Why address posterior tibial plateau fractures?

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Abstract

Management of posterior tibial plateau fractures has gained much interest over the past few years. Fracture morphology, trauma mechanism, and soft-tissue injury have been identified as the key factors determining the treatment strategy and outcome. We provide a rationale for the operative management of posterior tibial plateau fractures by discussing the interplay between fracture morphology, trauma mechanism, and soft-tissue injury. The trauma mechanism has proven to be an important tool, not only to understand fracture morphology, but also to assess concomitant soft-tissue (i.e. ligamentous) injury. Subsequently, soft-tissue injury might play a role in future classification and diagnostic work-up of tibial plateau fractures, particularly in fractures with posterior involvement. Plate osteosynthesis using a posterior approach is safe and should be considered routinely in coronal fractures of the posterior tibial plateau, as illustrated

I. Introduction

Tibial plateau fractures have significant impact on knee function [1, 2]. Posterior tibia plateau involvement has been increasingly recognized as a driver of poor functional outcome [3–5]. Incidence of these posterior tibial plateau fractures (PTPF) ranges from 28 - 70% [4,6–8]. Diagnosis and surgical planning are undoubtedly supported by CT-imaging and its three dimensional (3D) reconstructions [6, 9]. Furthermore, the use of MRI in the diagnostic work-up may provide further information on concomitant soft-tissue injury [10,11]. Although numerous different classification methods for tibial plateau fractures are available, only few have been thoroughly validated[12]. The most frequently used systems being Schatzker, AO/OTA and Luo's three-column classification. However, specific surgical guidance regarding PTPF is only minimally represented in few of these classifications. Moreover, soft-tissue injury is not taken into account by most of these classifications, while concomitant soft-tissue injuries do matter [11]. As for all tibial plateau fractures the main goal of treatment is to restore articular congruence, alignment, and achieve sufficient fracture stability that allows early mobilization. Therefore, choosing the right approach and fixation methods for the specific fracture type are crucial. However, this can be very challenging for the trauma surgeon, due to the large variability in fracture morphology.
The goal of this narrative review was to evaluate the current evidence regarding the surgical management of PTPF. Fracture morphology, trauma mechanism and soft-tissue injury have been identified as the key factors determining the treatment strategy and outcome [13]. We discuss their value guiding the operative treatment of PTPF, determine to what extent they may affect the outcome, and finally make a cautious statement about future treatment perspectives.

II. Fracture morphology

Early Classification Systems

Detailed understanding of fracture morphology is essential in order to optimize preoperative planning and surgical treatment. In 2016, Millar et al. reviewed all thirty-eight available classification methods for tibial plateau fractures [12]. Most of the older classification tools are intuitively focusing on the shape of the main fracture fragment, grouping fractures into split, depression or T- and Y-fractures. In fact, only three of the early classification systems appreciate PTPF (Duparc, Khan and Hohl & Moore) [14,15]. Nevertheless, besides acknowledging a posterior fragment, none of these three classifications pay attention to PTPF morphology. The most widely used Schatzker and AO/OTA classification systems were based on plain radiographs, giving insufficient information on fracture morphology, though they bear other merits on simplicity or documentation. The improved appreciation of fracture morphology using CT-imaging has been widely established, especially regarding PTPF [7,16,17].

3D Classification and Fracture mapping

3D classification systems such as the three column, four column or ten segments classification highlight the posterior aspect of tibial plateau and provide 3D understanding tibial plateau fractures. 3D classification approaches offer a more intuitive way to understand fracture morphology compared to 2D systems. Therefore, the widely used Schatzker classification was recently revisited 3D, dividing the tibia plateau into 4 quadrants in the axial plane, wherein the main fracture plane for each quadrant is identified. Subsequently, the main fracture plane is denoted by the two points of intersection at the tibia plateau rim, and by the exit point at the metaphyseal area [18].
The increased awareness of PTPF and importance to address these fractures, along with the improved imaging modalities such 3D CT-imaging, have boosted the search for more extensive classificationmethods. The CT-based three-column concept has gained much interest since the introduction by Luo et al. in 2010, and has proven beneficial in depicting PTPF [7,9]. In order to further differentiate specific fracture patterns, Krause et al. proposed the ten segment classification that provides more detailed information on fracture location at the level of the joint [19]. To better understand the frequency of fracture patterns, fracture mapping was introduced by Molenaars et

