Computer-Assisted Navigation System Helps Experienced Surgeon Improve Outcome in Total Knee Arthroplasty

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Abstract: Navigation-assisted total knee arthroplasty (TKA) reportedly improves component alignment. Also, experience on the knee surgery is complementary to the success of total knee arthroplasty even with the use of navigation system. One hundred and twenty-five consecutive patients who underwent navigation-assisted TKA and 125 patients who underwent conventional TKA by an experienced surgeon were evaluated for mechanical alignment, perioperative hemodynamic status, and early complications. Patients with navigation-assisted TKA showed better mechanical axis, coronal and sagittal axis of the femoral component and coronal axis of the tibia components. Patients in the navigation-assisted TKA group experienced less blood loss, needed fewer transfusions, and required fewer hospitalization days and fewer early complications. Navigation-assisted TKA improved mechanical and component alignment, perioperative hemodynamic status.
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1. Introduction

Navigation-assisted systems reportedly improves coronal and sagittal alignment of total knee arthroplasty (TKA)[1-7]. Previous reports demonstrated that navigation by sole reference to epicondylar axis along femur and tuberosity of tibia failed to improve rotational alignment of the femoral component [8]. Experienced knee surgeons usually determine the rotational alignment with several reference landmarks and complement the pitfall of computer system. Assistance with the navigation technology, femoral medullary violation and excessive soft tissue release can be avoided. Less invasive procedure in TKA is a prerequisite for a stable perioperative hemodynamic status which may contribute to fewer complications [9]. We compared the component alignment and perioperative medical status of patients who underwent navigation-assisted and conventional TKA. We hypotheses that an experienced knee surgeon can improve outcome of total knee arthroplasty with the usage of computer-assisted navigation system.

2. Material and Methods

This study protocol was approved by the institutional review board to review the charts and medical data of the patients. Between March 2005 and October 2007, one hundred and twenty-five consecutive patients who underwent navigation-assisted TKA for osteoarthritis, rheumatoid arthritis and traumatic osteoarthritis disorders were enrolled. One hundred and twenty-five patients were replaced with conventional TKA between February 2004 and September 2006. All patients received surgery in a single institution and performed by a single surgeon who had been performing knee arthroplasty for more than 15years. Within the overlap period (March 2005 to September 2006), 84 patients were separated for navigation-assisted and conventional TKA according to patients' wishes. Preoperatively, age, gender, laterality, body mass index (BMI), and the medical conditions of all patients were recorded. Pre-operative anesthetic status of the patients was graded according to the American Society of Anesthesiology classification system (ASA grade). The post-operative alignment of the components and related complications were documented.

Operative technique

Surgical site preparation

Both groups had received TKA in the same standard operation room. Aseptic dragging and skin preparation was applied as standard operative protocol. The operations were carried out using a pneumatic tourniquet at a pressure of 300 mmHg, with a single injection of antibiotics (cefamezin 1 g) before surgery. A mid-vastus approach was used through a midline skin incision.

Conventional total knee arthroplasty

In the conventional implantation group, femoral intramedullary and tibial intramedullary alignment guides were used. With IM guidance system, we used the standard knee arthroplasty instrumentation to perform the distal femoral cut, chamber cut, and proximal tibia cut. Proper implant sizing and position was adjusted with the surgeon's experience. The femoral and tibial components were implanted with cementing. The wound was closed over a suction drain. A compression bandage was applied from the ankle to the proximal portion of the thigh.

Navigation-assisted total knee arthroplasty

In the navigation-assisted procedures, both femur and tibia alignment cutting were measured extramedullary using a navigation system (BrainLab®; Heimstetten, Germany). This infrared-base system, by anatomically mapping the knee and kinematic registration, sets up a working model on patients' knee (Figure 1). Two fixed reference array with marker spheres which were fixed to the distal femur (4mm) and proximal tibial (3mm) by bi-cortical screws were tracked using an infra-red camera. The center of femoral head, mapping of distal femur, upper tibia, and bony landmarks of the ankle were registered. The femoral component was referenced parallel to the anterior cortex of distal femur. The marked epicondylar line was further checked using Whiteside's line and a posterior condylar line as used in the conventional manner to determine rotation of the femoral component. Then the size and positioning of the prosthesis was checked with the aid of the navigation system.

The distal femur cut and chamber cut were performed less than one degree deviation under navigation system guidance. An extramedullary guide connected to a reference array was employed to check the tibial cutting level, varus-valgus angle, and tibial slope angle. The rotation of the tibial component was adjusted parallel to the axis between the medial third of the tuberosity and the center of the tibial plateau. For double checking confirmation, an additional extramedullary guiding rod was used as a reference for the midpoint of the anterior ankle joint in determining the rotation of the tibial component. The mechanical axis of within 1 degree deviation was created by sequential soft tissue release under real time computer imagine guidance. The femoral and tibial components were implanted with cementing technique. The wound was subsequently closed over a suction drain and a compression bandage was applied. There were no patella re-surfacing in both groups.

