Current Concepts in Tibial Plateau Fractures

Zlomeniny plata tibie

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SUMMARY

Tibial plateau fractures can range from a simple lateral split pattern to very complex bicondylar injuries that can be a source of great disability. these fractures can provide a challenge for both junior as well as for senior surgeons alike. careful evaluation of the mechanism of injury and fracture pattern plays a crucial part in the operative planning. Assessment of the soft tissues shoul be performed carefully and adequate imaging is mandatory to allow a more detailed evaluation of the fracture architecture and pre-operativeplanning. Timely accurate reduction and fixation is the goal. Over the last decade the surgical approach chosen has been largely determined by the fracture pattern. Internal plate osteosynthesis through antero-lateral and postero-medial incisions is the most commonly utilised technique for complex bi-condylar fractures. An early range of motion with special attention to full knee extension is essential for a successful functional outcome. Application of the principles mentioned is a pre-requisite to achieve the best result. New fixation techniques, such as locking plates, have not changed those principles but helped to apply them more reliably.

INTRODUCTION

Tibial plateau fractures can be a challenging injury for even the most experienced surgeon. Fracture management requires precise analysis of the injury and careful operative planning. The more complex bi-condylar tibial plateau fractures involving the articular surface are often particularly difficult cases to treat. The surgeons experience and training often greatly influences the choice of anatomical approach and fixation method. However the soft tissue envelope, fracture pattern, bone stock and degree of comminution also heavily influences the decision-making process and is critically important to the surgical success. There are three widespread classification schemes for tibial plateau fractures that will be discussed along with surgical treatment techniques including both external and internal fixation. The commonly selected surgical approaches will be outlined and case studies used to illustrate the various stages of fixation and techniques.

INCIDENCE/EPIDEMIOLOGY

Fractures of the tibial plateau account for 1.3% of all fractures and affect males more commonly than females (15). Two groups of patients principally suffer this type of injury. Younger or middle-aged patients with moderate or high-energy injuries are often from motor vehicle accidents or a fall from a height. The second group is elderly, osteoporotic patients, who have a relatively low energy injury such as a simple fall (7, 15, 17). In falls from a height, tibial plateau fractures are often associated with calcaneal fractures and fractures of the thoraco-lumbar spine, but in the majority of cases the injury is isolated. This injury is rare in children and young adults prior to epiphyseal plate closure. The causes are road traffic accidents in 52% of cases, falls in 17% of cases (18) or sporting or recreational activities in 5% of cases (15). In the USA, the injury more commonly affects the left knee (15), perhaps because pedestrians are more often hit by a motor vehicle from the left side as they step off a kerb. The bi-condylar type and comminuted type are the most challenging subgroups, with an incidence ranging from 20–40% of all tibial plateau fractures (1). The mechanism of injury is believed to be a sideways bending force, a vertical compression of the lower limb, or a combination of both. Laboratory tests were able to reproduce fractures similar to those seen in clinical practice in cadaver knees using a machine producing a gradually increasing force of 1600 + 8000 lb (11).

ASSESSMENT

Initial patient assessment involves careful consideration of the mechanism of injury, examination for any associated injuries and investigation of the characteristics of the fracture itself. High energy injuries are frequently associated with concomitant injury to other bony structures and solid organs. Patients should be assessed according to emergency principles to exclude life and limb threatening concerns prior to management of the fracture. The neurovascular status of the limb should be carefully assessed and documented, remembering that the presence of distal pulses does not exclude an arterial injury. Neurovascular observations should be conti-

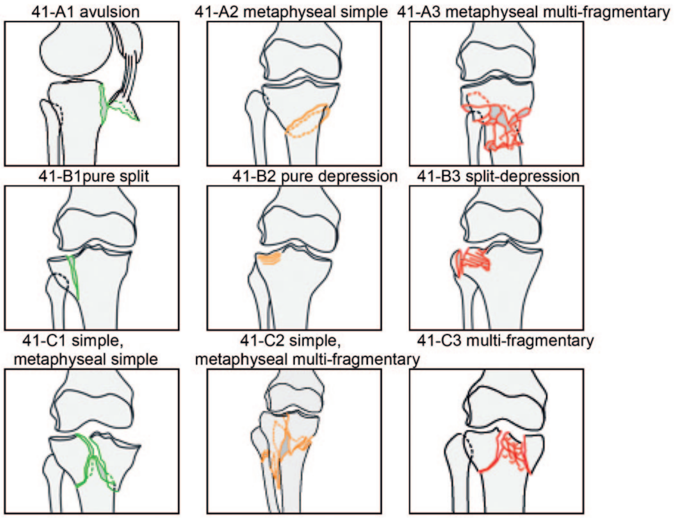

Fig. 1. AO classification of tibial plateau fractures (2)

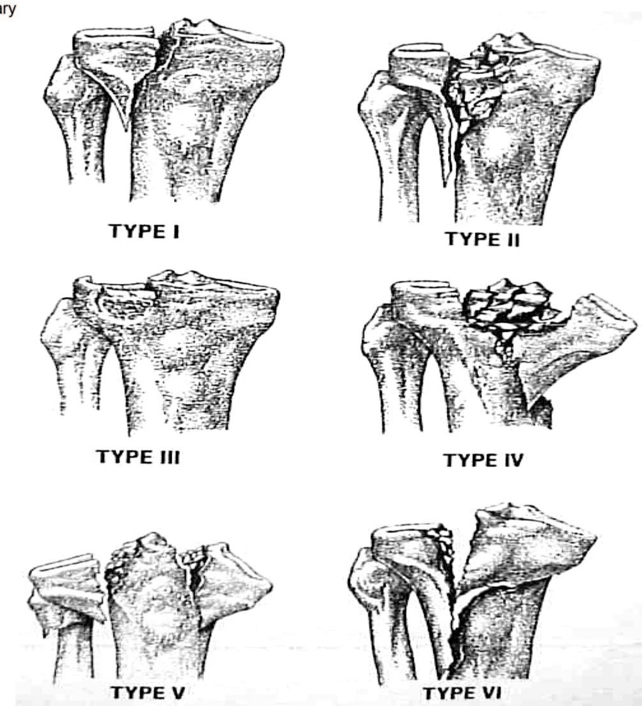

Fig. 2. Schatzker classification (19)

