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컴퓨터 단층촬영 소견을 이용한 근위 경골 골절에 동반된 외측 반월 연골판 손상의 예측

최원철 · 최윤성 · 김고탁

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Prediction of Concomitant Lateral Meniscus Injury with a Tibia Plateau Fracture Based on Computed Tomography Assessment

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Purpose: This study examined whether any fracture pattern shown in computed tomography (CT) scan is associated with the presence of lateral meniscus (LM) injury in a tibia plateau fracture.
Materials and Methods: Fifty-three tibia plateau fractures with both preoperative CT and magnetic resonance imagings (MRI) available were reviewed. The patient demographics, including age, sex, body mass index, and energy level of injury were recorded. The fracture type according to the Schatzker classification, patterns including the lateral plateau depression (LPD), lateral plateau widening (LPW), fracture fragment location, and the number of columns involved were assessed from the CT scans. The presence of a LM injury was determined from the MRI. The differences in the factors between the patients with (Group 1) and without (Group 2) LM injuries were compared and the correlation between the factors and the presence of LM injury was analyzed.
Results: The LM was injured in 23 cases (Group 1, 43.4%) and intact in 30 cases (Group 2, 56.6%). The LPD in Group 1 (average, 8.2 mm; range, 3.0-20.0 mm) and Group 2 (average, 3.8 mm; range, 1.4-12.1 mm) was significantly different (p<0.001). The difference in LPW of Group 1 (average, 6.9 mm; range, 1.2-15.3 mm) and Group 2 (average, 4.8 mm; range, 1.4-9.4 mm) was not significant (p=0.097). The other fracture patterns or demographics were similar between in the two groups. Regression analysis revealed that an increased LPD (p=0.003, odds ratio [OR]=2.12) and LPW (p=0.048, OR=1.23) were significantly related to the presence of a LM tear.
Conclusion: LPD and LPW measured from the CT scans were associated with an increased risk of concomitant LM injury in tibia plateau fractures. If such fracture patterns exist, concomitant LM injury should be considered and an MRI may be beneficial for an accurate diagnosis and effective treatment.

Key Words: Tibia, Lateral meniscus, Tibia plateau fracture, Computed tomography, Magnetic resonance image, Schatzker classification

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Introduction

Tibia plateau fracture is a complex fracture which is often associated with various intra-articular soft tissue injuries requiring surgical treatment. Among them, injury of lateral meniscus (LM) including meniscus tear or meniscocapular separation is known to commonly combined to this fracture.[1,2] Although the effect of primary treatment for concomitant LM injury is not clear yet, untreated LM injury may result in detrimental effect on the treatment outcome of tibia plateau fracture.[3,4] Therefore, preoperative identification of this injury is desirable to establish an appropriate surgical plan.

The computed tomography (CT) has been regarded as a routine modality for tibia plateau fracture diagnosis.[5-8] However, the diagnosis of the meniscus injuries accompanying the tibia plateau fractures with CT can be difficult and inaccurate. On the other hand, it has been reported that magnetic resonance imaging (MRI) is the most useful imaging modality in diagnosing combined meniscus injuries in the tibia plateau fracture.[9-12] In addition, MRI may be helpful to make more accurate diagnosis and establish the treatment plan.[2,13-15] However, MRI is not always readily available in many primary care centers or emergency settings. Moreover, routine use of MRI in every single tibial plateau fracture may not be cost-effective. Therefore, it would be helpful if combined soft tissue injury is predictable with certain CT findings. This study focused on the LM injury that commonly combines to tibia plateau fracture and aimed to determine if any fracture pattern shown in CT scan is associated with the presence of LM tear in tibia plateau fracture.

Materials and Methods

Among 91 tibia plateau fractures that presented between September 2014 and April 2018, 76 tibia plateau fractures with both preoperative CT and MRI available were reviewed retrospectively. Among them, 5 isolated medial tibia plateau fractures, 10 patients with age over 60 years and 8 cases with previous history of meniscectomy were excluded. Therefore, 53 cases with fracture involving the lateral column of the tibial plateau were included for the study. The average interval between CT and MRI images was less than one day (mean, 0.7±1.3 days). The study protocol was approved by Institutional Review Board of CHA Bundang Medical Center (no. 2017-12-013).

