Viewpoint

New Developments in Treatments of Tibial Plateau Fractures

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Tibial plateau fractures account for 1.66–2.0% of all fractures in adults and about 8% of fractures in the elderly.[1] Tibial plateau fractures should be considered as complex injuries representing a wide fracture spectrum: soft-tissue compromise, neurovascular damage, compartment syndrome, and ligament and meniscus tears, which remain a big challenge, even for experienced orthopedic trauma surgeons. Although the best treatment modality remains controversial, we aimed to present new developments in the treatment of tibial plateau fractures for reference.

Complex tibial plateau fractures (Schatzker IV–VI) caused by high-energy injuries are usually observed in young patients; low-energy fractures (Schatzker I–III) usually occur in the elderly. However, geriatric complex tibial plateau fractures usually accompany with associated soft-tissue compromise, which should be considered as substantial soft-tissue injuries with a fracture inside.[2] To protect the soft-tissue envelope, the usage of a staged approach using knee-spanning external fixators with ligamentotaxis, followed by definitive osteosynthesis, is recommended as the standard treatment modality in complex patterns and high-energy trauma, especially in cases of axial instability. A study[3] comparing immediate and delayed operative treatments of low-energy tibial plateau fractures was recently published, in which the early treatment group (<48 h) had an infection rate of 3.4% and total complication rate of 20.6%. The delayed group had an infection rate of 5.0% and total complication rate of 25%. There was no significant difference with respect to superficial and deep infections or total complications. Therefore, early surgical fixation (<48 h) of low-energy tibial plateau fractures can be performed safely. Additionally, a midline approach did not increase soft-tissue complications and could be utilized on a patient with a prior midline incision, or one who will soon require a knee arthroplasty. Regarding optimizing the timing of definitive treatment, in the authors' opinion, a staged approach utilizing knee-spanning external fixators with ligamentotaxis to restore alignment and offer the environment for soft-tissue recovery, followed by definitive osteosynthesis with positive wrinkle sign, is strongly recommended for high energy-induced complicated tibial plateau fractures with compromised soft tissues, which has been proven safer and more reliable.[4] For low energy-induced lateral column fractures (Schatzker I–III), the decision should be made based on the status of the soft-tissue envelope, the patient's expectations, the surgeon's experience, availability of equipment and implants, etc. Surgeons need to balance safety with satisfactory outcomes and rapidity with a high risk of complications. Clinically, since there are many approaches available to treat lateral column fractures, the anterior midline approach is not routinely recommended, even though it has some advantages. Unnecessary dissection might damage the soft tissues.

Understanding fracture characteristics is a prerequisite to treating tibial plateau fractures properly. There are many reported classification systems for tibial plateau fractures. They are divided into traditional classifications, including Schatzker, AO, Hohl and Moore, and Chertsey, based on simple bi-dimensional radiographs; newly described classifications, including Luo's three column concept and the revised Duparc classification;[5] and the "Ten segment classification",[6] which is based on bi- and tri-dimensional computed tomography. Each has its own advantages and disadvantages. Schatzker described his classification in 1979 and it is still commonly used today, with the advantages of being both simple and reliable. The AO/OTA classification published in 1996 has been shown to have good

