

Computer-Navigated Versus Conventional Total Knee Arthroplasty

A Prospective Randomized Trial

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Background: The literature lacks studies that confirm whether the improved radiographic alignment that can be achieved with computer-navigated total knee arthroplasty improves patients' activities of daily living or the durability of total knee prostheses. The purpose of this study was to determine whether computer-navigated total knee arthroplasty improves the clinical function, alignment, and survivorship of the components.

Methods: We prospectively compared the results of 520 patients with osteoarthritis who underwent computer-navigated total knee arthroplasty for one knee and conventional total knee arthroplasty for the other. The assignment of the knee to navigation or not was done randomly. There were 452 women (904 knees) and sixty-eight men (136 knees) with a mean age of sixty-eight years (range, forty-nine to eighty-eight years) at the time of the index arthroplasty. The mean follow-up period was 10.8 years (range, ten to twelve years). The patients were assessed clinically and radiographically with the rating system of the Knee Society and with the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score at three months, one year, and annually thereafter.

Results: Total knee scores, knee function scores, pain scores, WOMAC scores, knee motion, and activity scores did not show statistically significant differences between the two groups preoperatively or at the time of the final follow-up. Alignment and the survivorship of the components were not significantly different between the two groups. The Kaplan-Meier survivorship with revision as the end point at 10.8 years was 98.8% (95% confidence interval [CI], 0.96 to 1.00) in the computer-navigated total knee arthroplasty group and 99.2% (95% CI, 0.96 to 1.00) in the conventional total knee arthroplasty group.

Conclusions: Our data demonstrated no difference in clinical function or alignment and survivorship of the components between the knees that underwent computer-navigated total knee arthroplasty and those that underwent conventional total knee arthroplasty.

Level of Evidence: Therapeutic Level I. See Instructions for Authors for a complete description of levels of evidence.

Interest in the accurate positioning and alignment of total knee arthroplasty components has been the subject of controversy, particularly following the development of computer-navigated

surgery¹. Computer-navigated total knee arthroplasty is reported to improve the overall accuracy of tibial and femoral component positioning²⁻⁴. However, an acceptable target for alignment remains

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TABLE I Demographic Data of the 1040 Total Knee Arthroplasties*

Parameters	Study Groups		P Value
	PFC Sigma CR-Mobile-Bearing	NexGen LPS-Flex Fixed-Bearing	
Number of patients (knees)	200 (400)	320 (640)	0.511
Number of males/females	30/170	38/282	0.468
Age* (yr)	67.4 (49-88)	68.7 (50-86)	0.897
Height* (cm)	151.3 (141-168)	151.2 (140-181)	0.498
Weight* (kg)	63.1 (41-91)	64.0 (38-108)	0.721
BMI* (kg/m ²)	27.6 (21-32.3)	27.9 (19.4-32.9)	0.812
Diagnosis of osteoarthritis	400 knees	640 knees	0.125
Follow-up* (yr)	11.1 (10-12)	10.5 (10-12)	0.119

*Values are given as the mean, with the range in parentheses. BMI = body mass index.

a matter for debate. A mechanical axis within 3° of neutral has been used as the primary outcome measure in many clinical trials comparing computer-navigated and conventional total knee arthroplasty⁵⁻⁷. However, the evidence supporting this arbitrary value is somewhat unreliable because previous reports have been limited by small sample size, inadequate radiographic follow-up, short follow-up, and lack of clarity when defining a margin of accuracy⁸⁻¹⁰.

Advocates of computer-navigated total knee arthroplasty suggest that improved placement of the total knee components will lead to better midterm and long-term function and survival¹¹, although the literature lacks studies that confirm that the improved radiographic alignment achieved with computer-navigated total knee arthroplasty improves patient's activities of daily living or the durability of the total knee components. Available comparative studies of the two techniques had only short follow-up periods and used different assessment scales⁸⁻¹⁰.

The purpose of this study was to address the following questions: (1) Is computer-navigated total knee arthroplasty

associated with better clinical function as compared with the conventional procedure? (2) Is computer-navigated total knee arthroplasty associated with better alignment and longer survivorship of the implant? (3) Does a deviation of >3° from the mechanical axis of the lower limb increase the rate of aseptic loosening and failure?

