Fractures of the tibial condyles: current treatment methods and surgical approaches (literature review)

I.G. Belen’kii¹, A.Iu. Kochish², M.A. Kislitsyn¹

¹First St. Petersburg Pavlov Medical University, St. Petersburg
²FSBI Russian Vreden Order of Labor Red Banner Scientific Research Institute of Traumatology and Orthopaedics of the RF Ministry of Health, St. Petersburg

The review of the specialized literature showed that the incidence of intra-articular tibial condylar fractures that are located in the posterior tibial parts is rather high. However, the most commonly used classifications do not always provide with an accurate architectonics of such fractures. Therefore, three- and four-column classifications of the discussed fractures were proposed. Accurate reduction of bone fragments of the posterior tibial plateau from the standard approaches is rather difficult technically due to an inadequate visualization of the fracture zone. Thus, posterolateral and posterior approaches to the tibial plateau were introduced through which not only the visualization of the posterior tibial plateau structures but also their osteosynthesis with a support plate is possible. The authors analyzed the scientific publications related to the main surgical approaches to the tibial plateau and their use for osteosynthesis of the fractures in this area. It appeared that the most adequate reduction and fixation of the fragments of the posterior tibial plateau is provided by posterolateral and posterior approaches. Despite the risk of damage to major vessels and nerves by using these approaches their widespread introduction in practice is promising. However, further scientific studies are required that would be aimed at substantiation and improvement of the techniques of the posterior approach to the knee as well as at updating the indications for each of them.

Keywords Intra-articular fractures of tibial condyles (tibial plateau), internal osteosynthesis, knee joint, surgical approaches

In the recent years, the incidence of severe intra-articular fractures of the condyles of the proximal tibial metaepiphysis that form the tibial plateau continues to grow. It reaches 60 % from the total of injuries to all large joints and from 2 to 5 % in the general structure of skeletal injuries according to some authors [7, 29]. Moreover, isolated fractures of the lateral tibial condyle are observed in 55 to 70 % of cases from the total of the fractures in this location. Injuries to the medial tibial condyle or both tibial condyles are observed only in 10 to 30 % [11]. It should be also mentioned that poor long term treatment results of such fractures make from 6 % to 39 % [34, 47] and frequently lead to permanent disability [17].

The conventional approach to surgical treatment of the mentioned injuries consists in surgery planning which is based on the generally accepted classifications such as the Association for Osteosynthesis (AO) or J. Schatzker’s classifications. Osteosynthesis is performed from the standard anterolateral and/or posteromedial surgical approaches [1, 9, 11]. However, due to a constantly increasing number of severe high-energy injuries in the knee area it has become apparent that a significant number of the fractures of the tibial condyles cannot be adequately fixed from the standard approaches as far as the most damaged zone is located in the posterior parts of the tibial plateau [35, 38, 52]. The widespread introduction of computed tomography that has become a standard technique of preoperative examination in these injuries contributes to a more accurate diagnosis of the injury location. The facts mentioned above resulted in the theory of three- or four-column injuries of the tibial condyles with the emphasis on the fractures located in the posterior parts of the tibial condyles. Consequently, alternative surgical approaches to the mentioned zone were proposed [24, 39, 57].

To date, all the authors are unanimous in the opinion that it is necessary to achieve anatomical reduction of articular surface fragments in the process of surgical treatment of patients with the fractures of the tibial condyles irrespective of their location [3, 40]. However, there is no such unanimity when surgical approaches are to be chosen [49]. Several authors consider that osteosynthesis of the fractures that are located in the posterior parts of the tibial condyles may be performed through standard approaches [19, 33, 45]. On the contrary, other surgeons prefer posterior surgical approaches though their anatomical basics and technology have not been developed sufficiently [12, 14, 21, 42].

Purpose of this special literature review To summarize the available information on current treatment trends and surgical approaches that are used in patients with intra-articular fractures of the ibial condyles as well as to determine open problems and identify promising directions for further research.

