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Influence of Injury to the Kaplan Fibers of the Iliotibial Band on Anterolateral Rotatory Knee Laxity in Anterior Cruciate Ligament Injury: A Retrospective Cohort Study

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Influence of the injury to the Kaplan fibers of the iliotibial band on anterolateral rotatory knee laxity in the anterior cruciate ligament injury -a retrospective cohort study-

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of Kobe University (ID No. B190055).

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4	Influence of the injury to the Kaplan fibers of the iliotibial band on anterolateral rotatory know levity in the anterior cruciate ligement injury - a retrospective cohort
$\frac{5}{6}$	study
7	Abstract
8	Background: Biomechanical cadaveric studies have shown that Kaplan fibers (KF) of the iliotibial
9	band play a role in controlling anterolateral rotatory knee laxity in anterior cruciate ligament (ACL)
10	injury. However, in the clinical setting, the contribution of injury to KF on anterolateral rotatory laxity
11	remains unclear.
12	Purpose: To investigate the effect of MRI-detected concomitant injury to KF in ACL injured knees
13	on anterolateral rotatory laxity measured by pivot-shift test in the clinical setting.
14	Study Design: Case-control study; Level of evidence, 3.
15	Methods: Ninety-one patients with primary ACL tears (age: 25 ± 11 years, 46 male/45 female) whose
16	MRI was taken within 90 days after injury, were enrolled. KF injury was assessed by MRI according to
17	the previously reported criteria, and the subjects were allocated into KF injury group and non-KF injury
18	group. At the time of ACL reconstruction, the pivot-shift test was performed under anesthesia and
19	quantitatively evaluated by tibial acceleration using an electromagnetic measurement system. Manual
20	grading of the pivot-shift test was also assessed according to the IKDC guidelines. These were statistically
21	compared between two groups using Mann-Whitney U test and Fisher's exact test ($p < 0.05$).
22	Results: KF was identified in 85 patients (93.4%), and KF injury was detected in twenty patients out of

23	85 patients (23.5%). No significant differences were observed between KF injury group ($n = 20$) and non-
24	KF injury group (n = 65) in demographic data, the period from injury to MRI (8.0 ± 14.0 vs. 8.9 ± 12.1
25	days), the rate of meniscal injury (50.0% vs. 53.8%), or the rate of anterolateral ligament injury (45.0%
26	vs. 44.6%). Regarding the pivot-shift test, no significant differences were observed in tibial acceleration
27	(1.2 [interquartile range, IQR: 0.5-2.1] m/s ² vs. 1.0 [IQR: 0.6-1.7] m/s ²) or manual grading between two
28	groups.
29	Conclusion: Concomitant KF injury did not significantly affect the pivot-shift phenomenon in acute ACL-
30	injured knees. The findings suggest that the contribution of KF injury to anterolateral rotatory knee laxity
31	may be limited in the clinical setting.
32	Key terms: anterior cruciate ligament; anterolateral complex; iliotibial band; Kaplan fibers; magnetic
33	resonance imaging; pivot-shift; anterolateral rotatory knee laxity
34	
35	What is known about the subject: Biomechanical studies have shown contribution of the Kaplan
36	fibers to anterolateral rotatory laxity while one recent clinical study has reported that KF injury was
37	not associated with higher-grade pivot-shift test assessed by manual grading in ACL injury.
38	
39	What this study adds to existing knowledge: The present study showed that concomitant KF injury
40	did not significantly affect the pivot-shift phenomenon in acute ACL-injured knees by quantifying the 3

41 pivot-shift test using an electromagnetic measurement system. The present findings suggest that the

42 contribution of KF injury to anterolateral rotatory knee laxity may be limited in the clinical setting.

