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No difference in postoperative rotational laxity after ACL reconstruction in patients with and without anterolateral capsule injury:

Quantitative evaluation of the pivot-shift test at one-year follow-up

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No difference in postoperative rotational laxity after ACL reconstruction in patients with and without anterolateral capsule injury:

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Abstract

Purpose To compare rotational laxity in anterior cruciate ligament (ACL)-reconstructed knees retrospectively with and without concomitant anterolateral capsule (ALC) injury confirmed by magnetic resonance imaging (MRI) prior to ACL reconstruction.

Methods Sixty-two ACL-reconstructed knees (26 men, 36 women; median age, 20 (range, 13–59) years) were included. Pivot-shift test was performed before ACL reconstruction and 1 year postoperatively under anaesthesia with both clinical grading and quantitative measurement simultaneously. Clinical grading was determined according to the International Knee Documentation Committee (IKDC) criteria (none, glide, clunk, or gross), and an electromagnetic measurement system was used to provide tibial acceleration as a quantitative parameter. Presence of concomitant ALC injury was confirmed retrospectively by MRI. The pivot-shift test was compared between ACL-reconstructed knees with and without ALC injury using Pearson's chi-squared test for clinical grading and the independent *t*-test for quantitative evaluation.

Results ALC injury was identified in 26 of 62 (42%) knees. Before ACL reconstruction, there was no difference in the pivot-shift test results between the ACL-deficient knees with and without ALC injury in IKDC grading (n.s.) or tibial acceleration (1.1 ± 0.7 m/s^2 and 1.4 ± 1.1 m/s^2, respectively, n.s.). At 1 year postoperatively, no difference was observed between groups (IKDC, p=0.90; tibial acceleration, 0.6 ± 0.3 m/s^2 and 0.8 ± 0.6 m/s^2, n.s.).

Conclusions Concomitant ALC injury at the time of ACL injury had no effect on the rotational laxity of the knee in the postoperative course after ACL reconstruction. Therefore, additional treatment for ALC injury may not be warranted.

Level of evidence Cross-sectional study, Level IV

Keywords Anterior cruciate ligament; ACL reconstruction; Anterolateral capsule; Pivot-shift test; Quantitative measurement; MRI; Electromagnetic measurement system

Introduction

Post-surgical residual rotational laxity is still observed even after recent improvements in anterior cruciate ligament (ACL) reconstruction. Crawford et al. demonstrated clunk or gross pivot-shift in 0% to 20% of ACL-reconstructed patients [4], while there was an even higher rate of remaining pivot-shift, as high as 59%, reported in the comparison study between single- versus double-bundle ACL reconstructions [5]. One of the possible reasons for the residual postoperative rotatory instability is concomitant injury of the secondary restraints against rotational laxity. Nevertheless, the identity of the anatomic structures that are the secondary restraints remains a matter of debate.

The anterolateral capsule (ALC) complex was once suggested as the secondary restraint providing rotational knee joint stability [3, 29, 30]. However, growing concern over the biomechanical function of the ALC has been raised by some cadaveric studies [25, 29]. In vivo studies examining the impact of concomitant ALC injury on rotational laxity after ACL reconstruction are needed to provide more clinically relevant evidence; however, this has been impractical, primarily because of the lack of objective and sensitive evaluations of rotational laxity. Only a few quantitative evaluation systems for pivot-shift are readily applicable to clinical research, and an electromagnetic measurement system providing tibial acceleration of pivot-shift has already shown no effect of ALC injury on rotational laxity in ACL-injured knees preoperatively [18].

Nevertheless, even without initial impact on the pivot-shift in the ACL injured knees, ALC injury could have long-term detrimental effects on the rotational laxity in ACL-reconstructed knees. Therefore, the purpose of this study was to compare rotational laxity in ACL-reconstructed knees with and without concomitant ALC injury as determined by magnetic resonance imaging (MRI) before ACL reconstruction. It was hypothesized that knees with concomitant ALC injury would have larger pivot shift postoperatively, compared to those without ALC injury. The effect of concomitant ALC injury in the ACL injured knee on the pivot-shift in the postoperative course is not yet well understood and should be considered for the appropriate treatment of concomitant ALC injury at the time of ACL reconstruction.

