Static Lateral Tibial Plateau Subluxation Predicts High-Grade Rotatory Knee Laxity in Anterior Cruciate Ligament–Deficient Knees

ABSTRACT

Background: In anterior cruciate ligament–deficient (ACL-D) knees, injury pattern and bony morphologic features have been shown to influence both static anterior tibial subluxation relative to the femur and dynamic rotatory knee laxity. Therefore, the relationship between static anterior tibial subluxation and dynamic rotatory knee laxity was investigated.

Purpose: To determine whether static tibial subluxation as measured on magnetic resonance imaging (MRI) is associated with the grade of rotatory knee laxity in ACL-D knees.

Methods: Two-hundred fifty-eight knees underwent preoperative, image-guided assessment of lateral knee compartment translation during quantitative pivot shift (QPS). Subluxations of the medial and lateral tibial plateaus were measured on preoperative MRI in a subset of primary ACL-D knees meeting criteria for high-grade (QPS > 5.2 mm) and low-grade (QPS < 2.4 mm) rotatory laxity. Tibial subluxations on MRI were compared between patients with high- and low-grade rotatory laxity through use of pairwise t test and were analyzed via univariate and multivariate logistic regression. Significance was set at P < .05.

Results: On MRI, greater anterior subluxation of the lateral tibial plateau was observed in patients with high-grade compared with low-grade rotatory knee laxity (4.5 mm vs 2.3 mm; P < .05). No similar relationship was observed for the medial tibial plateau (-0.9 mm vs -0.4 mm; P > .05). Univariate logistic regression demonstrated that static subluxation of the lateral tibial plateau was associated with high-grade rotatory knee laxity (odds ratio [OR], 1.2; P < .05). An optimal cutoff of 2.95 mm of static lateral tibial subluxation was associated with high-grade rotatory knee laxity (sensitivity, 75%; specificity, 63%). Lateral meniscal injury was the first variable entered into a multivariate regression analysis and proved to be most associated with high-grade rotatory knee laxity (OR, 6.8; P < .05). When lateral meniscal injury was excluded from multivariate regression analysis, static anterior subluxation of the lateral tibial plateau alone was associated with high-grade rotatory knee laxity (OR, 1.2; P < .05).
**Conclusion:** Data from this MRI study of two distinct rotatory knee laxity groups showed that static anterior subluxation of the lateral tibial plateau of 2.95 mm or greater was associated with high-grade rotatory knee laxity, and each millimeter increase of lateral tibial plateau subluxation was associated with a 1.2-fold odds of high-grade rotatory knee laxity. Anterior subluxation of the lateral tibial plateau on MRI was not independently associated with high-grade rotatory knee laxity in the presence of concomitant lateral meniscal injury. Static measurements made preoperatively may aid in predicting high-grade rotatory knee laxity and refining the indications for individualized knee surgery.
INTRODUCTION

Advances in anterior cruciate ligament (ACL) reconstruction continue to be driven by an improved understanding of anatomy and biomechanics, both of which demonstrate patient-specific variation and contribute to distinct ACL injury patterns. As suboptimal clinical outcomes have been associated with residual rotatory knee instability following ACL reconstruction (ACLR), better diagnostic tools are needed to more accurately characterize the magnitude of instability, so treatment can be tailored accordingly. In the last decade, numerous measurement devices have been developed to quantify the pivot shift exam, but differences in accessibility, cost, and convenience, have led to discordance in preferred measurement technique. In this study, video capture using validated, custom software on an iPad tablet (iPad, Apple, Inc., Cupertino, CA, USA), was utilized on the ACL-D knee to quantify lateral knee compartment translation during pivot shift exam.

