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Systematic Technique-Dependent Differences in CT Versus MRI Measurement of the Tibial Tubercle–Trochlear Groove Distance

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Background: The tibial tubercle–trochlear groove (TTTG) distance is used to quantify the degree of lateralization of the patellar tendon insertion on the tibial tubercle relative to the deepest part of the trochlear groove. Disagreement exists as to whether the TTTG distance measured on computed tomography (CT) and magnetic resonance imaging (MRI) can be considered equivalent.

Purpose: To compare TTTG distance as measured on axial CT and MRI and to investigate the potential effect of patient positioning between modalities.

Study Design: Cohort study (diagnosis); Level of evidence, 3.

Methods: Patients who received both CT and MRI of the same knee for any indication from August 2010 to April 2014 were included in this study. The TTTG distances were measured twice by 2 raters in a randomized order, with at least 30 days between ratings to minimize recall bias. Inter- and intrarater reliability of CT and MRI measurements and intermethod reliability were assessed with intraclass correlation coefficients (ICCs). Bland-Altman plots were also created to assess agreement. Differences in patient positioning were investigated to determine its effect on the TTTG distance.

Results: Fifty-nine patients (age, 32.8 ± 12.9 years) were included. Interrater ICCs were excellent for both CT and MRI measurements. Intrarater ICCs were excellent for both raters. Absolute agreement ICCs for intermethod reliability were fair to good, but consistency type agreement was excellent. A systematic bias of lower MRI distances (bias = −2.8 mm) compared with CT was observed. The investigation of CT versus MRI imaging techniques demonstrated that the standard MRI examination places the knee in approximately 4.6° of relative varus alignment compared with CT.

Conclusion: A systematic bias toward lower TTTG distances on MRI compared with CT was found. This finding is likely dependent on imaging technique, including patient positioning. Patient knees were positioned in varus on the MRI compared with the CT examination, with resulting lower TTTG distances on MRI compared with CT. The TTTG distances on CT and MRI vary with imaging technique, which may be attributable to patient positioning and result in differences among imaging centers.

Keywords: tibial tubercle–trochlear groove distance (TTTG); patellar instability; CT; MRI

The tibial tubercle–trochlear groove (TTTG) distance has become an important parameter for the measurement of patellofemoral alignment, typically in patients with anterior knee pain, patellar instability, or major articular cartilage degeneration of the patellofemoral joint.[6,7,19] This measurement quantifies the medial-lateral distance between the deepest part of the trochlear groove and the center of the patellar tendon insertion on the tibial tubercle. A TTTG distance of greater than 20 mm is generally considered pathologic and has been proposed as a threshold for considering a tibial tubercle osteotomy or distal realignment procedure.[7,11] Therefore, accurate measurement of the TTTG distance is critical in assessing and determining the need for a tibial tubercle osteotomy with its associated risks, benefits, and morbidity.

In the past, computed tomography (CT) was considered the gold standard imaging modality; however, more

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recently, magnetic resonance imaging (MRI) has been proposed as an alternative to spare patients from increased radiation exposure. Previous studies are in disagreement about whether CT and MRI should be considered equivalent for measuring TTTG distances. Additionally, the causation of the disagreement between CT and MRI has not been fully understood in the literature and may be due to differing patient positioning techniques inherent to each modality. Schoettle et al[18] conducted a prospective study comparing the equivalency of CT and MRI. Twelve knees in 11 patients with patellofemoral instability were imaged with CT and MRI. Both bony and cartilaginous landmarks were used in determining the TTTG distances. It was observed that the bony TTTG distance measured by CT and MRI was sufficiently equivalent that MRI was a suitable substitute for CT.

In a retrospective cohort study by Camp et al,[5] CT and MRI measurements of TTTG distances were compared in 59 knees with patellofemoral instability from 2003 to 2011. The TTTG distances were not equivalent on CT compared with MRI. Of the patient pool, 11 patients had a TTTG of $\geq$20 mm on CT, and the mean TTTG distance on CT was 22.5 mm (range, 19.8-25.8 mm) and on MRI was 17.7 mm (range, 14.4-22.8 mm), resulting in a mean difference of 3.80 mm between the 2 modalities ($P <$ .001). Thus, previous studies do not agree whether CT and MRI can be considered equivalent.

The objectives of this study were to determine whether MRI can reliably and reproducibly measure TTTG distances and to compare MRI with CT measurements using intrarater, interrater, and intermethod reliability. We hypothesized that there would be excellent reliability when evaluating TTTG measurements on MRI and CT. We hypothesized that inter- and intrarater reliability would be excellent in measuring TTTG distances on both MRI and CT. Additionally, we hypothesized that systematic differences in imaging technique protocols, including patient positioning, contribute to systematic differences in TTTG measurements between MRI and CT.

