Primary Arthroplasty

Distal Femoral Rotation is not Associated With Preoperative Proximal Tibial Varus Angle in Patients With Isolated Medial Compartment Osteoarthritis

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A B S T R A C T

Background: Prior studies have found that greater proximal tibial varus was associated with increased external femoral rotation at time of total knee arthroplasty. These works suggest that measuring the tibial plateau-tibial shaft (TPTS) angle and posterior condylar line (PCL) could predict significant variations in the posterior condylar angle.

Methods: A minimum of 68 patients were needed to reach 80% power. Patients were included if they had adequate preoperative imaging to plan femoral component rotation. The clinical posterior condylar angle (cPCA) was defined as the angle between the posterior condylar axis and posterior condylar line. Correlation analyses were performed to test for any relationship between the TPTS angle and cPCA. Two patient groups were created based on TPTS angle: TPTS < 4° (mild varus) and TPTS > 4° (moderate varus). Mechanical axis and rotational measurements were compared between the groups using independent t-tests.

Results: The mean mechanical axis and TPTS angles were 6.9° and 4.8° of varus, respectively. The mean cPCA was 5.0° (standard deviation [SD], 1.4°; range, 2.4°-7.9°). No correlation was found between the TPTS angle and cPCA (P = .15). The mean cPCA in the mild varus group (n = 28 patients) was 5.2° (SD, 1.5°; range, 2.7°-7.9°), and the mean cPCA in the moderate varus group (n = 45 patients) was 4.4° (SD, 1.7°; range, 0.6°-7.5°). These groups were not statistically significantly different from each other (P = .62).

Conclusion: The present study does not support the conclusions of previous works and suggests that the amount of distal femoral rotation cannot be predicted by tibial varus alignment measured on preoperative long leg radiographs. Consequently, we believe that proximal tibial varus should not be used to predict external rotation of the femoral component in patients with isolated medial compartment osteoarthritis.

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study by Thienpont et al reported that patients with varus align-
ment requiring more distal femoral external rotation at time of TKA[3].

variations in this relationship may be associated with speci-
fic clinical TEA). We hypothesized that (1) increased tibial varus would
test the surgeon to preoperatively predict ideal femoral component
rotation during TKA.

The purpose of our study was to use computer tomography (CT)
scans in a large cohort of patients with end-stage isolated medial
compartment osteoarthritis and evaluate whether an increased
TPTS angle correlated with increased distal femoral rotation (PCL to
clinical TEA). We hypothesized that (1) increased tibial varus would
be a predictor of increased distal femoral rotation and that (2) variations in this relationship may be associated with specific
cartilage wear patterns in the degenerative osteoarthritic knee.

Materials and Methods

Study Design and Patient Selection

After institutional review board approval, a sample size calculation
was performed based on the cPCA reported in previous studies [3],[12], showing that 68 patients would be needed in the
study to reach 80% statistical power. An electronic knee arthro-
plasty registry search was performed and a total of 73 patients were
included. All HKA radiographs and CT scans were available for
surgical planning of robotic-arm-assisted unicompartmental knee
arthroplasty for primary medial compartment osteoarthritis (RESTORIS MCK Onlay, Stryker Corp, Mahwah, NJ). All surgeries
were performed by one of the senior authors over an 8-month
period (01/07/2016 until 08/12/2016) using a robotic surgical
platform (Mako system, Stryker Corp, Mahwah, NJ). Patients were
excluded if they had a valgus mechanical axis. The imaging studies
were retrospectively analyzed.

Radiographic Assessment

Radiographic evaluation was performed in a Picture Archiving
and Communication System version 16 (PACS; Sectra Imtec AB,
Linköping, Sweden). The mechanical axis and TPTS angle were
determined using HKA weight-bearing radiographs, and the
radiographic technique was standardized for all patients in this
cohort and performed by certified radiologic technologists. The
TPTS angle was measured using the angle measurement tool on
PACS version 16 as illustrated by Pagnano and Hanssen [3] and was
the angle formed medially between a line across the tibial plateau
connecting the medial and lateral edges of the tibial plateau and
line down the center of the tibial shaft.

Patients were instructed to stand straight with extended
knees and distribute their body weight evenly. The patellae were
aligned with the direction of the X-ray beam. The X-ray beam
was centered at the distal pole of the patella, aligning the image
parallel to the tibial joint line in the frontal plane. The me-
chanical axis was defined as the angle between the femoral
mechanical axis (center of the hip to intercondylar notch of the
knee) and the tibial mechanical axis (center between tibial
spines to center of the distal tibia). The TPTS angle was defined
as the proximal medial angle formed between the tibial me-
chanical axis and the knee joint line of the tibia in the frontal
plane [3],[15].

