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Research Article

MRI Evaluation of Anterolateral Ligament and Associated Lesions of the Knee

Anterolateral Ligament ve Dizdeki İlişkili Lezyonlarının MRI ile Değerlendirmesi

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Abstract

Aim: This study aimed to evaluate the anatomy of the anterolateral ligament (ALL), ALL injuries and the relationship between ALL injuries and other knee ligaments injuries, meniscal tears, bone injuries by retrospectively scanning patients' knee magnetic resonance imaging (MRI).

Material and Methods: Our study was designed as a retrospective, non-randomized, and single-center clinical study. We included knee MR images of 320 patients who applied to our tertiary care institution and underwent knee MRI between August 2021 and March 2022.

Results: A total 320 knee MRI's [female;163 (50.9%), mean age; 39.60±14.16 years, range; 21-77 years, left knee; 172 (53.7%)] were included study. At least one component of ALL was visualized in 319 (99.7%) cases [whole components: 276 (86.3%), meniscal: 311 (97.2%), femoral: 314 (98.1%), tibial: 280 (87.5%)]. Of the 182 ALL-injured knee, 182 (100%) had anterior cruciate ligament (ACL) injury, 116 (63.7%) had lateral meniscal injury, and 103 (56.6%) had bone injury. ACL (p=0.001), lateral meniscus (p=0.001), and bone injury (p=0.001) were more frequently in ALL-injured as compared with ALL-intact knee.

Conclusion: There is a statistically significant relationship between acute ACL rupture, lateral meniscus, bone injury, and ALL injury. When evaluating MRI in patients with ACL, lateral meniscus, and bone injury, ALL evaluation should also be performed.

Keywords: Anterolateral ligament, ALL, anterior cruciate ligament, ACL, MRI

Öz

Amaç: Bu çalışmada anterolateral ligament (ALL) yaralanmalarının anatomisi ve ALL yaralanmaları ile diğer diz bağ yaralanmaları, menisküs yırtıkları, kemik yaralanmaları arasındaki ilişkinin hastaların diz manyetik rezonans görüntülerinin (MRI) retrospektif olarak taranmasıyla değerlendirilmesi amaçlanmıştır.

Materyal ve Metot: Bu çalışma retrospektif, randomize olmayan ve tek merkezli bir klinik çalışma olarak tasarlandı. Üçüncü basamak kurumumuza başvuran Ağustos 2021 ile Mart 2022 arasında diz MRI çekilen 320 hastanın diz MR görüntülerini derlendi.

Bulgular: Toplam 320 diz MRI [kadın;163 (%50.9)), ortalama yaş; 39,60±14,16 yıl, yaş aralığı; 21-77 yıl, sol diz; 172 (%53,7)] çalışmaya dahil edildi. 319 (%99.7) olguda ALL'nin en az bir komponenti görüldü [bütün komponentler: 276 (%86.3), menisküs: 311 (%97.2), femoral: 314 (%98.1), tibial: 280 (%87.5)]. ALL yaralanmalı 182 dizden 182'sinde (%100) ön çapraz bağ (ÖÇB) yaralanması, 116'sında (%63.7) lateral menisküs yaralanması ve 103'ünde (%56.6) kemik yaralanması vardı. ÖÇB (p=0.001), lateral menisküs (p=0.001) ve kemik yaralanması (p=0.001) ALL-intakt diz ile karşılaştırıldığında ALL-yaralılarda daha sıktı.

Sonuç: Akut ÖÇB rüptürü, lateral menisküs, kemik yaralanması ve ALL yaralanması arasında istatistiksel olarak anlamlı bir ilişki vardır. ÖÇB, lateral menisküs ve kemik yaralanması olan hastalarda MRI değerlendirilirken ALL değerlendirmesi de yapılmalıdır.

