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Basic Science

Femoral Component Rotation in Total Knee Arthroplasty: A Comparison Between Transepicondylar Axis and Posterior Condylar Line Referencing

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ABSTRACT

Background: Proper rotational alignment of the femoral component is critical for a successful total knee arthroplasty (TKA). Controversy remains regarding the optimal intraoperative reference to determine femoral component rotation.

Methods: Thirty-one patients who underwent magnetic resonance imaging of a TKA between April 2008 and November 2015 were retrospectively reviewed. A single surgeon performed the TKA using a posterior condylar angle of 3° (PCA group) or surgical transepicondylar axis (TEA group) to determine femoral component rotation. The hip-knee-ankle angle and the tibial plateau-tibial shaft angle (TPTSA) were measured on full-length x-rays, and the rotation of the femoral component was measured as compared to the TEA on magnetic resonance imaging (negative values indicate internal rotation).

Results: The median measured rotational deviation of the femoral component from the TEA was significantly higher in the PCA group than in the TEA group (−3.8 ± 2.9° and −1.4 ± 1.9°, respectively) ($P = .02$). When knees with preoperative varus and neutral alignment were evaluated, the median measured rotational deviation of the femoral component was significantly higher in the fixed PCL group than in the TEA group (−3.4 ± 3.3° and −0.61 ± 1.3°, respectively) ($P = .04$). Linear regression used to evaluate the relationship between the TPTSA and femoral component rotational deviation from the TEA revealed similar near zero slopes ($P = .90$); however, the Y intercepts in the TEA group were significantly higher than the PCA group (−2.8 ± 0.7 and −5.5 ± 1.1, respectively) ($P = .007$).

Conclusion: The use of the surgical TEA as an intraoperative rotational reference is more reliable than the PCA in valgus, varus, and neutrally aligned knees independent from the magnitude of the TPTSA.

Proper rotation of the femoral component is critical for a successful outcome after total knee arthroplasty (TKA). Femoral malrotation has been associated with a large number of complications including patellofemoral maltracking [1], anterior knee pain [2,3], stiffness [4], flexion instability [5,6], abnormal torsional stress on the tibial component leading to wear or loosening [7], and cam post impingement in posterior-stabilized designs [7,8]. There is no consensus regarding the best method to achieve consistent intraoperative femoral component rotation. Traditionally, 2 techniques have been used: the gap-balancing technique in which the femoral component is positioned parallel to the resected proximal tibia with each collateral ligament equally tensioned and the measured resection technique in which bony landmarks are used as references to set femoral rotation regardless of the ligament tension [9,10].

Two most commonly used references for the measured resection technique are the surgical transepicondylar axis (TEA) and the posterior condylar angle (PCA). The surgical TEA is a line connecting the medial epicondylar sulcus with the most prominent point of the lateral epicondyle. It is considered to be the most accurate bony landmark for approximating the flexion axis of the knee and ultimately obtaining a rectangular flexion gap [11-13]. However, the

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reproducible and accurate identification of the TEA intraoperatively has been debated in the literature with contradictory reports [8,11-16]. The posterior condylar line formed by connecting the posterior aspect of the medial and lateral femoral condyles has been used as a surrogate for the TEA. In the presence of normal condylar anatomy, the posterior condylar line is 3°-4° internally rotated in relation to the TEA. However, several studies have shown variations with regard to the relationship of the PCA to the TEA that may lead to component malrotation in 25.5%-72% of patients [13,17,18].

There are multiple reports in the literature evaluating the utility of the TEA and PCA for femoral component rotation [8,13,17,18] but few have directly compared these 2 referencing techniques using postoperative imaging [18,19]. Previous work has suggested that the PCA exhibits a positive correlation with the preoperative tibial plateau-tibial shaft angle (TPTSA) [20]. Consequently, some authors have suggested that setting the femoral component in 3° of external rotation to the posterior condylar line (PCL) could be unreliable due to the notion that an increasing TPTSA often results in a PCA greater than 3° [20].

The purpose of this study was 2-fold. First was to evaluate the accuracy of femoral component rotation when either the TEA or PCA referencing technique was used based on postoperative metal artifact reducing magnetic resonance imagings (MRIs). Second, we sought to investigate the relationship between measured femoral component rotational deviation from the TEA and the preoperative TPTSA to determine if TPTSA had an influence on component rotation when either the PCA or TEA technique was used to set femoral rotation.

