The validity and reliability of CT scan based tibial plateau mapping for tibial plateau fractures

Radwan G. Metwaly, Hossam Saeed Diab, Mohamed Nader Niaz

Department of Orthopedics, Ain-Shams University, Cairo, Egypt

Correspondence to Radwan G. Metwaly, MD, Department of Orthopedics, Ain-Shams University, 38 Abbassia Square, Next to Al-Nour Mosque, Cairo 1181, Egypt
Tel: +20 127 222 1906; fax: +0223467013;
e-mail: radwanmetwaly@med.asu.edu.eg, dr_radwan05@yahoo.com

Received: 21-Apr-2024
Revised: 20-May-2024
Accepted: 01-Jun-2024
Published: 13-Sep-2024

The Egyptian Orthopaedic Journal 2024, 59:266–273

Introduction
The Schatzker and computed tomography (CT)-based three-column classifications are the most used for tibial plateau fractures. The newer “10-segment classification” suggested to have better fracture identification and more accurate planning. This study aimed to assess the interobserver and intraobserver reliability of this new classification and to clarify its validity in clinical practice.
Patients and methods
A retrospective analysis of 30 patients with tibial plateau fractures who were admitted to a university hospital through the period between January 2020 and December 2022 was done. Patients with complete preoperative imaging, including radiographs, CT scans with three-dimensional reconstruction, and postoperative radiographs were included. Missing imaging, open fractures, pathological fractures, conservative management, or definitive fixation by circular external fixator were excluded. Data were reviewed independently by three expert trauma surgeons twice with 2-week intervals with randomization of case sequencing to evaluate their interobserver and intraobserver reliability for the Schatzker, CT-based three-column, and the new 10-segment classifications. The validity of the 10-segment classification was assessed by the agreement on the approach and implant position suggested by the observers.
Results
Good interobserver and intraobserver reliability was found as regards the Schatzker and CT-based three-column classifications on both intervals. Moderate and poor interobserver reliability “on both intervals respectively” and poor intraobserver reliability was found for the 10-segment classification. As regards the agreement on surgical approach on both time intervals, moderate and good interobserver agreements were found. For the implant position, poor interobserver agreement on both intervals was found. Intraobserver agreement for the surgical approach was good, while the intraobserver agreement for the implant position was moderate.
Conclusion
The Schatzker and CT-based three-column classifications are still more reliable than the newer 10-segment classification. This may be explained as it is still not familiar to surgeons and needs more training to be applied in clinical practice.

Keywords:
tibial plateau fracture, reliability, validity, classification, three-dimensional computed tomography

Egypt Orthop J 2024, 59:266–273

1110-1148

Introduction

Tibial plateau fractures are intraarticular fractures that may pose a threat to the knee function and represent a great challenge to treat. Treatment with open reduction and internal fixation is variable because fractures vary from simple to complex with extensive articular involvement. Hence, recognition of the fracture features helps surgeons to understand the injury mechanism better and manage these fractures by planning optimal surgical procedures [1].

Multiple classification systems have been recognized for tibial plateau fractures [2]. Among these three classification systems have been commonly used in clinical practice: the Schatzker [3], the AO/OTA [4], and the computed tomography (CT)-based three-column classifications [5].

Based on plain radiographs, Schatzker and AO classifications describe the location and general pattern of the fracture without considering the fracture line orientation. They lack the adequate details of depression and the morphological characteristics that would facilitate surgical plan and therapeutic effect postoperatively. Failure to achieve the reduction of depression is associated with residual pain, posttraumatic arthritis, and deformity [6]. Yet, most surgeons are still dependent on Schatzker classification for its high reliability [2].

CT is indispensable in understanding fracture patterns precisely, especially in consideration of fracture line orientation, location, and magnitude of depression components. It provides surgeons with an opportunity to promote the ability of reduction and internal fixation. Although the three-column classification system locates the fracture based on CT, it overlooks the morphological characteristics of depression and the coronal and sagittal size of the fractured fragment [6].

