What is the Radiographic Factor Associated with Meniscus injury in Tibial Plateau Factures? Multicenter Retrospective (TRON) study

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Abstract

Purpose

Tibial plateau fracture (TPF) is a complex intra-articular injury involving comminution and depression of the joint, which can be accompanied by meniscal tears. The aims of this study were 1) to demonstrate the rate at which surgical treatment for lateral meniscal injury and 2) to clarify the explanatory radiographic factors associated with meniscal injury in patients with TPF.

Methods

We extracted the patients who received surgical treatment for TPF from our multicenter database (named TRON) included from 2011 to 2020. We analyzed 79 patients who were received surgical treatment for TPF with Schatzker type II and III and evaluation for meniscal injury on arthroscopy. We investigated the rate at which surgical treatment of the lateral meniscus was required in patients with TPF and the explanatory radiographic factors associated with meniscal injury. Radiographs and CT scans were evaluated to measure the following parameters: tibial plateau slope, distance from lateral edge of the articular surface to fracture line (DLE), articular step, and width of articular bone fragment (WDT). Meniscus tears were classified according to whether surgery was necessary. The results were analyzed by multivariate Logistic analyses.

Results

We showed that 27.7% (22/79) of cases of TPF with Schatzker type II and III had lateral meniscal injury that required repair. WDT ≥10 mm (odds ratio 10.9; p=0.005) and DLE ≥5 mm (odds ratio 5.7; p=0.05) were independent explanatory factors for meniscal injury with TPF.

Conclusion

Bone fragment size and the location of fracture line on radiographs in patients with TPF are associated with meniscus injuries requiring surgery.

Keywords

Tibial plateau fracture, Lateral meniscal injury, Distance from lateral edge of the articular surface to fracture line, Width of articular bone fragment

Statements and Declarations

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

Author contributions

KN: Data collection and assessment, Study design, Writing the paper. YT: Manuscript preparation, Study and Conception design. TS: Conception design. KT: Manuscript preparation, Study design. KS and YS: Data collection and assessment, Manuscript preparation. SI: Conception design, Guarantor

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Ethics approval: This study also received institutional ethical approval (reference number 2020-564). The registry also received ethical approval from all participating institutions. Informed consent: All eligible patients were registered using an opt-out consent process. Patients were provided with a letter and a brochure informing them that they had been registered, the purpose of the registration, and the procedure to remove themselves from the registry.

Declarations of interest: none

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Introduction

Tibial plateau fracture is a complex intra-articular injury involving comminution and depression of the joint, which can be accompanied by meniscal tears. Previous studies that have examined tibial plateau fracture using magnetic resonance imaging (MRI) or arthroscopic examination have shown that the incidence of meniscal tear ranges from 21% to 91% [1–4].

Meniscus injuries with vertical tear in vascularized repair are a highly important issue because of its high success rate in terms of recovery time, the functional prognosis, and cartilage protection [5]. When we treat a tibial plateau fracture, we must assess whether there is a meniscal injury that requires additional treatment [7, 8]. Several studies have evaluated meniscal injury using plain radiographs or computed tomography (CT). They reported that lateral meniscal injury with tibial plateau fracture is associated with fracture type, articular step off, and plateau slope [9–13]. However, these reports did not evaluate the degree of meniscus damage that necessitated additional surgery, including meniscus repair.

The present study aimed to demonstrate the rate at which surgical treatment of the lateral meniscus was required in patients with tibial plateau injury, and to clarify the explanatory radiographic factors associated with meniscal injury.

Patients and Methods

This multicenter retrospective study was approved by the ethics commission of 13 hospitals. All patients provided their informed consent for participation in the present study. The hospitals of our university's the Trauma Research Group (TRON) have registered cases of orthopedic trauma surgery in the TRON database annually since 2011. All hospitals associated with the Department of Orthopedic Surgery of our university hospitals participated in maintaining the database. Orthopedic surgeons performed all surgeries at these 13 hospitals in central Japan. Our database includes patient background information, such as sex, age, body mass index (BMI), mechanism of injury, Charlson comorbidity index (CCI), radiography and CT. We collected cases of surgically treated tibial plateau fracture from this database. This information was entered by the clerical assistants of each facility based on the information from the medical records written by the physicians [15].

