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Which Imaging Modalities are Neededfor Successful Treatment of Different Grades of Tibial Condylar Fractures?

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Abstract

Purpose: For success of surgery on different types of tibial condylar fractures, what are the different radiological modalities, plain x-ray, CT or MRI should be used in each fracture type of Schatzker classification.

Question: is the adding of CT or MRI to plain x-ray in tibial condyles fractures diagnosis can change the decision or the results of treatment?

Patients & methods: This study was prospectively performed on 40 patients presented by history of trauma or traffic accident complaining of pain, swelling and/or loss or weakness in leg movement. All cases were subjected to X ray, CT without contrast and with coronal and sagittal reconstruction and conventional MRI on the affected lower limb.

Results: This study included 22 males and 18 females. The main clinical presentation was pain and swelling in the affected limb (100% of cases) followed by loss of function (87.5%). The incidence of different types of Schatzker classification was as follows: Type I 15%, type II 12.5%, type IIIA 15%, type IIIB 17.5%, type IV 17.5%, type V 2.5% and type VI 20%. The overall accuracy of X-ray, CT and MRI for diagnosis of fracture site was 73.2%, 74.4% and 74.4% respectively, but the MRI soft tissue injuries assessment affected seriously the surgical decision.

Conclusion: CT scanning is more accurate than X-ray in precise localization of surgical landmarks and all tibial plateau fracture fragments. MRI is superior to CT in depiction of meniscal injuries and injuries to the collateral and cruciate ligaments and consequently the surgical decision can be changed completely in cases with bone comminution or associated soft tissue injuries.

Keywords: Tibial plateau, fracture; X-ray; CT; MRI; modalities.

Abbreviations: mAs, milliamperage-second; MCL, medial collateral ligament; ACL, Anterior cruciate ligament; PCL, Posterior cruciate ligament

Introduction

The Schatzker classification system for tibial plateau fractures is used by orthopedic surgeons to assess the primary injury and predict the prognosis as well as the accurate management. Many investigators have found that surgical plans based only on plain radiographic findings (X-ray) were changed when the patients :under wentpreoperative CT orMRI. The Schatzker classification divides tibial plateau fractures into six types, lateral plateau split fracture without depression (type I), lateral plateau fracture with depression (type II), compression fracture of the lateral(IIIA) or central (IIIB) tibial plateau, medial plateau fracture (type IV), bicondylar plateau fracture (type V), and plateau fracture with diaphyseal discontinuity (type VI) [1].

The location of soft-tissue injury as well as the degree of soft-tissue swelling guides the surgeons to the surgical approach and the timing of definitive surgery and helps also in making a decision of the need for provisional stabilization with an external fixator [2]. CT and MRI seem to be more accurate than X-ray for management of tibial plateau fractures, and the use of cross-sectional imaging can improve surgical planning [3].

CT is used by most orthopedists to further characterize fractures of the tibial plateau and assess the depression of the tibia and the degree of displacement of the fractured parts. Generally, slice thickness should be minimized (1 mm is ideal) and high milliamperage-second (mAs) technique should be used [4].MRIis excellent for detecting ligamentous and meniscal injuries.A major advantage of MRI over CT is that MRI does not use ionizing radiations. However, MRI has a higher cost and is needs longer time to complete the study (25 minutes for MRI vs 20 seconds for CT), which means that motion artifact can be a problem [5].

Aim of this study is to describe the rule of plain x-ray, C T, and MRI in diagnosis of tibial plateau fractures, and which radiological modalities should be used in each fracture type, and if it can change the surgical decision or the results of treatment.

Patientsand Methods

Study Design and Population

This prospective study was performed in the period between August 2013 and September 2015 after approval of our faculty ethical committee and included 40 patients 22 males (55%) and 18 females (45%), with age ranged from 30-59 years (average: 42 years) presented with history of motor vehicle accident followed by pain, swelling and/orloss or weakness of leg movement. The cases were referred from orthopedic department, Zagazig University and conducted in Radiodiagnosisdepartment. Informed consent was obtained from all participants in the study.

