Original Article

Association between Preoperative CT findings and Meniscal injury in the Fracture of Tibial Plateau: A Preliminary Report

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Objective: To determine the association between computerized tomography [CT] findings measurements and the incidence of meniscus injury diagnosed by arthroscopic technique.

Materials and Methods: A prospective cohort study was conducted with ten patients (6 males and 4 females) aged 18 to 80 years (mean 52.4) who had sustained a tibial plateau fracture and undergone open reduction internal fixation [ORIF] between June 2015 and July 2016. Data on age, sex, mechanism of injury, energy level of injury, type of meniscus injury, and Schatzker classification were collected. Seven of the patients (70%) had associated meniscal injury. Lateral plateau depression [LPD], medial plateau depression [MPD], lateral plateau widening [LPW] and medial plateau widening [MPW] were measured using pre-operative CT scans for each patient and the association between CT findings measurements and meniscus injury was calculated.

Results: LPW was found to be significantly associated with both lateral meniscus injury ($p = 0.044$) and medial meniscus injury ($p = 0.011$). Average 6-month postoperative WOMAC score in our study was 12.8. No patient scored higher than 19.

Conclusion: Measurements made using CT imaging are useful in predicting meniscal injury. This result supports the value of MRI or arthroscopic-assisted surgery in tibial plateau fractures in selected case.

Keywords: Tibial fracture, Arthroscopy, Meniscus, CT scan, Plateau depression, Plateau widening

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Fractures of the tibial plateau are often associated with local soft tissue injury. Previous studies have reported that 42 to 47% of tibial plateau fracture patients also had meniscus injury and 36% had an unstable meniscal tear(1,2). Gardner et al reported an incidence rate of up to 76% for lateral meniscus tears and 44% for medial meniscus tears(3). One of major long-term problem with meniscus injuries is posttraumatic osteoarthritis. Although a study by Rademaker et al stated that 64% of patients with a meniscal tear were well tolerated but that 31% developed secondary osteoarthritis(4). Joint congruency, joint stability and an intact meniscus are factors that influence weight distribution. It is important to be aware of these factors as they may lead to affect both management and prognosis. Meniscal repairs in acute tibial plateau fractures generally have good outcomes: a one study reported a 92% healing rate confirmed by second-look arthroscopy(5).

It is important to detect meniscus injury preoperatively as it alerts the surgeon to prepare for repair of that injury. Surgical planning can be improved

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with appropriate imaging[6]. Studies have reported that surgical plans based on plain radiographic findings were changed in 26% of cases after CT and in 23% of cases after MR imaging[7,8]. MRI can be equal or superior to two-dimensional CT reconstruction for depiction of fracture patterns[9]. However, MRI involves a high cost and is not available in all situations, so a lower cost and more widely available alternative using CT imaging would be an asset.

An association between tibial plateau depression, widening and meniscus injury has been reported in previous studies. Greater depression and displacement of fragments are related to higher risk for incidence of meniscus injury. Most meniscus injuries are diagnosed based on MRI[10,11]. However, the accuracy of MRI in acute knee trauma with associated ligament injury was found to be significantly lower than CT images in some cases[12].

To our knowledge, there have been no prospective studies of radiographic images as a predictor of meniscal injury with which have been subsequently confirmed by standard arthroscopic diagnosis of meniscus pathologies. The aim of this study was to determine the association between radiographic parameters in CT scans and meniscus injuries diagnosed using arthroscopy. The hypothesis was that tibial plateau depression and plateau widening are associated with meniscal injury and can alert the surgeon to preoperatively prepare for meniscal injury management.

Materials and Methods

A prospective cohort study was performed with a group of 10 patients aged 18 to 80 years who had sustained a tibial plateau fracture and had undergone open reduction internal fixation [ORIF] between June 2015 and July 2016. Operative treatment was indicated if a patient presented with 10 degrees of varus/valgus instability and/or signs of joint displacement of more than 5 mm. Patients with a history of meniscectomy or previous non-operative treatment were excluded from the study. Data on age, body mass index [BMI], sex, mechanism of injury, energy level of injury and Schatzker classification were obtained. Falls from a standing position, sport activities and physical assaults were classified as low energy mechanisms; motor vehicle accidents and falls from a height were classified as high energy mechanisms.

