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Original Article

Prevalence of anterolateral complex injury and associated injuries in knees with acute complete and partial anterior cruciate ligament injury

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Abstract

Aim: Kaplan fibers, Anterolateral capsule, Anterolateral ligament (ALL) and Iliotibial band are defined as secondary stabilizers of the internal tibial rotation of the knee. These structures have been summarized as the "Anterolateral complex" (ALC). We aimed to determine the ALC injury prevalence and the association between Anterior cruciate ligament (ACL) and ALC injury patterns.

Materials and Methods: MRI scans of ACL injuries were retrospectively evaluated for the presence of the ACL injury pattern (partial or complete), ALL, iliotibial band, Kaplans fiber, meniscus, bone marrow edema (BME) and collateral ligament pathology. The patients were divided into groups according to the ACL injury pattern. The prevalence of injury of the anatomical structures between groups was examined.

Results: MRI scans of 152 patients (152 knees) were evaluated. The mean age of the patients was 28.5±8.6 (range, 18-55). 138 patients were male and 14 were female. Complete ACL injury was detected in 127 (83.6%) patients confirmed by MRI and arthroscopic procedure and partial ACL injury was detected in 25 (16.4%) patients confirmed by MRI. 90 (59.2%) patients had an ALL injury, 87 (57.2%) had an iliotibial band injury, 82 (53.9%) patients had a Kaplans fiber injury, 53 (34.9%) patients had a meniscal injury, 99 (65.1%) patients had BME and 70 (46.1%) patients had a collateral ligament injury. In the complete ACL injury group, the ratio of ALL, iliotibial band, Kaplan fiber, meniscal injury, BME, collateral ligament injury was significantly higher than the partial ACL injury group ($p< 0.05$).

Conclusion: The prevalence of injury in at least one anatomic structure of ALC was significantly higher in patients with a complete ACL injury (73.2%) than those with partial ACL injury (32%) at our institution. This study demonstrated that ALC injuries were statistically higher as well as meniscal injuries, BME, collateral ligament injuries after complete ACL injury compared to partial ACL injury.

Keywords: Anterolateral complex; anterior cruciate ligament; anterolateral ligament; anotomy; knee; Iliotibial band; imaging

INTRODUCTION

Anterior cruciate ligament injuries usually occur as a result of multiplanar pathological movement called pivot-shift, which consists of an excessive anterior tibial translation and internal tibial rotation (1-3). This multiplanar pathological movement leads to both anterior and rotatory instability. Although good results have been reported with improved ACL reconstruction surgical techniques, persistent rotatory instability was observed in some of the ACL reconstructed patients (4,5). For this reason, the structures that contribute to rotatory stabilization were investigated. Meniscal injury, increased posterior tibial slope as well as anterolateral capsular injury have been demonstrated to play a role in rotatory stability (6-8).

As a result of re-describing the anatomy of ALL (9), numerous studies have been published on the function, imaging, injury and reconstruction of this forgotten ligament (10-16). Although some studies claim that ALL has an important biomechanical role in limiting internal tibial rotation (10,11), other studies have suggested that this effect can be negligible (12,13). There has been significant debate about ALL, with a wide variety of studies

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conducted on biomechanics, anatomy, imaging and reconstruction (14-16), so a meeting was held to generate a consensus (17). According to this meeting, the Iliotibial band (ITB) including the Kaplan fibers, the anterolateral capsule and the ALL are defined as secondary stabilizers of coupled internal tibial rotation. These structures have been summarized as the "Anterolateral complex". Although studies have concentrated on ALL in recent years, the rate of contribution of these four structures in rotatory stability has yet to be determined. Only examining ALL and neglecting the other parts of the complex will definitely lead to misinterpretation of data.

In the literature, the reported prevalence of ALL injuries on MRI ranges between 36.6% to 78.8% in patients with a total ACL injury (18,19). While there are numerous studies on the evaluation of ALL, studies on the prevalence of ALC injury after acute ACL rupture are limited (20). There is still a lack of literature that has compared the prevalence of ALC injuries in patients with total and partial ACL rupture.

