

# Computer-Assisted Surgical Navigation Does Not Improve the Alignment and Orientation of the Components in Total Knee Arthroplasty

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**Background:** Whether total knee arthroplasty with use of computer-assisted surgical navigation can improve the limb and component alignment is a matter of debate. We hypothesized that total knee arthroplasty with use of computer-assisted surgical navigation is superior to conventional total knee arthroplasty with regard to the precision of implant positioning.

**Methods:** Sequential simultaneous bilateral total knee arthroplasties were carried out in 160 patients (320 knees). One knee was replaced with use of a computer-assisted surgical navigation system, and the other was replaced conventionally without use of computer-assisted surgical navigation. The two methods were compared for accuracy of orientation and alignment of the components as determined by radiographs and computed tomography scans. The mean duration of follow-up was 3.4 years.

**Results:** The mean preoperative Knee Society score was 26 points, with an improvement to 92 points postoperatively, in the computer-assisted total knee arthroplasty group and 25 points, with an improvement to 93 points postoperatively, in the conventional total knee arthroplasty group. Preoperative and postoperative ranges of motion of the knees were similar in both groups. The operating and tourniquet times were significantly longer in the computer-assisted total knee arthroplasty group than in the conventional total knee arthroplasty group ( $p < 0.001$ ). The groups were not significantly different with regard to the accuracy of component positioning and the number of outliers for the various radiographic parameters ( $p > 0.05$ ).

**Conclusions:** Our data demonstrate that total knee arthroplasty with use of computer-assisted surgical navigation did not result in more accurate implant positioning than that achieved in conventional total knee arthroplasty, as determined by both radiographs and computed tomography scans.

**Level of Evidence:** Therapeutic Level II. See Instructions to Authors for a complete description of levels of evidence.

Recently, there has been increased interest in total knee arthroplasty with use of computer-assisted surgical navigation<sup>1-8</sup>. Computer-assisted surgical navigation systems are designed to increase the precision of implantation of the components. Some studies have found a clear tendency toward improved alignment of the limb and the component position with use of computer-assisted surgical navigation<sup>1,3,5,7,9-11</sup>. Other studies have indicated that no significant difference was found between total knee arthroplasty with use of computer-assisted surgical navigation and conventional total knee arthroplasty<sup>9,12</sup>. These conflicting results are partially attributed to the measure-

ment of the alignment of the limb and the position of the component on full-length standing radiographs of the lower extremity. A limitation to this measurement method is imaging errors caused by images that are not strictly coronal or sagittal, extension deficits, and rotation between the femur and the tibia<sup>13</sup>. The alignment and position of the component can only be precisely described with the use of a three-dimensional imaging procedure, separately evaluating the position of the femoral component in reference to the femur (from the hip to the knee center) and the position of the tibial component in reference to the tibia (from the knee to the ankle center).

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Apart from the mechanical axis, the rotational alignments of the femoral and tibial components are important for the functional outcome. It has been unclear whether rotational alignment can be improved with the use of computer-assisted surgical navigation systems.

We hypothesized that total knee arthroplasty with use of computer-assisted surgical navigation is superior to conventional total knee arthroplasty with regard to the precision of implant positioning as determined by radiographs and three-dimensional computed tomography scans.

### Materials and Methods

We prospectively enrolled 170 consecutive patients undergoing primary bilateral sequential total knee arthroplasties from January 2003 to March 2004. All patients provided informed consent. All operations were carried out by a senior author (Y.-H.K.). We obtained prior approval of our institutional review board. Ten patients who were originally enrolled in the study were lost to follow-up one year after the operation. The final study group comprised the remaining 160 patients (320 knees). Each patient had a total knee arthroplasty with use of computer-assisted surgical navigation in one knee and conventional total knee arthroplasty in the other. There was no significant difference between the two cohorts in terms of preoperative conditions, including the extent of the index disease, pain, functional disability, deformity, range of motion, bone loss, and prior surgical treatments.