Radiographic measurements

Pre-operative CT scans of each patient were reviewed by orthopedic surgeons before surgery using the PACS Imaging System (FUJIFILM Medical Systems, USA, Inc.). Coronal reformatted images were used to evaluate the fracture. A horizontal line was drawn from the highest point of the tibial plateau and perpendicular to the longitudinal axis of the tibial shaft. The maximum amount of depression of the articular fragment was noted using the highest point on the contralateral condyle as a reference. If the fracture pattern included a split fragment, the fragment level was approximated. In cases of bicondylar involvement, the less severely affected side was used as a reference. This was adjusted for the measurement used to determine the pre-traumatic horizontal plateau height line. The depression was measured in millimeters on a coronal view of the CT images and the lowest point of depression on the tibial plateau was noted (Figure 1).

Figure 1. CT image measurement method using coronal image with maximal fracture width and the deepest articular depression. Line a is a reference drawn from the extension of the medial plateau parallel to the joint line. Line b is parallel to a line drawn from the deepest articular depression of the lateral plateau. Lateral plateau depression [LPD] is the distance between lines a and b. Line c is tangential to the tibial plateau axis and perpendicular to line a. Line d is drawn from the point of maximum width of the lateral tibial plateau gap and is parallel to line c. Lateral plateau widening [LPW] is the distance between lines c and d. The same measurement method was used for the medial plateau.

Plateau widening was also noted as was the maximum width of the plateau fragment gap.

Surgical procedures

All surgical procedures were performed prospectively by one of the orthopedic trauma surgeons (PS or NK) and one of the sports medicine orthopedic surgeons (ST or CL). The operations were all dry-technique arthroscopy and ORIF with plate and screws. The presence or absence of a meniscus tear as determined by a combination of direct visual inspection and probe palpation at the time of the arthroscopy. The meniscus and intra-articular structure were examined using arthroscopic techniques. Any meniscal pathology, ligament, or cartilage injuries were recorded. After that, the fracture fragments were reduced under arthroscopy and temporarily held in place by Kirschner wires. Reduction alignment was checked using an intraoperative fluoroscope. If the reduction was satisfactory, osteosynthesis was performed using an anatomical locking plate (Synthes, USA). If peripheral detachment of the meniscus was detected, the meniscus was repaired using the arthroscopic all-inside technique and the FAST-FIX meniscal repair system (Smith & Nephew, USA). If a tear in the anterior horn of the meniscus was detected, the meniscus was repaired using the arthroscopic outside-in technique and polydioxanone No. 0 sutures (PDS, Ethicon, Somerville, NJ). In cases where the meniscus injury was to the inner one-third, involved a complex tear or was irreparable, debridement or a partial meniscectomy was done.

Postoperative evaluation and follow-up

In cases where no ligament or meniscus injury was found, the patient was encouraged to start passive range of motion on the first day after surgery. For patients with a ligament injury or meniscus repair, motion was restricted to between 0 and 90 degrees. Non weight bearing walking using crutches was permitted for a month, followed by partial weight bearing. Full weight bearing was allowed when clinical and radiographic union had been established. The patients had regular follow-up visits until bone union was achieved. Functional assessment and clinical outcomes were evaluated 6 months after surgery using the Western Ontario and McMaster Universities Osteoarthritis Index [WOMAC][13,14]. The WOMAC score is based on the combined ratings of pain, stiffness and physical function. The range of the WOMAC score is between 0 (best) and 96 (worst).

Statistical analysis

Statistical analysis was performed using SPSS for Windows v15.0 software (SPSS Inc., Chicago, IL, USA). The paired t-test was used for intragroup comparison of parameters with normal distribution and the Chi-square test for comparison of qualitative data. Values obtained for each group were compared using the Mann-Whitney U test. Results were evaluated with a 95% confidence interval; *p*-values of less than 0.05 were considered statistically significant.