Anatomical characteristics and mechanisms of the injury under discussion The difficulties in providing care for persons with tibial condylar fractures are caused by the features of the anatomy of the proximal tibial metaepiphysis.
As it is known, the tibial plateau is supported by two vertical columns formed by tibial condyles. In the frontal plane, the tibial plateau is perpendicular to the lower limb long axis, and in the sagittal plane it is inclined from 5 to 16 degrees backwards to the horizontal plane. The practical value of this inclination is in the fact that the appropriate angle of an X-ray emitter must be provided for optimal visualization of the tibial articular surface in the anteroposterior (AP) X-rays [4, 8]. The lateral tibial condyle has a more rounded shape on the horizontal section but its articular surface is convex. The medial tibial condyle is more massive, its articular surface is concave and the area of the contact with the femur is 1.5 times bigger than that of the lateral condyle. Moreover, the medial tibial condyle sustains significantly greater functional loads due to a denser trabecular bone when compared with the lateral condyle and is of a reverse V shape in its support part [2, 3].

Location of tibial plateau fractures depends on the direction of the injuring force. Most frequently, the injuring forces act from lateral to medial, or to valgus in the knee area. It results in abduction fractures with either an impression of the lateral tibial condyle central part or condyle splitting off, or to the combination of these injuries. Adduction or varus force application results in the fractures of the medial tibial condyle. The excessive axial load in high-energy injuries leads to splitting off of both tibial condyles and their fragmentation. Limb position at the moment of trauma is of great importance in the fracture architectonics as well. Thus, when the knee is extended the maximum load falls on the tibial plateau central and frontal parts. When the knee is flexed at 90° and more this load moves from the tibial plateau anterior parts to its posterior parts. Thus, the more acute is the angle of flexion in the knee the greater is the likelihood of injuring the posterior tibial plateau parts [38].

Classification of intra-articular fractures of the tibial condyles

In our country, the classifications of J. Schatzker (1978) and AO (2002) are the most used ones for treatment of tibial plateau fractures.

According to Schatzker classification, all the fractures of this location are divided into six types:

I – lateral tibial condyle split without articular surface impression;
II – lateral tibial condyle split with articular platform impression;
III – focal impression of the articular surface without lateral condyle split;
IV – fracture of the medial condyle with or without the eminence of the intercondylar fragment, intact lateral condyle;
V – fractures of the both condyles, tibial plateau central part involved or intact;
VI – fragmental fracture of both condyles with transverse fracture lines in the tibial metaphysis.

AO classification for intra-articular fractures of the tibial plateau has a general encoding of the anatomical location (41) and includes 3 groups in the type of incomplete articular fractures (41B) and 3 groups – in the type of complete articular fractures (41C).

41B1 – lateral tibial condyle split;
41B2 – pure impression of the articular platform without lateral condyle split;
41B3 – lateral tibial condyle split and articular platform impression;
41C1 – simple articular fracture, simple metaphyseal fracture;
41C2 – simple articular fracture, multifragmentary metaphyseal fracture;
41C3 – multifragmentary articular fracture, simple or multifragmentary metaphyseal fracture.

Thus, each of the two types includes 3 groups of intra-articular fractures that specify bone fragment position.

It should be noted that the above classifications are quite comparable in description of the tibial condylar fractures. In particular, isolated injuries of the lateral tibial condyle, impression of its articular surface, as well as their combination in the both classifications are completely identical and imply the traditional algorithm of osteosynthesis method selection. However, the alphanumeric encoding of AO classification is more convenient for statistical data processing.

Nevertheless, both classifications do not consider what parts of the tibial condyles are injured. Hence, they cannot be used for description of the fractures in the posterior parts of the tibial plateau. At present, this fact cannot be ignored as far as since the moment computed tomography has become an obligatory part of the examination for all intra-articular fractures in the knee area it has appeared that fractures in the tibial plateau posterolateral area constitute from 7 % to 44 % from the total of tibial articular surface fractures [19, 35, 38]. Therefore, the classification based on the tibial articular surface division into three [36, 54] or four columns [13] has been used nowadays along with standard classifications of the tibial plateau fractures. The feasibility of such approach is confirmed by the findings of G. Yang et al. (2013) who began to use the three-column classification and changed surgical tactics in 28.8 % out of 525 clinical cases [52]. Y. Zhu et al. (2012) could not classify tibial plateau fractures according to J. Schatzker and AO [26] in 5 % of 278 cases. Q. Zhai et al. (2013) detected significant posterior bone fragments in 33.5 % of 140 cases, and diagnosed fractures of the tibial plateau posterolateral and central areas in 10.7 % [41].