Introduction

Recently, much debate ensued regarding the biomechanical function of the anterolateral complex (ALC) 45of the knee in anterior cruciate ligament (ACL) injured knees after potential impact of ALC injury on 46anterolateral rotatory laxity has been extensively discussed in the setting of ACL injury.^{12,37,41,51} The ALC 47consists of the superficial and deep aspects of the iliotibial band (ITB) with its Kaplan fiber attachments 48on the distal femur, along with the anterolateral ligament (ALL), a capsular structure within the 49anterolateral capsule, according to the statements from the International ALC Consensus Group Meeting.²¹ 50The distal femoral attachment of the ITB was originally identified by Kaplan in 1958³⁴ and later known 51as the 'Kaplan fibers (KF)'.⁹ Anatomic studies found that KF were the transverse fibers attached to the 52femoral metaphysis and in close proximity to the branches of the superior genicular artery, and in recent 53years, it has been reported that the KF have two distinct bundles attached proximally and distally.^{23,26} KF 54and their injuries can be identified on MRI,^{8,9} and the rate of the concomitant KF injury in ACL tear has 55been reported to be 17.6-60%.^{9,10,13,15,40,45} Recent biomechanical studies have indicated that KF may 56function as a secondary restraint in the ACL-deficient knees,^{27,36} and one cadaveric study reported that KF 57played a greater role in tibial internal rotation at higher flexion angle than the ALL.²⁰ These biomechanical 58studies^{20,27,36} using cadaveric knees have shown the contribution of KF to anterolateral rotatory laxity in 59the ACL-injured knees. However, one recent clinical study has shown that KF injuries were not associated 60 with a higher-grade pivot-shift in acute ACL injuries;¹³ thus the role of KF in controlling anterolateral 61

62	rotatory knee laxity remains uncertain. ACL reconstruction combined with either ALL reconstruction or
63	lateral extra-articular tenodesis may better restore anterolateral rotatory knee laxity and decrease the
64	failure rate, ^{6,22,43,48} but there is not such evidence for KF repair/reconstruction so far.
65	In the clinical setting, the pivot-shift test is a valuable manual examination to detect anterolateral
66	rotatory knee laxity ^{19,39} although this assessment is subjective and widely variable. Additionally, the pivot-
67	shift test is multifactorial, and can be influenced by ALC lesions, meniscal tears, posterior tibial slope and
68	other osseous parameters. ¹⁸ Importantly, the pivot-shift has been shown to correlate with functional
69	outcomes after ACL reconstruction ⁷ although there is not always a complete correlation between
70	biomechanical instability and clinical inferior outcomes. Recently, there are some clinically usable and
71	validated quantitative evaluation systems for assessing rotatory knee laxity during the pivot-shift
72	test, ^{29,31,42,44} and the electromagnetic measurement system (EMS) has been shown to have high diagnostic
73	reliability for the pivot-shift test. ⁴⁴ The pivot-shift phenomenon can be quantitatively measured as tibial
74	acceleration (m/s^2) using the EMS.
75	Thus, the purpose of the present study was to investigate the effect of MRI-detected concomitant
76	injury to KF in acute ACL-injured knees on pivot-shift test measured by the EMS in the clinical setting.

acceleration and have higher grade of manual pivot-shift test compared to the ACL-injured knees without

79 concomitant KF injury.

77

It was hypothesized that the acute ACL-injured knees with concomitant KF injury would increase tibial

Materials and methods

81 Subjects

The present retrospective analysis of prospectively collected data included a total of 91 patients (46 82males/45 females; mean age 25 ± 11 years) with unilateral acute primary ACL tear, who underwent 83 primary ACL reconstruction in one institution. The diagnosis of the ACL tears was made based on clinical 84 85findings and MRI, which was confirmed arthroscopically. The inclusion criteria were as follows; unilateral acute primary ACL tears; time from injury to MRI < 90 days;⁹ preoperative evaluation using the EMS. 86 The exclusion criteria were as follows: concomitant ligament procedures (medial collateral ligament, 87 88 posterior cruciate ligament, and/or posterolateral complex) or realignment procedures; contralateral knee injury; previous injury or surgery in ipsilateral knee; more than one-year period from MRI to the surgery; 89 90 MRI quality was less than 1.5-T; insufficient data of the EMS measurement. Originally, 239 patients were identified from the medical records from March 2013 to September 2020. After reviewing inclusion and 9192exclusion criteria, a total of 91 patients were enrolled in the present study (Figure 1). The study was approved by the Institutional Review Board of Kobe University (ID No. B190055). 93

