Author's response to reviews

Title: Prosthesis Alignment Affects Axial Rotation Motion after Total Knee Replacement: A Prospective In vivo Study Combining Computed Tomography and Fluoroscopic Evaluations

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Version: 2 Date: 21 June 2012

Author's response to reviews: see over
June 10, 2012

Ms. Abigail Quiniquini (for Dr. Nobuo Adachi)
BMC Musculoskeletal Disorders
BioMed Central
236 Gray's Inn Road
London WC1X 8HB
United Kingdom

Dear Ms Quiniquini:

Please reconsider the enclosed research article MS1519767787664219 entitled “Prosthesis Alignment Affects Axial Rotation Motion after Total Knee Replacement: A Prospective In vivo Study Combining Computed Tomography and Fluoroscopic Evaluations” for publication in BMC Musculoskeletal Disorders. The authors who participated in the conception, execution, analysis and writing are Melinda Harman, PhD; Scott Banks, PhD; Stephan Kirschner, MD; and Jörg Lützner, MD.

All queries raised by the reviewers have been fully addressed in the text of the manuscript and a point by point response follows this letter. As Corresponding Author, I confirm that all authors have seen and agree with the contents of this manuscript.

Thank you for your kind attention to the review and publication of this manuscript.

Sincerely,

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Authors' Responses to Reviewers’ Comments:  The authors’ responses are in italic font. Bold font indicates text revision added to the manuscript. Strike through font indicates the text has been deleted from the manuscript.

Reviewer 1 (Goldhahn): The authors address a clinically relevant question in their study.

Authors’ Response:  We appreciate your review and kind response.

Reviewer 1: The authors’ focus on passive knee flexion enables standardization of the in-vivo trial but the consequences for gait and other activities of daily living remain unclear. The authors clearly mention this limitation and indicate ongoing research in this area. Therefore, the manuscript adds knowledge due to the simplified test procedure compared to a full gait analysis. Could the authors provide some thoughts how the observed patterns may influence the full gait cycle? Since the authors used a forced passive flexion there remains the question, whether a similar pattern will result from active flexion.

Authors’ Response:  The reviewer is correct, our data only represents kinematics during passive knee flexion. We purposefully avoided making conclusions about gait from these data since such conclusions would not be evidence-based. However, the following paragraph, which was included in the original submission, does provide some sense of how these observed kinematics could impact dynamic activities.

Discussion
Maintaining rotational mismatch within $\pm 5^\circ$ during TKR provided for controlled femoral external rotation motion occurring with passive flexion. In contrast, bearing motions in the mid-flexion range of motion were distinctly different among outlier TKR in both the Anatomic Landmarks and Rotational Mismatch groups compared to nominal TKR (Figures 4 and 5). This may have consequences for dynamic activities that demand stability during mid-flexion when joint loads due to muscle contraction are high. Furthermore, external rotation was essentially arrested beyond $80^\circ$ in Anatomic Landmarks outliers, which can interfere with patella function [14, 18, 34, 35]. In the Rotational Mismatch group, outlier TKR alignment was biased more than $6^\circ$ toward femoral internal rotation relative to the tibial component (Table 2), resulting in significantly less total axial rotation (decreased external rotation motion) compared to nominal TKR (Figure 5). A similar reduction in axial rotation motion with femoral-tibial component mismatch biased toward femoral internal rotational alignment has been observed during in-vitro testing of cadaver limbs loaded to simulate rising from a chair [35].

Reviewer 1: Could the authors provide more rationale for choosing the threshold for “outliers”?

Authors’ Response:  This point was raised by two of the reviewers. The magnitudes are justified in the following text.

Methods
The tolerances were established using both surgical norms and a clinical perspective, since acceptable tolerance for tibial rotational alignment and rotational mismatch between the components are not well-defined.[10, 15, 16, 18, 20, 31-33, 40]
Discussion

The nominal tolerances for component alignment and rotational mismatch in the transverse plane remain under debate [8, 11-16, 18-22]. In the current study, TKR were categorized as nominal if component alignment relative to anatomic landmarks was within \( \pm 3^\circ \) for femoral components and within \( \pm 10^\circ \) for tibial components, and if relative femoral-tibial mismatch was within \( \pm 5^\circ \). These ranges were established based on reported surgical precision for achieving targeted component alignment [10, 15, 16] and the magnitude of deviation from optimal alignment that has been associated with clinical and biomechanical complications.[18, 20, 31-33, 40]

