A Condylar-Column Integrated Classification for Tibial Plateau Fractures: A Modified Schatzker Framework and a Simplified CT-Based CCC System

***Dr. Nishant., Dr. Santosh Kumar**

Indira Gandhi Institute of Medical Science, Patna

***Corresponding Author**

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ABSTRACT

Background: Tibial plateau fractures show substantial morphological variability and are frequently associated with posterior fragments, ligament injury, and neurovascular compromise. Although several systems exist, the Schatzker classification remains widely used because it is simple; however, it incompletely encodes posterior column involvement and clinically important modifiers.

Methods: A focused narrative review of major tibial plateau fracture classification systems (Schatzker, AO/OTA, Duparc, and CT-based column concepts) was performed. Based on a condylar concept, a modified Schatzker-based system (Types I-VIII) was constructed to incorporate missing patterns and injury modifiers. To bridge condylar and column paradigms while preserving simplicity, a Condyle-Column Classification (CCC) was developed using a short code: condylar category (C), CT-derived column flag (K), morphology (M), and optional modifiers (e.g., MD dissociation, neurovascular deficit, dislocation, ligament injury).

Results: The modified condylar concept classification provides an expanded hierarchy for extra-articular injuries, unicondylar and multicondylar intra-articular patterns, and clinically meaningful modifiers (central depression/bone loss, neurovascular deficit, knee dislocation, ligamentous disruption, polytrauma, and special associated injuries). CCC remains compatible with Schatzker I-VI terminology while explicitly capturing posterior involvement using a simple posterior flag (P/AP) on CT. Tables provide a practical crosswalk between CCC, Schatzker, and AO/OTA categories.

Conclusion: A combined condylar-column approach can be operationalized into a concise classification that remains easy to communicate at the bedside, improves representation of posterior fragments on CT, and allows addition of clinically relevant modifiers that influence approach selection, fixation strategy, staging, and rehabilitation.

Keywords: tibial plateau fracture; classification; Schatzker; AO/OTA; posteromedial fragment; computed tomography; column concept

INTRODUCTION

Tibial plateau fractures are common periarticular injuries with a bimodal epidemiology: high-energy trauma in younger adults and low-energy mechanisms in older patients with reduced bone quality. The fracture patterns arise from combinations of axial loading, bending, and rotational forces, and they frequently coexist with meniscal, ligamentous, and neurovascular injury. Because treatment planning depends on articular involvement, fragment location (particularly posterior components), and soft-tissue status, a practical classification is essential for communication, surgical strategy, and research.

Several systems have been proposed, including early split/depression concepts, the Schatzker classification, AO/OTA coding, Duparc variants, and CT-based column approaches. Despite known limitations, Schatzker

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remains widely used in routine clinical practice, likely because it is simple and rapidly communicated. However, clinically important posterior fragments and modifiers such as central depression, bone loss, knee dislocation, ligamentous disruption, and neurovascular deficit are not consistently encoded in commonly used schemes. The present work proposes (1) a Schatzker-based modification organized by a condylar concept (Types I-VIII) and (2) a simplified CT-based Condyle-Column Classification (CCC) that integrates condylar and column paradigms without sacrificing usability.

MATERIALS AND METHODS

A focused narrative review was performed using PubMed/MEDLINE to identify widely used tibial plateau fracture classification systems and studies assessing their reliability with radiographs and computed tomography. The practical shortcomings most frequently cited in the literature were summarized, with particular attention to posterior fracture components and modifiers that alter operative planning.

Development of the condylar concept modification: The modified Schatzker-based classification was constructed by reorganizing injuries into extra-articular patterns (aligned with AO/OTA 41-A) and intra-articular patterns defined primarily by condylar and quadrant involvement. Additional types were created to encode features that commonly change surgical strategy (central depression, bone loss, neurovascular deficit, knee dislocation, major ligamentous disruption, polytrauma, and special associated injuries).

Development of CCC: CCC is a short code assigned in three components: (1) Condylar category (C): C0 extra-articular; C1L unicondylar lateral; C1M unicondylar medial; C2 bicondylar. (2) Column flag (K), derived primarily from axial CT: A (no posterior fragment), P (posterior fragment present in unicondylar patterns), AP (anterior and posterior involvement in bicondylar patterns), and X (central depression dominant; optional). (3) Morphology (M): S split, D depression, SD split-depression, MF multifragmentary. Metaphyseal-diaphyseal dissociation is recorded using an additional MD modifier. Optional clinical modifiers may be appended where relevant (neurovascular deficit, knee dislocation, major ligamentous injury, and open/severe soft-tissue compromise).