Newer classification systems tried to overcome the defects in the previous classifications. The four quadrant/column classification highlighted the posterolateral fragment [7], and the four-column/nine segments classification system further subdivided the plateau into nine segments, including the fibula [8], the revisited Schatzker classification modified the old version of the classification depending on CT scan images [9]. Recently, MRI had been used to reclassify the tibial plateau with the addition of soft tissue ligamentous injuries [10].

A new classification has been proposed by Krause and colleagues that divides the tibial plateau according to the three-dimensional (3D) CT cuts into 10 segments. The fracture pattern was analyzed based on CT imaging of the proximal tibial plateau 3 cm below the articular surface. In the axial view, the tibial plateau was divided into anterior and posterior columns for each of the medial and lateral tibial plateaus. Then, each of the anterior and posterior columns is further subdivided into five segments. This resulted in a total of 10 separate segments of the tibial plateau. This classification was suggested to have better fracture line identification and recognition of depression that allows better fracture planning, thus leading to better anatomic reduction and functional outcomes [11].

The primary aim of this study was to assess the interobserver and intraobserver reliability of the new 3D CT scan-based tibial plateau classification (the 10-segment tibial plateau mapping), and the secondary aim was to clarify its validity in clinical practice assisting the surgeons in choosing their approach and fixation implant during open reduction and internal fixation of such fractures. Our hypothesis was that this more sophisticated classification system may facilitate the choice of surgical approach and implants used and that this classification could be widely accepted among trauma surgeons.

Patients and methods

The ethical committee and university research institute approval for this study was obtained. Informed consent was obtained from all individual participants in this study.

A retrospective analysis of all patients with tibial plateau fracture who were admitted to a level (I) trauma center in a university hospital through the period between January 2020 and December 2022 was done for possible enrollment in this study. Patients included were skeletally mature adults (age above 18), of both sexes, with closed injury, and with available complete preoperative imaging including radiographs, CT scans with 3D reconstruction, and postoperative radiographs. Any missing data, improper radiograph views or CT scan cuts, lack of 3D reconstruction, pathological fractures, and patients who were managed conservatively or with circular ring fixator were excluded.

A total of 30 patients were included. Patients were numbered from 1 to 30 according to their time of admission in sequential order. The preoperative imaging data (plain radiograph films and CT scan with 3D reconstruction) and postoperative plain radiograph films of the 30 patients were organized in a folder numbered to the patients.

Three orthopedic surgeons who are experts in knee trauma (AO Trauma international faculty teaching in the AO Trauma Knee Master level course) were selected as observers.

Before starting the study, the observers received detailed illustrations of the surgical anatomy of the knee and the relevant classification systems. Each observer was given a detailed information and picture presentation covering Schatzker, three-column, and 10-segment classifications just to make sure that they were totally aware of these classification systems.

Observers were given adequate time to observe and evaluate the imaging data and to select their corresponding classification. The observers were asked to evaluate these images twice with two-week intervals with randomization of case sequencing, and the choices made on the first occasion were not visible on the second. No feedback was given after each evaluation.

Observers were asked first to observe plain radiograph films and make the corresponding classification as regards Schatzker classification. Observers then observed a CT scan and made the corresponding classification as regards three-column classification; then they observed 3D reconstruction and made the corresponding classification as regards 10-segment classification. The observers could not change the choices they made after observing the 3D reconstruction.

Observers were asked to plan and choose the appropriate surgical approach and the correct position of the plate according to the 10-segment classification for each case. After that postoperative radiographs were viewed, and observers were asked for their opinion, whether they agree or disagreed with what was already done for each case according to their planning.

Each observer worked independently of the other two observers using a private computer. During the study period, they were unable to communicate any information about the patients.

Interobserver and intraobserver reliability was assessed by calculating the kappa correlation coefficient as proposed by Cohen4. Interpretation of the kappa coefficients was performed using the criteria of Landis and Koch9, who define a kappa of more than 0.8 as excellent, between 0.6 and 0.8 as good, between 0.4 and 0.6 as moderate, and less than 0.4 as poor. The paired Student's t test was used to calculate statistical differences (P values) between mean kappa values and in order to consider. The level of significance was taken at P value less than 0.05, which is significant; otherwise, it is nonsignificant.