Femoral component alignment deviating from \( \pm 3^\circ \) was considered as outlier alignment since it does not represent precise surgical technique and has the potential to contribute to poor outcomes. Several studies report that \( \pm 3^\circ \) precision for femoral component rotation is readily achieved in more than 85% of TKR.[10, 15, 16] Femoral component rotation exceeding approximately \( \pm 5^\circ \) has been associated with clinical complications,[33] including pain [32] and patellar failure.[18] It is recognized that precise tibial component axial rotation relative to anatomic landmarks is difficult to achieve. Tibial component alignment deviating from \( \pm 10^\circ \) was considered as outlier alignment since it exceeds surgical norms and has the potential to contribute to poor outcomes. Reported alignment precision for tibial components exceeds \( \pm 3^\circ \) in approximately 50% of TKR[10] and exceeds \( \pm 10^\circ \) in approximately 30% of TKR.[15] Absolute mean deviations of \( 3^\circ \) to \( 8^\circ \) of tibial component axial rotation alignment have been reported,[10, 15] with pain [32] and patellar dislocation and failure[18] associated with deviations exceeding approximately \( 10^\circ \).

While several studies report combined rotation and rotational mismatch between the femoral and tibial components after TKR.[14, 18, 32, 41], few report clinical consequences associated with these parameters. Adverse consequences associated with approximately \( 10^\circ \) of combined rotation or rotational mismatch include no improvement in Knee Society function scores,[41] knee pain,[32] and patellar dislocation or failure.[18] In the current study, 7 of the 23 TKR categorized as outliers in the Rotational Mismatch group had rotational mismatch exceeding \( \pm 10^\circ \) and those patients previously were reported to exhibit no functional improvement.[41] Expanding the current analysis to include TKR with rotational mismatch exceeding \( \pm 5^\circ \) shows that even smaller magnitudes of mismatch can have significant biomechanical consequences (Figure 6B).

Reviewer 1: The chosen methodology is appropriate and well-described, but a short summary of the processing steps of the fluoroscopy would increase the understanding of the paper.

Authors’ Response: A short summary of the technique was provided as the Figure 2 heading in the original submission. The technique is also now summarized in the methods section, as follows.

Figure 2 Heading:
Model-based shape matching techniques were applied to (A) the acquired two-dimensional fluoroscopy images by (B) superimposing surface models of the components and embedded...
radiopaque markers and iteratively adjusting their three-dimensional pose to match the TKR silhouette. (C) Joint angles, including flexion, valgus, and axial rotation, were determined from the relative orientation between the femoral component and metal tibial baseplate and between the femoral component and polyethylene tibial bearing in each image (C).

Methods:
The three-dimensional position and orientation of femoral, tibial and polyethylene bearing components were determined using surface models of the components projected onto the fluoroscopy images and previously published model-based shape matching techniques (Figure 2) [25, 29]. Three radiopaque markers embedded in each polyethylene bearing provided geometrically defined point clusters suitable for tracking bearing motion, as demonstrated in other studies [25, 30-33]. Briefly, the measurement technique involved acquisition of two-dimensional fluoroscopy images, image calibration based on known dimensions of the imaging geometry (principal distance, beam center location), and projection of surface models of the prosthesis components and embedded radiopaque markers onto the fluoroscopic images with iterative adjustment their three-dimensional pose to match the TKR silhouette. Joint angles, including flexion, valgus, and axial rotation, were determined from the relative orientation between the femoral component and metal tibial baseplate and between the femoral component and polyethylene tibial bearing in each image.

Reviewer 1: The authors describe a very small variability of the surgeons with respect to alignment in different planes. Could the authors please comment on the high percentage (31%) of outliers?

Authors’ Response: The percentage of outliers in the current report (31%) results from the tight threshold for tibial component rotation. This value is very similar to our previous report [15], in which 8 of 80 (90%) TKR had femoral rotation exceeding ±3° and 23 of 80 (29%) TKR had tibia rotation exceeding ±10° e 31% of outliers

Discussion
However, these tolerances were exceeded in 31% and 34% of the TKR when evaluated relative to anatomic landmarks and rotational mismatch, respectively (Table 2). Rotational alignment of the tibial components proved especially variable and contributed to these relatively high percentages of outliers, similar to our previous report,[15] as surgical techniques referencing the tibial tubercle have proven inconsistent [15-17].

