acta orthopaedica belgica, 2023, 89, 265-273

ORIGINAL STUDY

doi.org/10.52628/89.2.11508

Management of tibial plateau fractures: a fresh review

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Tibial plateau fractures are complex injuries which carry significant morbidity and economic burden. They can present complex geometry depending upon the direction of the force and position of the limb and are often associated with significant soft-tissue injury. While the goals of adequate reduction, stable fixation, and early mobilization remain unchanged, the management of these injuries can be challenging even to experienced orthopaedic surgeons. Lacking consensus, this review aims to provide a summary of current state of orthopaedic practice in the face of tibial plateau fractures. A PubMed search for relevant recent articles as well as a reading of classical articles on tibial plateau fractures was carried out. The focus remained on articles concerned with management modalities and recent advances. A review of some classification systems was also done and included. A great majority of these fractures need operative fixation while respecting the soft tissues. Numerous methods have been reported in the literature including but not limited to plates, screws, external fixators, arthroscopy assisted methods, balloon-cement tibioplasty, or a combination thereof. There is a shortage of randomized controlled trials comparing various operative methods. This article provides a review of various techniques and latest advances made in the management of tibial plateau fractures. The key to achieving optimal functional outcome is using a tailored approach to the individual patient accounting for factors related to the injury pattern, type of host, surgical skills and experience, and local availability of implant devices while taking care of soft tissue. While there is no gold standard, a staged procedure is recommended with early spanning and definitive fixation at later stage by any appropriate methods while respecting the soft tissue, achieving anatomical reduction and adequate fixation and, early rehabilitation.

Keywords: Tibial plateau, tibioplasty, three column, locking plate.

INTRODUCTION

Tibial plateau fractures are complex injuries that can cause significant morbidity and loss of function in patients. They can be produced by high- or low-energy trauma. They principally affect young adults or the “third age” population[1]. The interaction between the anatomy of the tibial plateau, the position of the knee and the high energy impact force in axial as well as coronal planes[2] results in multiple force vectors which cause fractures with complicated geometry, limb malalignment[2] and comminution with extension through the epiphysis and metaphysis, frequently associated with compromise of the overlying soft tissue[3]. The complexity of the fracture geometry and comminution, and the extent of soft tissue damage not only impact the management of these injuries, but also have a direct bearing on poor prognosis[1,2]. The management of these injuries remains challenging even to most experienced surgeons[2] and fraught with controversies[2]. While the goal remains adequate reduction and stable fixation of the articular surface, restoration of the alignment of the limb, but the most crucial effect on the mode and timing of the intervention is dictated by the status of soft tissue cover[2].

Modern modalities of management of these injuries focus on the biological approach to fixation with attempt to minimize the damage to soft tissue envelope, preservation of vascularity of the fragments, optimize outcomes, as well as avoidance of post-operative complication[2]. Despite careful techniques, the recovery is slow and fraught with complications which include loss of movement, unstable knee, malalignment and secondary osteoarthritis (post-traumatic osteoarthritis), often requiring secondary surgical procedures with additional risks and economic burden[4,5]. At the moment there appears to be no clear consensus regarding management of these injuries[2]. The literature is full of numerous reported techniques and algorithms to manage these injuries. The purpose of this review is to present a succinct guide to advanced techniques in orthopaedic management of this injury pattern based on current evidence.

The complete understanding of the geometry of these fractures is the key to optimize decision-making when choosing the best possible line of management[6]. In a systematic review of the literature, Millar et. al[7] found at least 38 classification systems used to describe tibial plateau fractures which makes it impossible to summarize them all in a single article. Most prominent among those is one proposed by, Schatzker in 1974 who described six principal types[8,9], and has been used extensively to classify proximal tibial fractures across decades. This system can be linked with mode of injury and recommended treatment methods. The classification (Figure 1) categorizes proximal tibial fractures into six groups. The shortcoming of the Schatzker system is that it is based on antero-posterior radiographs, and hence fail to provide satisfactory information on the fracture geometry and unable to identify shearing fracture patterns of posterior tibia, leading to poor clinical categorization and poor outcome in terms of the treatment plan[10,11].

About 10% of all tibial plateau fractures do not render themselves to be classified based on Schatzker classification e.g. fracture dislocation or fractures associated with knee instability. For these injuries Hohl and Moore[12] system (Figure 2) can be used as shown in Figure 2.