al. in 2015 [6]. This innovative technique superimposes the contour of multiple fractures fragments and articular depression into one template. Xie et al. apply fracture mapping to categorize fracture morphology 3D. The contour of the fractures fragments and articular depression are illustrated in 3D maps [13]. These 3D fracture maps can reveal recurrent fracture patterns, provide (limited) information on soft-tissue injury, and underscore the inadequate appreciation by the most commonly used classification systems of fracture morphology, especially of PTPF[13, 20]. In addition, 3D fracture maps prevent misclassification of oblique posterolateral fracture lines in Schatzker type I or II tibial plateau fractures. Furthermore, 3D fracture maps distinguish classical posteromedial shear fractures from posterior shear-type fractures that do not fit into the Schatzker classification [17,21].

Clinical significance

New insights into fracture morphology significantly contribute to a better understanding of PTPF, which is crucial in defining treatment strategies. Molenaars et al. have shown that as much as 85% of all tibial plateau fractures with a posteromedial fragment, would possibly benefit from a non-standard customized lateral plating or additional medial or posterior plating [22]. Moreover, according to Kfuri et al. information on orientation of the main fracture plane should guide the plate application (i.e. plate application parallel to fracture plane) [18]. However, some major limitations should be noted. One-dimensional simplification of complex intra-articular fractures used in fracture mapping does not always account for specific 3D fracture characteristics and patterns. Furthermore, in highly comminuted fractures with several fracture lines, the extensive denomination of all fracture components using fracture mapping or main fracture planes, can become very complex and unreliable. Moreover, reproducibility and intra- or inter- observer reliability is still inadequate, which raises concern on the validity in daily clinical practice.

III. Trauma mechanism

New classification systems

Based on the three-column classification, Wang et al. introduced the updated three-column concept, which incorporates trauma mechanism (flexion/extension and varus/valgus), in order to guide surgical decision making [8]. More recently, Hua et al. evaluated a more extensive injury-mechanism centered classification system, wherein six main fracture types were defined: lateral condylar fracture (valgus type), fracture dislocation (complex force type), simple medial condylar fracture (varus type), bicondylar fracture (extension type), posterior condylar fracture (flexion type) and anterior condylar compression fracture (hyperextension type) [23]. The main strength of this study is the attention to collateral injuries, such as avulsion fractures of the intercondylar eminence and fibular head. A strong association was found here between posterior condylar fractures and evidence of soft-tissue injuries (e.g. avulsion fractures of the intercondylar eminence) [23]. Merging fracture-mapping with fracture-mechanism classification, Xie et al. aimed to combine the best of both concepts[13]. Adding hyperextension to Wang' updated three-column concept, they defined six injury categories: force vector in the sagittal plane (flexion/extension/hyperextension) and coronal plane (valgus/varus). In conjunction with Hua et al. an association between flexion-varus fractures, and anterior cruciate ligament (ACL) injury was established [8,23].

Clinical significance

These trauma mechanism-based studies focus primarily on flexion/extension/hyperextension and valgus/varus forces. It should be noted that force vectors other than in the axial plane, like rotation, translation, and forces anterior onto the tibia plateau are not considered to date. However, based on the recent studies, the simplification of force vectors into sagittal and coronal plane is assumed to account for the majority of tibial plateau fractures [8,13,23].