Materials and Methods

Demographics

The senior author (Y.-H.K.) performed bilateral simultaneous primary total knee arthroplasty in 536 consecutive patients. In each patient, the bilateral procedure was performed sequentially during the same anesthetic session. Five patients died from causes unrelated to surgery and eleven were lost to follow-up less than two years after the operation. Therefore, 520 patients (1040 knees) were included in the study (see Fig. E-1 in Appendix). The study was registered in the ClinicalTrials.gov Protocol Registration System (trial number, NCT 01422642). The study was approved by our institutional review board, and all patients signed and provided informed consent. Two hundred patients (400 knees) received a press-fit condylar posterior cruciate-retaining mobile-bearing knee prosthesis (PFC Sigma posterior CR mobile-bearing knee; DePuy, Warsaw, Indiana) with an all-polyethylene patellar component. Three-hundred twenty patients (640 knees) received a

TABLE II Comparison of Knee Scores at Preoperative and Mean 10.8-Year Postoperative Evaluations*

Parameters	Computer-Navigated Total Knee Arthroplasty (N = 520 Knees)		
	Preop.	Postop.	Difference
Knee Society knee score† (points)	24 (7 to 39)	93 (89 to 100)	69
Knee Society pain score† (points)	19 (0 to 25)	41 (42 to 50)	22
Knee Society deformity score† (points)	5 (1 to 99)	0.5 (0 to 3)	4.5
Knee Society function score† (points)	17 (13 to 28)	81 (67 to 100)	64
Range of motion† (degree)	126 (98 to 150)	123 (110 to 145)	3
WOMAC score† (points)	66.3 (55 to 85)	26.7 (19 to 35)	39.6
UCLA activity score† (points)	1.7 (1 to 3)	5.7 (4 to 7)	4

*Preop. = preoperative, Postop. = postoperative, CI = confidence interval, WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index, UCLA = University of California, Los Angeles. †The values are given as the mean, with the range in parentheses. ‡Paired t test. §Chi-square test.

posterior-stabilized high-flexion fixed-bearing knee prosthesis (NexGen LPS-Flex; Zimmer, Warsaw, Indiana) with an all-polyethylene patellar component. We used the mobile-bearing prosthesis in some patients and the fixed-bearing prosthesis in others so that our results would be applicable to both designs. There was no significant difference, based on the numbers, between the two cohorts in terms of preoperative conditions, including the extent of the index disease, pain, functional disability, deformity, knee motion, bone loss, and prior surgical treatments.

Randomization between the use of computer-navigated and conventional total knee arthroplasty was determined from a sequential pool on the basis of a table of random numbers. Each of the 520 patients received a computer-navigated total knee arthroplasty on one side and a conventional total knee arthroplasty on the contralateral side. Of the 520 patients, 200 had the press-fit condylar posterior cruciate-retaining mobile-bearing prosthesis implanted in both knees, and 320 had the posterior-stabilized high-flexion fixed-bearing prosthesis implanted in both knees. There were 452 women and sixty-eight men with a mean age of sixty-eight years (range, forty-nine to eighty-eight years) at the time of the index arthroplasty. The mean body mass index was 27.8 kg/m² (range, 19.4 to 32.9 kg/m²). The mean duration of follow-up was 10.8 years (range, ten to twelve years) (Table I).