Results

A total of 10 patients were enrolled in this prospective study, 6 males and 4 females, with a mean age of 52.4 years. The average BMI was 24.7 kg/m^2. The most common mechanism of injury was motor vehicle accident [MVA]. A high-energy mechanism of injury was involved in 7 of the cases (70%). The two most common fracture types were Schatzker type IV and type VI. Seven patients (70%) had associated meniscal injuries and 2 (20%) had an associated cruciate ligament injury (Table 1 and 2). The average 6-month postoperative WOMAC score was 12.8, and none of the patients had a score of more than 19.

Table 3 and 4 show the association found between radiographic parameters and the incidence of lateral meniscus injury in patients with lateral plateau fractures as well as the relative risk of lateral meniscus injury in these patients using a cut-off of >5 mm in the lateral plateau parameter and >3 mm in the medial plateau parameter. This study found a significant association between lateral meniscus injury and LPW >5 mm (*p*-value = 0.044) (Table 3) and a relative risk of 1.1 (95% CI 0.4 to 3.0) (Table 4). Similarly, Table 5 and 6 show the association between radiographic parameters and the incidence of medial meniscus injury in the patients with a medial plateau fracture and the relative risk of medial meniscus injury in those patients using the same a cut-off. The association between the medial meniscus injury and LPW >5 mm was significant (*p*-value = 0.011) (Table 5) with the relative risk of 6.7 (95% CI 0.5 to 93.5) (Table 6).

Discussion

The arthroscopic technique has been developed for use in many situations, e.g., assisting in tibial plateau surgery[15-21]. Bonasia et al reported excellent outcomes in a 5 year follow-up of arthroscopic -assisted lateral tibial plateau surgery[22]. Although there has been one report of compartment syndrome following arthroscopic examination of a tibial plateau

Table 1. Baseline characteristics, data related to fracture and meniscus injury, treatment, and clinical outcomes

Case No.	Duration to surgery (day)	Age (year)	BMI	Sex	Mechanism of injury	Schatzker classification
1	9	54	28.5	Male	MVA	V
2	12	51	25.1	Female	Body assault	IV
3	7	80	17.0	Female	Fall from standing	IV
4	14	56	38.5	Female	Sport accident	V
5	15	40	22.5	Male	MVA	VI
6	15	40	22.5	Male	MVA	VI
7	3	47	21.5	Male	Fall from height	II
8	1	35	29.4	Male	MVA	IV
9	3	60	19.7	Female	Fall from height	I
10	3	61	22.5	Male	MVA	VI

BMI = Body Mass Index; MVA = motor vehicle accident

fracture[23], arthroscopy is considered safe for use in fixation when used with appropriate surgical techniques[24-28]. In addition, postoperative rehabilitation has been shown to be easier and faster with arthroscopic-assistance than with conventional open reduction[29].

In 2010, Ringus et al demonstrated an association between depression of the tibial plateau and the incidence of lateral meniscus tears. In patients with $\geq$10 mm of depression on a CT scan, there was an eight-fold increase in the incidence of identification of a lateral meniscus tear using MRI[10]. Lateral plateau widening of $\geq$10 mm with plain radiography has also been used as indirect sign of a lateral meniscus tear[11]. However, the accuracy of MRI decreases in patients with multiple knee injuries. Meniscus injuries associated with a ligament injury are usually posterior and peripheral tears[30] which may be the cause of the lower sensitivity and accuracy of the MRI images[12,31].

The ability to predict the presence of a meniscal tear can potentially greatly reduce the need for further soft tissue imaging studies. It also allows surgeons to anticipate probable necessary meniscal lesion treatments. Arthroscopic-assisted surgery could be considered an operative treatment option for these fractures, especially fractures with suspected associated meniscus injury, a technique that allows surgeons to evaluate intraarticular lesions and consider appropriate treatments more accurately.