nued for the initial and peri-operative periods to look for signs of compartment syndrome or the delayed presentation of an intimal arterial tear. In the setting of compound injuries, early antibiotic cover has been shown to reduce infection rates. Appropriate antibiotics should be chosen after consideration of the likely contaminating organisms. In general, a first general cephalosporin antibiotic to provide gram-positive cover is appropriate. In the setting of motor vehicle accidents with mild contamination the addition of an aminoglycoside may be required to provide synergistic gram positive cover as well as gram negative cover. Farm yard injuries should also receive anaerobe cover. Wounds should be cleaned and dressed, and prophylactic tetanus cover given.

Generally low energy injuries are not an emergency and there is time for additional imaging and waiting for the soft tissue swelling to subside. However high energy injuries require more emergent treatment, often with initial joint bridging external fixation, soft tissue debridement and compartment release, followed by second look imaging and delayed definitive operative fixation.

Imaging is an important part of the evaluation of the injury and an essential tool for surgical planning. Initially, a minimum of AP and lateral x-rays should be taken. Computerised tomography (CT) scanning allows more detailed examination of the bony architecture, and magnetic resonance imaging (MRI) is useful if ligamentous or other soft tissue injuries are suspected. It is important to have a high index of suspicion for vascular injuries, especially in cases involving a high energy mechanism. If there is any concern regarding limb perfusion, duplex USS or angiography should be performed.

CLASSIFICATION

There are three commonly used classification schemes for tibial plateau fractures. The Müller AO Classification adopted by the Orthopaedic Trauma Association (OTA) uses an alphanumeric system according to the common principles of the AO method: type A fractures are extra-articular, type B fractures are partial articular (a part of the articular surface remains in contact with the diaphysis) and type C fractures are complete articular fractures with detachment of the fragments from the diaphysis. Each fracture group is further subdivided (1, 2 and 3) describing the degree of fragmentation and more detailed characteristics. The further subdivision of type C fractures includes C1 (articular and metaphyseal simple), C2 (articular simple and metaphyseal multi-fragmentary) and C3 (articular multi-fragmentary). Complex C3 tibial plateau fractures are subdivided into C3.1 (lateral multi-fragmentary), C3.2 (medial multi-fragmentary) and C3.3 (bilateral multi-fragmentary (16) (Fig. 1).

Particularly in North America, the classification according to Schatzker et al from 1979 is widely used. In this study 94 tibial fractures were classified in 6 groups, the groups were determined by the pattern of the fracture and then compared with the outcome (with increasingly worse prognosis). Type I is a simple cleavage fracture of the lateral tibia plateau, type II is a cleavage fracture combined with a depression of the lateral tibia plateau, type III is a pure central depression of the lateral tibia plateau, type IV are fractures of the medial tibia plateau, type V are bi-condylar fractures imitating an inverted Y and type VI are fractures of the tibia plateau with complete dissociation of the metaphysis and the diaphysis (19) (Fig. 2).

Moore described a fracture-dislocation classification of the knee with 5 types. This system helps to more clearly understand the grade of instability and associated injuries. Type I is a coronal split fracture of the medial tibia plateau which displaces distally. Type II compromises a fracture of the entire condyle, whereby the fracture extends on the contralateral side of the eminence. Type III are rim avulsion fractures with a high rate of associated neurovascular injuries. Type IV fractures are rim fractures displaced distally or impacted and crushed with often concomitant collateral ligamentous injury. Type V is a four-part fracture where the tibial eminence is separated from the diaphysis and the condyles, often associated with vascular injuries (14) (Fig. 3).

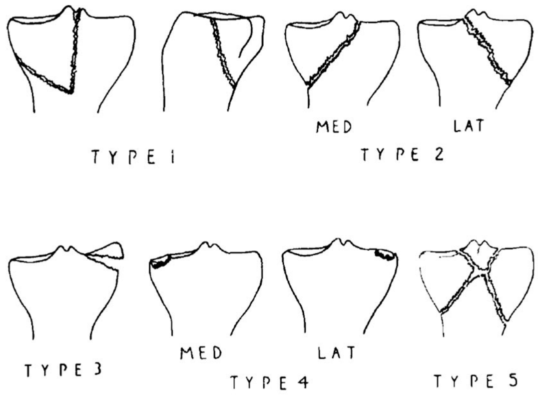

Fig. 3. Moore classification of fracture/dislocation of the knee (14)

INITIAL MANAGEMENT

Careful management of the soft tissue envelope is essential for the successful treatment of tibial plateau fractures. The level of energy involved in the injury determines the degree of soft tissue damage and this dictates the management plan. There is often significant soft tissue swelling and bruising which creates a hostile surgical environment, and early operative management commonly results in wound breakdown and infections. Temporary stabilisation, ice and elevation are required to allow quiescence of the soft tissue envelope prior to surgical management. In the setting of an open injury, the compound wound needs timely debridement, appropriate temporary stabilisation followed by delayed primary closure or grafting and definitive fixation.