METHODS

Patients

This study was approved by an institutional review board. Between August 2010 and April 2014, all patients who underwent both preoperative CT and MRI of the same knee for any indication during their standard clinical workup by a single orthopaedic surgeon (R.F.L.) were included in this study. A total of 75 patients met the inclusion criteria. Exclusion criteria included an MRI or CT scan performed at an outside facility, knee surgery in the interval between MRI and CT acquisition, a time between MRI and CT acquisition of more than 1 year, and incomplete or missing imaging records. Six patients were excluded who had an MRI or CT scan performed at an outside facility, 2 patients who had knee surgery between the acquisition of the MRI and CT scans, 2 patients with more than 1 year between MRI and CT, and 1 patient who had

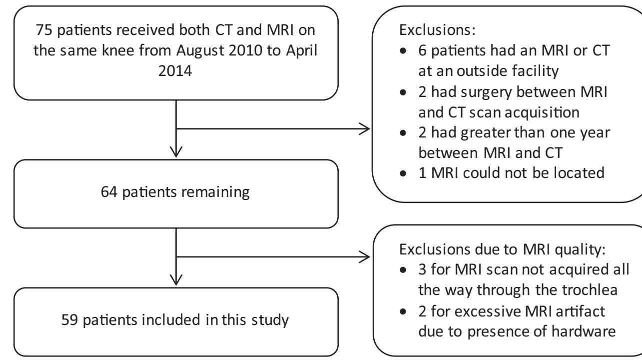

Figure 1. Patient flow chart for this study.

an in-house MRI that could not be located at the time of measurements (Figure 1). Additionally, 3 patients had MRI scans that did not include the entirety of the trochlea, and 2 patients had excessive artifact from hardware in the distal femur precluding measurement of the TTTG distance, and they were excluded. A total of 59 knees in 59 patients (mean age, 32.8 $\pm$ 12.9 years; 31 females, 28 males; 29 right knees, 30 left knees) satisfied all criteria and were included in this study. The time between MRI and CT scan acquisition (mean $\pm$ SD) was 32.1 $\pm$ 53 days. Patients included in this study generally fell into 2 categories: those with patellar instability and those undergoing revision knee ligament reconstruction or complex multiligament reconstruction (6 patellar instability, 52 revision ligament reconstructions [complex multiligament reconstructions with or without meniscal repair], 1 saphenous nerve reconstruction). For patients with patellar instability, MRI was obtained to investigate the integrity of soft tissue structures, while CT was used to calculate the TTTG distance according to the current gold standard technique. For patients undergoing revision knee ligament reconstructions, MRI was obtained to investigate the integrity of the ligament, cartilage, and meniscal tissue, while CT was obtained to examine existing cruciate ligament reconstruction tunnel sizes and locations. Six patients in this cohort were diagnosed with symptomatic patellofemoral instability. Three of these 6 patients had Dejour type A trochlear dysplasia and the other 3 patients had Dejour type B trochlear dysplasia.[12,15]

Imaging Protocols

All patients underwent our institution's standard clinical MRI and CT before surgical intervention. All MRI examinations were performed at 3.0 T on a Siemens Magenetom Verio (Siemens Medical Solutions) and included an axial T2-weighted turbo-spin echo scan (T2w TSE Ax) as part of our standard clinical MRI examinations used to measure the TTTG distance. For the MRI acquisition and patient positioning, all patients were scanned in a supine position with their knee tightly fixed in the center of a 15-channel multi-element phased-array knee coil (Quality Electrodynamics LLC). The dedicated knee MRI coil places the knee in slight flexion as the base of the coil is elevated slightly from the level of the examination table. The T2w TSE Ax sequence was acquired from the distal femoral metaphysis through the proximal tibial diaphysis below the level of the tibial tubercle (repetition time, 5320 ms; echo time, 100 ms; slice thickness, 3 mm; interslice gap, 0 mm; field of view, 110; matrix, 256 × 192; echo train length, 6; scan time, 4:46 minutes).

All CT examinations were performed on an Aquilion 64 (Toshiba America Medical Systems). Patients were positioned supine with the legs in full extension and the right and left forefoot taped together at the level of the metatarsophalangeal joint. The patients underwent a high-resolution CT scan of their knee to approximately 12 cm above and below the joint line. The sequence of images from the scan, representing slices of 0.5-mm thickness with a resolution of 512 × 512 pixels, were obtained using standard 120 kVp and 200 mA techniques.