Regarding the CT, measurements were made using the angle
measurement tool on PACS version 16, the surgical trans-
epicondylar axis (SEA) was defined as the sulcus on the medial side
and the most prominent point on the lateral epicondyle. The
anatomic transepicondylar axis (AEA) was constructed on axial CT
scans as a line between the medial and lateral epicondyles. The PCL
was the tangent line from the posterior bony edge of the medial
to the lateral condyles. The angles between the SEA or AEA and the
PCL were defined as the sPCA (sPCA = PCL – SEA) and the clinical posterior condylar angle (cPCA = PCL – AEA) (Fig. 1), respectively
[2],[3]. Measurements on CT scans were taken using the technique
described above by 2 independent observers. We chose to use the
cPCA in order to assess rotational alignment of the femur as a
previous study demonstrated that more significant osteoarthrosis
made detecting the medial sulcus as required in the sPCA mea-
surement to be unreliable [16]. Yoshino et al [16] concluded that the
cPCA should be used to measure distal femoral rotation in arthritic
knees and that the sPCA can be approximated by subtracting 3°
from the cPCA.

To test our second hypothesis, femoral wear patterns were
categorized on weight-bearing AP and posteroanterior (PA) flex
radiographs of the affected knee. Patients were grouped into 3
cohorts based on their wear patterns. The first group consisted of
patients with degenerative changes more distally on the femoral
condyle, showing severe medial wear on the AP radiograph and
minimal medial wear on the PA flex view. Group 2 had more pos-
terior medial femoral condyle wear, which was demonstrated by
severe medial wear on the PA flex view with minimal wear on the
AP radiograph. The third group had severe wear on both the PA flex
and AP views. Two independent researchers reviewed all radi-
ographs for all patients, based on the wear pattern assigned to 1 of
the 3 groups.

![Fig. 1. Surgical and clinical posterior condylar angles. The surgical posterior condylar angle (sPCA) is the angle between the posterior condylar line (PCL), which connects the most posterior aspects of the medial and lateral femoral condyles, and surgical epicondylar axis (SEA), which is a line from the lateral epicondyle to the medial sulcus. The clinical posterior condylar angle (cPCA) is the angle between the PCL and the clinical epicondylar axis (CEA), which connects the medial and lateral distal femoral epicondyles.](image)
 Seventy-three patients with preoperative HKA radiographs and preoperative CT scans were included in this study. The average age was 61.3 years (SD, 9.0; range, 41.4-87.5). Thirty-nine patients (53.4%) were male, and 34 patients (46.6%) were female (Table 1). The mean mechanical axis was 6.9° of varus (SD, 3.1°; range, 0.0°-17.3°). The mean TPTS angle was 4.8° of varus (SD, 2.1°; range, 0.2°-10.0°) with an interobserver reliability of 0.92 (95% confidence interval [CI], 0.87-0.95; Table 1).

The mean sPCA was 2.6° (SD, 1.3°; range, 0.0°-5.5°). The mean cPCA was 5.0° (SD, 1.4°; range, 2.4°-7.9°). The corresponding cPCA intraobserver and interobserver ICCs were found to be 0.94 (95% CI, 0.85-0.97) and 0.57 (95% CI, 0.11-0.79), respectively. This demonstrates excellent intraobserver reliability and moderate reliability of the interobserver measurements. No correlation was found between the TPTS angle and cPCA (P = .15; Fig. 2).

Based on the Pagnano and Hanssen’s article [3], the patients were then divided into 2 groups: those with a TPTS angle ≤4° (mild varus, n = 28 patients) and those with TPTS angle >4° (moderate varus, n = 45 patients). In the mild varus group, the mean mechanical axis was 5.3° of varus (SD, 2.2°; range, 0°-11.7°), and TPTS angle was 2.8° (SD, 1.0°; range, 0.2°-3.8°). The mean cPCA was 5.2° (SD, 1.5°; range, 2.7°-7.9°). The moderate varus group (TPTS >4°) had a mean mechanical axis of 7.9° (SD, 3.2°; range, 1.0°-17.3°) and mean TPTS angle of 6.1° (SD, 1.6°; range, 4.1°-10.6°). The mean cPCA of this group was 4.4° (SD, 1.7°; range, 0.6°-7.5°), which was not statistically different than the mild varus group (P = .62; Table 2).

Furthermore, wear patterns were evaluated (Table 3), and pattern 3 was found to be most prevalent (n = 36, 49.3%) compared to pattern 1 (n = 18, 24.7%) or pattern 2 (n = 19, 26.0%) (Table 3). Interobserver reliability for the wear patterns had an ICC of 0.91 (95% CI, 0.863-0.946), which suggests excellent correlation between the reviewers. The TPTS was statistically different between the different wear patterns, specifically patients with pattern 1 had a lower TPTS than patterns 2 and 3 (P = .046 and P = .017, respectively; Table 3). No differences in cPCA were observed between the 3 groups.