Currently, there are several known risk factors that are thought to portend a high-grade quantitative pivot shift (QPS), including female sex, increased lateral tibial slope, anterolateral capsule injury, meniscus injury, and generalized joint laxity. Debate exists among surgeons and biomechanists whether an ACLR is sufficient to address ACL-deficient patients with high-grade rotatory knee instability, and whether an extra-articular procedure, such as an extra-articular lateral tenodesis or an “anterolateral ligament” reconstruction, may be a necessary supplement to restore rotatory knee stability. However, a challenge many orthopaedic surgeons face is the inability to adequately assess rotatory knee instability prior to the examination under anesthesia, and thus diagnostic tools that may pre-operatively identify patients with high-grade rotatory knee instability would be useful for surgeons performing ACLR.

First described 20 years ago, the relationship between static tibial subluxation and ACL injury patterns has been the focus of several recent reports. When compared to that of the isolated, primary ACL-D knee, increases in static anterior subluxation of the lateral tibial plateau have been observed in the setting of failed ACLR, combined medial and lateral compartment chondral defects, and combined medial and lateral meniscus tears. Furthermore, since anterior tibial subluxation has
been shown to affect tibial tunnel placement during ACLR,\textsuperscript{4,5} surgeons must be aware of the biomechanical consequences of a malpositioned posterior tibial tunnel.\textsuperscript{9,11,27}

Therefore, the objective of this study was to investigate whether a difference between static, anterior subluxation of the medial and lateral tibial plateaus, as measured on MRI, would be seen between patients with high and low-grade rotatory knee instability. It was hypothesized that anterior subluxation of the lateral, but not the medial, tibial plateau would be significantly greater in patients with high-grade compared to low-grade rotatory knee instability. It was further hypothesized that anterior subluxation of the lateral tibial plateau would reliably predict high-grade rotatory knee instability, independent of age, sex, body mass index (BMI), time from injury to surgery, time from injury to MRI, degree of ipsilateral knee extension, and concomitant medial or lateral meniscus injury.

**METHODS**

A retrospective analysis was performed on a prospectively enrolled cohort of 254 patients (258 knees) undergoing ACL surgery by the senior author. This cohort included all patients undergoing primary ACLR, revision ACLR, and ACL augmentation procedures between September 2012 and September 2017. After institutional board approval, all patients indicated for ACL surgery underwent standardized QPS measurements using a validated iPad software application (Apple, Inc., Cupertino, CA, USA) during the examination under anesthesia.\textsuperscript{33}

**Quantitative Pivot Shift Testing**

A standardized pivot shift (Figure 1) maneuver of both the operative knee and the contralateral knee was performed after induction of anesthesia and prior to the start of the surgical procedure, by either the senior author or a sports medicine-trained orthopaedic surgery fellow. Three 2 cm-diameter, yellow, adhesive surface markers were placed on Gerdy's tubercle, 3 cm posterior to Gerdy's tubercle, and on the lateral femoral epicondyle (Figure 1A). During the pivot shift maneuver, video capture of the three markers was done using custom iPad software on an iPad tablet (iPad, Apple, Inc., Cupertino, CA, USA),
which analyzed lateral knee compartment translation.\textsuperscript{31} This method has previously been demonstrated to provide reliable and valid assessment of rotatory knee instability.\textsuperscript{33} All testers were trained in standardized pivot shift technique and demonstrated proficiency with the testing maneuver and software prior to onset of the study.\textsuperscript{33}

**Figure 1. Quantitative Pivot Shift Analysis.** A. Image guided analysis using iPad-tracking software of three yellow markers on (1) Gerdy’s tubercle (2) 3 cm posterior to Gerdy’s tubercle (3) Lateral femoral epicondyle during pivot shift examination under anesthesia. B. Software analysis of the distance of lateral compartment translation (mm) during the reduction event.

Lateral knee compartment translations during quantitative pivot shift were recorded for all 258 ACL-D knees (mean 4.0 mm; 95% Confidence Interval [CI] 3.8–4.3; range 0.4 – 14.0 mm) (Figure 2), and used to establish quantitative thresholds for high (75\textsuperscript{th} percentile; 5.2 mm) and low (25\textsuperscript{th} percentile; 2.4 mm) grade rotatory knee instability (Table 1).
Figure 2. A) Box Plot of Lateral Knee Compartment Translation During Quantitative Pivot Shift Analysis (N = 258) B) Histogram of Lateral Knee Compartment Translation (N = 258). Distribution of lateral knee compartment translation in 258 ACL-D knees whom have undergone QPS testing under anesthesia between 2012-2017.