Measuring the TTTG Distance

All measurements were performed using the same eFilm Workstation (v3.4; Merge Healthcare Inc). The TTTG distance was measured using a bony landmark technique consistent with the techniques reported by Camp et al[5] and Schoettle et al.[18]

The tibial tuberosity measurement was made at the most cephalad, central margin of the patellar tendon insertion (at the point in which the entire tendon inserted on the tibial tubercle). The location of the tibial tuberosity was defined as the most central, anterior point of the tibial tuberosity, while the trochlear grove location was defined as the deepest point of the trochlear groove level with the posterior cortices of the femoral condyles. Specifically on the MRI images, the location was the first axial image depicting a complete cartilaginous V-shaped or U-shaped trochlea. A posterior condylar line was established parallel to the posterior condylar cortices, and a trochlear line was established perpendicular to the posterior condylar line and passed through the deepest point of the trochlear groove. The tibial tubercle was next marked, as noted above. Finally, the trochlear line was transferred to the image showing the tibial tubercle location. The TTTG distance was defined as the perpendicular distance between the tibial tubercle and trochlear lines (Figure 2).

All measurements were performed by 2 experienced raters: a musculoskeletal radiologist with 5 years of experience (15 years of prior experience as a sports medicine physician) and a sports medicine orthopaedic surgeon with 6 years of experience. To assess intra- and interrater reliability, each MRI and CT was measured in a randomized order, twice by each rater, with at least 30 days of elapsed time between measurements. Measurements were recorded to the nearest millimeter. Raters were blinded to all patient identifiers including patient name, age, sex, diagnosis, and date of scan. In addition, each rater was blinded to the other rater's measurements and their previous measurement during the course of the study.

To evaluate any differences in patient positioning between MRI and CT, a pilot investigation was performed with a cohort of 9 asymptomatic volunteers (6 male, 3 female; mean age, 31 ± 7.5 years). The right knee of each volunteer was positioned in the respective scanner by the same experienced MRI and CT technologists, with the knee in the dedicated knee coil on the MRI table, in the same manner as the patient would be positioned for an examination, as described previously. One fellowship-trained sports medicine physician then performed all measurements of knee varus/valgus alignment using a standard goniometer. The goniometer was positioned directly over the patella, and the 2 limbs of the goniometer were aligned along the midline axis of the distal femur and proximal tibia based on direct palpation of the femur and tibia and gross visualization of the alignment. The degree of varus or valgus alignment at the knee was recorded for each patient.

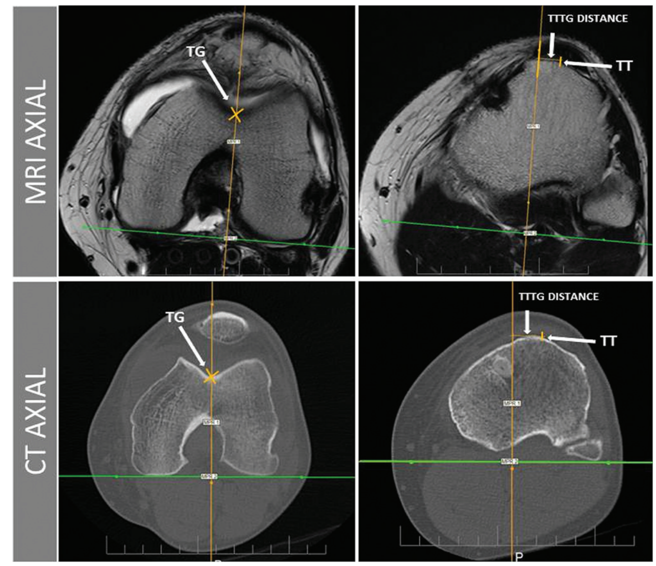

Figure 2. The tibial tubercle (TT)–trochlear groove (TG) distance is measured on (top row) axial MRI and (bottom row) axial CT images (left knee) to determine the degree of lateralization of the tibial tubercle relative to the deepest part of the trochlear groove.

Statistical Analysis

Inter- and intrarater reliability of MRI and CT measurements and intermethod (comparing MRI and CT) reliability of TTTG distances were assessed with intraclass correlation coefficients (ICCs). Because clinical decision making is often based on a TTTG threshold, the absolute measure of ICC agreement was used in all cases.

