Tibial Tuberosity to Trochlear Groove Distance (TT-TG): A Break-Down in Three Principal Components

Johannes Sieberer [1], Nancy Park [1], Albert Rancu [1], Armita Manafzadeh [1], Daniel Wiznia [1], John Fulkerson [1]
[1]Yale University, New Haven, CT
Johannes.sieberer@yale.edu

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INTRODUCTION: The tibial tuberosity to trochlear groove (TT-TG) distance has been considered the gold standard for clinical decision-making in patellar instability. It provides crucial information about the lateral component of the patellar force vector throughout flexion and extension. A high lateral force component increases the chance of lateral subluxation and instability. Since TT-TG is a metric dependent on the morphology of the femur and tibia, as well as their interaction, high TT-TG can have three prinicipal root causes: (1) tibial tuberosity is lateralized, (2) external tibiofemoral rotation, or (3) femoral trochlea is medialized. This study uses three-dimensional (3D) analysis to disentangle the relationship between these three components to better identify the factors behind patellar instability.

METHODS: 20 patients with lateral PF instability and 20 control knees from the New Mexico Decedent Image Database were segmented, and 3D models created. Landmarks were placed on the 3D models at the femoral and tibial posterior condyles, proximal, middle, and distal trochlea groove, tibial shaft center, and the tibial intercondylar tubercles. TT-TG, laterality of the tuberosity, TT-TG due to external tibiofemoral rotation (rotational TT-TG), and medialization of the trochlea groove were measured on 3D models. Distances were measured normal to a plane perpendicular to the posterior condyle line with the tibial axis, constructed by a line between the tibial shaft center and the midpoint between the intercondylar tubercles. Rotational TT-TG was measured by constructing a second reference plane perpendicular to the tibial posterior condyles. Measurements for patients and controls were compared via a Mann-Whitney U test. The correlation between rotation angle and rotational TT-TG was calculated via Pearson correlation coefficients. P-values < 0.01 were regarded as significant to account for multiple hypothesis testing. The study was regarded as exempt by the Institutional Review Board.

RESULTS SECTION: 3D TT-TG was significantly different ($p < 0.01$) between patients (mean±std: 17.8±4.2 mm; range: 10.9 to 26.6 mm) and controls (13.3±2.5 mm; 7.3 to 16.4 mm). Laterality of the tuberosity was not significantly different ($p=0.78$) between patients (12.3.0±3.3 mm; 7.2 to 19.5 mm) and controls (12.3±2.2 mm; 8.0 to 17.4 mm). Rotational TT-TG was significantly different ($p<0.01$) between patients (5.5±2.6 mm; 0.1mm to 11.3 mm) and controls (1.4±2.3 mm; -2.9 to 6.1 mm), corresponding to 11.1±5.3 degrees of tibiofemoral rotation for patients (plus defined as external rotation; R-value to rotational TT-TG: 0.96) and 2.7±4.3 degrees for controls (R-value: 1.00) respectively. The linear regression slope of the complete dataset was 0.49 (patients: 0.48 and patients: 0.53). Medialization of the trochlear groove did not differ significantly ($p = 0.678$) between patients (-0.1±2.2 mm; -3.6 (reduced TT-TG) mm to 3.7 (increased TT-TG) mm) and controls (-0.8±1.9 mm; -4.7 to 2.1 mm). Laterality of the tibial tuberosity contributes between 38% to 105% to total measured TT-TG for patients (70±15%) and 67% to 120% to total TT-TG for controls (94%±15%). (Values over 100% are achieved when the sum of rotational TT-TG and medialization of the trochlear groove contribute negatively to the overall TT-TG.)

DISCUSSION: The difference in TT-TG between patients and controls was mainly due to tibiofemoral rotation. As a rule of thumb, 2 degrees of tibiofemoral rotation adds 1 mm of TT-TG. The main contributor to overall TT-TG distance is the laterality of the tibial tuberosity for most patients, but at the same time, it is not significantly different between patients. Reducing the laterality of the tuberosity can mitigate TT-TG due to high rotation, even though it does not tackle the direct root cause for higher TT-TG. The methodology outlined can provide surgeons with more sophisticated information to guide clinical decision-making. Medialization of the trochlea can contribute to high TT-TG as a minor factor but does not differ significantly between patients and controls. Further research is required on whether high rotational TT-TG is significantly correlated with different patient outcomes, such as prognosis and prevalence of osteoarthritis. Additionally, different treatment methods, conservative or surgically, might be indicated for patients with high laterality of the tibial tuberosity compared to patients with high rotational TT-TG.

SIGNIFICANCE/CLINICAL RELEVANCE:
TT-TG has been the historical cornerstone of clinical decision-making in patellar instability, highlighting insights about the lateral patellar force vector through the knee's range of motion. This study discerns the 3D interrelationships between the trochlea, tibial tuberosity, and femur-tibia rotation to understand patellar instability determinants better and guide more patient-specific treatment of patellar instability.

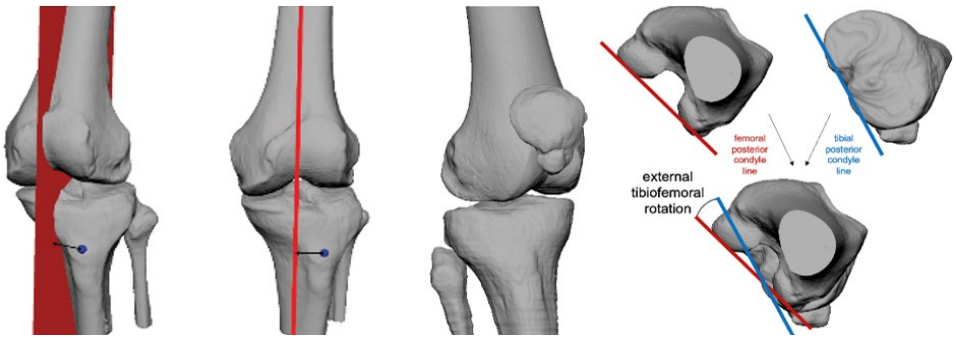

Figure 1: High tibial tuberosity to trochlea groove distance (TT-TG) can have three principal root causes: (1) High laterality of the TT, (2) High external tibiofemoral rotation, (3) Medialization of the trochlea groove. The (red) measuring plane is perpendicular to the posterior condyle line (red), external tibiofemoral rotation moves this plane away from the tuberosity thus increasing TT-TG. A neutrally rotated plane orientated by the tibial posterior condyle line (blue) is used to measure the laterality of the TT. The difference between the measurement to the measuring plane and the neutral plane was defined as rotational TT-TG. Medialization of the trochlea groove is measured by the distance of the selected point within the trochlea to the measuring plane.