The study group consisted of 141 women and nineteen men with a mean age of 68.5 years (range, fifty-six to eighty-one years) at the time of the index surgery. The preponderance of women in this series is due to this specific ethnic group of patients. The mean height of the patients was 151.2 cm (range, 141 to 168 cm), the mean weight was 63 kg (range, 37 to 113 kg), and the mean body mass index was 26.8 kg/m<sup>2</sup> (range, 22 to 45 kg/m<sup>2</sup>). In all knees, the diagnosis was osteoarthritis. All knees had a varus deformity ranging from 8° to 20°. A total of twenty-seven patients (17%) had undergone an arthroscopic débridement in one or both knees, and the remaining 133 had had no previous operation on their knee.

A NexGen cruciate-retaining high-flex total knee prosthesis (Zimmer, Warsaw, Indiana), with a NexGen modular tibial component and an all-polyethylene patellar component, was cemented in all knees. The procedure was carried out through a midline skin incision of 10 to 12 cm in length with use of a medial parapatellar arthrotomy. In all of the conventional total knee arthroplasties, extramedullary instrumentation was used for the tibial component and intramedullary instrumentation for the femoral side. The computer-assisted surgical navigation system (VectorVision CT-free knee; BrainLAB, Munich, Germany) that was used had an optical tracking unit, which detected reflecting marker spheres with an infrared camera.

Clinical and radiographic review was done at three months, one year, and yearly thereafter. The mean duration of follow-up was 3.4 years (range, three to four years). All of the clinical data analysis and the radiographic and computed tomographic scanning measurements were performed and com-

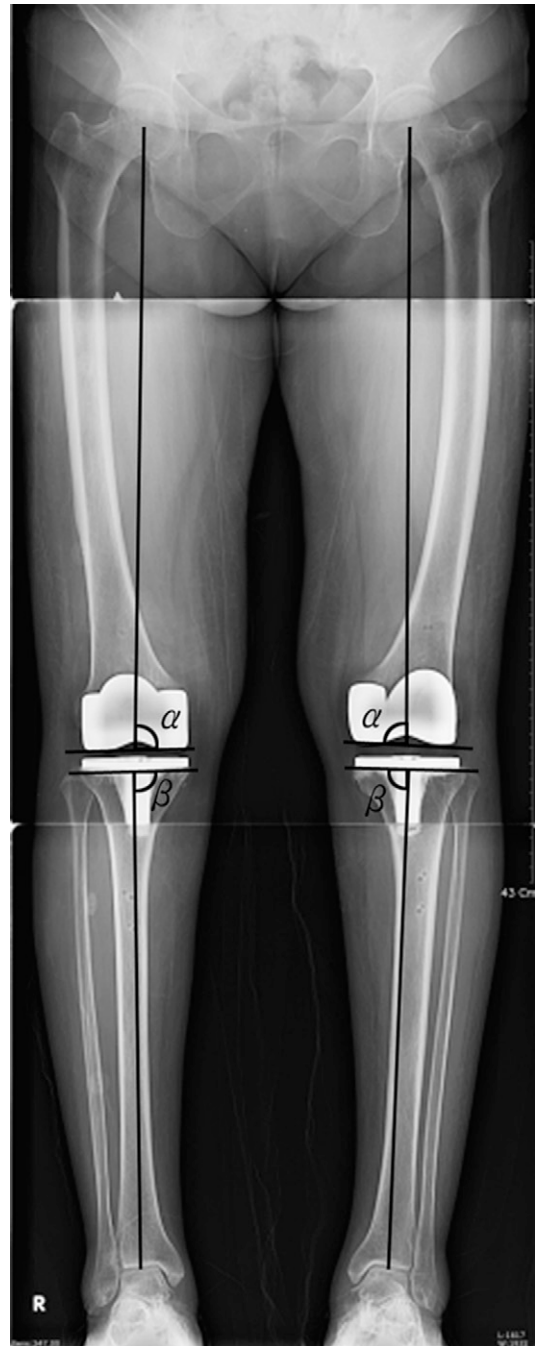


Fig. 1  
Radiograph showing the mechanical axis in the coronal plane. The alignment of the femoral and tibial components was measured by the intersection of a line drawn across the base of each component and the mechanical axis.  $\alpha$  = frontal femoral angle, and  $\beta$  = frontal tibial angle.

