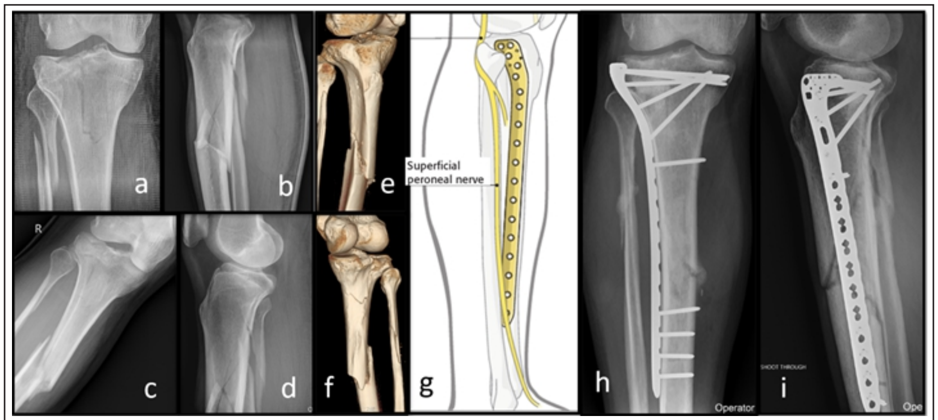


Figure 15: Iatrogenic superficial peroneal nerve injury in a long anterolateral plate placement. a-d) AP and Lateral Xray of tibial plateau fracture and ipsilateral tibial shaft fracture, e)&f) CT scans, g)relation of a long anterolateral plate to the superficial peroneal nerve, h)&i) postoperative AP and lateral Xrays with a long plate.

Table1: Posterolateral column fixations by different approaches.

Posterolateral Column Fixations			
Approaches	Fibular Osteotomy	Modified Posterolateral	Extended Anterolateral
Author	Lobenhoffer - 1997 [26]	Frosch - 2010[27]	J.W. Cho - 2017[24]
Variation	Utilize the fractured Fibular head	Lateral Femoral epicondylar osteotomy with LCL if tight lateral compartment[28]	
Indication	AC, ALC, ALL, PLL, PLC, PC (Figure.23c)	AC, ALC, ALL, PLL, PLC, PC (Figure.23c)	AC, ALC, ALL, PLL (Figure.23b)
Position	Lateral	Lateral, Floppy lateral	Supine
Advantages	Direct visualisation of posterolateral corner		
Disadvantages	Medial & Posteromedial columns cannot be accessed. Risk of damage to the trifurcation of popliteal artery, and anterior tibial artery crossing the interosseous membrane 5 cm below the joint line (Figure.16e)		
Structures in danger	Common peroneal nerve, Popliteal tendon, Popliteal artery trifurcation		

Neurovascular compromise or Compartment syndrome

Angular deformity in the sagittal or coronal plane >5 deg resulting in instability

Intra-articular incongruity

Patients with high velocity trauma with a severe soft tissue injury or open injuries and compartment syndrome, requiring initial stabilisation with external fixators and later plan later for a definitive fixation (Fig.10a,b). The principles of surgical reconstruction are restoration of the depressed articular fragments, reconstructing the widened condyles and correcting the altered proximal tibial mechanical axes.

Surgical Approaches

The selection of a surgical approach is a crucial decision in the treatment of Tibial plateau fractures., especially multiple-column involvement. A strategic surgical approach to address and fix the specific injured columns with appropriate pre-operative planning is the key to good functional outcome.

1)Anterolateral approach

This is the most common approach used to approach the lateral condyle. Incision is made between the fibular head and tibial tuberosity over the Gerdy's tubercle extending superiorly in a hockey stick fashion (Fig.11a&b), the iliotibial band is incised in line with the fascia (Fig.11c) and extending inferiorly over the fascia of tibialis anterior which is bluntly elevated from the tibia. The stay sutures are taken through the meniscotibial ligament (Fig. 11d). Lateral meniscus is elevated for a direct view of the lateral articular surface. Any joint depression is identified (Fig.12a,13a), elevated (Fig.12f) and fixed temporarily with subchondral K-wires (Fig.12g). These K-wires are passed through to exit from the medial condyle and kept flushed on the lateral condylar surface (Fig.12g) to allow easy placement of the plate. The elevated fragment is fixed with either a 3.5mm (AO Synthes) anterolateral raft plate only (Fig.12) or a 2.4 or 2.7mm AO Synthes foot plates with subchondral screws in a raft or a jail pattern augmented with the 3.5 mm raft plate (Fig.13). Finally, the meniscal sutures are passed through the plate and tied and tightened

