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Intraobserver and Interobserver Reliability of the Kneeling Technique of Stress Radiography for the Evaluation of Posterior Knee Laxity

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Background: Stress radiography provides an objective tool to measure posterior knee instability. Intraobserver and interobserver reliability has been reported for the Telos device, but it has not been studied using the kneeling technique.

Purpose: This study was conducted to evaluate the intraobserver and interobserver reliability of measurements made using kneeling stress radiography to quantify posterior knee instability.

Study Design: Case series (diagnosis); Level of evidence, 4.

Methods: One hundred thirty-two stress radiographs in 44 patients with suspected posterior knee instability were prospectively taken using the kneeling technique. The amount of posterior displacement on the radiographs was then measured independently by 3 blinded testers (an orthopaedic sports medicine faculty member, an orthopaedic chief resident, and a medical student) on 2 separate occasions. Changes in mean and intraclass correlation coefficients (ICCs) were examined to assess the intraobserver and interobserver reliability of the measurements.

Results: Intraobserver changes in displacement means were small (–0.307 mm, –0.294 mm, and +0.035 mm) and only significant for observer 1. The combined intraobserver ICC was 0.973 for the 3 observers (0.976, 0.959, and 0.981). Interobserver comparisons revealed significant differences in trial 1 between observers 2 and 3 (0.675 mm), no differences in trial 2, and significant differences between observers 1 and 2 (0.333 mm) and observers 2 and 3 (0.510 mm) in the combined trial data. The combined interobserver ICC was 0.955 for the 3 observers (0.959 and 0.951 for the 2 trials).

Conclusions: The kneeling technique for posterior cruciate ligament stress radiography provides a reproducible method to quantify posterior knee instability.

Keywords: stress radiography; posterior knee instability; posterior cruciate ligament

Posterior knee instability due to isolated and combined injuries remains a diagnostic challenge. The most sensitive clinical tests to detect posterior instability include the posterior drawer test, the posterior sag test, the quadriceps active test, the posterolateral drawer test, and the dial test at 30° and 90° of knee flexion.[1,6,7,16] Quantifying the amount of posterior instability has implications for the degree of injury, ranging from isolated posterior cruciate ligament (PCL) injury to combined injuries to the PCL, posterolateral corner, and/or posteromedial corner.[5,14,18] Tewes et al[20] reported that magnetic resonance imaging scans are unreliable to assess for chronic PCL tears and should not be used to infer functional status in cases with chronic injuries. Stress radiography provides a means to quantify the amount of posterior instability at the time of first presentation as well as to follow the resulting stability provided by the chosen treatment regimen.

Several techniques have been described to deliver a posteriorly directed force during stress radiography.[10,12-15] These include hamstring contraction,[3] gravity-assisted,[19] the Telos device (Austin and Associates, Fallston, Maryland),[17] and single-leg kneeling.[13] The Telos device and kneeling have been shown to be superior to the other methods for reproducibly demonstrating posterior knee instability.[12] Schulz et al[17] demonstrated excellent intraobserver and interobserver reliability when the Telos device was used to mechanically

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deliver the posterior directed force during stress radiography. However, kneeling stress radiography provides a more cost-effective, accessible, and potentially faster approach to quantify posterior instability.[12] Furthermore, while based on expert opinion and not on peer-reviewed literature, the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine has proposed that kneeling stress radiography be the preferred method for measuring and reporting posterior knee instability.[2]

Before any technique can be integrated into clinical practice, it must be assessed for its reproducibility. Therefore, the purpose of this study was to evaluate the intraobserver and interobserver reliability of measurements made using kneeling stress radiography to quantify posterior knee instability. Our hypothesis was that kneeling stress radiography would demonstrate high intraobserver and interobserver reliability for measuring posterior knee instability.

MATERIALS AND METHODS

Institutional Review Board Approval

This study was approved by the University of Minnesota Institutional Review Board. Because all patient identifiers were removed from the radiographs before archival storage and all images were being taken as part of routine clinic practice, the study was granted exemption from the informed consent and Health Insurance Portability and Accountability Act (HIPAA) processes.