Limited reports on the updated three-column concept demonstrate good radiographic and functional outcomes[8]. However it should be noted that long-term follow-up studies are not available. Also, no significant difference was found in functional outcome scores and range of motion between the different fracture groups, indicating limited association between classification and prognosis for patients [8]. Other limitations of these new classification systems are that split and depression type fractures are not distinguished. Furthermore, there is lack of attention to fracture orientation, which is often crucial in determining the need for additional plating, particularly in PTPF. Therefore, surgical guidance is still limited. Only the three-column classification has been adequately assessed for reliability, which is relatively high due to the simplicity of the classification system [24]. The mechanism-based interpretation provides a dynamic perspective to understand fracture morphology and concomitant soft-tissue injuries. PTPF are considered as the result of either a flexion or extension compression force vector in the sagittal plane, or a hyperextension force acting as a tension arc at the posterior cortex. As a consequence of the latter, a posterolateral ligamentous injury is likely and the fixation strategy is different.

IV. Soft-tissue injury

Diagnosis

Concomitant injuries to the collateral ligaments, cruciate ligaments and menisci are common with tibial plateau fractures. Incidences of soft-tissue injuries range from 52% up to 73%, with medial collateral ligament, posterolateral corner and lateral meniscus injury being most frequent, followed by ACL injury [8,11,25–28]. If left untreated, stability may be compromised, articular stress will increase, and early progression to osteoarthritis and joint collapse are inevitable. However, clinical detection of these lesions in the acute phase of the trauma can somehow be difficult to impossible due to pain and swelling. Although MRI is regarded as the gold standard to identify soft-tissue injuries, its routine use in tibial plateau fractures is limited by higher cost and limited availability ad hoc. In far most hospitals, plain radiographs and CT scans are part of the standard preoperative work-up. Therefore, great efforts were made to develop parameters based on preoperative plain radiographs and CT images, to predict soft-tissue injuries.

Predicting soft-tissue injury

Lateral tibia plateau depression and widening are regarded as important predictors of lateral meniscal tears. Although the thresholds for articular depression and fracture gap vary across literature, ranging from 6-14 mm and 5-10 mm respectively, most studies seem to agree that large displacements warrant high suspicion for a meniscal tears [29–36]. Though plenty of studies report on lateral meniscal injury, ligamentous injury is less well described, as only two studies report on radiographic parameters that predict ligamentous injury. Spiro et al. described an association between increased tibial plateau fracture depression and ACL lesions, and Kolb et al. found a significant effect of increasing lateral plateau widening on the incidence of lateral collateral ligament tears [31, 37]. Moreover, Mui et al. demonstrated that CT evaluation of the ligament contours is a reliable assessment, as torn ligaments could be identified with 80% sensitivity and 98% specificity. Smooth visible ligament contours without obscuration by increased attenuation in adjacent soft-tissues suggested intact ligaments [32].

The value of the Schatzker classification in predicting soft-tissue injuries is debatable. Most authors suggest that it is not suitable to estimate the probability of soft-tissue injuries in acute tibial plateau fractures, since they were unable to establish a significant association with meniscal or ligamentous injuries [31,34,36]. However, Hao-Chen et al. observed a greater risk of ACL avulsion fractures in patients with high-energy-pattern fractures types (Schatzker type IV-VI) (Figure 1), and also Stannard et al. found that ligament injuries occur more frequently in these groups [10,33]. Moreover, Chang et al.described higher injury rates for bucket-handle meniscal tears in type VI fractures [35].

Diagonal lesions are commonplace in knee sports medicine, however the recurrent patterns of a tibial plateau fractures and concomitant soft-tissue injury, are not concluded in the literature yet. The injury force mechanism theory is based on the understanding of 3D fracture morphology, which allows us to predict soft-tissue injuries. It gives us a more thorough understanding of PTPF due to forces on the posterior tibia plateau. PTPF are frequently associated with ACL avulsions due to flexion- varus forces and are accompanied by posterolateral ligamentous injury as a consequence of hyperextensions forces acting as a tension arc at the posterior cortex [8,13,23].