Patients with tibial plateau fracture suggested clinically were included in the study. On the other hand patients with previous operations of the tibia and those with a contraindication to MRI examination (artificial heart valve, cardiac pacemaker, metallic stents or joint prosthesis except that made of titanium)were excluded from the study.All patients were subjected to complete history taking, full clinical examination and imaging studies includingX ray of the affected limb (Anteroposterior and lateral views), CT imaging (axial cuts with reconstruction sagittal and coronal images) and conventional MRI (T1WI, T2WI, proton density (PD) and short T1 inversion recovery [STIR] sequences).

Technique of Computerized Tomography Examination

CT was done using 128 multislice machine (Philips, Ingenuity Core multislice 128 TM, Netherlands). The patient lied in supine position with knee extended and feet first into scanner. Straps were used to ensure patient stay in the correct position. The scanning parameters were as follows: Collimation: 1.25 cm, interval spacing: 0.65 cm, rotation time: 0.8 second.Thin axial slices were taken through the knee and leg and reconstructing the imagedata into sagittal and coronal planes.

Technique of MRI Examination

All MRI studies were done using Philips machine (Philips Achieva, 1.5 Tesla). All patients were asked to get rid of any metallic objects. MRI study was done with the patients in the supine position using the standard knee coil and different sequences were taken (T1WI, T2WI, PD and STIR).

Statistical Analysis

All data were collected, tabulated and statistically analyzed using SPSS 18.0 (SPSS Inc., Chicago, IL, USA). Continuous data were expressed as the mean ± standard deviation (SD) & median (range), while the categorical data were expressed as a number (percentage). Validity of X-ray, CT, MRI in diagnosis of tibial fracture was calculated with 95% confidence interval using diagnostic performance depending on sample 2x2 contingency tables generation using the operative and arthroscopic findings as the reference gold standard.

Results

Patients' Demographic Data and Clinical Picture

The patients' demographic data and clinical picture are presented in table (1). The main clinical presentation was pain and swelling in the affected limb (100% of cases) followed by loss of function (87.5% of cases).

Table1. *Demographic & Clinical data of the studied patients*

Demographic & Clinical data	The studied patients (N=40)	
	No.	%
Age (years)		
Mean ± SD	46.42 ± 8.51	
Median (Range)	46.50 (30 – 59)	
Sex		
Male	22	55%
Female	18	45%
Clinical picture		
Pain	40	100%
Swelling	40	100%
Loss of function	35	87.5%
Signs of vascular injury	0	0%
Signs of nerve injury	0	0%

Incidence of Different Types of Schatzker Classification

The incidence of different types of Schatzker classification based on plain x-ray was as follows: Type I15%, type II (Fig. 1) 12.5%, type IIIA (Fig. 2) 15%, type IIIB 17.5%, type IV 17.5%, type V(Fig. 3) 2.5% and type VI 20%.

Fig1. *A male patient 60 years with knee trauma and fracture*

A- (A) X-ray AP and lateral view which reveals fairly seen fracture line passing through tibial spine and lateral. tibial plateau

B&C and D): axial and coronal CT cuts reveals split and depressed fracture of lateral tibial plateau ….so it) diagnosed as type II tibial plateau fracture

E&F) are MRI coronal T2WI and coronal STIR reveals fracture line passing through lateral tibial plateau and) medial plateau so upgrade the type of fracture to type V

MRI images show that lateral meniscial body is fragmented and dislodged in to depressed lateral plateau

Fig2. *A female patient, 35 years old with history of previous knee trauma complaining of knee swelling and disability*

(A&B): X-ray AP and lateral views shows fracture line passing through lateral tibial plateau and tibial spine

(C&D): Axial CT cuts, (E,F, G&H): sagittal and coronal reconstructed CT cuts , the images reveal split fracture of lateral tibial plateau and tibial spine with no depression, associated with multiple bony fragments and fracture upper fibula.