Patient Selection

A consecutive and prospective series of patients were seen and examined at the Sports Medicine Institute at the University of Minnesota between June 2006 and January 2007. All patients between 18 and 65 years of age with suspected unilateral posterior knee instability based on a detailed history, physical examination, and available static radiographs and/or MRI examinations were enrolled in the study. When posterior knee instability was suspected and for clinical follow-up of both nonoperative and operative patients, bilateral kneeling stress radiographs were obtained to quantify the amount of posterior displacement in the injured knee compared with the normal contralateral knee. The radiology technicians subsequently made digital copies of the radiographs, removed all patient identifiers, assigned a unique number to each image, and placed the images in a secure computer file for later blinded examination.

Power Analysis

Before the initiation of the study, a power analysis was performed to determine the number of measurements that would be needed to demonstrate a statistically significant and clinically relevant difference. We believed a measurement difference between observers of 1.0 mm would be clinically relevant. We calculated that 26 images, each measured twice by 3 different observers (156 observation points), would be needed to demonstrate a statistically significant 1.0-mm difference with greater than 80% power.

Kneeling Technique for Posterior Knee Stress Radiographs

Bilateral kneeling stress radiographs were obtained to allow comparison of the amount of posterior displacement between the injured and uninjured knees. Before the initiation of the study, a 90° support jig was constructed to ensure comfortable, stable, and reproducible positioning of the patient during radiography. This consisted of a lightly padded horizontal limb and a vertical limb perpendicular to the floor. The horizontal limb supported the lower leg from the tibial tubercle to the distal tibia, with the patella and femoral condyles unsupported over the edge of the bench. The vertical limb ensured that the knee was flexed to approximately 90°. Patients were instructed to support their full weight on their tibial tubercles and to avoid placing any weight on the patella to provide the consistent, posterior force. They were allowed to stabilize themselves on a support structure in front of them (Figure 1). All radiographs were obtained by 1 of 2 experienced orthopaedic technicians and inspected by the senior author (R.F.L.) to verify that there was no rotation of the femoral condyles, as is done in normal clinical practice, before study inclusion.

Measurement Method

Three testers were involved in the study to determine the intraobserver and interobserver reliability: an experienced orthopaedic sports medicine surgeon (observer 1), an orthopaedic chief resident (observer 2), and a third-year medical student (observer 3). The blinded radiographs were measured by each of the investigators on 2 separate occasions at a minimum of 4 weeks apart. To limit recall bias, the radiographs were renumbered for the second trial. We measured the amount of displacement on the digital radiographs after transferring the images to Adobe Photoshop (Adobe Systems Inc, San Jose, California). A standard measurement scale included on each radiograph by the radiology technicians allowed us to measure the displacement in pixels within Photoshop and convert that value into millimeters. This process also corrected for magnification differences between radiographs.

When measuring the displacement on the radiographs, we used easily visible anatomic landmarks—the posterior cortex of the tibia and the farthest posterior point along the Blumensaat line.[11] A point on the posterior aspect of the tibia was identified 15 cm distal to the tibial plateau (Figure 2A). From that point, a line was extended parallel to the posterior cortex and proximally toward the knee joint (Figure 2B). A perpendicular line was drawn from this line to the posterior point of the Blumensaat line and the distance measured and recorded for each knee (Figure 2C). Displacement of the posterior tibial cortex line anterior or posterior to the posterior aspect of the Blumensaat line was given a positive or negative value, respectively.

Figure 1. Patient on support jig for kneeling technique of stress radiographs (left knee). The patient is instructed to put full weight on the tibial tubercle of the knee while obtaining the radiograph. Hands may be rested against the railing for support.