For comparison, the consistency measure of ICC agreement, which treats any systematic bias between measurement groups as irrelevant, was also reported for intermethod reliability. To reflect the nature of our experiment—2 raters among the pool of qualified raters measuring TTTG distances of our representative sample of patients—the single-measures, 2-way random effects form was used, ICC (A,1) and ICC (C,1).[13] To correspond with the most clinically likely scenario, intermethod reliability was calculated using the first round of

TABLE 1
Interrater, Intrarater, and Intermethod Agreement Measures[a]

		ICC	95% CI LB	95% CI UB	Observed Bias	95% LOA LB	95% LOA UB
Interrater (rating 1)	MRI	0.936	0.893	0.961	0.09	−3.03	3.20
	CT	0.914	0.851	0.949	−0.61	−4.21	2.99
Intrarater (rater 1)	MRI	0.954	0.924	0.973	−0.05	−2.74	2.63
	CT	0.957	0.929	0.974	0.00	−2.73	2.73
Intrarater (rater 2)	MRI	0.949	0.914	0.969	−0.29	−3.05	2.46
	CT	0.920	0.867	0.952	−0.46	−4.06	3.15
Intermethod (rater 1/rating 1)	Absolute	0.643	0.124	0.839	−2.79	−8.87	3.28
	Consistency	0.767	0.636	0.855			

[a]Rater 1 is the musculoskeletal radiologist. Rater 2 is the orthopaedic surgeon. CT, computed tomography; ICC, intraclass correlation coefficient; LB, lower bound; LOA, limits of agreement; MRI, magnetic resonance imaging; UB, upper bound.

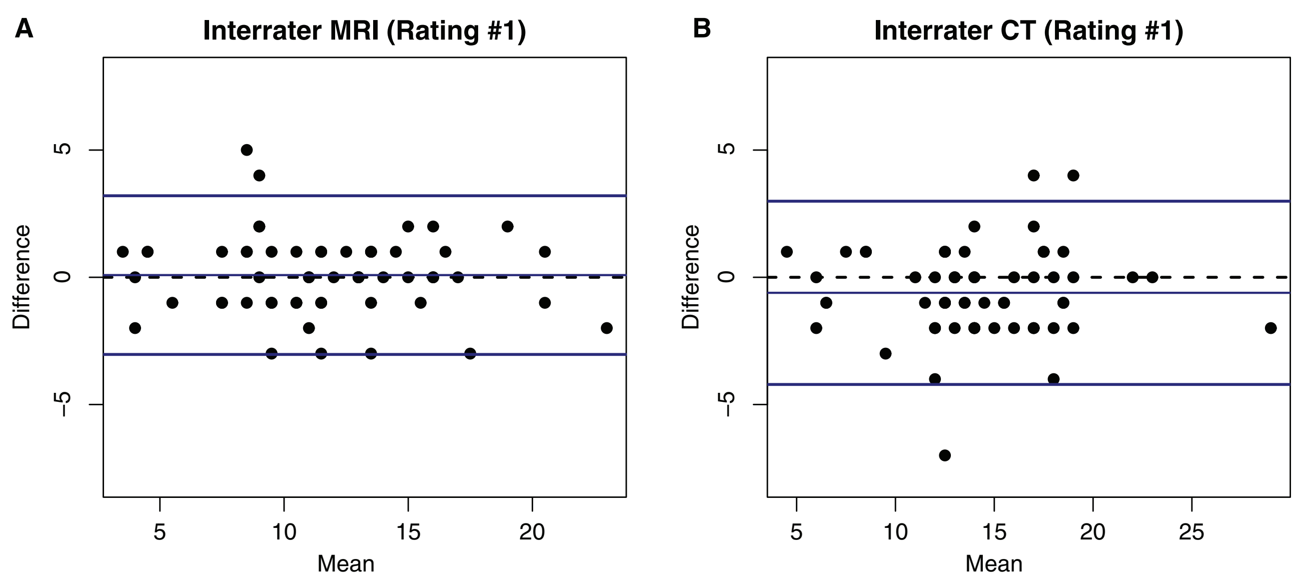

Figure 3. Bland-Altman plots of differences between raters on (A) MRI and (B) CT indicate little bias and variability between raters.

measurements of the fellowship-trained musculoskeletal radiologist (rater 1). The ICC values were interpreted as follows: ICC < 0.40 = poor agreement, 0.40 < ICC ≤ 0.75 = fair to good agreement, ICC > 0.75 = excellent agreement.[6] Additionally, 95% limits of agreement (LOA) were reported and Bland-Altman plots presented.[4] Statistical analyses were performed using SPSS Statistics v 20 (IBM Corp) and the statistical package R (R Development Core Team).

RESULTS

In the 59 knees analyzed, the mean TTTG distance was 11.7 ± 4.3 mm on MRI and 14.2 ± 4.5 mm on CT for both rater 1 and rater 2. For MRI, the average TTTG distance was 11.7 ± 1.3 mm for rater 1 and 11.7 ± 4.2 mm for rater 2. For CT, the average TTTG distance was 14.5 ± 4.5 mm for rater 1 and 13.9 ± 4.5 mm for rater 2.

