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Soft tissue injury prediction using joint depression in computed tomography in AO 41B lateral tibial plateau fractures

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Tibial plateau fractures are usually associated with soft tissue injury. This study aimed to use the extent of joint depression and lateral widening in computed tomography (CT) to predict the soft tissue injury accompanying fractures.The study included 23 patients with type Arbeitsgemeinschaft für Osteosynthesefragen-classified 41B fractures. Demographics, mechanism of injury, age, gender, and injury sites were assessed. Post-traumatic radiography, magnetic resonance imaging (MRI), and CT were obtained. MRI evaluated the meniscal, cruciate, and collateral ligament injuries, and CT measured the extent of joint depression and lateral widening in millimeters using digital imaging software. The relationship between joint depression, lateral widening, and soft tissue injuries was statistically analyzed. Of the 23 patients, 17 (74%) were males and 6 (26%) were females. Lateral meniscus injuries increased and the risk of bucket handle lateral meniscus tears increased as the CT joint depression exceeded 12 mm ($p < 0.05$). Joint depression of <5.9 mm was associated with medial meniscus injury ($p < 0.05$). The mean distribution examination of all soft tissue injuries and joint depression revealed no statistically significant difference between the groups ($p > 0.05$). Increased joint depression in lateral tibial plateau fractures increases the risk of lateral meniscus bucket handle tear, and decreased joint depression increases the risk of medial meniscus injury. Accordingly implementing the treatment plan and patient management will improve the clinical outcomes.

Keywords : Tibial plateau fracture, computed tomography, meniscus, trauma.

INTRODUCTION

Tibial plateau fractures are difficult to treat because of their frequent accompanying cartilage and ligament injuries. Fracture treatment mainly aimed to provide joint surface anatomical harmony and mechanical restoration[1]. These are sometimes provided in the treatment of tibial plateau fractures, but disappointing clinical results can occur. Pain and loss of movement and instability are among the clinical problems associated with these injuries[2,3]. Some studies examined the incidence of soft tissue injuries associated with displaced and undisplaced tibial plateau fractures[4,5]. Due to the nature of this injury and the energy required to generate the fracture, the incidence of soft tissue injuries, such as meniscus and ligament injuries, range from 47% to 99%[4,6]. Anteroposterior and lateral radiographs and computed tomography (CT) are mainly used in intra-articular fracture evaluation. These examinations show the type of bone injury, the amount of displacement, and their extent, but they do not provide sufficient information about soft tissue injury. Magnetic resonance imaging (MRI) is an examination that shows soft tissues very well, but it is not preferred in routine orthopedic trauma practice. Lateral plateau fractures (Schatzker type 1,2,3/ AO 41B) are the most common plateau fracture subtypes due to the lateral plateau being more proximal than the medial and its convex shape. Therefore, orthopedic surgeons more often deal with the treatment of these fracture types in daily practice. However, attention was inadequately paid to soft tissue injuries while treating the fracture. Therefore, this study aimed to examine the relationship between joint depression and lateral tibia widening on CT and accompanying ligament and meniscus injuries in lateral tibial plateau fractures.

MATERIALS AND METHODS

Among the 34 patients who underwent surgical treatment for tibial plateau fracture in our clinic

between January 2018 and December 2019, 23 patients who met the criteria were included in this study. Arbeitsgemeinschaft für Osteosynthesefragen (AO) classification was used in fracture assessments, and AO 41B lateral tibial plateau fractures were included in the study. Five patients without preoperative MRI and six patients with fracture types AO 41C and AO 41A were excluded from the study, as well as patients with polytrauma, those who underwent emergency surgery due to open fracture and accompanying vascular injury, and those with other accompanying bone fractures. A data table was created by recording the demographic data, mechanism of injury, age, gender, and affected parties of patients. Anteroposterior and lateral knee x-rays and CT (Revolotion Evo 128 detector General Electric Medical Systems, Milwaukee, WI, USA) were taken on all patients in the emergency department. Knee MRI (1.5 Tesla MRI device General Electric Medical Systems, Milwaukee, WI, USA) was obtained for all patients in an average of 3.2 days preoperatively. All patients were evaluated according to the AO classification by a radiologist with >20 years of experience in musculoskeletal radiological evaluations and an orthopedic trauma specialist with a high surgical volume.