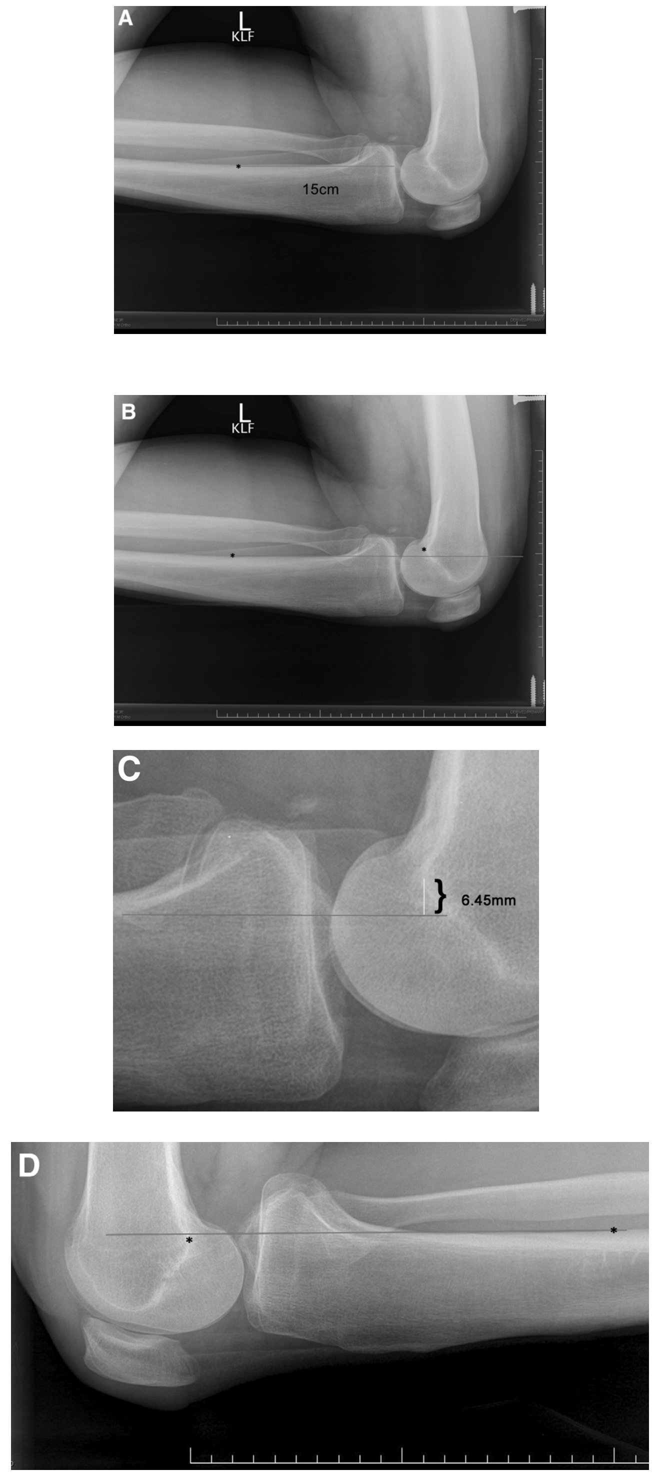

Figure 2. A, a point was identified along the posterior cortex 15 cm from the joint line. B, a line was then drawn from that point parallel to the posterior cortex, through the femoral condyles (line), and the most posterior point of the Blumensaat line was marked (asterisk). C, a perpendicular line was drawn from that point to intersect the first line and in this case measured 6.45 mm. D, in this patient with a posterior knee injury, the line along the posterior cortex falls 8.0 mm posterior to the most posterior aspect of the Blumensaat line.

Statistics

We examined intraobserver and interobserver reliability by looking at displacement means and intraclass correlation coefficients (ICCs). Statistical significance was assumed for $P < .05$.

Displacement Means. The mean displacements for each observer were calculated for trial 1, trial 2, and the combined trial data. We used a 2-way analysis of variance (ANOVA) in the general linear model for the individual trials and repeated-measures ANOVA for the combined trial data to generate Bonferroni-adjusted simultaneous 95% confidence intervals around each mean using SAS software (SAS 9.1.3 for Windows, SAS Institute, Cary, North Carolina). By using ANOVA, the potential sources of variability in the measurements (radiographic image, observer, and time interval) could be compartmentalized and their effect on measurement variability independently calculated.

Intraclass Correlation Coefficients. Intraclass correlation coefficients (ICCs) allow researchers to determine how much agreement exists between observers for a particular question. A value of 1.0 suggests complete agreement. The ICC is unaffected by changes in the mean between tests and allows generalization of the results to testers not participating in the study.[17] Single-measure ICCs for intraobserver and interobserver reliability were determined in a 2-way random effects model with an absolute agreement criterion using SPSS 15 (SPSS Inc, Chicago, Illinois).

