Femur Positioning in Navigated Total Knee Arthroplasty

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abstract

Navigated total knee arthroplasty (TKA) results in better restoration of neutral mechanical axis than does the conventional technique. Nevertheless, coronal malalignment has not been eliminated. It is yet unknown whether errors in implant positioning occur more on the femoral side, more on the tibial side, or equally on both sides. The hypothesis of this study was that a predominance of coronal component malalignment exists on the tibial side in navigated tibia-first TKA.

Fifty-seven consecutive navigated (OrthoPilot; B. Braun Aesculap, Tuttlingen, Germany) TKAs were included in this retrospective study. Pre- and postoperative digital whole-leg standing radiographs were analyzed. Coronal alignment was measured for the whole leg pre- and postoperatively. Lateral distal femur angle and medial proximal tibia angle were analyzed on the preoperative radiographs. On the postoperative radiographs, coronal alignment of the femoral and tibial components were measured separately in reference to the tibial and femoral mechanical axis. The coronal alignment improved from 8.2° ± 3.7° preoperatively to 1.1° ± 1.2° postoperatively, with 5 (8%) outliers outside the 3° window. The femoral component was malaligned (0.6° ± 0.6°), whereas the tibial component showed a significantly higher deviation from the mechanical axis of 1.0° ± 1.1° (P = .009).

The femoral component was positioned more precisely than the tibial component. The latter influences gap management in the tibia-first technique and may thereby have a relevant effect on joint stability. Accuracy of the surgical technique and differences in the mathematical algorithm for the determination of landmarks are possible reasons for the difference in precision between the femoral and tibial component positioning.

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Restoration of neutral leg alignment in the coronal plane is a major objective in TKA to provide satisfactory long-term outcomes. Despite improvements in surgical technique and implant design, considerable numbers of outliers are still found in coronal alignment with the conventional technique. A 3° varus or valgus malalignment is an accepted cutoff value for coronal alignment. Therefore, image-free navigation was introduced to improve the precision of implant positioning.

Several studies have shown that navigation in TKA reduces but does not eliminate coronal malalignment more than 3° when compared with the conventional technique. With approximately 10% of outliers remaining in navigated TKA, it is of particular importance to determine whether these errors in implant positioning occur more on the femoral side, more on the tibial side, or equally on both sides. This information is especially crucial in the navigated tibia-first technique. Although this technique provides excellent gap management and soft tissue balancing, it is strongly dependent on the precision of the tibial bone cut. An imprecise tibial bone resection influences extension and flexion gap symmetry and leads to a subsequent error because all of the following bone cuts are referenced to the initial tibial cut. Although many studies have compared the femoral and tibial components separately between conventional and navigated TKA, to the authors’ knowledge no study has compared the precision between the femoral and tibial components within a navigated TKA group.

The authors hypothesized that a predominance of coronal component malalignment exists on the tibial side in the navigated tibia-first TKA. The goal of this study was to measure the degree of tibial component malalignment and compare it with that of the femoral component.

**Materials and Methods**

A retrospective study including navigated (e.motion; B. Braun Aesculap, Tuttingen, Germany) cemented TKAs performed in 2011 by 2 experienced surgeons (T.P., G.M.) was undertaken. The OrthoPilot image-free navigation system (B. Braun Aesculap) and a 1-stage cementation technique of the tibial and femoral components were used in all cases. Inclusion criteria were osteoarthritis as the primary diagnosis and the availability of digital pre- and postoperative whole-leg standing radiographs. The radiographic evaluation of postoperative limb alignment is difficult due to flexion or rotational failure. This can lead to a significant measurement failure toward varus or valgus if unrecognized.

Based on the fact that no systematic error exists toward varus or valgus caused by the leg position on radiographs, the measurement inaccuracy produces a wide SD but does not influence the mean values in large groups. Therefore, results pointing out significant differences are not flawed by the method’s inaccuracy. Hauschild et al. observed a good correlation of postoperative radiographs and navigation data when patients had full extension and full weight bearing. Therefore, full extension, full weight bearing, and central patella position for correct rotation were defined as inclusion criteria for whole-leg standing radiographs. Patients who had radiographs that were unable to be assessed due to knee flexion or rotational failure were excluded. Diagnoses other than primary osteoarthritis were defined as exclusion criteria (eg, posttraumatic osteoarthritis or rheumatoid arthritis). Age, sex, TKA side, and appearance of complications were evaluated using the patients’ documentation.

