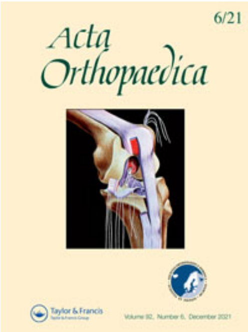

Acta Orthopaedica Scandinavica

ISSN: 0001-6470 (Print) (Online) Journal homepage: informahealthcare.com/journals/iort19

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To cite this article: Keita Miyanishi, Ryuji Nagamine, Sadayuki Murayama, Hiromasa Miura, Ken Urabe, Shuichi Matsuda, Go Hirata & Yukihide Iwamoto (2000) Tibial tubercle malposition in patellar joint instability: A computed tomography study in full extension and at 30° flexion, Acta Orthopaedica Scandinavica, 71:3, 286-291, DOI: 10.1080/000164700317411898

To link to this article: https://doi.org/10.1080/000164700317411898

Published online: 08 Jul 2009.

Tibial tubercle malposition in patellar joint instability

A computed tomography study in full extension and at 30° flexion

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Submitted 99-06-07. Accepted 00-01-17

ABSTRACT – We evaluated the tibial tubercle position in knees with patellar instability. CT in full extension and at 30° flexion was used in 18 knees with instability and 18 control knees. Scans were taken at the level of the femoral epicondyles, tibial tubercle and distal tibia. We found that in full extension, the tibial tubercle was in a more lateral position in the unstable than in the control knees. At 30° flexion, the tibial tubercle in the unstable knees rotated internally, but it was never within the normal range. CT scans taken in full extension and at 30° flexion seem to be of value for ascertaining the degree of tibial tubercle malposition during knee flexion in patellar instability.

■

An excessive lateral position of the tibial tubercle is reported to be a prime factor in patellar instability (Muneta et al. 1994). The position of this tubercle in relation to the femoral condyles varies with knee flexion, which affects patellar tracking (Nagamine et al. 1995, 1997). Although computed tomography (CT) is useful for evaluating knees with patellar instability, CT scans in other studies have been taken at one knee angle of limited flexion, which provides only static analyses (Inoue et al. 1988, Ando et al. 1993, Dejour et al. 1994, Eckhoff et al. 1994, Guzzanti et al. 1994, Muneta et al. 1994). We have found no CT study that assessed the position of the tibial tubercle in unstable knees at different flexion angles.

Therefore we carried out CT scans in full extension and at 30° flexion to evaluate the tibial tubercle position in normal subjects and patients with patellar instability. By comparing the position of the tibial tubercle in full extension and at 30° flexion, we detrmined whether unstable knees have a mechanical abnormality.

Patients and methods

The patellar instability group consisted of 18 knees in 15 (13 women) consecutive Japanese patients, who had been referred to our department between April 1995 and July 1998 with the diagnosis of isolated patellar instability. The mean age was 28 (12–44) years. The diagnosis required (1) anterior knee pain with bent knee activities, (2) one or more objective physical findings that indicated patellar instability—that is, passive subluxation of the patella, tenderness over the medial retinaculum, a positive patellofemoral grinding test, or a positive apprehension sign, and (3) radiographic evidence of patellar subluxation confirmed by more than 0° congruence angle using Merchant's technique (Merchant et al. 1974, Insall et al. 1983, Møller et al. 1986). Of the 15 patients with patellar instability, 6 (6 knees) had at least one documented dislocation caused by a discrete trauma followed by disability.

The control group consisted of 18 knees in 18 healthy volunteers (16 women). The mean age was 28 (18–51) years. None of them had knee symptoms and radiographs were normal.