Similar to Schatzker, the AO classification, while more extensive, is also based on AP radiographs, hence suffers from similar shortcomings as that of Schatzker[13,14]. With the use of CT scans for evaluation of these fractures, the importance of posterior fixation, especially the postero-medial fragment came to light. Luo et al.[15] described the “three column concept” for proximal tibial fractures, based on transverse sections of the tibial plateau on CT scans. The proximal tibia is divided into three columns, namely medial column, lateral column, and the posterior column. In the given figure (Figure 3) these three columns are separated by three lines (OA, OB, OC) radiating from somewhere in the centre at midpoint of tibial spines, O, to A (tibial tuberosity), B (postero-medial ridge, and C (anterior fibular head. The posterior sulcus divides the posterior column into medial and lateral parts. According to this classification, isolated depression/split of one particular column is considered to be a fracture of the corresponding column which can be “one column”, “two column” or “three column” fractures based on presence of independent fractured bone pieces in corresponding number of columns. Pure depression of articular surface (Schatzker type III) is labelled as a “zero column fracture”.

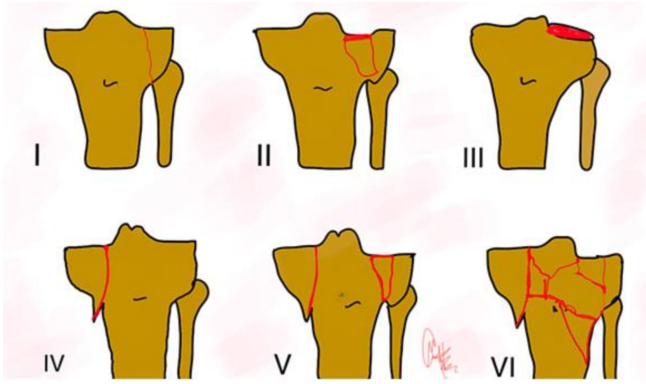

Fig. 1. — Schatzker Classification.

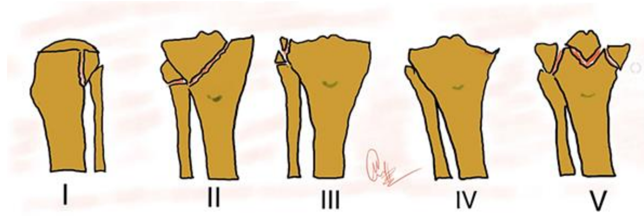

Figure 2. — Hohl and Moore Classification.

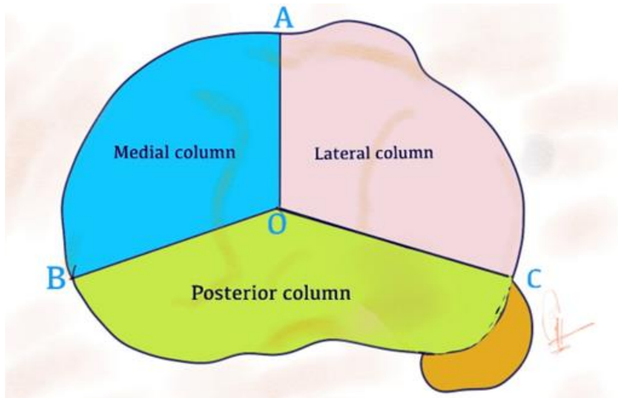

Figure 3. — Three Column Classification.

Complex tibial plateau fractures are a result of high energy trauma, hence significant comminution can be present. Interpretation of such fractures can be difficult on plain AP radiographs. CT scans can prove an invaluable tool for proper understanding of these fractures[16,17]. The three column concept provides improved understanding of these fractures in three dimensions, hence serving as a useful tool in planning proper operative approach and fixation technique.

Nevertheless, these classification systems don't define a critical area, the postero-lateral corner (PLC) properly. Hoekstra and colleagues[18] introduced a revised three column concept for the management of PLC injuries, which are serious and require prompt recognition and treatment to prevent long-term complications. The PLC is defined by connecting points C and D, which are the anterior and posterior borders of the fibular head, with point O in figure 4. If a lateral column fracture extends into the PLC, it is classified as a single "extended lateral column" fracture and can be stabilized with a lateral proximal tibial variable angle LCP. If a posterior column fracture extends into the PLC, it is classified as a single "extended posterior column" fracture and can be stabilized using a posterior approach.