The aim of this study was to determine the ALC injury pattern and its prevalence with both acute complete and partial ACL injuries and to demonstrate the other associated pathologies on MRI.

MATERIAL and METHODS

This study received the approval of the institutional review board (RY-2019-09). All patients provided written informed consent. Knee MRIs of patients who had been diagnosed with acute ACL injuries between 2015 and 2019 were retrospectively evaluated. The inclusion criteria were the presence of knee pain after a traumatic knee injury, and that at least one of the physical examination tests (Lachmann, anterior-drawer and pivot-shift test) was positive. Patients who had a knee MRI up to 21 days after trauma and who had acute ACL injuries on MRI in a manner consistent with physical examination were included. 127 patients (127 knees) were diagnosed with acute complete ACL tear confirmed by both knee MRI and arthroscopic procedures. All patients with complete ACL injury underwent arthroscopic ACL reconstruction surgery by senior specialists in the field of sports injury. The diagnoses of partial ACL injury of the remaining 25 patients (25 knees) were based on physical examination and MR findings. The exclusion criteria were the patients with age <18 years at the time of injury, previous knee surgery, severe arthritic changes (joint space narrowing, grade 3 or greater cartilage injury on MRI), low-quality MR images due to artifacts and unclear history of trauma. After exclusion, a total of 152 patients (152 knees) were included in this study.

MRI protocol

A total of 36 patients underwent knee examination with a 3T MRI machine (Siemens, Magnetom, Skyra, Erlangen, Germany) and 116 patients with a 1.5T MRI machine (Siemens, Magnetom, Skyra, Erlangen, Germany) a 15-channel knee-dedicated Tx/Rx 15-channel coil. We used our standardized protocol, which basically involves has three sequences in sagittal orientation: 1) fat-suppressed proton density weighted turbo spin-echo (FS PD TSE) sequence 2) T1-weighted (T1) turbo spin-echo sequence 3) T2 fat saturated water excitation double echo steady state-3D (T2 FS 3D DESS WE) sequence; two sequences in coronal orientation: 1) fat-suppressed proton density weighted turbo spin-echo (FS PD TSE) sequence; 2) T2 turbo inversion recovery magnitude short tau inversion recovery (T2_TIRM_ COR STIR) sequence; and one sequence in axial orientation: 1) fat-suppressed proton density weighted turbo spin-echo (PD_TSE_FS_TRA) sequence.

The knee MRI scans were evaluated according to the following injuries. If injuries were identified, they were classified according to the following criteria.

ACL injury: Hyperintense appearance in the T2 sequences and loss of integrity in any plane were considered direct signs of acute ACL rupture. In the sagittal plane, when the continuity was determined on some of the ACL fibers, it was decided that any bundle was intact by looking at the femoral attachment in the axial plane. ACL injury was divided into two groups as complete or partial.

ALL injury: The ALL integrity and differentiation to joint capsule was meticulously evaluated by proton density fat-saturated coronal and axial MRI sequence. When the integrity of the ALL was found to be impaired, it was classified as femoral, meniscal and tibial according to the region where the ALL was injured (Figure 1-2). In addition, the ALL injury was classified as a Segond fracture when an avulsion fracture was detected in the Gerdy's tubercle.