Surgical Technique

The procedure was carried out through a midline skin incision of 10 cm to 18 cm in length, with the knee extended and 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) had an optical tracking unit that detected reflecting marker spheres with the aid of an infrared camera. In all knees, femoral preparation was performed first. Ten millimeters of tibial bone was resected, as referenced from the least-involved tibial plateau, to achieve a surface perpendicular to the axis of the tibia in the coronal plane. A 3° to 5° posterior slope was prepared in the sagittal plane for the knees in the PFC Sigma CR-mobile-bearing group, and a 0° to 3° posterior slope was prepared for the knees in the NexGen LPS-Flex group. Nine millimeters of the distal part of the femur was resected. Anterior cortical reference was used for the anterior-posterior cut of the distal part of the femur. Femoral component rotation was determined with use of three reference axes: (1) the transepicondylar axis, (2) the midtrochlear (Whiteside) line¹², and (3) 3° of external rotation relative to the posterior aspect of the condyles. Ligamentous balance was established, first with the knee in extension and then with the knee in flexion, with use of a tensor. All patellae were resurfaced with a polyethylene implant. All implants were cemented after pulsed lavage, drying, and pressurization of cement. All implants were fixed with use of CMW cement without antibiotics (DePuy).

Rehabilitation

Starting with the second postoperative day, patients used a continuous passive-motion machine for passive range-of-motion exercises twice daily (thirty minutes per exercise period). On the same day, under the supervision of a physical therapist, they started active knee-motion exercise and began standing at the bedside or walking with crutches or a walker twice daily for thirty minutes per period. Patients used crutches or a walker with full weight-bearing for six weeks and a cane when needed thereafter.

Clinical Evaluation

Clinical evaluations were done at three months after the operation, at one year, and yearly thereafter. All clinical data at the time of each follow-up were recorded and compiled by a research associate (S.-M.L.) who was not part of the operative team and was blinded to allocation. We obtained the Knee Society knee score¹³ and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score¹⁴ separately for each knee.

Active knee motion, with the patient in the supine position, was determined with use of a standard (60 cm) clinical goniometer before surgery and at the time of the review. The patients were asked to extend the knees fully while lying in a supine position so that flexion contracture could be measured. The patients were told to bend the knees maximally while lying in a supine position so that flexion could be measured. Knee motion was measured for all patients on two occasions by two of the authors (J.-W.P. and J.-S.K.), both of whom were blinded to the type of implanted prosthesis. When the measured ranges of motion were different (i.e., a difference of >5°) between the two observers, the values were averaged and that number was reported. Interobserver agreement of the range of motion was 0.94 to 0.99. The level of activity was assessed with use of the University of California, Los Angeles (UCLA) activity score¹⁵.

Radiographic Evaluation

Anteroposterior hip-to-ankle radiographs (made with the patient standing as well as with the patient lying supine), lateral radiographs, and skyline patellar radiographs were made preoperatively and at each follow-up time and were assessed for the alignment of the limb (tibiofemoral angle), the position of the components, the posterior slope of the tibial components, the level of the joint line, and the presence and location of radiolucent lines at the bone-cement interface in accordance with the recommendations of the Knee Society¹³. Anteroposterior standing radiographs were used to determine the sequential change in the alignment of the limb as a result of polyethylene wear and/or loosening of the implant. Supine anteroposterior radiographs were used to determine the presence of a radiolucent line more precisely. Skyline patellar radiographs were examined to determine the presence of patellar tilt, subluxation, or dislocation. All radiographs were made under fluoroscopic guidance

TABLE II (continued)

Conventional Total Knee Arthroplasty (N = 520 Knees)			P Value		
Preop.	Postop.	Difference	Difference of difference	Preop.	Postop.
26 (7 to 41)	92 (91 to 100)	66	3 (95% CI, 2.1 to 4.2)	0.719†	0.8531†
22 (6 to 31)	42 (41 to 50)	20	2 (95% CI, 1.1 to 2.6)	0.912§	0.832§
4 (6 to 15)	0.4 (0 to 4)	3.6	0.9 (95% CI, 0.5 to 1.3)	0.141†	0.134†
19 (15 to 31)	83 (71 to 100)	64	0	0.831†	0.825†
127 (90 to 150)	125 (105 to 140)	2	1 (95% CI, 1.1 to 2.6)	0.935†	0.918†
65.8 (51 to 81)	28.1 (21 to 39)	37.7	1.9 (95% CI, 0.9 to 2.4)	0.912†	0.928†
1.6 (1 to 4)	5.9 (5 to 7)	4.3	0.3 (95% CI, 0.1 to 0.6)	0.919†	0.973†

