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Review Article

Tibia Plateau Fracture Down the Road: A Concise Review of Evolving Classifications

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Abstract

Tibial plateau fractures (TPFs) are complex intra-articular injuries that demand precise classification for optimal surgical planning and outcomes. Traditional systems such as Schatzker and AO Foundation/Orthopedic Trauma Association (AO/OTA) classifications have been instrumental in categorizing these fractures based on plain radiographic findings. However, they often fall short in accurately identifying posterior column involvement and coronal plane fractures. The advent of computed tomography (CT) imaging and three-dimensional (3D) reconstructions has led to the development of more precise classification systems, notably Luo's three-column model. This review provides a comprehensive review of the Schatzker, AO/OTA, and three-column classifications, highlighting their principles, clinical utility, and limitations. The updated three-column concept (uTCC) further incorporates injury mechanisms by assessing posterior tibia slope and medial plateau angles, offering enhanced guidance for surgical approaches. Studies comparing these systems suggest that the three-column model provides superior interobserver reliability and preoperative planning utility, especially in identifying and managing posterior column injuries. This review underscores the evolution toward 3D and mechanism-based classifications to improve treatment strategies for TPFs.

Keywords: Tibia; Classification; Trauma

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Background

Tibial plateau fractures (TPFs) are among the prevalent complex and challenging fractures causing post-traumatic knee arthritis and disability (1). Restoring the congruency of joint surface and stability is important to prevent these complications (2). This purpose is achieved through optimal fixation methods, which are best achieved through precise preoperative fixation planning and understanding the entire concept of fracture patterns (2, 3).

These fractures present challenges in terms of characterization, quantification, and treatment because of the intra-articular characteristics of the proximal tibia, the comminuted nature of the subchondral bone, and the significant impact on the surrounding soft tissues. Plain radiographs and computed tomography (CT) scans have introduced several classifications for better fixation planning (2). Among these classifications, the most widely-used ones are Schatzker (4), AO Foundation/Orthopedic Trauma Association (AO/OTA) (5), Hohl and Moore (6), and Luo's relatively new three-column classification system, which will be thoroughly reviewed here (1, 7).

Methods

This study is a narrative review and educational corner conducted by literature review on Embase, PubMed, and Scopus upon papers addressing different types of TPF classifications, their utility, and limitations.

Different Methods of Tibial Plateau Classifications

The Schatzker classification categorizes TPFs using anteroposterior (AP) plain radiographs (Figure 1). Types I through III specifically address fractures of the lateral tibial plateau. Type I is defined as a cleavage fracture of the lateral column. This type is more prevalent in younger individuals, who typically possess denser cancellous bone that provides greater resistance to impaction. Type II fractures are defined as split wedge fractures of the lateral column that are accompanied by depression. These fractures result from the same mechanisms of injury as type I fractures, including axial and valgus shearing and loading forces. However, in older patients with less dense metaphyseal bone, the articular surface may fail, leading to the impaction and depression of that surface. Treatment for type II fractures typically involves open reduction and internal fixation (ORIF). In contrast, type III fractures maintain the integrity of the cortex containing the metaphysis.

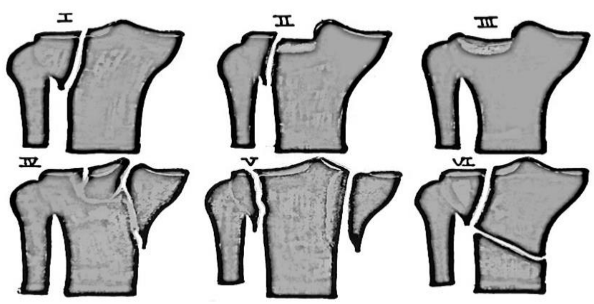

Figure 1. Schatzker classification of tibial plateau fractures (TPFs) based on anteroposterior (AP) view in plain radiographs

This type primarily presents as a joint depression and is generally stable. However, whenever there is a joint depression involving impaction and depression of the plateau rim, instability of the joint may be expected.