Patient demographics including age, sex, body mass index, and energy level of injury were recorded. Fractures occurred due to fall from standing height were defined as a low energy injury and traffic accidents or sports injuries were considered as a high energy injury.[16,17] From preoperative MRI findings, LM tear or lateral meniscocapsular separation were considered as the presence of LM injury. Meniscal tear was defined as high signal intensity reaching the articular surface or contour abnormality and meniscocapsular separation was defined as the presence of a perimeniscal abnormal signal due to disruption of the meniscofemoral and/or meniscotibial collateral ligament fibers with central meniscal displacement.[1,10] Since it was difficult to clearly distinguish between acute and chronic meniscal injury, we excluded patients age over 60 years who possibly have preexisted meniscal lesion. From preoperative CT scans, representative coronal section was chosen and the vertical depth of lateral plateau depression (LPD) and horizontal direction lateral plateau widening (LPW) were measured (Fig. 1). The fracture types were assessed using Schatzker classification.[18] In addition, the location of fracture fragment (lateral, medial, or posterior column) was determined according to the updated three-column concept for tibia plateau fracture[19] and the number of involved columns (uni- or multi-column) were assessed. All the radiographic measurements were done by two orthopedic surgeons residents (co-authors of the study) using Picture Archiving Communication System (Marosis; Infinity, Seoul, Korea) and the mean values were used for the final analysis.

Patients were divided into two groups according to the presence of LM injury; with (Group 1) and without (Group 2) LM injuries; and inter-group differences were compared. Also, the correlation between the fracture pattern and the presence of LM injury was analyzed.

Statistical analyses were performed using SPSS ver. 16.0

Fig. 1. Lateral plateau depression (LPD) and lateral plateau widening (LPW) measurements from a coronal reformatted computed tomography imaging. LPD was defined as the perpendicular distance 'A' between a tangential line to the neutral plane of the articular surface and a tangential line to the lowest point of depression. LPW was defined as the perpendicular distance 'B' between a tangential line to the lateral femoral epicondyle and a parallel line drawn from the most lateral part of the lateral tibial plateau.

for Windows (SPSS Inc., Chicago, IL, USA), with p<0.05 considered statistically significant. The inter-observer reliabilities of measurements were analyzed by intra-class correlation coefficient (ICC). A two-tailed independent t-test was used to compare the measured continuous variables between the two groups. Logistic regression analysis including all the covariates was carried out to adjust the possible cofounding factors and determine the factors correlated to concomitant LM injury. Receiver operating characteristic (ROC) analysis was performed to determine the possible cutoff value for LPD and LPW.

Results

LM was injured in 23 cases (Group 1, 43.4%) and intact in 30 cases (Group 2, 56.6%). Among Group 1, LM tear was found in 10 cases (43.5%) and lateral meniscocapsular separation was found in 13 cases (56.5%). Arthroscopic surgeries were done for 10 cases (partial meniscectomies for 5 cases and inside-out repairs for 5 cases) and open meniscal repairs during the fracture reduction were carried out for 8 cases. For other 5 cases, no specific treatment was performed. Demographics and injury mechanisms were similar between the groups. Schatzker type V fracture was the most common (n=9, 39.1%) in Group 1 and Schatzker type II fracture was the most common (n=13, 43.3%) in Group 2. The distribution of fracture types according to Schatzker classification showed no significant difference between the groups (Table 1). Six cases (26.1%) were uni-columnar fracture in Group 1 while 9 cases (30.0%) were uni-columnar fracture in Group 2, and the difference was not significant (p=0.762). Besides the lateral column fracture, additional fracture involved medial (n=12) and/or posterior column (n=18) were found in Group 1, while Group 2 had 13 medial and/or 18 posterior column fractures, respectively. The LPD was significantly different between Group 1 (average, 8.2 mm; range, 3-20 mm) and Group 2 (average, 3.8 mm; range, 1.4-12.1 mm) (p<0.001) (Fig. 2). The difference in LPW of Group 1 (average, 6.9 mm; range, 1.2-15.3 mm) and Group 2 (average, 4.8 mm; range, 1.4-9.0 mm) was not significant (p=0.097). The inter-observer reliabilities were excellent for both LPD and LPW measurements (ICC=0.92 and 0.90, respectively). The logistic regression analysis revealed that increased LPD (p=0.003, odds ratio [OR]=2.12, 95% confidence interval [CI]=1.68-2.83) and LPW (p=0.048, OR=1.23, 95% CI=0.48-2.63) were significantly related to the presence of LM injury. However, other factors were not related to the LM injury (Table 2). The ROC analysis indicated that the most appropriate cutoff value for LPD was 5 mm, which provided a sensitivity of 87% and a specificity of 80% for having combined LM injury. The area under the curve (AUC) was 0.87. On the other hand, a clear cutoff value for LPW that showed a combination of high sensitivity and specificity could not be determined. The sensitivity was only 57% if the cutoff value for LPW was determined as 7 mm and the AUC was 0.69.