CT scans were carried out as described in our previous study (Nagamine et al. 1997). The knees

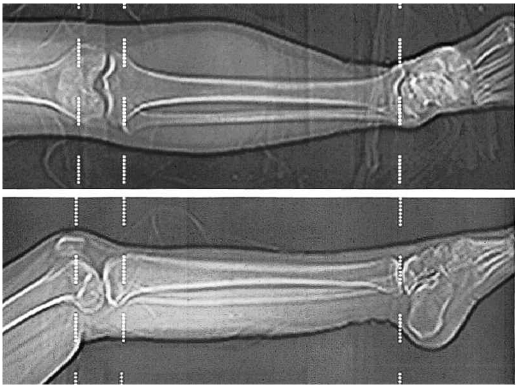

Figure 1. The CT scanning position was determined by a scanogram. Scans were taken at the level of the femoral epicondyle, the tibial tubercle, and the distal tibia, in full extension and at 30° flexion, with the quadriceps muscle relaxed.

were positioned supine on the CT table with the tibial axis parallel to the CT table in the coronal and sagittal planes. The position was confirmed by a scanogram. With the quadriceps relaxed, cuts were taken at the level of the femoral epicondyles, the tibial tubercle and the distal tibia, in full extension and at 30° flexion (Figure 1). At the level of the distal tibia, slices were cut along the proximal articular surface of the ankle joint, perpendicular to the tibial shaft. When CT scans were performed at 30° flexion, the leg was immobilized on a styrofoam box with elastic tape so as to prevent any rotation of the leg. If the CT image did not show the medial epicondyle clearly, an additional CT scan was taken after the scan level had been moved 2 mm distally or proximally until the medial epicondyle was clearly visible. The slices were superimposed. The image of the CT table was used as a reference point to align precisely each level of image to be superimposed.

Parameters were measured using the central point of the transepicondylar line (point C) as a reference point (Figure 2). These included: the tibial tubercle angle (TT angle), the tibial tubercle-lateral condyle angle (TT-LC angle) and the malleolar line angle (ML angle) (Figure 3). The TT angle was the angle between the transepicondylar line and the line from the central point of the patellar tendon to point C. The TT-LC angle was the angle between the line from the central point of the patellar tendon to point C and the line from the highest point of the lateral femoral condyle to

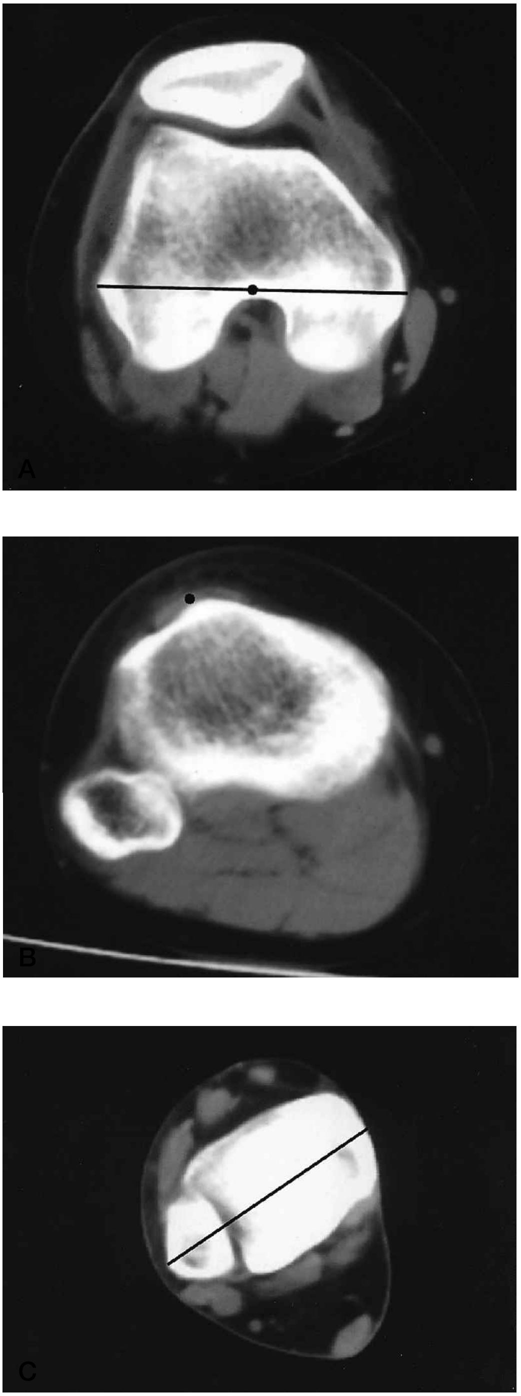

Figure 2. Three typical slices are shown. The reference lines and points were determined as follows: the transepicondylar line and the central point of the transepicondylar line at the level of the femoral epicondyle (A), the central point of the patellar tendon at the level of the tibial tubercle (B), and the line between the medial and lateral malleolus at the level of the distal tibia (C).

