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Comparison of Plain Radiography with Spiral Computed Tomography and 3D Reformation in Tibial Plateau Fractures: A Cross-sectional Study

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ABSTRACT

Introduction: Tibial plateau fractures may result in major disabilities if not diagnosed at the right time. Plain radiography is the first and foremost imaging modality of choice to evaluate trauma followed by Computed Tomography (CT).

Aim: To evaluate tibial plateau fractures on CT and compare them with 3D reformations and plain radiography, and classify the fractures using Schatzker's classification.

Materials and Methods: The prospective cross-sectional study was conducted at a tertiary care centre in Bengaluru, Karnataka, India, between November 2016 to June 2018. The study sample comprised of 53 patients who presented with fracture of the tibial plateau. Demographic details and brief clinical history of the subjects were recorded. All patients underwent conventional radiography as well as CT of the knee, including three-Dimensional (3D) reconstruction. The region of interest was assessed for the presence, displacement, depression, extent and comminution of the fracture. Data was analysed using R version 4.0.3. Chi-square test was used to see the association between different variables. Cohen's Kappa was employed to determine the agreement of plain radiograph and CT findings.

Results: The mean age of patients was 44.01±13.23 years. The extent of the fracture line and communition of fracture were visible on all sections of CT for all samples, but 3D CT did not reveal the extent of the fracture line in 9.43% of the sample (p=0.003) and communition was visible only in 15.09% of the sample. On comparing the plain radiograph and CT findings for tibial plateau fractures, a close to perfect agreement in diagnosing the displacement of fracture (Cohen's Kappa, 0.9618, p<0.001), followed by a fair agreement in diagnosing fracture communition (Cohen's Kappa, 0.3748; p=0.0015) were noted. The positive predictive value of tibial plateau fracture detection rate by plain radiography and CT findings were 88.7% and 98.1%, respectively. These fractures assessed as per Schatzker's classification revealed majority of the patients had bicondylar plateau with diaphyseal discontinuity 19 (35.85%) followed by bicondylar plateau 14 (26.42%).

Conclusion: In this study, CT was observed to be an excellent modality for the evaluation of tibial plateau fractures including depression, displacement, comminution and extent of fractures when compared to plain radiography.

Keywords: Schatzker's classification, Three-dimensional imaging, Tibial fractures, X-ray

INTRODUCTION

Knee fractures account for 6% of trauma admissions to hospitals due to the knee being a superficial joint and more exposed to external forces [1]. Tibial plateau fractures are essentially fractures of the proximal tibia that involves the articular surface and encompasses varied fracture configurations involving the medial condyle (10-23%), lateral condyle (55-70%) or both (11-30%) with varying degrees of articular depression and displacement [2,3]. These fractures account for approximately 1% of all lower extremity fractures, that can produce major disabilities, such as knee instability, persistent pain, limitation of movement or angular deformity, if not diagnosed and managed at the appropriate time [4-7].

Therefore, to restore the optimal functional joint, congruency of the articular surface, stability and correct load distribution must be restored for which an accurate preoperative planning is vital [8,9]. The first step in achieving this goal is to ensure early and accurate diagnosis. Plain radiography is the preliminary imaging modality to evaluate trauma [10-12]. In routine practice, the anteroposterior and lateral images in at least two planes are studied in cases of knee trauma [7,10,13]. But in case of severe injuries, obtaining additional images that include the internal/external oblique, sunrise or tunnel can be difficult and challenging with conventional radiography [13]. Therefore, CT scanning is another commonly used imaging method to evaluate trauma [10,14]. Owing to the high radiation dose and expensive cost, CT scanning is not recommended to all patients [15,16]. The CT has an advantage in determining the magnitude and location of joint depression [17]. A 3D image provides spatial resolution, allowing enhanced evaluation of complexity on multiple 2D axial CT imaging. The 3D reconstruction is very useful in visualising bone fragments from all angles and planes [18]. In case of tibial fractures, the Schatzker's classification is routinely used in clinical practice for diagnosis [17]. However, there are very few studies comparing conventional radiography and spiral CT, including 3D reformation, in evaluating the knee joint/tibial plateau fractures [10,14,19-21]. Therefore, the main purpose of the study was to compare the accuracy of CT with that of plain radiography in the evaluation of tibial plateau fractures. The secondary objective was to classify tibial plateau fractures using Schatzker's classification.