Measurements were made on tomography images by two orthopedic and traumatology specialists who were blinded to the soft tissue injuries of patients. Joint depression and lateral tibia widening were measured in millimeters (Figure 1 a,b,c).

MRI examined the medial and lateral menisci, anterior and posterior cruciate ligaments, and internal and external lateral ligaments for injuries that may require surgical intervention. Anterior and posterior cruciate ligament injuries with total, partial, and eminent injuries were considered significant. The evaluation of medial and lateral collateral ligaments examined the partial and total injuries. The medial and lateral menisci were evaluated as Grade 1: point signal increase; Grade 2: linear signal increase; and Grade 3: signal increase extending to the joint. Additionally, bucket handle meniscus tears were considered Grade 3 injuries. Patients with Grade 3 meniscal injuries were included in our study because they may require surgery.

The data was obtained by comparing the obtained data from CT and soft tissue injuries from MRI were evaluated using the Statistical Package for the Social Sciences (version 21 for Windows 10) and the Mann-Whitney U analysis, PearsonChi-Square, Fisher's

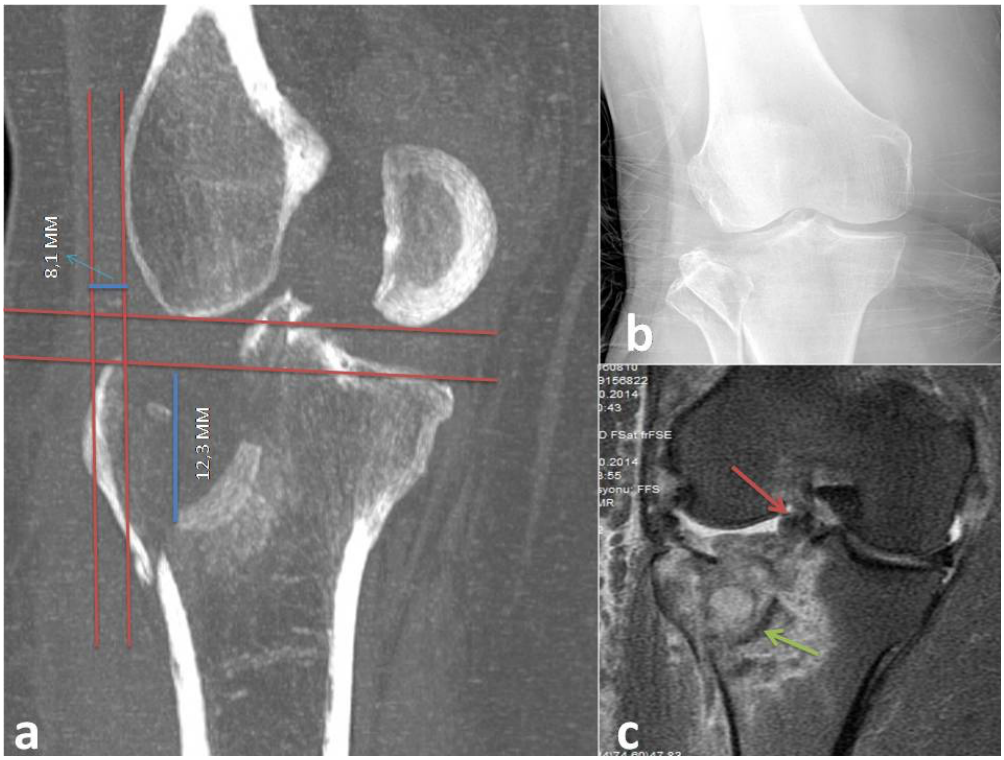

Fig. 1 — a) Measurement of joint depression and lateral widening in tibial plateau fracture on CT. The distance between the tibial joint line drawn parallel to the femoral condylar line and the most distally collapsed joint part indicates joint depression. The distance between the lateral femoral condyle and the lateral tibial plateau indicates joint widening. b) X ray. c) Red arrow indicates lateral meniscus bucket handle tear. Green arrow indicates displaced articular surface on MRI.

Exact test, and receiver operating characteristic analysis.

RESULTS

A total of 23 patients were evaluated in the study, of whom 17 were males and 6 were female. Injuries on the right side were observed in 8 and that on the left side in 15 patients (Table I). Injury etiologies included traffic accidents, falls from height, and sports injuries. Patients who had no previous trauma to the same knee and had no symptoms were included in the study. The mean age was 45 (22–55) years.