Anahtar Kelimeler: Anterolateral ligament, ALL, ön çapraz bağ, ÖÇB, MRI

INTRODUCTION

Anterolateral ligament (ALL) was first described by Segond as a "pearly, resistant and fibrous" band (1). ALL has been given various names such as capsule-osseous layers, short lateral ligament (2-4), lateral capsular ligament (5), and mid-third lateral capsular ligament (6). Vincent et al. identified and described a structure they called the 'anterolateral ligament' in 2012 (7).

ALL has an important function in femorotibial internal rotation. Therefore, it supports the thesis that ALL is a secondary restriction that stabilizes internal tibial rotation

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with increased flexion (8). Following anterior cruciate ligament (ACL) reconstruction, ALL may limit pivot shift and tibial internal rotation. In addition, this has developed ACL surgery that helps limit this pivot shift (9).

In 2014, Caterine et al. first reported the appearance of ALL on MRI (10). There is no standard protocol for the evaluation of ALL with MRI. There are variable results in studies investigating ALL with MRI. Few MRI studies are showing the relationship between ALL and ACL. Studies investigating ALL and its accompanying findings and possible associations between them are still insufficient. Studies are needed on this subject.

Our aim in the study is to evaluate the anatomy of ALL, especially in the axial and coronal planes, with the standard MRI knee examination sequences. It was aimed to evaluate where the ALL originates and where it ends, which parts are not visible, the rate of adhesion to the meniscus region, femoral - tibial band lengths, thickness, and width of ALL measured from the femoral level, and comparing this with the literature. Also to investigate the presence, shape, and localization of ALL injuries. To reveal whether there is a relationship between ALL damage and ACL, lateral collateral ligament (LCL), medial cruciate ligament (MCL), posterior cruciate ligament (PCL) injuries, meniscal tears, bone injuries, and fluid in the joint space.

MATERIAL AND METHOD

Our study was set up as a retrospective, non-randomized, and single-center study. The data was collected through the hospital information system. The age, gender, and knee MRI of the patients were examined from the patient files. The information system and picture archiving and communicating system (PACS) of the University. Hospital were used to evaluate the ALL and the other structures of the knee.

Patients' selection

We studied 320 MRI scans of the knee executed in our institution between August 2021 and March 2022. Patients with a history of fracture or bone procedure, suspected tumor in the knee region, patients with previous knee ligament surgery or injury, patients with MRI scans with poorer image quality, and patients under 16 years of age were excluded from the study.

MRI protocol

All the images were executed on two 1.5-T magnets (MAGNETOM Amira, Material Number 10836777, Serial number 174075 Siemens Healthcare, Erlangen, Germany 2019) with a dedicated knee coil.

Imaging parameters at 1.5 T included: PD TSE FS Sagittal 320 (TR/TE=4500/41 ms, BW 155), T1 TSE Sagittal 320 (TR/TE=4500/41 ms, BW 155), PD Turbo FS Coranal (TR/TE=4500/41 ms, BW 153), PD TSE FS trans axial (TR/TE=4500/41 ms, BW 154). All images were acquired with FOV 150 mm, slide 25, slide thickness 3.5mm, average 1, and phase 100. (FOV=field of view, RT=repetition time, TE=echo time)

MRI analyses

ALL was reviewed on all plans. The location and presence of tibial, femoral and meniscal adhesions were determined.

According to the location in the coronal and axial plane, the femoral insertion was classified into three types. These are anterodistal to the lateral epicondyle, the lateral epicondyle, and posteroproximal to the lateral epicondyle (6,9).

The meniscal attachment pattern of ALL was divided into four types in the coronal plane. These are central, complete, inferior-only, and bipolar.

The vertical distance of the tibial insertion of the ALL below the articular line was measured from the center of the tibial insertion of the ligament to the subchondral bone surface on coronal images. This measurement was elected to provide a correlation with former anatomical, surgical, and MRI studies. ALL thickness was measured at the subchondral bone level of the femur on coronal images. The plan that best shows the thickness of the ligament is the coronal sections. In Figure 1, the length and thickness measurement of ALL is presented.