point C. The latter two parameters were used to assess the position of the tibial tubercle relative to the femoral epicondyles. If the TT angle or the TT-LC angle is small, the tibial tubercle is thought to be located laterally. The patellar ligament was used for the measurement, not the center of the bony prominence of the tibial tubercle, because the center of the patellar tendon was usually more laterally positioned than the center of the bony prominence of the tibial tubercle (Muneta et al. 1994). The ML angle was the angle between the transepicondylar line of the femur and the line between the medial and lateral malleolus on the distal tibia. It was used to assess the rotation angle of the tibia relative to the transepicondylar line. The TT, TT-LC and ML angles were measured in full extension and at 30° flexion. The difference in the value of each measurement in full extension and at 30° flexion was used as the rotation range, which is thought to represent mechanical motion of the tibial tubercle or distal tibia from full extension to 30° flexion.

We measured three other parameters to evaluate the anatomic configuration of the femoral condyles: the lateral condyle angle (LC angle), the lateral condyle-medial condyle angle (LC-MC angle) and the lateral condyle-femoral groove angle (LC-FG angle) (Figure 3). The LC angle was the angle between the transepicondylar line and the line from the highest point of the lateral femoral condyle to point C. The LC-MC angle was the angle between the line from the highest point of the lateral femoral condyle to point C and the line from the highest point of the medial femoral condyle to point C. The LC-FG angle was the angle between the line from the highest point of the lateral femoral condyle to point C and the line from the deepest point of the femoral groove to point C. These angles were measured at 30° flexion.

We determined the reproducibility of the measurement technique by having 2 of the authors measure the TT angle in full extension on 2 occasions in each member of the patellar instability group and the control group. The interobserver differences (the differences between the measurement of the angle by KM and the measurement by RN in each person) are shown as the mean value (± 2 SD) of the differences in all subjects. The