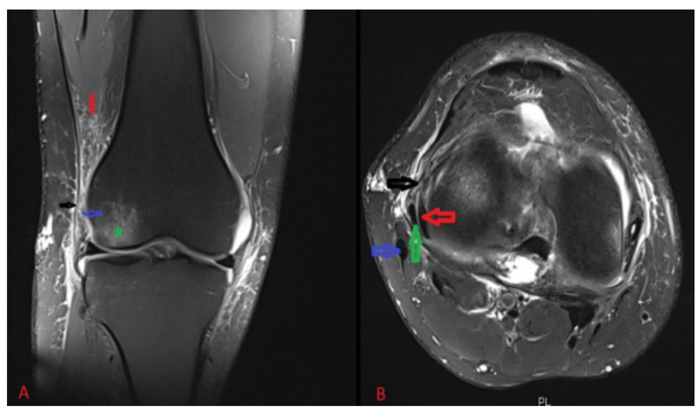

Figure 1. 3 T Magnetic resonance image of a complete ACL injured patient. (A) Coronal plane with proton density fat-suppressed sequence, black arrow shows torn iliotibial band, blue arrow shows ruptured anterolateral ligament femoral portion, red arrow shows Kaplans fiber injury, asterisk shows bone marrow edema in lateral femoral condyle. (B) Axial plane with proton density fat-suppressed sequence, black arrow shows ruptured anterolateral ligament femoral portion and torn iliotibial band, red arrow shows popliteus tendon, green arrow shows lateral collateral ligament, blue arrow shows biceps femoris tendon

Iliotibial band injury: In MRI examination, normal ITB appears as a hyposignal on all sequences and has a band-like structure with regular margins. Traumatic injuries of the ITB were classified as minor sprains, severe sprains and torn (21). Although the normal thickness and integrity of the ITB may have been intact, it was considered as a minor sprain if there was an adjacent edema. ITB injury was considered as a severe sprain in the presence of focal or diffuse thickening with abnormal signal and edema in adjacent tissues. ITB injury was considered as torn in the presence of impaired integrity of ITB or avulsion fracture in the Gerdy's tubercle.

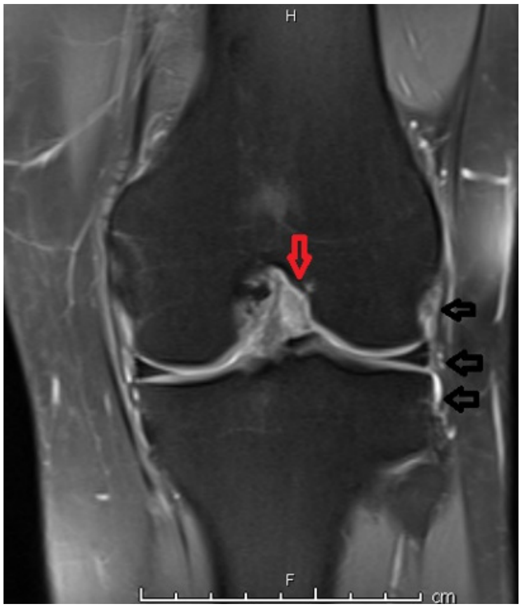

Figure 2. 1.5 T Magnetic resonance image of a complete ACL injured patient. (A) Coronal plane with proton density fat-suppressed sequence, black arrow shows intact Anterolateral ligament (femoral, meniscal and tibial portion), red arrow shows ruptured ACL femoral insertion

Kaplans fiber injury: The distal Kaplans fiber extends from the femur to the ITB approximately 48 mm above the femoral condyle with the branches of the superior genicular artery, while the proximal Kaplans fibers extends from the femur to the ITB at 68 mm proximal from the femoral condyle (22). The Kaplans fiber was considered as normal if low-signal intensity and intact fibers were seen between the femur and ITB. If high-signal intensity and impaired integrity of fibers with adjacent tissue edema were seen between the ITB and femur, this was considered as a Kaplans fiber injury.

Meniscal injury: A meniscal injury was considered as abnormal if there was an increase in signal intensity in FSE, PD and T1 FSE sequences and the signal change reached the superior or inferior articular surface, or both. Meniscus injuries were classified as radial, longitudinal, degenerative and bucket handle tears by indicating the side and region.

Bone marrow edema: Increased signal intensity in FSE and PD sequences and reduced signal intensity in T1 FSE sequences. Any signal changes in the lateral femoral condyle (LFC), lateral tibial plateau (LTP), medial femoral condyle (MFC), medial tibial plateau (MTP) and fibular head (FH) were considered as abnormal (Figure 3).