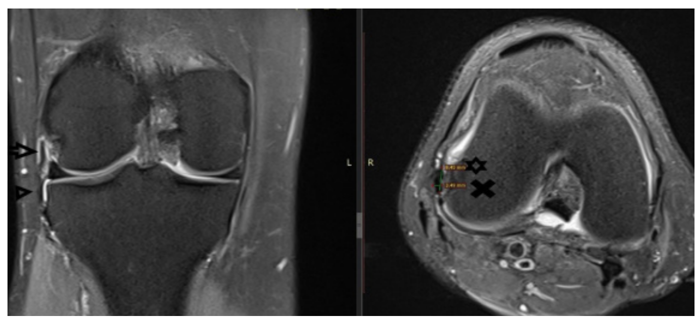

Figure 1. a. Coronal T2 image ALL femoral length (open arrow), ALL tibial length (arrow head) b. ALL width (star), and ALL thickness (cross)

Thickness is the size measurement in the segment where the femoral component is observed in the coronal section. The width is the size measurement of the femoral component on the side of the femoral component traced to the middle segment in the axial section.

We measured the femoral and tibial components. The most important point here is that we did not measure the meniscal segment, but only the femoral and tibial components.

We took care not to include the parts involved in the measurement at the level of the femoral collateral ligament (FCL) and the iliotibial band (ITT).

Other findings or accompanying findings such as ACL injury, MCL injury, LCL injury, PCL injury, MM (medial meniscus) anterior injury, MM posterior injury, LM (lateral meniscus) anterior injury, LM posterior injury, bone injury, fluid and synovial cyst hypertrophy were reviewed on MRI.

Statistical analysis

Statistical analysis was performed by Statistical Program in Social Sciences 25 program. Shapiro Wilk test was used to check whether the data included in the study fit the normal distribution. The significance level (p) for comparison tests was taken as 0.05. Since the variables did not have a normal distribution (p>0.05), the analysis was continued with non-parametric test methods. Comparisons in independent pairs; since the assumption of normality was not provided, the Mann-Whitney U test was used. In the analysis of categorical data, chi-square analysis was performed by creating cross tables. Correlation coefficients are criteria that give information about the degree and direction of the relationship between the variables. The correlation coefficients range from -1 to +1. The signs show the direction of the relationship. The strength of the relationship increases as it approaches -1and+1, and decreases as it approaches 0. Values that are frequently used in the evaluation of the findings; 0.00–0.19 no relevance, 0.20–0.39 weak relevance, 0.40–0.69 moderate relevance, 0.70–0.89 strong relevance, and 0.90–1.00 is interpreted as a very strong relevance. Since the variables included in the study showed normal distribution, the spearman rank correlation coefficient was used.

RESULTS

The study reviewed a total of 320 knee MRI images of the patients, including 163 (50.9%) female and 157 (49.1%) male patients. The mean age of patients was 39.60±14.16 years (range, 21-77 years). Of these patients, the mean age of female patients was 44.74±13.54, (range, 21-77) years. The mean age of male patients was 34.27±12.76 years, ranging from 21 years to 71 years.

Of the 320 knee MRI images, 148 (46.3%) were right knee and 172 (53.8%) were left knee. While the mean ALL femoral length, ALL tibial length, width, and thickness were 18.29±1.76, 11.05±1.77, 8.02±0.59, 3.32±0.76, respectively. A statistically significant difference was found between males and females according to the measurements of ALL femoral length (p=0.001), ALL tibial length (p=0.001), and thickness (p=0.006). There is a low level of statistically significant positive correlation between thickness and age (p=0.001). There was no statistically significant relationship between age and ALL femoral length (p=0.409) and ALL tibial length (p=0.260).

