

The pivot shift: a global user guide

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Received: 29 November 2011 / Accepted: 21 December 2011 / Published online: 1 January 2012
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Abstract

Purpose The use of several different maneuvers for the pivot shift test has resulted in inconsistent quantitative measurements. The purpose of this study was to describe, analyze, and group several surgeon-specific techniques for the pivot shift test and to propose a standardized pivot shift test.

Methods Twelve expert surgeons examined a whole lower cadaveric extremity with their preferred technique and assigned a clinical grade, I–III. Anterior tibial translation and acceleration were measured using an electromagnetic system. The test was repeated after watching an instructional video focused on a standardized pivot shift technique. Measurements were repeated and compared with the preferred technique.

Results The expert surgeons utilized valgus stress unambiguously in addition to fixed internal rotation ($n = 5$), fixed

external rotation ($n = 1$), a motion-allowing technique ($n = 3$), a dislocation-type maneuver ($n = 2$), and a fixed anterior drawer type of maneuver in extension ($n = 1$). Anterior tibial translation measured was on average 15.9 ± 3.7 mm. Average tibial acceleration was 3.3 ± 2.1 mm/s². Average clinical grading was 2.3 ± 0.5 . There were no differences in average clinical grading when using high stress (2.5 ± 0.6) versus low stress (2.3 ± 0.5 , n.s.), or using fixed rotation (2.2 ± 0.5) versus a motion-allowing technique (2.3 ± 0.6 ; n.s.).

Conclusions Clinical grading, tibial translation, and acceleration vary between examiners performing the pivot shift test. High forces and extremes of rotation are not necessary to produce a clinical detectable pivot shift. In the future, a standardized pivot shift test—which can be performed universally and utilizes only gentle forces allowing motion to occur—may be beneficial when assessing differences in outcome following ACL reconstruction.

Electronic supplementary material The online version of this article (doi:10.1007/s00167-011-1859-4) contains supplementary material, which is available to authorized users.

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Keywords Pivot shift · Standard technique ·
Acceleration · ACL

Introduction

The pathologic motion during the pivot shift is on most occasions subjectively graded by the examiner as a glide (grade I), clunk (grade II), or gross (grade III) [5]. The pivot shift test is subjective, yet we use the pivot shift commonly as an objective outcome tool; specifically, an outcome tool for testing so-called “dynamic laxity”. The pivot shift test is easy to perform and is not very time-consuming, especially when compared with the highly precise test of dynamic joint laxity, dynamic stereo radiography [25]. Those who criticize the validity and reliability

of the pivot shift test and its quantitative measurement might stress the subjectivity of the test.

It is a fact that the pivot shift test is the most specific test to establish the diagnosis of an ACL insufficiency [2] and has a relation to knee function [10, 13]. It is also generally accepted that the goal of any ACL reconstruction surgery should be to eliminate the shifting phenomenon, that is, to reduce or eliminate rotatory knee laxity. It is therefore necessary to improve and standardize the pivot shift test. It has been shown that several different approaches have aided in improving the pivot shift test: (1) the laxity during the pivot shift test can be measured, (2) the dynamics during the pivot shift test can also be quantified by means of acceleration, or (3) the pivot shift test can be instrumented and mechanized.

In a series of studies presented in this special issue of *Knee Surgery Sports Traumatology Arthroscopy* (KSSTA), it was the hypothesis that standardizing the pivot shift test would improve its inter-tester reliability. In a first step, the purpose of this study was therefore to describe, analyze, decompose, and group several surgeon-specific techniques of performing the pivot shift. A second purpose was to introduce the expert surgeon to a standardized pivot shift technique and assess the feasibility and the surgeon's acceptance of the standardized technique.

Materials and methods

Expert surgeons

The study was performed during the Panther Global Summit 2011 in Pittsburgh, PA, USA. Twelve expert surgeons from all over the world, who were invited as faculty members during the meeting, were asked to participate in the study. They were selected based on their expertise in the field. All of the expert surgeons have more than 10 years of experience to perform high volume ACL surgeries, that is, >52 ACL reconstructions per year [17], and are familiar with the pivot shift test.