Reviewer 1: The authors should either label the final paragraph as summary or derive specific conclusions.

Authors’ Response: We have labeled the final paragraph to Summary as suggested.

Reviewer 1: Could the authors superimpose the resulting curves of total rotation (4 and 5 as well as 6 and 7)?
Authors’ Response: We have added one additional figure (Figure 6) which superimposes the magnitude of total rotation versus flexion for both the Anatomic Landmarks group and the Rotational Mismatch group. The standard deviations of the measurements are provided and statistical differences between the nominal TKR and outlier TKR are marked with an asterisk.

![Figure 6: Direct comparison of total axial rotation kinematics](image)

Relative motion between the femoral component and tibial baseplate (total axial rotation) for TKR in the A) Anatomic Landmarks Group and B) Rotational Mismatch Group.

* = significant difference between nominal and outlier TKR in each group (ANOVA, \( p \leq 0.05 \))

Reviewer 1: Do the two cohorts (all subjects vs. kinematic cohort) really have the same age characteristics?

Authors’ Response: Yes, the two cohorts have very similar patient characteristics. Below are the specific statistics related to patient age, showing less than 1 year difference in Mean age and no difference in Median age. All data originally reported in Table 2 (reprinted below) have been double-checked for accuracy.

<table>
<thead>
<tr>
<th></th>
<th>All subjects</th>
<th>Kinematic cohort</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEAN</td>
<td>67.8</td>
<td>MEAN</td>
</tr>
<tr>
<td>STDEV</td>
<td>9.3</td>
<td>STDEV</td>
</tr>
<tr>
<td>COUNT</td>
<td>80</td>
<td>COUNT</td>
</tr>
<tr>
<td>MIN</td>
<td>47</td>
<td>MIN</td>
</tr>
<tr>
<td>MAX</td>
<td>87</td>
<td>MAX</td>
</tr>
<tr>
<td>MEDIAN</td>
<td>69.0</td>
<td>MEDIAN</td>
</tr>
</tbody>
</table>
Table 1: Patient demographics and preoperative clinical data for entire randomized subject population and cohort included in the kinematic analysis (medians and range for continuous data, absolute and relative frequencies for categorical data)

<table>
<thead>
<tr>
<th></th>
<th>All Subjects</th>
<th>Kinematic Cohort</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>80</td>
<td>67</td>
</tr>
<tr>
<td>Age (years)</td>
<td>69 (47 – 87)</td>
<td>69 (47 – 84)</td>
</tr>
<tr>
<td>Sex (% female)</td>
<td>51/80, 63.8%</td>
<td>41/67, 65.7%</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>84 (60 – 146)</td>
<td>85 (62 – 146)</td>
</tr>
<tr>
<td>Body Mass Index (kg/m²)</td>
<td>29.7 (22.0 – 47.7)</td>
<td>30.0 (22.0 – 47.7)</td>
</tr>
</tbody>
</table>

Reviewer 1: Legends for figures 6 and 7 are missing

Authors’ Response: We have reformatted the figures so that Figure 4 and Figure 5 match the text in the figure legends. These figures fit into a single column and display the appropriate A and B labels, as below.

Figure 4: Axial rotation kinematics in the Anatomic Landmarks group
Axial rotation kinematics in TKR categorized as A) nominal and B) outliers in the Anatomic Landmarks group. Relative motion between the femoral component and tibial baseplate (total axial rotation), between the femoral component and polyethylene bearing (articular axial rotation) and between the polyethylene bearing and tibial baseplate (bearing axial rotation) were distinguished.
Axial rotation kinematics in TKR categorized as A) nominal and B) outliers in the Rotational Mismatch Group. Relative motion between the femoral component and tibial baseplate (total axial rotation), between the femoral component and polyethylene bearing (articular axial rotation) and between the polyethylene bearing and tibial baseplate (bearing axial rotation) were distinguished.

* = significant difference between nominal and outlier groups for total axial rotation (ANOVA, *p* < 0.05)

**Reviewer 2:** Finding of this manuscript could provide information on understanding the component malalignment and mismatch’s effect on axial rotation motions in mobile-bearing knees. The data are pretty informative and convincing.

**Authors’ Response:** We appreciate your review and kind response.

**Reviewer 2:** Could the authors provide more details for the method and results section in the discretionary Revisions?

