Editorial Commentary: The Pivot Shift and Lachman Examinations: Teammates With Distinct Roles

Andrew D. Pearle, M.D., Danyal H. Nawabi, M.D., Niv Marom, M.D., Thomas L. Wickiewicz, M.D., and Carl W. Imhauser, Ph.D.

Abstract: The pivot shift and Lachman examinations are "teammates" with complementary but distinct roles in the successful diagnosis and treatment of anterior cruciate ligament rupture and injury to the surrounding soft-tissue envelope of the knee. The Lachman test measures anterior tibial translation in response to an applied anterior tibial load. This test assesses the integrity of the native or reconstructed anterior cruciate ligament and the secondary medial restraints including the medial meniscus and medial collateral ligament. In contrast, the pivot shift exam creates coupled tibiofemoral motions in response to a complex combination of multiplanar loads. This test assesses the stabilizing role of the native or reconstructed anterior cruciate ligament and the secondary lateral restraints including the lateral meniscus and anterolateral complex. The pivot shift grade depends not only on the soft the tissue stabilizers of the knee but also on the shape of the proximal tibia and the distal femur including lateral tibial slope and femoral condylar offset. Both examinations have unique strengths and weaknesses, but when combined as diagnostic tools, they achieve far more collectively than what each can achieve alone.

See related article on page 672

We view the pivot shift and the Lachman examinations as teammates with distinct roles in their assessment of the native anterior cruciate ligament (ACL) or ACL graft and the surrounding soft-tissue stabilizers of the knee. The Lachman test measures anterior tibial translation (ATT) in response to a uniplanar anterior tibial force. This test assesses the integrity of the native or reconstructed ACL and the secondary medial restraints, including the medial meniscus and medial collateral ligament, while minimally loading the lateral meniscus.[1,2] In contrast, the pivot shift examination creates coupled tibiofemoral motions in response to a complex combination of multiplanar forces and torques. This test assesses the stabilizing role of the native or reconstructed ACL and the secondary lateral restraints, including the lateral meniscus and anterolateral complex (anterolateral ligament/capsule, iliotibial band, Kaplan fibers, etc.), while minimally loading the medial meniscus.[3-7] The pivot shift grade depends not only on the soft-tissue stabilizers of the knee but also on the shape of the proximal tibia and the distal femur, including lateral tibial slope and femoral condylar offset.[3,8-11]

The Lachman and the pivot shift examinations play key roles in assessing not just the injured but also the ACL-reconstructed knee.[12,13] In this issue, Noyes, Huse, and Palmer quantify the impact of ACL graft slackening on ATT in response to simulated Lachman and pivot shift testing in their paper entitled: "A Biomechanical Study of Pivot-Shift and Lachman Translations in Anterior Cruciate Ligament-Sectioned, Anterior Cruciate Ligament-Reconstructed and With Partial Anterior Cruciate Ligament Graft Slackening:

New York, New York (A.D.P., D.H.N., T.L.W., C.W.I.) and Kfar Saba, Israel (N.M.).

The authors report the following potential conflicts of interest or sources of funding: A.D.P. is a consultant for and receives royalties from Zimmer Biomet, has received consulting fees from Stryker Exactech, and has received hospitality and other compensation from Smith & Nephew and Arthrex. D.H.N. has received education payments from Arthrex, Stryker, and Smith & Nephew and hospitality payments from DePuy Syntheses and Biomet Orthopedics. N.M. has received education payments from Gotham Surgical and hospitality payments from Smith & Nephew. T.L.W. receives royalties from Stryker-MAKO Surgical. C.W.I. reports grants from the Clark Foundation, Kirby Foundation, Gosnell Family, Ludwig Family, Surgeon-in-Chief Fund at the Hospital for Special Surgery, National Institute of Arthritis and Musculoskeletal and Skin Diseases of the National Institutes of Health R21AR073388 during the conduct of the study. In addition, he has patents US 10,750,979 issue and patent US 10,667,746 issued. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