The MRI examination revealed lateral meniscus injury (LML) in 8 patients, of which 3 were bucket handle meniscus injury; medial meniscus (MML) in 4; anterior cruciate ligament avulsion in 11; posterior cruciate ligament avulsion in 2; partial lateral collateral ligament injury (LCL) in 8; and partial medial collateral ligament injury in 4. No total lateral and cruciate ligament injuries were observed in any of the patients.

Joint depression values were statistically significantly high in those with bucket handle lateral meniscus tear ($p < 0.05$) (Table II) (Figure 2). Joint depression values were found to be statistically

Table I. — Data distribution.

		n	%
Gender	Man	17	73,9
	Woman	6	26,1
Side	Right	8	34,8
	Left	15	65,2
Bucket Handle Injury	No	20	87,0
	Yes	3	13,0
MML	No	19	82,6
	Yes	4	17,4
LML	No	15	65,2
	Yes	8	34,8
MCL	No	19	82,6
	Yes	4	17,4
LCL	No	21	91,3
	Yes	2	8,7
ACL	No	12	52,2
	Yes	11	47,8
PCL	No	21	91,3
	Yes	2	8,7

MML: Medial meniscus lesion, LML: Lateral meniscus lesion, MCL: Medial collateral ligament lesion, LCL: Lateral collateral ligament lesion, ACL: Anterior cruciate ligament lesion, PCL: Posterior cruciate ligament lesion.

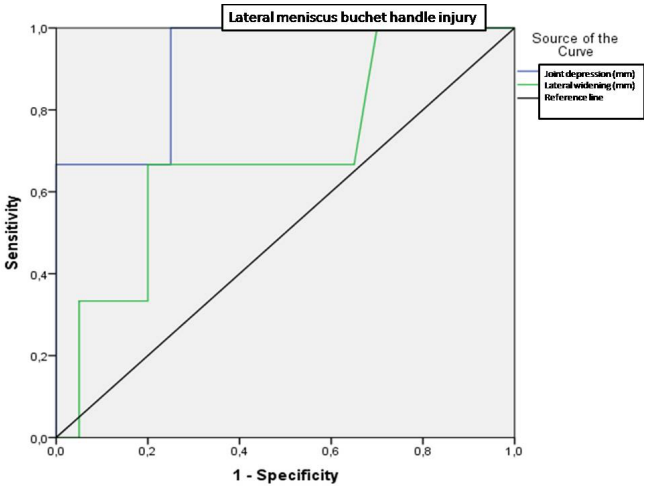

Fig. 2 — ROC analysis as models for predicting lateral meniscus bucket handle injuries.

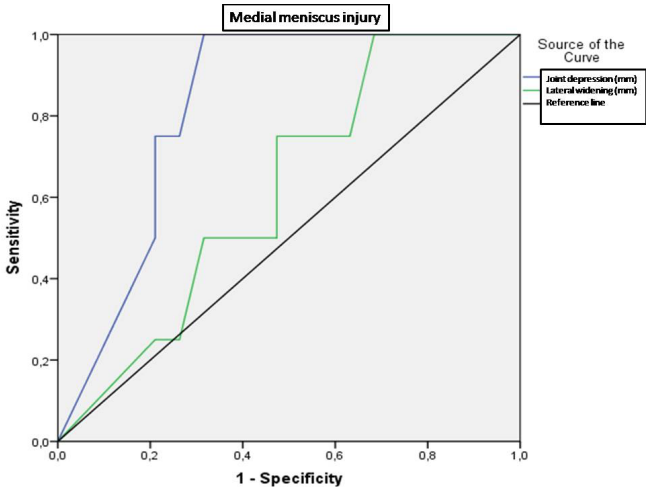

Fig. 3 — ROC analysis as models for predicting medial meniscus injuries.

significantly low in patients with MML ($p < 0.05$) (Table II) (Figure 3). No statistically significant difference was found between the soft tissue adjustments and the amount of lateral plateau separation ($p > 0.05$). The area under the curve (AUC) value calculated for LCL disintegration at a lateral tibial plateau of >4.2 mm was statistically significant ($p < 0.05$) (Table III). No statistically significant difference was found in the AUC values calculated for other injuries ($p > 0.05$) (Table III).