Experimental setup

We utilized a controlled laboratory setup for this experiment. The setup included a fresh whole lower body cadaveric specimen, a modified operating room table, an electromagnetic tracking system, and two video cameras to capture motion. Prior to testing, the specimen was evaluated by clinical examinations and radiographs for absence of previous joint injury and osteoarthritis. The right knee was utilized for this study. Diagnostic arthroscopy was performed to confirm absence of previous injuries. High-grade knee laxity was surgically created by resecting the ACL and the anterior horn of lateral meniscus. For the testing procedure, the

specimen was thawed for 48 h and positioned flat on the operating room table. The pelvis was fixed to the table for stabilization during the pivot shift test. Two K-wires (2.0 mm diameter) were placed in the femur and tibia, respectively, to firmly fix the electromagnetic sensors with a platform. A previously described digitization of standard bony landmarks was performed prior to testing in order to measure knee kinematics during the pivot shift test [6]. Movements of the joint and surgeons' hands were captured with two digital video cameras positioned at orthogonal angles, and simultaneous knee kinematics measurement was conducted by the electromagnetic system [6, 11].

Prior to performing the pivot shift test, the expert surgeons were briefed on the testing procedure and on the tasks they were asked to perform. The expert surgeons:

1. were blinded to the laxity status of the joint,
2. performed the pivot shift test according to their preferred clinical technique,
3. assigned a clinical grade for the pivot shift (I-III according to IKDC criteria) [8],
4. provided verbal feedback on their preferred technique,
5. described direction of stress applied (i.e., varus-valgus stress, internal-external rotation, axial compression),
6. described the amount of stress applied (minimal, moderate, maximum), and
7. estimated the anterior–posterior (AP) translation of the lateral compartment (<6, 6–12, and >12 mm).

Categorization of the pivot shift techniques

To analyze and group different types of pivot shift techniques, we attempted to decompose the testing maneuver. The motions that were focused on when analyzing the techniques included (1) knee flexion, (2) valgus rotation, (3) internal-external (IE) rotation, and (4) anterior–posterior (AP) translation. Through post hoc video observation of the performed pivot shift tests, we then attempted to categorize the pivot shift test into several groups. Although forces and moments were not measured in this experiment, the different pivot shift techniques were also categorized into how much stress was applied, that is, high or low stress and what stress was applied, that is, fixed rotation or motion allowing. The amount of stress was estimated from post hoc video observation and the expert surgeon's description of his own technique.

Introducing a standardized pivot shift

Finally, we introduced a standardized pivot shift technique to the participant experts and got their agreement of the testing procedure through actual trial testing and discussion. In order to design this standardized pivot shift

technique, the most intuitive and most commonly used components of the pivot shift test were gathered. We also used the experience from a previous study conducted during ISAKOS 2009 Osaka, Japan [11].

The degree of similarity between their preferred pivot shift technique and the standardized technique was assessed in grade 0 (different) to 3 (similar) from post hoc video observation and the expert surgeon's description of his own technique. Also, their acquisition level of the standardized technique after the instruction by the short video was graded into 0 (not at all) to 4 (fully acquired).

Statistical comparison

Clinical grading was averaged and compared between pivot shift groups. Anterior tibial translation and tibial acceleration were measured by the electromagnetic tracking system. For statistical analysis, a Fisher exact test was used to determine whether there was a significant difference of clinical grading and electromagnetic measurements between different groups of testing maneuver, that is, high versus low stress and fixed rotation versus motion allowing. Significance was set at $P < 0.05$.

Results

Pivot shift test categorization

Nine out of 12 expert surgeons used the reduction-type pivot shift test maneuver. The remaining three surgeons used either the dislocation type or a fixed anterior drawer type of maneuver in extension. The reduction-type pivot shift technique used by the 9 expert surgeons could be grouped into one of the three groups. They utilized valgus motion with fixed internal rotation ($n = 5$; Fig. 1), fixed external rotation ($n = 1$; Fig. 2), or a motion-allowing technique ($n = 3$; Fig. 3). Of the five surgeons that utilized fixed internal rotation, two used a high valgus stress with maximum internal rotation and three used a low valgus stress with a lesser degree of internal rotation. Two out of 12 surgeons used a dislocation-type maneuver (Fig. 4), which assesses the dislocation movement of the pivot shift. One surgeon utilized a fixed anterior drawer type of maneuver in extension [4] (Table 1).