(m&J): MRI coronal T2WIs. Images (K&L) sagittal & coronal T1WI reveal fracture line involve lateral tibial plateau, fracture upper end of fibula , joint effusion as well as PCL avulsed tibial attachment. Evidence of bucket handle tear of Posterior horn of medial meniscus absent bow tie sign & double PCL and detached central fragment (of MM is seen at intercondylar notch just below PCL origin

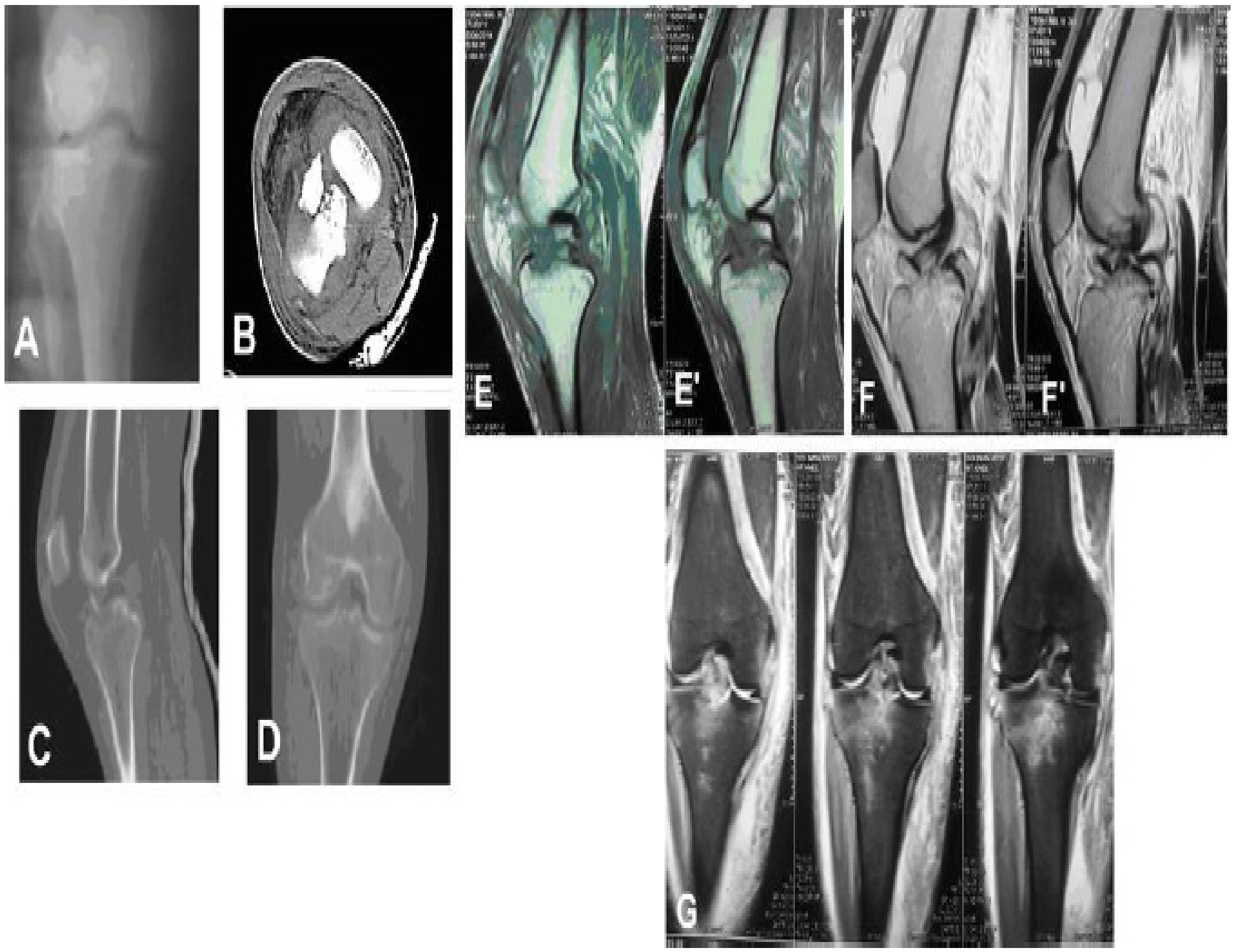

Fig3. *A male patient 50 years old with history of car accident complaining of knee pain , swelling and disability*