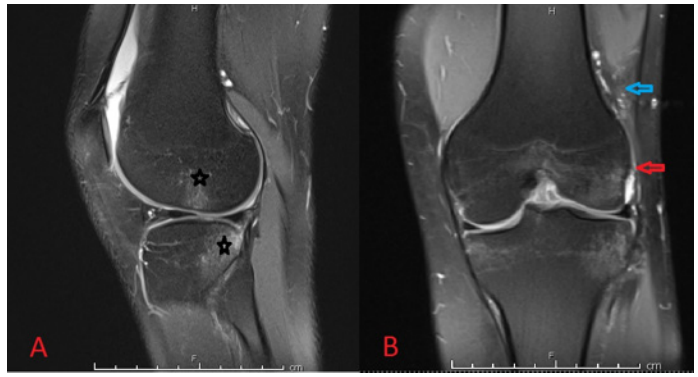

Figure 3. 1.5 T Magnetic resonance image of a complete ACL injured patient. (A) Sagittal plane with proton density fat-suppressed sequence, asterisk shows bone marrow edema in the central third of lateral femoral condyle and posterior third of lateral tibia plateau (Kissing lesion or Lateral femoral notch sign). (B) Coronal plane with proton density fat-suppressed sequence, blue arrow shows intact Kaplans fiber, red arrow shows ruptured anterolateral ligament femoral position

Collateral ligament injury: MCL and LCL injuries were graded according to Schweitzer et al. on MRI (23).

The 4th component of the ALC is where the anterolateral capsule runs overlap with the ALL. For this reason, some authors consider them to be the same structure (24). Therefore, we did not evaluate the anterolateral capsule separately. The injury pattern and prevalence of the above-mentioned anatomic structures were examined in the knee MRI of the patients. The patients were divided into groups according to the ACL injury pattern (partial or complete) and the presence of BME. The prevalence of injury of the anatomical structures between groups was examined.

Statistical analysis

Mean, standard deviation, median lowest, highest, frequency and ratio values were used in descriptive statistics of the data. The Chi-square test was used for the analysis of qualitative independent data and Fisher's test was used when the chi-square test conditions were not met. The Kappa compliance test was used in compliance analysis. SPSS 22.0 program was used in the analysis. One orthopedist and one radiologist (BP and MAD) with 5 and 9 years of experience in musculoskeletal imaging, respectively assessed all images independently. The image and the order were blinded and randomized. Where there was disagreement between the examiners, re-evaluation was performed until a consensus was reached.

RESULTS

The mean age of the patients was 28.5 ± 8.6 (range, 18-55). 138 patients were male and 14 were female. The mean BMI was 23.4 ± 3.1 (range 17.9-33.7). The right knee was affected in 88 patients, while the left knee was affected in 64 patients. The mean time from injury to MRI was 6.5 ± 5.8 (range, 1-21) days. Injury mechanism distribution was as follows: 87 (57.2%) football, 24 (15.8%) basketball, 16 simple fall (10.5%), 11 traffic accident (7.2%), 10 skiing (6.6%) and 4 tennis (2.6%) injuries (Table 1).

Table 1. Clinical and demographic data of patients				
	Min-Max	Median	Mean±sd/n-%	
Age	18.0 - 55.0	26.0	28.5 ± 8.6	
Gender				
Female			14	9.2%
Male			138	90.8%
Body Mass Index	17.9 - 33.7	23.3	23.4 ± 3.1	
Side				
Right			88	57.9%
Left			64	42.1%
Time from injury to MRI (day)	1.0 - 21.0	4.0	6.5 ± 5.8	
Injury Mechanism				
Basketball			24	15.8%
Fall			16	10.5%
Football			87	57.2%
Skiing			10	6.6%
Tennis			4	2.6%
Traffic Accident			11	7.2%