The detailed descriptions of the three major pivot-shift testing techniques are as follows.

Fixed internal rotation type

The examiner controls the patient's leg with his ipsilateral hand at the foot/ankle level (i.e., left hand for left leg). The examiner lifts the patient's leg off the table, while

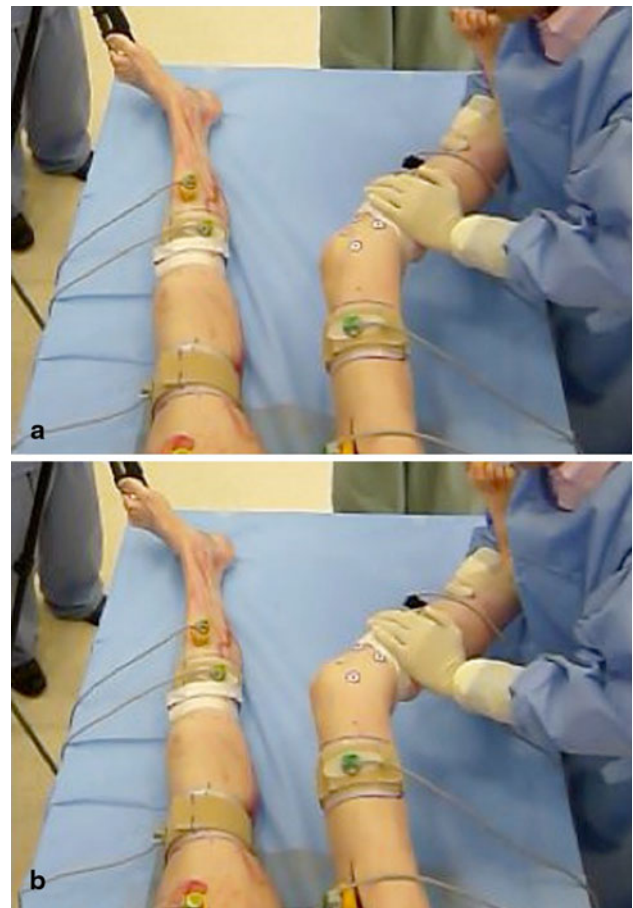


Fig. 1 Fixed internal rotation pivot shift just before (a) and after (b) shifting occurs

internally rotating the tibia. Internal rotation is maintained throughout the entire range of extension-to-flexion during the pivot shift test. The examiners' contralateral hand or palm controls valgus rotation at the proximal tibia just below the proximal tibia-fibula joint level. The valgus stress is also held at a constant level. Knee flexion is initiated while constant internal rotation and valgus stress is maintained. At approximately 30° of knee flexion, sudden shifting of the tibia, that is, reduction movement, occurs (Fig. 1).

Motion-allowing type

The examiner controls the patient's leg with his ipsilateral hand at the foot/ankle level (distal hand). The examiner lifts the patient's leg off the table while internally rotating the tibia. To control valgus stress, the examiners' contralateral palm is placed at just below the proximal tibia-fibula joint level with the thumb up. Knee flexion is initiated while constant internal rotation and valgus stress is maintained. Internal rotation is maintained until around 30° of knee flexion or until just prior to shifting. At the point of



Fig. 2 Fixed external rotation pivot shift just before (a) and after (b) shifting occurs

shifting, the examiner releases internal rotation applied by the ipsilateral hand and guides the proximal tibia into external rotation using the contralateral hand. The release of internal rotational stress and the supporting external rotation by the examiner accentuate perceived shifting (Fig. 3).