MATERIALS AND METHODS

The prospective cross-sectional study was conducted at a tertiary care centre in Bengaluru, Karnataka, India, between November 2016 to June 2018. Approval from the Institutional Ethics Committee (SS-1/EC/63/2016) and written informed consent from patients were acquired prior to the commencement of this study.

Inclusion and exclusion criteria: The study included 53 patients who presented with tibial plateau fractures, diagnosed using plain radiography and CT. Cases with surgical implants in the tibia were excluded from the study.

Sample size calculation: The sample size calculation was based on the proportion formula from a study by Manjula L et al., (2015), where the positive predictive value of detecting the tibial plateau fractures by plain radiography was reported as 80% [22]. Therefore, expecting similar results from this study, considering 13% absolute precision and 95% confidence level, a minimum of 36 patients was the required sample size.

Study Procedure

Demographic details and brief clinical history of all the subjects were recorded. All cases underwent the following examination of the knee in the axial plane: 1) plain radiography; performed on a computed radiography unit Siemens Heliophos -D 800 milliampere (mA) X-ray machine in the standard axial plane and lateral views with 57 peak kilovoltage (kVp) and 5 mA; 2) CT; performed on Siemens Somatom 128 slice scanner. These examinations were followed by multiplanar reformations and 3D reconstruction.

CT acquisition protocol: Axial images were obtained from upper pole of the patella up to caudal end of the head of fibula using a bone algorithm (slice thickness, 2 mm; Pitch, 1; tube current, 135 mA; voltage, 120 kV). The acquired data was processed for multiplanar reformations and volume rendered 3D reconstructions. Bone reconstruction algorithm was followed for multiplanar reformations. A 3D reconstruction was projected in two standard views and in rotational projection with 15° increments. To improve fracture visualisation, additional projections were performed.

Independent assessment of reformatted and volume rendered images in all three planes were performed. The region of interest was assessed for the presence of fracture, displacement of the fracture, depression of fracture, extent of fracture line and comminution. Specific scores were given for each finding [Table/Fig-1]. The axial images, coronal images and 3D images were evaluated.

Radiographic findings	Scoring				
	0	1	2	3	4
Presence of fracture	Not identified/ cannot be commented	Absent	Probably absent	Probably present	Present
Displacement of fracture	Undisplaced/ cannot be commented	Not detected	Not detected despite being displaced	Well detected	Extremely well detected
Depression of fracture	Cannot be commented	Not detected	Not detected despite being depressed	Well detected	Extremely well detected
Extent of fracture line	Cannot be commented	Not detected	Extent not visible	Partial extent visualised	Complete extent well visualised
Comminution of fracture	Cannot be commented	Not detected	Not detected despite being communited	Well detected but fragments could not be counted	Well detected and fragments could be counted

[Table/Fig-1]: Scoring pattern for radiographic findings.

STATISTICAL ANALYSIS

Data was analysed using R version 4.0.3. The categorical variables were presented as numbers (%) and analysed using Chi-square test, whereas continuous variables were presented as mean±standard deviation. Cohen's Kappa was employed to determine the agreement of plain radiograph and CT findings. Level of significance was set at $p \leq 0.05$.

RESULTS

The mean age of the subjects was 44.01±13.23 years, with a majority of them aged between 41 and 60 years. Male subjects comprised of a greater number 40 (75.47%). Road traffic accidents resulted in 49 (92.5%) of the fractures. Clinical examination revealed pain, crepitus, swelling and movement restrictions in patients [Table/Fig-2]. A greater number of cases presented with fractures in the anteroposterior plane (p=0.028) and the fracture line extended anteroposteriorly (p<0.001) in greater number of the subjects [Table/Fig-3].

Characteristics		No. of patients (%)
Age group (years)	≤20	2 (3.77)
	21-30	7 (13.21)
	31-40	12 (22.64)
	41-50	14 (26.42)
	51-60	14 (26.42)
	>60	4 (7.55)
Gender	Male	40 (75.47)
	Female	13 (24.53)
Mode of injury (history)	Road traffic accident	49 (92.45)
	Fall	4 (7.55)
Clinical examination findings	Pain	53 (100)
	Crepitus	38 (71.7)
	Swelling	53 (100)
	Restriction of movements	53 (100)

[Table/Fig-2]: Prevalence of demographic and clinical characteristics.