0749-8063/201925/$36.00
https://doi.org/10.1016/j.arthro.2020.12.001

Instrumented Lachman Tests Statistically Correlate and Supplement Subjective Pivot-Shift Tests."[14] Understanding the effect of surgically modifiable variables, like ACL graft slack, is a critical step to identifying those parameters that provide the greatest opportunity for the surgeon to improve a patient's clinical outcome. The work of Noyes et al. reveals that ATT of the lateral compartment during the pivot shift test is less sensitive to increasing ACL graft slack than ATT during the Lachman examination. More specifically, ATT during the 2 simulated pivot shift examinations conducted in their study is about one half (56%) to three quarters (74%) of that occurring during the Lachman test (as shown by the regression coefficients presented in Figure 4 of their paper). The regression coefficients support the authors' conclusion that a 3-mm increase in ATT during a Lachman test resulted in a negative pivot shift. Noyes et al. also reported that further graft slackening to achieve a 5-mm increase in Lachman ATT produced ATT increases in the pivot shift examination that were less than the ACL-deficient state in the majority (93%) of the 43 knees that were tested.

The findings of Noyes et al. suggest 3 additional questions regarding the relationship between the pivot shift and Lachman examinations: (1) Does a threshold exist for when an increase in Lachman ATT elicits a positive pivot shift? (2) Did the knees without definitive graft failure after a 5-mm increase in Lachman ATT exhibit a so-called "mini pivot shift" or "residual pivot?"[15,16] (3) If so, would these knees benefit from lateral extra-articular augmentation surgery? Addressing these clinical questions would require not only quantitative assessment of the Lachman test, as suggested by Noyes et al., but also of the pivot shift, which is not objectively standardized, relying instead on the subjective feel of the examiner. Thus, objective and quantitative assessment of the pivot shift, an ongoing area of development, is critical to answering these remaining questions.[17]

Considering previous studies that reported weak or no relationship between ATT of the Lachman and that of the pivot shift, one may infer that ACL graft slack is *not* the only factor controlling pivot shift grade.[18,19] In fact, numerous studies report that pivot shift grade is related to the status of the lateral meniscus, lateral capsular tissues, iliotibial band, and tibiofemoral morphology.[3-5,7,9,20,21] Patients often present with additional injuries concomitant to ACL rupture (e.g., lateral meniscus injuries, lateral tissues injuries, and medial meniscus injury); thus, both examinations play a vital role in the differential diagnosis of these lesions. We have observed clinical scenarios whereby the Lachman and pivot shift examination findings can be in stark contrast. For example, patients with a well-performed ACL reconstruction and a normal Lachman may present with a positive pivot shift due to elevated lateral tibial slope or significant lateral sided injury. Conversely, we have encountered patients who rupture their ACL and exhibit a positive Lachman but a damped pivot shift likely due to insignificant lateral injury or a "tight" secondary soft-tissue envelope. Moreover, findings from our laboratory indicate lateral augmentation exhibits strong control of lateral compartment ATT during simulated pivoting loads but limited control of ATT during a simulated Lachman test.[16,22] Our clinical experiences together with these laboratory-based and other clinical findings reinforce our belief that the Lachman and the pivot shift examinations have complementary roles in their assessment of the ACL and secondary knee stabilizers.

We also would like to comment on the implementation of the pivot shift in both clinical and cadaveric research. Most studies focus on the translations and rotations of the knee during the pivot shift.[17,23-27] However, far less attention is paid to the multiplanar forces and torques applied by surgeons when conducting this examination. We commend the authors for assessing the response of the knee to a range of multiplanar loads by modulating the applied internal rotation torque. Given the wide variety of pivoting maneuvers described in the literature,[24,28] myriad combinations of loads likely exist that generate the subluxation–reduction of the lateral compartment related to the pivot shift grade.[25] Thus, understanding the response of the knee to a variety of these loading conditions provides a broader understanding of how resilient various ACL treatments are to the complex loading conditions the ACL graft must withstand.

The multiplanar forces and torques applied by a surgeon during a pivot shift examination in an instrumented cadaveric knee joint model were recently measured by Colbrunn et al.[29] Although these data stem from a single surgeon, the findings call attention to an often-ignored aspect of the pivot shift: the application of compressive force. In fact, about twice as much compression was applied as anterior force (~100 N compression vs ~50 N anterior). Moreover, valgus was the greatest of the applied torques. These quantitative data corroborate early clinical descriptions of the pivot shift phenomenon by Galway and MacIntosh[30] and Losee[31] and are supported by unpublished data from our research team.[32] These findings also indicate that compressive force and valgus torque are key initiators of tibial subluxation in extension and immediately precede reduction of the lateral compartment as the knee is flexed during a pivot shift test. The combination of valgus and compression also indicate preferential loading of the lateral compartment, emphasizing the important role of the lateral articular surfaces in driving the resulting translations and rotations of the knee.