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99 ACL, anterior cruciate ligament; MRI, magnetic resonance imaging; EMS, electromagnetic measurement

- 100 system; KF, Kaplan fibers.
- 101

102 Identification of concomitant KF injury

- 103 Concomitant KF injury was identified using 1.5-T or 3.0-T MRI which was taken for the diagnosis of
- 104 ACL injury. Knee MRI was performed in the supine position with the leg extended. Three-plane (sagittal,

105	coronal and axial) sequences using both proton-density-weighted images and fat-suppressed proton-
106	density-weighted images were obtained. KF injury was assessed according to the previous report by Batty
107	et al.9 by a single examiner (an orthopaedic surgeon) after confirming the inter-rater reliability. Briefly,
108	the diagnosis of injury to the KF required at least 1 direct sign of injury or at least 2 indirect signs in any
109	plane. The direct signs included (1) discontinuity of the KF and (2) femoral avulsion of the KF; Indirect
110	signs included (1) thickening and/or intrasubstance signal change of the KF, (2) focal bone marrow edema
111	at KF insertion site (posterolateral femur), (3) localized soft tissue edema in the region of the KF, and/or
112	(4) wavy appearance to the KF. ⁹
113	The examiner was blinded to the results of the pivot-shift evaluations. Based on the MRI findings, the
114	patients were allocated into two groups: KF injury group and the non-KF injury group. The manual
115	grading and the quantitative evaluations of the pivot-shift test were compared between two groups.
116	
117	Assessment of the concomitant injury of meniscus, collateral ligament and ALL
118	The meniscal injury was diagnosed by MRI and arthroscopy during the surgery, and the collateral ligament
119	injuries were diagnosed based on MRI and clinical examination. The ALL injury was assessed by MRI
120	using the previously reported method. ¹⁴ All results were blinded at the time of pivot-shift evaluation.
121	
122	Measurement of the pivot-shift test and Lachman test

123	Pivot-shift test and Lachman test were performed under general anesthesia just prior to ACL
124	reconstruction. The standardized pivot-shift test was performed by experienced surgeons as previously
125	reported. ²⁸ For the quantitative evaluation of pivot-shift test, tibial acceleration was measured using the
126	originally developed EMS (JIMI Kobe, Arthrex Japan, Tokyo, Japan) as previously described ^{2,30,31,44}
127	(Figure 2). In addition, Lachman test was also measured using the EMS, and side-to-side difference (SSD)
128	in anterior tibial translation (mm) was calculated by subtracting the value in the contralateral knee from
129	the value in the injured knee as previously reported. ³
130	Briefly, two electromagnetic sensors were secured on the thigh and shank with plastic straps. Seven
131	anatomic bony landmarks of the femur and tibia (greater trochanter, medial and lateral epicondyles, the
132	crossing point of medial joint line and the medial collateral ligament, fibular head and the medial and
133	lateral malleoli) were digitized with a probe with a sensor to register three-dimensional positions of the
134	landmarks in relation to the two sensors. The positions of the femur and tibia were then recognized based
135	on the spatial relationship between the anatomic bony landmarks and sensors. The anatomic coordinates
136	of the knee were set according to the system proposed by Grood and Suntay. ²⁴ The six degree-of-freedom
137	knee kinematics were recorded during the pivot-shift test with a sampling rate of 240 Hz. Tibial
138	acceleration (m/s^2) at the time of posterior reduction of the tibia was then calculated from the data of the
139	tibial anteroposterior translation. For the accuracy of this measurement, it is reported that the average
140	standard deviation of three repeated measurements was $0.2 \pm 0.1 \text{ m/s}^2$. ^{30,31,44}

- At the same time, manual grade of the pivot-shift test was assessed according to the International Knee Documentation Committee (IKDC) guidelines³³, and categorized as low grade (IKDC grade 0 and 1) and high grade (IKDC grade 2 and 3). The manual grading was performed blinded to the quantitative evaluation result.
- 145