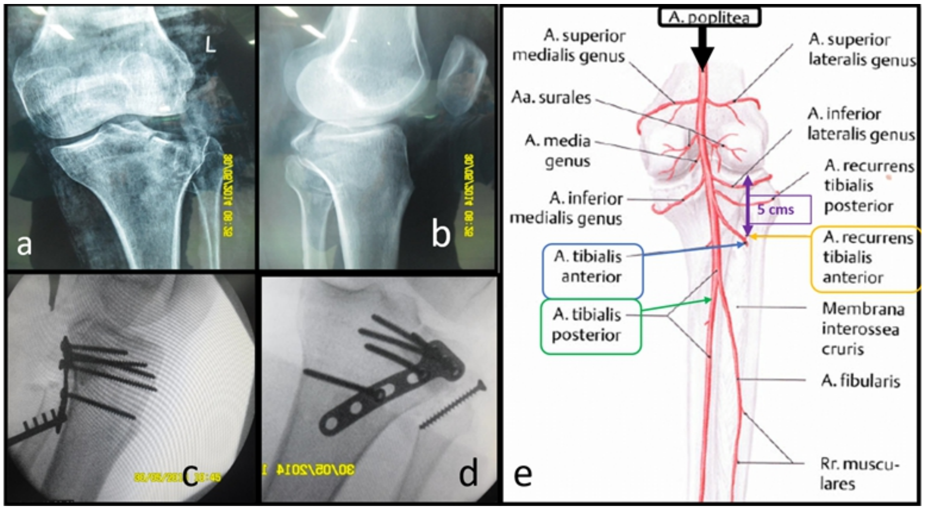


Figure 16: Fibular osteotomy approach of Lobenhoffer to approach the posterolateral tibial fragment (a-d), e)Vascular supply of the lower limb. The popliteal artery(in black) bifurcates into anterior tibial artery(in blue) and posterior tibial artery (in green). The anterior tibial artery enters into the interosseous membrane approximately 5cm below the joint line(in purple).

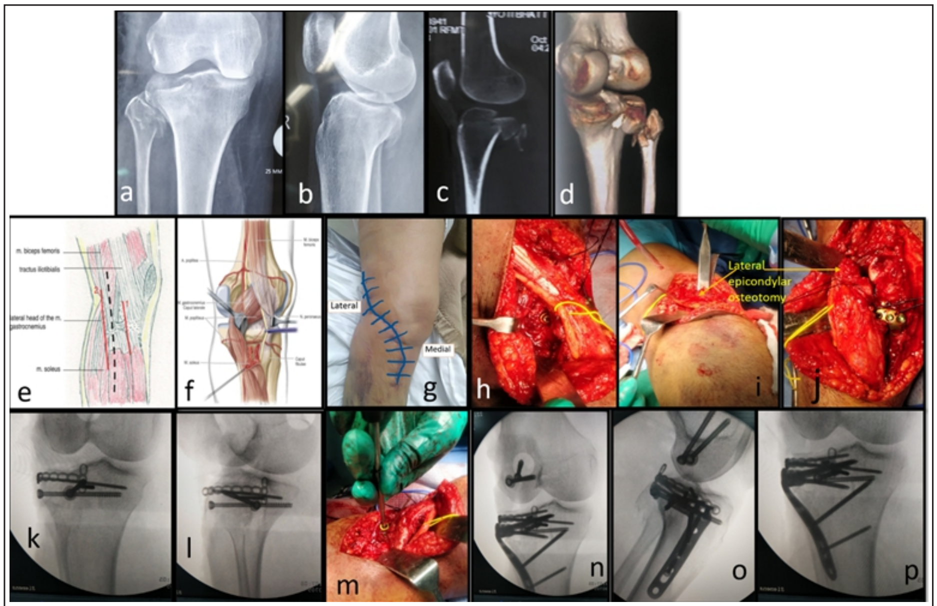


Figure 17: a)&b)AP and lateral views of posterolateral corner fracture with depression, c)&d)CT scans of the fracture depression, e)Frosch approach showing single incision double soft tissue window[27], f)retracting the lateral gastrocnemius medially protecting the neurovascular bundles[27], g)skin incision h)isolating the common peroneal with a yellow tag & posterior soft tissue window, i)Lateral epicondylar osteotomy of the femur along with the LCL, j)standard anterolateral soft tissue window splitting the tensor fascia lata, k)&l)intraoperative C-arm picture AP and Lateral view—depression elevated and fixed with a low profile plate, m)&n)fixing the epicondylar osteotomy with 6.5mm cannulated cancellous screws, o)&p)Final AP and Lateral C-arm picture of the fixation.

(Fig.13d). Allograft, autograft or bone graft substitutes may be used to fill up the void created by elevating the depression (Fig.12h&i). In a bicondylar fracture, the temptation to address both the columns with a single locked plate from the lateral side should be avoided. In presence of medial comminution or a medial cortex discontinuity, a low profile medial 3.5 plate as a support may be used (Fig.14a-e).[3][24]

Indication- Fractures of the anterolateral column (ALL, ALC, AC) (Fig.23a)

Position- Supine

Advantages- Direct visualisation of the articular surface with no danger to major neurovascular structures

Disadvantages- No direct visualisation of posterolateral column and medial column.