Types IV to VI represent high-energy injuries that cause instability in the knee joint, manifesting as either subluxation or dislocation. Type IV specifically describes an isolated fracture of the medial column of the tibial plateau, which typically results from a varus shearing force. Due to the greater density of the medial tibial plateau compared to the lateral side, a higher force is necessary to induce a fracture, indicating that the trauma energy associated with a type IV injury is generally considerable. This type of injury is often accompanied by a fracture-dislocation of the knee, posing a risk for potential neurovascular complications. Furthermore, bicondylar TPFs, classified as types V and VI, are also classified as high-energy injuries.

In 2018, Mauricio Kfuria and Joseph Schatzker introduced modifiers "A" (anterior) and "P" (posterior) for describing quadrants in the six principal types of TPFs, which remain unchanged (Figure 2).

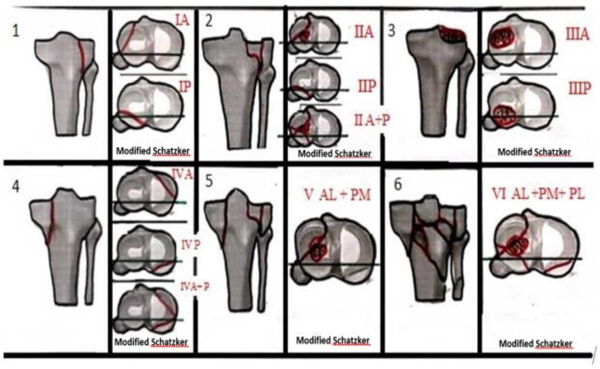

Figure 2. Comparison of old Schatzker (1974) versus modified Schatzker classification

Surgeons determine fracture localization by identifying the main fracture plane and where it bisects the articular rim of the tibial plateau. The virtual equator separates the anterior from the posterior part of the plateau and connects the front of the fibula head to the most posterior aspect of the medial collateral ligaments (MCLs). Split wedge fractures will disrupt the articular surface at two points and exit the metaphysis distally from the joint, at the apex of the wedge. The points where the wedge bisects the rim are indicated by lowercase letters, which denote their locations relative to a virtual equator: anterior ("a") or posterior ("p"). The third point, where the fracture exits at the metaphyseal area, is marked as "x". This metaphyseal exit point can be anterior (ax) or posterior (px). These three points –two on the rim and one at the metaphysis – define the main fracture plane. Unicondylar fractures include Roman numerals for lateral (I to III) or medial (IV) columns combined with "A" or "P". Sagittal fractures bisect the rim anteriorly and posteriorly ("a" and "p"), while coronal fractures can bisect twice in one direction (either "a" and "a" or "p" and "p"). For example, a typical posteromedial fragment in a bicondylar fracture intersects the rim twice posteriorly, leading to a description of "p" and "p", with the metaphyseal exit point marked as "px".

The AO/OTA introduced a classification system for long bone fractures to facilitate standardized communication among professionals involved in the documentation and research of fractures and dislocations. This system is recognized internationally and employs an alphanumeric format for clarity and precision. TPFs are specifically classified within this framework; those that involve a single tibial condyle are categorized as partial articular, while those affecting both condyles are classified as complete articular. Unicondylar TPFs are designated as type 41B, whereas bicondylar fractures are classified as type 41C.

Many classification systems such as Schatzker (Figure 1) and AO/OTA are based on plain radiographs that focus on the medial and lateral fracture fixation without paying attention to the actual need for posterior fixation. Besides, before the introduction of CT scans, many fractures in the coronal plane –often resulting from high-velocity trauma went unrecognized. Consequently, knowledge about the prevalence of certain TPFs in this orientation was quite limited. The advent of CT, a three-dimensional (3D) imaging technique, has raised the standard for understanding articular fractures. The most significant impact of 3D imaging on the assessment of tibial plateau injuries has been the improved recognition and characterization of fractures in the coronal plane (9) (Figure 3).