Anatomical features of ALL and ALL injuries (types and location) are represented in Table 1. When the meniscal insertion site of ALL was evaluated, it was found to be complete type in 138 (43.1%) patients, central type in 37 (11.6%) patients, bipolar type in 142 (44.4%) patients, and inferior type in only 3 (0.9%) patients.

Table 1. Anatomical features of ALL and ALL injuries (types and location)

Variable			n	%
The meniscal insertion site of ALL	Complete		138	43.1
	Central		37	11.6
	Bipolar		142	44.4
	Inferior only		3	0.9
The femoral origin point of ALL	None (not monitored)		6	1.9
	Lateral femoral		298	93.1
	Anterodistal to lateral femoral		15	4.7
	Posteroproksimal to lateral femoral		1	0.3
Visualization of ALL	Whole (F and or M and or T)	None	44	13.8
		There is	276	86.3
	Partial (F+M or M+T or F+T)	None	276	86.3
		There is	44	13.8
	Femoral (F)	None	6	1.9
		There is	314	98.1
	Meniscus (M)	None	9	2.8
		There is	311	97.2
	Tibial (T)	None	40	12.5
		There is	280	87.5
Localization of ALL injury	None		138	43.1
	Femoral		79	24.7
	Tibial		51	15.9
	Both		52	16.3
Type of ALL injury	None		138	43.1
	Partial		153	47.8
	Total		29	9.1
			Minimum	**Maximum**
Measurements of ALL (millimeter)	Femoral length		14.6	23.7
	Tibial length		3	17
	Thickness		1,4	5.8
	Width		6.5	9.3

When the femoral origin of ALL was evaluated, it was found that it was lateral femoral in 298 (93.1%) patients, anterodistal to lateral femoral in 15 (4.7%) patients, posteroproximal to lateral femoral in 1 (0.3%) patient, and it could not be monetarized in 6 (1.9%) patients. When visualization of ALL was investigated, it was detected in 276 (86.3%) patients as femoral and or meniscal and or tibial. This rate was 13.8% (44) for partial, 98.1 (314) for femoral, 97.2 (311) for meniscal and 87.5% (280) for tibial.

The localization of ALL damage was investigated. The femoral type was observed in 79 (24.7%) patients, tibial type was in 52 (15.9%) patients, and both femoral and tibial types were 52 (16.3%). It was determined that 153 (47.8%) patients had partial and 29 (9.1%) patients had total ALL damage. There were 138 (43.1%) patients without any damage.

Other findings or accompanying findings detected on MRI are represented in Table 2. It was determined that 30 (9.4%) patients had a total, 82 (25.6%) patients had subtotal, 175 (54.7%) partial injuries and 33 (10.3%) patients did not have an ACL injury.

Partial MCL injury was 19.7% (63) while subtotal MCL injury was 1.9% (6). These rates were 17.8% (57) and 2.5% (8), respectively, in PCL injury. Total, partial, and mild anterior MM injuries were determined as 3.1% (10), 15.6% (50), and 41.6% (133), respectively.

Total, partial, and mild anterior LM injuries were found to be 6.6% (21), 25.9% (83), and 17.5% (56), respectively. The bone injury was not detected in 171 (53.4%) patients, but 26 (8.1%) patients had the femoral bone injury, 21 (6.6%) patients had the patellar bone injury, 16 (5.0%) patients had the tibial bone injury, 15 (4.7%) patients had the femoral and patellar bone injury, 37 (11.6%) patients had the femoral and tibial bone injury, 2 (0.6%) patients had the tibial and patellar bone injury, and 26 (8.1%) patients had the subchondral cysts. Baker's cyst was observed in 46 (14.4%) patients.

The association between ALL injury and injury of other ligamentous structures, meniscus, and lesions is demonstrated in Table 3.

In patients with ALL damage; The incidence of ACL injury, MCL injury, LCL injury, PCL injury, anterior MM injury, posterior MM injury, anterior LM injury, posterior LM injury, bone injury, fluid and synovial cyst hypertrophy was found 100% (182), 31.3(57), 8.2%, (15), 31.9% (58), 70.3% (128), 95.6% (174), 63.7% (116), 52.2% (95), 56.6% (103), 87.4% (156), 7.1% (13), respectively.