Table 2. Prevalence of knee abnormalities		
	n	%
ALL Injury Pattern		
Intact	62	40.8%
Femoral	75	49.3%
Meniscal	3	2.0%
Segond Fracture	4	2.6%
Tibial	8	5.3%
Iliotibial Band Injury		
Intact	65	42.8%
Minor Strain	14	9.2%
Sever Strain	51	33.6%
Torn	22	14.5%
Kaplan Fiber İnjury		
(-)	70	46.1%
(+)	82	53.9%
Meniscal Injury		
(-)	99	65.1%
(+)	53	34.9%
LM Anterior Radial Tear	4	2.6%
LM Anterior Longitudinal Tear	1	0.7%
LM Bucket Handle Tear	2	1.3%
LM Corpus Longitudinal Tear	1	0.7%
LM Corpus Radial Tear	5	3.3%
LM Posterior Longitudinal Tear	1	0.7%
LM Posterior Radial Tear	12	7.9%
MM and LM Corpus Longitudinal Tear	2	1.3%
MM Anterior Radial Tear	1	0.7%
MM Bucket Handle Tear	13	8.6%
MM Corpus Longitudinal Tear	3	2.0%
MM Corpus Radial Tear	1	0.7%
MM Posterior Longitudinal Tear	3	2.0%
MM Posterior Radial Tear	3	2.0%
MM Posterior Degenerative Tear	1	0.7%
BME		
(-)	53	34.9%
(+)	99	65.1%
LFC	76	50.0%
MTP	34	22.4%
LTP	92	60.5%
FH	9	5.9%
MFC	11	7.2%
Collateral Ligament Injury		
(-)	82	53.9%
(+)	70	46.1%
LCL Grade 1	2	1.3%
LCL Grade 2	2	1.3%
MCL Grade 1	39	25.7%
MCL Grade 2	16	10.5%
MCL VE LCL Grade 1	10	6.6%
MCL VE LCL Grade 2	1	0.7%

ALL: Anterolateral Ligament, LM:Lateral Meniscus, MM:Medial Meniscus, BME:Bone Marrow Edema, LFC:Lateral Femoral Condyle, MTP: Medial Tibial Plateau, LTP: Lateral Tibial Plateau. FH:Fibular Head, MFC:Medial Femoral Condyle, LCL: Lateral Collateral Ligament, MCL:Medial Collateral Ligament

Complete ACL injury was detected in 127 (83.6%) patients and partial ACL injury was detected in 25 (16.4%) patients. 90 (59.2%) patients had an ALL injury, 87 (57.2%) had an iliotibial band injury and 82 (53.9%) patients had a Kaplan fiber injury. When we consider the ALC as a whole, 101/152 (66.4%) of all patients were injured in at least one component of the ALC. Furthermore, 93/127 (73.2%) of the patients with complete ACL injuries and 8/25 (32%) of patients with partial ACL injuries were detected to have an injury in at least one component of ALC. Associated knee injuries are summarized in Table 2. In the Complete ACL injury group, the ratio of ALL, iliotibial band, Kaplan fiber, meniscal injury, BME, collateral ligament injury was significantly higher than the partial ACL injury group ($p< 0.05$) (Table 3). In the BME (+) group, the ratio of ALL, iliotibial band, Kaplan fiber and collateral ligament injury was significantly higher than the BME (-) group ($p< 0.05$). In the group with BME (-) and BME (+), the meniscal injury rate was not significantly different ($p > 0.05$) (Table 4).

A significant ($p < 0.05$) agreement was observed between the ACL, ALL, Iliotibial band and Kaplan fibers evaluations of Observer I and Observer II. The compliance rates were 95.4%, 84.9%, 86.2%, 92.1%, respectively.