It is obvious that the division of the tibial plateau into three or 4 columns is conditional as far as it is rather difficult to identify anatomically the boundary between the
“anterior” and “posterior” columns of each of the condyles. Nevertheless, C.F. Luo et al. (2010) objectified this division significantly [54]. These authors identified three columns in the diagram of horizontal (transverse) CT-section separating them by the lines between certain points.

The diagram (Fig. 1) demonstrates that point A is the most ventral one on the anterior tibial plateau surface and, in fact, it is the front point of the tibial crest; point B is the posteromedial tibial crest; point C – the most ventral point of the lateral tibial condyle adjacent to the frontal edge of the fibular head; point D – the back edge of the intercondylar eminence; and point O divides the intercondylar line from A to D practically into two halves and it is in the center of the tibial plateau. Three conditional columns lie between OA, OB, and OC lines. Thereby, any injury of the tibial cortical layer in the posterior sector is attributed by the authors to the fractures of the tibial plateau posterior column.

![Fig. 1 Diagram of the tibial plateau division into 4 sectors (columns) according to Shi-Min Chang et al. (2014)](image)

Further on, S.M. Chang et al. (2014) presented the diagram of the tibial plateau division into 4 columns extending AD line of OD line segment [13]. Thus, the tibial plateau posterolateral and posteromedial sectors (columns III and IV) were identified. So, it became possible to more accurately specify the tactics of preoperative planning (Fig. 1). It should be noted that there is no doubt about the practical importance of the three-column and four-column classifications with the use of computed tomography for preoperative planning and treatment outcome prediction in such patients [36, 51, 58]. Thereby, the use of special computer programs assists in virtual three-dimensional (3D) planning of the surgery [59].

**Principles of tibial condylar fracture fixation**

To date, various modifications of internal and external osteosynthesis are the main types of tibial plateau fracture fixation. External fixators as the final form of osteosynthesis are most frequently used when internal osteosynthesis is impossible to apply [55]. However, the successful description of the use of extracortical hybrid devices for osteosynthesis can be found both in the national and foreign literature including for the cases of compound Schatzker Type V and VI fractures or AO Classification Types C1-C3 [25, 32, 43]. In the opinion of foreign specialists, the use of an internal or external osteosynthesis is determined not only by their potential of anatomic and reliable bone fragment fixation but also by the condition of soft tissues and the presence of the compartment syndrome that frequently accompanies high-energy injuries [60]. However, intra-articular tibial condylar fractures require an accurate (anatomic) restoration of the articular surface and interfragmental compression in the fracture zone regardless of the selected osteosynthesis technique [1, 3, 11, 40].

In order to create these conditions, it is necessary, first of all, to provide an adequate visualization of the intra-articular fracture area. Visualization can be improved by intraoperative radiographic control. However, the planar monitor picture of the image intensifier does not provide all the necessary information about the quality of bone fragment reduction due to a complex anatomical configuration of the tibial condyles [44]. Therefore, it seems promising to improve visualization of the fracture zone with an arthroscopic assistance. This technique could be of a particular relevance in cases of complex fractures of the tibial plateau involving its posterior parts. Examples of the osteosynthesis with an arthroscopic support were reported in the literature. Thus, a low invasive use of transcutaneously inserted cannulated screws was described in groups of patients with Schatzker Types I-IV injuries [5, 18]. The authors came to a conclusion that this technique provides a complete union of fragments and a more rapid postoperative recovery. However, it is acceptable only for simple fractures with minimum diastases between bone fragments. Moreover, it implies good technical equipment and training of surgeons for performing such operations.