TABLE III Operative Data*

Parameters	Computer-Navigated Total Knee Arthroplasty (N = 520 Knees)	Conventional Total Knee Arthroplasty (N = 520 Knees)	P Value
Operative time (<i>min</i>)	88 (67 to 109)	76 (54 to 87)	<0.001
Tourniquet time (<i>min</i>)	59 (45 to 82)	42 (31 to 61)	<0.001
Mean length of incision (<i>cm</i>)			
Extension	14.8 (13 to 17.8)	12.8 (10 to 14)	0.823
Flexion	16.3 (14 to 18.6)	13.9 (12 to 16.7)	0.894
Intraoperative blood loss (<i>mL</i>)	241 (71 to 530)	238.6 (96 to 596)	0.812
Drainage volume (<i>mL</i>)	761.8 (140 to 1280)	718.6 (67 to 1390)	0.519
Drainage duration (<i>days</i>)	3.9 (2 to 5)	3.1 (3 to 6)	0.176
Volume of transfusion (<i>mL</i>)	1678.4 (150 to 2670)	1785.5 (190 to 2540)	0.078

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

to control rotation of the knee. Radiographic data at the time of each follow-up were analyzed and recorded by a research associate (S.-M.L.) who was not part of the operative team. This assessment was blinded to technique allocation.

Computed Tomography Evaluation³

At the latest follow-up, all patients underwent a computed tomography (CT) scan with use of a multislice scanner (General Electric LightSpeed Plus; GE Medical Systems, Milwaukee, Wisconsin) to determine the rotational alignment of the component and osteolysis. The scan sequence was between 10 cm proximal to the superior pole of the patella and 10 cm distal to the tibial tuberosity and was made in contiguous 2.5 mm slices. Rotational alignment of the femoral component was determined by measuring the angle between the line joining the medial and lateral epicondyles of the femur and that joining the posterior margins of the femoral component. Rotational alignment of the tibial component was assessed by measuring the angle between the line connecting the tibial tuberosity anteriorly and the site of insertion of the posterior cruciate ligament posteriorly and the anteroposterior line passing through the center of the anterior and posterior margins of the tibial component. Osteolysis was defined as a nonlinear region of periprosthetic cancellous bone loss with delineable margins. A research associate (S.-M.L.) examined all CT scans.

Statistical Analysis

To minimize the chance of type-2 error and increase the power of our study, we assumed the difference in the Knee Society knee score to be 1.5 points with a power of 0.99, which revealed that a total of 468 patients would be needed in each group. We recruited approximately 10% more patients to account for possible dropouts. Intraobserver reliability was almost perfect for both the computer-navigated total knee arthroplasties and the conventional total knee arthroplasties. The value of kappa was 0.96 for the computer-navigated total knee arthroplasties and 0.94 for conventional total knee arthroplasties.

With the Bonferroni method¹⁶, the alpha level of each individual test was adjusted downward to ensure that the overall risk for a number of tests remained 0.05. For our study to reach significance, the alpha level needed to be <0.00129 after thirty-seven outcome measures.

The Kolmogorov-Smirnov test¹⁷ was used to evaluate whether the axial alignment followed a normal (Gaussian) distribution, and the Levene test¹⁸ 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.

Box-and-whisker plots were used to compare the postoperative alignment of the limb with median quartile 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 (CIs) were calculated. Two-tailed values of $p < 0.05$ were considered to be significant.

Survivorship analysis was performed to determine the cumulative rate of survival of the implant during the period of the study¹⁹. A comparative analysis was performed between an aligned group (i.e., in which the neutral mechanical axis was $\pm 3^\circ$) and a malaligned group (i.e., in which the neutral mechanical axis was $>3^\circ$).

Source of Funding

There was no external funding source for this study.