Materials and methods

Patients who underwent primary ACL reconstruction at a single hospital between 2014 and 2017 were prospectively enrolled. Patients with concomitant fractures, cartilage injuries, posterolateral corner injuries, and other knee ligament injuries, including those of the medial collateral ligament and posterior cruciate ligament, in the ipsilateral or contralateral knee, were excluded.

Patients were treated according to the clinical standard of care in the institution. After ACL injury was diagnosed clinically, with confirmation by MRI, ACL reconstruction was scheduled and then performed using an anatomic reconstruction technique [1]. Just prior to the index ACL reconstruction, the pivot-shift test was performed under anaesthesia and evaluated clinically and quantitatively in ACL-deficient knees. Meniscal repair or meniscectomy was added depending on the condition of the meniscus. No additional treatment for ALC injury was performed. Forty anatomical double-bundle reconstructions using hamstrings tendon autograft and 22 anatomical single-bundle reconstructions using either hamstrings tendon autograft (20 cases) or bone-patellar-tendon bone autograft (2 cases) were performed.

At around 1-year follow-up, the patients underwent post-screw removal surgery and second look arthroscopy as per clinical routine. The pivot-shift test evaluations were repeated under anaesthesia for follow-up surgery.

Pivot-shift evaluations

The clinical grading of the pivot-shift test was determined according to the International Knee Documentation Committee (IKDC) form: none (−), glide (+), clunk (++), or gross (+++). Grading was performed by a single examiner who was blinded to the quantitative evaluation result and the concomitant ALC injury status determined by MRI.

For the quantitative evaluation of the pivot-shift test, tibial acceleration was measured using an electromagnetic system (JIMI Kobe, Tokyo, Arthrex Japan) as previously described [1, 13, 22] (Fig. 1). This system includes a transmitter that produces electromagnetic fields and three electromagnetic receivers. Two of the receivers were firmly attached to the thigh and calf with a plastic brace and were used to track femoral and tibial motion, respectively. The third receiver was used to register seven anatomic landmarks of the femur and the tibia. The three-dimensional positions of the femur and the tibia were recognised in a virtual space based on the registered landmark locations. Each femoral and tibial coordinate system was then configured to provide the six degrees of freedom of knee joint kinematics, as described by Grood and Suntay [8].

The tibial acceleration of the pivot-shift was calculated by the second derivative of anteroposterior translation velocity over time during the pivot-shift test [13]. The accuracy of this system was surveyed by Hoshino et al. [13]; the average standard deviation of three measurements was 0.2 ± 0.1 m/sec^2.

The clinical grading and quantitative evaluation of the pivot shift test was compared in ACL-reconstructed knees with and without concomitant ALC injury at two time points, i.e. before ACL reconstruction and 1 year subsequently.

Diagnosis of concomitant ALC injury

The existence of a concomitant ALC injury was determined on MRI taken before ACL reconstruction to diagnose the ACL injury, retrospectively, after the measurements without knowing either clinical or quantitative evaluations of the pivot-shift. Magnetic resonance images were obtained using an Ingenia 3.0 T, Philips Medical System, Best, the Netherlands. Three-dimensional sequences (sagittal, coronal, and axial plane) using both proton density and fat-suppressed weighted images, with a slice thickness of 3 mm were obtained. The MRI diagnosis was conducted by a single examiner using the methods of Helito et al. [10], because the agreement of MRI diagnosis between examiners was only fair with the concordance ratio of 58.5% according to the previous report [18].

The clinical and the quantitative evaluations of the pivot-shift was compared between the ACL deficient knees with and without concomitant ALC injury in the statuses of pre-ACL reconstruction and 1-year follow-up after the ACL reconstruction.

Our study design and method were approved by the Institutional Review Board of Kobe University (ID No. B190055).

Statistical analysis

The measurement data was retrospectively collected and analysed. All analyses were performed using SPSS (SPSS Inc., Chicago, IL, USA). An independent *t*-test was used to compare tibial acceleration between the groups with and without a concomitant ALC injury. The Pearson's chi-squared test was used to evaluate between-group differences in the clinical grading of the pivot shift test. Statistical significance was set at $p < 0.05$ for two-sided test.