**Authors’ Response:** The request for additional methodological details was made by two reviewers. Therefore, we have added more details in the text of the methods, as follows.

**Methods:**
The three-dimensional position and orientation of femoral, tibial and polyethylene bearing components were determined using surface models of the components projected onto the fluoroscopy images and previously published model-based shape matching techniques (Figure 2) [25, 29]. Three radiopaque markers embedded in each polyethylene bearing provided...
geometrically defined point clusters suitable for tracking bearing motion, as demonstrated in other studies [25, 30-33]. Briefly, the measurement technique involved acquisition of two-dimensional fluoroscopy images, image calibration based on known dimensions of the imaging geometry (principal distance, beam center location), and projection of surface models of the prosthesis components and embedded radiopaque markers onto the fluoroscopic images with iterative adjustment their three-dimensional pose to match the TKR silhouette. Joint angles, including flexion, valgus, and axial rotation, were determined from the relative orientation between the femoral component and metal tibial baseplate and between the femoral component and polyethylene tibial bearing in each image.

Reviewer 2: Was alignment of the femoral component measured relative to the surgical epicondylar axis or clinical epicondylar axis?

Authors’ Response: The manuscript text in the methods, Figure 1A heading and Table 2 heading have been modified as follows.

Rotational alignment with respect to anatomic landmarks was measured for the femoral component relative to the surgical transepicondylar axis and for the tibial component relative to the medial third of the tibial tuberosity (Figure 1), as previously described [15].

Figure 1 (A) Femoral component alignment was measured as the angle between an axis defined by the femoral fixation pegs (dotted line) and the surgical epicondylar axis (dashed line)...

Table 2: Rotational alignment of components (median, range) measured from postoperative CT images for alignment groups defined with respect to anatomic landmarks (surgical transepicondylar axis, medial third of the tibial tuberosity)...

Reviewer 2: For TKR with rotational mismatch as outliers, it is better to divide the group into outliers with negative value and outliers with positive value, because axial rotation kinematics between the two groups maybe opposite, so we could analysis them differently.

Authors’ Response: Out of the 23 outliers in the Rotational Mismatch group, there were 9 TKR with negative mismatch (femoral external rotation relative to the tibial component) and 14 TKR with positive mismatch (femoral internal rotation relative to the tibial component). Analysis of kinematics was limited due to the small sample sizes in each group, but revealed virtually no differences between the two groups (see figure below).
These findings (without inclusion of the above figure) are presented in the manuscript as follows.

**Results**

Outlier TKR in the Rotational Mismatch group included nine TKR with negative mismatch (femoral external rotation relative to the tibial component) and 14 TKR with positive mismatch (femoral internal rotation relative to the tibial component), resulting in had 6.4° more femoral-tibial mismatch biased toward tibial external rotation (femoral internal rotation) compared to the nominal TKR.

Dividing the outliers in the Rotational Mismatch group into TKR with negative mismatch and TKR with positive mismatch revealed nearly identical total axial rotation motion from 10° to 90°, with no significant differences over the flexion range (ANOVA, p>0.05). This finding suggests that both positive and negative mismatch similarly alter femoral-tibial axial rotation relative to TKR with nominal mismatch.

**Abstract**

TKR with rotational alignment outside of defined surgical norms, with either positive or negative mismatch, experienced measurable kinematic differences and presented different patterns of axial rotation motions during passive knee flexion compared to TKR with nominal mismatch.

**Reviewer 3 (Majima):** This is an interesting study.

**Authors’ Response:** We appreciate your review and kind response.

**Reviewer 3:** In the abstract (Page 3 line 7-9) and conclusion (Page 14, line 7-8), the authors concluded that the relationship between Knee Society function score and rotational mismatch.
However, there is no actual data. Also, the authors already reported the relationship between clinical results and rotational mismatch. Results of the present study cannot conclude the relationship between rotational mismatch and clinical results. The present study must answer only for the research question.

**Authors’ Response:** We agree that the relationship between clinical outcome and rotational mismatch is not part of the data reported in this study, and all reference to such have been removed. However, in addition to our own work on this topic (refs 36, 37), there are several previous studies (see refs 14, 18, 21) that describe adverse clinical and functional consequences of rotational malalignment. Our study provides some biomechanical rationale supporting those previous findings, and we have reworded our conclusions accordingly.