Results

Clinical Results

There was no difference in clinical function for patients who received computer-navigated total knee arthroplasty as compared with those who received conventional total knee arthroplasty. The mean preoperative and postoperative Knee Society knee and functional scores in both groups were similar. Also, the preoperative and postoperative ranges of knee motion were similar. All clinical data showed no difference between groups at a mean of 10.8 years after the operation (Table II). With use of the Bonferroni method for multiple comparison correction, the mean operative and tourniquet times were significantly longer in the computer-navigated total knee arthroplasty group than in the conventional total knee arthroplasty group. The length of the incision, the intraoperative blood loss, the duration and volume of drainage, and the transfusion volume were not significantly different ($p > 0.05$) (Table III).

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 as determined with use of the Levene test.

Radiographic Results

There was no difference in the alignment of the components between the computer-navigated total knee arthroplasty group and the conventional total knee arthroplasty group. Radiographic

TABLE IV Radiographic Results at a Mean of 10.8 Years of Follow-up*

	Computer-Navigated Total Knee Arthroplasty (N = 520)	Conventional Total Knee Arthroplasty (N = 520)	P Value
Mechanical axis (coronal plane)	5.3° of varus to 4.8° of valgus alignment	5.1° of varus to 5.1° of valgus alignment	0.912
Outliers (>3°)	57 (11%)	67 (13%)	0.673
Femoral angle (coronal plane)	92°-101°	90°-103°	0.746
Outliers (>3°)	48 (9%)	53 (10%)	0.704
Femoral angle (sagittal plane)	2.1° ± 1.9°	2.8° ± 2.1°	0.132
Outliers (>3°)	31 (6%)	47 (9%)	0.231
Tibial angle (coronal plane)	86°-93°	84°-95°	0.121
Outliers (>3°)	57 (11%)	78 (15%)	0.133
Tibial angle (sagittal plane)	75°-93°	74°-91°	0.379
Outliers (>3°)	68 (13%)	78 (15%)	0.496

*Outlier values are given as the number of knees, with the percentage of the 520 total knees in parentheses.

results were similar in both the computer-navigated 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°, the prevalence of outliers ranged from 9% to 13% for all parameters in the computer-navigated total knee arthroplasty group and from 9% to 15% in the conventional total knee arthroplasty group. These differences between the groups were not significant ($p > 0.05$) (Table IV). No knee in either group had osteolysis around the components (see Figs. E-2 and E-3 in Appendix).

Computed Tomographic Results

Results of three-dimensional CT evaluations were similar in both the computer-navigated total knee arthroplasty group and the conventional total knee arthroplasty group with regard to alignment of the knee and position of the femoral and tibial components in the coronal, sagittal, and axial planes (Table V). If one assumes a tolerance level of 3°, the prevalence of outliers was between 6% and 17% in the computer-navigated total knee arthroplasty group and between 8% and 20% in the conventional total knee arthroplasty group. These differences were not significant between the two groups ($p > 0.05$). Rotational

TABLE V Three-Dimensional Computed Tomography Results at a Mean of 10.8 Years of Follow-up*

	Computer-Navigated Total Knee Arthroplasty (N = 520 Knees)	Conventional Total Knee Arthroplasty (N = 520 Knees)	P Value
Mechanical axis (coronal plane)	4.5° varus to 4.3° valgus	5.3° varus to 5.3° valgus	0.821
Outliers (>3°)	57 (11%)	68 (13%)	0.571
Femoral angle (coronal plane)	90° to 102°	92° to 103°	0.532
Outliers (>3°)	31 (6%)	42 (8%)	0.321
Femoral angle (sagittal plane)	3.3° ± 1.9° flexion	3.4° ± 2.1° flexion	0.512
Outliers (>3°)	31 (6%)	42 (8%)	0.323
Tibial angle (coronal plane)	85° to 93°	84° to 93°	0.131
Outliers (>3°)	57 (11%)	73 (14%)	0.167
Tibial angle (sagittal plane)	83° to 87°	82° to 86°	0.431
Outliers (>3°)	47 (9%)	57 (11%)	0.121
Rotational alignment of femoral component	5.7° of internal rotation to 6.9° of external rotation	5.1° of internal rotation to 6.4° of external rotation	0.778
Outliers (>3°)	57 (11%)	62 (12%)	0.575
Rotational alignment of tibial component	9.9° of internal rotation to 9.4° of external rotation	9.5° of internal rotation to 9.8° of external rotation	0.726
Outliers (>3°)	88 (17%)	104 (20%)	0.392

