Original Article

Computed tomographic evaluation of femoral component rotation in total knee arthroplasty

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Abstract

Background: Optimal femoral component rotational alignment in total knee arthroplasty (TKA) is crucial to establish a balanced knee reconstruction. Unbalanced knees can lead to instability, patellofemoral problems, persistent pain, stiffness, and generally poorer outcomes including early failure. Intraoperative techniques to achieve this optimal femoral component rotation include the use of the transepicondylar axis (TEA), the posterior-condylar-cut-parallel-to-the-tibial-cut (PCCPTC) technique and the anteroposterior axis technique (Whiteside's line). The purpose of this study was to compare the PCCPTC technique to the TEA technique using computed tomography (CT) scans to assess femoral component rotational alignment.

Materials and Methods: This study used postoperative CT scans to compare the degree of femoral component rotation obtained with the use of PCCPTC technique and the TEA. The femoral component rotation of 30 TKA was measured on postoperative CT scans the angle of deviation between the two lines radiographic trans-epicondylar axis (rTEA) and femoral prosthesis posterior condylar line (FPPCL) was determined. This angle represented the rotation of the femoral component relative to the true rTEA.

Results: The degree of rotation measured 2.67 ± 1.11 degrees in the PCCPTC group and 5.60 ± 1.64 degrees in the TEA group.

Conclusion: The use of the TEA technique for determining rotational alignment in TKR results in excessive external rotation of the femoral component compared to the PCCPTC technique.

Key words: Transepicondylar axis, mal-alignment, rotational alignment

Introduction

Achieving optimal femoral component rotational alignment in total knee arthroplasty (TKA) is crucial in establishing a balanced knee reconstruction and ensuring adequate patello-femoral tracking.[1-10] Unbalanced knees can lead to instability, patellofemoral problems, persistent pain, stiffness, and generally poorer outcomes including early failure. Various intraoperative techniques have been described to achieve the optimal femoral component rotation. These include the use of the transepicondylar axis (TEA),[11] the posterior-condylar-cut-parallel-to-the-tibial-cut (PCCPTC) technique[2,12-14] and the anteroposterior (AP) axis technique (Whiteside's line)[15] [Figure 1].

In the TEA method the anterior and posterior cuts are made parallel to the clinical epicondylar axis that is drawn by connecting the perceived peaks of medial and lateral epicondyles. The PCCPTC technique involves taking the posterior condylar cut parallel to the tibial cut and confirming the presence of a rectangular flexion space visually after applying the lamina spreader between the cut tibial surface and posterior condyle. The AP axis method involves making a posterior cut perpendicular to a line joining the center of trochlear sulcus anteriorly and the midpoint of the posterior aspect of the intercondylar notch.

The purpose of this study was to compare the PCCPTC technique to the TEA technique using CT scans to assess femoral component rotational alignment.

Materials and Methods

Between January 2001 and December 2004, 30 consecutive TKA were performed in 20 patients (18 women and 2 men). The underlying disease was osteoarthritis in 22 knees joints and rheumatoid arthritis in 8. Bilateral TKA was performed

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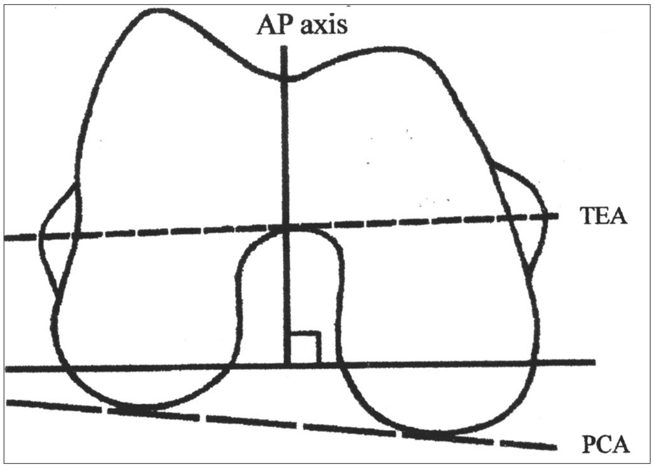