Materials and Methods

Before the start of the study, expedited review was obtained from our institutional review board. Between January 1, 2005 and February 1, 2016, 1402 consecutive patients underwent 1503 primary TKAs by a single specialized orthopedic surgeon (A.G.D.V.). In the first 945 patients, operated on before August 2013 (1019 knees—74 bilateral), a PCA of 3° was used to determine the femoral component rotation in knees without a preoperative valgus deformity. The TEA was used to determine rotation of the femoral component for knees with a valgus deformity. After August 2013, the surgical TEA was used to guide femoral rotation in all 447 patients (484 knees—37 bilateral). Patients with prior open surgery, septic arthritis of the knee, history of posttraumatic deformity, posterior condylar bone defect, history of rheumatoid arthritis, or other inflammatory diseases were excluded for this study.

Thirty-one of these patients underwent postoperative MRI evaluation for the assessment of residual knee symptoms. The MRI evaluation was performed at an average of 22 months postoperatively (range 1-84) in the same institution where the surgery was performed. These knees were retrospectively reviewed. All patients had primary knee arthritis, and preoperative radiographs were reviewed to rule out the presence of congenital or posttraumatic deformity. All patients underwent TKA between May of 2006 and June of 2015. In the first 23 TKAs, the PCA was used to guide femoral rotation (PCA group), and in the remaining 8, the TEA was used (TEA group). Knee Society Scores (KSS) were used to evaluate clinical outcomes. The preoperative characteristics of the groups are shown in Table 1. No statistically significant differences were found in preoperative alignment between the PCA group and the TEA group.

All surgeries were performed under standardized regional anesthesia, and with the use of an inflated pneumatic tourniquet. A standard medial parapatellar approach was used. The tibial cut was performed perpendicular to the tibial mechanical axis using an extramedullary guide, and the distal femur was cut in 5° of valgus using intramedullary instrumentation. The extension gap was assessed with standard spacing blocks and balanced with selective soft-tissue releases as needed. Femoral component rotation was then determined using either the TEA or the PCA as reference. In the PCA group, the PCL was identified utilizing a neutral posterior condylar-surface referencing guide with 3° of external rotation. In the TEA group, the surgical TEA was drawn connecting the medial epicondylar sulcus with the most prominent aspect of the lateral epicondyle. The surgical TEA was always determined by the operating surgeon (A.G.D.V.). The anterior-posterior cutting gig was then set parallel to this line. Among the surgical and clinical TEA landmarks described by Berger et al [11], we used the surgical TEA as biomechanical studies have previously demonstrated it better approximates the functional flexion-extension axis of the knee [21,22]. After sizing and cutting the distal femur, the flexion gap balance was assessed, and additional selective releases were performed if needed. The tibial component was rotated according to the anteroposterior axis by Akagi et al [1], and all patellae were resurfaced with a cemented polyethylene component.

Table 1
Patient Characteristics in the TEA and PCA Groups.

Patient Characteristics	TEA (n = 8)	PCA (n = 23)	*P*-Value
Age ± SD	61.8 ± 9.2	64.4 ± 8.0	.61
BMI	31.8 ± 5.8	31.0 ± 3.9	.70
Gender female/male	5/3	13/10	.76
Alignment			
Valgus: n [mean alignment]	2 [−6.1 ± 4.8]	10 [−12.2 ± 7.2]	.36
Neutral: n	1	5	
Varus: n [mean alignment]	5 [5.5 ± 1.9]	8 [5.3 ± 3.2]	.90
TPTSA	2.4 ± 1.7	2.9 ± 1.8	.42
Preoperative			
Functional KSS	50.8 ± 18.1	41.5 ± 14.6	.25
Knee-specific KSS	47.1 ± 16.9	35.2 ± 13.7	.03

TPTSA, tibial plateau-tibial shaft angle; KSS, Knee Society Score; TEA, transepicondylar axis; PCA, posterior condylar angle; SD, standard deviation; BMI, body mass index.

Four cemented posterior-stabilized knee implants were used during the study period: Genesis II (Smith and Nephew, Memphis, TN) in 23 cases, Vanguard (Biomet, Warsaw, IN) in 2 cases, Triathlon (Stryker Orthopaedics, Mahwah, NJ) in 3 cases, and TriMax (Ortho Development Draper, UT) in 3 cases. The 4 prosthetic designs have cobalt chromium femoral components with symmetric posterior condyles. Standardized preoperative full-length standing lower extremity x-rays were reviewed. The hip-knee-ankle (HKA) angle and the TPTSA were measured in all patients. The HKA represents the angle formed by a line drawn from the center of the femoral head to the center of the femoral condyles and a connecting line drawn from the center of the intercondylar notch to the center of the talus. The HKA angle was noted as a deviation from 180°. Negative values represent valgus alignment, and positive values represent varus alignment of the lower limb. A range between −2° and 2° was considered as neutral alignment. The TPTSA was defined as the angle between the tibial articular margins and the central tibial shaft axis [23]. Varus was defined as a positive deviation from 90°.

