

# Measuring Malalignment on Imaging in the Treatment of Patellofemoral Instability

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## Abstract

Assessment of malalignment is an important factor in determining surgical treatment options for patellar instability. Measurement of tibial tubercle-trochlear groove (TT-TG) distance is valuable in planning surgical treatment for patellar instability, because it quantifies a component of malalignment and aids in deciding whether to perform tibial tuberosity osteotomy. In this paper we review how TT-TG distance should be understood in the context of many measurement factors to allow for an individualized procedure that addresses the specific contributors to patellar instability in each patient. Understanding the limitations of and variability in radiographic assessments of TT and TG positions can help in deciding whether to perform TT osteotomy for patellar instability.

Assessment of malalignment is an important factor in determining surgical treatment options for patellar instability. Although soft-tissue reconstruction of the medial soft-tissue stabilizers is often performed to address patellar instability, bony malalignment may increase stress on the medial soft tissues; therefore, it must be adequately identified and addressed.

Bony malalignment, which is often thought of as lateralization of the tibial tubercle (TT), can be influenced by tibiofemoral alignment, external tibial torsion, and femoral anteversion.

Clinically, coronal alignment can be assessed with a measurement such as quadriceps (Q) angle, but this has been reported to have low interrater reliability and high variability in the reported optimal conditions and positions in which the measurement should be made.<sup>1-3</sup>

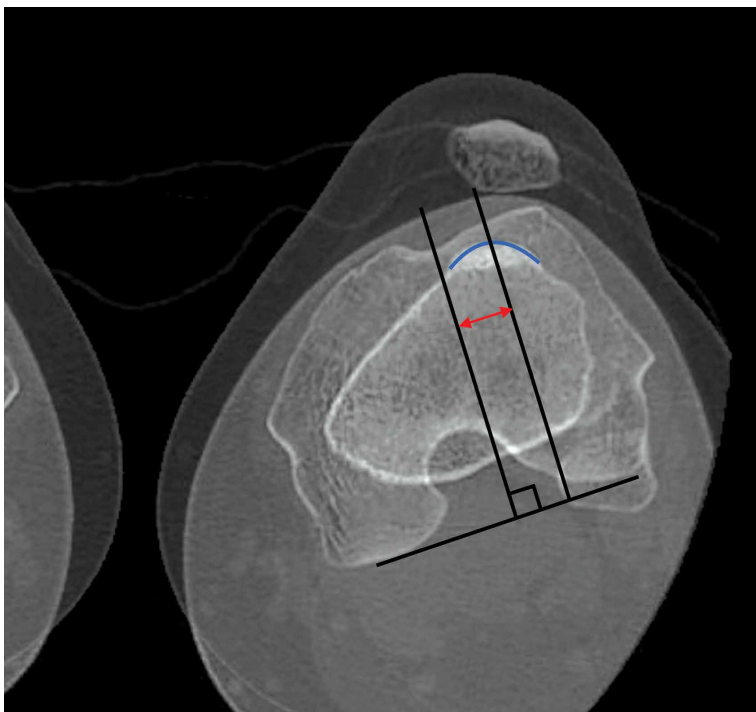
An anatomically lateralized TT pulls the extensor mechanism laterally with respect to the trochlear groove (TG), and this can accentuate problems related to patellofemoral instability. A recent biomechanical study found that increased TT lateralization significantly increased lateral patellar translation and tilt in the setting of medial patellofemoral ligament (MPFL) deficiency.<sup>4</sup> Although MPFL reconstruction restored patellar kinematics and contact mechanics, this restoration did not occur when the TT was lateralized more than 10 mm relative to its normal position.

Realigning the extensor mechanism by moving the TT medially decreases the lateralizing forces on the patella and the stress on the soft-tissue restraints. This raises the issues of when to correct a lateralized TT and how to identify and measure malalignment.

Radiographic assessment of TT position is most commonly performed by measuring TT-TG distance, which is the distance between the extensor mechanism attachment at the TT and the center of the TG. Originally described on radiographs and subsequently on computed tomography (CT) and magnetic resonance imaging (MRI) scans, distances of more than 15 mm or 20 mm have been reported as indications for TT osteotomy.<sup>5,6</sup>

However, there has been significant variability in reported TT-TG measurements. Studies have found that TT-TG distance is 3.8 mm larger on CT scans than on MRI scans.<sup>7</sup> Furthermore, factors such as knee flexion angle at time of imaging have been found to reduce TT-TG distance.<sup>1</sup> More recently, patient size and TT-TG ratios relative to patellar and trochlear width were identified as important factors in assessing TT-TG distance.<sup>8</sup> Therefore, TT-TG distance measurements should serve as a guide rather than a rigid threshold in the context of imaging and patient factors when deciding whether to perform TT osteotomy for patellar instability.

**Authors' Disclosure Statement:** The authors report no actual or potential conflict of interest in relation to this article.



**Figure.** Lines perpendicular to the posterior condylar axis are placed through the deepest part of the trochlear groove (blue line) and the center of the tibial tubercle. The tibial tubercle-trochlear groove measurement is the distance between these two lines (red line), measured in millimeters.