- 147 **Figure 2.** The electromagnetic measurement system for the pivot-shift test. Two electromagnetic sensors
- 148 were secured on the thigh and shank with plastic straps. The anatomic coordinates of the knee were set
- 149 via electromagnetic transmitter. The acceleration of tibial reduction (m/s^2) was calculated.
- 150

151 Statistical Analysis

152 All analyses were performed using StatView 5.0 (Abacus Concepts Inc., Berkeley, CA, USA). Shapiro-

153	Wilk test was used to assess normal distribution of each parameter. Mann-Whitney U test was used to
154	compare tibial acceleration between KF injury group and non-KF injury group. Fisher's exact test was
155	used to compare the manual grading of the pivot-shift test between the two groups. Statistical significance
156	was set at $p < 0.05$. The mean \pm standard deviation (SD) was reported for the data with normal distribution.
157	The median and interquartile range (IQR) was reported when the data was not normally distributed.
158	Inter-rater reliability of the KF injury diagnosed by MRI was assessed using complete cohorts by two
159	orthopaedic surgeons. The Cohen's κ coefficient for categorical variables was calculated. ³⁸ Agreement
160	rate (percentage of all inter-observer comparisons with agreement/disagreement on a parameter) was also
161	reported. κ values were classified as described by Landis and Koch, with values of 0–0.20, slight
162	agreement; 0.21–0.40: fair agreement; 0.41–0.60: moderate agreement; 0.61–0.80: substantial agreement;
163	and 0.80–1.00: excellent agreement. ³⁸
164	An a priori power calculation was performed using G*Power 3.1.9.4 (Franz Paul, Kiel, Germany)
165	based on the past studies that used the EMS to quantify the pivot-shift test. ⁴⁴ A prior power analysis
166	showed that a total sample size of 84 knees was required to detect a difference in acceleration of the tibia
167	of 0.5 m/s ² during pivot shift using Mann-Whitney U test (effect size $d = 0.80$) at a power and significance
168	level of 0.80 and 0.05, respectively (Supplemental Figure 1, 2). A difference of 0.9 m/s ² in acceleration
169	was assumed to be clinically significant as previously reported.44

Results

172	KF was identified in 93.4% (85/91 cases) of the cases. In six cases, KF was not entirely visualized in the
173	MRI. No significant difference was observed in the rate of KF identification between 3.0-T MRI (93.5%,
174	29/31 cases) and 1.5-T MRI (93.3%, 56/60 cases) (Pearson's chi-squared test, $p = 0.78$). Twenty of 85
175	patients (23.5%) were diagnosed with KF injury by MRI. Typical images of KF injury are shown in Figure
176	3 . In KF injury group ($n = 20$), eleven cases (55%) fulfilled one direct sign and nine cases (45%) fulfilled
177	two indirect signs.
178	The rate of KF injury was not significantly different between 3.0-T and 1.5-T MRI (24.1% vs
179	23.2%, $p = 0.92$). In terms of inter-rater reliability of KF injury diagnosis, the agreement rate of the
180	presence of KF injury between two examiners was 92.9% and Cohen's κ coefficient was 0.797, which is
181	considered to be substantial agreement ³⁸ (Table 1).
182	Patient demographics of KF injury group ($n = 20$) and non-KF injury group ($n = 65$) are
183	summarized in Table 2. There were no significant differences in age, sex, the period from injury to MRI
184	$(8.0 \pm 14.0 \text{ days vs. } 8.9 \pm 12.1 \text{ days, } p = 0.78)$, injury pattern (contact or non-contact), medial meniscus
185	injury rate (30.0% vs. 32.3%, p = 0.85), lateral meniscus injury rate (35.0% vs. 40.0%, p = 0.69), medial
186	collateral ligament injury, lateral collateral ligament injury, and ALL.
187	No significant difference was observed in tibial acceleration during the pivot-shift test between