For each patient, postoperative MRI was performed on a clinical 1.5-T unit (Gemera; Electric Healthcare, Milwaukee, WI) using an axial fast spin echo sequence optimized to reduce the production of metal artifact as previously described by Murakami et al [24] with slice thickness of 3 mm. The rotation of the femoral component was determined drawing a line tangent to the dorsal medial and lateral prosthetic condylar surfaces and compared to the TEA defined as the line connecting the medial epicondylar sulcus with the most prominent aspect of the lateral epicondyle. External rotation of the

component as compared to the TEA was noted as a positive value, and internal rotation was represented with negative values (Fig. 1). Measurements were made by 2 reviewers (S.R.N. and V.F.) blinded to the rotational technique used to place the femoral component. Averages of the values obtained from the reviewers were used in the final analysis.

Group demographics and characteristics were analyzed with descriptive statistics. Categorical data were analyzed with a Fischer's exact test and continuous variables with nonparametric Mann-Whitney U tests. Rotational values were reported as means with standard deviations. External rotation of the component as compared to the TEA was noted as a positive value, and internal rotation was represented with negative values. A linear regression (GraphPad Prism version 5.0, San Diego, CA) was used to evaluate the relationship between the TPTSA and measured femoral external rotation between the 2 groups. A *P*-value less than .05 was considered statically significant.

Results

Mean measured rotational deviation of the femoral component was significantly higher in the PCA group at −3.8 ± 2.9° (range, −10.2° to 1.5°) as compared to the TEA group at −1.4 ± 1.9° (range, −3.2° to 1.5°) ($P = .02$). When only knees with preoperative varus and neutral alignment were analyzed, the mean measured rotational deviation of the femoral component was significantly higher in the fixed PCA group at −3.4 ± 3.3° (range, −10.2° to 1.5°) than in the TEA group at −0.61 ± 1.3°(range, −2.2° to 1.5°) ($P = .04$).

With an unacceptable surgical outlier defined as an error of more than 5° from the reference TEA, the percentage of outliers was 30.4% in the PCA group and 0% in the TEA group. Taking into account only knees with preoperative varus and neutral alignment, the percentage of outliers was 23.1% in the PCA group and 0% in the TEA group.

Linear regression revealed the slopes between the TEA measured component deviation (Y = 0.66X + −2.8 ± 0.7) and PCA measured component deviation (Y = 0.58X + −5.5 ± 1.1) were similar ($P = .90$) as plotted against the TPTSA; however, the Y intercepts in the TEA group (−2.8 ± 0.7) were significantly higher than the PCA group (−5.5 ± 1.1) ($P = .007$) (Fig. 2).

In the PCA group, the MRI revealed 12 patients with nonspecific synovitis, 5 with suprapatellar or infrapatellar scarring without arthrofibrosis, 2 with patellar button loosening, 2 with patellar tendinosis, 1 with a mall quadriceps tear, and 1 MRI with no significant findings. In the TEA group, 7 patients had nonspecific synovitis, and 1 with a distal femoral cartilaginous lesion unrelated to the knee arthroplasty.

Postoperative functional KSS scores were similar in both the PCA and TEA group (79.7 ± 16.7 vs 71.2 ± 20.2; respectively, $P = .37$) as were the knee-specific KSS (81.8 ± 17.8 vs 80.2 ± 13.6; respectively, $P = .76$).

Discussion

Surgeons who subscribe to the measured resection philosophy believe that femoral component rotation should approximate the flexion-extension axis of the knee. The present study was undertaken to assess the accuracy of femoral component rotation when either a fixed PCA of 3 degrees or the surgical TEA was used as a reference. Our results suggest that the use of the surgical TEA as a rotational reference is more reliable than PCA not only in the valgus knee but also in presence of varus or neutral alignment. In addition, we demonstrated that a more consistent femoral rotation can be achieved using the TEA independently from the value of the TPTSA.