### What You Need to Know About Measuring Patellofemoral Malalignment

TT-TG distance can guide decisions about performing a medializing TT osteotomy for patellar instability because the measurement can aid in assessing bony malalignment caused by an anatomically lateralized tubercle. TT-TG distance can be used to determine when and how far to move the tubercle in TT osteotomy. However, a surgeon using this measurement should understand how it is obtained because many technical factors are involved. The **Figure** shows TT-TG distance on a CT scan.

#### Background

A normal TT-TG value is approximately 10 mm. The measurement originally used bony landmarks, including the deepest part of the bony TG and the anterior-most part of the TT, as described by Goutallier and colleagues.<sup>9</sup> In their original study, Dejour and colleagues<sup>5</sup> found that patients with recurrent symptoms of patellar instability had TT-TG distances >20 mm.

Increased TT-TG distance has been shown to correlate with patellar position, including increased lateral shift and lateral tilt of the patella. In a study using dynamic CT scans of patients with recurrent

patellar instability, we found that TT-TG distance increased with knee extension, and that this increase correlated with the lateral shift and lateral tilt of the patella.<sup>10</sup>

An excessively lateralized TT can be corrected with a medializing osteotomy that reduces TT-TG distance to within the normal range. TT surgery can be performed with flat osteotomy, as described by Elmslie and Trillat,<sup>11</sup> or with oblique osteotomy, as described by Fulkerson,<sup>6</sup> to obtain concomitant anteriorization. In a computational study, Elias and colleagues<sup>12</sup> found that medializing TT osteotomy not only reduced TT-TG distance but led to correction of lateral patellar tilt and displacement. Patellofemoral contact forces have also shown to be reduced with anteromedialization.<sup>6</sup>

#### Take-Home Points

- Radiographic assessment of TT position is most commonly performed by measuring TT-TG distance, which is the distance between the extensor mechanism attachment at the TT and the center of the TG.
- TT-TG distances of more than 15 mm or 20 mm have been reported as indications for TT osteotomy.
- TT-TG distance criteria should serve as a guide, rather than a rigid threshold, in the context of imaging and patient factors when deciding whether to perform TT osteotomy for patellar instability.
- Factors such as knee flexion angle, imaging modality, and landmarks used for the measurements should be considered when using TT-TG distance as an indication for surgery.
- There has been significant variability in reported TT-TG measurements. A surgeon using this measurement should understand how it is obtained because many technical factors are involved.



Although reported outcomes of TT osteotomy have been excellent for patients with patellar instability, the procedure has higher risks and longer rehabilitation relative to a soft-tissue procedure alone. Reported risks associated with TT osteotomy include fracture, nonunion, delayed union, painful screws, and deep vein thrombosis.<sup>6,10,13,14</sup>

Understanding the limitations of and variability in radiographic assessments of TT and TG positions can help when deciding whether to perform TT osteotomy for patellar instability.

## Discussion

When considering TT osteotomy for patellar instability, some surgeons use a TT-TG distance of more than 15 mm or 20 mm as a threshold for performing medialization. The variability is based on the multiple patient and imaging factors that can influence TT-TG distance measurement.

Several TG and TT landmarks have been used to measure TT-TG distance. The deepest part of the TG, based on bony anatomy, was used originally, but the cartilaginous landmark at the deepest part of the cartilaginous TG has also been described.<sup>15</sup> Similarly, on the TT, the original description of TT-TG distance, by Goutallier and colleagues,<sup>9</sup> involved the anterior-most part of the TT on CT scan, though the central part of the TT has also been described.<sup>15</sup> We found a 4.2-mm difference in TT-TG distance with use of different landmarks (central tubercle, anterior tubercle) within the same study population.<sup>16</sup> Therefore, within a practice, the distance used as an indication for TT osteotomy should be measured consistently.

Knee flexion angle at the time of imaging can also affect measurement of TT-TG distance. Several authors have reported smaller TT-TG distance with increased knee flexion angle.<sup>10,16,17</sup> In a study of patients with symptomatic patellar instability, we found that TT-TG distance decreases by an estimated 1 mm for every 4.4° of knee flexion >0°. In measurements of TT-TG distance, the sagittal view can be used to assess knee flexion angle because positioning protocols and patient comfort at the time of imaging may produce variable knee flexion angles.

Given the variability that occurs in TT-TG distance with knee flexion angles, some surgeons use TT–posterior cruciate ligament (PCL) distance as another measurement of TT lateralization.<sup>18</sup> This measurement is made with both tibial landmarks, from the TT to the medial border of the PCL insertion on the tibia, and theoretically eliminates knee flexion angle as a measurement factor. Seitlinger and col-

leagues<sup>18</sup> found that values >24 mm were associated with symptoms of patellar instability. More study is needed to determine the precise indications for TT osteotomy with use of this measurement.

In addition to patient positioning during knee imaging, patient size should be considered when TT-TG distance is used for malalignment measurement. Camp and colleagues<sup>9</sup> discussed the importance of “individualizing” TT-TG distance on the basis of patient size and bony structure. They reported that the ratio of TT-TG distance to trochlear width or patellar width more effectively predicted recurrent patellar instability than TT-TG distance alone.

Measurement of TT-TG distance is valuable in planning surgical treatment for patellar instability because it quantifies a component of malalignment and aids in deciding whether to perform TT osteotomy. However, this distance should be understood in the context of many measurement factors to allow for an individualized procedure that addresses the specific contributors to patellar instability in each patient.

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