*Outlier values are given as the number of knees, with the percentage of the 520 total knees in parentheses.

alignment of the femoral component was from 5.7° of internal rotation to 6.9° of external rotation for knees that underwent computer-navigated total knee arthroplasty and from 5.1° of internal rotation to 6.4° of external rotation for knees that had conventional total knee arthroplasty. The rotational alignment of the tibial component was from 9.9° of internal rotation to 9.4° of external rotation for the knees that underwent computer-navigated total knee arthroplasty and from 9.5° of internal rotation to 9.8° of external rotation for the knees that received conventional total knee arthroplasty. These differences were not significant between the two groups ($p > 0.05$). No knee in either group had osteolysis adjacent to the components.

Complications

Six knees (1%) that received a NexGen LPS-Flex prosthesis (four knees with the computer-navigated technique and two knees with the conventional technique) were revised as a result of aseptic loosening of the femoral component. Four knees (1%) with a PFC Sigma CR-mobile-bearing prosthesis (two knees with the computer-navigated technique and two knees with the conventional technique) were revised for aseptic loosening of the tibial component.

Twenty-six knees (5%) had anterior femoral notching in the navigation group and six (1%) in the conventional group. Five knees (1%) in the navigation group had excessive resection of the tibia and required a tibial insert of 14 mm. The cause of anterior femoral notching and excessive tibial resection was not certain. We speculate that a registration error of computer navigation might have been the cause. Two knees (0.4%) in the navigation group had a deep wound infection; both knees were managed with open debridements followed by intravenous antibiotics for six weeks with no further evidence of infection.

Survival of the Implants

Survivorship of the implants at 10.8 years after the operation was not significantly different. Kaplan-Meier survival analysis, with revision used as the end point for failure, revealed a 10.8-year rate of survival of 98.8% (95% CI, 0.96 to 1.00) in the computer-navigated total knee arthroplasty group and 99.2% (95% CI, 0.96 to 1.00) in the conventional total knee arthroplasty group.

Survival of the Implants in the Aligned and Malaligned Group

A deviation of $>3^\circ$ from the mechanical axis of the lower limb did not increase the rate of aseptic loosening and failure. The prevalence of revision due to aseptic loosening at 10.8 years after the operation was 0.9% (one of 124 knees) in the malaligned group ($>3^\circ$ from neutral axis) and 1.0% (nine of 916 knees) in the aligned group (Fisher exact test, $p = 0.38$).

Discussion

Proper alignment of the prosthesis during total knee arthroplasty is critical in maximizing implant survival^{9,20-22}. It has been claimed that computer-navigated total knee arthroplasty allows a higher degree of accuracy in component alignment²⁻⁴.

Nevertheless, we are aware of no literature that documents whether or not radiographic improvement leads to an improvement in clinical and functional scores or implant survival at midterm and long term follow-up. We found that computer-navigated total knee arthroplasty did not improve clinical function or the alignment and survivorship of the components as compared with conventional total knee arthroplasty.

Several studies have shown that computer-navigated total knee arthroplasty improved the overall accuracy of positioning of the femoral and tibial components²⁻⁴. Choong et al.²³ concluded that the use of computer-navigated total knee arthroplasty resulted in greater accuracy of implant alignment, better knee function, and improved quality of life than that achieved with conventional total knee arthroplasty. By contrast, studies comparing the clinical and functional results of total knee arthroplasty performed with or without computer navigation have found no differences, even in the short term²⁴⁻²⁹. In the current study, Knee Society scores (knee and functional scores) and WOMAC scores were not significantly different between the two groups at 10.8 years after the operation. The absence of severe malalignment ($\geq 6^\circ$) in the conventional total knee arthroplasty group may explain these findings.