For minimally displaced fractures, or fractures in low demand or high anaesthetic risk patients, non-operative management may be appropriate. A knee immobilising splint or a long leg cast may be used. A short period of bed rest with limb elevation and icing is used initially, followed by 6-8 weeks of non-weight bearing with crutches. Appropriate DVT prophylaxis should be considered during this period. Depending on the fracture configuration, some knee range of movement exercises may be begun after 4-6 weeks.

The indications for operative management include intra-articular fractures with >2mm joint depression or separation, metaphyseal components which are significantly displaced or angulated >5 deg, open injuries, vascular injury, and associated ligamentous injuries requiring stabilisation. The options for operative management include percutaneous screw fixation, open reduction and internal fixation with plate osteosynthesis, external fixation with a bridging fixator or a ring fixator, or primary total joint replacement.

Bennett et al found in a series of 30 tibial plateau fractures an overall incidence of 56% with associated soft tissue injury. The medial collateral ligaments were injured in 20% (six of 30), the lateral collateral ligaments in 3% (one in 30), the menisci in 20% (six in 30), the peroneal nerve in 3% (one in 30), and the anterior cruciate ligaments in 10% (three in 30) (5). Shepherd et al found an incidence of 90% (18 of 20) of MRI detected soft tissue injuries in non-displaced or minimally displaced non-operatively treated fractures of the tibial plateau (80% were meniscal tears and 40% ligamentous injuries) (20).

More important in complex fractures of AO type C3 is the damage of the skin and the soft tissues. Compound injuries are widely classified according to Gustilo et al. (9, 10). The classification of the injury is based upon the amount of skin injury, soft-tissue damage, fracture severity, contamination, and vascular status (9). This classification is formally done in the operating room, but an initial assessment using Gustilo's system is performed in the emergency department to guide early care of open fractures. In general, injuries involving more extensive soft tissue injury require staged procedures to allow stabilization of the soft tissue envelope prior to definitive fixation.

Compound fracture or fractures associated with significant soft tissue injury may be optimised using a temporary bridging external fixator. This allows skeletal stabilisation, while maintaining physiological tension of musculo-ligamentous structures and a degree of reduction of the fracture. This can be particularly important in restoring anatomical length in complex fractures which can only be operated on 2-3 weeks later. Direct observation can be made of the progress of the soft tissue envelope and in the case of open fractures; it allows access to the wounds for dressings and monitoring. Usually two pins are placed anteriorly in the femur, however, pins placed laterally in the femur prevent damage to the quadriceps muscle and possible scarring and stiffness. Two pins are placed in the anterior tibia, if possible their localization should be away from the planned surgical approach for definitive internal fixation. Connecting bars are used to bridge the knee articulation. The knee is then held in 10-15 degrees of flexion. The connecting clamps should be positioned to maintain sufficient stability, but so as not to interfere with further imaging of the injury. The timing of definitive internal fixation of the fracture is chosen based on evaluation of the soft tissues, but should not be delayed more than three weeks (21). After this time there is increased risk of pin site infections and the reduction of the fracture becomes more difficult due to early fracture consolidation and building of callus .

Egol et al treated 53 patients with 57 high-energy fractures of the tibial plateau (16 were open) with a protocol of staged management. First the fractures (AO type C1, C2 and C3) were stabilised with an external fixator before definitive fixation with different methods of internal fixation after 3–111 days. They reported a low rate of complications with 3 deep infections, 2 non-unions and 2 with knee stiffness (8).

Occasionally external fixation (as an ilizarov type or hybrid construct) may be used as the definitive treatment for tibial plateau fractures. This may be the case for injuries involving severe soft tissue damage that requires flap coverage, or if the patient has other contra-indications to internal fixation. In general fractures with severely articular comminution (AO type C3) are not suitable for definitive fixation with external fixators (6). Open, anatomical reduction of the articular surface should be performed, and the use of an external fixator in this setting increases the risk of joint penetration and subsequent intra-articular infection.

In the case of a severely comminuted intra-articular injury, primary joint replacement has been advocated by some authors. This is usually more appropriate for elderly, lower demand patients in whom the risk of revision is lower.

A high index of suspicion for compartment syndrome should be maintained when dealing with high-energy plateau fractures, and it must be ruled out in every patient with these injuries. A study in 83 patients with type C3 fractures found 11 (13%) of which were open and 12 patients (14%) developed a compartment syndrome (3, 4). If compartment syndrome is suspected by the surgeon then early fasciotomy is warranted. The clinical diagnosis is often supplemented by compartment pressure measurements, but this is primarily a clinical diagnosis and surgical decompression should be done as an emergent procedure to prevent permanent ischemic injury.

Surgical approach

In general over the past decade the choice of surgical approach has become more fracture specific. The traditional ventral midline incision is very rarely used due to the high rate of wound complications. The most commonly utilised approaches are the antero-lateral and the postero-medial approaches, which are often combined in the case of bi-condylar fractures. Sometimes if the fracture pattern requires it, a posterior approach may be used with the patient in prone position. However this approach is more challenging for the surgeon and carries a higher risk of neurovascular complications.

Anterior-lateral approach:

An antero-lateral approach is chosen in the majority of internal fracture fixation cases. The incision is made in the mid-axial line of the femur just proximal to the lateral joint line leading anterior to Gerdy's tubercule, then distally and ending approximately 0.5-1 cm laterally of the tibial crest in a "lazy S" shape. Then the iliotibial tract is split proximally and the incision deepened to the periosteum over Gerdy's tubercule. Distally the tibilais anterior muscle is elevated and retracted posteriorly, leaving a cuff of fascia anteriorly for closure. A horizontal sub-meniscal arthrotomy, dividing the coronary ligament, is performed. Often the meniscus is elevated from the plateau as a result of the injury. To aid in the exposure of the fracture and for later repair the meniscus is held upwards with 2.0 PDS sutures and artery clamps. From here the fracture is washed out to more clearly expose the fracture fragments. The depressed fragments are then gradually elevated reducing the plateau. Often the articular surface requires "over reduction" in order to restore the articular height. There is commonly a residual defect in higher velocity injuries that requires grafting with autologous bone or bone substitute. In case of a pure depression injury (Schatzker type 3), a cortical window may need to be created in the anterolateral tibia to allow the articular surface to be elevated from below using a punch. The defect subsequently created under the articular surface is then filled with graft or bone substitute to maintain the reduction. The cortical window can be re-inserted prior to internal fixation.

