

A novel tibial tubercle to trochlear groove (TT-TG) distance for the assessment of patellar instability : an upright weight-bearing computed tomography analysis

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INTRODUCTION:

Tibial tubercle to trochlear groove (TT-TG) distance and Insall-Salvati ratio (I/S ratio) have been used to evaluate patellofemoral alignment and patellar position in patients with patellar instability. The magnitude of TT-TG distance and I/S ratio substantially influences treatment strategies for patellar instability. Reportedly, the patellar instability with TT-TG distance >20 mm or I/S ratio >1.3 needs the distal realignment in combination with medial patellofemoral ligament reconstruction. The two parameters are typically assessed using various imaging modalities such as computed tomography (CT) scans or magnetic resonance imaging (MRI) in supine position. However, since patellar dislocation clinically occurs in the weight-bearing condition, the TT-TG distance and I/S ratio should be evaluated in the upright weight-bearing condition rather than the nonweight-bearing (NWB) supine position. The purpose of the present study was to investigate and define the TT-TG distance and I/S ratio using upright full-weight-bearing (FWB) CT scans and compare them with NWB CT scans. Our hypothesis was that the newly defined FWB TT-TG distance and FWB I/S ratio would differ from the those in the NWB condition.

METHODS:

The present study investigated 49 knees of 26 healthy volunteers (15 females and 11 males with the mean age of 28.8 ± 4.3 years and the mean body mass index [BMI] of 21.3 ± 2.8 kg/m²). Exclusion criteria were a history of knee injury, developmental abnormalities, and a history of tibial tubercle apophysitis. Each participant provided written informed consent, and the study protocol (ID#20150293) was approved by our institutional review board.

CT images were acquired from the distal femur to the entire foot using the 320-row upright CT scanner (prototype TSX-401R; Canon Medical Systems). Both NWB and single-leg FWB data were obtained from each participant.

We used the coordinate system reported by Enomoto et al (Figure 1). The origin was defined as the midpoint of the bilateral tibial eminences. The axial axis was defined as the line connecting the origin and the apex of the tibial plafond. A line was formed connecting the medial margin of the proximal end of the tibial tuberosity and the center of the tibial attachment of the posterior cruciate ligament. This line was projected onto the axial plane, and this projected line was defined as the coronal axis. Finally, the sagittal axis was defined as the line perpendicular to both the axial and coronal axes.

TT-TG distance and I/S ratio were measured in axial and sagittal plane, respectively, using ZedView 3D version 16.0.1.0 (LEXI Co., Ltd.). The change of the TT-TG distance and I/S ratio from NWB to FWB condition was defined as the incremental TT-TG and incremental I/S ratio, respectively.

All Statistical analysis were performed using SPSS version 27.0 (IBM). The normality of the TT-TGs and I/S ratios was confirmed using the Shapiro-Wilk test, and the data were represented by mean \pm standard deviation (SD). Paired t-tests were performed to compare between FWB and NWB conditions, with the statistical power approximated at 100% to detect the patellar alignment change due to weight-bearing.

RESULTS:

The FWB TT-TG distance averaged 20.3 ± 3.9 mm (range, 13.3–29.3), while the NWB TT-TG distance was 12.3 ± 4.7 mm (range, 0–25.6). The incremental TT-TG distance was 7.9 ± 4.1 mm (range, 0.2–17.3) (Table 1). The FWB TT-TG distance was significantly larger than the NWB TT-TG distance ($P < 0.001$) (Table 2). The FWB I/S ratio averaged 0.98 ± 0.15 (range, 0.70–1.40), whereas the NWB I/S ratio was 1.00 ± 0.12 (range, 0.78–1.32). The incremental I/S ratio was -0.02 ± 0.14 (range, -0.29 to 0.33). The I/S ratio exhibited no significant difference between FWB and NWB conditions ($P = 0.285$).

DISCUSSION:

The present study revealed that the newly defined FWB TT-TG distance was 20.3 ± 3.9 mm exceeding 20 mm of cut-off value of the TT-TG distance. Incremental TT-TG from NWB to FWB condition was 7.9 ± 4.1 mm. The major reason for increased TT-TG from NWB to FWB was the femorotibial rotation, so-called screw home movement under the weight-bearing condition. In this study, the maximum value of incremental TT-TG distance was 17.3mm, and 5 knees (10.2 %) exhibited >15 mm of incremental TT-TG. Even in the normal knees, patellofemoral alignment substantially changes with weight-bearing. Taken together, the cutoff value for TT-TG distance should be revised to around 28 mm (at least 8 mm larger than the traditional value) when considering an indication for distal realignment.

SIGNIFICANCE/CLINICAL RELEVANCE:

The newly defined FWB TT-TG distance by using upright CT scan was 20.3 ± 3.9 mm, exceeding the cutoff value of the traditional TT-TG distance in normal healthy subjects. The incremental TT-TG distance from NWB to FWB conditions was 7.9 ± 4.1 mm and thus, cut-off value of TT-TG distance should be changed to around 28mm.

Figure 1. Coordinate system

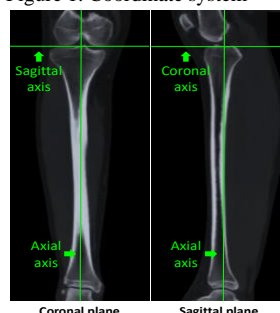


Table 1. The values of the TT-TG distances and I/S ratio.

variables	mean	SD	range
FWB TT-TG (mm)	20.3	3.9	13.3 to 29.3
NWB TT-TG (mm)	12.3	4.7	0 to 25.6
Incremental TT-TG (mm)	7.9	4.1	0.2 to 17.3
FWB I/S ratio	0.98	0.15	0.70 to 1.40
NWB I/S ratio	1.00	0.12	0.78 to 1.32
Incremental I/S ratio	-0.02	0.14	-0.29 to 0.33

Table 2. Comparison of the TT-TG distances and I/S ratio.

variables		P value
FWB TT-TG	NWB TT-TG	<0.001
FWB I/S ratio	NWB I/S ratio	0.285