Patients

Four hundred thirty patients received surgical treatment for tibial plateau fractures. The following inclusion criteria were applied. (1) The patient underwent preoperative radiography and CT. (2) The patient showed Schazker type Ⅱ and Ⅲ fracture (all fractures were radiographically classified according to the Schatzker classification) [1]. The Schatzker classification divides tibial plateau fractures into six types: split fracture of the lateral plateau without depression (I), split depression fracture of the lateral plateau (II), pure depression fracture of the lateral or central plateau (III), medial plateau fracture (IV), bicondylar plateau fracture (V) and plateau fracture with meta-diaphyseal discontinuity (VI). Schatzker Ⅳ, Ⅴ and Ⅵ reflect a highly unstable and poor soft tissue condition, and arthroscopy is difficult to perform in these cases. (3) The patient underwent arthroscopy along with fracture surgery. (4) The patient received open reduction and internal fixation using plates or cannulated cancellous screws (CCSs). (5) The patient who was followed for one year or longer after surgery.

The following exclusion criteria were applied: (1) patients no available preoperative radiography or CT; (2) patients with a history of postoperative infection; (3) patients who could not perform weight bearing even after undergoing surgery due to traumatic spine or brain injury; (4) patients who underwent amputation due to a severe crushing injury; (5) patients <18 years of age; (6) patients who had a history of previously known knee pain or dysfunction of knee (meniscus, ACL or PCL injury); (7) patients with multiple fracture (Fig. 1) [16].

Radiographic measurements

Anteroposterior and lateral knee radiographs and CT were obtained at the first visit in all cases. Knee radiographs were obtained immediately when the patient visited the outpatient clinic or emergency room. If the physician recognized a fracture on the plain radiograph, the physician could order a CT scan on the same day to evaluate the fracture in greater detail.

MDCT was performed using a 64-row (Brilliance 64, Philips Healthcare, Best, the Netherlands) or 256-row MDCT scanner system (iCT 256, Philips Healthcare, Best, The Netherlands) and 64 mm90.625 mm collimation. The tube rotation time was set to 0.75 s and the pitch was kept constant at 0.6. Multiplanar reformations were calculated in the coronal and sagittal planes with a slice thickness of 3 mm.

Radiographs were evaluated to measure the following parameters. A horizontal line was drawn perpendicular to the anterior tibial cortex (Fig. 2a). A third line was drawn along the tibial plateau. The tibial plateau slope formed by the horizontal perpendicular line and the proximal tibial margin represented the slope angle [17]. The distance from the lateral edge of the articular surface to the fracture line (DLE) was calculated in millimeters from the distance from the lateral edge to the medial edge of the depressed tibia bone fragment (Fig. 2b). As for the distance from lateral edge of the articular surface to the fracture line, the width of the articular surface of the lateral bone fragment was calculated in millimeters in Schatzker type Ⅱ. The distance from the lateral edge of the articular surface to the fracture line was calculated in Schatzker type Ⅲ [17]. Articular step off was calculated as the distance between the line of the articular surface and the line of tangential to the lowest point of articular depression (Fig. 2c). Finally, The width of articular bone fragment (WDT) was calculated from the lateral to the medial edge of the depressed articular bone fragment (Fig. 2d).

In general, the indication for surgery was a depressed fragment of ≥10 mm. We divided the WDT into ≥10 mm and <10 mm. The middle of the lateral meniscus have boundary of structural difference and weight bearing. In the tibial plateau, 5 mm from the lateral edge of the articular surface is equivalent. We divided the distance from DLE into ≥5 mm and <5 mm.