Table 3. Association between ACL injury (complete vs. partial) and associated injuries

	ACL Injury Pattern				
	Complete		Partial		p
	n	%	n	%	
ALL Injury Pattern					
Intact	43	33.9%	19	76.0%	**0.000** X^2
Femoral	71	55.9%	4	16.0%	**0.001** X^2
Meniscal	2	1.6%	1	4.0%	0.991 X^2
Segond Fracture	4	3.1%	0	0.0%	0.829 X^2
Tibial	7	5.5%	1	4.0%	0.856 X^2
Iliotibial Band Injury					
Intact	44	34.6%	21	84.0%	**0.000** X^2
Minor Strain	12	9.4%	2	8.0%	
Sever Strain	50	39.4%	1	4.0%	
Torn	21	16.5%	1	4.0%	
Kaplan Fiber Injury					
(-)	48	37.8%	22	88.0%	**0.000** X^2
(+)	79	62.2%	3	12.0%	
Meniscal Injury					
(-)	76	59.8%	23	92.0%	**0.002** X^2
(+)	51	40.2%	2	8.0%	
BME					
(-)	32	25.2%	21	84.0%	**0.000** X^2
(+)	95	74.8%	4	16.0%	
Collateral Ligament Injury					
(-)	61	48.0%	21	84.0%	**0.001** X^2
(+)	66	52.0%	4	16.0%	

X^2 Chi-square test

Table 4. Association between BME group (absent (-) vs. present (+)) and associated injuries

	BME (-)		BME (+)		p
	n	%	n	%	
ALL Injury Pattern					
Intact	31	58.5%	31	31.3%	**0.000** X^2
Femoral	19	35.8%	56	56.6%	**0.024** X^2
Meniscal	1	1.9%	2	2.0%	0.578 X^2
Segond Fracture	0	0.0%	4	4.0%	0.341 X^2
Tibial	2	3.8%	6	6.1%	0.825 X^2
Iliotibial Band Injury					
Intact	37	69.8%	28	28.3%	**0.000** X^2
Minor Strain	7	13.2%	7	7.1%	
Sever Strain	6	11.3%	45	45.5%	
Torn	3	5.7%	19	19.2%	
Kaplan Fiber Injury					
(-)	38	71.7%	32	32.3%	**0.000** X^2
(+)	15	28.3%	67	67.7%	
Meniscal Injury					
(-)	39	73.6%	60	60.6%	0.110 X^2
(+)	14	26.4%	39	39.4%	
Collateral Ligament Injury					
(-)	49	92.5%	33	33.3%	**0.000** X^2
(+)	4	7.5%	66	66.7%	

X^2 Chi-square test

DISCUSSION

The most important finding of this study is the presence of a wide variety of ALC injury patterns and frequencies in knees with acute ACL injuries. This incidence was found to be 73.2% in complete ACL injuries and 32% in partial ACL injuries. In knees with complete ACL injury, 66.1% had an ALL injury, 65.4% had an iliotibial band injury and 62.2% had a Kaplan fiber injury. In 53.6% of the complete ACL injured knees, it was detected that all three structures forming the ALC were injured. As a result, it is assumed that the ALC structures act as a whole in rotatory stability and injuries of these structures are correlated. The contribution of the ALL to rotatory stability has been shown by biomechanical studies (10). In a recent clinical study, the internal rotation of knees with ALL injuries was found to be significantly higher than ALL-intact knees, as measured by rotameter after ACL reconstruction, although patients' complaints were not different; however, the patients in this study were not elite athletes (13). In a recent clinical study on elite athletes, patients with ACL and ALL reconstruction had excellent clinical outcomes and 85.7% of athletes returned to the same level of professional competition (25). As we have deduced from these studies, it has become important to evaluate the ALC after ACL injury, particularly in elite athletes.