Another study deals with an arthroscopic assistance in osteosynthesis of complex fractures with the use of support plates and cannulated screws in a group of 25 patients with Schatzker Types IV-VI posteromedial fractures that resulted in 92 % of excellent and good outcomes [15]. However, most authors find the use of the arthroscopic control for bone fragment reduction reasonable only in cases of pure impression of the tibial condyles [6, 10, 22, 27]. If the tibial condyle splits there is an increased risk of a compartment syndrome due to penetration of the liquid used for arthroscopy into the fascial membranes [16, 31, 48]. Therefore, a direct examination of the tibial condyle fracture zone from a sufficiently comfortable and safe surgical approach is the most efficient way of its visualization.
Surgical approaches in internal osteosynthesis of the fractures under discussion. Traditional approaches to the proximal tibia are the anterior and lateral surfaces of the tibia in its upper third due to a small soft tissue bulk and lack of major neurovascular structures in these areas. Moreover, all the skin incisions are of longitudinal orientation. It is recommended to cut soft tissues in the tibial metaepiphysis as a single block down to the periosteum that is then detached for bone fragment mobilization and reduction.

An anterior (anterolateral, midline) approach was developed for fractures of both tibial condyles. Fasciocutaneous incision starts from the lower patellar pole and runs down to the upper border of the middle tibial third. The approach allows a wide exposure of the entire anterolateral bone mass in the proximal tibia. Some modifications have been developed lately, and the most popular among them is the procedure of subcutaneous soft tissue cutting according to Textor (Y-shaped), as well as the procedure of cutting off the tibial tuberosity together with the patellar ligament. However, these approaches have been recently used in rare occasions due to a long skin incision and great soft tissue invasiveness that worsen blood supply to bone fragments [1, 2, 4].

The posteromedial surgical approach begins just above the plane of the articular knee gap and extends down along the posteromedial tibial surface. In this case, the medial and posteromedial surfaces of the medial tibial condyle are exposed between the medial belly of the gastrocnemius muscle and the tendon of the semimembranous muscle. This approach allows manipulations with the entire medial column of the tibial plateau as well as provides visualization of the posteromedial tibial segment. In the presence of posteromedial bone fragments, the medial head of the gastrocnemius muscle should be shifted laterally in order to improve their visualization, particularly if there is a large split fragment of the medial tibial condyle [20].

Currently, most surgeons consider the standard anterolateral surgical approach to be a method of choice for fractures of the lateral tibial condyle as far as it provides good visualization of the frontal and lateral parts of this condyle which forms the tibial plateau. Upon completion of a slightly curved skin incision from the point that lies 2 to 3 cm above the articular space down to the level just below the tibial tuberosity, the knee arthrotomy is performed along the joint gap under the body of the lateral meniscus. Then, the latter is displaced upwards thus exposing the articular surface of the tibial plateau [40]. However, this approach does not allow reduction of the posterior column fragments of the tibial lateral condyle due to its inadequate visualization which is hindered by the tension of the joint capsule soft tissues and the joint posterolateral tendo-ligamentous complex. Thus, the possibilities of bone fragment reduction for tibial condylar fractures from this surgical approach are limited to the anterior and lateral tibial plateau segments, and partially to the central one.

As it is known, a large posterior fragment of the tibial plateau that lies at a short distance from the lateral condyle and is free of soft tissue interposition can be reduced from the standard anterolateral approach under the control of an image intensifier. Its fixation is performed with one or two screws inserted from the anterior to posterior direction and off the plate. However, if the posterior fragment is significantly displaced the use of this surgical approach may not lead to the desired result. Moreover, the risk of damaging the popliteal artery by insertion of the screws from the anterolateral approach in the anteroposterior direction must not be forgotten [38].

The modification of the anterolateral approach from a direct skin incision was also proposed. The vastus lateralis muscle should be detached from the lateral intermuscular septum and then the incision should pass by the Gerdy tubercle through the iliotibial tract upwards, proximal to and in front of it thereby exposing the knee capsule. The latter should be opened along the joint space at the edge of the articular surface of the lateral tibial condyle. Then, the lateral meniscus should be sutured and brought upwards for opening the articular bone surface [40]. In order to perform osteosynthesis of the lateral column fractures in the tibial plateau, this approach should be modified according to H. Tscherne and E. Johnson [37, 56] that imply that the iliotibial tract is taken sideways after the Gerdy tubercle osteotomy has been done.