A): X-ray AP view shows , fracture line hardly seen passing through tibial spine)

B,C&D) CT axial , sagittal and coronal cuts of the knee shows depressed fracture of tibial spine with) detached small intra-articular fragment

E,E',F&F') MRI sagittal T1WI and sagittal T2WIs show abnormal contour and signal of ACL denoting complete ACL) tear(avulsed tibial attachment with avulsed bone fragment) with buckling of PCL

G) MRI coronal STIR images at 3 subsequent levels show bone marrow edema of tibial spine as well as MCL) tear and fluid signal is seen surrounding it

Diagnostic Performance of X-ray

The diagnostic performance of X-ray in diagnosis of tibial fracture and associated injuries is presented in table (2). The sensitivity and specificity for detection of fracture site, displacement, bony fragments, ligamentous injury and meniscal injury were 96.3% and 50%, 4.4% and 93.8%, 1.4% and 92.9%, 1.5% and93.8%, 1.7% and96.2% respectively. The overall accuracy was 73.2%, 31.4%, 47.1%, 47.6% and 48.9% for diagnosis of fracture site, displacement, bony fragments, ligamentous injury and meniscal injury respectively.

Table2. *Diagnostic performance of X-ray in diagnosis of tibial fracture and associated injuries*

Finding	TP	FP	TN	FN	SN %	SP %	PPV %	NPV %	+ve LR	-ve LR	Accuracy	DOR
Fracture site	39	0	0	1	96.3% (85.6-99.2)	50% (5.5-94.5)	98.8% (89.1-99.9)	25% (2.7-80.2)	1.9 (0.3-13.7)	0.07 (0-0.9)	73.2% (59.8-86.6)	26.3 (0.4-1837.9)
Displacement	1	0	7	32	4.4% (1-17.1)	93.8% (59.8-99.3)	75% (19.8-97.3)	18.8% (9.6-33.4)	0.7 (0-15.7)	1.0 (0.8-1.2)	31.4% (16-46.7)	0.1 (0.0-3.5)
Bony fragment	0	0	6	34	1.4% (0.1-12.3)	92.9% (56.1-99.2)	50% (5.5-94.5)	15.9% (7.7-29.9)	0.2 (0-9.3)	1.1 (0.9-1.3)	47.1% (32-62.2)	0.2 (0.0-10.4)
Ligamentous injury	0	0	7	33	1.5% (0.2-12.6)	93.8% (59.8-99.3)	50% (5.5-94.5)	18.3% (9.4-32.6)	0.2 (0-10.9)	1.1 (0.9-1.3)	47.6% (32.5-62.7)	0.2 (0.0-12.2)
Meniscal injury	0	0	12	28	1.7% (0-14.6)	96.2% (71.7-99.6)	50% (5.5-94.5)	30.5% (18.6-45.7)	0.4 (0-21.3)	1.0 (0.9-1.2)	48.9% (33.8-64.1)	0.4 (0.0-23.4)

TP: True Positive; FP: False Positive; TN: True Negative; FN: False Negative; SN: Sensitivity; SP: Specificity; PPV: Positive Predictive Value; NPV: Negative Predictive Value; +ve LR: positive Likelihood Ratio; -ve LR: negative Likelihood Ratio; DOR: Diagnostic Odds Ratio.