This manuscript presents the framework, definitions, and illustrative schematics. Formal reliability testing and outcome correlation are proposed as future work.

Key variables and definitions

Table 1 summarizes the variables used to operationalize the condylar and column concepts on CT and radiographs.

Variable	Operational definition	Best imaging plane	Clinical relevance
Condylar involvement	Extra-articular (C0), unicondylar lateral (C1L), unicondylar medial (C1M), bicondylar (C2)	X-ray + CT coronal	Determines overall injury group and fixation complexity
Posterior fragment	Presence of a distinct posteromedial/posterolateral fragment or posterior shear component (K=P/AP)	CT axial	Influences approach, buttress fixation, and need for posterior/medial plating
Anterior involvement	Predominant anterior/anterolateral split or depression without posterior fragment (K=A)	CT axial	Supports anterolateral approach and standard lateral fixation
Central depression	Central impaction/depression dominant pattern (K=X, optional)	CT coronal/sagittal	May require elevation, void filling, rafting screws
Split	Discrete fracture line separating a major fragment (M=S)	CT axial	Fragment-specific reduction and fixation strategy
Depression	Articular surface depression without major split (M=D)	CT coronal	Elevation and subchondral support required

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Split-depression	Combined split and depressed articular segment (M=SD)	CT axial/coronal	Often requires dual strategy: reduction + elevation
Multifragmentary	Articular/metaphyseal comminution (M=MF)	CT multi-planar	Higher instability; may require dual plating/external fixation
Metaphyseal-diaphyseal dissociation	Loss of metaphyseal-diaphyseal continuity (MD)	X-ray + CT sagittal	Corresponds to high-energy patterns; staging and fixation planning
Knee dislocation	Clinical/radiographic dislocation with plateau fracture (DIS)	Clinical + X-ray	High risk of ligament and vascular injury; may require staged management
Neurovascular deficit	Clinical deficit or vascular injury on Doppler/CTA (N)	Clinical + Doppler/CTA	Time-sensitive evaluation and management
Major ligament injury	Bicruciate and/or corner disruption (L)	Clinical + MRI (if used)	May change stability assessment, fixation, and rehabilitation

RESULTS

The proposed framework consists of two complementary components: (1) a condylar concept modified Schatzker-based hierarchy (Types I-VIII) that encodes clinically relevant modifiers and associated injury contexts, and (2) a simplified CT-based CCC code compatible with Schatzker I-VI terminology while capturing posterior involvement using a posterior flag.