188 KF injury group (median 1.2 m/s², IQR: 0.5–2.1) and non-KF injury group (median 1.0 m/s², IQR: 0.6–

189	1.7) ($p = 0.73$, Figure 4). In addition, there was no significant difference in manual grading of the pivot-
190	shift test between the two groups (Table 3 , $p = 0.06$). No significant difference was also observed in SSD
191	in anterior tibial translation during the Lachman test between KF injury group (median 4.3 mm, IQR: 0.8-
192	7.4) and non-KF injury group (median 6.4 mm, IQR: 4.4–9.6, p = 0.06).
193	

Table 1. Inter-rater agreement on diagnosing Kaplan fibers injury with all subjects

			Examiner 1		
			Kaplan fibers injury +	Kaplan fibers injury –	Total
	Examiner 2	Kaplan fibers injury +	16	2	18
		Kaplan fibers injury –	4	63	67
		Total	20	65	85
196					
197					
198					
199					
200					
201					

	KF injury group	non-KF injury group	\mathbf{p} value ^b	
	(n=20)	(n=65)	p value	
A an at time of initial (many)	27.6 ± 12.6	25.0 ± 11.3	0.41	
Age at time of injury (years)	(range, 13–55)	(range, 11–59)	0.41	
Sex (male / female)	9 / 11	35 / 30	0.49	
Derived from injury to MPI (days)	8.0 ± 14.0	8.9 ± 12.1	0.78	
r chod from injury to wiki (days)	(range, 1–63)	(range, 0–50)		
Period from MRI to surgery (days)	67.3 ± 49.5	69.1± 55.7	0.83	
Injury pattern (contact / non- contact)	5 / 15	16 / 49	0.97	
Medial meniscal injury (yes / no)	6 / 14	21 / 44	0.85	
Lateral meniscal injury (yes / no)	7 / 13	26 / 39	0.69	
Medial collateral ligament injury	4 (20.0%)	11 (16.9%)	0.54	
(Grade 1/2/3)	3 / 1 / 0	5 / 6 / 0	0.54	
Lateral collateral ligament injury	1 (5.0%)	0 (0%)	0.07	
(Grade 1/2/3)	1 / 0 / 0	0 / 0 / 0	0.07	
Anterolateral ligament injury	9 (45.0%)	29 (44.6%)	0.98	

202 **Table 2.** Patient demographics and baseline characteristics^a

^aKF, Kaplan fibers. MRI, magnetic resonance imaging.

^{*b*}Statistical significance: p < 0.05.





206 (D, E, F) There is diffuse edema around KF with signal changes and thickening (indirect signs, white

207 arrow).

- 208 KF, Kaplan fibers; ACL, anterior cruciate ligament.





Figure 4. Comparison of tibial acceleration during the pivot-shift test between the KF injury and non-KF

- 214 injury groups.
- 215 There was no significant difference between the groups.
- 216 ns, not significant; KF, Kaplan fibers.
- 217
- **Table 3**. Manual grading of the pivot-shift test in KF-injury group and non-KF injury group^{*a*}

		Kaplan fibers			
	-	Injury group	Non-injury group	Total	p value
Pivot-shift test	Low grade (0 / 1)	9 (45.0%) (0 / 9)	45 (69.2%) (1 / 44)	54 (63.5%) (1 / 53)	0.06
	High grade (2 / 3)	11 (55.0%) (11 / 0)	20 (30.8%) (18 / 2)	31 (36.5%) (29 / 2)	
	Total	20	65	85	

^{*a*}KF, Kaplan fibers.