### Discussion

This study demonstrates that distal femoral rotation does not correlate with tibial varus in patients with a varus mechanical axis and isolated medial compartment osteoarthritis, and this work is the first to examine preoperative distal femoral rotation in patients indicated for a unicompartmental knee arthroplasty. These results do not support previous work by Pagnano and Hanssen [3] and Thienpont et al [2] demonstrating a correlation between tibial...
Posteroanterior-fl

(Asterisk indicates statistical significance. Post hoc testing demonstrated that patients with pattern 2 (P = .046) and pattern 3 (P = .017) distal femoral wear (ie, more severe postero medial condyle wear on the posteromedial flex view) had significantly greater TPTS than patients with isolated medial condyle wear on the anteroposterior view. SD, standard deviation.

Table 2

<table>
<thead>
<tr>
<th>Radiographic Measurements</th>
<th>TPTS ≤4 (Mild Varus)</th>
<th>TPTS &gt;4 (Moderate Varus)</th>
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<tbody>
<tr>
<td>Mean TPTS</td>
<td>2.8° (SD, 1.0°; range, 0.2°–3.8°)</td>
<td>6.1° (SD, 1.6°; range, 4.1°–10.6°)</td>
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<tr>
<td>Mean mechanical axis</td>
<td>5.5° (SD, 2.5°; range, 0°–11.7°)</td>
<td>7.8° (SD, 3.1°; range, 1.0°–17.3°)</td>
</tr>
<tr>
<td>Mean cPCA; P value =.62</td>
<td>5.2° (SD, 1.5°; range, 2.7°–7.9°)</td>
<td>6.1° (SD, 0.6°–7.5°)</td>
</tr>
</tbody>
</table>

There was no significant difference in the mean external rotation of the distal femur as measured by the cPCA between the 2 groups (P = .62). TPTS, tibial plateau-tibial shaft; SD, standard deviation; clinical posterior condylar angle.

Table 3

<table>
<thead>
<tr>
<th>Tibial Plateau-Tibial Shaft Angle (TPTS) and Clinical Posterior Condylar Angle (cPCA) by Distal Femoral Wear Pattern.</th>
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<tbody>
<tr>
<td>Distral Femoral Wear Pattern</td>
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<tr>
<td>-----------------------------</td>
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<tr>
<td>Pattern 1</td>
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<tr>
<td>Pattern 2</td>
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<tr>
<td>Pattern 3</td>
</tr>
</tbody>
</table>

Asterisk indicates statistical significance.

References

[4] Wright SJ, Boymans TAEJ, Grimm B, Miles AW, Kessler O. Strong correlation between the morphology of the proximal femur and the geometry of the axial alignment during TKA. The mean sPCA as measured from the PCL to the SEA was 4° [2]. In a multivariate model, they found that tibial varus was significantly correlated with mean external rotation, mechanical axis, and patient age [2]. However, the clinical implication of this was unclear as the mean difference in external rotation was only 0.3° and no minimal clinically important difference was calculated. The authors reported that patients with 1°–2° of tibial varus had a mean external rotation of –3.9° whereas those with 5°–16° of tibial varus had a mean external rotation of –4.2° [2].

The present study does not support the work of Pagnano and Hanssen [3] or the conclusions drawn by Thienpont et al [2]. In our work, the average cPCA in varus knees was 5.2° (SD, 1.5°) in patients with TPTS angle ≤4° and 4.4° (SD, 1.7°) in patients with a TPTS angle >4°. There was no statistically significant difference in the rotation of the native distal femur between the 2 groups, and no significant correlation was found between the cPCA and the TPTS angle measured on preoperative standing radiographs. Based on our work as well as the small clinically insignificant difference found by Thienpont et al [2], tibial varus seems to be a poor predictor to assess variations in distal femoral rotation.

Our cohort consisted of patients with medial compartment osteoarthritis, which was thought to influence the correlation between TPTS and cPCA. We anticipated that patients with a TPTS greater than their cPCA would have more distal femoral wear than posterior medial femoral condyle wear. However, the location of the degenerative changes on the femoral condyle did not account for the differences found between our study and the previous literature. No differences in cPCA were found between the 3 wear patterns, only the tibial varus angle of pattern 1 was significantly lower than patterns 2 and 3. Therefore, in our study, different patterns of distal and posterior medial bone loss could not account for our finding that distal femoral rotation was not correlated with varus and valgus alignment of the proximal tibia on weight-bearing radiographs.

One weakness of our study was the small sample size compared with previously published reports on distal femoral rotation. Additionally, the CT scans used in this study did not have residual cartilage medially, which has been shown to affect calculation of the posterior condylar angle [6], [7].

In conclusion, this study showed that the amount of distal femoral rotation in patients with isolated medial compartment osteoarthritis cannot be predicted by tibial varus alignment measured on preoperative long leg radiographs. This conflicts with the previously published work by Pagnano and Hanssen [3]. This study suggests that the amount of varus alignment of the proximal tibia is not related to the amount of distal femoral rotation and, consequently, long leg radiographs and proximal tibial varus cannot be used to preoperatively predict which patients with isolated medial compartment osteoarthritis may require more external rotation of the femoral component during TKA. Alternative radiographic predictors should be investigated that more reliably predict accurate rotation of the femoral component.