The collected data was tabulated and statistically analyzed using the SPSS program (Statistical Package for Social Sciences) software, version 26.0 (IBM Corp., Armonk, New York, USA, released 2019), Microsoft Excel 2016 and MedCalC program software, version 19.1

Descriptive statistics were done for numerical parametric data as mean±SD and minimum and maximum of the range and for numerical nonparametric data as median and first and third interquartile range, while they were done for categorical data as number and percentage.

Inferential analyses were done for quantitative variables using an independent t test in cases of two independent groups with parametric data and Mann–Whitney U in cases of two independent groups with nonparametric data. χ^2 test was used for categorical variables to compare between different groups. McNamara's test was used to examine the relationship between two (paired) qualitative variables.

Results

This retrospective study was done on 30 patients (20 males and 10 females) with a mean age of 46.17 ± 10.95 years (range, 23 to 69 years). The detailed data is represented in Tables 1, 2, and 3 and Fig. 1.

Using plain radiograph films, the mean kappa values for interobserver reliability regarding preoperative Schatzker classification was 0.749 ± 0.07, representing good agreement. After 2-week intervals, the mean kappa values for interobserver reliability regarding preoperative Schatzker classification was 0.639 ± 0.06, also representing good agreement.

Using CT scan images, the mean kappa values for interobserver reliability regarding preoperative three-column classification was 0.692 ± 0.08, representing good agreement. After 2-week intervals, the mean kappa values for interobserver reliability regarding preoperative three-column classification was 0.667 ± 0.08, representing good agreement again.

Using 3D CT scan images, the mean kappa values for interobserver reliability regarding preoperative 10-segment classification was 0.409 ± 0.30, representing moderate agreement. After 2-week intervals, the mean kappa values for interobserver reliability regarding preoperative 10-segment classification was 0.081 ± 0.17, representing poor agreement.

The mean kappa values for interobserver reliability regarding surgical approach choice was 0.411 ± 0.20, representing moderate agreement. After 2-week intervals, the mean kappa values for interobserver reliability regarding surgical approach choice was 0.665 ± 0.17, representing good agreement.

The mean kappa values for interobserver reliability regarding planning the plate position was 0.190 ± 0.22, representing poor agreement. After 2-week interval, the mean kappa values for interobserver reliability regarding planning of the plate position was 0.167 ± 0.08, representing again poor agreement.

The mean kappa values for intraobserver agreement regarding Schatzker classification was 0.766 ± 0.22, representing good agreement. The mean kappa values for intraobserver agreement regarding three-column classification was 0.697 ± 0.17, representing also good agreement. Unfortunately, the mean kappa values for intraobserver agreement regarding 10-segment

Table 1 Interobserver reliability of preoperative Schatzker classification, three-column classification, the 10-segment classification, surgical approach choice, and planning of position of plate among the studied patients in two times with 2-week interval (*N*=30)