Table 1. Defining High and Low-Grade Rotatory Instability (N = 258).

<table>
<thead>
<tr>
<th>Quantitative Pivot Shift</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentiles:</td>
<td></td>
</tr>
<tr>
<td>25&lt;sup&gt;th&lt;/sup&gt;</td>
<td>2.4 mm</td>
</tr>
<tr>
<td>50&lt;sup&gt;th&lt;/sup&gt;</td>
<td>3.7 mm</td>
</tr>
<tr>
<td>75&lt;sup&gt;th&lt;/sup&gt;</td>
<td>5.2 mm</td>
</tr>
</tbody>
</table>

Once quantitative thresholds were established, a subset of patients were selected, based on specific inclusion/exclusion criteria, for MRI analysis of static subluxation of the medial and lateral tibial plateaus. Inclusion criteria consisted of: clinical, MRI, and arthroscopic evidence of complete, primary ACL deficiency, and a lateral knee compartment translation of either less than the 25<sup>th</sup> percentile (< 2.4 mm) or greater than the 75<sup>th</sup> percentile (> 5.2 mm) during QPS exam. Exclusion criteria included: ACL disruption in the setting of multiligamentous knee surgery, revision ACL surgery, partial ACL disruption, history of contralateral ACL surgery, and/or open epiphyseal growth plates. Patient selection was isolated to primary ACLR in order to avoid known confounding factors with failed ACLR.\(^{43}\)

**MRI Measurement Technique for Tibial Subluxation**

MRI was performed using a 1.5-T open-bore magnet utilizing 3-mm slice thickness (Signa; GE Healthcare). Patients were supine and the knee was placed near full extension.
One of two independent investigators, blinded to QPS values, reviewed MRI scans to measure medial and lateral tibial plateau subluxation relative to the posterior femoral condyle as previously described. Briefly, on sagittal proton density images, a best-fit circle was drawn over the subchondral bone of the posterior femoral condyle. A line perpendicular to the tibial plateau and tangential to the posterior margin of the circle was drawn. A second line perpendicular to the tibial plateau was then drawn along the posterior aspect of the tibia. The distance between the two lines was defined as the degree of tibial subluxation (Figure 3). If the tibia was subluxed anteriorly, the value was considered positive, and if the tibia was subluxed posteriorly, the value was considered negative.

Figure 3. Static Anterior Subluxation of the Lateral and Medial Tibial Plateaus in ACL-D patients with (A) High-Grade and (B) Low Grade Rotatory Knee Instability. Sagittal T1-weighted images of the ACL-D knee were used to measure tibial subluxations with respect to the femur as previously described. The medial-most MRI scans in which continuity between the head and neck of the fibula, and the attachment between the medial gastrocnemius tendon and femur, could be visualized, were used to measure static subluxation of the lateral and medial tibial plateaus, respectively. Subluxation was measured as the distance between (1) a line perpendicular to the tibial plateau and tangential to the posterior margin of the best fit-circle of the femoral condyle, and (2) the line perpendicular to the tibial plateau and along the posterior aspect of the tibia.
Previous reports of static tibial subluxation in ACL-intact knees have reported mean values of 0.9 ± 2.1 mm and 0.8 ± 1.7 mm for the medial and lateral compartments, respectively. The medial and lateral compartments were defined by the medial-most MRI scans in which (1) the attachment between the medial gastrocnemius tendon and femur and (2) continuation between the head and neck of the fibula, could be visualized, respectively. When the contour of the posterior femoral condyle and/or posterior tibia could not be clearly visualized using the aforementioned criteria, the adjacent MRI scan in which it was, was utilized instead. Interobserver correlation was calculated using a sample of 10 knees prior to investigation, and was shown to be near perfect agreement for anterior subluxation of the medial tibia (0.962) and lateral tibia (0.977) compartments.