Joint depression of >12 mm was statistically significant for bucket handle lateral meniscus injury, and joint depression of <5.9 mm was statistically significant for medial meniscus injury ($p < 0.05$) (Table 4). No statistically significant difference was found in the AUC values calculated for other injuries ($p > 0.05$) (Table IV).

Table II. — The mean distribution of joint depression values in CT according to the lesions.

	YES		NO		Z	p
	Ort.±SS	Median (Min.-Max.)	Ort.±SS	Median (Min.-Max.)		
Bucket Handle Injury	20,77±7,23	22 (13-27,3)	8,23±5,49	5,95 (2-19,5)	-2,287	***0,022***
MML	3,98±1,79	4 (2-5,9)	11,11±7,11	11,4 (2-27,3)	-1,992	***0,046***
LML	13,95±8,98	13,4 (2-27,3)	7,69±4,77	5,9 (2-16,1)	-1,488	0,137
MCL	9,1±5,82	8,65 (3-16,1)	10,03±7,39	9,3 (2-27,3)	-0,041	0,968
LCL	4,45±2,05	4,45 (3-5,9)	10,38±7,14	10 (2-27,3)	-1,039	0,299
ACL	12,08±8,14	11,4 (2-27,3)	7,83±5,4	5,9 (2-16,1)	-1,234	0,217
PCL	7,55±3,46	7,55 (5,1-10)	10,09±7,29	9,3 (2-27,3)	-0,328	0,743
Mann Whitney U analizi						

Table III. — ROC analysis for lateral tibial plateau widening values in the diagnostic power of soft tissue injuries.

Lateral tibial plateau widening	Bucket handle injury	MML	LML	MCL	LCL	ACL	PCL
Cutoff	>8	≤8	≤7,6	≤5,9	≤4,2	>8	≤7,2
Sensitivity	66,67	100	75	75	100	36,36	100
95% CI	9,4 - 99,2	39,8 - 100,0	34,9 - 96,8	19,4 - 99,4	15,8 - 100,0	10,9 - 69,2	15,8 - 100,0
Specificity	80	31,58	40	57,89	80,95	83,33	42,86
95% CI	56,3 - 94,3	12,6 - 56,6	16,3 - 67,7	33,5 - 79,7	58,1 - 94,6	51,6 - 97,9	21,8 - 66,0
+LR	3,33	1,46	1,25	1,78	5,25	2,18	1,75
95% CI	1,0 - 10,9	1,1 - 2,0	0,7 - 2,2	0,8 - 3,9	2,2 - 12,7	0,5 - 9,7	1,2 - 2,5
-LR	0,42	0	0,63	0,43	0	0,76	0
95% CI	0,08 - 2,1		0,2 - 2,4	0,08 - 2,5		0,5 - 1,3	
+PV	33,3	23,5	40	27,3	33,3	66,7	14,3
95% CI	4,3 - 77,7	6,8 - 49,9	16,3 - 67,7	6,0 - 61,0	4,3 - 77,7	22,3 - 95,7	1,8 - 42,8
-PV	94,1	100	75	91,7	100	58,8	100
95% CI	71,3 - 99,9	54,1 - 100,0	34,9 - 96,8	61,5 - 99,8	80,5 - 100,0	32,9 - 81,6	66,4 - 100,0
AUC	0,692	0,618	0,542	0,566	0,857	0,534	0,512
95% CI	0,467-0,865	0,395-0,811	0,324-0,749	0,345-0,769	0,649-0,966	0,317-0,742	0,297-0,723
p	0,334	0,409	0,751	0,752	***<0,0001***	0,788	0,928

DISCUSSION

This study aimed to detect accompanying soft tissue injuries by correlating preoperative CT images with MRI in patients with acute tibial plateau fractures. The biggest difference between this study and previous studies was that only AO 41B class lateral tibial plateau fractures were included. The obtained results revealed an association of the increased tibial plateau joint depression with lateral meniscus bucket handle tear, whereas a low joint depression was associated with medial meniscus injuries.