Anatomical and biomechanical studies have demonstrated the perpendicularity of the TEA to the mechanical axis of the femur and to the mechanical axis of the tibia with the knee flexed to 90° concluding that placing the femoral component parallel to the TEA best approximates the flexion-extension axis of the knee [8,25,26]. Moreover, in a study by Olcott et al, the TEA represented the most accurate of all bony landmarks in obtaining a rectangular flexion gap (90% using the TEA and 70% using the PCA) [13]. Berger et al [11] further distinguished the surgical TEA (a line connecting the prominence of the lateral epicondyle to the medial epicondylar sulcus) from the clinical TEA (line connecting the lateral epicondylar prominence and the most prominent point of the medial epicondyle) and recommended using the surgical TEA as a

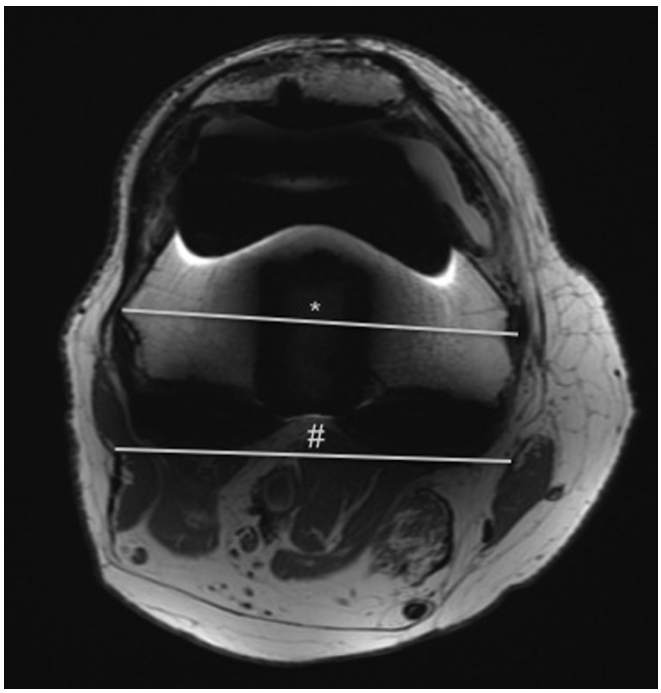

Fig. 1. The angle formed between a line drawn tangent to the dorsal medial and lateral prosthetic condylar surfaces and a line drawn through the TEA defined as the line connecting the medial epicondylar sulcus with the most prominent aspect of the lateral epicondyle were used to evaluate femoral component rotation. External rotation of the component as compared to the TEA was noted as a positive value, and internal rotation was represented with negative values. (*transepicondylar axis and #posterior condylar line). TEA, transepicondylar axis.

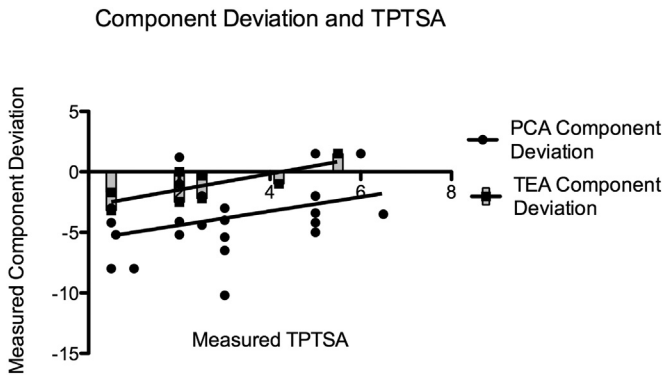

Fig. 2. Component deviation from the TEA in both groups as compared to the preoperative TPTSA. Slopes were similar between groups; however, the Y intercepts were significantly different. (TEA group −2.8 ± 0.7 vs PCA group −5.5 ± 1.1; $P = .007$). TPTSA, tibial plateau-tibial shaft angle; PCA, posterior condylar angle.

more reliable reference. However, different authors have described the difficulty in accurately identifying the TEA intraoperatively [15,27,28]. Jerosch et al [15] examined the interobserver reproducibility of this landmark comparing the difference in position of medial sulcus and lateral epicondyle marked by different surgeons. They demonstrated that the range of position chosen by the surgeons varied 22.3 mm on the medial side and 13.8 mm on the lateral epicondyle. Kinzel et al [16] using postoperative computed tomography scans found that only 75% of TKA were aligned within 3° of the true TEA. They described a large range of error ranging from 6° of external rotation to 11° of internal rotational and concluded that the TEA was an unreliable reference to set femoral component rotation. Our results may differ from these previous reports since a single specialized arthroplasty surgeon marked all the surgical TEA's intraoperatively which may have allowed for consistent and reproducible results. As previously evaluated by Siston et al [29], establishing femoral rotation alignment through the TEA is influenced by an individual surgeon's skill and preference. Results of the present study may only apply to surgeons who are experienced in using TEA as reference landmark. After several years of practice, a devoted arthroplasty surgeon may reach acceptable reproducibility in the intraoperative identification of TEA. However, the use of this landmark may have lower reproducibility in low-volume surgeons. This may partially explain the variation reported in literature.