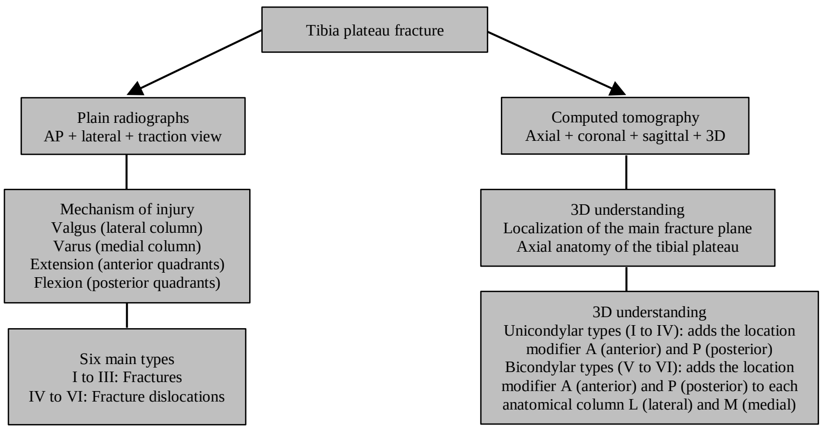

Figure 3. The mechanics of the three-dimensional (3D) tibial plateau classification based on the use of plain radiographs and computed tomography (CT) scans. Plain radiographs allow for an overall picture of the mechanism and energy of the injury, while CT determines the exact fracture pattern and location in all three planes (AP: Anteroposterior; 3D: Three-dimensional).

CT scans in axial views for evaluation of tibial plateau fixation and in identifying the need for posterior fixation have been used in the three-column classification (7, 8). Moreover, the incidence of complex TPFs accompanied by posterior column injuries is realized to be more than expected noticing recent studies (9).

The three-column classification of TPFs was first described by Luo et al. in 2010 (7). In this method, an axial CT-scan view in which the fibular head first appeared is used to define fracture types of the plateau (9).

Zhu et al. (1) evaluated the reliability of AO/OTA, Schatzker, and three-column classification of TPFs and concluded that the three-column classification of Luo et al. (7), which focused on understanding fracture concept using axial CT-scan views and 3D reconstructions, would best define posterior column fractures and also this classification had the highest agreement among different surgeons so that it could be more widely used in other clinical centers (1). Moreover, Patange Subba Rao et al. studied 52 patients with TPFs to assess the reliability and reproducibility of the Schatzker and three-column classification. They concluded that the tree-column method was more easily reproducible and reliable than the Schatzker method and helped orthopedic surgeons in planning the best surgical approach preoperatively (10). On the other hand, as described by Millar et al., although this classification has high reliability, it provides less information about the exact pattern and morphology of the fracture site (2).

The three-column classification is based on the transverse CT view of the tibial plateau, which includes the fibular head. In addition to the transverse view, accurate classification is typically achieved using the frontal view and 3D reconstruction.

As demonstrated in figure 4, there is a focal point (point O) at the center of the knee or midpoint of two tibial spines. Point A is considered the most anterior part of the tuberosity of tibia. Point D stands for the medial posterior ridge of the plateau and point C represents the most anterior part of the fibular head (1, 7). Thus, the tibial plateau is fragmented into three parts named lateral column, medial column, and posterior column by the OA, OD, and OC lines. Besides, the posterior column is divided by an OB line to posterolateral and posteromedial parts. Point B is the posterior sulcus of the tibial plateau (1).