Figure 1: A schematic diagram showing the posterior condylar axis (PCA), the TEA, and the anteroposterior (AP) axis. The TEA is identified by connecting a line between the epicondylar peaks. The AP axis is identified as a line connecting the deepest portion of the trochlear groove with the midpoint of the posterior intercondylar notch. Then a line perpendicular to the AP axis is drawn as the axis of proper rotational alignment

in 10 patients. The alignment of the knee joint was varus in 21 knees and valgus in 9. All surgeries were performed by the same surgeon (SVV). Patients with severe deformities in both planes were excluded (upto 20°). All patients were implanted with cemented, posterior stabilized knee prosthesis (PFC Sigma, Depuy Orthopaedics, Inc. Warsaw, IN). Patients were divided into two groups, 10 consecutive patients in each group (6 pts OA and 4 pts RA) of 15 TKA each for this prospective study.

Group I was a cohort of the first 15 consecutive TKA in which the PCCPTC method was used and group II was a cohort of next 15 TKA in which the TEA technique was used. The mean age in group I was 65 years (61-70 years) and group II was 57 years (54-61 years). In bilateral cases both knees were operated by one single method depending upon the group of the patient There were five valgus knees in group I and four valgus knees in group II. The average frontal plane malalignment in group I was 14.07° (Range =7-19°) and in group II was 12.67° (Range = 6 to 20°). The mean weight of group I was 61kg (5-78 kg) and that of group II was 62 kg (55-72 kg). All knees were evaluated preoperatively at 4 to 6 weeks and postoperatively at 1 year. Postoperatively, patients in both groups were subjected to the same intensive, physiotherapy program which includes active and passive range of motion exercises, full weight bearing walking, and stair climbing. Patients in both groups were analyzed with 1 mm CT (Siemens Somatom volume zoom, 4 slice detector) at 6 months of followup. CT images were obtained in a leg holder to minimize the motion of lower extremity. The scan direction was aligned at 90° to the tibial axis. A slice in which both lateral and medial epicondyles were clearly visualized was chosen for measurements. An experienced radiologist who was blinded to study groups obtained the measurement. The rotation of the femoral component was determined using two reference lines: the radiographic or "true" TEA (rTEA) and femoral prosthesis posterior condylar line (FPPCL). The rTEA was defined as line connecting the lateral epicondyle identified by its prominent appearance, and the center of the medial epicondyle that was identified as the base of the medial sulcus. The FPPCL was defined as a line that connected the lowest point on both posterior femoral prosthetic condyles. The angle of deviation between these two lines (rTEA and FPPCL) was determined using somatom CT software. This angle represented the rotation of the femoral component relative to the rTEA. An angle of 0° indicated that the femoral component was set parallel to the rTEA, a positive value indicated external rotation and a negative value indicated the internal rotation.

Data were analyzed using SPSS/pc + statistical package. Students unpaired *t*-test, was applied to cohort, divided in 2 groups. 95% confidence interval of the difference was also calculated. 95% confidence interval for bias was also calculated for the data 16. The level of significance (alpha) was taken at 0.05.

Group I (PCCPTC technique)

The proximal tibia is cut at 90°. The distal femur is cut at 5° of valgus for a varus knee or 3° of valgus for a valgus knee. The soft-tissues are balanced in extension. The knee is flexed to 90°. An anteroposterior femoral cutting block of appropriate size is placed on the cut surface of distal femur and preliminarily fixed with pins. A lamina spreader is then applied between posterior margins of the block and cut tibial surface with the knee at 90° flexion. The block is then rotated until a rectangular gap is created equal to the extension gap [Figure 2a].

Group II (TEA technique)

In the TEA method the anterior and posterior cuts were made parallel to the epicondylar axis that is drawn by connecting the perceived peaks of medial and lateral epicondyles. Two observers independently identified the TEA. For each set of repeated measurements, distal femur was resected thinly before each observer identified the axis. The sequence of observers was varied for each knee. TEA was marked using methylene blue [Figure 2b].

Results

The mean degree of femoral component rotation in group I (PCCPTC technique) was + 2.67 ± 1.11 degrees and in group II (TEA technique) was 5.60 ± 1.60 degrees [Figures 3a and b]. The difference in two groups was statistically significant ($P < 0.001$).