Details of inter- and intrarater agreement measures, including observed bias, lower and upper bounds of 95% CIs, and lower and upper 95% LOA, are presented in Table 1. The interrater reliability was excellent for both MRI (0.936; 95% CI, 0.893-0.961) and CT (0.914; 95% CI, 0.851-0.949). Intrarater ICCs were excellent for the musculoskeletal radiologist on MRI (0.954; 95% CI, 0.924-0.973) and CT (0.957; 95% CI, 0.929-0.974) as well as the orthopaedic surgeon on MRI (0.949; 95% CI, 0.914-0.969) and CT (0.920; 95% CI, 0.867-0.952).

Evaluation between raters using Bland-Altman analysis demonstrated an observed bias/mean TTTG difference between rater 1 and rater 2 of 0.09 mm (95% LOA, –3.03 to 3.2) on MRI and −0.61 mm (95% LOA, –4.21 to 2.99) on CT (Figure 3). When differences between the first and second rating of rater 1 were evaluated via Bland-Altman analysis, there was an observed bias of −0.05 mm (95% LOA, −2.74 to 2.63) on MRI and 0 mm (95% LOA, −2.73 to 2.73) on CT (Figure 4).

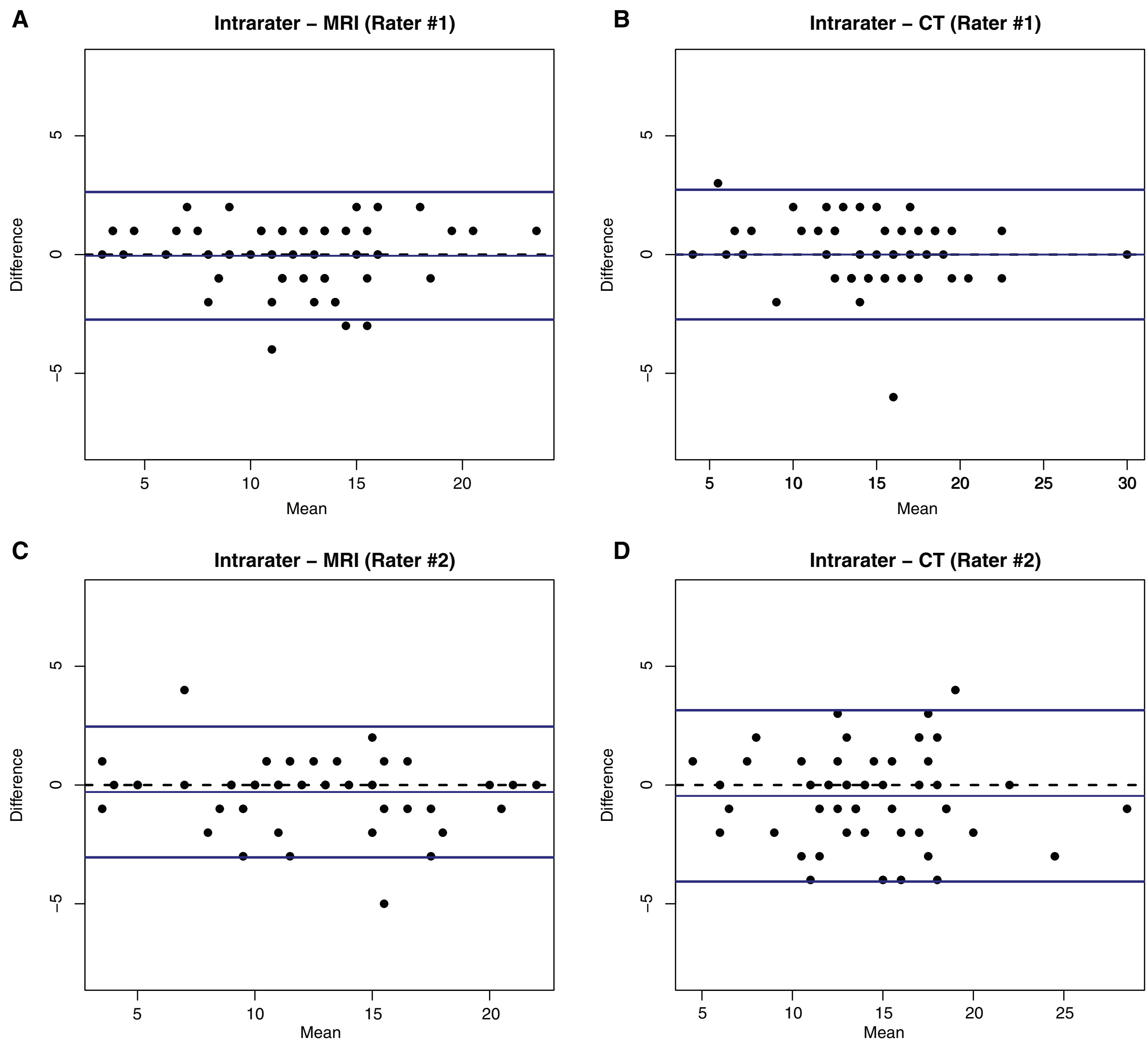

Figure 4. Bland-Altman plots of differences within the musculoskeletal radiologist rater on (A) MRI and (B) CT and the orthopaedic surgeon on (C) MRI and (D) CT, together indicating little bias and variability.

Absolute agreement ICC measurements for intermethod reliability were fair to good (0.643; 95% CI, 0.124-0.839). The absolute consistency type agreement was excellent (0.767; 95% CI, 0.636-0.855). This is reflected by the systematic bias toward lower TTTG distances on MRI (bias = −2.79 mm). Comparing the absolute consistency between imaging modalities (MRI vs CT) using rater 1's first rating, there was a bias of −2.79 mm (95% LOA, –8.87 to 3.28) using Bland-Altman analysis (Figure 5), such that MRI consistently underestimated the TTTG distance compared with CT. A minimal positive correlation, although statistically nonsignificant, was found between TTTG distance (as measured by CT) and the MRI-CT difference (r = 0.209, P = .115).