Structures in danger- Superficial branch of the peroneal nerve has a variable course particularly when using a longer plate. (Fig.15)[25]

2)Posterolateral approach

Lobenhoffer et al[26] described the posterolateral approach in 1997 involving the fibular head osteotomy. This approach is challenging because of the close proximity of the common peroneal nerve to the fibular head. The interval between the fibular head and the tibial tuberosity is identified and the incision starts at the middle 3 cm below the tibial tuberosity and proximal curved posterolaterally over the fibular head behind the lateral epicondyle of the femur (Fig.17g). The common peroneal nerve is isolated and fibular osteotomy is performed taking care of the fibular neck, and reflected along with the LCL relaxing the lateral compartment which along with the meniscal stay sutures gives a direct view from the anterolateral to the posterolateral corner. The popliteal artery bifurcates into posterior tibial artery running just medial to the lateral head of Gastrocnemius muscle and anterior tibial artery which enters in to the interosseous membrane at approximately 5 cm below the joint line (Fig.16e), hence avoiding the placement of a long plate on the posterolateral corner needs to be kept in mind (Fig.16c&d). A low profile 3.5 distal radius plate, 2.0 and 2.4mm plate of the hand system or 2.4 and 2.7mm plates of the foot system (AO Synthes) could be molded (Fig.17k&l) around the lateral tibial condyle fixed using raft or a jail screw technique[26].

Frosch et al in 2010[27], explained a posterolateral approach without the osteotomy of the fibular head. A single

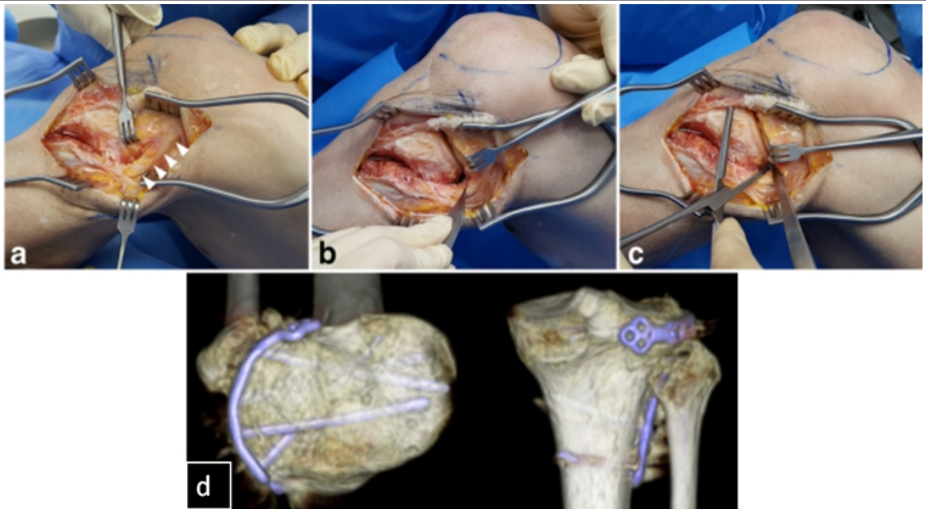


Figure 18: Extended anterolateral approach on a cadaver by Cho et al[29] a)dissection of the para-LCL space, b)coronary ligament is incises and whole posterolateral corner is visualised, c)Hohmann retractor placed anterior to the LCL, d) a low profile 3.5mm hugging plate placed and fixed in a raft screw manner.

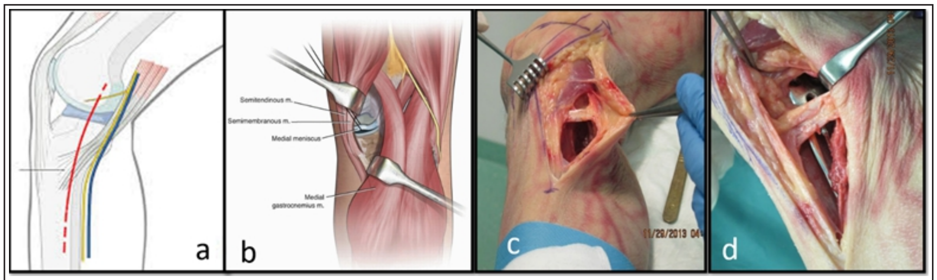


Figure 19: Posteromedial approach: a)posteromedial incision, b)retracting the medial gastrocnemius laterally and the pes anserinus medially with meniscotibial resection, c)cadaveric dissection showing the hamstrings, d)sliding the plate under the hamstrings.

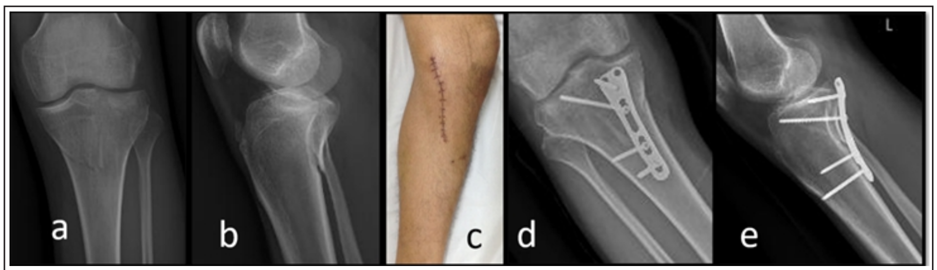


Figure 20: Medial condyle fracture a)&b)Xrays AP and lateral view, c)Posteromedial incision, d)&e)3.5mm AO Synthes posteromedial buttress plate.