In group I, the mean tibial cut angle was 90° (range, 88-92) and in group II, the mean tibial cut angle was 90° (range, 89-95). The difference in the two groups was not statistically significant ($P = 0.642$) [Table 1].

Discussion

The long term success of TKA depends largely on the correct alignment of the components and proper ligamentous balance.[5,16-18] The impact of optimum femoral component rotational orientation on flexion gap balance, patello femoral tracking, and normal kinematic function is well known. Despite the improvements in surgical technique and instrumentation, major patellar complications secondary to femoral component malalignment have been reported in 1-12% of TKA and constitute an important cause of revision total knee arthroplasties. Malalignment of the femoral component increases the risk of anterior knee pain, patellar subluxation, anterior femoral cortex notching, periprosthetic fractures, and loosening.[19-22]

Laskin, *et al.* in their study showed that patients in whom AP femoral resections were externally rotated to allow rectangularization of the flexion space had increased range of flexion and decrease in incidence of medial tibial pain and zone I radiolucencies.[23]

Olcott, *et al.* compared four intraoperative methods to determine femoral component rotation.[24] Katz, *et al.* conducted a study on cadaveric knees to determine the reliability of the TEA, AP axis, and balanced flexion gap tension line techniques for femoral component rotation. The TEA was less predictable and significantly more externally rotated than the AP axis and the balanced tension line. Flexion gap tensioning may offer superior reliability because of its independence of obscured or distorted bone landmarks.[25]

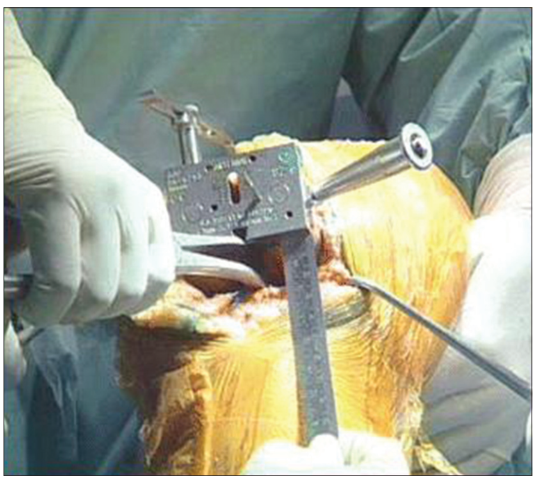

Figure 2a: The PCCPTC technique: Confirmation of a rectangular flexion gap using a lamina spreader

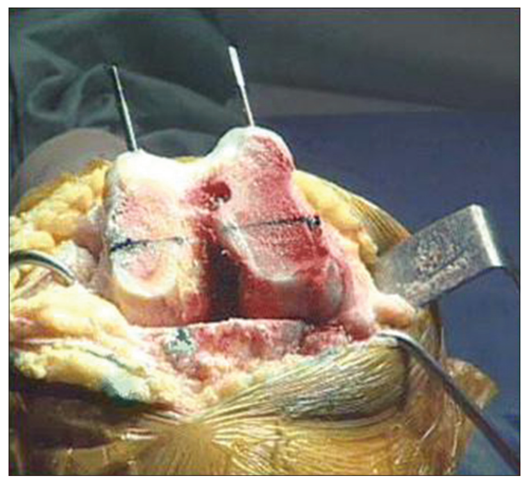

Figure 2b: The TEA technique: Identification of the epicodyles using methylene blue

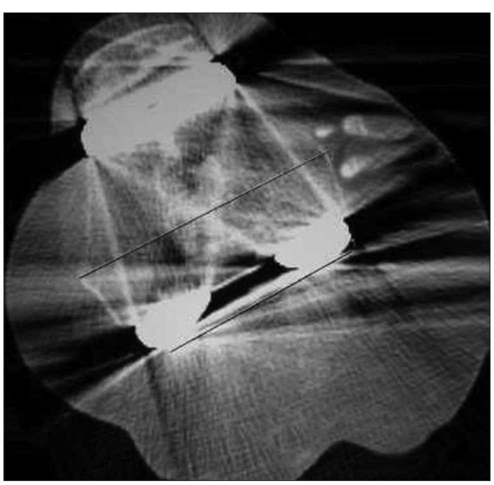

Figure 3a: CT scan image showing the rotational alignment of the femoral component compared to the true TEA. Note the more optimal rotation using the PCCPTC technique