**Abstract:**
Conclusions: Maintaining relative rotational mismatch within $\pm 5^\circ$ during TKR provided for controlled knee axial rotation during flexion. TKR with rotational alignment outside of defined surgical norms experienced measurable kinematic differences and presented different patterns of axial rotation motions during passive knee flexion. Moreover, preliminary clinical outcomes for patients with excessive rotational mismatch are trending toward inferior Knee Society function scores. These findings support previous studies linking prosthesis rotational alignment with inferior clinical and functional outcomes.

Conclusions:
TKR with rotational alignment outside of defined surgical norms experienced measurable kinematic differences and presented different patterns of axial rotation motions during passive knee flexion. Preliminary clinical outcomes for patients with excessive rotational mismatch are trending toward inferior Knee Society function scores. These findings support previous studies [14, 18, 21, 36, 37] linking prosthesis rotational alignment with inferior clinical and functional outcomes.


**Reviewer 3:** The authors need to assess coefficient of variation (CV) in order to show intraobserver consistency. (Page 6, line 3-5.)
Authors’ Response: We agree that intraobserver consistency is an important factor for collecting good measurement data. We used only one trained observer to make the measurements of component alignment on the CT images, specifically to avoid added error due to interobserver inconsistency. In addition, we used commercially available software typical of that which is in widespread use in many orthopaedic departments and is familiar to the surgeon observer. These points have been addressed in the manuscript as follows.

Methods:
Three quantitative descriptors of the components’ rotational alignment were measured (ID.PACS 3.6, Image Devices, Idstein, Germany) from computed tomography (CT) images of the knee in extension acquired for each patient 5 to 7 days after surgery. Rotational alignment with respect to anatomic landmarks was measured for the femoral component relative to the surgical transepicondylar axis and for the tibial component relative to the medial third of the tibial tuberosity (Figure 1), as previously described [15]. Relative rotational mismatch between the femoral and tibial components was measured by superimposing the CT images and measuring the angular divergence of the femoral component relative to the tibial component. This procedure of using commercially available software to measure prosthesis alignment from CT images was selected because it has very good intraobserver accuracy (intraclass correlation coefficient > 0.8) and coefficient of variation of 11% to 17%.[29, 30] All CT measurements were completed by the same skilled observer (JL) who was blinded to kinematic measurements.


Reviewer 3: There are two femoral rotational landmarks, clinical epicondylar axis and surgical epicondylar axis. Which axis did the authors measure? (Page 5, line 23)

Authors’ Response: The manuscript text in the methods, Figure 1A heading and Table 2 heading has been modified as follows.

Rotational alignment with respect to anatomic landmarks was measured for the femoral component relative to the surgical transepicondylar axis and for the tibial component relative to the medial third of the tibial tuberosity (Figure 1), as previously described [15].

Figure 1 (A) Femoral component alignment was measured as the angle between an axis defined by the femoral fixation pegs (dotted line) and the surgical epicondylar axis (dashed line)...
Reviewer 3: Why do the authors define rotational misalignment in Femoral component for ±3°, and Tibial component for ±10°? (Page 6, line 13)

Authors’ Response: This point was raised by two of the reviewers. The magnitudes are justified in the following text.

Methods
The tolerances were established using both surgical norms and a clinical perspective, since acceptable tolerance for tibial rotational alignment and rotational mismatch between the components are not well-defined.[10, 15, 16, 18, 20, 31-33, 40]

Discussion
The nominal tolerances for component alignment and rotational mismatch in the transverse plane remain under debate [8, 11-16, 18-22]. In the current study, TKR were categorized as nominal if component alignment relative to anatomic landmarks was within ±3° for femoral components and within ±10° for tibial components, and if relative femoral-tibial mismatch was within ±5°. These ranges were established based on reported surgical precision for achieving targeted component alignment [10, 15, 16] and the magnitude of deviation from optimal alignment that has been associated with clinical and biomechanical complications.[18, 20, 31-33, 40]

Femoral component alignment deviating from ±3° was considered as outlier alignment since it does not represent precise surgical technique and has the potential to contribute to poor outcomes. Several studies report that ±3° precision for femoral component rotation is readily achieved in more than 85% of TKR.[10, 15, 16] Femoral component rotation exceeding approximately ±5° has been associated with clinical complications,[33] including pain [32] and patellar failure.[18] It is recognized that precise tibial component axial rotation relative to anatomic landmarks is difficult to achieve. Tibial component alignment deviating from ±10° was considered as outlier alignment since it exceeds surgical norms and has the potential to contribute to poor outcomes. Reported alignment precision for tibial components exceeds ±3° in approximately 50% of TKR[10] and exceeds ±10° in approximately 30% of TKR.[15] Absolute mean deviations of 3° to 8° of tibial component axial rotation alignment have been reported,[10, 15] with pain [32] and patellar dislocation and failure[18] associated with deviations exceeding approximately 10°.