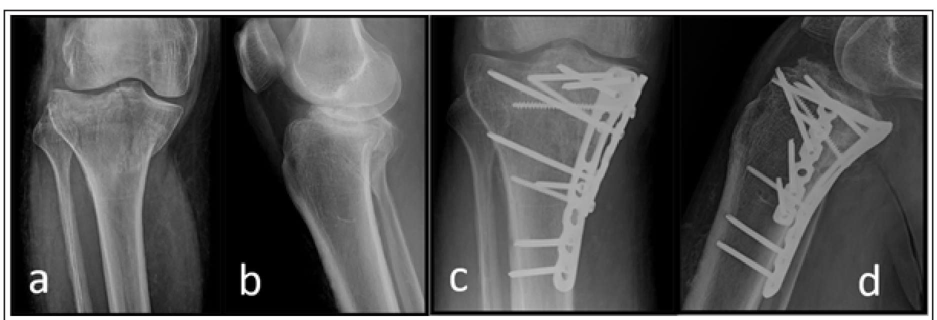


Figure 21: a)&b)AP and lateral view showing a comminuted medial condyle fracture, c)&d)3.5 posteromedial plate and low-profile medial plate.

posterolateral skin incision (3cm proximal to the joint line and follows the fibular head in a distal direction) (Fig.17e&g), with two soft tissue windows- one standard anterolateral arthrotomy anterior to the Biceps Femoris(Fig.17e&j) (splitting the Tensor Fascia Lata and elevating it from the Gerdy's Tubercle to visualise and achieve the intra-articular reduction) and one posterior to the Biceps Femoris (Fig.16e&h) (isolating the peroneal nerve and retracting it (Fig.17h), followed by a blunt dissection of the popliteal fossa between the lateral head of Gastrocnemius and Soleus, the popliteus muscle is exposed and the popliteal artery and vein are protected under the lateral gastrocnemius head, the popliteus muscle is reflected medially and soleus detached of the dorsal surface of the fibular head) (Fig.17f). Now the fragments can be directly visualised and mobilised from the posterior window and fixed with K-wires (Fig.12g) or a hoop/rim plate (Fig.16k&l) to hold the reduction. Frosch et al[28] has recently also advised for a femoral epicondylar osteotomy along with the LCL (Fig.17i) for a better view of the tight lateral compartment if the need arises. The osteotomy is fixed with cancellous screws (Fig.17m&n).

Extended anterolateral approach by J.W. Cho et al in 2017 [24] used a single standard anterolateral approach with the fracture of the posterolateral and antero-lateral column where the posterolateral fragment needs buttres-sing with no direct visualisation of the PLC and PC for fixation. Following the similar anterolateral incision and splitting the iliotibial band and reflecting it off the Gerdy's tubercle. The dissection was extended posteriorly by reflecting the extensor muscles off the lateral tibial plateau until the para-LCL (Fig.18a). Here the knee is flexed and the LCL and CPN are relaxed. Further elevation has to be done and kept below the level of the plateau to avoid damaging the popliteus tendon. Later, meniscotibial incision and reflecting the meniscus superiorly to view the plateau (Fig.18b). The knee is internally rotated to bring the postero-