In conclusion, we have more to learn about the complementary roles of the Lachman and pivot shift examinations in assessing the integrity of the ACL and surrounding stabilizers in the injured and reconstructed knee. Both exams have unique strengths and weaknesses, but when combined as diagnostic tools, they achieve far more collectively than what each can achieve alone. Ultimately, the Lachman and the pivot shift examinations are teammates, each playing a unique part in the successful diagnosis and treatment of patients suffering ACL rupture.

References

1. Kent RN, Imhauser CW, Thein R, et al. Engagement of the secondary ligamentous and meniscal restraints relative to the anterior cruciate ligament predicts anterior knee laxity. *Am J Sports Med* 2020;48:109-116.
2. Papageorgiou CD, Gil JE, Kanamori A, Fenwick JA, Woo SL, Fu FH. The biomechanical interdependence between the anterior cruciate ligament replacement graft and the medial meniscus. *Am J Sports Med* 2001;29:226-231.
3. Tanaka M, Vyas D, Moloney G, Bedi A, Pearle AD, Musahl V. What does it take to have a high-grade pivot shift? *Knee Surg Sports Traumatol Arthrosc* 2012;20:737-742.
4. McDonald LS, Boorman-Padgett J, Kent R, et al. ACL deficiency increases forces on the medial femoral condyle and the lateral meniscus with applied rotatory loads. *J Bone Joint Surg Am* 2016;98:1713-1721.
5. Petrigliano FA, Musahl V, Suero EM, Citak M, Pearle AD. Effect of meniscal loss on knee stability after single-bundle anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2011;19:S86-S93 (suppl 1).
6. Geeslin AG, Chahla J, Moatshe G, et al. Anterolateral knee extra-articular stabilizers: a robotic sectioning study of the anterolateral ligament and distal iliotibial band kaplan fibers. *Am J Sports Med* 2018;46:1352-1361.
7. Hoshino Y, Hiroshima Y, Miyaji N, et al. Unrepaired lateral meniscus tears lead to remaining pivot-shift in ACL-reconstructed knees. *Knee Surg Sports Traumatol Arthrosc* 2020;28:3504-3510.
8. Rahnemai-Azar AA, Abebe ES, Johnson P, et al. Increased lateral tibial slope predicts high-grade rotatory knee laxity pre-operatively in ACL reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2017;25:1170-1176.
9. Pfeiffer TR, Burnham JM, Kanakamedala AC, et al. Distal femur morphology affects rotatory knee instability in patients with anterior cruciate ligament ruptures. *Knee Surg Sports Traumatol Arthrosc* 2019;27:1514-1519.
10. Voos JE, Suero EM, Citak M, et al. Effect of tibial slope on the stability of the anterior cruciate ligament-deficient knee. *Knee Surg Sports Traumatol Arthrosc* 2012;20:1626-1631.
11. Hoshino Y, Wang JH, Lorenz S, Fu FH, Tashman S. The effect of distal femur bony morphology on in vivo knee translational and rotational kinematics. *Knee Surg Sports Traumatol Arthrosc* 2012;20:1331-1338.
12. Getgood AMJ, Bryant DM, Litchfield R, et al. Lateral extra-articular tenodesis reduces failure of hamstring tendon autograft anterior cruciate ligament reconstruction: 2-year outcomes from the STABILITY study randomized clinical trial. *Am J Sports Med* 2020;48:285-297.
13. Magnussen RA, Reinke EK, Huston LJ, Group M, Hewett TE, Spindler KP. Effect of high-grade preoperative knee laxity on anterior cruciate ligament reconstruction outcomes. *Am J Sports Med* 2016;44:3077-3082.
14. Noyes FR, Huse LE, Palmer M. A biomechanical study of pivot-shift and Lachman translations in anterior cruciate ligament-sectioned knees, anterior cruicate ligament-reconstructed knees, and knees with partial anterior cruciate ligament graft slackening: Instrumented Lachman tests statistically correlate and supplement subjective pivot-shift tests. *Arthroscopy* 2021;37:672-681.
15. Lie DT, Bull AM, Amis AA. Persistence of the mini pivot shift after anatomically placed anterior cruciate ligament reconstruction. *Clin Orthop Relat Res* 2007;457:203-209.
16. Ueki H, Nakagawa Y, Ohara T, et al. Risk factors for residual pivot shift after anterior cruciate ligament reconstruction: Data from the MAKS group. *Knee Surg Sports Traumatol Arthrosc* 2018;26:3724-3730.
17. Musahl V, Griffith C, Irrgang JJ, et al. Validation of quantitative measures of rotatory knee laxity. *Am J Sports Med* 2016;44:2393-2398.
18. Markolf KL, Jackson SR, McAllister DR. Relationship between the pivot shift and Lachman tests: A cadaver study. *J Bone Joint Surg Am* 2010;92:2067-2075.
19. Dawson CK, Suero EM, Pearle AD. Variability in knee laxity in anterior cruciate ligament deficiency using a mechanized model. *Knee Surg Sports Traumatol Arthrosc* 2013;21:784-788.
20. Suero EM, Njoku IU, Voigt MR, Lin J, Koenig D, Pearle AD. The role of the iliotibial band during the pivot shift test. *Knee Surg Sports Traumatol Arthrosc* 2013;21:2096-2100.
21. Bernholt DL, Dornan GJ, DePhillipo NN, Aman ZS, Kennedy MI, LaPrade RF. High-grade posterolateral tibial plateau impaction fractures in the setting of a primary anterior cruciate ligament tear are correlated with an increased preoperative pivot shift and inferior postoperative outcomes after anterior cruciate ligament reconstruction. *Am J Sports Med* 2020;48:2185-2194.
22. Marom N, Ouanezar H, Jahandar H, et al. Lateral extra-articular tenodesis reduces anterior cruciate ligament graft force and anterior tibial translation in response to applied pivoting and anterior drawer loads. *Am J Sports Med* 2020;48:3183-3193.
23. Noyes FR, Grood ES, Cummings JF, Wroble RR. An analysis of the pivot shift phenomenon. The knee motions and subluxations induced by different examiners. *Am J Sports Med* 1991;19:148-155.
24. Arilla FV, Yeung M, Bell K, et al. Experimental execution of the simulated pivot-shift test: A systematic review of techniques. *Arthroscopy* 2015;31:2445-2454.e2442.
25. Bedi A, Musahl V, Lane C, Citak M, Warren RF, Pearle AD. Lateral compartment translation predicts the grade of pivot shift: A cadaveric and clinical analysis. *Knee Surg Sports Traumatol Arthrosc* 2010;18:1269-1276.