Observer	Kappa value	SE	95% CI	*P* value
	Preoperative Schatzker classification			
1–2	0.678	0.117	0.448–0.908	0.918 (NS)
1–3	0.821	0.082	0.661–0.981	0.001 (HS)
2–3	0.749	0.105	0.543–0.954	0.025 (S)
Mean±SD	0.749 ± 0.07			
	Preoperative Schatzker classification (after 2-week time intervals)			
1–2	0.580	0.150	0.286–0.874	0.003 (HS)
1–3	0.692	0.112	0.471–0.912	<0.001 (HS)
2–3	0.644	0.148	0.353–0.934	0.025 (S)
Mean±SD	0.639 ± 0.06			
	Preoperative three-column classification			
1–2	0.583	0.123	0.342–0.823	0.0002 (HS)
1–3	0.716	0.091	0.538–0.893	0.002 (HS)
2–3	0.777	0.070	0.639–0.915	0.009 (HS)
Mean±SD	0.692 ± 0.08			
	Preoperative three-column classification (after 2-week time intervals)			
1–2	0.721	0.103	0.52–0.922	<0.001 (HS)
1–3	0.571	0.123	0.331–0.811	<0.001 (HS)
2–3	0.7096	0.112	0.491–0.929	0.0001 (HS)
Mean±SD	0.667 ± 0.08			
	Preoperative 10-segment classification			
1–2	0.752	0.085	0.586–0.919	0.157 (NS)
1–3	0.267	0.185	−0.095 to 0.63	0.028 (S)
2–3	0.209	0.185	−0.155 to 0.572	0.053 (NS)
Mean±SD	0.409 ± 0.30			
	Preoperative 10-segment classification (after 2-week time intervals)			
1–2	0.259	0.175	−0.084 to 0.602	0.977 (NS)
1–3	−0.085	0.141	−0.363 to 0.193	0.974 (NS)
2–3	0.069	0.115	−0.157 to 0.295	0.124 (NS)
Mean±SD	0.081 ± 0.17			
	Surgical approach choice			
1–2	0.580	0.101	0.382–0.779	<0.001 (HS)
1–3	0.459	0.17	0.126–0.792	0.020 (HS)
2–3	0.193	0.144	0.126–0.792	0.0001 (HS)
Mean±SD	0.411 ± 0.20			
	Surgical approach (after 2-week time intervals)			
1–2	0.851	0.059	0.737–0.965	<0.001 (HS)
1-3	0.6099	0.124	0.737–0.965	<0.001 (HS)
2-3	0.533	0.162	0.216–0.85	0.0001 (HS)
Mean±SD	0.665 ± 0.17			
	Position of plate			
1–2	−0.02	0.099	−0.214 to 0.174	<0.001 (HS)
1–3	0.175	0.076	0.025 to 0.324	0.004 (HS)
2–3	0.415	0.163	0.095 to 0.735	0.082 (NS)
Mean±SD	0.190 ± 0.22			
	Position of the plate (after 2-week time intervals)			
1–2	0.15	0.057	0.039–0.261	0.0002 (HS)
1–3	0.092	0.034	0.026–0.158	0.002 (HS)
2–3	0.258	0.186	−0.107 to 0.624	0.0195 (S)
Mean±SD	0.167 ± 0.08			

classification was 0.342 ± 0.10, representing poor agreement.

The mean kappa values for intraobserver agreement regarding surgical approach was 0.667 ± 0.16, representing good agreement. The mean kappa values for intraobserver agreement regarding the planning of the plate position was 0.487 ± 0.26, representing moderate agreement.

Upon evaluation of postoperative radiographs twice on 2-week intervals, observers showed no significant difference (P>0.05) regarding their opinion on

Table 2 Intraobserver agreement of Schatzker, three-column, 10-segment classifications, surgical approach, and planning for position of plate among the studied patients (*N*=30)

Observers	Schatzker classification		
	Kappa value	SE	95% CI
Observer 1	0.868	0.089	0.69292–1.00000
Observer 2	0.515	0.169	0.18354–0.84637
Observer 3	0.914	0.044	0.82770–1.00000
Mean±SD		0.766 ± 0.22	
		Three-column classification	
Observer 1	0.727	0.105	0.52262–0.93464
Observer 2	0.513	0.137	0.24407–0.78247
Observer 3	0.852	0.08	0.69558–1.00000
Mean±SD		0.697 ± 0.17	
		10-segment classification	
Observer 1	0.279	0.209	–0.132 to 0.689
Observer 2	0.460	0.120	0.225–0.695
Observer 3	0.286	0.174	–0.095 to 0.666
Mean±SD		0.342 ± 0.10	
		Surgical approach	
Observer 1	0.842	0.080	0.684–0.9995
Observer 2	0.517	0.127	0.2675–0.766
Observer 3	0.643	0.187	0.277–1.00
Mean±SD		0.667 ± 0.16	
		Position of plate	
Observer 1	0.705	0.119	0.471–0.937
Observer 2	0.199	0.142	–0.080 to 0.477
Observer 3	0.558	0.205	0.155–0.960
Mean±SD		0.487 ± 0.26	