**Radiological Investigation**

Digital pre- and postoperative whole-leg standing radiographs were analyzed. All measurements were performed with DICOM image processing software (Centricity; GE Healthcare, Buckinghamshire, United Kingdom). On preoperative radiographs, coronal whole-limb alignment, lateral distal femur angle, and medial proximal tibia angle were evaluated. On postoperative radiographs, coronal whole-limb alignment, coronal position of the femoral, and tibial component in relation to the femoral and tibial mechanical axis were measured (Figure 1).

**Statistical Analysis**

Descriptive statistics (mean, minimum, maximum, and SDs) were calculated from the measured data. Nonparametrical analysis between the groups was performed with the Mann-Whitney U test. A P value less than .05 was defined as the level of significance.

**Results**

A total of 65 patients were screened and met the inclusion criteria. Nine patients were excluded due to incomplete documentation or inaccurate radiographs. The remaining 54 patients (57 knees; 24 right and 33 left) had an average age of 68.3±9.3 years. Eighteen men and 36...
women were included. No complications were observed in any patients.

The preoperative whole-leg coronal axis averaged 8.2°±3.7° (17.7° varus to 14.5° valgus) (Figure 2A). Postoperative whole-leg coronal alignment differed an average of 1.1°±1.2° from the mechanical axis (4.2° varus to 3.9° valgus) (Figure 2B). Five (8%) patients had coronal malalignment more than 3°.

Mean preoperative lateral distal femur angle was 88.3°±2.6° (range, 81.8°-95.4°; 95% confidence interval [CI], 87.6°-88.9°) and mean medial proximal tibia angle was 86.6°±3.3° (range, 78.8°-96.1°; 95% CI: 85.7°-87.5°). Postoperative femoral component alignment showed a mean deviation from the femoral mechanical axis of 0.6°±0.6° (2.1° varus to 2.9° valgus; 95% CI: 0.44°-0.75°) (Figure 2C). The tibial component differed an average of 1.0°±1.1° from the tibial mechanical axis (3.9° varus to 4.2° valgus; 95% CI: 0.71°-1.29°) (Figure 2D). The coronal alignment of the femoral component was significantly more precise than the alignment of the tibial component (P=.009).

**Discussion**

The main finding of this study was that coronal malalignment in navigated TKA is not equally distributed between the femoral and tibial component. Image-free navigation with the OrthoPilot is more precise for the femoral component compared with the tibial component. Recent studies showed a larger deviation for the final tibial implant position than for the femoral component when compared with the navigation data. General precision of both components’ alignment in the current study was superior compared with the literature. However, the number of outliers in whole-limb coronal alignment more than 3° in the current study (8%) was comparable with other studies using navigation.

A question still exists regarding whether the improved precision implicates a superior clinical outcome or an increased longevity of the implant, but until no evidence of a safe zone of malalignment exists, the aim is still neutral leg alignment.

Two possible causes exist for the inferior coronal alignment of the tibial
component. In contrast to the femur, the tibial bone cut consists of only 1 plane. This means that the tibial component has a lower primary stability than the femoral component during implantation. This sensitivity of implant fixation and possible cutting errors due to minor bone quality makes the tibia more susceptible to malalignment in the coronal plane.\textsuperscript{21,22} Therefore, the current authors recommend using a 2-stage cementation technique with navigation for evaluation of the tibial component alignment after placement. With this technique, verification of the coronal alignment is possible during implant fixation.

Another possible cause for this discrepancy may be the mathematical algorithm used by the navigation software. The determination of the hip center is known to be precise.\textsuperscript{30,31} It may be more accurate to functionally determine the center of a ball joint than the ankle joint, which is primarily found by direct palpation. Brin et al\textsuperscript{32} confirmed this observation and showed that landmarking errors during navigation of the tibia can lead to inappropriate bone resection following malalignment in the coronal plane. Because all of the following bone cuts are based on the tibial cut, this can lead to subsequent errors. In contrast to this, the femur-first technique follows a completely different philosophy. Resections are based on independent bony landmarks so that alignment errors are not transferable from the tibia to the femur.\textsuperscript{33} Both techniques have their own advantages, which results in a decision based on the surgeon’s personal preference regarding which one is used.\textsuperscript{14,34,35}

One limitation of this study is the sensitivity of the whole-leg standing radiographs.\textsuperscript{18,19} Particularly, rotational errors can falsify the measurements for the femur and the tibia. The used implant requires 0° of slope at the tibial bone cut, so rotational errors should not influence the measurement of tibial component alignment.

**CONCLUSION**

The navigation of the femoral component in TKA is highly precise when compared with the tibial component. Possible causes are inaccuracy during implantation and differences in the precision of the mathematical algorithms to determine the correct landmarks. Therefore, the authors recommend assuring a proper determination, especially of the tibial landmarks, performing a 2-stage cementation, and reevaluating the tibial alignment after positioning of the tibial component.\textsuperscript{30}

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