Krause and colleagues[19] introduced a three-dimensional, segment-based mapping of the tibial plateau in order to approach fractures in a specific way. They divided the proximal 3 cm of the tibial plateau beneath the articular surface into ten segments, five anterior and five posterior, by considering the tibial plateau in an axial view and dividing it into an anterior and posterior column, each further divided into five segments each. This resulted in a total of ten separate segments of the tibial plateau as shown in figure 5.

Proximal tibial fractures have been treated by a wide variety of methods including conservative methods for selected cases, temporary external fixators preceding definitive management by locked plates, fine wire devices, arthroscopically assisted procedures, and intramedullary nailing in selected cases[20-23]. A good prognosis depends largely on anatomical restoration of the articular surface, adequate fixation, and early range of motion. Besides, restoration of the tibial length and alignment remain critical for a satisfying post operative result. However, the status of local soft tissues and the patient's co-morbidities are crucial in deciding the time of the intervention[3].

Splints, casts, and traction are options for initial damage control treatment for severe cases. However, the procedure of choice for such severe cases remains a knee spanning external fixator[24]. Such fixators help reduce the fracture fragments by means of ligamentotaxis, immobilize the fracture, and additionally offer pain relief and promote soft tissue healing by minimizing further trauma[3]. A possible drawback of these spanning fixators is residual knee stiffness[25]. For the femur construct, antero-lateral pin placement is preferred than lateral pin placement. Even though the anterolateral construct is biomechanically less stable but is preferred due to convenience for the patient when lying in bed[26].

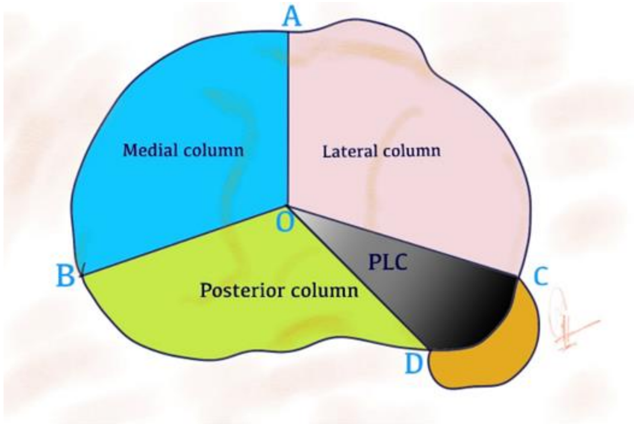

Figure 4. — Revised Three Column Classification.

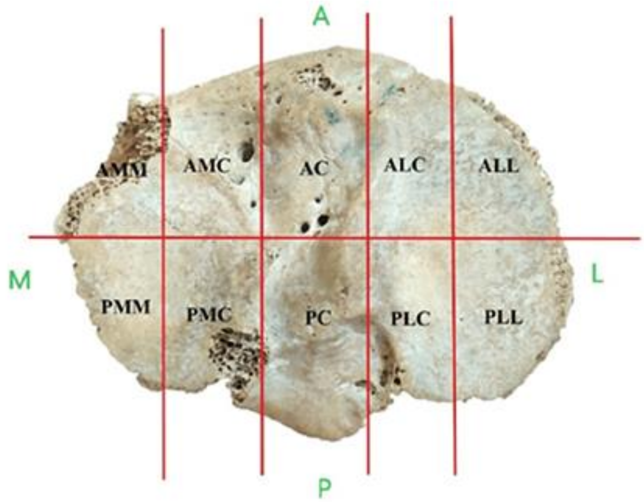

Figure 5. — Segmental Classification.
A: Anterior, P: Posterior, M: Medial, L: Lateral. PMM: Posteromedio medial, PMC: Posteromedio central, PC: Posterocentral, PLC: Posterolatero central, PLL: Posterolateral lateral, AMM: Anteromedial medial, AMC: Anteromedial central, AC: Anterocentral, ALC: Anterolateral central, ALL: Anterolateral lateral.

The placement of tibial pins is dictated by the location of planned incisions in the next step[23].

Since the initial recommendation by Schatzker in 1979[27], dual plating of both medial and lateral components with conventional plates using a single midline incision was the gold standard for treating bicondylar tibial fractures. However, subsequent high rates of soft tissue complications, wound dehiscence and deep infection lead to an ongoing debate using a more biological osteosynthesis[28,29]. Over the next years, a double incision approach (postero-medial/antero-lateral) for dual plating was advocated by several authors. They reported lower wound complications and less adverse effects[30,31]. However, recently studies attempt to revise the approach to a single midline one, exploiting the advantages of clear exposure of fracture sites and allow salvage arthroplasty at a later stage, if needed[32,33].