All measurements were made by two doctors, and the mean values were used for the final analysis. Two orthopedic trauma surgeons (KN, KS) reviewed 100 randomly selected radiographs. The mean of the two values was adapted when the values of two measurements were not same. The Kappa coefficient (categorical data) and intraclass correlation coefficient (ICC) for inter-observer reliability for fracture type were 0.88 and 0.84, respectively.

Surgical management

The indications for surgical treatment were intra-articular displacement of ≥2 mm, metaphyseal-diaphyseal translation of >1 cm, angular deformity of >10° in the coronal (varus-valgus) or sagittal plane, open fracture, or associated compartment syndrome. The surgeons performed the operations under general anesthesia or lumbar anesthesia. Depending on the fracture type and the soft-tissue condition, surgeons selected an anterolateral approach, anteromedial approach, posteromedial approach, or posterior approach. The surgeons performed articular tibial plateau fracture restoration under an arthroscopic view. The surgeons treated the articular depression of the fractures by elevating the fragments from below with a bone impactor introduced through the fracture or a small cortical window. The surgeons filled the remaining bony defect with artificial bone grafts or autologous cancellous bone grafts from the ipsilateral iliac crest. Then unilateral, dual, or triple plates were applied, depending on the fracture type and soft tissue condition. The following plates were utilized: Stryker AxSOS 3 Ti Proximal Tibia plate (Stryker, Kalamazoo, MI), DePuy Synthes 3.5mm Variable Angle Locking Compression Plate (VA-LCP) Proximal Tibia Plate (DePuy Synthes, West Chester, PA), DePuy Synthes 3.5mm LCP Proximal Tibia Plate in the Small Fragment LCP system (DePuy Synthes, West Chester, PA), and the Zimmer Biomet A.L.P.S. Proximal Tibia Plate (Biomet Orthopedics, Warsaw, IN).

Arthroscopic measurements and meniscus suture

The meniscus examination and study data were obtained by an arthroscopic examination under anesthesia through arthroscopic recordings. Operative arthroscopy for the knee was performed with gravity only, without the use of a pump, in order to avoid fluid extravasation and the onset of compartment syndrome. Tibial plateau fractures and associated meniscus soft tissue injuries were assessed by arthroscopy so that optimal treatment could be planned. Patients with meniscal injury were treated after the performance of fracture fixation, according to the type of soft tissue injury that was observed.

Meniscal tears are often classified as below. We classified meniscal tears as vertical longitudinal, vertical radial, horizontal or oblique. Partial meniscectomy is indicated for flap tears, radial tears in the inner area [19, 20]. Meniscal sutures are indicated for acute vertical longitudinal lesions and vertical radial lesions [21–23]. We used 2-0 ETHIBOND (ETHICON), FAST FIX (SMITH ＆ NEPHEW) or 4-0 nylon (Alfresa Pharma) to suture the meniscus lesion using outside-in suture, inside-out suture, all-inside suture, and open suture.

Statistical analysis

We performed univariate and multivariate analyses to identify the factors associated with lateral meniscal injury. The threshold for statistical significance was set at $P < 0.05$. All statistical analyses were performed using the EZR software program (version 1.40, Saitama Medical Center, Jichi Medical University) [24].

Results

The patient demographics and arthroscopy findings are shown in Table 1. A total of 79 patients with Schatzker type 2 and 3 acute tibial plateau fractures underwent open reduction, internal fixation, and arthroscopy between January 2011 and December 2020 (male, n=46; female, n=33). The mean follow-up period was 28.0 (range 0–73) months. The average patient age was 55.5 ± 16.3 (range, 20–92) years.

Twenty-four of the 79 patients (30.3%) had lateral meniscal injury. Of the 24 patients with lateral meniscal injury, 22 patients underwent meniscal suture. Partial meniscectomy was performed for two patients with flap tears and one patient with radial tears in the inner area.

The results of the univariate analyses are shown in Table 2.