It is critical that the joint height is restored as post operatively often the lateral plateau can subside. If the articular surface is comminuted with a defect in the cartilaginous substance a simple filling with graft and subsequent fibrocartilaginous healing can be achieved. Alternatively, large defects may require osteochondral allograft, which can be taken from different locations, preferably from the femoral condyle ridge or the proximal fibula head. This is often done as a delayed procedure.

Once reduced, the fracture is held with screws or a plate. Usually a peri-articular locking plate is inserted providing a raft of proximal locking screws to support the articular surface, and buttressing the lateral wall of the proximal tibia, and extending distally to adequately support the construct. Fixation of 6 cortices (i.e. 3 bicortical screws) distal to the most inferior extent of the fracture is recommended.

The elevated meniscus can then be brought down and repaired using the holes at the proximal end of the plate or to the remaining cuff of joint capsule. The ITB and tibialis anterior muscle and deep fascia are closed over the plate. It is important that during closure as much of the plate is covered as possible, to minimise the risk of infection. A drain is occasionally inserted temporarily.

Case study 1

48 y.o male, fall from ladder. Schatzker II, AO 41.B3.

Fracture was addressed using an antero-lateral conventional plating technique. Note the use of k-wires placed very sub-chondrally to aid in elevation of the depressed fragment and create supporting effect (Fig. 4–8).

(Note: normally k-wires don't interfere with the soft tissues causing discomfort, however if this occurs they have to be removed.)

Posterior-medial approach:

Complex bi-condylar fractures often require an additional medial approach to reconstruct the medial plateau. The postero-medial approach may be performed