While several studies report combined rotation and rotational mismatch between the femoral and tibial components after TKR,[14, 18, 32, 41], few report clinical consequences associated with these parameters. Adverse consequences associated with approximately 10° of combined rotation or rotational mismatch include no improvement in Knee Society function scores,[41], knee pain,[32] and patellar dislocation or failure.[18] In the current study, 7 of the 23 TKR categorized as outliers in the Rotational Mismatch group had rotational mismatch exceeding ±10° and those patients previously were
reported to exhibit no functional improvement.[41] Expanding the current analysis to include TKR with rotational mismatch exceeding ±5° shows that even smaller magnitudes of mismatch can have significant biomechanical consequences (Figure 6B).

Reviewer 3: The figures need SD bar

Authors’ Response: As requested by one reviewer, we have added one additional figure (Figure 6) which superimposes the magnitude of total rotation versus flexion for both the Anatomic Landmarks group and the Rotational Mismatch group. The standard deviations of the measurements are clearly provided and statistical differences between the nominal TKR and outlier TKR are marked with an asterisk.

We did not add standard deviation bars to Figures 4 and 5 because it made the graphs too busy and interfered with clarity. Rather, measurement SD is clearly shown in Figure 6.

![Figure 6](image1)

**Figure 6: Direct comparison of total axial rotation kinematics**
Relative motion between the femoral component and tibial baseplate (total axial rotation) for TKR in the A) Anatomic Landmarks Group and B) Rotational Mismatch Group. * = significant difference between nominal and outlier TKR in each group (ANOVA, p<0.05)

Reviewer 3: There are no figure legends for Fig. 6 and 7. Also, There are no A) and B) in figure 4, and 5 that is mentioned in figure legends. The figures may be miss-numbered.
Authors’ Response: We have reformatted the figures so that Figure 4 and Figure 5 match the text in the figure legends. These figures fit into a single column and display the appropriate A and B labels, as below.

**Figure 4: Axial rotation kinematics in the Anatomic Landmarks group**
Axial rotation kinematics in TKR categorized as A) nominal and B) outliers in the Anatomic Landmarks group. Relative motion between the femoral component and tibial baseplate (total axial rotation), between the femoral component and polyethylene bearing (articular axial rotation) and between the polyethylene bearing and tibial baseplate (bearing axial rotation) were distinguished.
Figure 5: Axial rotation kinematics in the Rotational Mismatch Group
Axial rotation kinematics in TKR categorized as A) nominal and B) outliers in the Rotational Mismatch Group. Relative motion between the femoral component and tibial baseplate (total axial rotation), between the femoral component and polyethylene bearing (articular axial rotation) and between the polyethylene bearing and tibial baseplate (bearing axial rotation) were distinguished. * = significant difference between nominal and outlier groups for total axial rotation (ANOVA, p<0.05)

Reviewer 3: Are patients of outliers in Anatomic Landmark group and patients of outliers in Rotational mismatch group the same? That is to say, whether rotational platform implant has self-alignment mechanism?

Authors’ Response: There are 10 patients that are included in the outlier category for both the Anatomic Landmarks group (10 of 21) and the Rotational Mismatch group (10 of 23). Therefore, it does not appear that the rotational platform self-aligned those patients. This is summarized as follows.

Results
There were 16 (24%) TKR with isolated malrotation of the tibial component, 4 (6%) with isolated malrotation of the femoral component, and 1 (1%) with malalignment of both the tibial and femoral components. Ten TKR were identified as being outliers in both the Anatomic Landmark group and the Rotational Mismatch group.

Discussion
Therefore, contrary to some studies suggesting that mobile-bearing TKR designs compensate for errors in rotational alignment [17, 19, 21-24], patients with mobile-bearing TKR can experience measurable kinematic differences and worse functional outcomes [41] when rotational alignment is outside of defined surgical norms.