**Statistical Analysis**

All analyses were performed using STATA® Version 14.2 (StataCorp). Pearson’s chi-square test for independence and t-tests with unequal variance were used to compare demographic and clinical variables between patients with high and low grade rotatory knee instability, while boxplots and pairwise t-tests were used to examine differences in static tibial subluxation. Univariate and multivariate logistic regression models were utilized to assess significance for prediction and control for covariates of interest. Discrimination and model fit were evaluated utilizing the Receiver Operating Characteristic (ROC) curve, the C-statistic (equivalent to the area under the curve), and sensitivity and specificity of each model respectively. A post hoc sensitivity analysis was performed using forward step-wise logistic regression. An optimal cut-off value for anterior subluxation of the lateral tibial plateau was independently established using the Liu method. Statistical significance was set at $P < .05$. 


RESULTS

**Demographic Characteristics of ACL-D Patients with High and Low-Grade Rotatory Knee Instability**

Comparisons were made between ACL-D patients exhibiting high and low-grade rotatory knee instability, to assess for differences in demographic variables and the presence or absence of associated chondral and/or meniscal injuries. There were no significant differences in demographics between groups, nor was there a difference in the incidence of associated medial meniscal injuries (17.9% vs. 30.0% for high and low rotatory knee instability, respectively; p = n.s.). However, there was a significantly higher incidence of lateral meniscal tears in patients with high-grade rotatory knee instability (32.1% vs. 10.0% for high and low rotatory instability, respectively; p < 0.05) (Table 2).

**Table 2. Demographic Information (n = 58)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>High-Grade Rotatory Instability (n = 28)</th>
<th>Low-Grade Rotatory Instability (n = 30)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>23.6 ± 9.1</td>
<td>28.5 ± 9.8</td>
<td>0.053</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td>0.19</td>
</tr>
<tr>
<td>Female</td>
<td>16 (57.1%)</td>
<td>18 (60.0%)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>12 (42.9%)</td>
<td>12 (40.0%)</td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td>26.2 ± 5.0</td>
<td>27.1 ± 5.2</td>
<td>0.52</td>
</tr>
<tr>
<td>Time from Injury to surgery (d)*</td>
<td>67 ± 1567.5</td>
<td>49 ± 284.8</td>
<td>0.26</td>
</tr>
<tr>
<td>Time from Injury to MRI (d)**</td>
<td>26 ± 1570.1</td>
<td>7 ± 280.8</td>
<td>0.24</td>
</tr>
<tr>
<td>ACL-D Knee Extension (deg)^</td>
<td>1.2 ± 2.6</td>
<td>2.7 ± 1.4</td>
<td>0.30</td>
</tr>
<tr>
<td>Isolated Medial Meniscus Injury</td>
<td>5 (17.9%)</td>
<td>9 (30.0%)</td>
<td>0.28</td>
</tr>
<tr>
<td>Isolated Lateral Meniscus Injury</td>
<td>9 (32.1%)</td>
<td>3 (10.0%)</td>
<td>0.04</td>
</tr>
<tr>
<td>Medial and Lateral Meniscus</td>
<td>9 (32.1%)</td>
<td>6 (20.0%)</td>
<td>0.29</td>
</tr>
</tbody>
</table>

*Presented are Median ± SDs; ^Based on 54 observations

**Static Tibia Subluxation on MRI in Patients With High and Low-Grade Rotatory Knee Instability**

Anterior subluxations in both the medial and lateral knee compartments were measured on MRI for ACL-D patients with high and low-grade rotatory knee instability. A significantly greater static anterior...
subluxation of the lateral tibial plateau was observed on MRI in patients with high-grade rotatory knee instability compared to low-grade rotatory knee instability (4.5 mm; [CI] 2.9-6.1, vs 2.3 mm; [CI] 1.2-3.3; \( p < 0.05 \)) (Figure 4). In contrast, no differences in subluxation of the medial tibia were observed on MRI between patients with high and low-grade rotatory knee instability (-0.9 mm; [CI] -2.1-0.4, vs -0.4 mm; [CI] -1.3-0.5; \( p = \text{n.s.} \)) (Figure 4).