According to ALL injury, there is not a statistically significant difference between ALL injury and MCL, LCL, and PCL injury (p>0.05). According to ALL damage, there is a statistically significant difference between ACL, lateral meniscus, and bone injury (p=0.001).

Table 2. Accompanying findings detected on MRI

Associated lesions	Group	n	%
ACL injury	None	33	10.3
	Partial	175	54.7
	Subtotal	82	25.6
	Total	30	9.4
MCL injury	None	251	78.4
	Partial	63	19.7
	Subtotal	6	1.9
LCL injury	None	305	95.3
	Partial	15	4.7
PCL injury	None	255	79.7
	Partial	57	17.8
	Subtotal	8	2.5
MM anterior injury	None	127	39.7
	Mild	133	41.6
	Medium	50	15.6
	Total	10	3.1
MM posterior injury	None	24	7.5
	Mild	40	12.5
	Medium	96	30.0
	Total	160	50.0
LM anterior injury	None	160	50.0
	Mild	56	17.5
	Medium	83	25.9
	Total	21	6.6
LM posterior injury	None	189	59.1
	Mild	74	23.1
	Medium	44	13.8
	Total	13	4.1
Bone injury	None	171	53.4
	Femoral (F)	26	8.1
	Patellar (P)	21	6.6
	Tibial (T)	16	5.0
	F+P	15	4.7
	F+T	37	11.6
	T+P	2	0.6
	F+T+P	6	1.9
	Subchondral cyst	26	8.1
Fluid	None	67	20.9
	Retro patellar	127	39.7
	Lateral	18	5.6
	Total	108	33.8
Synovial cyst hypertrophy	None	257	80.3
	Baker's cyst	46	14.4
	Other	17	5.3

Table 3. The association between ALL injury and injury of other ligamentous structures, meniscus, and lesions is demonstrated

Factors associated with ALL injury		ALL injury	
		Yes	No
ACL injury	Yes	182 (100)	105 (76.1)
	No	0 (0)	33 (23.9)
MCL injury	Yes	57 (31.3)	12 (8.7)
	No	125 (68.7)	126 (91.3)
LCL injury	Yes	15 (8.2)	1 (0.7)
	No	167 (91.8)	137 (99.3)
PCL injury	Yes	58 (31.9)	8 (5.8)
	No	124 (68.1)	130 (94.2)
MM anterior injury	Yes	128 (70.3)	65 (47.1)
	No	54 (29.7)	73 (52.9)
MM posterior injury	Yes	174 (95.6)	122 (88.4)
	No	8 (4.4)	16 (11.6)
LM anterior injury	Yes	116 (63.7)	44 (31.9)
	No	66 (36.3)	94 (68.1)
LM posterior injury	Yes	95 (52.2)	36 (26.1)
	No	87 (47.8)	102 (73.9)
Bone injury	Yes	103 (56.6)	46 (66.7)
	No	79 (43.4)	92 (33.3)
Fluid	Yes	159 (87.4)	94 (68.1)
	No	23 (12.6)	44 (31.9)
Synovial cyst hypertrophy	Yes	13 (7.1)	4 (2.9)
	No	126 (69.2)	131 (94.9)

ACL – anterior cruciate ligament; MCL – medial cruciate ligament; LCL – lateral collateral ligament; PCL – posterior cruciate ligament; MM – medial meniscus; LM – lateral meniscus

DISCUSSION

ALL is a ligamentous structure that can be clearly distinguished from the femoral joint capsule. Histopathologically, it is in a ligament structure. ALL originates from the femoral epicondyle near the lateral collateral ligament. It attaches in two places. One is the tibial plateau and the other is the lateral meniscus. MRI shows the oblique and intracapsular course of the ligament (11). ALL has three components. These are femoral, meniscal, and tibial components (8).