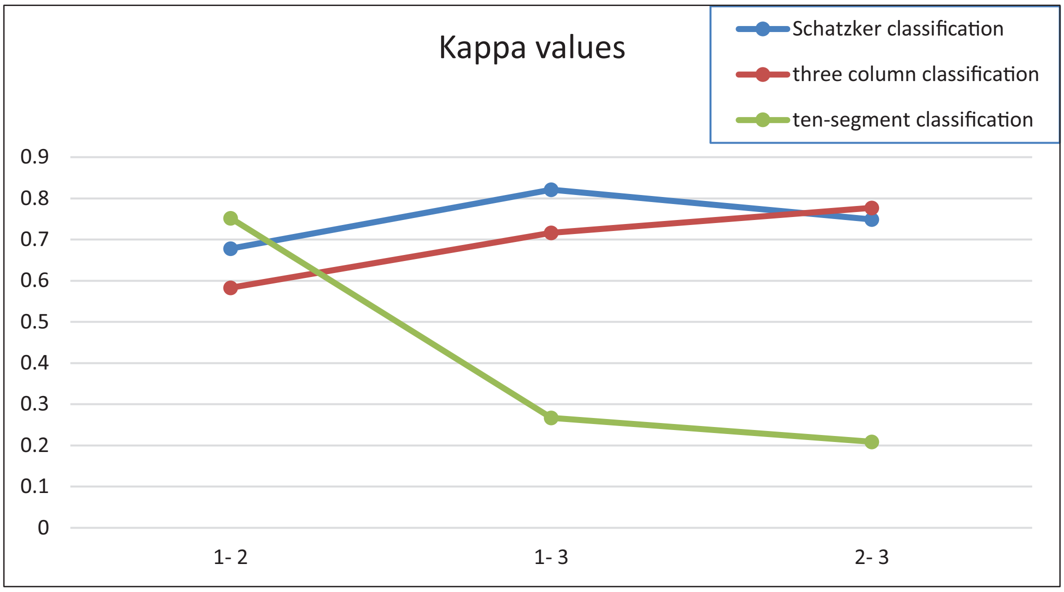
Table 3 Doctors' opinion based on postoperative radiograph at the 2-time interval

Doctors' opinion based on postoperative radiograph at first time	Studied patients (*N*=30)	
	n (%)	*P* value
Observer 1		
Agree	23 (76.7)	*P*1–2=0.065 (NS)
Disagree	7 (23.3)	
Observer 2		
Agree	16 (53.3)	*P*1–3=0.388 (NS)
Disagree	14 (46.7)	
Observer 3		
Agree	19 (63.3)	*P*2–3=0.581 (NS)
Disagree	11 (36.7)	
Doctors' opinion based on postoperative radiograph at second time		
Observer 1		
Agree	24 (80.0)	*P*1–2=0.727 (NS)
Disagree	6 (20.0)	
Observer 2		
Agree	22 (73.3)	*P*1–3=1.00 (NS)
Disagree	8 (26.7)	
Observer 3		
Agree	23 (76.7)	*P*2–3=1.00 (NS)
Disagree	7 (23.3)	

P value less than 0.05 is significant, *P* value less than 0.01 is highly significant.

what had been done. The percentage of agreement for (observer 1) was 76.7%, 53.3% for (observer 2) and 63.3% for (observer 3) at the first time and the percentage of agreement for (observer 1) was 80%, 73.3% for (observer 2), and 76.7% for (observer 3) at the second time (Table 3).

Figure 1



Interobserver reliability for the three classification systems using the kappa values.

Discussion

This study was conducted to assess interobserver and intraobserver reliability of three widely used classification systems in clinical practice for tibial plateau fractures, evaluating their diagnostic value and their role in decision-making and assessing the validity of the new 10-segment classification in surgical planning.

The interobserver and intraobserver reliability of Schatzker, three-column, and 10-segment classification were compared using kappa values. The results showed that Schatzker and three-column classification systems had higher interobserver mean kappa values (0.749 ± 0.07, 0.692 ± 0.08, 0.639 ± 0.06, 0.667 ± 0.08 after 2-week interval), respectively, representing good interobserver reliability in relation to the 10-segment classification which showed mean kappa value of 0.409 ± 0.30 and 0.081 ± 0.17 after 2-week interval representing moderate and poor interobserver reliability respectively. As regards intraobserver reliability, both Schatzker and three-column classifications had higher mean kappa values (0.766 ± 0.22, 0.697 ± 0.17, respectively), representing good intraobserver reliability in relation to 10-segment classification which showed mean kappa value (0.342 ± 0.10) representing poor intraobserver reliability. In our opinion, this may reflect that 10-segment classification is still not popular among knee trauma surgeons, and it still needs a learning and training curve for better assessment of cases using this new classification.