Figure 4. Static subluxation of the lateral and medial tibial plateau in patients with high- and low-grade rotatory knee laxity. Data are presented as mean ± SD. MRI, magnetic resonance imaging; n.s., not significant; QPS, quantitative pivot shift.

Univariate logistic regression analysis demonstrated that static anterior subluxation of the lateral tibial plateau on MRI was a significant predictor for high-grade rotatory knee instability (Odds ratio [OR] 1.2; [CI] 1.0-1.4; \( p < 0.05 \)). In other words, the odds of high-grade rotatory knee instability was increased 1.2-fold per millimeter increase in static anterior subluxation of the lateral tibial plateau on MRI (Table 3). Receiver operating curve (ROC) analysis revealed an area under the curve (AUC) of 0.72 (Figure 5A). Lateral tibial plateau subluxation of 2.95 mm on MRI was determined to be an optimal cut-off point for predicting high-grade rotatory knee instability (sensitivity: 75%; specificity: 63%).
Table 3. Univariate and Multivariate Logistic Regression Analysis.

<table>
<thead>
<tr>
<th></th>
<th>Logistic Regression</th>
<th>Odds Ratio</th>
<th>95% Confidence Interval</th>
<th>Confidence</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Univariate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior Subluxation of Lateral Tibial Plateau</td>
<td></td>
<td>1.2</td>
<td>1.02-1.44</td>
<td></td>
<td>0.026</td>
</tr>
<tr>
<td><strong>Multivariate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior Subluxation of Lateral Tibial Plateau</td>
<td></td>
<td>1.2</td>
<td>0.92-1.45</td>
<td></td>
<td>0.21</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td>0.9</td>
<td>0.85-1.02</td>
<td></td>
<td>0.14</td>
</tr>
<tr>
<td>BMI</td>
<td></td>
<td>0.9</td>
<td>0.74-1.10</td>
<td></td>
<td>0.32</td>
</tr>
<tr>
<td>Female Sex</td>
<td></td>
<td>1.1</td>
<td>0.25-5.03</td>
<td></td>
<td>0.87</td>
</tr>
<tr>
<td>Time to Surgery</td>
<td></td>
<td>1.0</td>
<td>0.96-1.01</td>
<td></td>
<td>0.18</td>
</tr>
<tr>
<td>Time to MRI</td>
<td></td>
<td>1.0</td>
<td>0.99-1.05</td>
<td></td>
<td>0.15</td>
</tr>
<tr>
<td>Ipsilateral Knee Extension</td>
<td></td>
<td>0.9</td>
<td>0.78-1.06</td>
<td></td>
<td>0.23</td>
</tr>
<tr>
<td>Medial Meniscus Injury</td>
<td></td>
<td>1.1</td>
<td>0.21-6.22</td>
<td></td>
<td>0.88</td>
</tr>
<tr>
<td>Lateral Meniscus Injury</td>
<td></td>
<td>4.3</td>
<td>0.999-18.52</td>
<td></td>
<td>0.05</td>
</tr>
</tbody>
</table>

Figure 5. Receiver Operating Curves (ROC) of A) Univariate, and B) Multivariate Logistic Regression Models
In order to determine whether static anterior subluxation of the lateral tibial plateau observed on MRI was an independent predictor for high-grade rotatory knee instability, a multivariate, logistic regression analysis was performed. Specifically, the following variables were included in the model: anterior subluxation of the lateral tibial plateau on MRI, age, BMI, sex, time between ACL injury and surgery, time between ACL injury and MRI, degree of ipsilateral knee extension, concomitant medial meniscus injury, and concomitant lateral meniscus injury (Table 3). In this model, static anterior subluxation of the lateral tibial plateau was no longer found to be an independent predictor for high-grade rotatory knee instability (p = n.s.) (Table 3). However, ROC analysis using the multivariate, logistic regression revealed an increased AUC of 0.88 (Figure 5B).