An a priori power calculation was performed based on past studies that used an electromagnetic system to quantify the pivot-shift test [13, 18, 22]. To detect a difference in rotational acceleration of the tibia of 0.5 m/s^2 during pivot shift, using a two-sided Student's *t*-test for between group comparisons, at a power and significance level of 0.90 and 0.05, respectively, a total sample size of 46 knees was required. Informed consent was obtained from all individual participants included in this study. A difference of 0.5 m/sec^2 was assumed to be clinically meaningful because it is the average side-to-side difference of a grade (+) pivot-shift patient in the original report of acceleration measurement using a similar system [13].

Results

After obtaining informed consent, 62 patients (26 men and 36 women, mean age of 25.6 ± 11.8 years) were included in the analysis. Patient demographics are detailed in Table 1. There were no statistically significant difference between groups in gender, age, concomitant meniscus injury, surgical technique, and time from injury to surgery.

ALC injury was identified in 26 of 62 knees. Results of the preoperative clinical grading of the pivot-shift test were as follows: glide (+) in 33 patients, clunk (++) in 26 patients, and gross (+++) in three patients. By comparison, at the 1-year follow-up, the test was negative (-) in 50 patients, with glide (+) detected in the other 12 patients. There were no differences in the clinical grading of the pivot-shift tests between the ACL-reconstructed knees with and without ALC injury (n.s.; Table 2). The clinical grading of the pivot-shift test significantly improved pre- to postoperatively in both groups.

The tibial acceleration during the pivot shift test was similar in ACL-reconstructed knees both with and without concomitant ALC injury before surgery (1.1 ± 0.7 m/s^2 and 1.4 ± 1.1 m/s^2, respectively, n.s.; Fig. 2). Similarly, there were no significant differences in tibial acceleration between the groups at the 1-year follow-up (0.6 ± 0.3 m/s^2 and 0.8 ± 0.6 m/s^2, respectively, n.s.; Fig. 3).

Discussion

The most important finding of the current study was that concomitant ALC injury did not have a significant impact on the rotational laxity of ACL-reconstructed knees at 1 year after ACL reconstruction. In a previous study [18], although ALC injury could not be consistently detected on MRI, there was no effect of the preoperative ACL-deficient knee on rotational laxity, measured using an electromagnetic measurement system to perform the pivot-shift test [18]. The current study confirmed this finding, and further demonstrated no effect of the ALC injury on rotational laxity after ACL reconstruction.

The plausible contribution of ALC injury to rotational stability of the knee after ACL reconstruction has been proposed in various studies [4, 5, 29, 30]. Specifically, the existence of the anterolateral ligament (ALL) has been debated, with the ALL and ALC considered anatomically synonymous [9]. Kittl et al. suggested that the ALC played a relatively minor role in restraining rotation stability of the knee [14]. Moreover, Schon et al. recently demonstrated an over-constraint knee kinematics in terms of axial rotational angle after combined ACL and ALL reconstruction [24]. By comparison, a recent clinical preoperative study demonstrated that ALC injury, concomitant with ACL rupture, induced a larger pivot-shift [26, 27]. Nevertheless, the postoperative effect of a concomitant ALC injury has not been previously evaluated. Moreover, the natural course of concomitant ALC injury remains unknown; spontaneous healing of the ALC might be possible after reconstruction. Of note, as these previous studies did not include a reliable measurement of knee joint rotational laxity, clinical assessment of the pivot-shift test is subjectively determined and resulted in a wide variation in terms of final judgement and knee movements [15, 20, 23]. Therefore, translation of these results to clinical practice should be done cautiously.

Various non-invasive devices have been developed to quantify knee laxity during the pivot shift test. These include the electromagnetic measurement device we used in this study, the KiRA system, which uses triaxial accelerometers [2], an iPad [12, 19], and a navigation system [17]. The effect of the ALC injury on the rotatory knee laxity in the ACL deficient knees has been examined in preoperative condition using some pivot-shift measurement systems, providing controversial results. iPad evaluation of the lateral compartment translation detected increases in lateral translation during the pivot-shift due to the concomitant ALC injury in the ACL-deficient knee [21], while tibial acceleration of the pivot-shift as measured by the electromagnetic system was not detected [18]. The pivot-shift is not a simple movement; it could be evaluated by several modalities, including translation, rotation and acceleration. Pivot-shift evaluation by translation or rotation might detect some effect of concomitant ALC injury on the rotational laxity in ACL-reconstructed knees. However, it was reported that the acceleration correlates best with the clinical grading of the pivot-shift [16]. Little effect of concomitant ALC injury on pivot-shift in ACL-reconstructed knees suggests the possibility of practicing conservative treatment, i.e. leaving in situ even when identified, for this injury. According to recently published consensus statements on the ALC [7], there is no indication for additional extraarticular augmentation, including ALL reconstruction, to the ACL reconstruction [7]. Concomitant ALC injury confirmed by the MRI does not necessitate the additional procedure on top of the ACL reconstruction.