Clinical significance

The question remains whether early detection of these soft-tissue injuries will alter the treatment strategy, since the effect of these injuries on the outcome remains controversial [26]. Moreover, consensus about the need for operative treatment of soft-tissue injuries in tibial plateau fractures as well as on the timing of operative treatment is lacking. Available evidence on soft-tissue injury management is often based on isolated soft-tissue injuries without the presence of a tibial plateau fracture [38,39]. Reconstruction of cruciate ligament tears is usually deferred after fracture consolidation. Due to the anatomic properties of the medial collateral ligament, even high-grade sprains might not require surgery, though some authors do recommend reconstruction [40–42]. In contrast, lateral and posterolateral ligamentous injuries seem to be less forgiving if left untreated [11,27].Meniscal tears are generally repaired or debrided acutely to maintain knee joint stability and congruence, and to minimize articular contact pressure, thereby preventing the development of posttraumatic osteoarthritis. Nevertheless, there are insufficient treatment guidelines, due to the lack of follow-up data on soft-tissue repair in large cohorts of tibial plateau fractures [43–45].

V. Surgical management and perspectives

Approach consideration

Surgical planning should include a strategy for all affected columns and concomitant soft-tissue injury in a step-by-step manner. Regarding PTPF, there are multiple posterior approaches described in the literature (Figure 2). Recently, Krause et al. introduced a surgical approach-specific map of the tibial plateau providing information on specific visualization of the articular surface for different approaches [46]. However, the direct posterior approach and posteromedial reversed L-shaped approach (PRLA) were not addressed. In most cases the PRLA is sufficient to provide posteromedial and posterolateral buttress without the need to open the posterior joint capsule [47]. Subsequently, articular reduction can be achieved either through a posterior cortical window with the use of pusher, fluoroscopy or dry arthroscopy (fracturoscopy). Pierrie et al. demonstrated that combining a posteromedial and anterolateral approach, provides sufficient articular exposure of both the posterior aspect and lateral joint surface of the tibia plateau (Figure 3) [48]. However, exposure of the posterolaterocentral tibia plateau (according to the 10-segment classification) remains difficult [49]. The posterolateral or extended anterolateral approach (including a lateral femur condyle osteotomy) might be a good alternative here [50, 51]. A comprehensive treatment algorithm for these posterolateral fractures has been proposed by Cho et al. with specific interest towards rim plating[49]. However, no long-term follow-up is available to support these protocols. Moreover, treatment and approach choices for these posterolateral fractures should be tailored to possible other approaches used during definitive surgery.

So why address PTPF?

1) Cadaveric studies have clearly indicated the unstable nature of posteromedial fractures during motion of the knee, with and without weight-bearing[52, 53].
2) Multiple outcome studies have indicated the important prognostic impact of sagittal malalignment; given the risk of secondary displacement, stabilization and restoration of sagittal alignment is very important in PTPF[3, 4, 54].
3) According to Wang et al., posterior fixation is based on trauma mechanism and column classification and the main principle being the need for buttress plating on the compression side of the fracture pattern.[8] However, previously we have shown that there is only minimal impact on outcome regarding PTPF using the column concept. Therefore, it was hypothesized that the simplification of fracture morphology in just 3 column groups insufficiently represents all treatment choices a surgeon makes during preoperative planning[5].

4) Recently implicated ‘main fracture planes’ imply that the direction of the fracture should guide plate osteosynthesis. Fracture mapping clearly shows the high frequency of coronal fractures ranging up to 85% in Schatzker types IV-VI, with possible benefit of additional posteromedial or posterior fixation[18, 20, 22]. Kfuri et al. proposed that the location of a buttress plate should be parallel to the main fracture plane in each quadrant. This further underscores the need for posterior buttress plating in coronal fracture patterns[18].
5) PTPF are associated with high energy trauma and specific soft-tissue injuries depending on the diagonal injury pattern [13]. Therefore, addressing these concomitant soft-tissue injuries simultaneously seems obvious.
6) Posterior approaches have clearly shown to be safe and feasible in order to address and fixate PTPF with good clinical results[5, 8, 55, 56]. Figure 4 shows a demonstrative case regarding a three-column fracture using triple plating.