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Discussion

221	The main finding of the present study was that concomitant injury to KF did not have a significant
222	impact on anterolateral rotatory laxity measured by quantifying the pivot-shift test using the EMS in the
223	acute ACL-injured knees. This finding is in line with the recent clinical study showing that KF injury was
224	not associated with a higher-grade pivot-shift test, assessed by manual grading. ¹³ In addition, there were
225	no differences in the injury patterns or in the existence of the concomitant injuries to collateral ligament,
226	meniscus, and/or ALL between the KF injury group and non-KF injury group. Thus, in the clinical setting
227	the contribution of KF injury on anterolateral rotatory knee laxity may be limited in ACL injury in contrast
228	to the previous biomechanical studies showing significant contribution of the KF on anterolateral rotatory
229	knee laxity. ^{20,36}
230	Recently, potential impact of anterolateral complex (ALC) injury on anterolateral rotatory laxity has
231	been extensively discussed in the setting of ACL injury. ^{4,5,12,16,22,25,26,35} The ALC consensus group meeting
232	stated that the ALC consists of the superficial and deep aspects of the ITB with its KF attachments on the
233	distal femur, along with the ALL, a capsular structure within the anterolateral capsule. ²¹ In 1958, Kaplan ³⁴
234	originally described the layers and attachments of the ITB to the femur. In 1976, Hughston et al. ³²
235	described "lateral capsular ligament", and in 1986, Terry et al. ⁴⁹ classified the ITB into the aponeurotic

236 layer, the superficial layer, the middle layer, the deep layer and the capsule-osseous layer, and the KF has

shown to be included in the deep layer. In 1993, they also reported that the injury to the capsule-osseous
layer of the ITB in ACL-deficient knees was significantly correlated with the grading of the pivot-shift
test.⁵⁰ Descriptions of the ALC anatomy are confused by overlapping nomenclature.²¹ Vieira et al.⁵² are
often attributed to being the first to describe the ALL, although this was the same name that Terry et al.
used to describe the capsule-osseous layer of the ITB.

242One biomechanical study has shown that the deep and capsule-osseous layer of the ITB, which includes KF, contributed to the restraint of internal rotation in ACL-deficient knees at all range of motion 243 $(0^{\circ}, 30^{\circ}, 60^{\circ}, 90^{\circ})$, and internal rotation in simulated pivot-shift test.³⁶ A different biomechanical study has 244245shown that in ACL-deficient knees, the contribution of KF to internal rotation was greater than ALL, particularly at knee flexion deeper than 60° .²⁰ However, the present clinical study did not show significant 246247influence of KF injury on anterolateral rotatory knee laxity contrary to the hypothesis. One recent clinical study also showed that injury to KF did not result in a higher manual grade of the pivot-shift test with 267 248patients with ACL-injured knees.¹³ In contrast to the study by Devitt et al, the novelty of the present study 249was that the pivot-shift test was quantitatively evaluated using the EMS; despite precise assessment of the 250pivot-shift test, no significant differences were observed between KF injury and non-KF injury groups, 251which supports the previous report.¹³ Moreover, the incidence of ALL injury was not significantly different 252between two groups, and confounding by ALL injury would be minimal in the present study. 253

Although MRI would be a useful tool in identifying the structure of the ALC, KF injury diagnosed

255	by MRI may not be an indication for additional procedures such as lateral extra-articular tenodesis based
256	on the current findings whereas some have reported inferior outcomes after ACL reconstructions with
257	ALL injury diagnosed with preoperative MRI. ^{11,47} A discrepancy between biomechanical study and
258	clinical study could include potential healing of the soft tissue structures in the interval between MRI and
259	physical examination. Moreover, it is worth mentioning that in the biomechanical model of ALC injury
260	including KF injury, an extensive cutting of not only anterolateral capsule and ALL but also the KF
261	attachment of the ITB is performed to create the worst-case scenario of injury, and this might be at least
262	one reason for the discrepancy between biomechanical findings and clinical findings.
263	Regarding the identification of KF on MRI, Batty et al. ⁸ reported that intact KF could be identified
264	in 96% of intact ACL knees on the sagittal slice of 3.0-T MRI, which was similar with the identification
265	rate in the present study (93.4%). The rate of the KF injury varies among the previous reports ranging
266	from 17.4% to 53.8% (Table 4). ^{9,10,13,15,40,45} Importantly, only one study investigated the association
267	between KF injury and anterolateral rotatory knee laxity among these studies. The wide spectrum of the
268	injury rate could be partially attributable to the different diagnosis criteria, different inclusion criteria,
269	and/or different MRI protocol. This is similar to the reports related to ALL injury with the high variability
270	in the identification of normal and injured ALL definition and the respective MRI findings. ¹ The injury
271	rate of the ALL has been reported to range from 11 to 88%. ^{1,17} It has been described that hemorrhage in
272	the region of the KF can be observed during surgical exploration, ^{16,50} but these studies did not explicitly