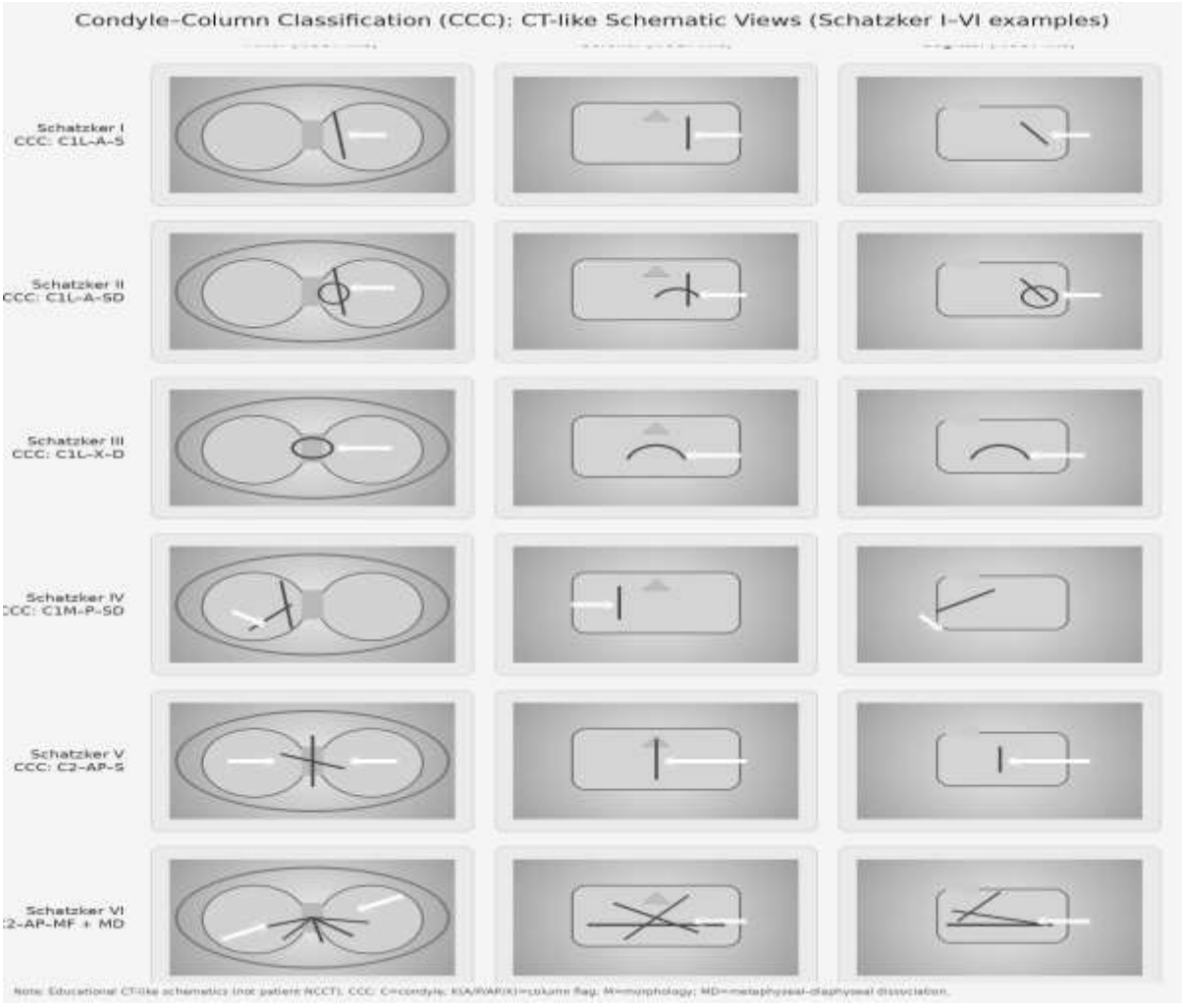

Figure 1. CT-like schematic axial, coronal, and sagittal views of Schatzker I-VI patterns with corresponding CCC codes (educational schematic, not patient imaging).

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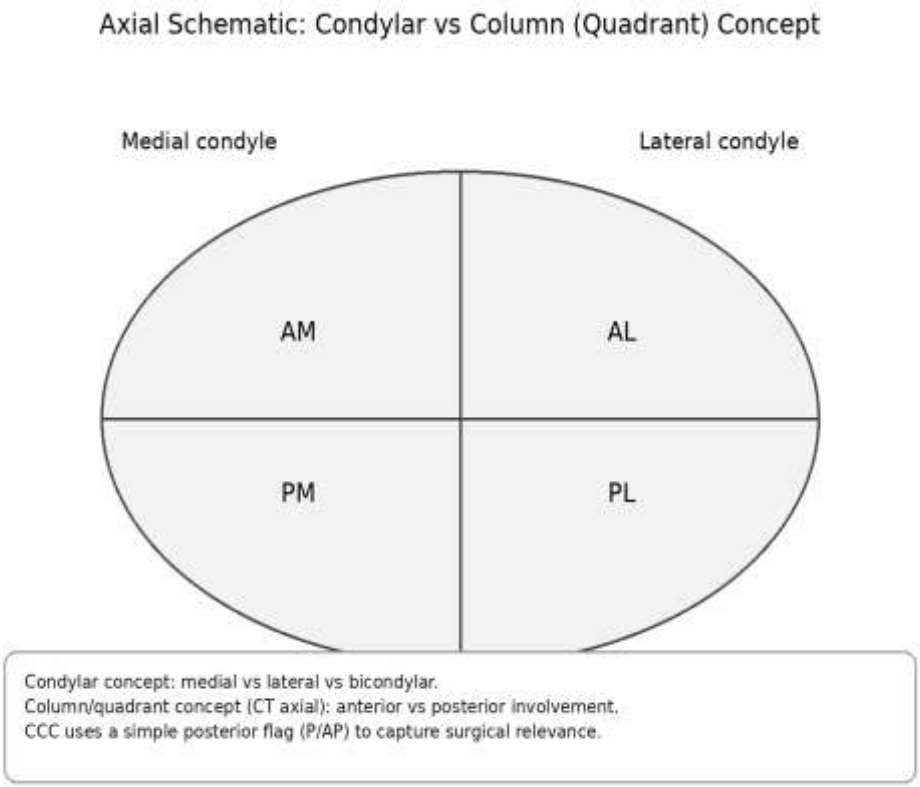

Figure 2. Axial schematic showing condylar (medial/lateral) and quadrant/column (anterior/posterior) concepts used in CCC.