Table3. *Diagnostic performance of CT in diagnosis of tibial fracture and associated injuries*

Finding	TP	FP	TN	FN	SN %	SP %	PPV %	NPV %	+ve LR	-ve LR	Accuracy	DOR
Fracture site	40	0	0	0	98.8% (89.3-99.9)	50% (5.5-94.5)	98.8% (89.3-99.9)	50% (5.5-94.5)	1.9 (0.2-14.0	0.02 (0-0.7)	74.4% (61.2-87.6)	81 (0.7-9949.9)
Displacement	31	1	6	2	92.6% (78.9-97.7)	81.3% (46.7-95.5)	95.5% (82.5-98.9)	72.2% (40.2-91)	4.9 (1.7-20.9)	0.1 (0-0.3)	86.9% (76.8-97.1)	54.6 (6.1-489.5)
Bony fragment	34	0	6	0	98.6% (87.7-99.9)	92.9% (56.1-99.2)	98.6% (87.7-99.9)	92.9% (56.1-99.2)	13.8 (0.9-199.5)	0.0 (0-0.2)	95.7% (89.6-100)	897 (16.3-49369)
Ligamentous injury	0	0	7	33	1.5% (0.2-12.6)	93.8% (59.8-99.3)	50% (5.5-94.5)	18.3% (9.4-32.6)	0.2 (0-10.9)	1.1 (0.9-1.3)	47.6% (32.5-62.7)	0.2 (0.0-12.2)
Meniscal injury	0	0	12	28	1.7% (0-14.6)	96.2% (71.7-99.6)	50% (5.5-94.5)	30.5% (18.6-45.7)	0.4 (0-21.3)	1.0 (0.9-1.2)	48.9% (33.8-64.1)	0.4 (0.0-23.4)

TP: True Positive; FP: False Positive; TN: True Negative; FN: False Negative; SN: Sensitivity; SP: Specificity; PPV: Positive Predictive Value; NPV: Negative Predictive Value; +veLR: positive Likelihood Ratio; -ve LR: negative Likelihood Ratio; DOR: Diagnostic Odds Ratio.

Diagnostic Performance of CT

The diagnostic performance of CT is presented in table (4). The sensitivity and specificity for detection of fracture site, displacement, bony fragments, ligamentous injury and meniscal injury were 98.8% and50%, 92.6% and 81.3%, 98.6% and 92.9%, 1.5% and 93.8%, 1.7% and 96.2% respectively. The overall accuracy was 74.4%, 86.9%, 95.7%, 47.6% and 48.9% for diagnosis of fracture site, displacement, bony fragments, ligamentous injury and meniscal injury respectively.

Diagnostic Performance of MRI

The diagnostic performance of MRI is presented in table (4). The sensitivity and specificity for detection of fracture site, displacement, bony fragments, ligamentous injury and meniscal injury were 98.8% and 50%, 27.9% and 93.8%, 7.1% and 92.9%, 98.5% and 93.8%, 98.3% and 96.2% respectively. The overall accuracy was 74.4%, 60.8%, 47.1%, 96.1% and 97.2% for diagnosis of fracture site, displacement, bony fragments, ligamentous injury and meniscal injury respectively.

Table4. *Diagnostic performance of MRI in diagnosis of tibial fracture and associated injuries*

Finding	TP	FP	TN	FN	SN %	SP %	PPV %	NPV %	+ve LR	-ve LR	Accuracy	DOR
Fracture site	40	0	0	0	98.8% (89.3-99.9)	50% (5.5-94.5)	98.8% (89.3-99.9)	50% (5.5-94.5)	1.9 (0.2-14.0)	0.02 (0-0.7)	74.4% (61.2-87.6)	81 (0.7-9949.9)
Displacement	9	0	7	24	27.9% (15.7-44.7)	93.8% (59.8-99.3)	95% (65.5-99.5)	23.4% (12.1-40.4)	4.5 (0.3-69.1)	0.8 (0.6-1.0)	60.8% (46.1-75.6)	5.8 (0.3-112.1)
Bony fragment	2	0	6	32	7.1% (2.2-20.5)	92.9% (56.1-99.2)	83.3% (31-98.2)	16.7% (8.1-31.2)	1 (0.1-18.7)	1 (0.8-1.3)	47.1% (31.7-62.7)	0.2 (0.0-11.0)
Ligamentous injury	33	0	7	0	98.5% (87.4-99.8)	93.8% (59.8-99.3)	98.5% (87.4-99.8)	93.8% (59.8-99.3)	15.7 (1.1-230.9)	0.0 (0-0.2)	96.1% (90.3-100)	1005 (18.4-54825)
Meniscal injury	28	0	12	0	98.3% (85.4-99.8)	96.2% (71.7-99.6)	98.3% (85.4-99.8)	96.2% (71.7-99.6)	25.6 (1.7-387.3)	0.0 (0-0.3)	97.2% (92.2-100)	1425 (26.7-75956)