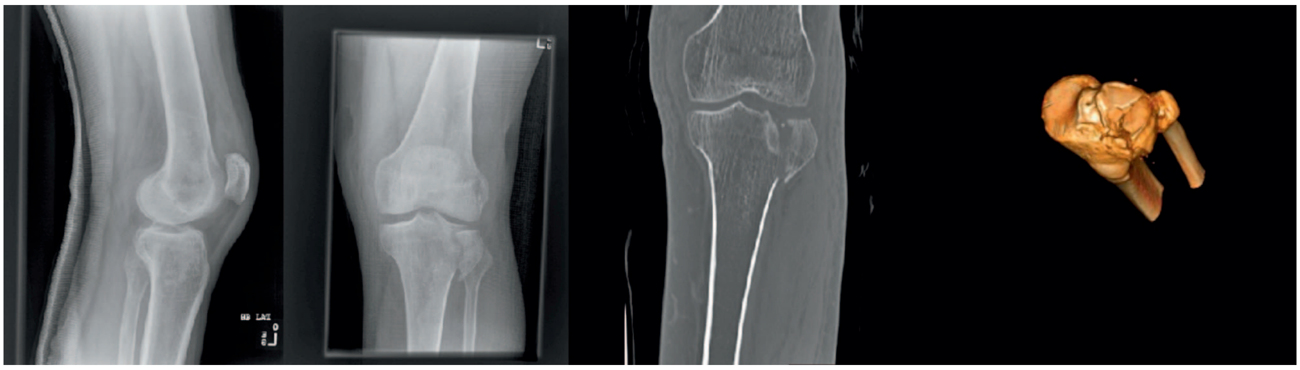

Fig. 4. Pre-operative X-ray and CT images of injury with 3-D reconstruction

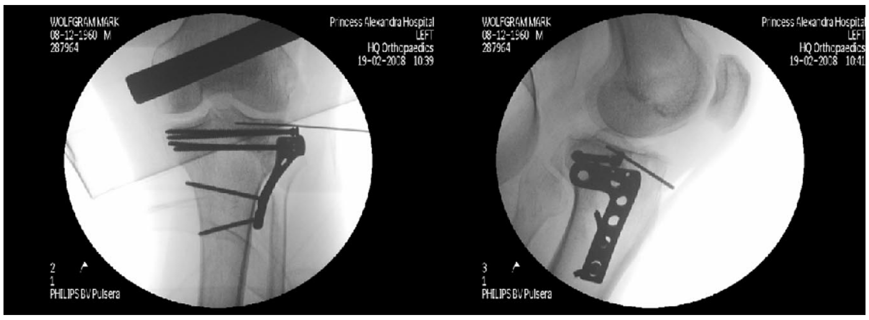

Fig. 5. Intra-operative views showing screw and K-wire positioning

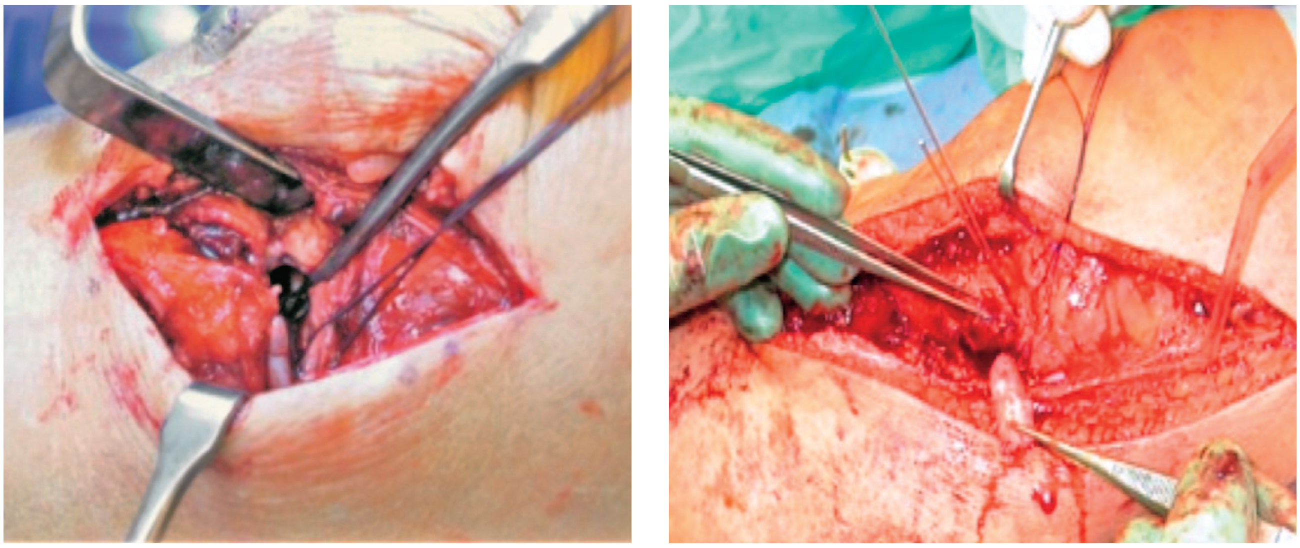

Fig. 6. Antero-lateral approach showing submeniscal arthrotomy and lateral plateau exposure

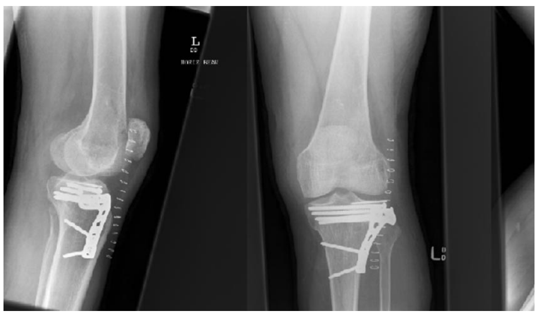

Fig. 7. Initial post-op images to check position

Fig. 8. 6 months post operation, showing maintained reduction of plateau on AP and lateral images and K-wire remaining

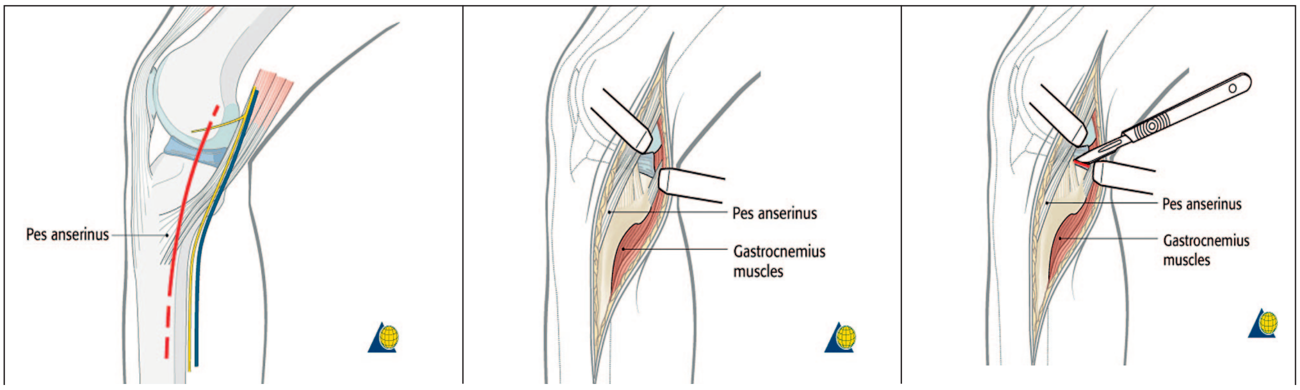

Fig. 9, 10. 11. Shows the AO described postero-medial approach (2) to the plateau

Fig. 12. Shows the surface anatomy of the plateau and positioning of incision

Fig. 13. Shows the position of the buttress plate.

Fig. 14. Today most of the bi-condylar fractures are addressed using a combined antero-lateral and postero-medial approach

through a variety of surgical windows. The most common is between medial gastrocnemius and semimembranosus. The medial popliteus muscle may be elevated and retracted. Access may be gained by deep dissection between the medial collateral ligament and the posterior oblique ligament. The postero-medial joint can be accessed, and with careful subperiosteal dissection, elevating popliteus and soleus, the posterior flare of the tibia can be accessed. Alternatively the interval between semimembranosis and the pes anseurina can be used to access the joint. Dividing the pes anseurina can improve the exposure.

Postero-medial reconstruction has traditionally involved a medial buttress plate, supplemented by a lateral peri-articular locking plate. The postero-medial fragment is important for the stability of the knee, and often reduction is achieved by keying the distal spike of the fragment into the metaphysis. This is the important point of stability for a buttress plate. A rigid 3.5mm plate is generally used in an anti-glide or buttress fashion. More comminuted fractures of the medial plateau can occur in high energy injuries. Newer devices now allow the application of specific medial locking plates, which can provide a stable raft of supporting screws from the medial side.

Whichever surgical approach taken, it is important to be mindful of the soft tissue envelope and its preservation. Additionally by attempting to minimize the surgical approach fewer stabilizing structures require repair enhancing the construct stability (Fig. 9–13).