A post hoc sensitivity analysis was performed utilizing forward step-wise logistic regression. Lateral meniscus injury ([OR] 6.8; [CI] 1.9-24.8; p < 0.05) was the first variable to enter and proved to be most predictive of high-grade rotatory knee instability (Table 4). When lateral meniscus injury was removed from the selection pool, anterior subluxation of the lateral tibial plateau on MRI ([OR] 1.2; [CI] 1.0-1.5; p < 0.05) was the next variable to prove most predictive of high-grade rotatory knee instability (Table 4).
### Table 4. Post Hoc Forward Step-wise Logistic Regression Sensitivity Analysis

<table>
<thead>
<tr>
<th>Step Description</th>
<th>Variable of Interest</th>
<th>Odds Ratio</th>
<th>95% Confidence Interval</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: Full Model</td>
<td>Isolated LM Injury</td>
<td>6.8</td>
<td>1.88-24.81</td>
<td>0.004</td>
</tr>
<tr>
<td>2: LM removed</td>
<td>Anterior Subluxation of Lateral Tibial Plateau</td>
<td>1.2</td>
<td>1.01-1.45</td>
<td>0.04</td>
</tr>
</tbody>
</table>

### DISCUSSION

The main findings of this study were as follows: (1) MRI-measured, static anterior subluxation of the lateral tibial plateau in patients with high-grade rotatory knee instability was twice that of patients with low-grade rotatory knee instability, (2) an optimal cut-off of 2.95 mm of anterior subluxation of the lateral tibial plateau observed on MRI was predictive of high-grade rotatory knee instability (sensitivity: 75%; specificity: 63%), with each millimeter increase in anterior subluxation being associated with a 1.2-fold odds of high-grade rotatory knee instability, and (3) a multivariate, logistic regression model was created with high predictive value for identifying patients with high-grade rotatory knee instability, as measured by AUC. Static anterior subluxation of the lateral tibial plateau observed on MRI may therefore be an important diagnostic tool to assess a patients’ risk of high-grade rotatory knee instability.

Our initial hypothesis – that patients with high-grade rotatory knee instability would exhibit significantly increased static, anterior subluxation of the lateral but not the medial tibial plateau, compared to patients with low-grade rotatory knee instability – was confirmed. Patients with high-grade rotatory knee instability exhibited a two-fold increase in static, lateral tibia compartment translation. Interestingly, the degree of static subluxation of the lateral tibial plateau in primary ACL-D patients exhibiting high-grade rotatory knee instability (4.5 mm) was similar to that observed in a previous MRI study of patients with failed ACLR (3.9 mm). In a separate study, which utilized a multivariate regression analysis controlled for meniscus injury, failed ACLR was independently predictive of static, lateral tibia compartment subluxation. The interrelation between static lateral tibia compartment subluxation, rotatory knee...
instability, and failed ACLR may provide insight into why certain knees may be more likely to fail ACLR than others.

Our second hypothesis – that anterior subluxation of the lateral tibial plateau on MRI would reliably predict high-grade rotatory knee instability, independent of age, sex, BMI, time from injury to surgery, time from injury to MRI, degree of ipsilateral knee extension, and concomitant medial or lateral meniscus injury – was not supported by the data. Multivariate logistic regression analysis was unable to capture a statistically significant relationship between static, anterior subluxation of the lateral tibial plateau and high-grade rotatory knee instability, because lateral meniscus injury proved to be a confounder for both variables, as evidenced by post-hoc sensitivity analysis. This is consistent with previous reports, which have shown that lateral meniscus injury exacerbates rotatory knee instability, and that combined medial and lateral meniscus injury increases passive anterior tibial subluxation in the lateral compartment. Despite this limitation, in both a univariate regression analysis and a separate, logistic regression model, which excluded patients without lateral meniscus injury, the odds of having high-grade rotatory knee instability were increased 1.2 fold per millimeter increase in static, anterior subluxation of the lateral tibial plateau. Therefore, while our working multivariate logistic regression was limited by the presence of a known confounder (lateral meniscus injury), separate analyses demonstrated that static anterior subluxation of the lateral tibial plateau on MRI could reliably predict high-grade rotatory knee instability.