Patient Positioning Data

Seven of the asymptomatic volunteers had varus alignment and 2 had neutral alignment when measured using our institution's standard MRI patient setup within the dedicated knee coil (mean alignment measurement = 1.7° varus; range, 0° neutral to 4° varus). All 9 of the asymptomatic volunteers had valgus alignment when in the standard CT patient setup (mean alignment measurement = 2.9° valgus; range, 1°-4.5° valgus). The mean change was 4.6° of relative varus of the knee positioning on the MRI table compared with on the CT (see the Appendix, available online at http://ajsm.sagepub.com/supplemental).

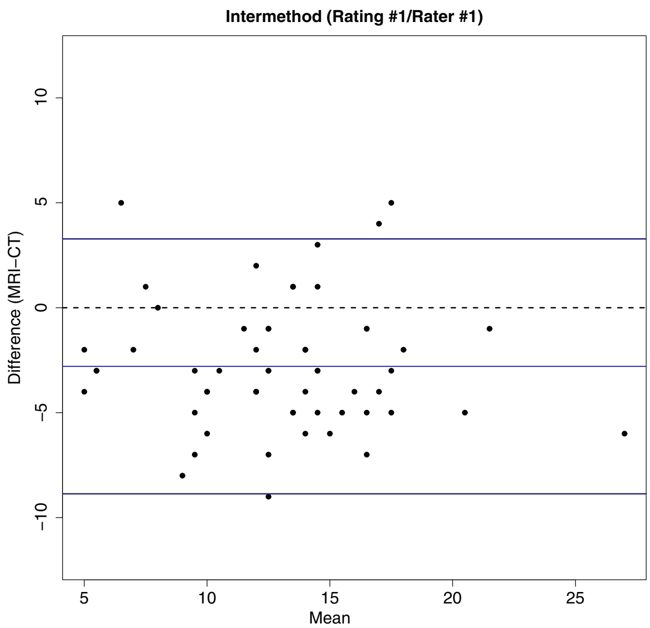

Figure 5. Bland-Altman plots indicating bias and variability between measurements performed on CT and MRI.

DISCUSSION

This study demonstrated excellent interrater and intrarater reliability for the measurement of the TTTG distance on CT and MRI, indicating that the TTTG distance may be reliably performed by individuals both with and without formal musculoskeletal imaging training. Results also demonstrated that CT and MRI should not be considered interchangeable for determining the TTTG distance when the MRI is obtained with the knee in a dedicated knee coil, as well as potentially with other differences in imaging technique. The absolute agreement ICC for intermethod reliability was fair to good, while the consistency type agreement was excellent, suggesting that some of the disagreement expressed in the absolute ICCs can be explained by a systematic bias toward larger TTTG distances measured on CT than MRI.