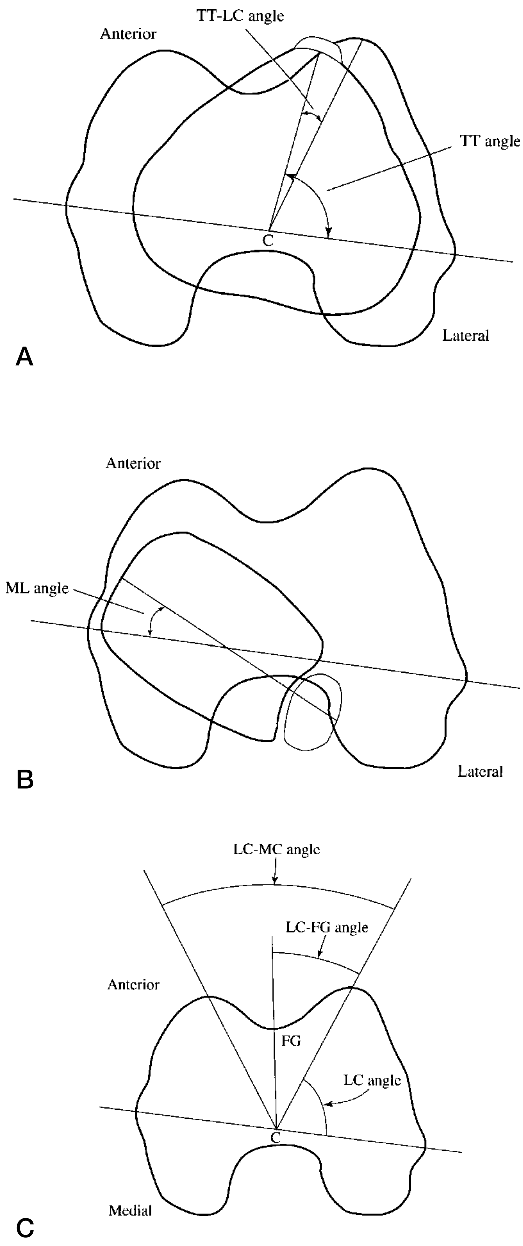

Figure 3. Diagram showing the tibial tubercle angle (TT angle) and tibial tubercle-lateral condyle angle (TT-LC angle) (A). Both parameters were used to assess the position of the tibial tubercle relative to the femoral epicondyles. Diagram showing the malleolar line angle (ML angle) (B). This angle was used to assess the rotation angle of the tibia relative to the transepicondylar line. Diagram showing the lateral condyle angle (LC angle), the lateral condyle-medial condyle angle (LC-MC angle), and the lateral condyle-femoral groove angle (LC-FG angle) (C). These parameters were used for the anatomic evaluation of the femoral condyle. C corresponds to the central point of the transepicondylar line.

Results of CT parameters (degrees) in knees with patellar joint instability (PJI) and control knees

	TT angle in full extension	TT angle at 30° flexion	TT angle rotation range	TT-LC angle in full extension	TT-LC angle at 30° flexion	TT-LC angle rotation range
PJI knees	55 (5.7)	70 (7.2)	15 (8.0)	–9 (7.8)	9 (7.0)	17 (10)
Control knees	66 (4.5)	75 (5.5)	10 (6.8)	3 (4.1)	15 (4.8)	12 (5.7)
P-value [a]	< 0.001	0.01	0.04	< 0.001	0.004	0.05
	ML angle in full extension	**ML angle at 30° flexion**	**ML angle rotation range**	**LC angle**	**LC-MC angle**	**LC-FG angle**
PJI knees	33 (11)	23 (12)	10 (6.0)	61 (4.3)	55 (6.7)	34 (7.4)
Control knees	25 (9.5)	18 (8.2)	7 (6.9)	61 (2.3)	55 (3.5)	30 (1.9)
P-value [a]	0.04	0.19	0.21	0.81	0.80	0.08

[a] Student's t-test. Values represent mean (SD).
TT angle – tibial tubercle angle, TT-LC angle – tibial tubercle-lateral condyle angle, ML angle – malleolar line angle,
LC angle – lateral condyle angle, LC-MC angle – lateral condyle–medial condyle angle,
LC-FG angle–lateral condyle-femoral groove angle.

intraobserver differences (the differences between 2 measurements by KM in the same person at different times) are shown as the mean value (± 2 SD) of the differences in all subjects (Bland and Altman 1986).

We compared the 12 parameters in the knees with patellar instability and the control knees using the Student's t-test, with $p < 0.05$ being considered significant.

Results

Significant lateralization of the tibial tubercle (the TT angle and TT-LC angle) was found in knees with patellar instability in full extension and at 30° flexion, when compared to the control knees. The extent of lateralization was less significant at 30° flexion, and the dynamic internal rotation of the tibial tubercle from full extension to 30° flexion (rotation ranges of the TT angle and TT-LC angle) was greater in knees with patellar instability. Significant external rotation of the tibia (ML angle) was also found in knees with patellar instability in full extension (Table).

The anatomic parameters of the femoral condyles, the LC angle, LC-MC angle and LC-FG angle, were similar in the unstable and control knees.

The mean interobserver variation of the variables measured was 0.51° (SD 2.6°) and the limits of agreement were -4.7–5.7°. The mean intraobserver variation of the variables was 0.65° (SD 3.1°) and the limits of agreement were -5.6–6.9°.

Discussion

A change in location of the tibial tubercle during knee motion is an important variable in patellar tracking (Nagamine et al. 1995). This concept has led to the current CT assessment of tibial tubercle position in unstable knees at 2 flexion angles. We found that the knees with patellar instability had significant lateralization of the tibial tubercle in full extension, which was shown to exist together with tibial external rotation. The tibial tubercle was then rotated internally towards the normal range when flexion was initiated, however it never entered the normal range at 30° flexion.