An important, additional feature of our multivariate logistic regression model was its overall, high predictive value for identifying patients with high-grade rotatory knee instability. The AUC, a measure of a given test to correctly discriminate patients with and without the outcome of interest (i.e. high-grade rotatory knee instability) was 0.88, which is considered near excellent. As more variables are added to the multivariate logistic regression analysis (i.e. bony morphological parameters), increased confounding may occur; perhaps then, an increased focus should be steered away from the level of significance ($p = 0.05$) and more on the predictive ability of a given model, as measured by AUC. Studies that emphasize this facet of analysis may prove useful in producing a predictive algorithm for identifying patients with high or low-grade rotatory instability.
The clinical importance of identifying patients with high and low-grade rotatory knee instability is clear. Previous studies have observed greater anterior subluxation of the lateral tibial plateau in patients with similar features to those of high-grade rotatory knee instability, such as “anterolateral ligament”/capsule injury, combined medial and lateral meniscus tears, and increased posterior tibial slope. Furthermore, patients with failed ACLR may even lie in a “resting pivoted position” near full extension. For surgeons who advocate for combined intra- and extra-articular procedures in patients with high-grade rotatory instability, a preoperative prediction of a patient’s knee instability provides a useful tool for surgical planning. For example, orthopaedic surgeons may be more inclined to perform lateral-sided augmentation procedure if patients exhibit risk factors for high-grade rotatory instability, and preoperative conversation between the surgeon and patient may be better informed. While a multifactorial and complicated problem, an increased understanding of risk factors for rotatory knee instability can help improvement of intra-operative decision making.

Lastly, as objective measures for rotatory knee instability continue to develop, quantitative thresholds for high and low-grade rotatory knee instability will increase the precision with which comparisons between groups can be made. This is particularly important to standardize communication and outcome measures of ACL surgery across surgeons. Previous reports utilizing QPS analysis have defined high and low-grade rotatory instability using the median value or have avoided defining a threshold and elected to quantify rotatory instability on a continuous scale. Though we acknowledge that the choice in 25th and 75th percentiles was arbitrary, these thresholds may be useful for clinical application and provide a necessary dichotomization to evaluate outcomes in two distinct patient populations. More precise definitions of low and high-grade rotatory knee instability could be of great value in exploring the objective differences between those ACL-D patients previously categorized as “copers” and “non-copers”. This information would be invaluable for decision making of nonoperative versus operative treatment.

The strengths of our study include the use of a validated, objective measurement of the degree of rotatory knee instability, which to date have commonly been reported using a subjective grading scheme, among a large, prospectively enrolled cohort. Additionally, multiple statistical analyses were
performed to control for demographic variables and concomitant pathology to assess the nature of the
relationship between static tibial subluxation and rotatory instability.

There are several limitations to our study. Since it was cross-sectional in nature, no outcomes
were assessed. While a clear association between rotatory instability and static anterior subluxation of
the lateral tibial plateau was observed, the current study does not prove why this relationship occurs.

CONCLUSION

Data from this MRI study of two distinct rotatory knee laxity groups showed that static anterior
subluxation of the lateral tibial plateau of 2.95 mm or greater was predictive of high-grade rotatory knee
laxity, and each millimeter increase of lateral tibial plateau subluxation was associated with a 1.2-fold
odds of high-grade rotatory knee laxity. Static measurements made preoperatively may aid in predicting
high-grade rotatory knee laxity and refining the indications for individualized knee surgery.
REFERENCES