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inter-observer agreement and is commonly used in scientific publications. The Hohl and Moore fracture-dislocation classification highlights the importance of recognizing that a tibial plateau fracture may also be a consequence of knee dislocation, and the associated soft-tissue injury means that supporting structures of the knee are significantly compromised. The Chertsey classification focuses on injury mechanisms that correspond to valgus, varus, and axial loading. All the above have limitations in their descriptions of complex fracture configurations, as sometimes important information might be missed. Luo's classification divides the tibial plateau into lateral, medial, and posterior column to improve surgical decision-making.[7] The revised Duparc classification is supposed to be sufficient for classifying nearly all tibial plateau fractures.[8] The more recent "Ten segment classification", which is a segment-based mapping of the tibial plateau, has been introduced to address fractures with a fracture-specific surgical approach.[6] According to research,[9] the AO/OTA, Schatzker, and Luo classifications showed good reproducibility, whereas the revised Duparc was less favorable. The inter-observer reliability of the Schatzker classification is significantly superior to that of Luo's classification.[10] Tibial tuberosity and intercondylar eminence fractures are not included in Luo's classification.[5] Nowadays, complex tibial plateau fractures involve not only bony structures, but also peri- and intra-articular soft-tissue injuries. Total solutions might be the treatment tendency for complex tibial plateau fractures associated with soft-tissue injuries. Unfortunately, although the classifications made progress when they were presented, all focus on bony structures, except for the Hohl and Moore classification, which is limited in its description of the comminuted fracture pattern. None of the classifications cover everything. At present, analyzing fracture characteristics in combination with other classification systems is recommended. Ideally, a classification system should be reliable, all-inclusive, reproducible, and should act as a guide to surgical approach and fixation. A new classification system meeting the above-mentioned criteria is needed in the future.

A vast majority of tibial plateau fractures are associated with soft-tissue injuries, including soft-tissue envelope around the knee and intra-articular soft-tissue injuries in different patterns. Severe trauma-related injuries produce comminuted fractures with significant soft-tissue damage, as well as disruption of primary and secondary knee stabilizers. Management of soft-tissue damage is of critical importance and affects the outcomes directly. The status of local soft-tissue is crucial in deciding the timing and modus of the intervention.[11] Besides the soft-tissue envelope, the authors would appeal to pay much more attention to intra-articular soft-tissue injuries. In a study of 103 patients with various Schatzker-type fractures, a total of 99% presented associated soft-tissue injuries and 77% a complete anterior cruciate ligament (ACL) or lateral collateral ligament (LCL) injury, whereas 81% presented with a significant lateral meniscal tear and 44% a medial meniscal tear.[2] Abdel-Hamid *et al*.[12] showed that 71% of tibial plateau fractures came with intra-articular soft-tissue injuries. Hung *et al*.[13] revealed an incidence of 38% for ACL injuries, 19% for collateral ligament injuries, and 31% for lateral meniscal injuries. Thus, tibial plateau fractures do not just involve damage to bony structures. Surgeons must also take into consideration peri- and intra-articular soft-tissue injuries so as to achieve optimized surgical outcomes.

How are intra-articular soft-tissue injuries diagnosed? An magnetic resonance imaging (MRI) can adequately show intra-articular soft-tissue injuries.[14] MRI examination was more accurate in diagnosing ACL injuries than meniscal injuries. Although MRI was regarded as a tool in the diagnosis of internal derangements of the knee, the longer scan time, higher cost, and lack of availability limit its use in the setting of acute tibial plateau fractures. Recent research argues that the capability of an early MRI scan to identify ligamentous or meniscal lesions is questionable.[15] Some indirect signs used as indicators for intra-articular soft-tissue injuries were presented. For example, increased lateral tibial plateau depression, with a threshold of 11 mm, is associated with a higher risk of lateral meniscal tear. A higher incidence of ACL avulsion fractures is observed when medial tibial plateau displacement is >3 mm and when the fracture also involves the anteromedial or posterolateral column. In addition, younger age and high-energy pattern of tibial plateau fractures are risk factors for an ACL avulsion fracture. Articular depression >6 mm and/or articular widening >5 mm is associated with the existence of lateral meniscus, LCL, or posterior cruciate ligament injuries.[2] We appreciate that appropriate osteosynthesis for tibial plateau fractures is necessary, but most importantly, correct management of peri- and intra-articular soft-tissue injuries determines eventual outcomes.

Selecting the correct surgical approaches for treating posterior column fractures is another contentious area. Usually, adequate posteromedial fragment reduction and buttress plating require a direct posteromedial approach, or a combination with an anterolateral approach. It can be achieved either in supine or in prone position. The direct posterior approach is useful for posterior coronal shear fractures that need a posterior buttress with prone position. Isolated posterolateral fragments can be reached and reduced through a posterolateral approach with or without a fibular head osteotomy. Recently, other posterior approaches, for example, the extended posterolateral approach, the modified fibular head osteotomy approach, the inverted "L-" shaped approach, were reported. It is our belief that the selection of approaches depends on injury mechanism, fracture pattern, position of the fragments, type of the implants, and the surgeon's preference. The ideal approach should be direct, limited if possible, and less damaging to normal anatomical structures. Excessive and unnecessary dissection should be avoided.