The limitations of the current study should be acknowledged prior to application of our results in practice. First, it there was a short follow-up period: 1 year after reconstruction. Therefore, the long-term clinical effects of ALC injury on knee joint stability remain unknown. Second, during ACL reconstruction, a separate exposure of the ALC was not performed to substantiate the MRI findings. Nevertheless, considering the lack of difference in preoperative rotational laxity between ACL-injured knees with and without ALC injury, an additional investigation for ALC injury may not be warranted. Furthermore, the diagnosis of ALC injury on MRI is relatively poor and varied between examiners [6, 11, 28]. MRI examination in our study was conducted by a single examiner. With respect to MRI detection of the ALC, Helito et al. reported that the ALL could be identified in 97.4% of cases [11], while Taneja et al. reported a detection rate of only 51% [28]. Therefore, the diagnosis rate of an ALC injury concomitant with ACL rupture using MRI may be highly susceptible to the quality of the image and the examiner's experience. Therefore, a single examiner was utilised in this study to avoid inter-examiner variability. Finally, two types of ACL reconstruction, i.e. single-bundle and double-bundle, were utilised according to our standard clinical practice, without consideration of the diagnosis (or non-diagnosis) of ALC injury on MRI. Nevertheless, no differences were observed in terms of rotational laxity between the ACL-reconstructed knees with and without ALC injury at 1-year follow-up. Based on the current study findings, any additional treatment of ALC injury may not be necessary to improve the rotatory stability even when ALC injury is detected on MRI.

Conclusions

MRI-based assessment of ALC injury, concomitant with ACL rupture, had no effect on the rotational laxity of the knee over the 1-year postoperative course after ACL reconstruction. Therefore, additional treatment for ALC injury may not be warranted.

Conflict of Interest

The authors have no conflicts to disclose.

Author contributions

YH designed the study and wrote the initial draft of the manuscript. YH, NM, TT, DA, and TM contributed to analysis and interpretation of data, and assisted in the preparation of the manuscript. YH, NM, TT, DA, KN, TM and RK contributed to data collection and interpretation, and critically reviewed the manuscript. All authors approved the final version of the manuscript and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee (the Institutional Review Board of Kobe University (ID No. B190055) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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Figure legends

Fig. 1 Electromagnetic measurement system for the pivot-shift test.

Two of the receivers were firmly attached on the thigh and the calf with a plastic brace. The six degree-of-freedom knee kinematics were recorded based on the relative motion between sensors and were used to calculate tibial acceleration.

Fig. 2 The pre-operative tibial acceleration during the pivot shift test. There was no statistically significant difference between the groups (n.s.).

Fig. 3 Tibial acceleration during the pivot shift test at one-year follow-up. There was no statistically significant difference between the groups (n.s.).

Table 1. Demographic data

	All cases	ALC (+)	ALC(-)	p-value
Gender (male/female)	26/36	9/17	17/19	n.s.
Age (years)	25.6±11.8	26.8±12.1	24.8±11.4	n.s.
Delay from injury to surgery (days)	330±778	204±408	393±648	n.s.
ACL reconstruction procedure (double/single/bone-patella tendon-bone)	40/20/2	15/10/1	25/10/1	n.s.
Meniscal tear (medial/lateral)	20/24	8/12	12/12	n.s.

