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Basic Science

Reproducibility and Precision of CT Scans to Evaluate Tibial Component Rotation

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ABSTRACT

Background: Component rotation likely plays a greater role on the survivorship and outcomes of total knee arthroplasties than is currently known. Our goal was to evaluate the precision, interobserver reliability, and intrarater reliability of tibial component rotation as measured by computed tomography (CT) scan, regardless of measurement technique.
Methods: Three fellowship-trained, academic arthroplasty surgeons independently measured tibial component rotation on CT scans of 62 total knee arthroplasties using their methods of choice. Measurements were repeated at least 2 weeks after the initial measurement. The precision of the measurements was assessed using a formal 8-step protocol as the gold standard. Intraclass correlation coefficients (ICCs) were calculated to evaluate precision, interobserver agreement, and intrarater reliability
Results: The interobserver agreement between the 3 surgeons for tibial component rotation was also moderate (ICC = 0.52). The intrarater reliability of tibial rotation was excellent (ICC = 0.81). Comparison of surgeons' measurement to a validated gold standard revealed only moderate precision for tibial component rotation (ICC = 0.64).
Conclusion: Practicing surgeons measuring tibial rotation were internally consistent, but failed to demonstrate satisfactory precision and interobserver agreement. We support the adoption of standardized criteria for the measurement of tibial component rotation on CT scans.

Component rotation in total knee arthroplasty (TKA) likely plays a greater role on the survivorship and outcomes of TKA than is currently known [1-3]. Optimal rotational positioning of the tibial component continues to pose a challenge given the complexity and dynamic nature of natural knee alignment [4]. Study of this topic has previously proven difficult because of the wide variety of intraoperative techniques [5]. Previously described methods are targeted at restoring a normal Q angle to optimize patellar tracking while optimizing tibiofemoral biomechanics to minimize wear [6]. Intraoperatively, maximizing tibial coverage, allowing the tibia to “float” and self-align, and aligning the center of the tibial tray relative to the junction of the medial and middle one-thirds of the tibial tubercle as a landmark are options for estimating optimal tray placement [6,7]. However, there remains dissention regarding which of these techniques is correct, as each technique has limitations [8-12]. Tibial tray rotation has been described as a cause of painful TKA in the absence of infection or component loosening [13,14]. Excessive malrotation of the tibial component can result in patellar maltracking [14,15], and early revision surgery [16]. However, plain films are an inadequate means of assessing tibial tray rotation. Both 2-dimensional and 3-dimensional computed tomography (CT) has been used in the past, using a wide variety of methods for rotational assessment [17-19]. To our knowledge, no study to date has described the utility of CT assessment of tibial

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rotation without a standardized protocol for measurement. Our goal was to evaluate the precision, interobserver agreement, and intrarater reliability of tibial component rotation as measured by CT, regardless of measurement technique.

Methods

Institutional review board's approval was granted for a retrospective review of patient records and imaging studies. From 2008-2011, 58 patients (62 knees) who presented with pain after TKA were evaluated with a CT scan of the involved knee. There were 28 male (48%) and 30 female (52%) patients. There were 32 right (52%) and 30 left (48%) knees. The mean age at the time of CT scan was 68.2 ± 9.9 years with a range of 46-89 years of age. None of the CT scans were excluded. The tibial components evaluated in the study were manufactured from titanium, cobalt-chrome, or all-polyethylene. Each CT scan was performed according to a standard metal reduction protocol on a Siemens Sensation 64 (Siemens Medical Solutions USA, Inc, Malvern, PA) CT scanner with 0.6 mm slices at 140 kVp and from 350-600 mA depending on patient body habitus. The protocol includes flexing the contralateral knee up and out of the field of view, if possible, to minimize beam-hardening artifact; if the patient was unable to flex the knee up, padding was used to elevate the contra-lateral leg as far from the knee of interest as possible. Scans were reconstructed using a soft tissue kernel (B30) and the "extended scale" option on the scanner, which uses a wider range of Hounsfield units (from −10,240 to 30,710), thus including metal within the grayscale instead of "whiting out" the metal.