Fixed external rotation type

The examiner controls the patient's leg with his ipsilateral hand at the foot/ankle level. The examiner lifts the patient's leg off the table while externally rotating the tibia. External rotation is maintained throughout the entire range of extension-to-flexion during the pivot shift test. To control valgus stress, the examiners' contralateral palm is placed at just below the knee joint line level with the thumb up. The valgus stress is also held at a constant level. Knee flexion is initiated with the hand while constant external rotation and valgus stress is maintained. At approximately 30° of knee flexion, sudden posterior shifting of the tibia, that is, reduction movement, occurs (Fig. 2).

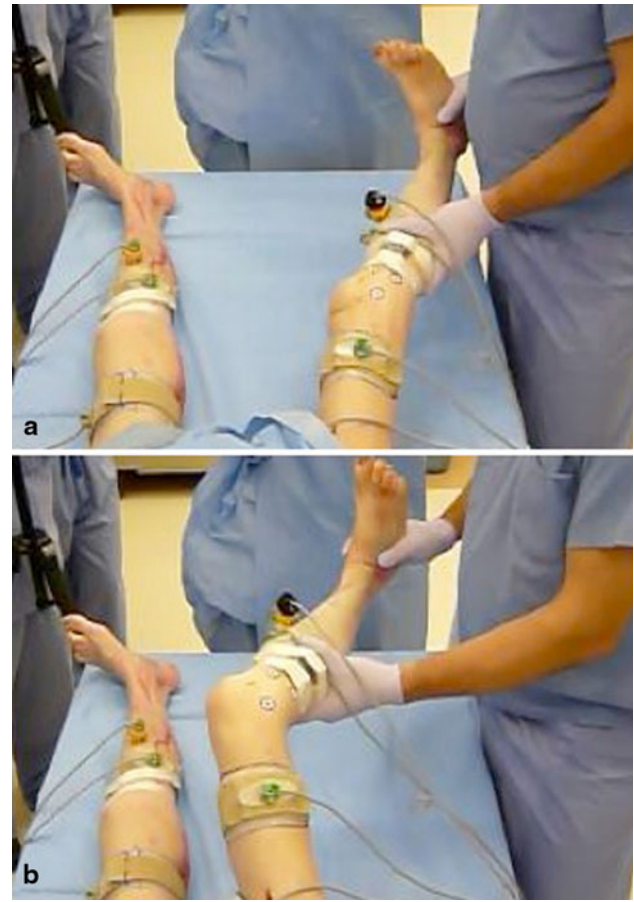


Fig. 3 Motion-allowing pivot shift just before (a) and after (b) shifting occurs

Subjective and objective assessment of the applied force and resultant knee kinematics

The amount of valgus stress varied from moderate to manual maximum. Four expert surgeons self-reportedly rated their applied valgus stress as manual maximum (33%), seven as moderate (59%), and one as minimal (8%). We assessed surgeons as using high force for 2/5 surgeons (fixed internal rotation), 1/1 (fixed external rotation), and 1/2 (dislocation type). The amount of observed internal rotation applied during the fixed internal rotation maneuver varied from 10 to 30 (maximum) degrees.

Anterior tibial translation of the lateral compartment was estimated by one expert surgeon as 3–6 mm (8%), by seven expert surgeons as 6–12 mm (59%), and by four expert surgeons as >12 mm (33%). The actual anterior tibial translation measured was on average 15.9 ± 3.7 mm. Average tibial acceleration was 3.3 ± 2.1 mm/s². The highest tibial acceleration was measured with the fixed external rotation type (9.0 mm/s²), followed by the dislocation type