The difficulty in accurately identifying the TEA intraoperatively has resulted in PCA referencing guides to be routinely used during TKA. Simple and accurate instrumentation systems have been developed to assure a preselected amount (3°-5°) of external rotation relative to the PCL, which serves as a surrogate landmark for the TEA [30]. Although acknowledged to be unreliable in the valgus knee due to the hypoplasia of the posterior aspect of the lateral femoral condyle, several authors advocated the use of this bone landmark in presence of a normal condylar anatomy [19,31]. Benjamin et al [6] found that the PCA most frequently corresponded to the rotational alignment of the implanted femoral component, falling within ±1° in 62% of patients. In contrast, the registered TEA was accurate within 1° in 34% of the patients. However, distal femoral anatomy shows wide variability, and the decision to externally rotate the cutting guides 3°-5° relative to the PCL is based off of mean data [30].

Our results showed significantly more malrotation as well as higher variability in the PCA group compared to the TEA group suggesting the TEA to be a more reliable landmark. In particular, the percentage of outliers (error of more than 5° from the reference TEA) in the PCA was high when compared to the TEA group (30.4% vs 0%).

The results were similar with or without exclusion of knees with a preoperative valgus deformity. This suggests that the PCA is not only unreliable in the valgus knee but also in presence of varus or neutral alignment. Pagnano and Hanssen [20] have previously showed a positive and significant correlation between the magnitude of the PCA and the TPTSA. They suggested the variability in the PCA may result in component malrotation when references are systematically made off the PCL [20]. Our results concur with their findings.

The second aim of the study was to investigate whether TPTSA had an influence on component rotation when either the PCA or TEA technique was used. Despite the insightful work by Pagnano et al [20], in a recent study, Park et al [32] reported no significant difference in the PCA in knees with and without tibia vara. The results of our study showed similar near zero slopes when the component deviation was plotted against the TPTSA in both groups; however, the Y intercept was further from zero in the PCA group than the TEA group. This suggests for any given TPTSA angle, the malrotation of the femoral component may be higher in the PCA group and that the TPTSA may have had less influence on the component rotation even as it increased in the TEA group.

The limitations of this study include its retrospective, nonrandomized nature, and the small sample size. Only a small proportion of knees in patients who were experiencing pain with unremarkable radiographic findings underwent MRI examination. It is unclear if the component positioning had an influence on the postoperative outcomes of these patients, and it is possible there was a selection bias toward patients with malrotated components. However, both study groups were evaluated using these postoperative MRIs, and if a bias was present, it would be present in both groups. Perfoming MRI scans in patients with asymptomatic TKAs would have resulted in unnecessary costs to the health care system. In spite of the small sample size, we were able to detect significant differences between the TEA and the PCA groups. A second limitation is that measurement of radiographic and MRI parameters can be affected by intraobserver and interobserver variability. To diminish reliability error, the average of measurements made by 2 independent and blinded observers was used for our analysis. Another limitation is the use of 4 different prosthetic designs each with a different instrumentation. Although this does not affect femoral rotation in the TEA group, as its identification is independent from any device, it might introduce some variability in the PCA group as different PCA-assessment devices may have different posterior condylar contact points. However, in the PCA group, 21 of 23 patients received the same implant, whereas only 2 patients received a different implant. Finally, the intraoperative assessment of the surgical TEA is affected by intraobserver and interobserver error; consequently, our results may not be extrapolated to all surgeons.

Conclusion

In conclusion, our findings suggest the surgical TEA is a more reliable technique than a fixed 3° PCA to achieve adequate femoral component rotation during TKA. In our study, the TPTSA had less of an influence on component rotational deviation when the TEA was utilized as compared to PCA referencing. In light of this data, we recommend caution when using a fixed PCA to set femoral component rotation during TKA, as it may result in a high incidence of outliers.

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