Table 1. Demographic and Clinical Characteristics of the Patients

Characteristic	Group 1 (Injured LM)	Group 2 (Intact LM)	p-value
Subject	23	30	
Demographic			
Age (yr)	46.7±11.3 (29-60)	42.1±10.1 (34-60)	0.874
Sex (%)			0.753
Male	18 (78.3)	24 (80.0)	
Female	5 (21.7)	6 (20.0)	
Body mass index (kg/m^2)	25.5±3.0 (19.3-31.5)	23.9±2.9 (18.1-29.4)	0.889
Clinical			
Energy level of injury			0.392
Low	9 (39.1)	9 (30.0)	
High	14 (60.9)	21 (70.0)	
Schatzker classification			0.286
Type I	0	1 (3.3)	
Type II	8 (34.8)	13 (43.3)	
Type III	3 (13.0)	3 (10.0)	
Type V	9 (39.1)	8 (26.7)	
Type VI	3 (13.0)	5 (16.7)	
LPD (mm)	8.2±9.7 (3.0-20.0)	3.8±6.6 (1.4-12.1)	<0.001
LPW (mm)	6.9±9.4 (1.2-15.3)	4.8±5.1 (1.4-9.0)	0.097

Values are presented as number only, mean±standard deviation, or number (%). LM: lateral meniscus, LPD: lateral plateau depression, LPW: lateral plateau widening.