Combined approach results

Barei et al treated 83 patients with 83 fractures AO type C3 (11 open, 12 with compartment syndromes) with a combined antero-lateral and postero-medial approach for bilateral internal fixation with conventional plates. 42 patients were managed with a provisory external fixator. Firstly, the medial plate was placed by a postero-medial approach, and then the lateral plate was placed by an antero-lateral approach with sub-meniscal arthrotomy. 7 patients (8%) underwent second surgery for non-septic major complication, 16 patients (19%) underwent removal of the osteo-synthetic material and 16 patients (19%) developed deep venous thrombosis. 7 patients (8%) suffered from deep wound infection and 8 patients (10%) developed superficial wound infection (3). 41 of these patients were interviewed for the functional outcome with a mean follow-up of 59 months with the help of the Musculoskeletal Function Assessment (MFA) questionnaire. It showed a significant relationship between better functional subjective outcome and satisfactory radiographic articular reduction (4). With combined approaches the medial plateau is usually fixed first so it is important to consider placement of screws so as not to hinder fixation of the lateral side (Fig. 14).

Posterior approach

The posterior approach is technically more difficult than the previous two mentioned. Most fractures can be adequately reduced via antero-lateral and postero-medial approaches. However, use of this approach is uncommon and as a result, orthopaedic residents and practicing orthopaedic surgeons may not be familiar with the appropriate surgical anatomy.

The direct posterior approach requires mobilization and retraction of the medial head of gastrocnemius muscle. The fracture can be visualized by partial subperiosteal detachment of the popliteal muscle. The medial head of gastrocnemius and the semimembranosus muscle are preserved. Simplified reduction of the posteromedial fragment by extension of the knee and axial traction can be achieved, and stabilization with lag screws and placement of a buttress plate. The surgical treatment of highly unstable tibial postero-medial fracture-dislocations is demanding and may cause significant problems. Neither the antero-lateral nor the postero-medial approach allows optimal posterior positioning of a buttress plate for a purely posterior fragment. Lobenhoffer et al. describe a direct posterior approach and an operative treatment of medial split fractures with open reduction and internal fixation in a prone position. This position simplifies the reduction of the posteromedial fragment by hyperextension and axial traction, as well as osteosynthesis with lag screws and the placement of the buttress plate (radial T-plate). This surgical exposure requires minimal soft tissue dissection. The inferior spike of the fragment can be visualized by partial subperiosteal detachment of the popliteal muscle. The medial gastrocnemius muscle and the semi-membranous muscle are preserved (12, 13).

Due to the voluminous subcutaneous tissue in the posteromedial tibial aspect, the closure of the skin incision over the medial gastrocnemius muscle can be performed without difficulty (12).

Summary for complex bi-condylar fractures

More complex fractures require good preoperative management and planning. The procedure should be staged with definitive management between days 5–14 depending on the soft tissue envelope. The approach selected using angular stable implants can be either a single side approach, when one side is non-displaced or a combined postero-medial and antero-lateral approach. The posterior medial corner is often the key fragment and most important for long-term knee stability. Intra-operatively anatomic reduction of joint surface is crucial. Accurate restoration of axis and rotation is also essential for a good functional outcome. This is where peri-articular locking plates have proved successful as chances of secondary dislocation are minimised. Postoperatively it is important to start early ROM exercises. Continuous passive motion (CPM) can usually be started within 1 to 2 days post-operatively and the range can gradually be increased. The weight bearing status should be partial for 6–12 weeks depending on the stability of the fixation and the state of the soft tissues. It is essential for a successful functional outcome that full knee extension is achieved and this must be addressed early in the rehabilitation program.

Case study 2

34 y.o female, low velocity sports injury, Schatzker II, AO 41 B3.

Conventional plating technique used (Fig. 15–18).