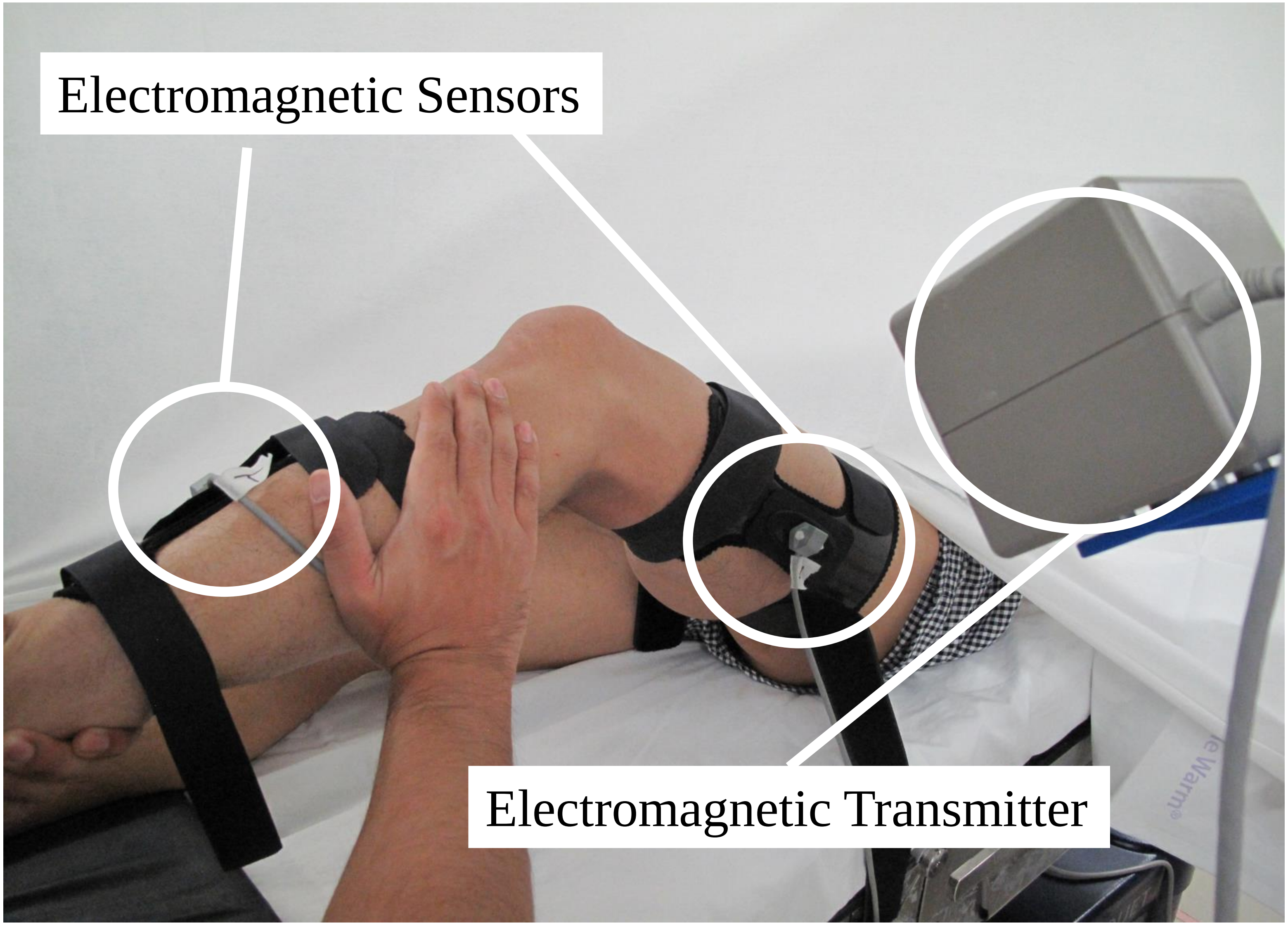
ACL, anterior cruciate ligament; ALC(+), Cases with concomitant ALC injury; ALC(-), Cases without concomitant ALC injury; p-value was calculated in comparison between ALC(+) and ALC(-) groups.

Table 2. Clinical grading of the pivot shift test, preoperatively and at 1-year follow-up

		Pre-operative		**1-year follow-up**	
		ACL injured knee with concomitant ALC injury	**ACL injured knee without concomitant ALC injury**	**ACL reconstructed knee with concomitant ALC injury**	**ACL reconstructed knee without concomitant ALC injury**
Clinical Grading	**None (-)**	**0**	**0**	**22**	**28**
	Glide (+)	**13**	**20**	**4**	**8**
	Clunk (++)	**12**	**14**	**0**	**0**
	Gross (+++)	**1**	**2**	**0**	**0**

The clinical grade on the pivot shift test was similar in the ACL reconstructed knees with and without ALC injury. In both groups, the clinical grading in the pivot-shift test significantly improved pre- to postoperatively. ACL, anterior cruciate ligament; ALC, anterolateral knee joint capsule.