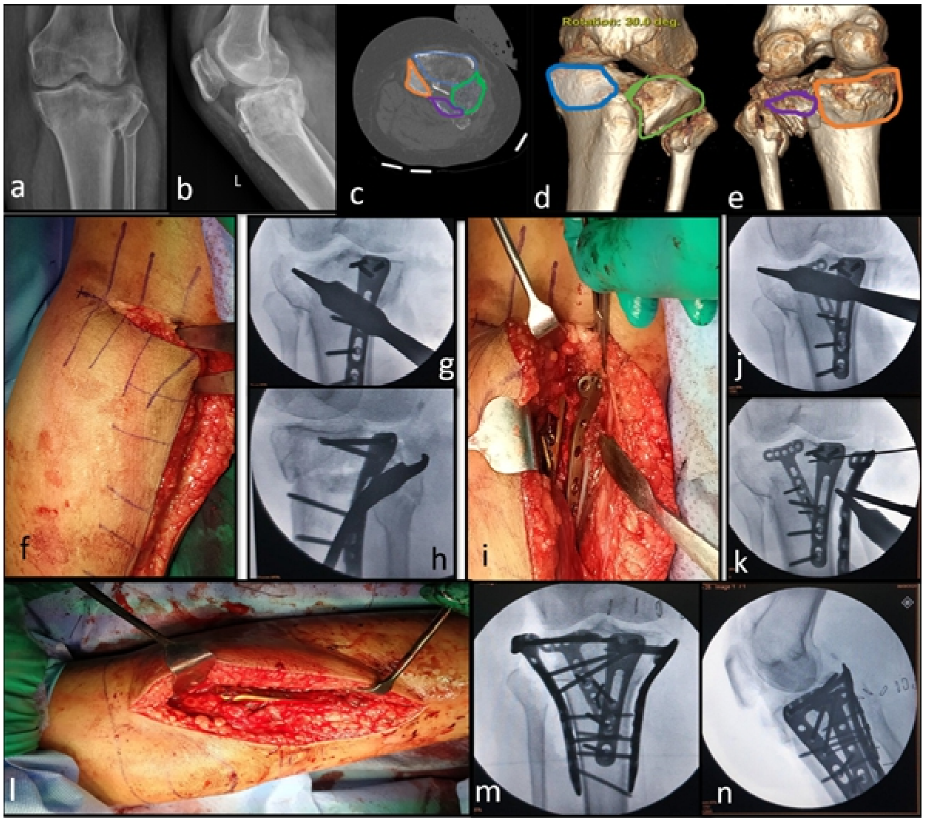
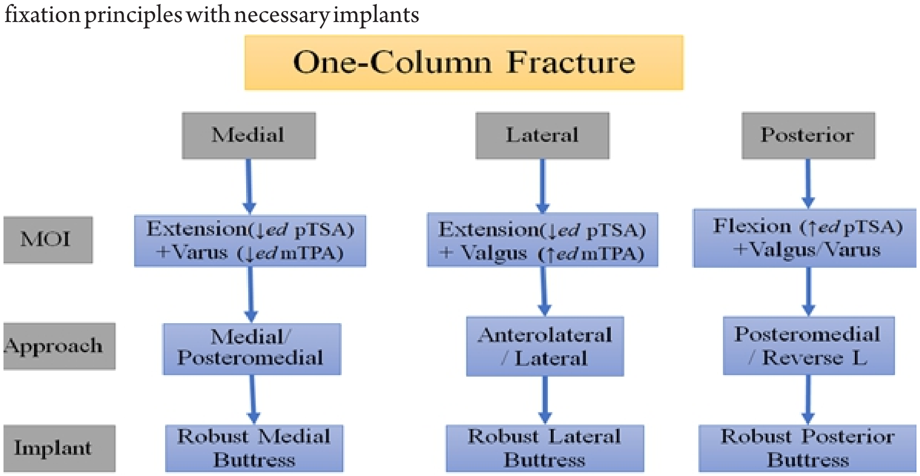


Figure 22: Reverse-L approach for a comminuted tibial plateau fracture. a)&b)AP & lateral Xrays, c),d)&e)CT-scans showing involvement of all 4 columns {green-anterolateral, blue-anteromedial, orange-posteromedial, purple-posterolateral}, f)Reverse-L skin incision, g)&h)3.5mm posteromedial buttress plate with shorter proximal screws to accommodate the longer screws from medial and anterolateral plates, i)intra op picture of Medial, posteromedial and 3.5mm distal radius plate for the posterolateral column, j)3.5mm distal radius plate for posterolateral column placed obliquely to avoid damage to the anterior tibial artery, k)3.5mm medial buttress plate, l)separate anterolateral approach for lateral column, m)&n) final intra-op C-arm image in AP and lateral view

Table 2: One Column fracture showing MOI(mechanism of injury), approaches taken and fixation principles with necessary implants



lateral corner out. A femoral distractor or an LCL osteotomy may be performed to view the tight lateral compartment. The advantages of this approach include: no need for common peroneal nerve dissection and exposure, the surgery can be performed in the familiar supine position[27].

3)Posteromedial Approach

This approach is commonly used for the fixation of medial and large posteromedial fragment of the proximal tibia (Fig.23e). A congruent reduction is critical to allow reconstruction of the joint and prevent future varus collapse deformities. An incision is taken posterior to the tibial crest and can be extended proximally to the femoral condyle across the joint line (Fig.19a). Due care must be taken to protect the medial collateral ligament and hence dissection must always be performed posterior to this area. The pes anserinus is usually visualised and must be carefully retracted and if required divided and repaired at the end (Fig.19c). A submeniscal arthrotomy is performed to visualise the medial plateau (Fig19b). 3.5mm AO Synthes posteromedial buttress plate is used for fixation (Fig.19d,20), may need to be slid under the hamstrings (Fig.19d) and also can be used to reinforce fixation in multiple column involvement (Fig.14 d, e, h & I, 21, 22k&m). In case of dual plating, shorter proximal screws (Fig.22h) should be placed to accommodate the longer screws of the 3.5mm lateral plate or a 3.5mm medial buttress plate (Fig.22k&m)[30].

Indications: Medial, Posteromedial columns (AMM, AMC, PMC, PMM, PC) (Fig.23e)

Position: Supine (30° knee flexion and external rotation of the ipsilateral hip for better access or keeping a sand bag under the contralateral hip), Lateral, Semi-prone, Prone position

Advantages - Unlike the medial approach, the MCL is deeper to the pes anserinus, hence not in as danger.

Disadvantages - Danger of damaging the pes-anserinus as the plate has to be slid beneath it.

Structures in danger - Saphenous nerve, posterior tibial artery and nerve.