Evaluation of ALL only with MRI coronal images may have entrapment effects in distinguishing the blended image of the ligament with surrounding structures (10-14). Despite the proximity of the fibular collateral ligament and the iliotibial band on MRI, the coronal and axial planes help us differentiate ALL (16,17). There is no clinical examination yet to identify ALL injuries. Its intracapsular and oblique course is demonstrated by MRI. The incidence of ALL injuries in patients with acute ACL-knee injury have been investigated. Therefore, MRI has a very important role in the diagnosis and treatment of ALL (8).

It is accepted that ALL is best observed on coronal sections (16,17). In our study, all segments of ALL could not be shown in a single plane in coronal or axial sections. Femoral and or tibial and or meniscal segments were observed in 276 patients, but all segments were observed in a single plane in only 4 of these patients (1.25%) (Figure 2). The main reason for this is the course of the ligament. In our opinion, the other reasons why the entire course of ALL is not seen are as follows; section thicknesses (3.5-4mm) on MRI, the resolution strength of MRI, regressed tears that occurred before the shooting, or congenital agenesis.

Figure 2. Three components of ALL in a coronal view; femoral (arrow), meniscal (star), tibial (arrowhead)

Claes et al. and Kosy et al. divided the femoral origin of ALL adjacent to the LCL into three (9,12,18). These are lateral femoral, anterodistal to lateral femoral, posteroproximal to lateral femoral. In our study, it was found to be 93.1% lateral femoral, anterodistal to lateral femoral 4.7%, posteroproximal to lateral femoral lateral 0.3%. The rate of not being seen is 1.9%. These data are compatible with the literature.

In anatomical and MRI studies of ALL, the incidence of whole components was between 21.3-97.5%, partial or any part of it was between 37-97.4%, the femoral component was 59-89.7%, the meniscal component was 0-94%, and the tibial component was 39.3-94.8% (9,12,13,15,18,19). In our study, the incidence of whole components was 86.3%, partial 13.8%, femoral 98.1%, meniscal 97.4%, and tibial 87.5%. In our study, the incidence of partial was low.

According to meniscal adhesion patterns, complete type (42.5%) and bipolar type (44.4%) were most frequently observed in our study (Figure 3). In Kosy et al.'s study, inferior only was 31.9%, which was quite high compared to our series (9). The central type was 5.32% in Kosy et al. and 11.6% in our case, which was close.

Figure 3. Meniscal attachment types in coronal images: a. complete type meniscal attachment (arrow) b. central type meniscal attachment (arrow), c. bipolar type meniscal attachment (arrow) and accompanying genicular artery and vein (star), d. inferior only type meniscal attachment (arrow)

In the MRI study, Cleas et al. (12) did not state that they could not clearly distinguish ALL from the proximal lateral capsule and distally from the iliotibial band. However, in their anatomical study (18), they stated that they found no connection between ALL and ITB. Considering the length measurements of eight anatomical or MR-based studies, the length was measured 33.2-59mm, width 1.9-8.3mm, and thickness 1.3-5.6mm (7,8,13,15,18). In our study, lengths were measured by excluding the parts that interfere with the femoral collateral ligament in the proximal ALL segment and with the iliotibial band distally. The length measurement was 29.34±1.77mm, and the width was 8.02±0.59 mm. Contrary to the studies above, the thickness was made from the femoral band and was found to be 3.33±0.76 mm. As stated above, considering the length of the involved components of ALL, the measurements were evaluated in accordance with the literature.

The incidence of ALL injuries in patients with acute ACL-knee injury has been investigated. This ratio was determined by Barera et al. (16), Claes et al. (12), Kow et al. (19), Song et al. (20) Ferretti et al. (21) they were found to be 88.2%, 79%, 46%, 38.9%, and 88.2%, respectively. They suggested that these injuries often share a common mechanism of injury, characterized by excessive internal tibial torque (12,16,19-20). They assessed that a clinical ACL injury might often be accompanied by a concomitant ALL injury (12,19).