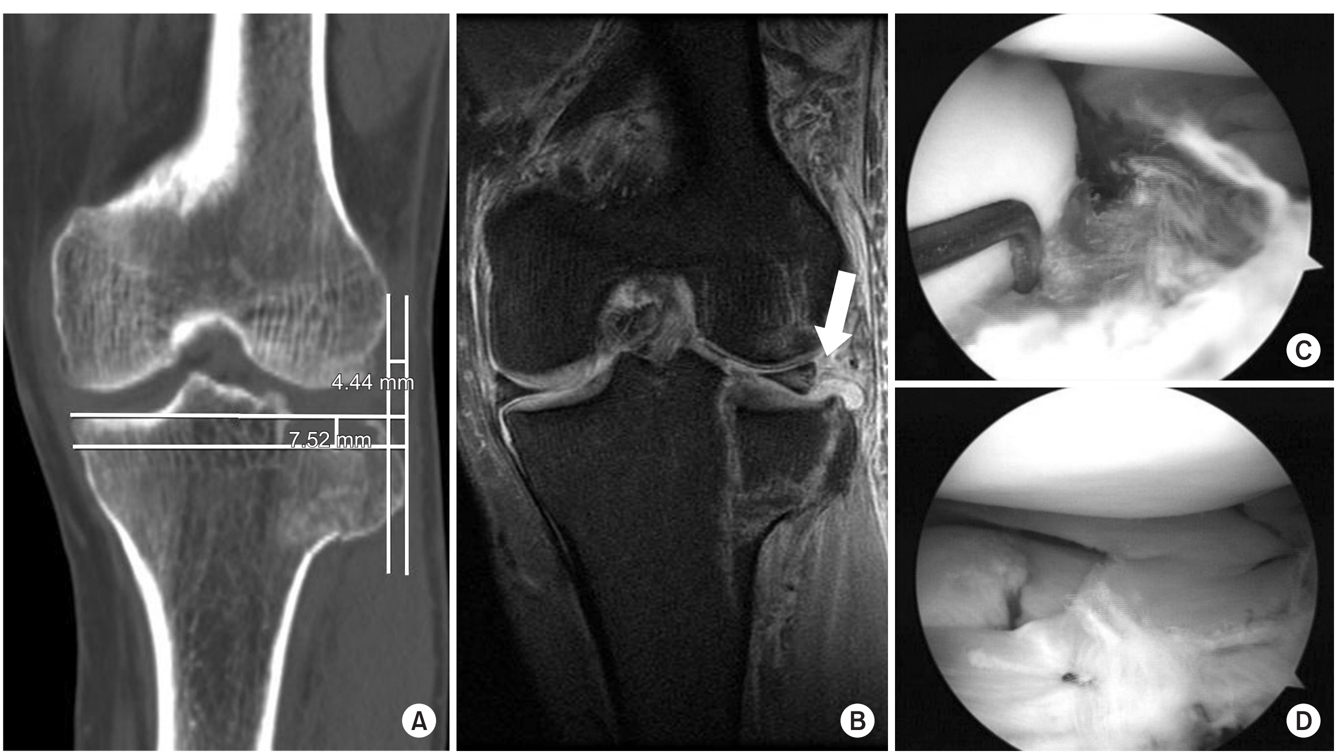

Fig. 2. A 52-year-old man presented with a Schatzker type II tibia plateau fracture of the left knee. (A) Computed tomography coronal reformatted imaging demonstrated 7.52 mm of lateral plateau depression and 4.44 mm of lateral plateau widening. (B) Meniscocapsular separation and central migration of lateral meniscus (white arrow) was shown in the coronal magnetic resonance imaging. (C) Lateral meniscus injury was confirmed during arthroscopy. (D) The lateral meniscus was repaired to the capsule using the inside-out repair technique.

Table 2. Result of Linear Regression Analysis

Covariate	Correlation coefficient	p-value	Odds ratio
Age	−0.046	0.850	0.99
Sex (male=0, female=1)	−0.113	0.732	0.97
Body mass index	0.122	0.837	1.06
Energy level of injury (low=0, high=1)	0.121	0.184	1.14
Schatzker type	1.262	0.834	0.71
Column involvement (uni=0, multi=1)	0.082	0.752	1.18
Lateral plateau depression	0.250	0.003*	2.12
Lateral plateau widening	0.074	0.048*	1.23

*p<0.05.

Discussion

This study demonstrated that the degree of lateral tibia plateau depression measured from CT scan is associated with higher chance of combined LM injuries in tibia plateau fracture. Also, the degree of lateral tibia plateau widening was weakly but significantly associated to the presence of LM injury. Although it was not significant in univariate analysis, lateral tibia plateau widening was significant in multivariate analysis, which may be the result of unbalanced sample size, group variation or the presence of interaction.[20] Other demographic factors, energy level of injury, or fracture classification were not associated with the combined LM injury.

Several studies examined the association between the degree of fracture depression or widening and the combined LM injury in tibia plateau fracture. Gardner et al.[21] first reported that in Schatzker type II tibia plateau fractures with both at least 5 mm of widening and 6 mm of depression, 83% had lateral meniscal lesions on MRI. More recently, Durakbasa et al.[22] retrospectively reviewed 20 cases of Schatzker type II tibia plateau fractures and showed that the degree of LPD and widening were significantly related to the LM injury confirmed during operation. However, these studies measured the extent of articular depression or widening from plain radiographs. Plain radiographic measurements may be not accurate enough since adequate, reproducible posture for radiograph is often difficult in acutely injured situation and normal posterior tibia slope exists.[14,19,21] The amount of articular depression was measured from CT images of 85 lateral tibia plateau fractures in a study by Ringus et al.[23] They reported that patients with 10 mm or more of LPD had an eightfold increase in risk of having a combined LM tear compared to those with less than 10 mm of LPD. Similarly, Spiro et al.[24] retrospectively reviewed CT scans of 54 patients with acute tibial plateau fracture and described that enhancement of articular depression by 1.0 mm significantly increases the risk of LM tears up to 15.0%. Meanwhile, Wang et al.[14] examined the impact of LPD and LPW on combined LM tear from CT scans of 54 tibia plateau fractures and found out that LPD and LPW of injured meniscus cases were higher than those of non-injured, but the differences were not statistically significant. Our study results were generally concordant with previous studies that the amount of LPD was significantly correlated to the increased likelihood of the presence of concomitant LM injury. With a cutoff value of 5 mm or more for LPD, the sensitivity was 87% for sustaining a LM tear. It is recommended to consider MRI examination if this finding is present on preoperative CT. Although it was only shown in regression analysis, the amount of LPW was also correlated to the LM injury.