In a study published in 2004, Barei et al.[31] treated 83 complex bicondylar plateau fractures with dual plating using two separate incisions. They reported an incidence 8.4% of deep infection[31]. The incidence of deep infection reported by Jiang et al.[34] in a 2008 study (84 patients) was 4.7% and in a 2012 study involving 79 patients with tibial plateau fractures, Zhang et al.[30] reported even lower incidence of 3.8%. This demonstrated a distinct decrease in infection rates in two incision technique compared to the previously reported with single incision procedures.

In addition to improvement in understanding of surgical approach, the introduction of better and more biologic implants has further revolutionised the fixation in severely comminuted or osteoporotic fractures. The introduction of Less Invasive Stabilisation System (LISS) and locking compression plates (LCP) along with the introduction of minimally invasive percutaneous plate osteosynthesis (MIPPO) technique has offered the potential for a stable construct with a more biologic, low implant profile fixation[3,34,35,36]. These improved implant designs can be used alone or in combination with more conventional implants.

The literature suggests that there is no significant difference between LCP/buttress and double buttress fixation construct in terms of stability[36]. With regards to dual plating, satisfying results have been reported in literature with recent studies observing loss of reduction in around 4.5% to 10%[37]. However, some studies are critical with regards to dual plating, giving less optimistic results in terms of complication rates including deep infection, non-union or wound healing problems[38].

Some surgeons have advocated using a single LCP/LISS plate laterally, fixing the lateral condyle and trying to capture the medial fragment[25,39]. However, reduction technique for exact alignment can be challenging and post operative loss of reduction can be problematic[41]. While some studies, for example by Egol et. al.[25] and Ikuta et. al.[39], have reported favourable results, other studies including those from Barei et al.[31] and Weaver et al.[40] have reported higher incidence of malreduction or loss of reduction following single plate fixation. Literature remains unclear about the matter and contradicting results have been published. The use of CT based classification systems like those of Luo et al.[15] have improved our understanding of the injury as well as allowed better decision making in terms of the approach and implant used to address each injury. They introduced the concept of "three-column fixation" by using a posterior approach using inverted L-shaped incision, combined with an anterolateral approach to fix all three columns. Since then, this concept has been followed by other authors describing slight modifications based on the same concept[14,15,41,42].

In complex tibial plateau fractures, the minimally invasive ARIF technique allows for direct visualization of the joint space, providing a better understanding and control of the articular reduction, and the possibility of both evaluating and treating intra articular lesions[43].

ARIF has been widely accepted as a safe procedure for Schatzker type I through IV fractures. However, ARIF remains controversial for type V and VI fractures[44,45]. In a systematic review of 19 studies including 609 patients, Chen et al.[46] reported that most common fracture types treated by this technique were Schatzker types II and III. Good or excellent outcome was seen in 90.5% of the patients as per clinical Rasmussen scoring system[47], and 90.9% of the patients were satisfied with the treatment. Only 6 severe complications were reported, including one case of compartment syndrome[46]. The risk of iatrogenic compartment syndrome due to fluid extravasation, remains a serious concern in complex tibial plateau fractures. Even though the incidence of such a complication is extremely rare, careful monitoring of the patient in post operative period is mandated[48,49]. The incidence of infection has been shown to be lower in ARIF when compared to ORIF but the conclusion is based on limited data[46]. Dry arthroscopy or "fracturoscopy" using the standard 4.0 mm, 30-degree angled scope, has more recently been advocated for the intraoperative assessment of fracture reduction[50]. In fractures of the posterolateral corner or posterolateral central fragment, it been shown to be superior to fluoroscopy in assessment of reduction[50], and arthroscopy assisted techniques have been advocated by many surgeons[50,51,52,53,54]. In a very recent cadaveric study by, Behrendt et al.[51] on fractures of the latero-central segments of tibial plateau, the authors used fluoroscopy, "fracturoscopy" using a 4.0 mm, 30-degree angled scope, and "nanoscopy" using a 1.9 mm straight scope to assess fracture reduction. They demonstrated that "nanoscopy" provides superior visualization of the entire lateral condyle than fluoroscopy or "fracturoscopy"[51].