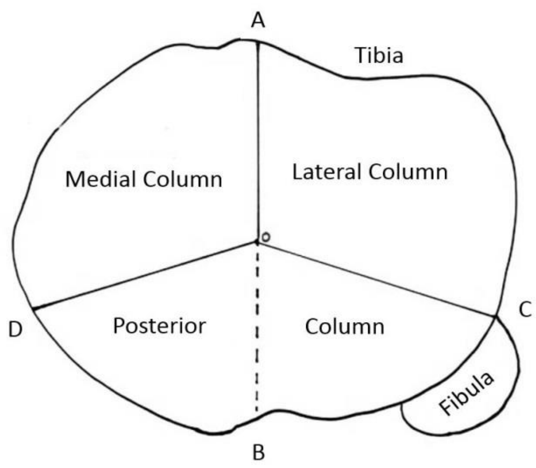

Figure 4. Three-column classification of tibial plateau fractures (TPFs) to medial, lateral, and posterior columns. The posterior column is further divided into posteromedial and posterolateral columns by the OB line.

The division into three parts is based on two primary considerations. Firstly, this approach is straightforward, intuitive, and easily memorable. Secondly, it is highly pertinent to treatment, as each column is defined according to anatomical location and the corresponding surgical approach.

According to this classification system, a column is assumed to be fractured if the articular depression is accompanied by a cortical split (fracture of the extra-articular cortical bone) of the relevant column. Therefore, in the three-column classification, injuries are categorized into simple zero and one-column fractures or more complex two-column or three-column injuries.

Zero-Column Fracture

Pure articular depression which is classified as type III by Schatzker is described as a zero-column fracture. Zero-column injury is defined as the disruption of the articular surface with intact extra-articular cortices. This is mostly a depression-type fracture. The increased sensitivity of CT imaging to detect cortical disruption has shown that zero-column fractures are not as common as once thought.

Regardless of the location of the articular disruption, stabilization is performed using minimally invasive techniques whenever possible. Plate fixation is utilized to support the reduced articular surface and is placed at the rim of the tibial plateau (11).

One-Column Fracture

One-column injuries are further categorized into medial, lateral, and posterior column fractures. Simple fracture patterns are typically managed using the traditional three-column classification. However, applying the updated three-column concept (uTCC) allows for improved planning and construction of the final fixation method (7, 11).

Simple lateral split or split depression fractures as in Schatzker type I and II are among one-column (lateral column) fractures. Lateral column split fracture, with or without articular surface depression, is relatively common. Noticing previous studies, lateral column fractures commonly occur through valgus and axial forces applied during extension of the knee; we should, therefore, buttress the lateral column with proper plating and prevent secondary valgus deformity through a standard lateral or anterolateral approach (11).

Varus and axial forces applied while the knee is in extension cause medial column fractures, with or without articular surface depression. In order to buttress the medial column while keeping away from varus deformity, a medial-based plate should be used. It is also very important for this type of fracture to note any accompanying posterolateral soft tissue injuries that may need to be looked after at the time of surgery (11).

Less commonly, there is an isolated posterior column fracture. Isolated posterolateral split or split depression fractures do not fit in the Schatzker classification; they are assumed as one-column injuries by the Luo three-column classification (Figure 4) (2, 7, 8). The posterior coronal fracture reveals a shearing force, caused by an axial load with the knee in flexion. Placing a posterior plate could buttress this shearing fracture fragment and prevent further displacement (11).

Two-Column Fracture

In two-column fractures, there are three conditions: split in the medial and posterior column, lateral and posterior column, and medial and lateral column. When an anterolateral fracture occurs alongside a distinct posterior-lateral articular depression and a break in the posterior wall, the injury is classified as a “two-column (lateral and posterior column) fracture”. A typical "two-column fracture" involves an anteromedial fracture accompanied by a distinct posteromedial fragment, representing a fracture of both the medial and posterior columns, which is traditionally classified as Schatzker type IV (medial condylar fracture). Additionally, simple lateral split or split depression fractures with a posterolateral or posteromedial split are classified as two-column fractures.

Management of two-column fractures, especially those involving the posterior column, is still debated. The assessment of the injury mechanism through fracture morphology is important in planning the proper location of the plate and fixation approach (11).