The posterolateral surgical approach is used by planning the interventions on the lateral tibial condyle when its lateral parts and the posterior column are involved in the fracture. As a rule, the surgery is performed with the patient lying on his/her side. The skin cut of 10 to 12 cm begins posteriorly from the lateral femoral epicondyle and runs longitudinally downwards in front of the fibular head. After that the space between the iliotibial tract and the fibular head is exposed. Knee capsulotomy and the manipulations with the lateral meniscus described above for the anterolateral approach follow. Thus, the injury to massive soft tissues can be avoided. However, inadequate visualization of the distant parts of the lateral tibial condyle posterior column is a shortcoming of the classic posterolateral approach, especially in the presence of their great depression and diastasis between bone fragments. Furthermore, if fractures of the tibial plateau are located in the area of its posterolateral angle (7 % from the total of intra-articular fractures of the tibial condyles), the approach to bone fragments is hindered by the fibular head, ligamentous structures and the popliteal muscle that...
In 1968, E. Trickey developed one of such approaches for tibial metaepiphysis [28]. This transfibular path after fibular head osteotomy, capsulotomy, as well as an obligatory cut of the lateral meniscus ligament and detachment of the posterolateral ligamentous structures allows for the visualization of the entire posterolateral tibial plateau column. The shortcomings of this approach include a significant invasiveness and the likelihood of iatrogenic neuropathy of the common peroneal nerve [23].

Several authors discuss the advisability of this approach for proper reduction of isolated fractures of the tibial plateau posterior column in the latest publications [30, 42]. In the same works, the authors presented another modification of the posterolateral approach that involves entering the popliteal fossa between the tendons of m. biceps femoris and the lateral head of m. gastrocnemius without fibular head osteotomy. Good visualization of the common popliteal nerve and bringing it aside is an important feature of this modified approach. The popliteal muscle is the upper border of the approach and the proximal part of m. soleus belly is its lower border. Consequently, the main neurovascular bundle of the popliteal fossa is left medially and the common popliteal nerve remains laterally. Capsulotomy allows for further exposure of the fragments of the posterior column of the lateral tibial condyle, including its central segment in the place of the posterior cruciate ligament attachment. Obviously, this technique implies a proper training of surgeons to perform an intervention.

Some authors in their comparative analysis point to the impossibility to stabilize the posterolateral column fragments in unicondylar fractures of the tibial plateau from the classic anterolateral approach due to the absence of direct bone fragment visualization. The transfibular technique that uses the posterolateral approach appeared to be the most appropriate in such clinical cases that was demonstrated by the results of its use [50]. Other authors in a similar study preferred the posterolateral approach above the fibular head in 20 patients for osteosynthesis of the posterior tibial column fractures emphasizing its simplicity, safety and high efficiency [23]. Several authors gave an exclusive priority to the transfibular technique approach for the fractures of the lateral condyle and the posterolateral column of the proximal tibial metaepiphysis [28].

It should be also mentioned that in the current literature the description of the posterior direct approaches through the popliteal fossa for osteosynthesis of isolated fractures of the tibial plateau posterior column is frequently encountered. In 1968, E. Trickey developed one of such approaches for restoring the tibial component of the posterior cruciate ligament [57]. The author performed an S-shaped midline skin incision of 8 to 10 cm in the popliteal area. Upon creation of a large skin-fat flap and pulling aside the main neurovascular bundle of the popliteal fossa, an approach was formed to the posterior parts of the knee capsule which was opened longitudinally. The median structures of the posterior tibial column were the target approach point either for the posterior cruciate ligament fixation or for fixation of the fragment displaced along with this ligament at bone fragment injury. The attempt of adapting this approach to the conditions of isolated or combined fractures of the tibial plateau posterior column was quite justified. However, this approach is not always effective for management of the tibial posterior column fractures as far as they are located more frequently in the area of the lateral condyle. In view of the said, the S-shaped incision was modified into an inverted L-shaped one [50] which was produced above the lateral condyles of the femur and tibia. The mentioned approach implies by-layer vertical cutting of soft tissues in the direction of the posterior surface of the lateral knee portion. The medial wall of the operation wound is the lateral head of m. gastrocnemius which is brought to the center, the distal wall is m. soleus, the popliteal muscle is the proximal wall, and the lateral border is formed by the posterior surface of the fibular head, the biceps femoris tendon and the knee lateral ligament. The opening of the knee capsule posterior portion is performed vertically as well. Bone fragments are reduced using a support plate prepared for osteosynthesis [30].