TP: True Positive; FP: False Positive; TN: True Negative; FN: False Negative; SN: Sensitivity; SP: Specificity; PPV: Positive Predictive Value; NPV: Negative Predictive Value; +veLR: positive Likelihood Ratio; -ve LR: negative Likelihood Ratio; DOR: Diagnostic Odds Ratio.

Table (5) shows the operative and arthroscopic findings of the studied patients to which the findings of the imaging modalities were compared.

Table5. *Operative and arthroscopic findings of the studied patients.*

Operative and arthroscopic findings	The studied patients (N=40)	
	No.	%
Lateral plateau fracture		
Absent	7	17.5%
Present	33	82.5%
Type of lateral plateau fracture		
Split fracture	14	35%
Compression fracture	9	22%
Both	10	25%
Lateral plateau fracture displacement		
Absent	7	17.5%
Depression	18	45%
Anterior displacement	7	17.5%
Posterior displacement	1	2.5%
Medial plateau fracture		
Absent	24	60%
Present	16	40%
Type of medial plateau fracture		
Split fracture	16	40%
Compression fracture	0	0%
Both	0	0%
Medial plateau fracture displacement		
Absent	4	10%
Depression	0	0%
Anterior displacement	11	27.5%
Posterior displacement	1	2.5%
Diaphyseal continuity		
Continous	32	80%
Discontinuous	8	20%
Diaphyseal displacement		
Absent	0	0%
Anterior displacement	8	20%
Posterior displacement	0	0%
Bony fragments		
Absent	7	17.5%
Present	33	82.5%
Other fractures		
Absent	33	82.5%
Present	7	17.5%

Discussion

Moore, t. M. and Patzakis, m. J. reported that fractures of the tibial plateau account for 1.3% of all fractures and affect males more commonly than females [6]. Two groups of patients principally suffer this type of injury. The first group is Younger or middle-aged patients with moderate or high-energy injuries are often from motor vehicle accidents or a fall from a height. The second group is elderly, osteoporotic patients, who have a relatively low energy injury such as a simple fall.

Tibial plateau fracturesare classified into six types according to the site of fracture. In the Schatzker classification, each increasing numeric fracture category indicates increasing severity [1].

In this study, 40 patientswith tibial plateau fracture were enrolled. We found that fractures affected males more than females (22 males& 18 females) and most of the cases suffered high-energy injuries (motor traffic accident).

In his study Canalestated that type I tibial plateau fracture according to Schatzker classificationrepresent 6% of all tibial plateau fractures and is more frequent in youngpatients with normal bone mineralization [7].In our study, 6 cases were suffering from type I tibial plateau fracture (15 %) and surgical decision was not changed.

Impaction injury to one side of the knee is associated with distraction injury to the opposite side of the knee therefore may be associated with a distraction injury to the medial collateral ligament (MCL) or Anterior cruciate ligament (ACL). In our study,in patients with type I tibial plateau fracture we found two cases with PCL injuries and normal ACL, consequently the patients were informed that they need another operation for reconstruction of PCL after healing of the fractures. Wickyand Blaser reported that a Schatzker type II fracture is a combined cleavage and compression fracture of the lateral tibial plateau. Depression may not be appreciated on plain radiographs. They stated that 20% of patients who have associated distraction injuries to the MCL or medial meniscus can be appreciated well with MRI [8]. In our study, depression fracture was not welldiagnosed in all cases and only two of five cases featured MCL injury and four cases showed ACL tear.