In the present study, the authors performed arthroscopic-assisted surgery which provided diagnosis of meniscal pathology under direct visualization. Arthroscopy is the gold standard for meniscal pathology diagnosis, providing more accurate and comprehensive meniscus evaluation than other methods. The present study demonstrated a statistically significant association between the amount of lateral plateau widening [LPW] and lateral meniscus injury (p = 0.044), and between LPW and medial meniscus injury (p = 0.011). The results could also help make surgeons aware of soft tissues injuries of the knee through the process of looking for meniscal injuries that could lead to long term discomfort or osteoarthritis. These findings regarding coronal CT scans might be a useful predictor of associated meniscus injury in tibial plateau fractures.

The significant association between LPW and medial meniscus injury (p = 0.011) might be explained by the fact that the LPW was calculated only from the patients who had bicondylar tibial plateau fractures. Another factor possibly related to the association is that both the degree of displacement of a medial and lateral plateau fracture might be affected by the severity of the injury mechanism.

Limitations of the present study include the small sample size, the inability to verify previous meniscal pathologies, and the lack of a standard radiological criteria for measuring tibial plateau depression/widening. Also, this study modified a reliable method used in previous studies[10,11]. A large prospective study is needed to more thoroughly analyze the strength of the relationship between fragment depression and displacement with meniscus injury.

Conclusion

Measurements of CT images can be useful in preoperatively predicting meniscal injury, alerting the surgeon to prepare to deal with that injury. The results

Table 2. Measurements, characteristics of ligament and meniscus injury, treatment, complications and clinical outcomes at 6 months postoperatively

Case No.	Degree of depression (mm)		Degree of widening (mm)		Arthroscopic findings		Meniscus tear type	Meniscus procedures	Complications	WOMAC at 6 months
	LPD (n = 7)	MPD (n = 8)	LPW (n = 7)	MPW (n = 8)	Ligament and meniscus injury	ICRS grading				
1	5.6	2.86	2	0	ACL + PCL	3	-	-	Wound breakdown	19
2	N/A	2.5	N/A	3.85	M M	4	Complex	Debridement	-	14
3	N/A	1.01	N/A	1.02	-	1	-	-	-	9
4	1.62	5.27	7.49	3.04	MM + LM	3	Complex	Debridement	-	17
5	1.03	3.71	0	4.56	PCL	2	-	-	-	12
6	1.38	0	1.96	0	LM	2	Longitudinal	Meniscus repair	-	14
7	5.02	N/A	8.16	N/A	LM	1	Radial	Debridement	-	9
8	N/A	2.14	N/A	3.54	M M	2	Bucket handle	Meniscus repair	-	11
9	8.68	N/A	6.37	N/A	LM	2	Complex	Debridement	-	11
10	10.1	3.62	6.22	4.25	MM + LM	2	Complex tear	Meniscus repair		12
Mean	4.92	2.64	4.46	2.75	MM: 4 LM: 5					Mean: 12.8

LPD = Lateral plateau depression; MPD = medial plateau depression; LPW = lateral plateau widening; MPW = medial plateau widening; MM = medial meniscus; LM = lateral meniscus; ICRS = International Cartilage Repair Society; N/A = not available due to no plateau fracture involvement on that side

Table 3. Difference in radiographic parameters between lateral plateau fracture patients with and without lateral meniscus injury (n = 7)

Radiographic parameters	Lateral meniscus injury	No lateral meniscus injury	*p*-value
Lateral plateau parameters (mm) ■	(n = 5)	(n = 2)	
LPD	5.36	3.32	0.553
LPW	6.04	1.00	0.044*
Medial plateau parameter [B] (mm) ■	(n = 3)	(n = 2)	
MPD	2.96	3.29	0.884
MPW	2.43	2.28	0.953

■ = value presented as mean
LPD = lateral plateau depression; LPW = lateral plateau widening; MPD = medial plateau depression; MPW = medial plateau widening
[B] = calculated only cases with bicondylar fracture (Schatzker V&VI); * = statistically significant (*p*-value <0.05)