Plain radiograph findings		Number of patients (%)		p-value
		Anteroposterior plane	Lateral plane	
Presence of fracture	No	6 (11.32)	15 (28.3)	0.028C*
	Yes	47 (88.68)	38 (71.7)	
Displacement of fracture	No	24 (45.28)	30 (56.6)	0.244C
	Yes	29 (54.72)	23 (43.4)	
Depression of fracture	No	53 (100)	53 (100)	1C
	Yes	0	0	
Extent of fracture line	No	27 (50.94)	45 (84.91)	<0.001C*
	Yes	26 (49.06)	8 (15.09)	
Communition of fracture	No	32 (60.38)	51 (96.23)	<0.001C*
	Yes	21 (39.62)	2 (3.77)	

[Table/Fig-3]: Plain radiographic findings for tibial plateau fractures.
*Significant (p<0.05); C: Chi-square test; CT: Computed tomography; 3D: 3 dimensional

The presence of fracture was detected on all planes of CT and 3D CT modality. The extent of fracture line was visible on all sections of CT for all samples, but 3D CT did not visualise the extent of fracture line in 9.43% of the sample (p=0.003) [Table/Fig-4].

CT findings		Number of patients (%)				p-value
		Axial	Coronal	Sagittal	3D CT	
Presence of fracture	No	0	0	0	0	1C
	Yes	53 (100)	53 (100)	53 (100)	53 (100)	
Displacement of fracture	No	25 (47.17)	23 (43.4)	23 (43.4)	24 (45.28)	0.976C
	Yes	28 (52.83)	30 (56.6)	30 (56.6)	29 (54.72)	
Depression of fracture	No	53 (100)	28 (52.83)	29 (54.72)	53 (100)	<0.001C*
	Yes	0	25 (47.17)	24 (45.28)	0	
Extent of fracture line	No	0	0	0	5 (9.43)	0.003MC*
	Yes	53 (100)	53 (100)	53 (100)	48 (90.57)	
Communition of fracture	No	14 (26.42)	13 (24.53)	13 (24.53)	45 (84.91)	<0.001C*
	Yes	39 (73.58)	40 (75.47)	40 (75.47)	8 (15.09)	

[Table/Fig-4]: The CT findings of tibial plateau fractures.
*Significant (p<0.05); 3D: 3 dimensional; C: Chi-square test; CT: Computed tomography; MC: Monte carlo simulation

On comparing the plain radiograph and CT findings for tibial plateau fractures, a close to perfect agreement in diagnosing the displacement of fracture with Cohen's Kappa of 0.9618 (p<0.001), followed by a fair agreement in diagnosing fracture communition (Cohen's Kappa, 0.3748; p=0.0015) was noted [Table/Fig-5]. The most frequent condylar type fracture observed in patients was bicondylar with diaphysis in both plain radiographic 17 (32.08%) and CT findings 20 (37.74%). Plain radiograph did not identify condylar type in six patients. Additional fractures were observed in

19 (35.85%) and 27 (50.94%) patients as per plain radiographic and CT findings, respectively [Table/Fig-6].

Parameters	Radiograph findings	CT findings		Cohen's kappa	p-value
		No	Yes		
Presence of fracture	No	0	6 (11.32%)	0	0.5
	Yes	0	47 (88.68%)		
Displacement of fracture	No	23 (43.4%)	1 (1.89%)	0.9618	<0.001*
	Yes	0	29 (54.72%)		
Depression of fracture	No	28 (52.83%)	25 (47.17%)	0	0.5
	Yes	0	0		
Communition of fracture	No	14 (26.41%)	18 (33.96%)	0.3748	0.0015*
	Yes	0	21 (39.62%)		
Extent of fracture line	No	0	27 (50.94%)	0	0.5
	Yes	0	26 (49.06%)		

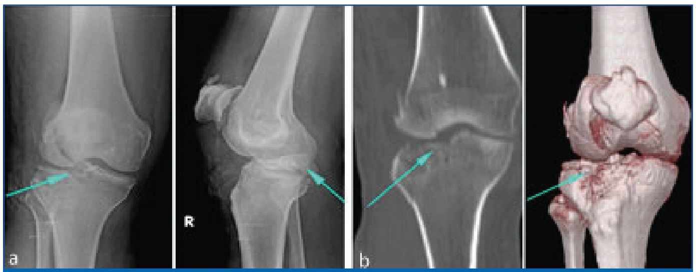
[Table/Fig-5]: Inter-method agreement between plain radiograph and CT findings in detecting tibial plateau fractures.
*Significant (p<0.05); CT: Computed tomography; Cohen's Kappa test

