Relationship between Tibial Tuberosity-Trochlear Groove Distance and Patellar Tracking in Patellar Instability

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Introduction: An elevated tibial tuberosity-trochlear groove (TT-TG) distance, which is measured to characterize the lateral pull of the patellar tendon acting on the patella, is a common feature of recurrent patellar instability [2]. The TT-TG distance has been shown to increase as the knee extends from a flexed position [1]. The current study was performed with two aims: 1) characterize the dynamic relationship between TT-TG distance and patellar tracking in patients with recurrent instability, and 2) characterize how the TT-TG distance contributes to unilateral patellar instability.

Methods: Computational reconstruction of in vivo patellofemoral function was performed to dynamically characterize the TT-TG distance and patellar tracking in patients being treated for unilateral instability. The study was IRB approved. The authors routinely use dynamic CT for clinical evaluation of recurrent instability. The analysis was based on dynamic CT scans performed between 2008 and 2013 for patients with unilateral instability who had not undergone a previous patellar stabilization procedure. The scans were performed with both knees centered in the gantry of a dynamic CT scanner (Aquilion ONE, Toshiba Medical Systems), as the patient extended against gravity from a flexed position to full extension and back. Twenty-one volumes of 320 axial images separated by 0.5 mm were acquired over 10 seconds. A subset of volumes were analyzed, including the position of maximum flexion, maximum extension, and at approximately 10° increments in between. Flexion angle was measured on a sagittal section through the intercondylar eminence, as the angle between lines along the femoral and tibial shafts. A total of fifteen scans meeting the criteria were identified, although two were excluded due to data not being available for flexion angles lower than 15°.

TT-TG distance and patellar alignment with the trochlear groove were assessed from the axial images. Within the most distal slice showing the intercondylar notch as a Roman arch, the posterior condylar axis was drawn through the most posterior points on the medial and lateral condyles. A line perpendicular to the posterior condylar axis was drawn through the deepest point of the trochlear groove. The patellar width line was drawn connecting the most medial and lateral points on the patella at the widest section of the patella. The bisect offset index, which assesses lateral shift of the patella, was calculated as the length along the patellar width from the most lateral point to the line through the groove, divided by the total width (Figure 1). The patellar lateral tilt was measured as the angle between the patellar width line and the posterior condylar axis. An additional line perpendicular to the posterior condylar axis was drawn bisecting the perimeter of the tibial tuberosity. The TT-TG distance was measured as the distance between the parallel lines through the deepest point of the trochlear groove and the tibial tuberosity. Investigators performing measurements were not told which knees were symptomatic. A single investigator repeated the measurements from three knees on three separate occasions. Two additional investigators also performed the measurements independently. Linear regression analyses were performed to relate measures of lateral tilt and bisect offset index to TT-TG distance for all measurements. Interpolation was also used to get the output measures at 10°, 20°, 30°, and 40° of flexion for all knees. For eight subjects, data was measured at knee flexion angle of 1° or lower for both knees. Interpolation and extrapolation were used to obtain output measures at 0° for these knees. Paired t-tests were used to compare TT-TG distance, lateral tilt and bisect offset index between the unstable and contralateral knees at 0° to 40°. Interclass correlation coefficients were also quantified based on the repeated measurements.
Results: The lateral tilt and bisect offset index tended to vary with the TT-TG distance. The TT-TG distance, lateral tilt and bisect offset tended to be larger for the unstable knees than the contralateral knees. The differences were greatest near full extension, with the differences significant (p < 0.05) at 0°, 10°, and 20° for the TT-TG distance, at 0° and 10° for the bisect offset index, and 0° for the lateral tilt (Figure 2). Over all measurements, the bisect offset and lateral tilt were significantly correlated with the TT-TG distance for both the unstable and contralateral knees (p < 0.001), with the square of the correlation coefficient ($r^2$) ranging from 0.51 for the bisect offset index with the contralateral knees to 0.64 for the lateral tilt with the unstable knees. Interclass correlation coefficients for intraobserver variability were 0.994 for patellar tilt, 0.990 for bisect offset, and 0.944 for TT-TG distance. Interclass correlation coefficients for interobserver variability were 0.984 for patellar tilt, 0.867 for bisect offset, and 0.911 for TT-TG distance.

Discussion: The data indicates that variations in the TT-TG distance contribute to variations in dynamic patellar tracking in knees with recurrent instability. The TT-TG distance tends to increase as the knee extends [2], with similar increases noted in the patellar lateral tilt and bisect offset index. The larger TT-TG distance in the unstable knees compared to the contralateral knees corresponded to larger values of lateral tilt and bisect offset index. Relatively large values of patellar lateral tilt and bisect offset index with the knee extended likely contribute to instability episodes. The primary limitation of the study is the lack of external resistance during knee extension, which could be addressed in a future prospective study.

Significance: The current study indicates that the TT-TG distance is a contributor to tracking patterns that can lead to instability episodes. The data helps show the value of characterizing the TT-TG distance during clinical assessment and the benefit of tibial tuberosity realignment in recurrent dislocators with an elevated TT-TG distance.

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