A WDT of ≥10 mm was associated with a difference in lateral meniscal injury. Twenty-one of the 55 patients with a WDT of ≥10 mm had lateral meniscal tears on arthroscopy (38.2%, p=0.031). Of the 24 patients with WDT values below this value, 2 (8.3%) had lateral meniscus damage. Regarding DLE, the level of displacement that was associated with a difference in lateral meniscal injury was 5mm. Twenty (32% p=0.039) of the 62 patients with a DLE of ≥5 mm had a lateral meniscal injury on arthroscopy. Of the 15 patients with DLE values below these levels, 2 (13%) had lateral meniscus damage. The incidence of lateral meniscal injury in patients with a WDT of ≥10 mm was significantly higher than that in patients with a WDT of <10 mm (22/56 [33%] vs. 2/24 [8.3%]). The incidence of lateral meniscal injury in patients with a DLE of ≥5 mm was significantly greater than that in patients with a DLE of <5 mm (2/24 [31.2%] vs. (2/15 [13.3%]).

WDT ≥10 mm and DLE ≥5 mm were identified as independent explanatory factors for meniscal injury in patients with tibial plateau fracture. Sex, age, BMI, fracture type, articular step off and plateau slope were not significantly associated with soft tissue injuries in the present study.

Discussion

We showed that 27.7% (22/79) of patients with Schatzker type Ⅱ or Ⅲ tibial plateau injury had lateral meniscal injury that required surgical repair, and identified WDT ≥10 mm and DLE ≥5 mm as independent explanatory factors for meniscal injury with tibial plateau fracture.

Some previous studies evaluating tibial plateau fractures revealed that the incidence of injury to the lateral meniscus was 50-74% [25–28]. The incidence in the present study, as determined by arthroscopic examination, was lower than this. We thought that previous studies counted signal changes in the meniscus, even though there were no visible meniscal injury, made the difference.

We also showed that the presence of WDT ≥10 mm (odds ratio, 10.9) and DLE ≥5 mm (odds ratio, 5.7) was associated with a higher incidence of lateral meniscal injury. Based on our analysis, WDT ≥10 mm is a risk factor of meniscal injury.

WDT refers to the size of the compression of the bone fragment of the tibial plateau fracture. We showed that greater depressed the bone fragment was associated with increased meniscal injury. WDT ≥10 mm was not only an indication for the surgical treatment of fracture, it was also associated with meniscal injury. Partial meniscectomy was performed for one patient with flap tear and one patient with discoid tear. The average width of the lateral plateau is 33 mm, while the average width of the lateral meniscus is approximately 10 mm [29]. Thus, the width of the lateral meniscus occupies approximately one-third of the width of the lateral tibial plateau. We thought that an expanded range of the impact on the tibial plateau, reflected by the WDT, would increase the lateral meniscal injury.

The meniscus is composed of water and collagen. In the lateral zone, collagen fibers are oriented circumferentially, parallel to the peripheral border. In the medial zone, medial zone collagen fibers are oriented vertically. Weight bearing on the lateral meniscal is higher on the medial half than on the lateral half [30]. There is a boundary with a structural difference at approximately 5 mm. We thought that this structural difference could lead to lateral meniscal tear.

Articular step off is not associated with lateral meniscal injury. A previous study showed a significant correlation between increased tibial plateau fracture depression and the incidence of meniscus lateralis tears [31]. However, another study showed no correlation between the degree of articular depression and meniscal injury on arthroscopic examination [32]. In our arthroscopic study, we also found that nondisplaced tibial plateau fractures can be associated with severe meniscal injuries and that clearly displaced tibial plateau fractures can have normal menisci. This may be why there was no correlation between the degree of articular depression and meniscal injury.

The tibial plateau slope was not associated with lateral meniscal injury. To our knowledge, no similar studies have investigated this association. An increase in the tibial slope, especially on the lateral tibial plateau, seems to increase the risk of meniscal tear [33]. Usually, half of the impact is transmitted to the meniscus. We hypothesize that when the impact is transmitted to the bone and causes a fracture, the impact on the meniscus is transmitted in a different pattern, which allows the meniscus to escape damage.