In our study, 182 patients (56.9%) with ALL damage (partial+total) and 287 patients (89.7%) with ACL damage (partial+subtotal+total) were detected. The coexistence of ALL and ACL damage (Figure 4) at the same time was 84.6%, in our study.

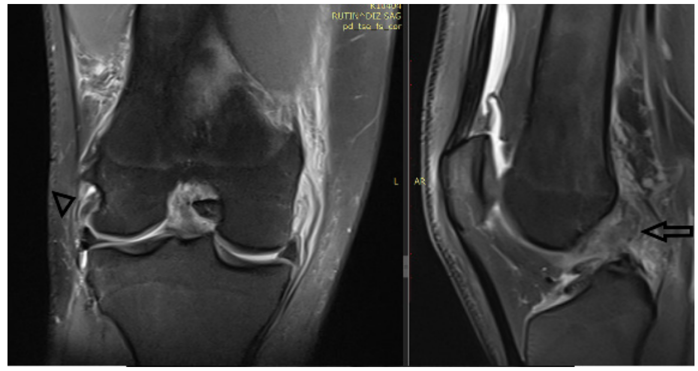

Figure 4. ALL femoral component tear (arrowhead) is seen in the coronal view. ACL rupture (arrow) is seen in the sagittal view

In most of the publications, the association of ALL damage with lateral meniscal tears was not found statistically significant (8,15,16,18). Vieira et al. stated that ALL is closely related to the lateral meniscus. ALL is important in lateral meniscus stability even in the absence of ACL damage. It can prevent anteroposterior rotation and meniscal tear during knee flexion (17). Dyck et al. found a significant association between ALL injury and tears of the lateral meniscus in their study (22). Monaco et al. suggested that if a patient with ACL tear has ALL injury, radiologists should carefully investigate whether there is a lateral meniscal tear (23).

In our study, anterior horn predominant lateral meniscus damage was detected in 162 patients (50.3%). The association of ALL damage with the lateral meniscus anterior horn (Figure 5) was found to be approximately 55.2% and this was statistically significant ($p<0.003$).

Figure 5. In the coronal image, comminuted tear (arrow) and accompanying grade 3 lateral meniscus tear (star) are observed in ALL

Some studies have found that knees with abnormal ALL have more frequent bone injuries compared to healthy knees. Interestingly, a significant correlation was found between ALL injuries and posteromedial tibial bone contusions in these studies (5,7,12). Coup or countercoup bone lesions and contusions were observed.

In our study, bone contusional damage was observed in 123 patients (38.5%). The incidence of bone damage with ALL injuries was 52.8%. This rate was found to be statistically significant (p=0.001).

In previous studies, no statistically significant relationship was found between ALL injury and MCL, LCL, PCL injury, and other structures (15,19,22). No significant relationship was found in our study either.

Our study has some limitations. The main reason for the limitation is the retrospective design of our study. We performed our MRI evaluation according to the routine departmental protocol without acquiring thin-sliced, volumetric, or oblique sequences. In the results we obtained, there is no direct correlation with MRI arthrography, the anatomical dissections of specimens, or surgical results in the patients.

However, our study may guide further clinical studies including the correlation between ALL findings and clinical instability findings in possible knee lateral ligament injuries.

CONCLUSION

There is a statistically significant relationship between acute ACL rupture, lateral meniscus injury, bone injury, and ALL injury. When evaluating MRI in patients with an ACL injury, ALL evaluation should also be performed.

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Conflict of interest: *The authors declare that they have no competing interest.*

Ethical approval: *This study was approved by the Institutional Ethics Committee of Malatya Turgut Ozal University Medicine Faculty Training and Research Hospital (20 August 2021, protocol no.,2021/66). The patients' consent was not required.*

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