In Schatzker type III fractures depression may not be immediately evident on plain radiographs and may be clearly demonstrated only at Computed Tomography [5]. In our study, plain radiographs detected split with depression in 4 cases out of 6 but was not able to measure the degree of depression while cross sectional imaging (CT) clearly definedthe degree of depression in millimeters, and the surgical decision was changed by preparing for corticocancellous bone graft augmented by screws to fill the defect and help union and prevent redisplacement. In the same group of type III, MRI diagnosed 2 cases with medial meniscus tear were operated on later after information of the patients.

A Schatzker type IV fracture is a medial tibial plateau fracture with a split or depressed component commonly associated with a component of subluxation or dislocation that reduces spontaneously. Owing to the subluxation or dislocation, Computed Tomography may be more accurate than standard radiography for assessment of fracture extent. The fracture-dislocation mechanism of type IV fractures increases the incidence of injury to the peroneal nerve or popliteal vessels. This fracture is also frequently associated with distraction injury to the lateral compartment, resulting in lateral collateral ligament (LCL) complex or posterolateral corner injury or in fracture or dislocation of the proximal tibiofibular joint [9]. In our study, no cases showed peroneal nerve or popliteal vessels injuries or additional fracture of proximal fibula. MRI showed three cases out of 7 had LCL injury and one case has MCL injury.The case of lateral collateral ligament was treated in the same sitting by reconstruction using semi tendinosis graft to restore knee stability, while the case of MCL was treated conservatively.

Which Imaging Modalities are Neededfor Successful Treatment of Different Grades of Tibial Condylar Fractures?

A Schatzker type (V) fracture consists of a wedge fracture of the medial and lateral tibial plateau, often with an inverted "Y" appearance. Articular depression is typically seen in the lateral plateau, and there may be associated fracture of the intercondylar eminence. Up to one-half of patients with type V fractures have peripheral meniscal detachment, and one-third have ACL avulsion injury [10].

Bony avulsion of ACL was found in two cases out of seven of type V fractures in this study and treated by lag screw fixation. In other five cases the management was double plate and screws fixation of the fractures.

Gardnerand associates stated that Schatzker type VI fracture represent 20% of all tibial plateau fractures. One-third of type VI fractures are open, and associated with extensive soft-tissue injury with increased risk of compartment syndrome [11].

In two of six cases of schatzker type VI, compartmental syndrome was detected by MRI demonstrating muscular hyper intensity at T2WIs and STIR without swelling.

In our study we demonstrated the same benefit of CT in precise localization of surgical landmarks, as well all fracture fragments, degree of comminution of the fracture, and the degree of fragment depression.

G. Scuderi and A. Tria stated that MRI is very sensitive to the presence of osseous injury. Injuries to osseous structures manifest as areas of edema within bone marrow. However, fractures through the cortex are less well depicted, as cortical bone appears as an area of low signal (generally black) on MRI sequences. Thus, fractures through cortical bone can be difficult to depict with MRI. Complex and comminuted fractures with multiple cortical fragments are exceedingly difficult to analyze with MRI [12].

In our study MRI was difficult to detect multiple bone fragments and degree of bone depression, and it was the main method in detecting soft tissue and ligamentous injury.

Conclusion

CT scanning is more accurate than X-ray in precise localization of surgical landmarks and all tibial plateau fracture fragments, depressions, and bony avulsions. MRI is superior to CT in depiction of meniscal injuries and injuries to the collateral and cruciate ligaments and consequently the surgical decision can be changed completely in cases with bone comminution or associated soft tissue injuries. We recommend using the three modalities for complete evaluation and management of these cases, and not to lose any hidden injury.

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