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273	describe the disruption to the continuity of the KF. The present study used rigorous diagnostic criteria
274	described by Batty et al, ⁹ in which the presence of soft tissue edema around the KF was only one factor,
275	and it needed to be associated with at least one other direct or indirect sign of injury of the KF. Devitt et
276	al. ¹³ emphasized that it is crucial not to assume that the presence of hemorrhage or edema alone on MRI
277	heralds serious structural damage to the ALC of the knee. In terms of magnetic strength of MRI, no
278	significant difference was observed in the identification rate of KF or the rate of KF injury between 1.5-T
279	and 3.0-T MRI in the present study, suggesting that diagnosis of injury to KF is feasible with 1.5-T MRI.
280	There are several limitations in the present study. Firstly, the MRI scans in the present study were
281	from various sources with differing protocols. However, we believe that this scenario does reflect the
282	current realities for orthopaedic surgeons evaluating MRI scans in the day by day clinical practice.
283	Secondly, the bony morphology, which might have affected the results of pivot-shift (i.e. posterior tibial
284	slope), was not assessed and compared in the present study. Thirdly, the pivot-shift tests were performed
285	by four surgeons. However, it was performed by experienced surgeons in a standardized technique, which
286	reduced inter-examiner variability. ²⁸ Thus, inter-examiner variability would have been minimized. Fourth,
287	KF injury may have healed in some cases during the period between the MRI and clinical evaluations
288	under anesthesia, which may have affected the results of the pivot-shift test. However, no significant
289	correlations were found between the period from MRI to surgery and tibial acceleration during the pivot-
290	shift test (single linear regression analysis, $R = 0.11$, $p = 0.30$), suggesting the influence of period from

291	MRI to surgery would be minimal. Moreover, healing potential of the KF is still unknown as the recent
292	study has shown that the ALL has limited intrinsic healing potential. ⁴⁶ Fifth, there is inherent bias from
293	the retrospective nature of the methodological design in the present study. Lastly, a post hoc power analysis
294	of Fisher's exact test showed that actual power was 0.52, which suggested the analysis of the manual
295	grading of the pivot-shift test was underpowered, although the present comparison of tibial acceleration
296	between two groups had sufficient power (Supplemental Figure 2).
297	The strength of the present study is that anterolateral rotatory knee laxity was quantitatively evaluated
298	by using EMS during the pivot-shift test, and compared between KF injury and non-KF injury groups.
299	The present findings showed that no significant effect of the KF injury on anterolateral rotatory knee laxity
300	was observed in the clinical setting.
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309 **Table 4**. Comparison between the present study and the previous studies in terms of Injury rate of KF in

310 ACL tears^a

Lead author	MRI	Period from injury to MRI	KF injury rate
Van Dyck P ¹⁵	3.0-T	< 6 weeks	33%
Batty LM ⁹	3.0-T	< 90 days	23.7%
Marom N ⁴⁰	3.0 or 1.5-T	< 6 weeks	Proximal KF: 50-58% Distal KF: 46-60%
Devitt BM ¹³	3.0 or 1.5-T	< 60 days	17.6%
Runer A ⁴⁵	3.0-T	Not reported	21.3%
Berthold DP ¹⁰	3.0 or 1.5-T	< 3 months	35.6-53.8%
The present study	3.0 or 1.5-T	< 90 days	22.0%

^{*a*}KF, Kaplan fibers. ACL, anterior cruciate ligament. MRI, magnetic resonance imaging.

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Conclusion

The KF injury was detected in 22.0% of acute ACL-injured knees using MRI. Concomitant KF injury did not significantly affect the pivot-shift phenomenon in acute ACL-injured knees. The findings suggest that the contribution of KF injury to anterolateral rotatory knee laxity may be limited in the clinical setting.

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