Four fellowship-trained, high-volume, academic arthroplasty surgeons performed the measurements independently using individual methods for measurement. The entire measurement process was repeated on a second occasion at least 2 weeks after the first measurement to allow calculation of both interobserver agreement and intrarater reliability. Those performing the measurements were blinded to the original interpretation of the CT scan and to the specific indication for the scan, although they were aware that all patients had been referred for evaluation of a painful or otherwise failing TKA. Measurements were made by 3 surgeons (MJT, TMM, and MPA) intentionally with minimal instruction to assess the true variability in measurement of tibial component rotation by CT scan. It is important to note that the rotational axis of the tibial tray was measured relative to the junction of the medial and middle third of the tibial tubercle. This anatomical tibial landmark, although controversial and lacking consensus opinion, has been advocated by Insall and others [8,10-12]. Furthermore, use of this rotational reference point is associated with excellent clinical results, and represents the clinical choice of surgeons at our institution [8]. One additional fellowship trained arthroplasty surgeon (HDC) with experience using an established 8-step protocol for determining tibial component rotation measured each case according to the previously published method: (1) draw a line tangent to the posterior aspect of the tray, (2) draw a second line parallel to the first line, measuring the transverse diameter of the tray, (3) at the midpoint of the second line, draw a perpendicular line measuring the anterior-to-posterior dimension of the tray, (4) move the second line to the midpoint of the third line, thus identifying the center of the tray, (5) measure the width of the tibial tuberosity, (6) identify the junction of the medial and middle thirds of the tibial tuberosity, (7) measure the angle between the line connecting the center of the tibial tray to the junction of the middle and medial third of the tibial tubercle, and the line bisecting the tibial tray, and (8) measure the angle between the line connecting the center of the posterior aspect of the tibial tray to the junction of the middle and medial third of the tibial tubercle, and the line bisecting the tibial tray [19].

A sample size was conducted to ensure adequate power for the study. We determined that a minimum of 60 CT scans read twice by the same observer will achieve 80% power to detect an intraclass correlation coefficient (ICC) of 0.89 compared with an ICC of 0.76 under the null hypothesis with a significance level of 0.05 [18]. For interobserver agreement with 60 CT scans read by each of the reviewers, we had 80% power to detect an ICC of 0.75 compared with an ICC 0.62 under the null hypothesis [18]. To assess intrarater reliability, ICC values were calculated using a 1-way analysis of variance model for agreement and for interobserver agreement, we calculated ICC values with 2-way mixed-effects 1-way analysis of variance models using IBM SPSS Statistic 22.0 (IBM Corporation, Somers, NY); 95% confidence intervals (CIs) for ICC values are provided. An ICC value of 1.00 indicates perfect reliability, 0.99-0.81 is very good, 0.80-0.61 is good, 0.60-0.41 is moderate, and less than or 0.40 is poor [20]. We also calculated the average difference in degrees between the measurements, and determine the measurement bias and standard deviation using a Bland and Altman analysis [21]. As an additional metric, we calculated the proportion of the time that the same measurement by different observers and by the same observer would fall within 3° of each other, called the margin of equivalency [22].

Results

Intrarater Reliability

When comparing the 2 measurements of the same observer, we found a mean difference of 2.7° ± 2.4°, a mean ICC of 0.81 (CI 95% 0.71-0.88; Table 1).

Interobserver Agreement

When comparing the measurement between the 3 observers, we found a mean difference of 5.5° ± 5.6°, a mean ICC of 0.52 (CI 95% 0.31-0.68; Table 2).

Precision

When comparing the measurement of the 3 observers and the gold standardized analysis, we found a mean difference of 6.6° ± 4.8° and a mean ICC of 0.64 (CI 95% 0.46-0.76; Table 3).

Discussion

Practicing surgeons measuring tibial rotation were internally consistent, but failed to demonstrate satisfactory precision and interobserver agreement. We support the adoption of standardized criteria for the measurement of tibial component rotation on CT scans.

CT has proven utility in TKA, with applications in osteolysis, periprosthetic fracture, aseptic loosening, and rotation [17,23,24]. We sought to identify the utility of CT in assessing tibial component rotation as it relates to intraobserver agreement, interrater

Table 1
Intrarater Reliability.

IRR	ICC	CI 95%	Difference	Bias	95% Limit
Observer 1	0.72	0.58-0.82	4.0 (±3.3)	−0.1 (±5.2)	−10° to 10°
Observer 2	0.70	0.55-0.81	3.7 (±3.1)	0.1 (±4.7)	−9° to 9
Observer 3	0.99	0.99-1.00	0.5 (±0.7)	0.1 (±0.9)	−2° to 2°
Overall	0.81	0.71-0.88	2.7 (±2.4)		

IRR, intrarater reliability; ICC, intraclass correlation coefficient; CI, confidence interval.