puted by one observer who was blinded to the type of total knee arthroplasty. Preoperative and postoperative scores were obtained for all patients with use of the Hospital for Special Surgery<sup>14</sup> and the Knee Society<sup>15</sup> knee-scoring systems.

The operative time, tourniquet time, amount of blood loss, amount of transfusion, duration and volume of drainage, and rate of key complications were used to identify the potential proficiency of the surgeon's surgical technique.

### Radiographic Measurements

All patients had complete radiographic follow-up examinations. All of the radiographs were reviewed by one observer who had no knowledge of the patient. Full-length anteroposterior radiographs of the knee, including the femoral head and the ankle, made with and without weight-bearing, and lateral and skyline patellar radiographs were made preoperatively and postoperatively and were assessed for the mechanical axis (Fig. 1), the position of the components (Fig. 2), and the location of radiolucent lines at the cement-bone interfaces as recommended by the Knee Society<sup>15</sup>.

### Computed Tomographic Measurements

Postoperative computed tomographic scans were obtained with use of a multislice scanner (Light Plus; General Electric Medical Systems, Waukesha, Wisconsin). Three-dimensional component alignment was determined with use of the method described by Matziolis et al.<sup>16</sup> (see Appendix). From the spatial relationship between the femoral and tibial components and the femoral and tibial mechanical axes, the following angles were determined: the varus or valgus position of the femoral component relative to the femoral mechanical axis, the varus or valgus position of the tibial component relative to the tibial mechanical axis, the varus or valgus position of the entire limb as the sum of the tibial and femoral mechanical axes, the extension-flexion of the femoral component in relation to the femoral mechanical axis, the tibial posterior slope, the rotational deviation of the femoral component from the epicondylar axis, and the rotational deviation of the tibial component from the referenced axis.

### Statistical Analysis

Intraobserver reliability was almost perfect for both the computer-assisted total knee arthroplasties and the conventional total knee arthroplasties ( $p < 0.01$  in each case)<sup>17</sup>. The value of kappa was 0.97 for the computer-assisted total knee arthroplasties and 0.95 for the conventional total knee arthroplasties.

With use of the Bonferroni method<sup>18</sup>, the alpha level of each individual test was adjusted downward to ensure that the overall risk for a number of tests remained 0.05. In our study, the alpha level should be  $<0.00135$  after thirty-seven outcome measures to have significance.

The Kolmogorov-Smirnov<sup>19</sup> test was used to evaluate whether the axial alignment followed a normal (Gaussian) distribution, and the Levene<sup>20</sup> test was used to assess the homogeneity of variance (constant variance). The alignment of the limb and the duration of the operation were compared with use of an unpaired Student *t* test, with the assumption of homogeneity of variance used as appropriate.