In the current study, the postoperative mechanical axis of the limb was not significantly better in the patients who had computer-navigated total knee arthroplasty than it was in those who had conventional total knee arthroplasty. This result is consistent with the results of Bauwens et al.⁷, Mielke et al.³⁰, and Jenny and Boeri³¹, who found no significant difference in the postoperative mechanical axis alignment of the limb between patients who underwent conventional or computer-navigated total knee arthroplasty. By contrast, our findings were not in agreement with the results of the many investigators who have demonstrated that, in comparison with conventional total knee arthroplasty, computer-navigated total knee arthroplasty is associated with more accurate alignment on radiographs^{4,32-34}. However, the improvement in accuracy through computer-navigated total knee arthroplasty is a few degrees, which is within the margin of error produced by projection-related errors in standing radiographs³⁵.

With regard to the effect of postoperative alignment of the mechanical axis (measured with use of long-leg radiographs and three-dimensional CT scans) on the midterm risk of revision surgery, our results demonstrate only a weak relationship between alignment and the need for revision surgery. Survival analysis reveals a tendency toward improved implant survival with accurate alignment, but the validity of this result is limited by the lack of significance. This may be explained by the relatively small number of total knee arthroplasties in the malaligned group compared with the numbers in previous reports^{20,36}. Our study, along with other reports, suggests that the relationship between the postoperative mechanical axis and implant survival is marginal^{21,22}. Although the neutral mechanical axis is a valuable intraoperative target, its achievement does not necessarily confer satisfactory kinematics and implant survival^{29,37}.

Alignment in the coronal plane does not guarantee the accurate position of each component in flexion and extension,

valgus and varus, or balanced tibiofemoral rotation. The effect on implant survival of accurate positioning of each individual component in six degrees of freedom is not clearly established. There is anecdotal evidence that early mechanical failure is more likely when there is a mismatch of the femoral and tibial component in rotation³⁸. However, reliable evidence of the effect of rotational alignment on implant survival is limited because intraoperative and postoperative measurement techniques are often inaccurate and the optimal rotational alignment target has not been defined. However, our study and other studies^{2,26,27,39} do not demonstrate any difference in rotational alignment with computer-navigated or conventional total knee arthroplasties. We used the same landmarks for rotational alignment of the femoral and tibial components in both computer-navigated and conventional total knee arthroplasties. Although the trend was toward a greater outlier for each category in the conventional total knee arthroplasty group, there was no significant difference in rotational alignment between the computer-navigated or conventional total knee arthroplasty groups.


There are several strengths of this study. First, drawing a large series of patients from a single surgeon and single center allows specific coordination of surgical technique or implants used in the study. Second, the follow-up was long enough to determine functional outcome, survivorship of the implants, and prevalence of osteolysis and loosening. Third, data regarding the activity level of the patients were collected and can be analyzed as a risk factor for failure. Finally, three-dimensional CT was obtained to measure more accurately the mechanical axis of the limb, the rotational alignment of the component, and osteolysis.

There are some limitations of this study. First, we did not perform a side-by-side comparison of each patient to determine whether or not the alignment of the conventional total knee arthroplasty, if performed after the computer-navigated total knee arthroplasty, was improved by feedback gained by the surgeon during the performance of the first surgery. Second, the fact that all arthroplasties were performed by an ex-

perienced surgeon may have limited the number of outliers. Third, while our data support the contention that, at 10.8 years after the procedure, computer navigation does not offer an advantage over conventional total knee arthroplasty relative to survivorship and alignment, the data do not support an extrapolation past this time frame. Finally, it is frequently difficult for a patient who has undergone a bilateral total knee arthroplasty procedure to determine which knee is functioning better than the other. Therefore, the WOMAC function scores should be interpreted with caution because it is difficult for patients to attribute functional status to a particular knee.

Our data demonstrated that there was no difference in clinical function, alignment, and survivorship of the components between the computer-navigated and conventional total knee arthroplasties. In our study, the effect of computer-navigated total knee arthroplasty compared with conventional total knee arthroplasty on long-term implant survival remains unproven.

Appendix

 Figures showing the postoperative radiographic results in knees after conventional total knee arthroplasty or computer-navigated total knee arthroplasty are available with the online version of this article as a data supplement at jbsj.org. ■

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