4)Posterior - Reverse 'L' Approach

X. He et al in 2013 [31] explained the direct posterior approach for the fixation

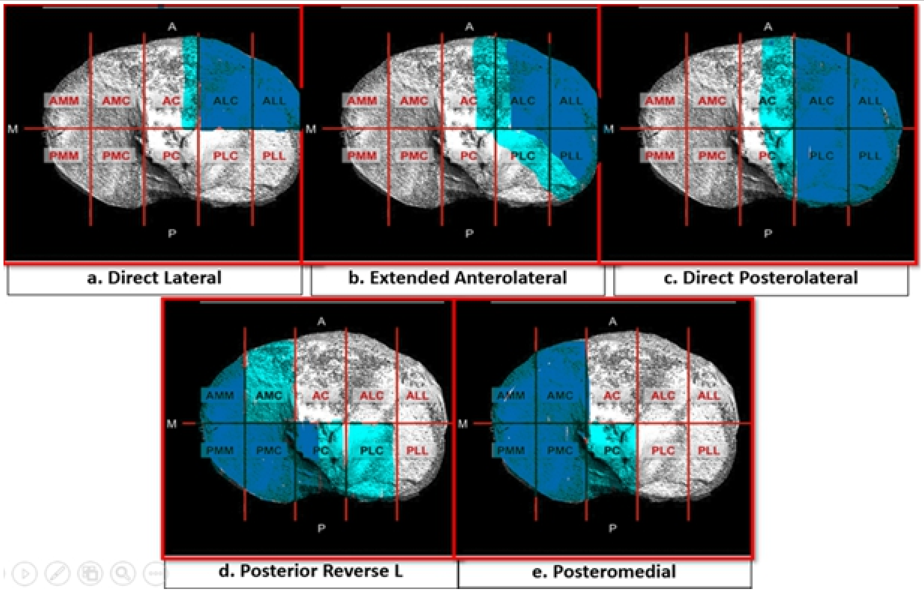


Figure 23: Showing the various areas covered by the approaches described in the text, the dark blue shade represents the areas that can be directly visualized and a lighter blue shade represents areas that can be approached indirectly or with a little difficulty. a)Direct Lateral approach, b)Extended anterolateral approach, c)Direct posterolateral approach, d)Posterior Reverse-L approach, e)Posteromedial approach.

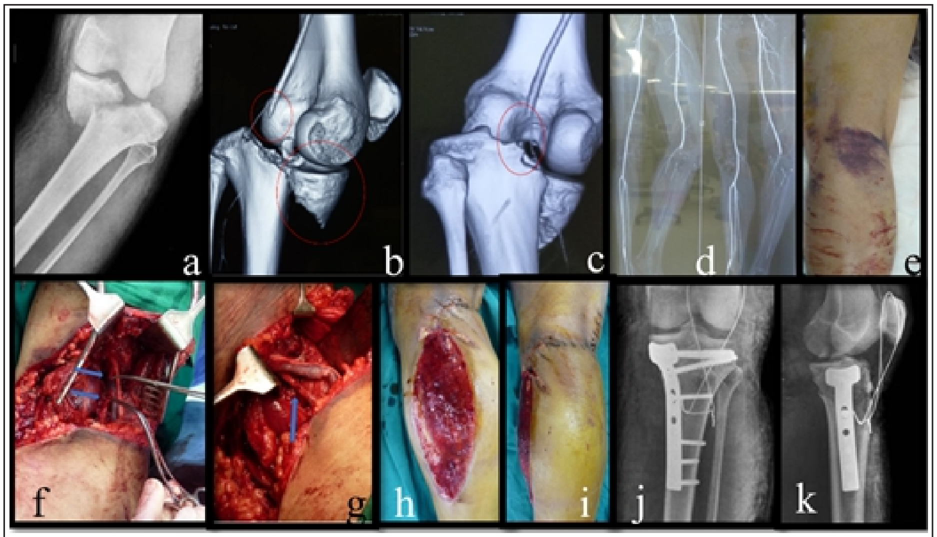


Figure 24: A medial condyle displaced fracture a)medial condyle fracture. b)&c)3-dimensional CT, d)CT angiography showing a block in the arterial flow to the lower limb, e)shows bruising over the posterior aspect of the knee, f) shows a rupture of the popliteal artery g)the popliteal artery repaired with a vein graft, h)&i) prophylactic fasciotomy was done, j)&k) AP and lateral Postoperative Xray

of tibial plateau fractures. The reverse 'L' shaped incision is taken along the flexor crease on the popliteal fossa and extended along the medial border of the calf. The incision can then be extended upto the lateral end of the flexor crease (Fig.22f). Sural nerve is identified and isolated. The medial head of gastrocnemius is retracted laterally to visualise the fractured fragment (Fig.22i). Retraction should be carefully done under the popliteus muscle to prevent damage to the anterior tibial artery. Any retraction should be performed over the fibular head if necessary (Fig.22g&h). The popliteus muscle needs to be incised on the medial margin insertion on the tibia. A 3.5mm posteromedial plate to address the posteromedial fragment (Fig.22g,h&i) and 3.5mm distal radius contoured plate placed obliquely (Fig.22i,j&k) to fix the posterolateral fragment. Due care must be taken while applying these plates to prevent damage to the anterior tibial artery that bifurcates from the popliteal artery and enters into the interosseous membrane travelling anteriorly, which is present 5 cm below the joint line. The posterior recurrent tibial artery (branch of anterior tibial) is at risk if retraction is done too far lateral[31][3].