In this study, a consecutive series of both symptomatic and asymptomatic patients, with or without patellar instability, were included. Some may consider this a limitation because in clinical practice patients who undergo TTTG evaluation are typically individuals with symptomatic patellar instability. However, our reasoning for examining both symptomatic and asymptomatic patients was twofold. First, we did not set out to correlate TTTG distances on CT and MRI with patellar instability, because this has been demonstrated by others.[2,3] Rather, we set out to compare the intermethod effect of imaging modalities on the measurement of the TTTG distance, a measurement that previous studies have demonstrated is reliable in both symptomatic and asymptomatic patients from pediatric and adult populations.[5,8,16] Second, Nizic et al[14] recently raised the concern that high-grade trochlear dysplasia may influence landmark selection during TTTG measurements, particularly in the case of raters without formal musculoskeletal imaging training. The cohort evaluated in this study was largely asymptomatic for patellar instability, increasing the likelihood of optimal landmark selection using nondysplastic trochleae. Of the patients with patellar instability in our study, all 6 had Dejour type A and B dysplasia and none had severely dysplastic Dejour type C and D dysplasia.[12,15] Finally, we did not subjectively experience any variability in the ease of positioning patients for imaging both with and without patellar instability.

Previous studies have demonstrated excellent interrater reliability for measuring TTTG distances on CT and MRI between 2 musculoskeletal radiologists.[5,18] However, reliability between raters with extensive musculoskeletal imaging training and raters with other medical training has not been evaluated.[14] We reported excellent interrater reliability between a fellowship-trained musculoskeletal radiologist and a fellowship-trained sports medicine orthopaedic surgeon on CT (0.914) and on MRI (0.936). These values were higher than the interrater reliability on CT (0.78) and MRI (0.84) reported by Camp et al,[5] which may be explained in part by inclusion of a large number of nondysplastic trochleae in our study. Compared with Camp et al, in which all trochleae displayed some degree of dysplasia, only 6 of 59 trochleae were dysplastic in this study, which may have led to improved landmark selection and greater agreement between raters. Additionally, the intrarater reliability for each rater was excellent and only differed slightly, with the fellowship-trained sports medicine orthopaedic surgeon having a slightly lower agreement (0.92) compared with the fellowship-trained musculoskeletal radiologist (0.957). Together, the results presented in this study support the reliability of TTTG measurements performed by raters without any specific training in musculoskeletal imaging. However, additional investigation is required to demonstrate similar findings across a universally symptomatic patient cohort for patellar instability.

Since the consistency type agreement was excellent in this study, we believe that one or several factors other than imaging modality influenced image acquisition in a systematic fashion, resulting in consistent disagreement between TTTG distances on CT and MRI. Measuring TTTG with either CT or MRI assumes that the long axis of the knee/lower extremity is parallel to the long (z) axis of the scanner and table, as measurements in the axial plane on either scanner are calibrated to be orthogonal to the z-axis. However, the positioning of the patient's knee relative to the z-axis is imaging protocol dependent, and reproducibility and differences of patient positioning on the CT or MRI table have not been established.

At our institution, knee MRI and CT examinations were obtained with the patient lying supine, approximately centered on and along the long z-axis of the scanner tables. MRIs are obtained with the knee positioned in a dedicated knee coil, which is fixed to the MRI scanner table at a fixed distance to the side of midline. The dedicated knee coil is necessary for standard high-resolution clinical MRI examinations of the knee, from which we also measure the

TTTG. The CT examinations of the knee are performed with the legs in full extension and stabilized with the right and left forefoot taped together at the level of the metatarsophalangeal joint. With these standard protocols at our institution, the MRI coil and positioning put the affected knee in relative varus compared with the CT positioning during the imaging examinations. Systematic differences in relative varus on MRI compared with CT result in measured TTTG values that would be systematically smaller on MRI compared with CT, as the TTTG has been shown to be sensitive to small changes in femoral alignment and therefore should be interpreted with caution between modalities and with nonstandardized axial image acquisition.[20] Further, reproducibility of patient positioning and effect on measured TTTG values for either imaging modality could also be in question.

In addition, the knee MRI coil places the knee in slight flexion as the base of the coil is elevated slightly from the level of the examination table. A recent study by Aarvold et al[1] compared TTTG distances obtained in 32 symptomatic knees in a dedicated knee coil to distances obtained in a full body coil, where the knee is unconstrained or less constrained on the scanner table. Knees were in slight flexion in the knee coil compared with full extension in the full body coil, which produced a pronounced difference in TTTG distance measurements. The mean TTTG distance was 11.3 mm in the knee coil images and 19.9 mm in the body coil images. While Aarvold et al noted that the knees were in slight flexion in the knee coil, the authors did not describe the effect on varus versus valgus positioning of the knee placed in the knee coil versus less constrained or unconstrained on the body coil images. This may also have been a factor in their study.