Some new techniques were recently introduced. Besides the femoral distractor, or an external fixator, a specific bi-directional traction device was developed by a Chinese

surgeon, Prof. Zhang, and has been used for tibial plateau fractures with ligamentotaxis with satisfactory results. In fact, most cases can be reduced by ligamentotaxis, which is critically important to obtain good alignment. Traditionally, open reduction is performed through different approaches from outside to inside reaching intra-articular fragments. In some fracture patterns, anatomic reduction of the articular surface can be obtained through a new window technique using a special tamper for articular elevation followed by bone graft or structural bone substitutes. Minimally invasive plate osteosynthesis is then used for plate augmentation. We believe that this might be one of the better options for lesser tibial plateau fractures.

A multicentric study showed that "balloon-tibiaplasty" represented an improved and accurate modality for restoration of articular congruence, with the advantage of being minimally invasive and creating a symmetric, contained defect to hold a bone filler for subchondral support.[16] It has been proven both in the laboratory as well as clinically to be superior to the conventional method of manual elevation. On the other hand, higher costs due to the disposable instruments, limited patients, and fracture patterns make its application restricted. The authors stipulate that balloon-tibiaplasty is useful for lateral column but not for all patterns.

Three-dimensional printing provides an accurate anatomical structure of the fracture for preoperative planning and the simulation of surgery, with a significant reduction in surgical time and the surgeon's exposure to radiation.[17,18]

Arthroscopy plays an increasingly important role in the treatment of tibial plateau fractures. It can be useful for controlling articular surface reduction and for diagnosing and enabling the repair of meniscal/ligament tears. A new concept of "fracturoscopy" has been presented.[16,19] Krause *et al.*[20] revealed that the postero-latero-central segment is especially hard to visualize, and satisfactory reduction by fluoroscopy only was unsuccessful in 89% of the cases involving this fragment. Instead, the additional insertion of an endoscopic optic device resulted in full visualization and anatomic reduction of the posterior articular surface. Furthermore, arthroscopically assisted reduction and internal fixation is recommended not only for avoiding misdiagnosis and improving reduction quality, but also for repairing concurrent injuries of the meniscus, cartilage, and ligaments. In the future, it could become increasingly popular in the management of tibial plateau fractures.

Some reports mentioned that complex articular fractures can be treated by ring external fixators and minimally invasive osteosynthesis, with the advantage of respecting the soft tissue. However, current existing evidence from the latest meta-analysis does not support the conclusion that external fixators are better than open reduction and internal fixation in managing complex tibial plateau fractures.[21]

Total knee arthroplasty (TKA) might be the primary treatment of complex patterns in specific geriatric patients, with strict indications such as nonreconstructable defects and severe osteoporosis accompanying complex instability.[2] We do not recommend the routine use of TKA as the primary treatment of tibial plateau fractures, even for complicated patterns. Orthopedic trauma surgeons should try their best to carry out reconstructive surgeries first.

The main objectives when treating articular fractures of the knee are the restoration of articular congruity and stability, the axial and rotational alignment of the lower limb, and stability and early motion of the joint. As one of the principles, articular fractures should be reduced anatomically. However, many surgeons primarily focus on reduction and fixation, and neglect the restoration of mechanical alignment of the lower limb so that malunion with varus or valgus is often seen clinically as a complication. The author has performed many revision surgeries for this problem. Although anatomic reduction of articular fractures and restoration of mechanical alignment are both critical, especially in young patients, there is some evidence that limb alignment and knee stability are most critical, whereas nonanatomical articular reduction is less important for functional results.[2]

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Conflicts of interest

There are no conflicts of interest.

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