Medial and Posterior Column

Having a medial column fracture, a posteromedial fragment, or posterolateral articular surface depression will also be found in this type of fracture. Two distinct injury mechanisms create this fracture pattern. Decreased medial posterior tibial slope angle (pTSA) and medial tibial plateau angle (mTPA) indicate an extension-varus mechanism, requiring the main buttress of the medial through a medial approach. Usually, a 4.5 mm medial locking T-plate is used. For the more complex flexion-varus mechanism, a posteromedial reversed L-shaped approach is preferred, especially when lateral aspect of the posterior column is involved and requires fixation to buttress the unstable fragment (11).

Lateral and Posterior Column

The most common type of TPFs are lateral column fractures extending to the posterior column. Either the mechanism of extension-valgus or flexion-valgus can cause this subtype of two-column fracture. Increased pTSA indicates a flexion-valgus mechanism, thus requiring main buttressing by an anterolateral or lateral approach for the lateral column fracture and buttressing of the posterolateral column through a reversed L-shaped approach. Decreased pTSA and increased mTPA indicate an extension-valgus mechanism, which is best addressed with lateral column buttressing via a traditional anterolateral approach (11).

Medial and Lateral Column

Combined medial and lateral column fractures are often caused by an axial force with the knee in extension. Implant placement at both anterolateral and anteromedial sides is necessary to restore the pTSA. The mTPA helps to determine which side failed due to compression and will require more robust fixation. If the mTPA is increased, there is usually associated comminution on the lateral side, and a longer and stronger anterolateral plate works best as the main buttress. A decreased mTPA indicates a stronger varus force causing failure, requiring the primary implant to be placed on the anteromedial side as a buttress (11).

Three-Column Fracture

The “three-column fracture” is defined as containing at least one articular fragment in each of the columns. This type of fracture is the most complex among others. This type of TPF, known as the classic three-column fracture, refers to Schatzker types V and VI, which are bicondylar fractures accompanied by a separate posterolateral articular fragment (11). Accordingly, Wang et al. described their best approach for each type of fracture using uTCC in table 1 (11).

More recently, an updated three-column classification system has been described by Wang et al. (11). They performed another cohort study on 287 patients suffering from TPFs and used the updated method of tibial plateau classification to identify the affected column, locate the depression or comminution, and plan the surgical approach. In this method, they first used the previously described three-column classification method to classify the patients in subsequent groups for further surgical planning. Furthermore, they evaluated the position of the knee (extension/flexion) during the injury time by determining the tibial slope angle (TSA) measured by lateral X-ray or sagittal CT-scan view and also the force (valgus/varus) which caused the fracture through measuring mTPA measured by AP X-rays or coronal CT-scan views of the knee (Figures 5 and 6). Afterward, first, the main buttress plate at the compression side and then the secondary plating of the tension side were placed for comminuted or unstable fractures (11). Using this method, they could classify TPFs as follows.

Figure 5. A and B) Parameters in computed tomography (CT) scans for injury mechanism. A) Posterior tibial slope angle (pTSA), is defined as the angle created by the tibial plateau and the long axis of the tibia in the sagittal plane. Either medial or lateral pTSA can be measured on sagittal CT slices; the decreased (or in a negative value) pTSA indicates the injured knee in extension mode, while the increased indicates a flexion mode; B) Medial tibial plateau angle (mTPA), is defined as the angle created by the medial tibial plateau surface and the long axis of the tibia in the coronal plane; decreased mTPA indicates a varus force, while the almost normal value of mTPA indicates a valgus force.