Indication- Medial, posteromedial, posterolateral columns (PC, PLC not PLL) (Fig.23d)

Position - Prone, Semi-prone

Advantages - More than one column can be visualised directly

Disadvantages - Major neurovascular structures in danger, extensive and careful dissection is vital, needs repositioning in case of additional surgical approach. The posterolateral corner of the tibial plateau (PLL) is not accessible (Fig.23d). to address the PLL the direct posterolateral approach is superior[32].

Structures in danger - Popliteal artery, tibial nerve, sural nerve and short saphenous vein, posterior recurrent branch of the anterior tibial artery.

5) Arthroscopy

Arthroscopy has proven to be a useful tool in treating tibial plateau fractures and managing the associated soft tissue injuries. The standard arthroscopy portals are used for visualization of the depressed intra-articular fragments [20][33][34].

Indication:- Depressed intra-articular fractures (AC and PC)

Advantages:- Direct visualization of the fragments helps in better reduction and repair of concomitant ligament injuries if any, especially Schatzker type 3 fractures.

Disadvantages: Risk of post-operative compartment syndrome.

Approaches and Algorithm for Column Specific Fixation (Figure.23) (Table 2 to 4)

Discussion

Treating Tibial plateau fractures is a challenge even for experienced surgeons. An understanding of the classification systems, MOI and various approaches is important for optimal patient care. Understanding the MOI could simplify many steps in the treatment of the complex tibial plateau fractures [27] [8] [12]. Imaging modalities are the corner-stone in evaluating and managing these injuries. Xrays can give a fair picture of the injury but with the availability of CT scan, a better picture of the fracture pattern and surgical planning is possible.

Almost 47% of proximal tibia fractures are associated with soft tissue injuries[7]. These injuries can be assessed clinically under anesthesia and intra-operatively, but to diagnose these injuries at the time of presentation is difficult. The role of MRI preoperatively is useful, however no definitive guidelines recommend this in an acute trauma situation. In a 3 column fractures or high velocity trauma there may be a need for MRI scan[35].

Position of the knee with respect to the direction of the deforming forces defines the severity of injury and the fracture pattern. The most common injury pattern described is the extension valgus force causing a lateral condyle split or a split+depressed fracture pattern (33%), the second being flexion varus (19%) and the third most common pattern is the extension varus (17%) pattern. Classifications helping in recognizing the fracture patterns and MOI have been recommended in aiding surgical approach and deciding the fixation protocol[13].

In addition to the sagittal and coronal forces, rotational forces also act and hence cause additional ligamentous injuries along with complex fracture patterns. External rotation is associated with valgus injury patterns and Internal rotation is associated with varus injuries[12].

The more challenging fracture patterns are the Schatzker type V & VI and uTCC 3-column fracture. These may require a combined dual-incision approach based upon the position of the fracture lines along with each of the columns to be reconstructed. The surgical protocol including the MOI, the surgical approach and the principle of fixation for each column is listed (Table. 3&4). Dual plating in a bicondylar fracture is justified when there is a medial comminution or a medial column discontinuity, one needs to overcome the temptation to fix all the fragments from the lateral side only (Fig.14&22).

The anterolateral approach is the most commonly used approach to address the lateral column. The extended antero-lateral approach, the Lobenhoffer's approach and Frosch approach address the lateral and the posterolateral column. The Reverse 'L' approach addresses the posteromedial, medial and posterolateral (except PLL) columns (Fig.23).

In a high velocity trauma, the extent of injury to the soft tissue, compartment syndrome and other neurovascular compromise must be anticipated. These patients may need to be treated in a staged manner[36]. The MCL and LCL stability is checked after primary fixation of the bone and repaired if required to prevent post-operative instability (Fig.9). Though some series recommend addressing this in a staged manner. The instability may still persist due to a tibial eminence fracture and cruciate ligament injury, some studies recommend this to be dealt with at a later stage [20] [37] [38].