In addition to above mentioned techniques, many other methods of managing tibial plateau fractures are practiced in orthopaedics. External fixators of various designs, apart from being used as temporary spanning devices, can be used for definitive management as well. Circular or hybrid frame fixators using fine wires for reduction and fixation are considered appropriate for tibial plateau fractures associated with significant soft

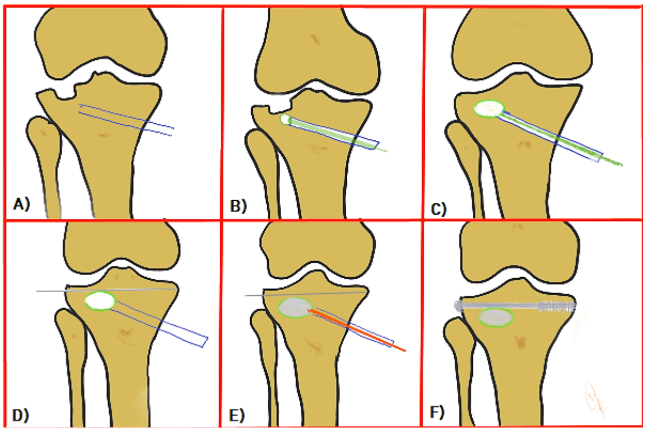

Figure 6. — Tibioplasty technique.
A: Trocar inserted under the depressed fragment; B: Cannula with balloon inserted underneath the depressed fragment; C: Balloon inflated with contrast and reduction observed in fluoroscopy; D: Fragment provisionally stabilized with K wire and balloon retrieved; E: Cavity filled with bone cement/filler; F: K wire exchanged for definitive fixation with screws/plate-screw construct.

tissue injury where a surgical approach through the injured soft tissue is contraindicated. The additional benefit of these fixators is to allow immediate mobilization and weight bearing for accelerated rehabilitation[55]. Circular fixators like Ilizarov frames and Taylor Spatial frames have been extensively used in the definitive management of these injuries, with some concern about inadequate reduction and risk of pin tract infections with reported incidence between 10 and 20 percent[56,57].

In terms of patient satisfaction, continuation of external fixators for protracted duration causes dissatisfaction and poor compliance but in complex tibial plateau fractures with extensive soft tissue trauma, these devices remain the compromise in best interest of the patient[52]. To address the issues with malreduction or inadequate fixation, as reported by Subasi et. al.[57] in 2007, many surgeons have adopted a combination of external fixators with some form of minimal open reduction and internal fixation using cannulated cancellous screws, frame extension or bone grafting through small incisions to address metaphyseal gap or extensive comminution[57,58,59,60,61].

Depressed tibial plateau fragments can be a challenge to reduce, especially in osteoporotic bones. The depressed fragments can be lifted up with a metal tamp and bone graft might be needed to fill the space. These may result in joint damage, incongruity and even penetration in osteoporotic bone[62]. Borrowing from the successful technique of vertebral kyphoplasty, a technique of tibioplasty has been developed lately[59].

Through a hole in the medial metaphysis, the osteointroducer with a trocar tip is inserted underneath and the depressed fragment[62]. (Figure 6) The balloon is slowly inflated with contrast and the pattern of contrast examined under fluoroscopy to ascertain proper positioning.

The balloon is inflated up to approximately 200 psi and reduction is observed using live fluoroscopy until satisfactory reduction is achieved in AP and lateral views. Subsequently the balloon is deflated, withdrawn[63] and the cavity filled with calcium phosphate cement filler through the trocar, which has better mechanical stability[64], thus augmenting the fracture. To avoid cement overflow, the amount of contrast used for the balloon is used as a guide to estimate the amount of cement to be used[59]. The balloon offers the advantage of being minimally invasive and creating a symmetric, contained defect to hold a bone filler for subchondral support[65].

Jail screw technique

A minimally invasive technique using two parallel tension screws was first introduced by Schatzker et al. in 1979[26] Minimally invasive techniques of screw fixation for Schatzker type I fractures have long been advocated in literature. The conventional technique involves placing two lateral cancellous screws to