Table 1. Preferred fixation methods using the updated three-column classification

Type		Injury mechanism		Approach	Main (Buttress plate)
		Knee position	Possible force		
One-column fracture	L	Extension	Valgus	Lateral	L
	M	M extension varus	Varus	Medial	M
	P	P flexion valgus	Valgus	Reversed L	PL
			Varus	Posteromedial	PM
Two-column fracture	L + P	Flexion	Valgus	Lateral (+ reversed L)	L
		Extension		Lateral	L
	M + P	M + P flexion varus	Varus	Reversed L	PM
		Extension		Medial	M
	L + M	Extension	Valgus	Lateral	L
			Varus	Medial	M
Three-column fracture		Extension	Valgus	Lateral + posteromedial	L
		Extension	Varus		M
		Flexion	Valgus	Lateral + posteromedial (or reversed L)	L
		Flexion	Varus		PM

L: Lateral; M: Medial; P: Posterior

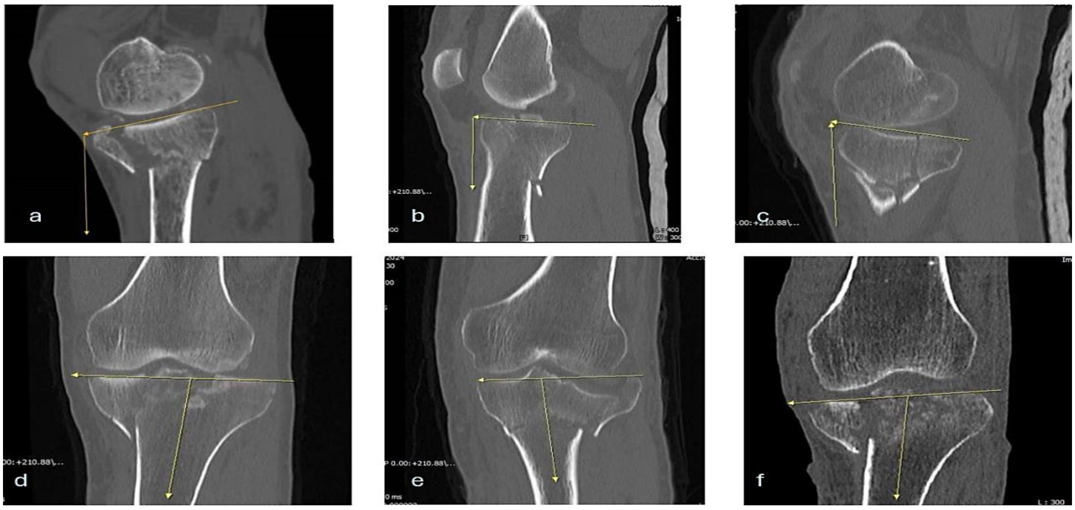

Figure 6. Parameters in computed tomography (CT) reconstruction images for injury mechanism. a to c) Posterior tibial slope angle (pTSA), defined as the angle created by the tibial plateau and the long axis of the tibia in the sagittal plane; a) The increased pTSA indicates a flexion mode of the initial position of the knee joint; b) the normal or unchanged pTSA indicates extension injury pattern; c) The decreased pTSA (or retroversion) means the injured knee in hyperextension pattern; d to f) Tibial plateau angle (TPA) defined as the angle created by the medial angle of tibial plateau surface and the long axis of the tibia shaft in the coronal plane; d) The increased TPA indicates a valgus force; e) The normal or unchanged TPA indicates axial force; f) The decreased TPA means a varus force.

Injury Mechanism

TPFs typically result from an axial load applied to the knee joint in various positions, combined with either a varus or valgus deforming force. The uTCC system was developed based on fracture morphology three-column classification (TCC) and the mechanism of injury. To identify the correct mechanism of injury, two questions need to be considered: 1) What was the initial position of the knee joint? and 2) What was the main direction of the force applied to the tibial plateau?

Therefore, the position of the knee joint at the time of injury, specifically the relative alignment of the femur to the tibia (extension, flexion, and hyperextension) and the direction of the deforming force (valgus, varus, and axial) must be noted. Unfortunately, patients with a TPF typically cannot recall the position of their knee joint at the time of the injury. However, the specific location and appearance of the fracture, along with any associated soft tissue injuries seen on imaging, enable surgeons to interpret this information and deduce the mechanism of the injury (12).