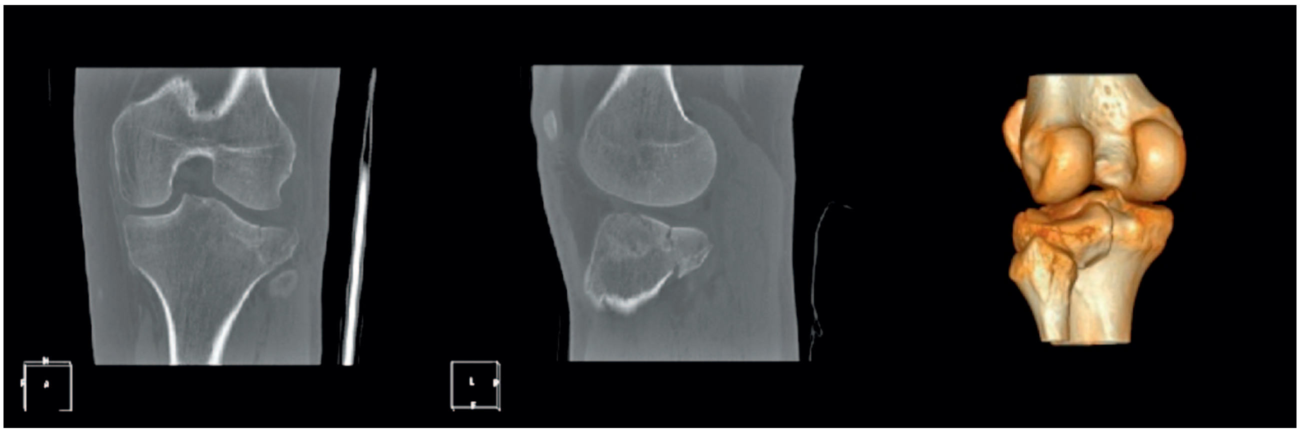

Fig. 15. Pre-operative CT images with 3-D reconstruction

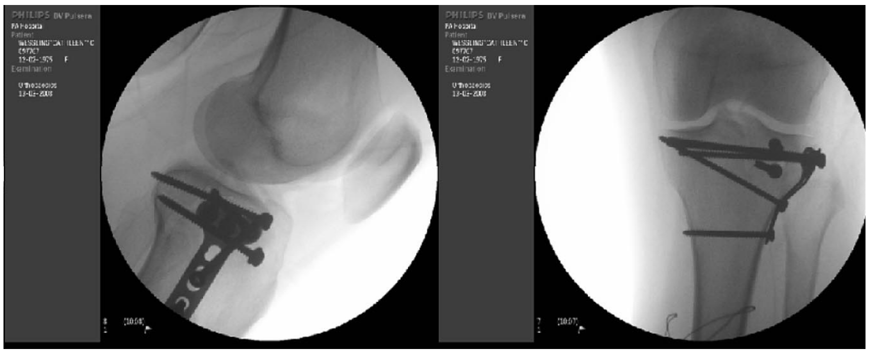

Fig. 16. Intra-operative images showing positioning of the AP screws. (Note the placement of screws to create a „rafting“ effect, providing additional support.)

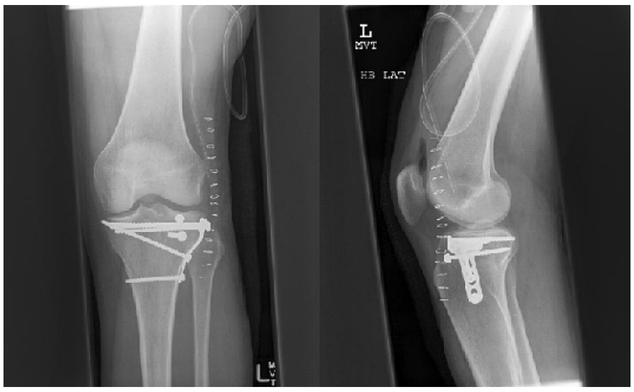

Fig. 17. Initial post-op images to check position. Note knee in 10–15 degrees flexion.

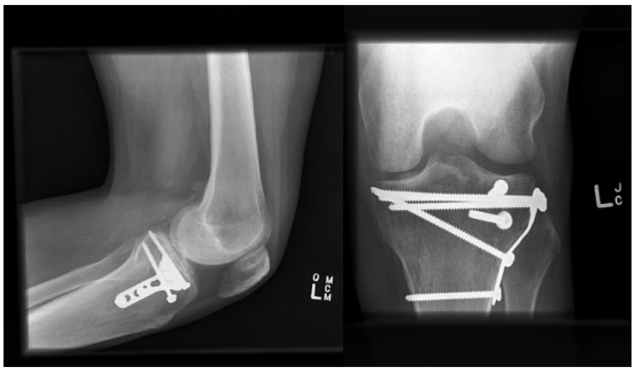

Fig. 18. Maintenance of reduction at 6 months. (Note full knee range of motion was achieved.)

Case study 3

48 y.o female MVA, single limb trauma, Schatzker VI, AO 41 C3, managed as a 2 stage procedure (Fig. 19–23).

Fig. 19. Shows pre-operative x-rays and CT imaging showing the complexity of the injury ▼

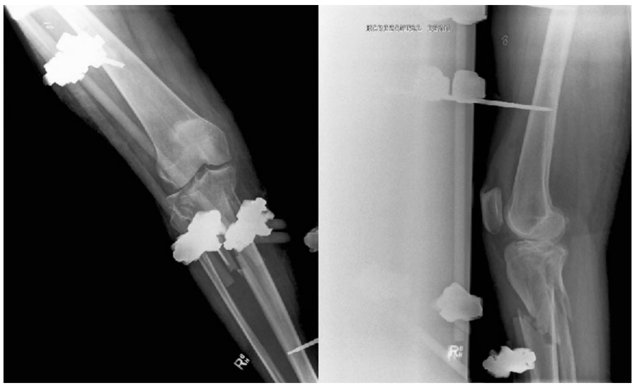

Fig. 20. Shows initial management with external fixator and pin position to keep the bony alignment and soft tissue management

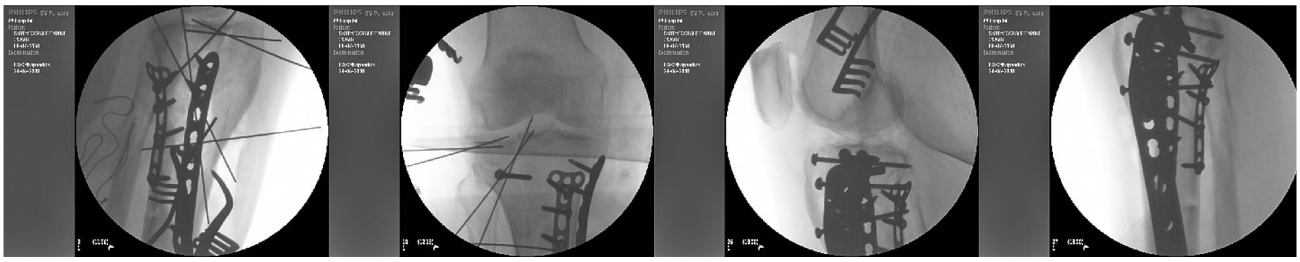

Fig. 21. Intra-operative images demonstrate the use of k-wires to hold reduction and the complex fracture requiring 3-4 hours surgical time. In this case a double buttressing on the posterior-medial aspect were required (3.5 plates)