As regards planning the surgery according to the 10-segment classification by choosing the appropriate surgical approach, the mean kappa value showed good interobserver reliability but showed poor interobserver reliability as regards choosing plate position. The results showed that there was no significant difference between observers' opinions regarding what was done based on postoperative radiograph (P>0.05). Their agreement ranged from 53.3 to 76.7% in the first time and from 76.7 to 80% in the second time after 2-week intervals. In our opinion, this may reflect that the 10-segment classification may not be helpful for planning the choice of plate position, and no added value for plate position can be obtained by applying this classification in clinical practice.

Many reliability studies have been done over the past years assessing both interpersonal and intrapersonal variability of the widely used classification systems, trying to reach to which extent they could be reliable in clinical practice.

Charalambous and colleagues performed a study to assess both interobserver and intraobserver reliability between Schatzker classification and AO/OTA classification. The results of their study concluded that there is high interpersonal and intrapersonal variability when using Schatzker and AO/OTA systems and that classifying tibial plateau into unicondylar and bicondylar, pure splits versus articular depression ±split could be more reliable [12].

Maripuri and colleagues assessed the interobserver and intraobserver reliability of the Schatzker, AO/OTA, and Hohl-Moore, and the results concluded that none of them met the criteria for an ideal classification system and that Schatzker classification has the upper hand compared to AO/OTA, and Hohl-Moore in terms of the interobserver and intraobserver reliability [13].

Zhu *et al.* [14] conducted a study assessing the reliability of three-column, Schatzker, and AO/OTA classifications and concluded that the three-column classification has higher reliability than the Schatzker and AO/OTA classifications. This could be rendered to the effect of the use of CT scans with 3D reconstruction.

Hu *et al.* [15] performed a study to assess reliability between the Schatzker, AO classification systems by a combination of plain radiographs and 2D CT images compared to the combination of plain radiographs and 3D CT images and concluded that 3D CT imaging is more reliable than 2D CT and that it helps in improving reliability of these classification systems.

A study done on the impact of CT scanning on the interobserver and intraobserver reliability of the OTA/AO, the Schatzker, and the Hohl and Moore classification systems concluded that interobserver and intraobserver reliability of the three classification systems improved when they were classified with CT scans [16].

The use of 3D CT in the diagnosis of tibial plateau fractures can help orthopedic surgeons to diagnose posterior tibial plateau fractures, which were usually overlooked by the traditional classification systems, and this will improve surgical decision-making. Schatzker proposed a modified Schatzker classification 40 years of the original Schatzker classification to combine his classification with 3D CT scan [17].

However, a study done by Crijns *et al.* [18] found that the use of 3D CT scans did not necessarily improve interobserver agreement across all fracture types.

A recent study performed in 2022 assessing interobserver and intraobserver reliability of the Schatzker, updated three-column, and 10-segment classification systems concluded that the new CT-based 10-segment classification system has high interobserver and intraobserver agreement when using 2D and 3D CT scans [19]. Their study depended on a larger number of cases, and their observers were of the younger generation than this study. On the other hand, this study assessed not only the reliability but also the validity of the new 10-segment classification.

In this study, there was a significant difference between 10-segment classification and other classification systems, such as Schatzker and three-column classification, in terms of interobserver and intraobserver reliability, showing moderate to poor reliability. There was no added value as regards the choice of plate position, and this may reflect that the 10-segment classification is still not valid yet to use in clinical practice for planning surgery and choosing plate position. As Krause *et al.* [11] himself said, “10-segment classification” should be seen as a complement to, not a replacement for, the classic three-column classification or four-column classification.

As a point of limitation in this study, the number of patients included was small and the number of observers was small. All of three observers are working in the same center, which may reflect a one way of thinking, and nearly they are at the same level of seniority, which may reflect common learning and training capabilities.