RESULTS

Data Collection

The 3 observers independently measured the posterior tibial displacement observed on 132 consecutive lateral kneeling radiographs obtained in clinical practice. Each image was measured on 2 separate occasions 4 weeks apart. Displacements ranged from –20.54 to +22.31 mm. The overall mean displacement was 3.32 mm (n = 792). The average angle of knee flexion on the radiograph was 105.7° (range, 91°-120°; standard deviation, 5.6°). Knee flexion angle did not correlate with the amount of posterior displacement measurement on the radiographs or with the reliability of the measurements.

Intraobserver Reliability

Intraobserver changes in means between trials 1 and 2 were –0.307 mm, –0.294 mm, and 0.035 mm for observers 1 (sports medicine faculty member), 2 (chief orthopaedic resident), and 3 (medical student), respectively (Table 1). It is important to note that while 1 observer demonstrated a statistically significant difference in measurements between trials, all 3 observers demonstrated a change in mean <0.31 mm. We considered a value >1 mm to be clinically relevant.

Intraobserver ICCs were 0.976, 0.959, and 0.981 for observers 1, 2, and 3, respectively (see Table 2). The combined intraobserver ICC was 0.973. This demonstrates a high likelihood that persons not involved with this trial would arrive at similar measurements when presented with these same radiographs.

Interobserver Reliability

Interobserver reliability was assessed by comparing the mean tibial displacement measured by each of the observers in trial 1, trial 2, and both trials combined (Table 3). In trial 1, observers 2 and 3 demonstrated significantly different measurements of displacement (0.675-mm difference) ($P < .001$). There were no differences between any of the observers in trial 2. When the data were combined for both trials, there was a small but statistically significant difference noted between observers 1 and 2 (0.333 mm) and observers 2 and 3 (0.510 mm) ($P < .001$).

The interobserver ICCs for trial 1, trial 2, and both trials combined are presented in Table 4. The interobserver ICC for the combined trials was 0.955.

DISCUSSION

It was not our intention to determine the accuracy of the kneeling technique to assess for the degree of PCL tears and overall posterior knee laxity compared with other posterior knee stress measurement techniques because this has already been done.[17] A previous study has demonstrated that both the Telos device and the kneeling technique are the most accurate posterior stress radiograph techniques to measure posterior knee laxity with very little difference found between these 2 techniques.[17] Our goal was to determine if the kneeling technique for stress radiography is a reliable and reproducible tool to quantify posterior knee instability.

This study is the first to demonstrate the high intraobserver and interobserver reliability of kneeling stress radiographs for evaluating posterior knee instability. For intraobserver reliability, our ICC of 0.973 compared closely with that found with the Telos device (0.95)[17] and exceeded values (0.79) reported by an experienced user using the KT-1000 arthrometer device (MEDmetric Corp, San Diego, California).[9] In our study, only 1 of the 3 observers demonstrated significantly significant changes in mean displacement between trials 1 and 2 (0.307 mm). Again, while statistically significant, we did not consider these small differences to be clinically relevant. For interobserver reliability, we demonstrated an ICC of 0.955 with kneeling stress radiography, suggesting that persons not involved with this study would have a very high probability of measuring similar displacement. This was similar to historical ICC values of 0.95 reported with the Telos device[17] and superior to the ICC of 0.62 reported with the KT-1000 arthrometer.[9]

We believe that for both intraobserver and interobserver reliability, the small statistical differences we found are of

TABLE 1
Intraobserver Change in Means of Measurements of Posterior Tibial Displacement Using the Kneeling Technique for 132 Consecutive Lateral Knee Radiographs

	Trial 1 Mean (mm)	Trial 2 Mean (mm)	Change in Mean (mm)
Observer 1	3.402	3.095	–0.307[a]
Observer 2	3.728	3.434	–0.294
Observer 3	3.056	3.090	0.035

[a]Denotes significance at $P < .05$.