The ALL is better depicted in the coronal sections, but due to the oblique path from the posterosuperior to the anteroinferior of the knee, several sequential slices should be evaluated together. Furthermore, the ALL runs adjacent to the joint capsule causing difficulties in MR recognition. These anatomical features of the ALL, the heterogeneity in the patient selection and the differences in the criteria of ALL injury lead to a very wide range of frequencies for associated ALL injuries in the knees with ACL injury in the literature (18,19). In some studies, it was reported that the most commonly injured part of the ALL was the tibial side (19,26), while in other studies, the femoral portion was mentioned as the most commonly injured area (27). Segond fracture forms the minority of injury patterns in almost all studies (26,27). In our study, the femoral portion of the ALL was the most common injury pattern associated with acute ACL injury. Van Dyck et al. reported that the rate of iliotibial band injury was 51% and for Kaplan fiber injury, it was 33% (20). In our study, these rates were slightly higher for complete ACL injured patients, with 65.4% and 62.2%, respectively. In the study of Van Dyck et al., MRI evaluation was used up to 6 weeks after ACL injury; however, in our study, we only included patients who had MRI up to 3 weeks after trauma (20). We assumed that earlier MRI evaluation, as in our study, may have shown higher rates of ligamentous edema and injury. When evaluating the ALC, interobserver compliance was 84.9%, 86.2% and 92.1% for ALL, iliotibial band and Kaplan fibers, respectively. We noticed that three anatomical structures were evaluated with significant interobserver compliance. We assumed that the highest compliance in the evaluation of Kaplan fibers was a result of easier discrimination of the high signal intensity in the T2 coronal sections. We thought that the relatively low compliance in the ALL evaluation was caused by its thin, elongated structure and oblique position close to the joint capsule. In a recent study, the MRI findings of ALL were found to be well correlated with surgical exploration (28). This suggests that the evaluation of ALC's on MRI will be increasingly popular in the preoperative planning of knee stabilization procedures. This is the clinical significance of this radiological study.

In our study, it was presented that ALC injury was statistically higher in addition to meniscal injuries, BME, and collateral ligament injuries after complete ACL injury rather than partial ACL injury (18,29). In our study, BME was detected in 74.8% of patients with complete ACL injury and 65.1% of all patients. ALC and collateral ligament injury rates were found to be statistically higher than those without BME, but no difference was found between meniscal injury rates. This situation was also supported by the literature (30). Of the patients with 127 complete ACL injuries, 70 (55.1%) patients were found to have BME in both the central third of LFC and posterior third of LTP. This BME pattern, which is thought to be a pivot shift injury footprint, is called a kissing lesion in the literature (31). In addition, this pivot shift injury leads to a contusion at the central third of LFC. This contusion is seen on both radiography and MR sagittal sequences. This contusion is called a 'lateral femoral notch sign' (32). It has been stated that the lateral femoral notch sign is an indication for combined ACL and ALL reconstruction (33). This study demonstrated the accuracy of this indication radiologically. In our study, we determined that ALL injuries occurred in all 70 of the kissing lesion or lateral femoral notch sign positive patients (100%). Therefore, we think that these MRI findings are pathognomonic for ALL injury.

There are some limitations to this study. Complete ACL injury was confirmed for 127 patients arthroscopically. However, the diagnosis of 25 patients with partial ACL injury was based on the patient's history, positive examination findings and MRI findings. This study was conducted in two different hospitals, so two different MRI scanners were used (1.5T and 3T) for image analysis and the absence of a control group was another limitation of our study.

CONCLUSION

The prevalence of ALC injury in at least one anatomic structure was significantly higher in patients with complete ACL injuries (73.2%) than those with partial ACL injuries (32%). Anatomical structures forming the ALC (ALL, Iliotibial band, Kaplan fiber) can be examined with significant interobserver compliance in the knee MRI. This study demonstrated that ALC injuries were statistically higher as well as meniscal injuries, BME, collateral ligament injuries after complete ACL injury compared to partial ACL injuries.

Competing interests: The authors declare that they have no competing interest.

Financial Disclosure: There are no financial supports.

Ethical approval: Ethics committee approval was received for this study from the Ethics Committee of Kyrenia University Medical Faculty (ID: RY-2019-09 Date:27/03/2019).

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