The studies performed on the anatomical material revealed a high risk of damage to the anterior tibial artery below the fibular head by the use of the posterolateral approach for tibial plateau osteosynthesis if bone fragments were exposed distally by mean amount of 46.3±9.0 mm to the articular surface of the lateral tibial condyle where this artery passes through the interosseous membrane [53]. In another similar study, the mentioned distance was close to 76 mm and the distance from the tibial plateau articular surface to the common popliteal nerve where it crosses the fibular neck was equal to 42 mm on the average. Besides, the angle between these structures was about 15° [14].

Secured control of the location of the popliteal neurovascular bundle and common popliteal nerve that runs distal and lateral to the intervention zone is considered to be the main technical difference between the posterior midline (S-shaped) and the posterior (L-shaped) approaches. In order to prevent the injury to the vessels and nerves, it is also recommended to detach soft tissues from the bone fragment as a single block, but without its full exposure. Subsequent mounting of a straight or L-shaped support plate and screws is performed in the...
same sagittal plane and under good visualization that helps a surgeon not to cause iatrogenic damage to large vessels and nerve trunks.

A very limited visualization of the tibial plateau is attributed to the disadvantage of isolated posterior surgical approaches. Therefore, two approaches are used more frequently in cases of multifragmental fractures of the lateral tibial condyle with the posterior column damage, the anterolateral and isolated posterior ones [12, 24]. A similar medial inverted L-shaped approach was also proposed that is performed in the projection of the medial condyles of the femur and tibia that provides visualization of the medial tibial condyle between the medial head of m. gastrocnemius and the junction of m. gracilis, m. semitendinosus, and m. semimembranosus tendons [21].

CONCLUSION

Thus, the increase in the number and severity of intra-articular tibial condylar fractures as well as the inclusion of computed tomography in the standard of preoperative examination has led the traumatological society to understand the necessity of identifying a group of fractures that localize in the tibial plateau posterior parts, in addition to the standard classifications. The study of these injuries demonstrates that the use of anterior approaches that are most frequently used in such clinical situations was not sufficiently efficient due to an inadequate visualization of the fracture zone, extreme difficulty of performing anatomic reduction of the articular tibial surface and impossibility of support plate implantation.

A number of posterior approaches have been described in the special literature that allow for visualization and adequate fixation of all the tibial plateau parts. Thus, the posterior parts of the lateral tibial condyle can be reached using different modifications of the posterolateral approach with fibular head osteotomy or without it. The variants of the posterior and posteromedial approaches are used for osteosynthesis of the posterior medial tibial condyle parts. However, the analysis of the available publications shows that these approaches are technically difficult. They do not eliminate the risk of damage to large vessels and nerves as well as they are insufficiently substantiated from topographic and anatomic positions. Therefore, the substantiation and improvement of the technique of performing posterior approaches to the knee in the patients of the mentioned profile as well as specifying the indications for each of them appear, in our opinion, to be promising directions of research in the area under consideration.

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**Information about the authors:**

1. Igor’ G. Belen’kii, M.D., Ph.D., Pavlov First Saint Petersburg State Medical University, St. Petersburg, Associate Professor at the Department of Traumatology and Orthopaedics; e-mail: belenkiy.trauma@mail.ru

2. Aleksandr Iu. Kochish, M.D., Ph.D., FSBI Russian Vreden Order of Labor Red Banner Scientific Research Institute of Traumatology and Orthopaedics of the RF Ministry of Health, St. Petersburg, Deputy Director for Scientific and Educational Work, Professor; e-mail: auk1959@mail.ru

3. Mikhail A. Kislitsyn, M.D., Pavlov First Saint Petersburg State Medical University, St. Petersburg, Department of Traumatology and Orthopaedics; e-mail: 89111664610@mail.ru