Clinical characteristics		Radiographic findings- Number of patients (%)		p-value
		Plain radiograph	CT	
Condylar type	Not identified	6 (11.32)	0	0.024*
	Lateral condyle	15 (28.3)	19 (35.85)	
	Medial	7 (13.21)	1 (1.89)	
	Bicondylar	7 (13.21)	12 (22.64)	
	Lateral plateau with diaphysis	1 (1.89)	1 (1.89)	
	Bicondylar with diaphysis	17 (32.08)	20 (37.74)	
Additional fractures	Absent	34 (64.15)	26 (49.06)	0.117
	Present	19 (35.85)	27 (50.94)	

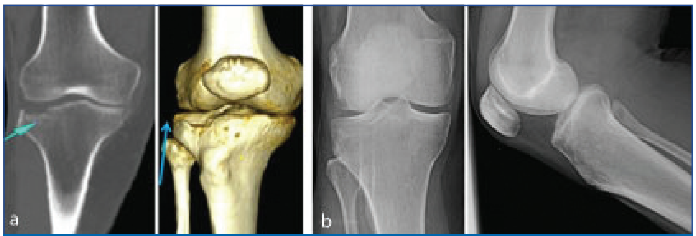
[Table/Fig-6]: Association of condylar type and additional fractures among radiographic findings.
*Significant (p<0.05); CT: Computed tomography; Chi-square test

The positive predictive value of tibial plateau fracture detection rate by plain radiography and CT findings were 88.7% and 98.1%, respectively. The management strategy for various types of tibial plateau fractures based on Schatzker's classification for a significant number of cases was surgical 46 (86.79%) and the rest were subjected to conservative treatment. Few case representations from this study are illustrated [Table/Fig-7-12].

[Table/Fig-7]: Type I Schatzker's fracture (lateral condyle)-(a) plain radiograph and (b) coronal reformatted and 3D CT images demonstrating undisplaced fracture of the lateral tibial plateau.

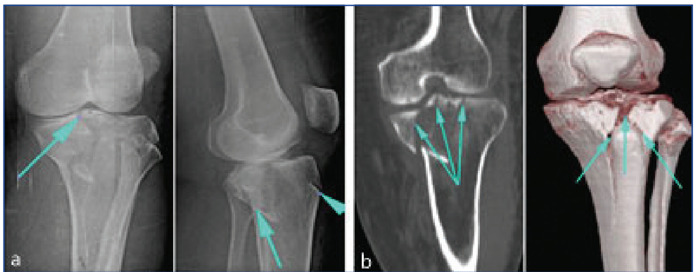


[Table/Fig-8]: Type II Schatzker's fracture (lateral with depression)-(a) Anteroposterior and lateral plain radiographic images demonstrating undisplaced lateral plateau fracture with extension to the intercondylar eminence, (b) coronal reformatted and 3D CT images demonstrating undisplaced lateral plateau fracture with depression of 6 mm, showing extension of the fracture line into the intercondylar eminence.

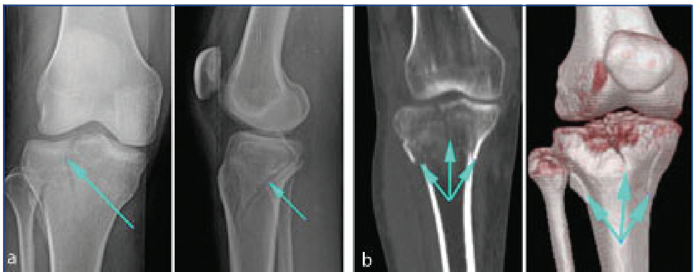


[Table/Fig-9]: Type II Schatzker's fracture (lateral with depression)-(a) Coronal reformatted and 3D CT images demonstrating undisplaced lateral plateau fracture with depression of 4 mm and (b) this finding was not identified on plain radiography.

[Table/Fig-10]: Type V Schatzker's fracture (bicondylar)-(a) anteroposterior and lateral plain radiographs showing undisplaced fracture of lateral tibial condyle and minimally displaced fracture of the medial tibial condyle and (b) CT axial and 3D reformatted images showing comminuted mildly displaced bicondylar fracture of tibia. Comminution was not identified on plain radiographs.



[Table/Fig-11]: Type VI Schatzker's fracture (bicondylar plateau with diaphyseal discontinuity)-(a) plain radiographs (anteroposterior and lateral) showing minimally displaced tibial bicondylar fracture with extension of fracture line to the metadiaphysis and (b) CT coronal and 3D reformatted images showing comminuted minimally displaced tibial bicondylar fracture with extension of fracture line to the metadiaphysis.