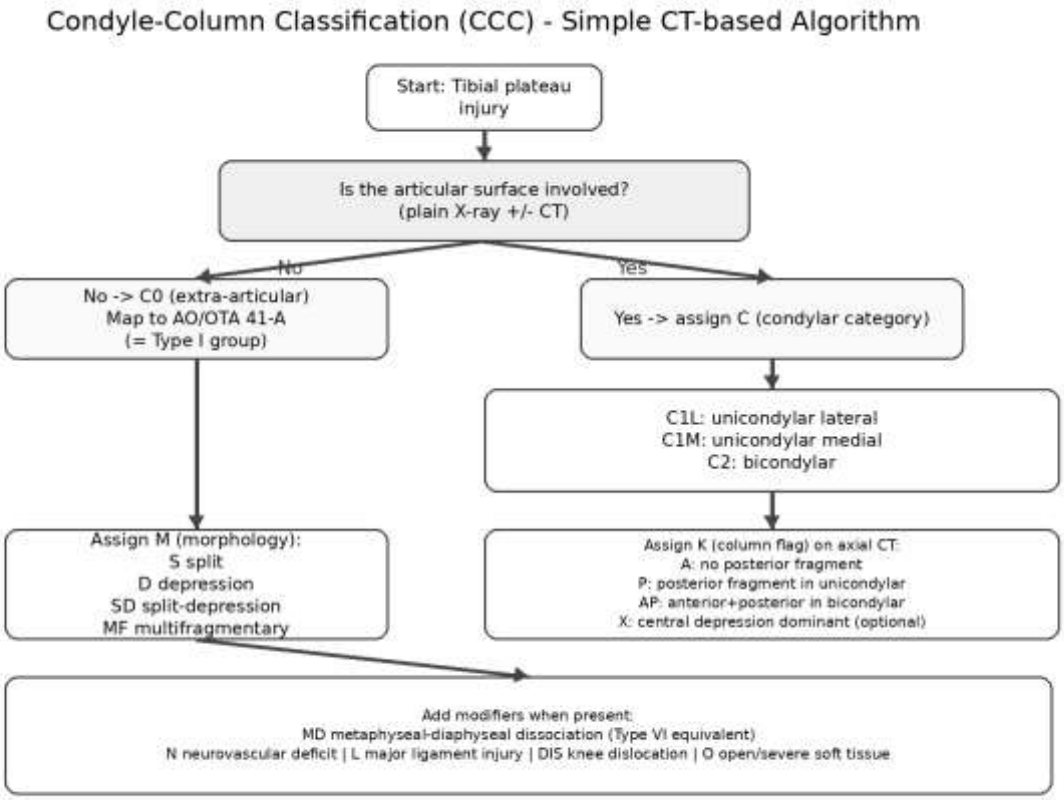

Figure 3. CCC decision algorithm for assigning C (condyle), K (column flag), M (morphology), and modifiers on radiographs and CT.