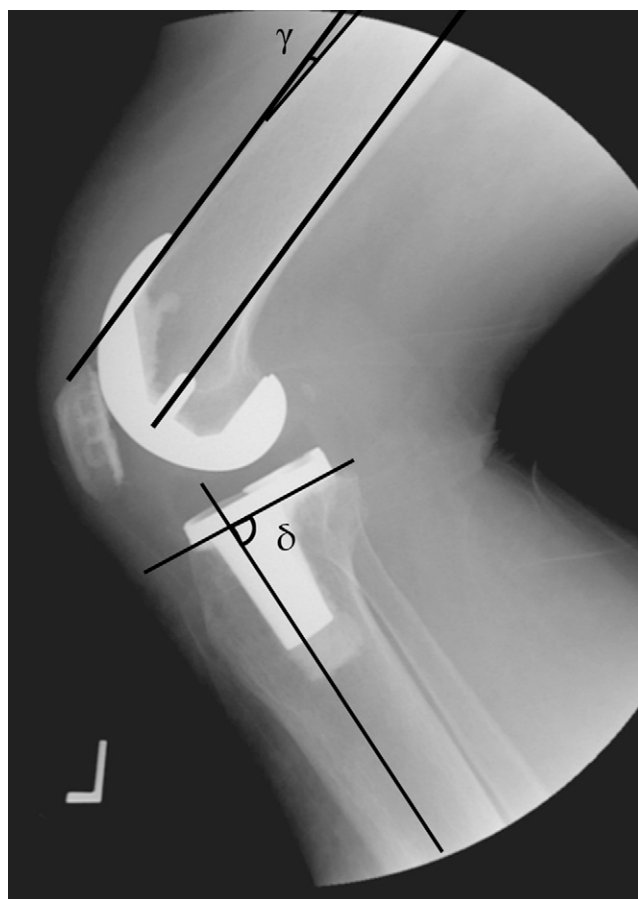


Fig. 2  
Radiograph showing the measurement of flexion and extension of the femoral component and measurement of the posterior slope of the tibial component.  $\gamma$  = sagittal femoral angle, and  $\delta$  = sagittal tibial angle.

Box-and-whisker plots were used to compare the postoperative alignment of the leg with use of median quartiles and interquartile ranges, and deviations were compared with use of the nonparametric Mann-Whitney *U* test. For continuous variables and differences between two means, 95% confidence intervals were calculated. Two-tailed values of  $p < 0.05$  were considered to be significant.

Power studies suggested that forty-five patients were needed in each group to determine whether there was a clinically significant difference (power = 0.8 and  $p < 0.05$ ) between the groups with respect to the clinical, radiographic, and computed tomographic findings.

### Source of Funding

There was no external funding for this study.

### Results

With use of the Bonferroni method for multiple comparison correction, the mean operating and tourniquet times were found to be significantly longer in the computer-assisted total knee arthroplasty group than in the conventional

**TABLE I Operative Data**

Parameters*	Computer-Assisted Total Knee Arthroplasty (N = 160)	Conventional Total Knee Arthroplasty (N = 160)	P Value
Operating time ( <i>min</i> )	97 (65 to 110)	79 (55 to 91)	<0.001
Tourniquet time ( <i>min</i> )	75 (59 to 90)	49 (56 to 85)	<0.001
Mean length of incision ( <i>cm</i> )			
Extension	14.2 (12 to 16.5)	13.0 (11 to 16)	0.818
Flexion	15.9 (13.5 to 18)	14.4 (12.5 to 17.5)	0.961
Intraoperative blood loss ( <i>mL</i> )	231 (65 to 550)	245.6 (110 to 620)	0.834
Drainage ( <i>mL</i> )	759.8 (130 to 1330)	716.4 (55 to 1550)	0.624
Drainage duration ( <i>days</i> )	4.7 (2 to 6)	4.6 (3 to 7)	0.152
Volume of transfusion ( <i>mL</i> )	1534.3 (100 to 2780)	1883.5 (270 to 2650)	0.061

\*The values are given as the mean, with the range in parentheses.

total knee arthroplasty group ( $p < 0.001$ ) (Table I). There were no differences between the groups in terms of knee score, range of motion, implant position, or the prevalence of outliers of implant position. The length of the incision, the intraoperative blood loss, the duration and volume of drainage, and the transfusion volume were not significantly different between the groups ( $p > 0.05$ ) (Table I).

The Kolmogorov-Smirnov test revealed that the groups arose from the same population distributions ( $p = 0.05$ ). The samples in our study had equal variances according to the Levene test.

The mean preoperative and postoperative Knee Society knee and functional scores and the Hospital for Special Surgery knee scores in the groups were similar. Also, the preoperative and postoperative ranges of motion of the knee were similar in the two groups of patients (Table II). All clinical data demonstrated no difference between the groups at three months, one year, and a mean of 3.4 years after the operation.