26. Sundemo D, Alentorn-Geli E, Hoshino Y, Musahl V, Karlsson J, Samuelsson K. Objective measures on knee instability: Dynamic tests: A review of devices for assessment of dynamic knee laxity through utilization of the pivot shift test. *Curr Rev Musculoskelet Med* 2016;9:148-159.
27. Lane CG, Warren RF, Stanford FC, Kendoff D, Pearle AD. In vivo analysis of the pivot shift phenomenon during computer navigated ACL reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2008;16:487-492.
28. Lane CG, Warren R, Pearle AD. The pivot shift. *J Am Acad Orthop Surg* 2008;16:679-688.
29. Colbrunn RW, Dumpe JE, Nagle TF, Kolmodin JD, Barsoum WK, Saluan PM. Robotically simulated pivot shift that represents the clinical exam. *J Orthop Res* 2019;37:2601-2608.
30. Galway HR, MacIntosh DL. The lateral pivot shift: A symptom and sign of anterior cruciate ligament insufficiency. *Clin Orthop Relat Res* 1980:45-50.
31. Losee RE. Concepts of the pivot shift. *Clin Orthop Relat Res* 1983;172:45-51.
32. Jahandar H, Amirtharaj M, Tao M, et al. Loads of the pivot shift clinical exam of the knee: A cadaveric model. *Orthoapedic Research Society 2019 Annual Meeting;* New Orleans, 2019.