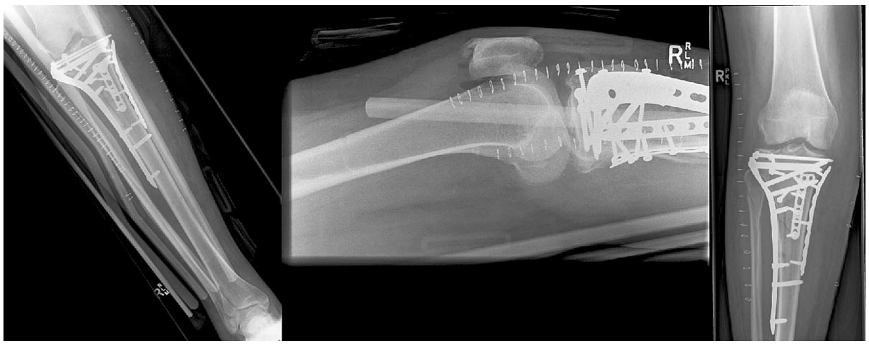

Fig. 22. Show initial post-op images with good reduction and positioning of plates and AP „rafting" screws

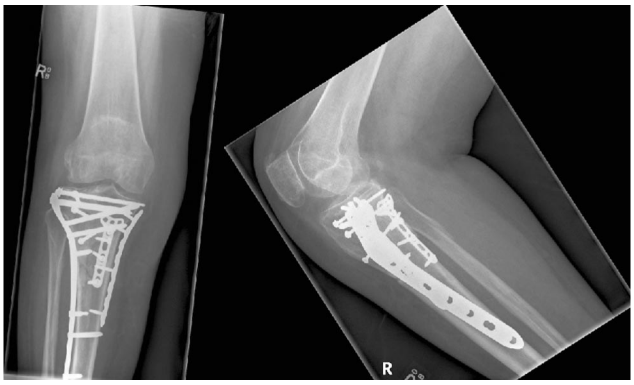

Fig. 23. 6 month follow-up reduction maintained and excellent knee ROM. (Note: in complex fractures locking plates provide the required stability to enable accurate fracture fixation.)

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Case study 4

37 y.o female, tree fell on patient, Schatzker VI, AO 41 C3.

Additional spinal trauma T4/T5 fracture.

(Managed as a 2 stage procedure with initial external fixation and definitive surgery at day 10.) (Fig. 24–27).

Fig. 24. Pre-op x-ray images and CT images. Note: the extra detail and the degree of comminution evident on CT.

Fig. 25. Intra-op images of lateral plate placement and PDS holding the meniscus ready to be attached down to the plate

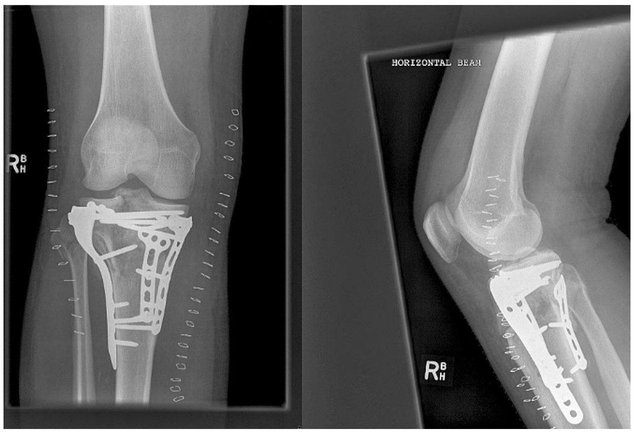

Fig. 26. Shows the plateau reconstruction using combined approaches

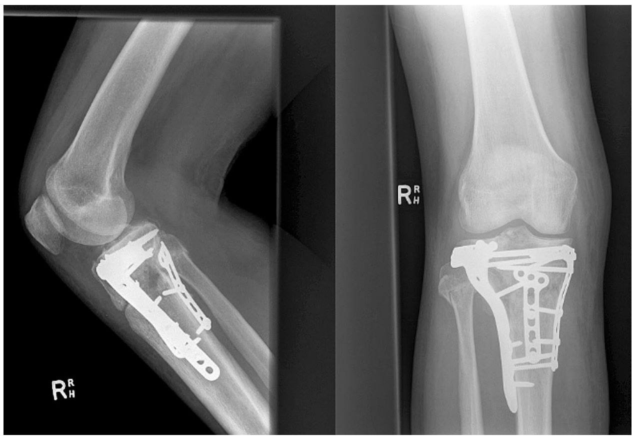

Fig. 27. At 6 months the plateau has maintained its reduction and the patient has a good functional ROM of knee

ZÁVĚR

Zlomeniny plata tibie mají podobu od jednoduchých laterálních štěpných zlomenin po velmi komplexní bikondylární poranění, která mohou být původcem závažné invalidity. Tato poranění představují výzvu jak pro mladé, tak pro zkušené chirurgy. Pečlivé posouzení mechanismu úrazu a typu zlomeniny hraje hlavní roli v předoperačním plánování. Zhodnocení stavu měkkých tkání musí být provedeno zodpovědně. Adekvátní využití zobrazovacích metod je nezbytné k detailnějšímu posouzení tvaru zlomeniny a stanovení předoperačního plánu. Cílem je časně provedená repozice a fixace. Během poslední dekády byla volba chirurgického přístupu ovlivněna zejména typem zlomeniny. Vnitřní dlahová osteosyntéza s využitím anterolaterálního a posteromediálního přístupu je nejpoužívanějším postupem pro ošetření komplexních bikondylárních zlomenin. Častá mobilizace a dosažení dostatečného rozsahu pohybu se zvláštním zřetelem na plnou extenzi kolena je nezbytná pro dobrou funkci kloubu. Použití popsaných principů je předpokladem k dosažení nejlepšího výsledku. Nové techniky fixace, jako jsou zamykací šrouby a dlahy, nemění tyto principy, ale umožňují je spolehlivěji aplikovat.

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