In previous CT studies of patellar instability, slices were taken with knees placed in one position, either in full extension or at slight flexion, which means that only static patellofemoral relationships could be evaluated (Inoue et al. 1988, Ando et al. 1993, Dejour et al. 1994, Eckhoff et al. 1994, Guzzanti et al. 1994, Muneta et al. 1994). Since assessmentof the patellar joint at 0°–20° flexion has been emphasized as diagnostically important, providing good information on the pathophysiology of unstable knees (Laurin et al. 1979, Schutzer et al. 1986), measurements of the CT parameters in full extension may be sufficient for clinical use. However, the purpose of our study was to determine scientifically any mechanical abnormality in unstable knees. Using CT scans at 2 angles, we showed, in knees with patellar instability, not only the lateralization of the tibial tubercle in full extension but also what happened when the knee was flexed. Dynamic or multipositional scans from 0° through the power zone may be more useful for better understanding of the pathomechanics of the patellar joint.

The line between the posteriormost edges of the medial and lateral femoral condyles (posterior condylar line) has been used as a reference line in several articles (Ando et al. 1993, Dejour et al. 1994, Eckhoff et al. 1994, Guzzanti et al. 1994, Muneta et al. 1994). In these articles, the CT scans were taken with the knees in only one flexion angle. Since we compared 12 parameters at full extension and at 30° flexion, our reference line needed to be constant during knee flexion. The flexion-extension axis is reported to pass close to the transepicondylar line (Hollister et al. 1993), which we therefore used as a stable reference.

Some similar CT studies have been done regarding patellar instability. Dejour et al. (1994) reported that tibial tuberosity-trochlear groove displacement is a CT parameter of lateralization of the tibial tubercle in unstable knees, using the deepest point of the intercondylar groove of the femur as a reference. Although this point is important in evaluating patellar instability (Ando et al. 1993, Dejour et al. 1994), the midpoint of the transepicondylar line (point C) may be more useful as a stable reference when the CT scans are taken at different flexion angles (Hollister et al. 1993). Using CT scans in full extension, Muneta et al. (1994) showed that the tibial tubercle rotation angle differed significantly between patients with patellar instability and the controls. Our results were compatible with their data since we found general lateralization of the tibial tubercle in patients with patellar instability in full extension. However, by using CT scans at 2 angles we could also show that the tibial tubercle was rotated internally towards the normal range when flexion was started.

Bone and soft-tissue abnormalities have been reported in cases of patellar instability, including lateral condylar hypoplasia, proximal insertion of the vastus medialis, and external tibial torsion (Fulkerson 1996). We found that the mean LC-FG angle was larger in unstable knees than in the control knees although the difference was not statistically significant, which may suggest a hypoplastic tendency of the lateral condyle in cases of patellar instability. We speculate that some of these bone and soft-tissue abnormalities may account for the mechanical difference in knees with patellar instability. However, our CT method could not clarify which factor was responsible for the difference.

Since patellar tracking is 3-dimensional, 3-dimensional assessment might evaluate patellar kinetics more precisely. Normal contact zones and/or pressure distributions of the patellar joint have been studied to clarify their relationship with patellar instability (Huberti et al. 1984, Van Kampen and Huiskes 1990). The effect of the position of the tibial tubercle along an anteroposterior line on patellofemoral pressure may thus be an important factor for evaluating patellar instability, which could not be assessed in this study. Further investigations concerning this issue need to be undertaken.

Medial transfer of the tibial tubercle is one of the most popular procedures for correcting patellar malalignment. However, no standards have been established for determining the optimal amount of transfer. The amount of medialization of the tibial tubercle was previously assessed only by checking the patellar tracking on the operating table (Fulkerson 1983, Brown 1984). Our study provides an anatomic basis for determining the amount of tibial tubercle transfer. The amount of transfer required to normalize the position of the tibial tubercle can be determined by measuring the TT angle or the TT-LC angle with a CT scan prior to surgery.

We thank Hitoshi Baba for his technical assistance. This study was supported by a Grant-in-Aid for General Scientific Research (09771096) from the Ministry of Education, Science, Sports and Culture (Japan).

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