During knee flexion, the smaller radius of the femoral articular surface slides posteriorly on the relatively flat or slightly convex tibial plateau. When an axial impact load is transmitted from the femoral to the tibial articular surface, it may lead to a fracture in the posterior plateau. The pTSA, which is formed by the line connecting the medial and lateral tibial plateaus and a perpendicular line to the anterior tibial cortex in the sagittal plane, is used to represent the initial position of the knee. Cadaveric and radiological studies measuring the knees of Chinese and Asian patients indicate that the average pTSA in the normal population is 11°, with a variable range. Furthermore, the medial pTSA tends to be slightly greater than the lateral pTSA, and there is a weak association between the pTSAs of the medial and lateral tibial plateaus.

The initial position of the knee can be classified as follows: it is considered hyperextension when the pTSA is reversed (less than 0°, indicating recurvation), as extension when the pTSA ranges from 0° to 11°, and as flexion when it exceeds 11° (12).

As a result, the force exerted on the tibial plateau can be determined by the inclination tendency of the proximal tibia in the coronal plane, referred to as the tibial plateau angle (TPA). The TPA is defined as the medial angle between the tangential line of the tibial plateau and the anatomical axis of the tibia, with an average measurement of 85° in the Chinese population. A decrease in TPA signifies a primarily varus force, while an increase in TPA indicates a primarily valgus force. In the presence of varying degrees of axial force, a stable or unchanged TPA suggests a predominantly axial load. The evaluation of force direction should not rely solely on changes in TPA. If the TPA shows minimal change, only the side of the fracture may provide insight into the direction of the force. In some cases of Schatzker types IV or V, the TPA may remain nearly normal or exhibit a near-perpendicular angle, allowing the knee joint to be subjected to an axial-load mechanism without apparent varus or valgus, as seen in bicondylar hyperextension fractures of the tibial plateau (12).

There is also another study by Hoekstra et al., presenting a modified method for the division of columns through axial imaging (13). They used the posterior border of the fibula as the C point which creates the posterior border of the lateral column, as shown in figure 7.

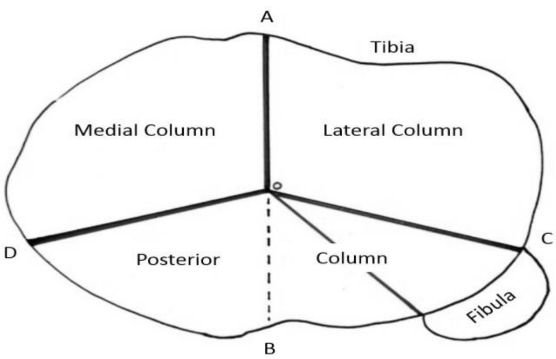

Figure 7. New revised borders of three-column classification (Pay attention to the new posterior border of the lateral column)

Thus, by this method, extended lateral column fractures are presented to be single lateral-column injuries that extend posteriorly instead of being categorized as two-column fractures, as this type of fracture is fixed using lateral proximal tibial plating. Vice versa, the posterior column fracture covering the posterolateral column is now classified as a single posterior column fracture and can be reduced and fixed through a posterior approach only (13).

Conclusion

The accurate classification of TPFs is pivotal for determining the most effective surgical intervention and reducing long-term complications such as post-traumatic arthritis. While traditional systems like Schatzker and AO/OTA remain widely used, their reliance on plain radiographs limits their ability to detect complex fracture patterns, particularly those involving the posterior column. Luo's three-column classification, enhanced by CT imaging and 3D analysis, offers a more comprehensive understanding of fracture morphology and facilitates tailored surgical planning. The uTCC, which incorporates injury mechanism assessment, represents a significant advancement in fracture characterization. Evidence from comparative studies supports the adoption of the three-column framework due to its higher reproducibility, reliability, and clinical relevance. Moving forward, broader adoption of CT-based, mechanism-informed classifications may enhance surgical outcomes and standardize care across institutions.

Conflict of Interest

The authors declare no conflict of interest in this study.

Acknowledgements

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