#### **Radiographic Results (Table III)**

Radiographic results were similar in both the computer-assisted and the conventional total knee arthroplasty groups with regard to the alignment of the knee and the position of the femoral and tibial components in the coronal and sagittal planes. If one assumes a tolerance level of  $3^\circ$ , the prevalence of outliers ranged from 8% to 15% for all parameters in the computer-assisted arthroplasty group and from 13% to 21% in the conventional total knee arthroplasty group. These differences between the groups were not significant ( $p > 0.05$ ). Also, these differences were not clinically meaningful. The radiographic data were not different between the groups at three months, one year, and a mean of 3.4 years after the operation.

#### **Results of Three-Dimensional Computed Tomography (Appendix)**

The three-dimensional computed tomographic evaluations were similar in both the computer-assisted and the conventional

**TABLE II Comparison of Knee Scores in Groups at Preoperative and Mean 3.4-Year Postoperative Evaluations**

Parameters	Computer-Assisted Total Knee Arthroplasty (N = 160)		Conventional Total Knee Arthroplasty (N = 160)	
	Preop.	Postop.	Preop.	Postop.
Knee Society knee score* ( <i>points</i> )	26 (9 to 41)	92 (91 to 100)	25 (10 to 42)	93 (89 to 100)
Knee Society pain score* ( <i>points</i> )	21 (0 to 30)	42 (41 to 50)	20 (9 to 35)	43 (39 to 50)
Knee Society deformity score* ( <i>points</i> )	5 (2 to 10)	0.4 (0 to 2)	5 (0 to 30)	0.5 (0 to 5)
Knee Society function score* ( <i>points</i> )	19 (15 to 31)	83 (69 to 100)	23 (17 to 41)	81 (69 to 100)
Hospital for Special Surgery knee score* ( <i>points</i> )	48 (11 to 57)	89 (75 to 100)	51 (16 to 55)	91 (78 to 100)
Range of motion* ( <i>deg</i> )	125 (100 to 148)	123 (115 to 145)	128 (95 to 150)	126 (100 to 145)
Prior arthroscopic débridement ( <i>patients/knees</i> )	15/22		12/19	

\*The values are given as the mean, with the range in parentheses.

TABLE III Radiographic Results at a Mean of 3.4 Years of Follow-up

Parameters	Computer-Assisted Total Knee Arthroplasty (N = 160)	Conventional Total Knee Arthroplasty (N = 160)	P Value
Mechanical axis (coronal plane)	4.8° of varus to 5.1° of valgus alignment	4.9° of varus to 4.7° of valgus alignment	0.900
Outliers (>3°) (no. of knees)	20 (13%)	30 (19%)	0.708
Femoral angle (coronal plane)	94°-104°	89°-102°	0.797
Outliers (>3°) (no. of knees)	18 (11%)	28 (18%)	0.712
Femoral angle* (sagittal plane)	1.8° ± 2.6°	2.9° ± 2.6°	0.112
Outliers (>3°) (no. of knees)	12 (8%)	20 (13%)	0.213
Tibial angle (coronal plane)	84°-95°	86°-95°	0.102
Outliers (>3°) (no. of knees)	14 (9%)	28 (18%)	0.113
Tibial angle (sagittal plane)	77°-92°	76°-89°	0.450
Outliers (>3°) (no. of knees)	24 (15%)	34 (21%)	0.514

\*The values are given as the mean flexion and the standard deviation.

total knee arthroplasty groups with regard to the alignment of the knee and the position of the femoral and tibial components in the coronal, sagittal, and rotational planes.

### Complications

Six knees (4%) in the computer-assisted total knee arthroplasty group had anterior femoral notching. One knee in the computer-assisted total knee arthroplasty group had a wound infection, which was managed with open débridement followed by intravenous antibiotics for six weeks. There was no further recurrence of infection.

No complication was noted in the 160 total knee arthroplasties that were performed without computer-assisted surgical navigation.