Evolving perspectives

In tibial plateau fractures, research has evolved over the previous year’s towards a more trauma mechanism-based view. In ankle fractures, the trauma mechanism based Lauge-Hansen classification has been used for many years in guiding treatment and predicting instability. This system is built on a comprehensive understanding of trauma mechanism and interplay between fracture morphology and ligamentous injury. One of the key aspects in such a concept is the in-depth appreciation and diagnosis of soft-tissue injury. Xie et al. introduced the diagonal injury pattern, integrating the trauma mechanism based three-column classification and associated ligamentous injuries[13]. A thorough understanding of fracture morphology, trauma mechanism and ligamentous injury can lead to further integration of diagonal tension-compression principles. To date, the impact of residual ligamentous instability in tibial plateau fractures remains for the most part unclear. Insufficient evidence is available to guide decision making for ligamentous stabilization procedures and their optimal timing. In most hospitals, a systematic preoperative MRI is not yet part of standard work-up in tibial plateau fractures. Hence, intraoperative assessment and recording of soft-tissue injury is crucial.

Further research should focus on diagnosis and classification of concomitant soft tissue (i.e. ligamentous) injury in order to guide future treatment protocols and positively affect functional outcome. Ultimately, the goal should be a comprehensive treatment concept which incorporates fracture morphology, trauma mechanism and soft-tissue injury.

Declaration of Competing Interest

The authors declare that they have no known competing finan- cial interests or personal relationships that could have appeared to influence the work reported in this paper.

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LEGENDS

Figure 1.

A 72 year old female sustaining a left-sided tibial plateau fracture due to a fall with a motor scooter. Standard X-rays (anteroposterior and lateral, A), preoperative CT (axial and sagittal, B) and MRI were performed. Fracture morphology indicates a flexion-varus trauma. CT/MRI fusion images (C) clearly reveal the presence of an anterior cruciate ligament (ACL) avulsion fracture without ACL rupture (red arrow). Furthermore, patellar avulsion fracture, total avulsion of distal medial collateral ligament insertion and partial tear of lateral collateral ligament with associated posterolateral corner injury were detected. Timing of surgery was delayed for 8 days until clinical resolution of swelling. During surgery with dual plating, specific care was taken for fixation of ACL footprint and medial collateral ligament avulsion fragments (suturing). Standard postoperative X-rays in lateral and anteroposterior view showed good overall reduction and stable fixation (D). Postoperative care consisted of progressive mobilization (flexion /extension) with varus-valgus stabilizing brace, and 8 weeks plantar touch (non-weight bearing).

Figure 2.

Posterior approaches of the tibia plateau

a, Lobenhoffer or direct posteromedial approach (green line); b, 'FCR' or direct posterior approach (orange line); c, S-shaped posteromedial approach (blue line); d, posteromedial reversed L-shaped approach (red line); e, posterolateral approach (purple line). The medial border of the medial head of the gastrocnemius muscle indicated by the black line.

The posteromedial approach has been described by several authors under several names and in different configurations [56-59]. The inverse L-configuration allows for more visualization towards the lateral aspect of the posterior articular surface [47]. Careful creation of a fasciocutaneous flap will function as protection for sural structures. Berwin et al. proposed a more lateral incision to increase visualization towards the lateral tibial aspect, however with increasing risk of damage to the sural structures [57]. All described approaches dissect along the medial border of the gastrocnemius muscle, in order to retract it laterally. Some authors propose transection of the medial gastrocnemius tendon (leaving sufficient stump for reattachment) in order to gain further exposure [55,56]. The popliteus muscle is longitudinal incised at the medial border and dissected off posterior wall. Careful dissection below the popliteus muscle and its retraction will protect the popliteal neurovascular bundle. Only blunt retractors should be used and traction should be minimized to prevent damage to the anterior tibial artery and popliteal neurovascular bundle.

Figure 3.

Schematic exposure of the proximal tibia as demonstrated by Pierrie et al. for different surgical approaches[48]. AL, anterolateral approach (grey line); PL, posterolateral approach (black dashed line); PM, posteromedial approach (black line).

Figure 4.