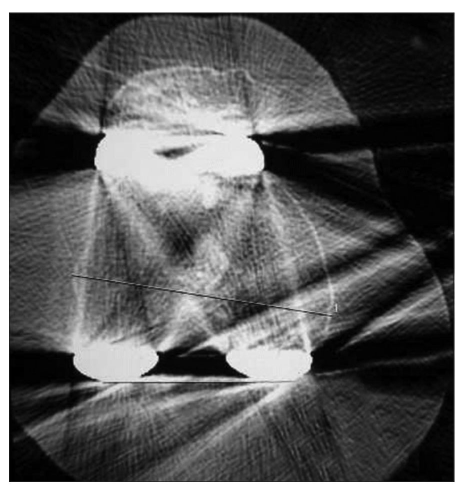

Figure 3b: CT scan image showing the rotational alignment of the femoral component compared to the true TEA. Note the excessive external rotation using the TEA technique

Table 1: A summary of patient demographics and postoperative computed tomography rotational alignments

	Method	Cases N (diagnosis)	Age/weight	Frontal plane malalignment	Mean femoral component rotation)	Mean tibial cut
Group I (TEA)	Anteroposterior cut parallel to clinical TEA	15 (11 OA and 4 RA)	65/61kg	14.07° (7-19°)	+5.60°±1.6°	90°
Group II (PCCPTC)	Posterior cut parallel to tibial cut	15 (11 OA and 4 RA)	57/62kg	12.67° (6-20°)	+2.67°±1.11°	90°

(+external rotation/−internal rotation); OA = Osteoarthritis; RA = Rheumatoid arthritis, N= number

Yau, *et al.* in their *in vivo* study attempted to compare the precision of four commonly used methods (transepicondylar axis (TEA), 3° external rotation [ER] from posterior condylar line (PCL), perpendicular cut to Leo Whiteside line (WSL), and balanced flexion gap [GAP]) in determining the rotational alignment of the femoral prosthesis. They showed that the three alignment techniques that made reference to fixed anatomical landmarks (namely, the TEA, PCL, and WSL methods) resulted in highly variable rotational alignment of the femoral prosthesis. The GAP method seemed to be the most precise method in terms of having the least variability and the lowest percentage of surgical outliers.[26]

Yan, *et al.* in their cadaveric study showed that the accuracy of rotational alignment of the TEA and Whiteside's line were operator-dependent, and their intraoperative reproducibility was low.[27]

Aligning the femoral component to the TEA of the femur is a commonly used technique. Anatomic and biomechanical studies have also shown that the TEA corresponds to the primary center of rotation of the knee.[11,28,29] However, although the epicondyles have been shown to be a reliable anatomic landmark in a cadaveric study, it is difficult to identify the peaks of the epicondyles during TKA. The identification of the TEA therefore suffers from a large inter- and intra-observer variability.[30,31]

In this study the excessive external rotation that resulted from the use of the TEA may be explained in part by the inability to accurately recognize the peak of epicondyles during surgery. These findings highlight the possible pitfalls of using anatomical bony landmarks to determine the posterior femoral cut. The PCCPTC technique which involves attaining the rectangular flexion gap, also suffers from interobserver variability but it proved to be a more reliable technique in providing optimal femoral component rotation as it is independent of obscured and distorted bone landmarks.[2,12,13,32]

CT scan has been shown to be a valid and reproducible technique for accurately measuring the total knee component rotation.[5,11,33-36] Computer-assisted navigation may further improve the bony alignment, but proper soft-tissue balance remains the most important variable. There is currently no system which can reproducibly assess this balance and therefore determining this balance is what remains of the art of reconstructive surgery

In conclusion, this study demonstrates that the use of the TEA technique for determining rotational alignment in TKA results in excessive external rotation of the femoral component compared to the PCCPTC technique.

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