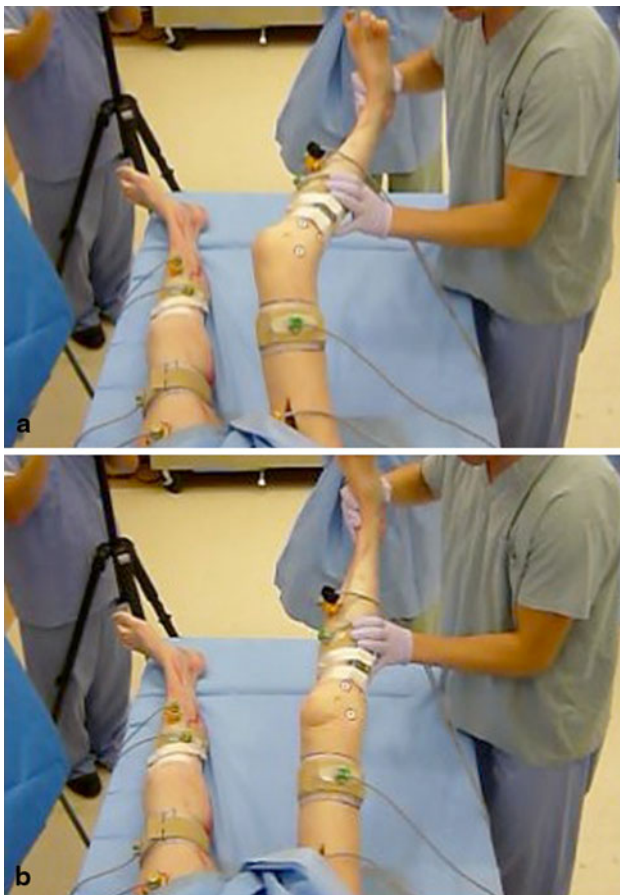


Fig. 4 Dislocation-type pivot shift just before (a) and after (b) shifting occurs

(3.8 mm/s²), the motion-allowing type (2.9 mm/s²), and the fixed internal rotation type (2.4 mm/s²).

Comparison of clinical grading

The average clinical grading of the pivot shift by the 12 expert surgeons was 2.3 ± 0.5 . There was no difference in average clinical grading when using high stress (2.5 ± 0.6) versus low stress (2.3 ± 0.5) or using fixed rotation (2.2 ± 0.5) versus a motion-allowing technique (2.3 ± 0.6).

The standardized pivot shift technique was well accepted by 6 of 12 expert surgeons, somewhat accepted by 4 of 12 expert surgeons, and not well accepted by the remaining two expert surgeons (Table 2).

The standardized pivot shift technique

After introducing a standard pivot shift technique and discussing the details of the maneuvers with the experts, the agreement was reached for the testing maneuver. The standardized pivot shift test will be described in this manuscript, and the demonstration video is available on

Table 1 Data of the amount of force and type of pivot shift used

Expert surgeon	Force	Type	ATT	ACC
1	High	IR	14.1	2.4
2	High	IR	19	2.8
3	High	ER	14.9	9
4	High	Dislocation	18.1	3.7
5	Low	Dislocation	14.8	3.9
6	Low	Dejour	16.5	2
7	Low	Motion	7.7	3
8	Low	Motion	22.3	5
9	Low	Motion	18.2	0.8
10	Low	IR	14.4	2.9
11	Low	IR	12.6	2.2
12	Low	IR	17.8	1.9

Resulting anterior tibial translation (ATT) and tibial acceleration (ACC) by each surgeon ($n = 12$)

the *KSSSTA* website (<http://www.editorialmanager.com/ksst/>; Fig. 5). This 2-min instructional video includes step-by-step instructions, and the important components of the pivot shift are carefully explained.

Step 1: The examiner controls the patient's leg with his ipsilateral hand at the heel level. The examiner lifts the patient's leg off the table and slightly abducts the hip. The leg is internally rotated with the ipsilateral hand.

Step 2: To control the valgus stress, the examiners' contralateral hand is placed on the lateral side of the joint with the thumb up at just below the proximal tibia-fibula joint level. A gentle valgus stress is applied. The knee is naturally flexed with the combined stress of internal rotation and valgus stress. The examiner does not need to control this flexion and continues to the next step.

Step 3: Knee flexion is advanced with both the hands. Internal rotation- and valgus stress are maintained until approximately 20° of knee flexion. At the point of shifting, the rotational stress of the ipsilateral hand is released, and the proximal tibia is guided into external rotation by the contralateral hand. In other words, at the time of shifting, the lateral side of the proximal tibia suddenly drops by gravity and the tension of the iliotibial band. The contralateral hand on the lateral side of the proximal tibia just gently supports this movement, which accentuates the reduction movement. The movement is felt at around 20–40° of knee flexion.