Complications

1. Infection: Superficial and deep infec-

Table 3: Two column fractures showing MOI(mechanism of injury), approaches taken and fixation principles with necessary implants

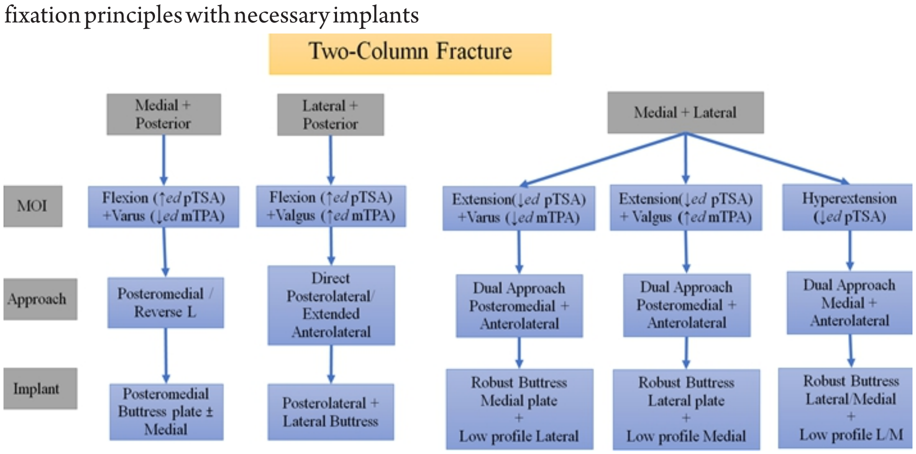
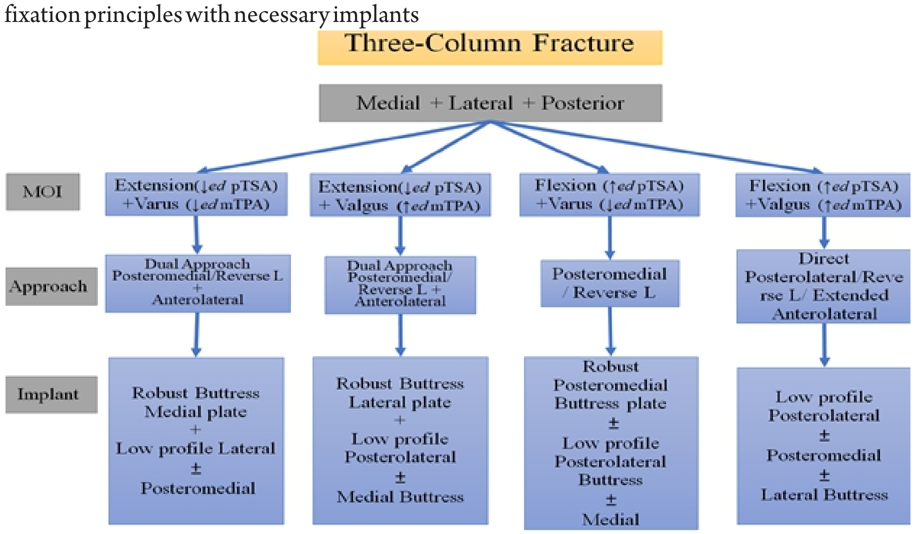


Table 4: Three column fractures showing MOI(mechanism of injury), approaches taken and fixation principles with necessary implants



tion rates are a dreaded complication reported (between 2 to 28%) in literature. The chances of infection in an open fracture or high energy trauma is high. With the advent of Vacuum assisted closure and soft tissue flaps, the rate of infection in the open fractures has decreased[39].

2. Malunion/Nonunion: occurs at the meta-diaphyseal junction and can be prevented by doing an alignment test using a diathermy wire and providing robust fixation with 2 or 3 plates where required. Post operatively if malalignment is suspected a scanogram needs to be done. Literature quotes a malunion rate of 10 to 40 percent in operated proximal tibia fractures.[40]

3. Compartment syndrome: an associated condition commonly seen with proximal tibial plateau fractures mostly occurring due to high velocity traumas leading to three column injuries. In such cases an early intervention with fasciotomy needs to be performed urgently and temporarily spanning the joint with an external fixator. The reported incidence in high velocity trauma is 1 percent to as high as 9 percent by some authors[41] (Fig.10a).

4. Vascular injury: More commonly seen in Schatzker type IV, V, VI. One should be aware of such a complication and CT-Angiogram at an early stage to identify the level and extent of injury. A vascular surgeon needs to be involved and reperfusion injury should also be kept in mind for such cases where a vessel repair with a prophylactic fasciotomy may be required [39] (Fig.24).

5. Hardware irritation incidence is extremely variable reported to be between 5 to 18 percent[39][36].

6. Post traumatic arthritis in long term series is reported to be 23 to 44 percent. Almost 9 percent patients with proximal tibial fractures need a future Total Knee Arthroplasty.[42]

7. A possible iatrogenic superficial peroneal nerve injury during the placement of a long anterolateral plate in MIPPO technique.[43](Fig.15)

Conclusion

It is important to identify the fracture pattern along with the mechanism of injury for surgical planning.

The principle of surgery must be followed, that is anatomical reduction with restoration of the articular surface and limb alignment.

Plating in tibial plateau fractures works, understanding the function of each of the plates in a specific column fixation has to be understood.

Getting familiar with anterior and posterior approaches.

Minimal soft tissue damage and identifying key anatomical structures and protecting them

Intra operative stability assessment and Soft tissue reconstruction to prevent postoperative instability.

In bicondylar fractures addressing the fixation only from the lateral side only is not a good option. Dual plating to be considered in cases of medial comminution and / or medial cortex discontinuity.

Following the above principles ensures early rehabilitation and optimal function.

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