A similar effect of slight knee flexion in the knee coil in our study compared with the less constrained position on the CT table (and likely on the MRI table without the knee coil) may have contributed to the lower TTTG distances on MRI compared with CT. These results are consistent with those of other studies which have demonstrated that the TTTG distance decreases with increased knee flexion.[9,10] Izadpanah et al[10] reported that the TTTG distance on MRI decreased by a mean of 4.3 mm from 0° to 30° of knee flexion. Dietrich et al[9] reported similar findings, with a mean difference in TTTG distance of 5.1 mm and 5.4 mm on MRI for raters 1 and 2, respectively, from 0° to 15° of knee flexion. Further, Dietrich et al[9] postulated that the variation in TTTG distance with knee flexion angle may be attributable to the "screw-home mechanism"[17] in which the tibial tubercle is lateralized near terminal extension. A recent study by Yao et al[20] demonstrated that even small variations in knee adduction and abduction relative to neutral axial alignment (varus and valgus orientation) can alter the TTTG distance by as much as 40%. Finally, we hypothesize that, just as alterations in knee flexion angle and knee adduction and abduction have been shown to alter the TTTG distance, it is conceivable that inconsistencies in other planes of motion such as internal and external rotation would likewise alter the TTTG distance. This should be investigated in future studies.

In the 2 previous studies comparing TTTG distance on CT and MRI, Camp et al[5] used a dedicated knee coil for MR image acquisition, while Schoettle et al[18] did not report whether a dedicated knee coil was used. On CT image acquisition, Camp et al reported that patients were positioned with the knee in full extension, while CT positioning was not specified by Schoettle et al. Since nearly identical patient positioning parameters were used for CT and MRI image acquisition in our study and that of Camp et al, it is not surprising that results of both of these studies found lower TTTG values by MRI. The MR images were obtained with the knee likely in slight flexion in a knee coil, compared with CT TTTG values, which were obtained with the knee in full extension. We hypothesize that patient positioning, rather than a factor intrinsic to the CT modality or MRI modality and measurement of the TTTG distance itself, is likely responsible for the systematic bias toward a higher TTTG on CT compared with MRI.

For this reason, discussions regarding use of a conversion factor to adjust the TTTG distance obtained on MRI compared with the gold standard of CT should be tempered until discrepancies and reproducibility in patient positioning for CT and MRI are resolved.[5] Differences and reproducibility in CT and MR imaging technique may vary from center to center. In addition, CT may not be a single absolute gold standard, as positioning for the CT examination could vary, and a conversion factor may vary from center to center and also possibly from time point to time point and patient to patient. We believe developing a protocol or device to allow for consistent patient positioning for MRI as well as for CT image acquisition is needed, with the ultimate goal of eliminating CT for measuring the TTTG distance to avoid unnecessary radiation exposure in the predominantly young patient population with patellar instability.

We acknowledge limitations in this study. First, we included both symptomatic and asymptomatic patients for patellar instability. While we acknowledge that many patients in this study fall outside the normal indications for evaluating the TTTG distance clinically, our patient selection is defensible because previous studies have demonstrated that the TTTG distance can be reliably measured in symptomatic and asymptomatic adult and pediatric patients. Second, knee MRIs were performed with the knee in a dedicated knee coil, which a recent study demonstrated produces a decreased TTTG distance due to positioning of the knee in slight flexion, as well as our own results indicating relative varus positioning of the knee in the knee coil that also contributes to decreased measured TTTG results.[1] Future studies will be needed to compare results and reproducibility of CT versus MRI for measuring the TTTG distance with control of patient knee positioning to be comparable for either CT or MRI examination. Patients included in this study were seen at a tertiary referral orthopaedic sports medicine practice and may not reflect other practice settings. Finally, imaging modality specific patient positioning measurements taken on a group of asymptomatic volunteers did not include image acquisition to avoid unnecessary radiation exposure through CT for this volunteer cohort, but instead served as a means of identifying and estimating the differences in standard patient positioning protocols across imaging modalities at our institution.

CONCLUSION

The TTTG distance can be measured on both CT and MRI with excellent intrarater and interrater reliability. However, TTTG distances measured on CT and MRI may not be considered equivalent since there is systematic bias on MRI compared with CT that was dependent on imaging protocol techniques, including patient positioning, for each imaging modality. Our results and those in other studies in the literature noted previously suggest that TTTG measurements are strongly dependent on patient positioning and that controlled, reproducible positioning certainly within each center and ideally from center to center is vital. Pending future studies to optimize this patient positioning, each center likely would benefit from instituting a controlled patient positioning protocol (eg, by using a fixed knee coil for MRI and an equivalent fixed knee positioning device for CT) to lessen variability among patients, from time point to time point for a given patient, and from MRI to CT. Future studies should be undertaken to further examine the effect of imaging protocol including patient positioning, as opposed to imaging modality, as a determinant of reproducibility and differences in TTTG measured on CT and MRI.

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