The agreement of the standardized pivot shift technique

Nine surgeons performed their own pivot shift test in quite a different manner compared with the standardized pivot shift technique (graded 0–1 in Table 2). However, after

Table 2 Cross-table match between similarity of preferred pivot shift to the standardized technique (horizontal) and acquisition level of the standardized pivot shift technique (vertical) for $n = 12$ expert surgeons

Instructed	Preferred			
	0	1	2	3
0				
1	1	1		
2	1	3		
3	1	2	2	1

Similarity grading: 0 = different, 1 = somewhat different, 2 = somewhat similar, 3 = similar. Acquisition level: 0 = not at all, 1 = somewhat acquired, 2 = reasonably well, 3 = fully acquired

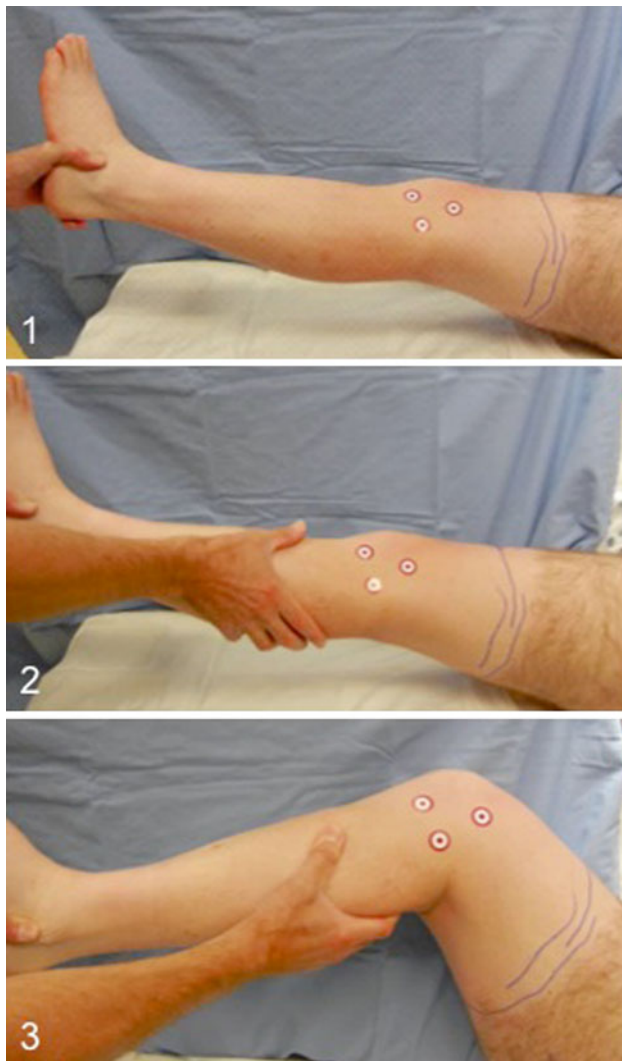


Fig. 5 Three-step standardized pivot shift test. *Step 1*: internal rotation of the tibia in extension; *step 2*: application of valgus; *step 3*: knee flexion and release of internal rotation—let tibia externally rotate

watching the standardized technique during the short video, the majority of the expert surgeons, 10 out of 12, performed the pivot shift test according to the video description (graded 2–3 in Table 2).

Discussion

The most important finding of the present study was that there is no consensus on the optimal technique for the pivot shift examination. Grouping the pivot shift technique into 3 general categories, fixed internal rotation, motion allowing, and fixed external rotation, was possible for 9 out of 12 expert surgeons. Clinical grading varied among surgeons, but not between different techniques, and was also independent on the amount of force applied during the pivot shift test. This study also successfully introduced a standardized pivot shift technique, but correlation with clinical grading could not be improved.

Several authors have previously found that the pivot shift phenomenon can be accentuated by rotating the tibia externally at the initiation of the pivot shift [16, 24]. This will emphasize the posterior reduction of the tibia, at around 30° of knee flexion, as the reduction movement is a combination of posterior translation and external rotation [3, 22]. In the present study, it was found that the greatest magnitudes of tibial acceleration occur with the fixed external rotation pivot shift (9.0 mm/s²) and the dislocation-type pivot shift (3.8 mm/s²).