It may be difficult to draw a clear conclusion since there are variations between the studies in the number of subjects, used diagnostic modalities, the type of fractures involved, and the method for diagnosing LM injury. However, at least, the result of our study suggests that the amount of plateau depression or widening found on preoperative CT is a potential predictor of combined LM injury in acute tibial plateau fracture.

It is possible to infer that the fractures due to higher energy injury may result in the more severe articular damage, so more of LM injury would be combined as a result. However, the energy level of injury was not associated with the LM injury in the current study. Previous studies also failed to find out a significant correlation between the energy level of injury and combined LM injury.[10,22]

High incidences of combined LM injury have been reported in Schatzker type II fracture.[3,21,22] However, there was no study that showed a significant correlation between the Schatzker classification and LM injury,[12,14,23,24] and our result was also similar. In addition, the location or number of fractured column based on three-column concept was not significant, either. According to the results so far, the current classification system for tibia plateau fractures may be insufficient to estimate the probability of combined LM injuries in acute tibial plateau fracture, although a larger study with more numbers of subjects corresponding to each type is needed.

A study has reported that age (48 years or younger) was a factor that associated to the increased likelihood of LM injury in tibia plateau fracture.[23] Although no correlation was found between the age and the incidence of combined LM injury in our study, it should be noted that patients of more than 60 years old were excluded from the analysis. It has been reported that the prevalence of meniscus tear increases with age, reaching 50% in 70-year-old,[25] and up to 60% of degenerative meniscus tear can be asymptomatic.[26] Thus, we intentionally excluded patients over 60-year-old to minimize the effect of possible preexisted meniscal pathology. In addition, it was common not to take preoperative MRI if the patient already had advanced arthritic change on injured knee, and those patients were screened out.

This study had some limitations. First, it was a retrospective study without a priori sample size analysis, so the result may be underpowered. Second, the presence of LM tear was determined from MRI without operative or arthroscopic confirmation. Finally, although the patients with histories of previous meniscectomy were excluded, complete verification for pre-existed meniscal pathology was impossible.

Conclusion

The amount of LPD measured from preoperative CT scan was mainly associated with an increased risk of concomitant LM injury with tibia plateau fractures. Also, widened lateral plateau was weakly related to the combined LM injury. Finding such fracture patterns with preoperative CT scan may be beneficial for predicting the possibility of concomitant LM injury and establishing a proper treatment strategy for tibia plateau fracture.

요 약

목적: 경골 고평부 골절에 동반된 외측 반월 연골판 손상을 예측하는 컴퓨터 단층촬영 골절 양상을 분석하였다.

대상 및 방법: 수술 전 컴퓨터 단층촬영과 자기공명영상을 시행한 53예의 경골 고평부 골절 대상으로, 컴퓨터 단층촬영에서 Schatzker 분류, 외측 경골 함몰, 확장 정도, 골절 위치, 단일/다수 고평부 column 골절 여부를 확인하였다. 자기공명영상 진단을 통해 외측 반월 연골판 손상군과 비손상군으로 나누어 두 군 간의 차이를 분석하였다.

결과: 손상군에 23예, 비손상군에 30예가 포함되었다. 외측 경골 함몰 정도는 손상군(평균 8.2 mm)과 비손상군(평균 3.8 mm) 간에 유의한 차이가 있었다($p<0.001$). 외측 경골 확장 정도는 손상군(평균 6.9 mm)과 비손상군(평균 4.8 mm) 간에 유의한 차이를 보이지 않았다($p=0.097$). 그 외의 인구학적 및 방사선적 요인들은 양 군 간의 차이를 보이지 않았다. 회귀 분석 결과, 외측 경골 함몰($p=0.003$, odds ratio [OR]=2.12) 및 확장($p=0.048$, OR=1.23)이 외측 반월 연골판 손상 동반과 유의한 상관 관계를 나타냈다.

결론: 경골 고평부 골절 컴퓨터 단층촬영 소견상 외측 경골의 함몰, 확장 정도가 클수록 외측 반월 연골판 손상 동반 가능성이 높았다.

색인 단어: 경골, 외측 반월 연골판, 경골 고평부 골절, 컴퓨터 단층촬영, 자기공명영상, Schatzker 분류

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