This case presents a 59 year old female who sustained a unilateral accident with her bicycle. Preoperative CT-scan shows a three-column tibial plateau fracture with severe comminution. A major coronal fracture line was observed with complete separation of the posterior fracture components in axial and sagittal view. (A,B) Posterior fracture fixation was performed in prone position firstly. Secondly the patient was turned and additional medial and lateral approaches were performed for triple plating. Postoperative CT-scan at three months follow-up showed adequate reduction and buttress using the WAVE proximal tibia plate (7S medical, Switzerland) of the whole posterior column reaching the posterolateral corner. (C,D)

Figure 1

Figure 2

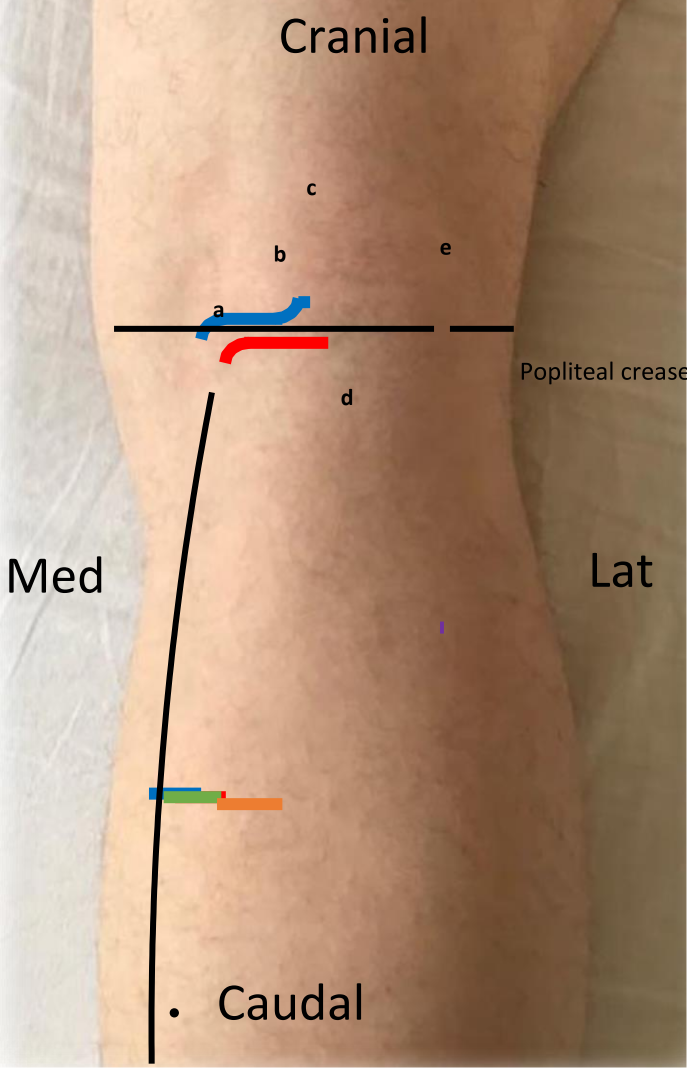

Figure 3

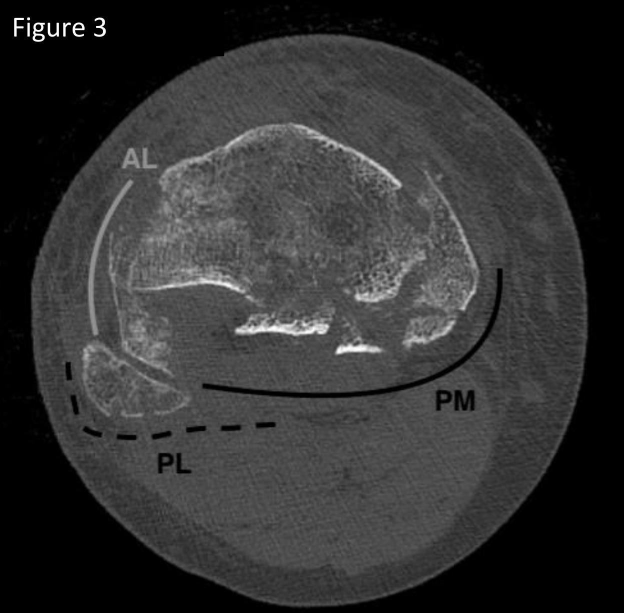

Figure 4