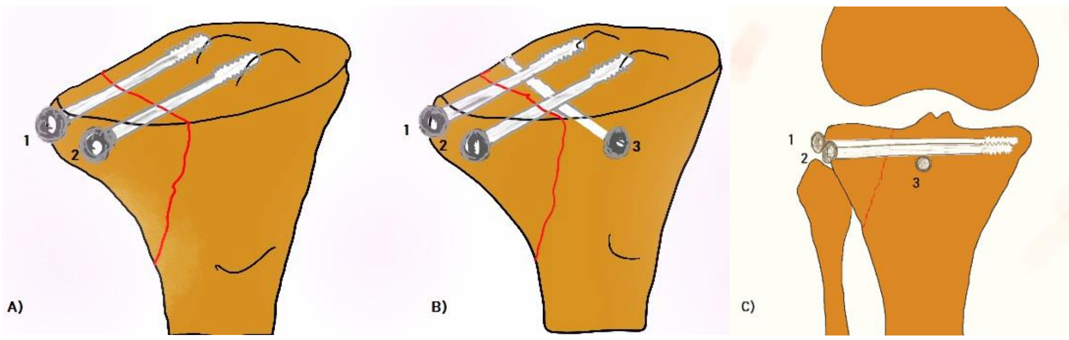

Figure 7. — Representation of "Jail screw" technique. Screw 3 acts as the "jail" screw.

secure the lateral “split” fragment. However, a novel three screw technique has been advocated, which uses a third “jail” screw implanted from anterior to posterior at 90 degrees below the two lateral screws[66] (Figure 7). The third or the jail screw provides a counter bearing surface and provides a protection mechanism for screw cut-out through the cancellous bone.

In a biomechanical study by Boisrenoult et al.[63], the authors compared the biomechanical strengths of the conventional two screw technique with the jail screw technique and found that both the techniques had similar biomechanical properties but the jail screw technique had some minor benefits. The jail technique showed better outcomes in terms of maximal load in single cycle loading tests, yield load, stiffness and displacement though the differences were not statistically significant. Another potential benefit of the jail technique was that it was protective against screw cut-out through the cancellous bone[67]. A clinical study by Lone et. al.[67] concluded that jail screw technique can be used with comparable results to the conventional two-screw technique with potential added benefits of lower chances of screw cut out and prevention of progressive subchondral collapse with weight bearing.

Patient optimised surgical tools (POST) have been frequently used in pelvi-acetabular fracture management for pre-operative planning using a 3D-printed life-sized model and pelvic fixation plate templates. This has been shown to reduce the operative time and blood loss, improve fracture reduction, and resulted in lower complication rates[68]. Conventional radiographs and CT scans can be limited in their utility for understanding the fracture geometry while 3D printing technology allows clinicians to create a 3D physical model of the injury pattern allowing more intuitive observation of the fracture geometry, which guide to a better choice of surgical approaches and fixation methods[69]. A study by Huang et al.[70] used a combination of CT scans and 3D printing technology in planning and assessment of complex tibial fractures. They printed life sized models of injured proximal tibial and performed simulated surgical fixation with various implants in the office. The simulation was used to guide the approach, type of implant, placement of screws, and position and sizes of screws. They observed that in addition to guiding approach, this improved the intraoperative reduction and fixation[70].

CONCLUSIONS

The management of tibial plateau fractures continues to evolve as our understanding of the complexity of this injury spectrum improves with advances in and increased availability of 3D imaging modalities, technological changes in fixation devices, and the observation of variable outcomes achieved employing those treatment options. Most surgeons agree that the primary objective of the surgery is to achieve and maintain exact articular reduction and rigid fixation, aligning the mechanical axis of the lower limb which allows early rehabilitation. As tibial plateau fractures are serious injuries associated with significant soft tissue trauma, respecting the soft tissue envelope by avoiding undue surgical insult should be used as a guide to achieve optimal outcomes.

There is no “gold standard” of treatment for these injuries as the method employed is dependent on numerous factors including fracture pattern and complexity, degree of soft tissue disruption, systemic patient factors, institutional factors, and vast selection of fixation devices. While general principles are agreed upon, the detailed management of these complex and high energy injuries remains open to debate and need of further clinical studies cannot be overstated. The key to optimising functional outcome is using an approach tailored to the individual patient taking into account all the factors related to the injury pattern, type of host, surgical skills and experience, and local availability of implant devices. It is important to prioritize soft tissue status and use of damage control early in the process is important. Staged procedures are recommended by most trauma surgeons and for definitive fixation any chosen method or combinations can be used by experienced surgeons as long as the principles of soft tissue care, anatomical reduction, adequate fixation and early rehabilitation are adhered to.

Abbreviations

AO: Arbeitsgemeinschaft für Osteosynthesefragen
CT: Computerised Tomography
PLC: Posterolateral corner
ORIF: Open reduction and internal fixation
LISS: Less Invasive Stabilisation System
LCP: locking compression plates
ARIF: Arthroscopically assisted reduction and internal fixation
PSI: Pounds per square inch
POST: Patient optimised surgical tools

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