Limitations

The study was associated with some limitations. First, this was a retrospective study using a clinical database, and because the subjects were not randomly assigned, the selection bias must be potentially considered. Second, there is no clear definition why they used arthroscopy as an inclusion criterion for the study. Third, the sample size is small because only patients who underwent arthroscopic surgery were included. Although more patients with meniscus injuries could be found using MRI evaluation, MRI is too sensitive and may lead to overmedication.

Conclusion

Due to the limited availability of MRI in some centers, the correlation of lateral WDT and DLE, as measured on plain CT, with lateral meniscal injury may be helpful in planning surgical procedures. When managing patients with Schatzker type II and III fracture, the presence of WDT ≥10 mm and DLE ≥5 mm should raise the suspicion of meniscal injury and indicate the need for MRI or an arthroscopic examination.

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Figure legends

Fig.1: Flow diagram of the participants included in the study.

Fig.2: a: A horizontal line is drawn perpendicular to the anterior tibial cortex. A third line is drawn along the tibial plateau. The tibial plateau slope formed by the horizontal perpendicular line and the proximal tibial margin represents the slope angle. b: Distance from lateral edge of the articular surface to fracture line (DLE) was calculated in millimeters by the distance from the lateral edge to the medial edge of the depressed tibia bone fragment. c: Articular step off was calculated the distance between line of the articular surface and the line tangential to the lowest point of articular depression. d: Width of articular bone fragment (WDT) was calculated from the lateral to the medial edge of the depressed articular bone fragment.

Table 1: Patient demographics

	Lateral meniscal injury		
	No (N=55)	Yes (N=24)	P-value
Sex (%)			1
Male	32 (59.3)	14 (58.3)	
Female	22 (40.7)	10 (41.7)	
Age (SD)	54.2 (16.4)	58.6 (16.3)	0.28
BMI (SD)	24.4 (4.26)	24.5 (4.00)	0.99
Mechanism (%)			0.65
Walking	15 (27.3)	5 (20.8)	
Bicycle	7 (12.7)	5 (29.2)	
Car crash	15 (27.3)	7 (29.3)	
High fall	10 (18.2)	2 (8.3)	
Sports	8 (14.3)	5 (20.8)	
Fracture type (%)			0.099
Schatzker II	38 (69.1)	21 (87.5)	
Schatzker III	17 (30.9)	3 (12.5)	
DLE (%)			0.039
<5mm	13 (23.6)	2 (8.3)	
≥5mm	42 (76.4)	20 (91.7)	
WDT (%)			0.031
<10mm	21 (38.2)	2 (8.3)	
≥10mm	34 (61.8)	22 (91.7)	
Mean articular step off (range)	5.50 (0.00, 27.22)	6.40 (0.00, 21.30)	0.79
Mean plateau slope (range)	12.00 (4.70, 20.10)	14.00 (3.20, 88.10)	0.33

DLE, distance from lateral edge of the articular surface to fracture line,

WDT, width of depressed tibial plateau bone fragment

Table 2: Multivariate analysis of risk factors for lateral meniscal injury.

Variables	Multivariate analysis Odds ratio (95% confidence interval)	P value
Sex		0.82
Male	0.856 (0.224 – 3.27)	
Female	1 (Ref)	
Age	1.02 (0.985– 1.07)	0.22
BMI	0.95 (0.823 – 1.10)	0.48
Mechanism	1.06 (0.682 – 1.65)	0.79
Fracture type		0.18
Schatzker II	0.344 (0.0711 – 1.67)	
Schatzker III	1 (Ref)	
DLE		0.05
<5mm	1 (Ref)	
≥5 mm	5.70 (0.996 – 32.6)	
WDT		0.005
<10 mm	1 (Ref)	
≥10 mm	10.9 (2.00 – 59.80)	
Articular step off	0.973 (0.86 – 1.10)	0.67
Plateau Slope	1.05 (0.929 – 1.18)	0.46

DLE, distance from lateral edge of the articular surface to fracture line;
WDT, width of depressed tibial plateau bone fragment