Figure



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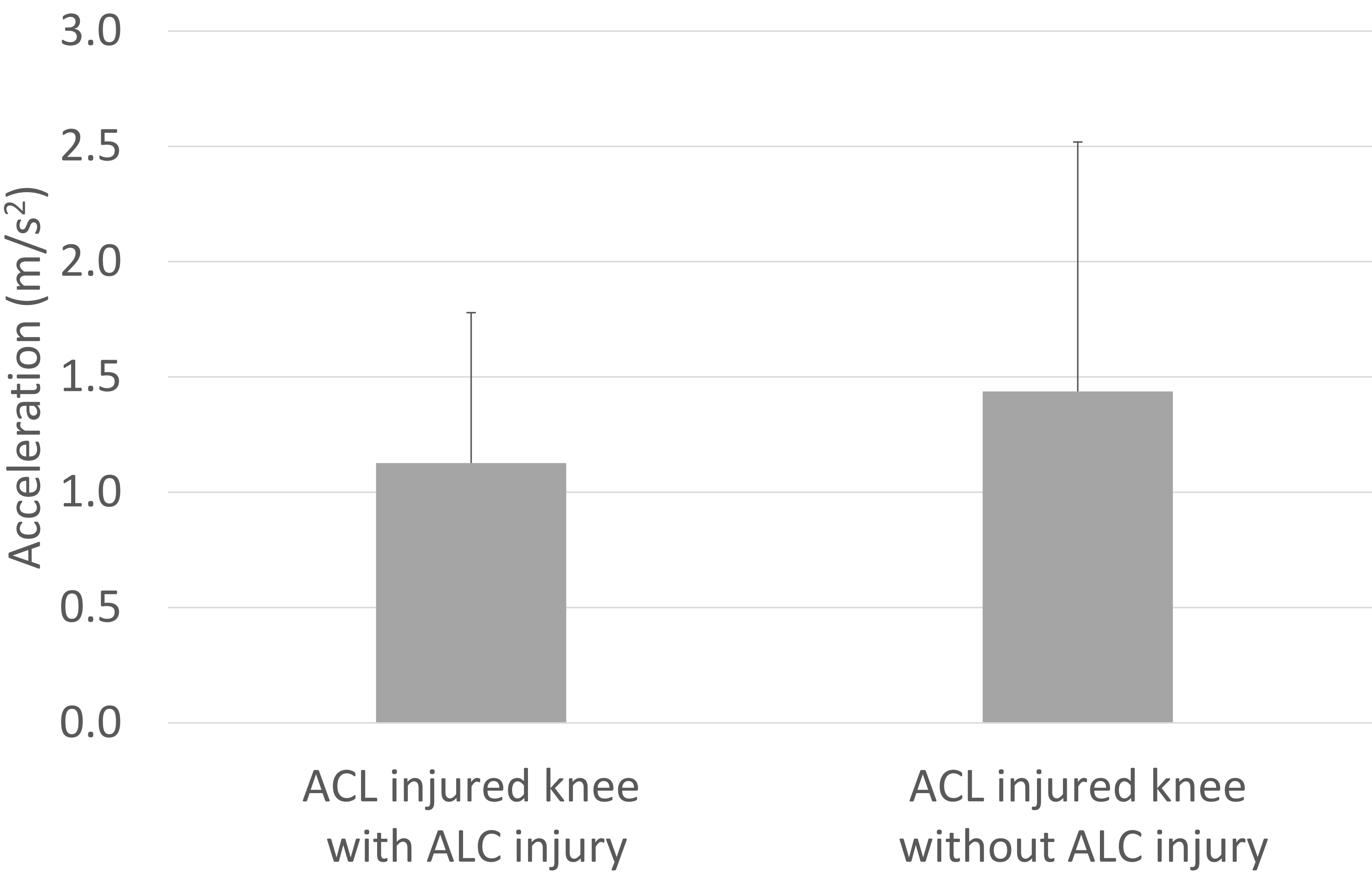

Fig. 2 The pre-operative tibial acceleration during the pivot shift test. There was no statistically significant difference between the groups (n.s.).