### Discussion

In the current study, the postoperative mechanical limb axis as determined by radiographic evaluation was not significantly better in the group that had total knee arthroplasty with use of computer-assisted surgical navigation than in the group that had conventional total knee arthroplasty. The postoperative mechanical limb axis exceeded 3° of varus-valgus deviation in 13% of the patients managed with use of computer-assisted surgical navigation and in 19% of the patients managed with the conventional method. This difference was not significant and is consistent with the results of Bauwens et al.<sup>21</sup>, Mielke et al.<sup>12</sup>, and Jenny and Boeri<sup>9</sup>, who found no significant difference in postoperative mechanical limb axis alignment between total knee arthroplasty with computer-assisted surgical navigation and conventional total knee arthroplasty. By contrast, our findings were not in agreement with the results of many investigators who have demonstrated that total knee replacements implanted with computer-assisted surgical navigation have more accurate alignment, on the basis of plain radiographs, than those implanted conventionally<sup>1,3,5,7,9-11</sup>. How-

ever, the improvement in accuracy through computer assistance has been shown to be a few degrees, which is within the range of inaccuracy produced by projection-related errors in standing radiographs<sup>15</sup>.

To avoid inaccuracy produced by projection-related errors in standing radiographs, three-dimensional computed tomographic evaluation has been adopted by several investigators<sup>2,8,16,22</sup>. With this method, many authors<sup>2,8,16,22</sup> have demonstrated a higher accuracy of implant alignment through the use of a computer-assisted surgical navigation system in both the coronal and the rotational plane. In contrast, Oberst et al.<sup>22</sup> did not show a difference in the accuracy of implant alignment, particularly in the rotational alignment of femoral and tibial components, between total knee arthroplasties performed with or without computer-assisted surgical navigation. Our findings are consistent with those of Oberst et al.

Regardless of which implantation method is used, the rotational alignment of the tibial component had a considerable range, from 9.2° of internal rotation to 10.4° of external rotation. The high variability of tibial component rotation was attributed to two factors. First, intraoperative determination of selected landmarks (the tibial tuberosity and the center of the tibia) was highly variable. Second, postoperative determination of selected landmarks of the tibia and the tibial components in the computed tomographic scanning also was highly variable. To minimize this variability, precision of the surgical technique (the center of the tibial component being directed to the medial one-third of the tibial tuberosity) and the use of a software program of computed tomographic scanning to reduce metallic interference are necessary. We found no significant difference between the two methods with regard to the accuracy of implantation of the tibial component.

The fact that we found no association between implant alignment and the early postoperative range of motion or the Hospital for Special Surgery and Knee Society scores may be


explained by the considerably low deviation from the designated axes in both groups of knees in this series.

Almost as important as the improved accuracy is the reduction in the number of outliers for the various radiographic and computed tomographic parameters. The surgical outlier rate is dependent on the skill of the surgeon, the number of total knee arthroplasties performed, and his or her familiarity with the implant<sup>1,10,11,22</sup>. No significant difference was detected between the groups of knees in our study with respect to the number of radiographic and computed tomographic outliers. This finding suggests that experienced surgeons can perform total knee arthroplasties with computer-assisted surgical navigation or in the conventional manner to the point that the radiographic and computed tomographic results associated with the two techniques are equivalent.

Our data demonstrate that total knee arthroplasty with use of computer-assisted surgical navigation does not result in more accurate implant positioning with regard to the alignment of the femoral and tibial components in the coronal, sagittal, and rotational planes than that achieved in conven-

tional total knee arthroplasty, as determined by both radiographs and three-dimensional computed tomography scans.

### Appendix

 Figures and tables showing the computed tomographic measurements and their results are available with the electronic versions of this article, on our web site at [jbjs.org](http://jbjs.org) (go to the article citation and click on "Supplementary Material") and on our quarterly CD/DVD (call our subscription department, at 781-449-9780, to order the CD or DVD). ■

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