Table 4. Relative risk of lateral meniscus injury using radiographic parameters and cut-off values in patients with lateral plateau fracture (n = 7)

Radiographic parameters	Lateral meniscus injury	No Lateral injury meniscus	Relative risk	*p*-value	95% CI
Lateral plateau parameter ○	(n = 5)	(n = 2)			
LPD >5 mm	3	2	1.1	0.812	0.4 to 3.0
LPW >5 mm	4	0	1.5	0.160	0.9 to 2.6
Medial plateau parameter[B] ○	(n = 3)	(n = 2)			
MPD >3 mm	1	0	2.3	0.574	0.1 to 38.1
MPW >3 mm	2	1	1.3	0.725	0.3 to 6.6

○ = value presented as number of cases having that condition
LPD = lateral plateau depression; LPW = lateral plateau widening; MPD = medial plateau depression; MPW = medial plateau widening
[B] = calculated only cases with bicondylar fracture (Schatzker V&VI)

Table 5. Difference in radiographic parameters between medial plateau fracture patients with and without medial meniscus injury (n = 8)

Radiographic parameters	Medial meniscus injury	No medial meniscus injury	*p*-value
Lateral plateau parameters [B] (mm) ■	(n = 2)	(n = 3)	
LPD	5.86	2.67	0.450
LPW	6.86	1.32	0.011*
Medial plateau parameters (mm) ■	(n = 4)	(n = 4)	
MPD	3.38	1.94	0.181
MPW	3.67	1.82	0.135

■ = value presented as mean
LPD = lateral plateau depression; LPW = lateral plateau widening; MPD = medial plateau depression; MPW = medial plateau widening
[B] = calculated only cases with bicondylar fracture (Schatzker V&VI); * = statistically significant (*p*-value <0.05)

Table 6. Relative risk of medial meniscus injury using radiographic factors and cut-off value in the patients having medial plateau fracture (n = 8)

Radiographic parameters injury	Medial Meniscus Meniscus injury	No medial risk	Relative	*p*-value	95%CI
Lateral plateau parameter[B] ⭘	(n = 2)	(n = 3)			
LPD >5 mm	1	1	1.5	0.707	0.2 to 12.5
LPW >5 mm	2	0	6.7	0.159	0.5 to 93.5
Medial plateau parameter ⭘	(n = 4)	(n = 4)			
MPD >3 mm	1	0	2.0	0.488	0.3 to 14.2
MPW >3 mm	4	1	4.0	0.109	0.7 to 21.8

⭘ = value presented as number of cases having that condition
LPD = lateral plateau depression; LPW = lateral plateau widening; MPD = medial plateau depression; MPW = medial plateau widening
[B] = calculated only cases with bicondylar fracture (Schatzker V&VI)

of this study are consistent with the previous studies comparing plain radiographs and MRI images. The use of the arthroscopic-assisted technique should be encouraged as it can help the surgeon make a more accurate diagnosis and can help in performing meniscal debridement or repair. However, further long-term prospective studies are needed.

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What is already known in this topic?

Association between tibial plateau depression, plateau widening and meniscus injury have been reported in previous studies. Those studies found that greater the depression and greater the displacement of fragments were associated with greater likelihood of a meniscus injury. Although most diagnoses of meniscus injury are done using MRI, accuracy of MRI in identifying associated ligament injury is decreased in cases involving acute knee trauma.

What this study adds?

Previous studies using MRI associated meniscus injury with fracture displacement (LPW, and LPD). In contrast, this study diagnosed meniscal injury based on arthroscopic findings. Arthroscopy is the gold standard for diagnosis of meniscus injury. This study found a statistically significant association between LPW and both the medial and the lateral meniscus injuries. The results of the present study encourage the use of CT imaging to predict meniscal injury and to allow for better preoperative planning in cases of acute tibial plateau fracture.

Potential conflicts of interest

The authors declare no conflict of interest.

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