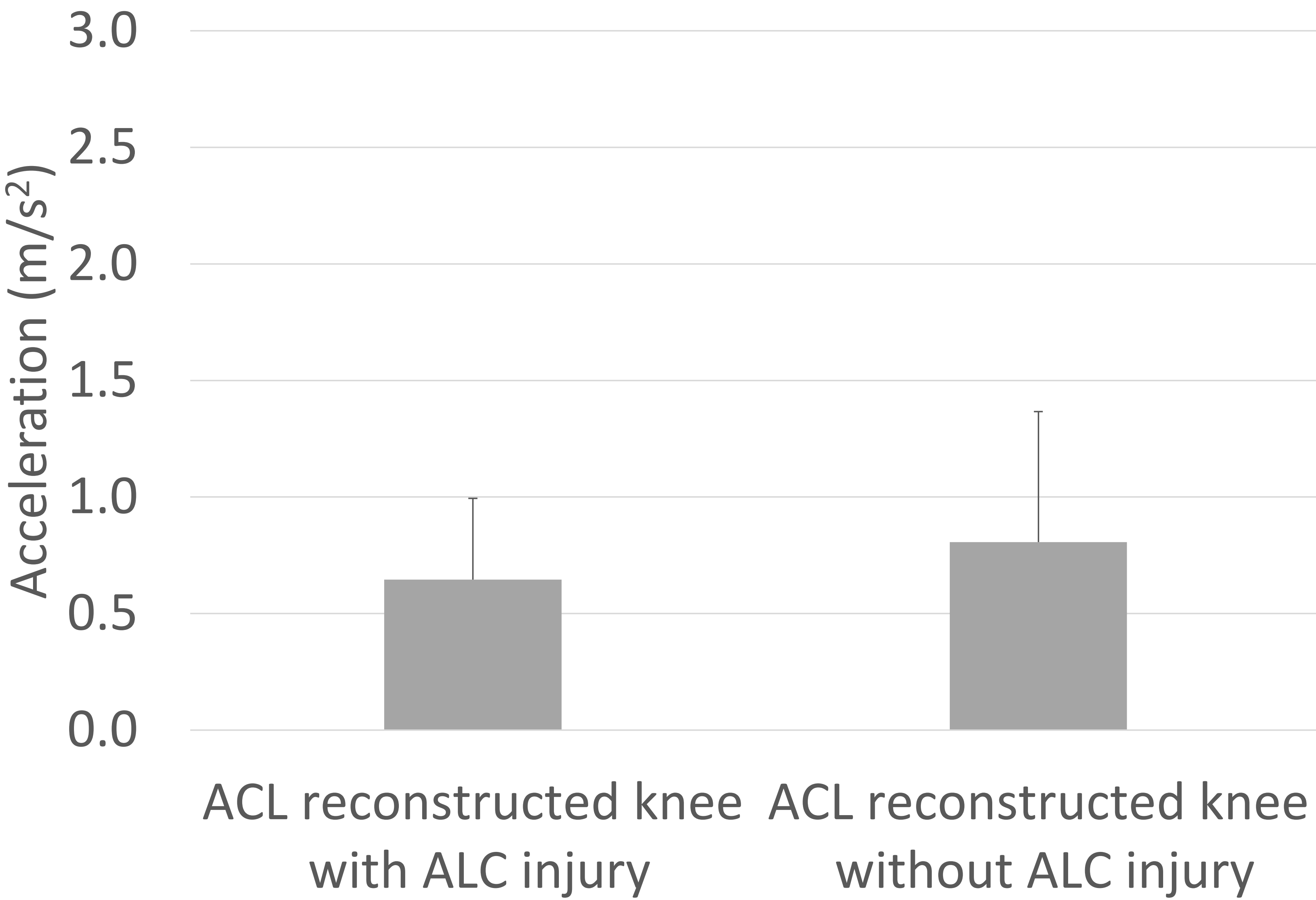

Fig. 3 Tibial acceleration during the pivot shift test at one-year follow-up. There was no statistically significant difference between the groups (n.s.).