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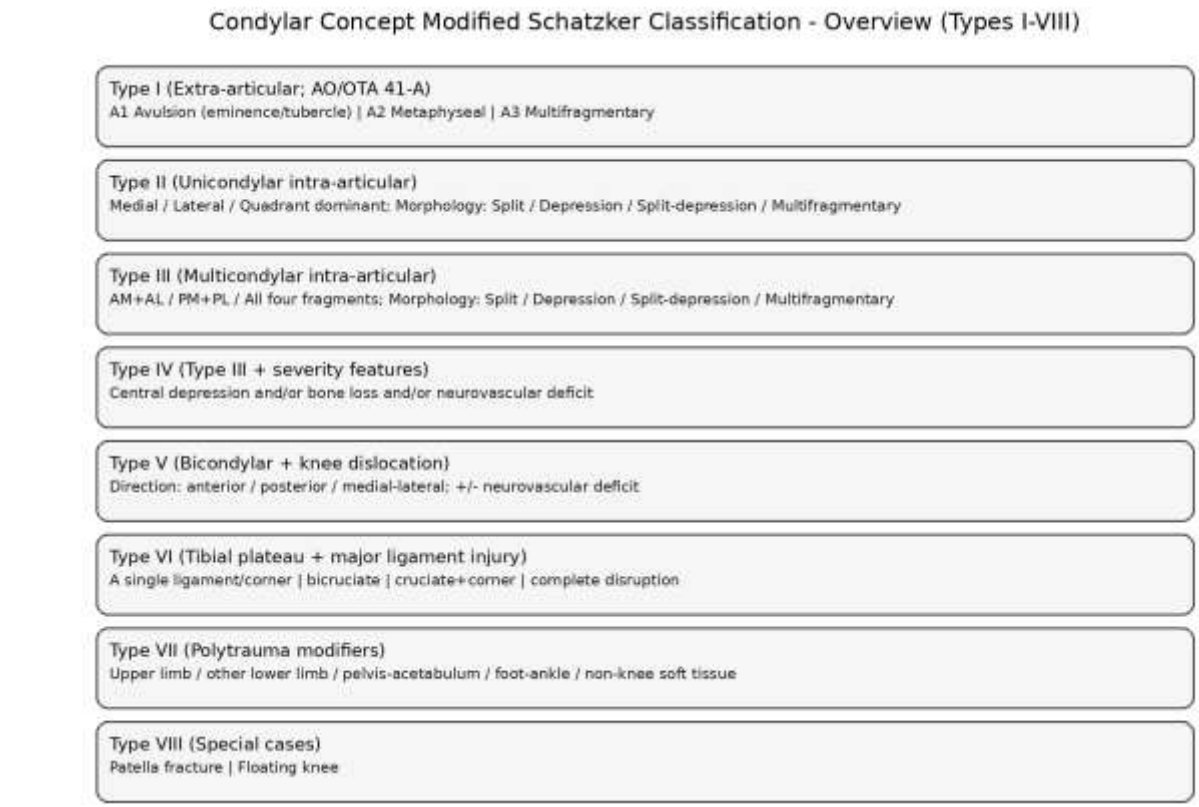

Figure 4. Overview of the condylar concept modified Schatzker classification (Types I-VIII).

Condylar concept modified the Schatzker classification (Types I-VIII)

Table 2 provides the proposed modified Schatzker-based hierarchy with AO/OTA mapping for extra-articular patterns.

Type	Definition	Groups	Subtypes / Notes
I	Extra-articular injuries (AO/OTA 41-A)	A. Avulsion (41-A1)	1) Medial intercondylar eminence 2) Lateral intercondylar eminence 3) Tibial tubercle 4) Gerdy's tubercle
		B. Metaphyseal (41-A2)	Extra-articular metaphyseal fracture
		C. Multifragmentary metaphysis (41-A3)	Extra-articular comminution
II	Single-condyle intra-articular fractures (unicondylar)	A. Medial condyle	Morphology (applies to all Type II and Type III groups): 1) Split 2) Depression 3) Split-depression 4) Multifragmentary
		B. Lateral condyle	Apply morphology 1-4
		C. Predominant quadrant	Posteromedial / posterolateral / anteromedial / anterolateral; apply morphology 1-4
III	Intra-articular fractures involving more than one condyle (multicondylar)	A. Anteromedial + anterolateral fragments	Apply morphology 1-4
		B. Posteromedial + posterolateral fragments	Apply morphology 1-4
		C. All four fragments	Apply morphology 1-4

