

# The Tibial Tubercle–to–Trochlear Groove (TT-TG) Distance Is Reliable in the Setting of Trochlear Dysplasia, and Superior to the Tibial Tubercle–to–Posterior Cruciate Ligament (TT-PCL) Distance When Evaluating Coronal Malalignment in Patellofemoral Instability

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**Purpose:** To determine best practices for consistent and accurate evaluation of coronal alignment in patients with patellofemoral (PF) instability. **Methods:** Six reviewers examined 239 knee magnetic resonance images (MRIs) in patients with PF instability and anterior cruciate ligament (ACL) rupture. Measurements included tibial tubercle–to–trochlear groove (TT-TG) distance measured at the most proximal and distal portions of the trochlea, tibial tubercle–to–PCL (TT-PCL) distance, and Dejour classification of trochlear dysplasia. **Results:** Interrater reliability was low for Dejour classification ( $k = 0.289$ ), but improved to moderate ( $k = 0.448$ ) when patients were separated into normal/Dejour A and Dejour B/C/D. Interrater reliability was high for proximal and distal TT-TG measurements (interclass correlation coefficients [ICCs] = 0.807 and 0.936, respectively). TT-PCL was moderately reliable (ICC = 0.625), and correlated with TT-TG ( $r = 0.457$ ,  $P < .001$  proximal and  $r = 0.451$ ,  $P < .001$  distal). No significant difference was found between the proximal and distal measurements of TT-TG in each patient, though the PF group exhibited higher values than the ACL group ( $P < .001$  for both). TT-PCL was significantly higher for the PF group than the ACL group ( $P = .015$ ), but this difference lost significance when the group was divided by the TT-PCL cutoff of 24 mm ( $P = .371$ ). **Conclusions:** The proximal and distal techniques for measuring the TT-TG distance are similar to each other, and reliable despite level of reviewer training or presence of dysplasia. The TT-TG distance was predictive of patellofemoral instability. The TT-PCL distance was found to be less reliable than either method of measuring the TT-TG distance. Thus, this study demonstrated TT-TG to be superior to TT-PCL as a measurement of coronal malalignment. Given the variability in Dejour classification in this and other studies, a more reliable classification system for trochlear dysplasia as defined on cross-sectional imaging is warranted. **Level of Evidence:** Level III, retrospective clinical trial.

Coronal plane malalignment is thought to be a risk factor for primary and recurrent patellofemoral (PF) instability.<sup>1-3</sup> Previously popular as a clinical assessment,

the Quadriceps, or Q, angle was found to be subject to interobserver variability partially because of variations in 3 factors—patient and limb positioning, contraction of the

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quadriceps, and the examiner's ability to identify bony landmarks.<sup>4-6</sup> The tibial tubercle-to-trochlear groove (TT-TG) distance measurement has thus largely replaced the Q angle measurement as a clinical tool.<sup>7,8</sup> The TT-TG is measured on axial computed tomography (CT) or magnetic resonance imaging (MRI) to determine the lateralization of the tibial tubercle relative to the center of the trochlear groove.<sup>1</sup>

The literature varies in the specific techniques for measuring the TT-TG. The reference point for the tibial tubercle is described as either the most proximal aspect of the bony tubercle<sup>9</sup> or the most distal axial MRI depicting the insertion of the patellar tendon.<sup>10</sup> The reference point for the trochlear groove has been described as the deepest portion of the trochlea on an axial image with well-defined posterior femoral condyles,<sup>10</sup> and as the deepest portion of the trochlea on an axial image with the largest anterior-to-posterior femoral condylar dimension.<sup>11,12</sup> It has also been described as the deepest portion of the trochlea on the most proximal axial image with a complete cartilaginous trochlea.<sup>13</sup> Patients with patellofemoral instability have been shown to demonstrate higher TT-TG values than their stable counterparts, and a threshold of 20 mm has been popularized for consideration of bony realignment in the setting of recurrent patellofemoral instability,<sup>1</sup> though recent biomechanical studies suggest that the number may be higher.<sup>14</sup>

The tibial tubercle-to-posterior cruciate ligament (TT-PCL) distance is a measurement of coronal plane malalignment that has been proposed as an alternative to the TT-TG because of concerns raised over the reliability of TT-TG with respect to flexion and rotation about the knee.<sup>15</sup> Because the TT-PCL references 2 points on the tibia, it is a measurement of pure lateralization of the tibial tubercle, and is not affected by any limb rotation in the setting of knee motion. For this reason, we sought to determine the interrater reliability of the TT-PCL, and whether the TT-PCL correlates well with proximal and distal measurements of TT-TG.

Trochlear dysplasia, an alteration in normal trochlear morphology, has also been shown to be a risk factor for recurrent patellofemoral instability.<sup>1,16</sup> Trochlear morphology has been classified into 5 types according to the Dejour classification.<sup>1</sup> Patients with trochlear dysplasia have been shown to have "shorter" and "flatter" trochleae, and higher TT-TG measurements when referenced proximally on the trochlea.<sup>17</sup> Lack of consensus regarding measurement techniques can make clinical decision making for patients with recurrent patellofemoral instability challenging.

The purpose of this study was to determine the best practices for consistent and accurate evaluation of coronal alignment (TT-TG) in the setting of patellofemoral instability. We hypothesized that the TT-TG

measurement would show greater variability among observers in the setting of trochlear dysplasia, where the deepest portion of the trochlea may be more difficult to accurately assess than in normal trochleae.

## Methods

In this IRB-approved retrospective comparative study, the MRIs of 239 patients evaluated between 2006 and 2013 were reviewed. Contributing to this group were 130 patients who underwent surgery for recurrent lateral patellofemoral instability, and who had preoperative MRIs within the institution available for review, identified from the complete surgical records of the senior authors. Surgical interventions included medial patellofemoral ligament repair or reconstructions, and/or tibial tubercle osteotomy. The inclusion criteria were all patients who had surgery for instability—bony realignment or soft tissue stabilization. The exclusion criterion was patients with revision surgery (i.e., no preoperative MRI). To compare this "PF group" to a group of representative patients without patellofemoral instability, an identical number of patients within the same age range and time frame were randomly selected from our institution's anterior cruciate ligament (ACL) registry database (the "ACL group"). Once the patients with revision surgery and without in-house preoperative imaging were removed, 109 MRIs remained in the ACL group. No patients were found to have concomitant ACL rupture and patellofemoral instability. The ACL group and the PF group were combined and placed in random order before distribution, to reduce potential bias among reviewers. As our investigation was retrospective, all positioning in the MRI scanner was routine: patients were placed into a standard knee coil, which rendered the knee in slight flexion and external rotation. All of the MRIs were done at our institution.

Six reviewers reviewed the MRI studies for the patients in each group: 3 fellowship-trained orthopaedic surgeons with a practice focus in patellofemoral pathology, 2 orthopaedic sports medicine fellows, and 1 fellowship trained musculoskeletal radiologist. To standardize the measurements, the authors met as a group and agreed upon their techniques. A slideshow was created with example images and directions for each measurement, for simultaneous reference during MRI review. The measurements are listed in detail below. To control for potential confounding variables, the MRIs were also examined for the knee flexion angle in the scanner, as well as the presence or absence of an effusion, which were both recorded. Degree of knee effusion was categorized by "none," "small," or "significant" by each reviewer.

### Trochlear Morphology

The axial and sagittal MRIs were used to identify the trochlear morphology of each patient according to the

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