[Table/Fig-12]: Type VI Schatzker's fracture (bicondylar plateau with diaphyseal discontinuity)-(a) plain radiographs (anteroposterior and lateral) showing minimally displaced fracture of the medial condyle of tibia with fracture line extending into the metadiaphysis and coronal and 3D reformatted CT images showing minimally displaced fracture of medial condyle with extension to the lateral condyle and metadiaphysis.

DISCUSSION

Tibial plateau fractures present as an isolated injury or as a part of multiple traumatic injuries. They are clinically important as, if not detected accurately, can have severe sequalae. They are dramatic intra-articular traumatic lesions of a weight bearing joint. They can evolve into secondary osteoarthritis, because of postoperative axial defect of the lower limb, residual incongruous articular surface, ligamentous instability and enzymatic aggression of the cartilage. Efficient medical management is vital in reducing the incidence of secondary osteoarthritis [23]. Cross-sectional imaging results alter the surgical plans by more precisely demonstrating the fracture pattern, depression, and displacement. Therefore, the study was carried out to assess tibial plateau fractures via plain radiography, CT and 3D CT in trauma patients that would aid in deciding further treatment options. In this era of speed, increased incidence of accidents is bound to occur which in turn causes increase in cases of long bone fractures [24]. This is demonstrated in this study as a significant number of patients met with road accidents and experienced pain, swelling and movement restriction. The anteroposterior view was efficient in detecting the fracture on plain radiography. However, the presence of fractures was detected efficiently in all patients via CT, although it was insignificant with respect to different CT images which could be due to the small sample size considered for this study. Avci M and Kozaci N reported low sensitivity with respect to X-ray imaging in identifying knee bone fractures when compared to CT imaging [14]. The low sensitivity was seen to have gradually decreased with the elevation in the fractured bone numbers, which in turn is attributed to increased deterioration of the anatomy.

Assessing a fracture based on depression and displacement has become the current standard of preoperative evaluation of bone injury, giving insights to future treatment plans [25]. The anteroposterior view was efficient in detecting the displacement of fracture on conventional radiographs and CT but was extremely well detected via CT imaging. The depression of fractures were visualised in the coronal and sagittal view on CT but were not detected on plain radiographs. The CT has proven value in determining the location and magnitude of joint depression along with degree of diastasis to plan for surgical intervention [26]. In this study, by coronal reconstruction of knee images, 4-7 mm depression of tibial plateau fracture fragments was detected.

On interpretation and study of images in anteroposterior and lateral planes, it was found that the complete visualisation of the fracture line was more accurately visible on the anteroposterior view than lateral view by conventional radiography. The extent of fracture line was visualised to a partial extent on CT imaging for all the cases except for five of them on 3D CT. But complete visualisation was not observed in both plain and CT imaging. Molenaars RJ et al., first described the CT imaging technique to develop a fracture mapping for tibial plateau fractures, where they used the axial plane CT images to superimpose fracture lines and zones of communication to create a visual map of major and minor fracture lines [27]. However, this is not advantageous in conventional radiographs which make CT imaging superior in detecting the extent of fracture line.

The anteroposterior view was comparatively efficient in detecting the comminution of fracture on plain radiography. Similarly, in a majority of cases, comminution was well detected but fragments were not counted on CT imaging. In only 5 (9.43%) cases, comminution was well detected along with fragments in CT imaging but not on conventional radiographs. Published literature shows that CT can demonstrate the comminution better along with the extent of plateau depression when compared to plain radiographs, which corroborates with present findings [23]. Plain radiograph did not identify condylar type in six patients. Additional fractures were noted in 19 (35.85%) and 27 (50.94%) patients as per conventional ragiography and CT findings, respectively. Therefore, the overall findings support CT imaging being more efficacious when compared to conventional radiography in characterising the tibial plateau fractures, similar to existing studies [14,28,29].

Limitation(s)

The limitations of the study include a limited sample size because of limited study period and it being a single centre study. Overcoming these limitations would statistically prove CT and volumetric imaging beneficial in diagnosing tibial plateau fractures accurately and in detail.

CONCLUSION(S)

In this study, CT was observed to be an excellent modality for tibial plateau fracture evaluation including depression, displacement, comminution and extent of fractures when compared to conventional radiography.

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- Plagiarism X-checker: Jul 23, 2021
- Manual Googling: Oct 12, 2021
- iThenticate Software: Nov 15, 2021 (10%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
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