The pivot shift can also be mechanized, which was shown to be beneficial for enhanced repeatability in the laboratory setting [19–21]. Quantifying forces and moments that are applied during the pivot shift test may be of benefit as well when attempting to standardize the pivot shift. Simulated pivot shifts are also a powerful tool to quantify the pivot shift in the laboratory setting [18, 23]. However, in the clinical setting, a mechanized system or simulated pivot shift systems may actually eliminate the real-time sensation of the pivot shift and cannot adjust the force and moment properly to individual size, morphology, and laxity to maximize the pivot shift.

Ambiguous criteria for interpreting the results have been a major limiting factor of the pivot shift test. Some therefore question the value of the pivot shift test. New technologies have been developed in an attempt to quantify the pivot shift test [3, 7, 15]. However, when different pivot shift maneuvers are applied, the results may still vary greatly [11, 22]. Therefore, the idea of a standardized pivot shift might be helpful. This study showed that the standardized pivot shift technique was accepted by most of the expert surgeons (10/12), after viewing the 2-min video one single time.

Noyes et al. analyzed the pivot shift techniques of 11 different surgeons in a controlled laboratory setting. They also identified great variations (from 6 to 17 mm) in tibial translation of the different techniques [22]. Kuroda et al. pointed out limitations of manual pivot shift tests as well. In their study, 5 expert surgeons performed a pivot shift test on the same ACL-injured knee. They found that tibial rotation measurement by the different examiners varied widely while translation and acceleration measurements were relatively consistent so that those measurement can be used for quantitative comparison [11].

In an attempt to increase the diagnostic value of the pivot shift test, we standardized the technique itself. However, the difficulty is that clinical grading is still subjective and should be standardized as well. Bedi et al. were able to show that clinical grading correlates well with lateral compartment translation, but not with tibial rotation [1]. During the design of the standardized technique, the goal for clinical grading was therefore to focus on lateral compartment translation. As described by Lane et al., the grading should then be based on the amount of translation in the lateral compartment, that is, 6 mm = grade 1; 12 mm = grade 2; 18 mm = grade 3 [12].

The wide variation of the pivot shift technique all over the world was recognized in this study as it was in a previous report [11]. The pivot-shift testing technique is often reported in a few words and figures. The dynamic nature of the maneuver does not permit the abrupt movement, testing speed, and timing of the pivot shift to be easily demonstrated and reproduced. Therefore, surgeons naturally acquire their technique through personal instruction from mentors. Preferred techniques largely depend on geographic regions, mentors, and training experience. As shown in this study, the standardized technique is easy to acquire for most of the ACL surgeons by use of the instructional video in which the detailed movements, speed, and timing are demonstrated in a dynamic fashion.

In the present study, forces and moments were not measured. There were no comparative measurements to the intact knee or a low-grade pivot shift situation. Clinical grading could not be measured/correlated during the standardized pivot shift technique. The Lachman test has a sensitivity of 80%, which can be improved to over 90% when it is instrumented [9, 14]. Clinical grading itself may require a standardized procedure and measurement that could be based on either acceleration or translation or both.

Conclusion

Several different pivot shift maneuvers are described in this article. Clinical grading, the magnitude of perceived as well as actual lateral compartment translation, and the

magnitude of tibial acceleration vary between the different techniques. However, high forces and extremes of rotation are not necessary to produce a clinical detectable pivot shift. In the future, a standardized pivot shift test, utilizing gentle forces and allowing motion, may be beneficial when comparing outcomes following ACL reconstruction.

Acknowledgments The authors would like to sincerely thank the expert surgeons for their participation and inspiring comments during the study (Drs. Roland Becker, Shiyi Chen, Moises Cohen, Andreas Imhoff, Timo Jarvela, Masahiro Kurosaka, Benjamin Ma, Willem van der Merwe, Philippe Neyret, Robert Smigielski).

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