Many studies conducted to date have emphasized the importance of soft tissue injury in tibial plateau fractures in terms of clinical outcomes[5,7-11]. Generally, soft tissue injury increases in proportion to trauma severity. Knowing these injuries, especially those that require surgery, provides an advantage in terms of treatment. Therefore, MRI is generally used for preoperative evaluation of menisci, cruciate ligaments, and lateral ligaments[4,12-15]. However, obtaining an MRI before the operation is not always possible. X-rays and CT are insufficient in diagnosing the concomitant meniscus and ligament injuries, although bone fragments and displacement amounts are evaluated. Gardner et al. investigated the relationship between joint depression and lateral widening and soft tissue injury in lateral tibial plateau fractures and reported that >8 mm depression or widening increases medial meniscus

Table IV. — ROC analysis for joint depression values in the diagnosis power of soft tissue injuries.

Joint depression	Bucket handle injury	MML	LML	MCL	LCL	ACL	PCL
Cutoff	>12	≤5,9	>11,4	>11,4	≤5,9	>5,9	≤10
Sensitivity	100	100	75	25	100	72,73	100
95% CI	29,2 - 100,0	39,8 - 100,0	34,9 - 96,8	0,6 - 80,6	15,8 - 100,0	39,0 - 94,0	15,8 - 100,0
Specificity	75	68,42	80	57,89	61,9	58,33	47,62
95% CI	50,9 - 91,3	43,4 - 87,4	51,9 - 95,7	33,5 - 79,7	38,4 - 81,9	27,7 - 84,8	25,7 - 70,2
+LR	4	3,17	3,75	0,59	2,62	1,75	1,91
95% CI	1,9 - 8,5	1,6 - 6,1	1,3 - 11,1	0,1 - 3,5	1,5 - 4,5	0,8 - 3,7	1,3 - 2,9
-LR	0	0	0,31	1,3	0	0,47	0
95% CI			0,09 - 1,1	0,7 - 2,6		0,2 - 1,4	
+PV	37,5	40	66,7	11,1	20	61,5	15,4
95% CI	8,5 - 75,5	12,2 - 73,8	29,9 - 92,5	0,3 - 48,2	2,5 - 55,6	31,6 - 86,1	1,9 - 45,4
-PV	100	100	85,7	78,6	100	70	100
95% CI	78,2 - 100,0	75,3 - 100,0	57,2 - 98,2	49,2 - 95,3	75,3 - 100,0	34,8 - 93,3	69,2 - 100,0
AUC	0,917	0,822	0,692	0,507	0,726	0,652	0,571
95% CI	0,724-0,990	0,608-0,948	0,467-0,865	0,293-0,719	0,502-0,889	0,427-0,836	0,351-0,773
p	***<0,0001***	***<0,001***	0,206	0,967	0,059	0,206	0,604

injury[4]. Additionally, Durakbasa et al., in their study using intraoperative evaluations, reported that a 14-mm joint depression and 10-mm lateral widening resulted in a high risk for lateral meniscus injury[16]. Both authors predicted the presence of meniscus injury by making direct radiograph measurements. Wang et al. used CT and MRI, as well as direct radiography, to predict soft tissue injury in their study in which they examined 54 plateau fractures and suggested a prediction criterion accordingly[17]. Likewise, Kolb et al. recommended CT and MRI in addition to direct radiography to predict meniscus and ligament lesions[18]. Our study aimed to develop predictive criteria for accompanying soft tissue injuries based on CT examination. Today, we think that the evaluation of intra-articular fractures with CT will be more practical than direct radiography since it is routinely used in many centers.

Our study revealed that joint depression of >12 mm is significant for lateral meniscus bucket handle tear. Additionally, unlike the literature, we found an increased risk of medial meniscus injury in cases with joint depression of <5.9 mm. We think that we have reached this conclusion because some of the trauma severity is absorbed by the medial compartment and especially by the medial meniscus. Therefore, the medial knee should be arthroscopically evaluated, especially in lateral tibial plateau fractures.

Our study's most significant limitation is the relatively low number of patients, its retrospective nature, and the non-inclusion of clinically functional results. Additionally, including isolated lateral tibial plateau fractures and MRIs is valuable for soft tissue injury examinations.

CONCLUSION

Soft tissue injuries in tibial plateau fractures are too common to ignore. With joint depression of <5.9 mm, a medial meniscus injury should be suspected, whereas a lateral meniscus bucket handle tear in >12 mm joint depression. This will contribute to patient management and clinical outcomes. Orthopedic surgeons should be alert for a lateral meniscus tear and other soft tissue pathologies, especially in fractures with >10 mm articular depression.

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