TABLE 2
Intraobserver Single-Measure Intraclass Correlation Coefficients (ICCs) and Confidence Limits for Measurements of Posterior Tibial Displacement Using the Kneeling Technique for 132 Consecutive Lateral Knee Radiographs

	ICC	Lower 95% Limit	Upper 95% Limit
Observer 1	0.976	0.966	0.983
Observer 2	0.959	0.943	0.971
Observer 3	0.981	0.974	0.987
Combined	0.973	0.967	0.978

TABLE 3
Mean Tibial Displacements Measured for Each Observer in Trial 1, Trial 2, and the Combined Data[a]

Trial	Observer	Mean Displacement (mm)	Difference in Mean Compared to Observer 1 (mm, *P* value)	Difference in Mean Compared to Observer 2 (mm, *P* value)
1	1	3.402	—	0.326 mm, $P = .24$
	2	3.728	0.326 mm, $P = .24$	—
	3	3.056	–0.349 mm, $P = .19$	–0.675 mm, $P = .001$[b]
2	1	3.095	—	0.338 mm, $P = .26$
	2	3.434	0.338 mm, $P = .26$	—
	3	3.090	–0.005 mm, $P = 1.0$	–0.344 mm, $P = .25$
Combined	1	3.248	—	0.333 mm, $P = .031$[b]
	2	3.581	0.333 mm, $P = .031$[b]	—
	3	3.071	–0.177 mm, $P = .51$	–0.510 mm, $P < .001$[b]

[a]Means and comparisons of means used to evaluate interobserver reliability. *P* values are Bonferroni-adjusted.
[b]Denotes significance at $P < .05$.

TABLE 4
Interobserver Single-Measure Intraclass Correlation Coefficients (ICCs) and Confidence Limits for Measurements of Posterior Tibial Displacement Using the Kneeling Technique for 132 Consecutive Lateral Knee Radiographs

All Observers	ICC	Lower 95% Limit	Upper 95% Limit
Trial 1	0.959	0.945	0.970
Trial 2	0.951	0.935	0.963
Combined	0.955	0.945	0.963

limited clinical relevance. Our measurement differences were in the tenths of millimeters while those of 1 mm or more are typically considered clinically relevant. This is based on work done by Schulz et al[17,18] with the Telos device. They showed that the magnitude of posterior displacement during stress radiography correlates with the degree of underlying injury. An uninjured subject will demonstrate 0 to 4 mm of side-to-side difference between knees with posterior stress radiography. Subjects with isolated PCL injuries demonstrated 5 to 12 mm of increased posterior displacement compared with the uninjured extremity. Subjects with combined posterior knee injuries to the PCL, posterolateral corner, and/or posteromedial corner had increased posterior displacement measuring >12 mm compared with the contralateral side.[18] Thus, although statistically significant, the small measurement differences seen in this study between the observers with kneeling radiography fall within a range that is not clinically relevant.

Although stress radiography provides an objective measure of posterior instability detected during the history and physical examination, its accuracy can be influenced by several important components. These include patient compliance, radiographic technique, and landmark identification during measurements. Based on calculations by Woodson[22] that a typical 80-kg patient would have 75.75% of their body weight proximal to their unilateral kneeling knee, on average they would deliver 594 N of posteriorly directed force during single-leg kneeling, a significantly higher amount than the 150 N delivered by the Telos device. However, this assumes a willing patient who is able to exert a consistent effort between measurement episodes. However, pain (or the fear of causing pain) while kneeling may cause the patient to put less stress on the injured leg and translate weight to the unaffected side. This does represent a potential limitation to the use of kneeling stress radiography and must be carefully addressed by both the physician and the radiographer. Another potential source of variability in the measurements is imprecise radiography leading to obscuration of the radiographic landmarks. This is most affected by rotation of the femoral condyles on the radiograph and can be caused by imprecise x-ray beam direction, rotation of the limb, or coupled rotation due to multiligamentous knee injuries.[4,8] Regardless of measurement method, the accuracy of kneeling stress radiographs can be optimized by reproducible patient positioning, precise lateral knee radiography with overlapping of the posterior aspect of the femoral condyles, and consistent use of reproducible landmarks when making measurements of posterior knee displacement.[21]

In conclusion, we found that measurements made using the kneeling technique to assess for posterior knee instability demonstrate very high interobserver and intraobserver reliability. Kneeling stress radiography provides a reproducible means to measure posterior knee instability both at the time of injury and after nonoperative or operative treatment.

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