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		(AM + AL + PM + PL)	
IV	Multicondylar fractures with complicating features (any Type III pattern plus one or more)	A. Central depression	Record as Type IV-A (with underlying Type III group)
		B. Bone loss / impaction defect	Record as Type IV-B (with underlying Type III group)
		C. Neurovascular deficit	Record as Type IV-C; document clinical/imaging findings
V	Knee dislocation associated with bicondylar fracture	A. Anterior dislocation	Add V-D if neurovascular deficit
		B. Posterior dislocation	Add V-D if neurovascular deficit
		C. Medial or lateral dislocation	Add V-D if neurovascular deficit
		D. Neurovascular deficit	Popliteal artery/nerve deficit, etc.
VI	Tibial plateau fracture with major ligamentous/soft-tissue injury (knee-based)	A. Any one: ACL or PCL or PMC or PLC	Specify injured structure(s)
		B. ACL + PCL	Bicruciate injury
		C. Cruciate + PMC or PLC	Combined corner + cruciate pattern
		D. Complete disruption	Global instability / complete ligamentous disruption
VII	Polytrauma-associated patterns	A. Upper limb injury	Associated injury influencing staging/rehabilitation
		B. Lower limb injury (excluding proximal tibia and patella)	Associated injury influencing staging/rehabilitation
		C. Pelvic and/or acetabular fracture	Associated injury influencing staging/rehabilitation
		D. Foot and ankle fracture	Associated injury influencing staging/rehabilitation
		E. Soft-tissue injury other than knee	Associated injury influencing staging/rehabilitation
VIII	Special cases	A. Concomitant patellar fracture	Record when it changes approach or rehabilitation
		B. Floating knee	Ipsilateral femur + tibia fractures

Condyle-Column Classification (CCC) and crosswalk

Table 3 provides a practical translation between CCC, typical Schatzker types, and broad AO/OTA categories.

CCC (core code)	**Fracture description (CCC)**	**Typical Schatzker type**	**Typical AO/OTA category***
C1L-A-S	Unicondylar lateral; no posterior fragment; split	I	41-B1
C1L-A-SD	Unicondylar lateral; no posterior fragment; split-depression	II	41-B3
C1L-X-D	Unicondylar lateral; central/impaction dominant depression	III	41-B2
C1M-P-(S/SD/D)	Unicondylar medial; posterior fragment common; morphology varies	IV	41-B (B1/B2/B3)
C2-A/AP-(S/SD/MF)	Bicondylar; anterior and/or posterior involvement; morphology varies	V	41-C (often C1/C2)
C2-AP-MF + MD	Bicondylar; posterior involvement; multifragmentary with dissociation	VI	41-C3 (often)

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*AO/OTA categories shown represent common broad groupings; exact subtype depends on specific fracture morphology and comminution.

DISCUSSION

The principal intent of combining condylar and column concepts is to preserve the bedside usability that has made Schatzker widely adopted, while adding CT-derived information that materially changes fixation strategy. Posterior fragments, particularly posteromedial components, are now recognized as common in complex injuries and are associated with specific surgical requirements, including posteromedial buttress fixation and alternative approaches. CT has been shown to improve the reliability of classification systems and surgical planning in multiple studies, and contemporary CT-based frameworks emphasize fragment-based fixation. Nevertheless, highly detailed schemes can be difficult to apply rapidly and may reduce adoption.

The condylar concept modification (Types I-VIII) expands the traditional fracture-only perspective by incorporating modifiers that influence staging and outcomes. Central depression and bone loss may indicate the need for elevation, grafting, and subchondral rafting. Neurovascular deficit, knee dislocation, and major ligament disruption are time-sensitive clinical problems that may prompt staged management and multidisciplinary input. Polytrauma and special associated injuries alter rehabilitation trajectories and can justify deviations from standard protocols.

CCC operationalizes the fusion of concepts into a short code that can be written in clinic notes and communicated in team discussions. The condylar component (C) keeps the familiar medial/lateral/bicondylar language, while the column flag (K) adds a minimal but high-impact CT decision: whether a posterior fragment is present (P/AP). This approach is intentionally conservative; it does not attempt to encode every nuance of AO/OTA coding, but it provides immediate guidance on approach selection and fixation priorities.

Limitations include the absence of formal inter- and intra-observer reliability testing and the lack of outcome correlation. These steps are required before the system can be recommended for widespread research reporting. Future validation should include multi-center CT-based reliability studies with surgeons of varying experience levels and correlation of CCC modifiers with approach selection, fixation constructs, complications, and functional outcomes.

CONCLUSION

A combined condylar-column framework can be simplified into a concise classification that remains compatible with Schatzker terminology while explicitly capturing posterior fragments on CT and allowing clinically meaningful modifiers. The proposed system is designed to support rapid communication and surgical planning, but it requires formal reliability and outcome validation.

DECLARATIONS

Ethics approval and consent: Not applicable (conceptual classification proposal with schematic figures).

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Data availability: Not applicable.

Author contributions: To be completed by the authors.

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