Conclusion

This study concluded that 10-segment classification has moderate to poor reliability compared to the conventional widely used Schatzker and three-column classifications and is still not valid for use in clinical practice. In our opinion 10-segment classification is still not familiar to orthopedic surgeons and needs more learning and training for better assessment of cases using this new classification so that it can be applied in clinical practice.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1 Jeelani A, Arastu MH. Tibial plateau fractures–review of current concepts in management. Orthop Trauma 2017; 31:102–115.
2 Millar SC, Arnold JB, Thewlis D, Fraysse F, Solomon LB. A systematic literature review of tibial plateau fractures: what classifications are used and how reliable and useful are they? Injury 2018; 49:473–490.
3 Schatzker J, McBroom R, Bruce D. The tibial plateau fracture. The Toronto experience 1968--1975. Clin Orthop Relat Res 1979; (138):94–104.
4 Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF. Fracture and dislocation classification compendium-2018. J Orthop Trauma 2018; 32 Suppl 1:S1–S170.
5 Luo CF, Sun H, Zhang B, Zeng BF. Three-column fixation for complex tibial plateau fractures. J Orthop Trauma 2010; 24:683–692.
6 Yao X, Zhou K, Lv B, Wang L, Xie J, Fu X, *et al*. 3D mapping and classification of tibial plateau fractures. Bone Joint Res 2020; 9:258–267.
7 Chang SM, Hu SJ, Du SC, Ma Z, Xiong WF, Yao XZ. Four-quadrant/column classification of tibial plateau fractures. Int Orthop 2018; 42:725–727.
8 Yao X, Xu Y, Yuan J, Lv B, Fu X, Wang L, Yang S, Meng S. Classification of tibia plateau fracture according to the ‘four-column and nine-segment’. Injury 2018; 49:2275–2283.
9 Kfuri M, Schatzker J. Revisiting the Schatzker classification of tibial plateau fractures. Injury 2018; 49:2252–2263.

10 Tuncez M, Akan I, Seyfettinoğlu F, Çetin Tunçez H, Dirim Mete B, Kazımoğlu C. Is it necessary to add soft tissue injury to the classification in tibial plateau fracture management? Cureus 2022; 14:e22236.

11 Krause M, Preiss A, Müller G, Madert J, Fehske K, Neumann MV, *et al*. Intra-articular tibial plateau fracture characteristics according to the 'Ten segment classification'. Injury 2016; 47:2551–2557.

12 Charalambous CP, Tryfonidis M, Alvi F, Moran M, Fang C, Samarji R, *et al*. Inter- and intra-observer variation of the Schatzker and AO/OTA classifications of tibial plateau fractures and a proposal of a new classification system. Ann R Coll Surg Engl 2007; 89:400–404.

13 Maripuri SN, Rao P, Manoj-Thomas A, Mohanty K. The classification systems for tibial plateau fractures: how reliable are they? Injury 2008; 39:1216–1221.

14 Zhu Y, Hu CF, Yang G, Cheng D, Luo CF. Inter-observer reliability assessment of the Schatzker, AO/OTA and three-column classification of tibial plateau fractures. J Trauma Manag Outcomes 2013; 7:7.

15 Hu YL, Ye FG, Ji AY, Qiao GX, Liu HF. Three-dimensional computed tomography imaging increases the reliability of classification systems for tibial plateau fractures. Injury 2009; 40:1282–1285.

16 Brunner A, Horisberger M, Ulmar B, Hoffmann A, Babst R. Classification systems for tibial plateau fractures; does computed tomography scanning improve their reliability? Injury 2010; 41:173–178.

17 Van den Berg JD, Quintens L, Zhan Y, Hoekstra H. Why address posterior tibial plateau fractures? Injury 2020; 51:2779–2785.

18 Crijns TJ, Mellema JJ, Özkan S, Ring D, Chen NC; Science of Variation Group. Classification of tibial plateau fractures using 3DCT with and without subtraction of unfractured bones. Injury 2020; 51:2686–2691.

19 Yao P, Liu Y, Shan L, Zhao Y, Wang D, He Y, *et.al*. Intra- and inter-observer reliability assessment of widely used classifications and the 'Ten-segment classification' of tibial plateau fractures. Knee 2022; 35:149–156.