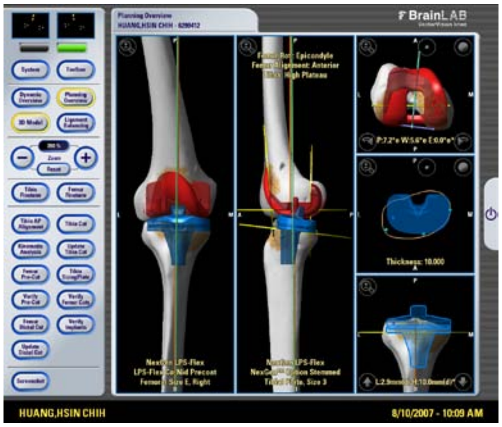


Fig. 1 The photograph shows a working model for TKA after anatomic mapping and kinematic registration

Postoperative management

Both groups received the same postoperative rehabilitation protocol. Antibiotic (cefamezin 1g per 8 hours) was administered for 1 day postoperatively following the guide of infection department. The amount of blood in the drains was recorded. For post operation pain control, passive continuous movement of the knee started after removal of the drainage, alone with intramuscular and oral analgesics. Active knee motion was encouraged 2 days after surgery. With the exception of non-steroid anti-inflammatory drugs for at least 3 weeks, no additional thromboprophylaxis was used in this study series.

Blood transfusion was given if the hemoglobin level was less than 8 mg/dl or if the hemoglobin level was more than 8mg/dl with an unstable hemodynamic status during or after surgery. The hemoglobin levels of all patients were examined on the next morning postoperatively. Patients were discharged after their knee motion approached 95 degrees flexion. All complications within 90 days after surgery were recorded.

Radiographic measurements

At the 6-weeks follow-up, radiography of the knee and long-leg standing radiograph were taken and the weight-bearing femorotibial angle and the mechanical axis were calculated [10]. All measurements were performed by a single colleague. The coronal femoral component angle (ideal angle: 90°) was measured from the medial angle between the mechanical load axis of the femur and the horizontal axis of the 2 prosthetic condyles on an anterior-posterior radiograph. The coronal tibial component angle (ideal angle: 90°) was measured from the medial angle between the anatomic axis of the tibia and the horizontal axis of the tibial tray on the radiograph. Sagittal plane alignment was measured on a lateral radiograph. The sagittal femoral component angle (ideal angle: 90°) was measured from the angle between the anterior cortex of the distal femur and a line drawn perpendicular to the distal part of the femoral component on a lateral radiograph. The sagittal tibial component angle (ideal angle: 83–90°) was measured from the posterior angle between the midline axis of the tibia and a line drawn across the tibial tray.

Statistical analysis

Patient demographics were analyzed using Pearson's chi-square test, whereas the component alignment and the data of medical status were analyzed using an independent sample t-test. A *p*-value of less than 0.05 was considered to be significant.

3. Results

There were no significant differences in the age, gender, laterality, BMI, causes of operation, and ASA grade between patients who underwent navigation-assisted TKA and conventional TKA (Table 1).

Implant alignment

Table 2 showed that the mechanical axis in the navigation-assisted TKA group was closer to the normal axis than those of conventional TKA group (0.39 ± 2.15° versus 2.01 ± 2.76°, $p < 0.01$). The mean coronal angle of the femoral component was 89.58 ± 1.69° in the navigation-assisted TKA group and 88.95 ± 2.15° in the conventional TKA group ($p = 0.22$). The mean coronal angle of the tibia component was 90.01 ± 1.26° in the navigation-assisted TKA group and 89.34 ± 1.73° in the conventional TKA group ($p < 0.01$). There was a significant difference between the 2 groups with respect to the coronal femoral component position and the coronal tibial component position within 3° deviation ($p = 0.04$ for the femoral components, $p < 0.01$ for the tibial components) and within 1° deviation ($p = 0.05$ for the femoral components, $p < 0.01$ for the tibial components). There were suggestive of more precision of coronal component alignment in the navigation-assisted group than in the conventional group.

The sagittal alignment of the femoral component reflects the anatomical alignment with respect to the anterior femoral cortical bone. The mean sagittal angle of the femoral component was 90.5 ± 2.4° in the navigation-assisted TKA group and 93.3 ± 3.7° in the conventional TKA group ($p < 0.01$). Greater precision was noted for the femoral component sagittal angle within both a 3° and a 1° deviation of the ideal 90° in the navigation-assisted TKA group ($p < 0.01$ and $p < 0.01$, respectively). In terms of the tibial component sagittal alignment of 83–90°, the sagittal angle of the tibial component did not differ between the 2 groups ($p = 0.396$). The posterior slope of the tibial component was 2.26 ± 2.25° in the navigation-assisted TKA group and 2.3 ± 2.63° in the conventional TKA group ($p = 0.986$).

During of the learning period of navigation technique, the component alignments were compared between the conventional TKA group and navigation group in the overlap period. The femoral and tibial coronal alignments were closer to the ideal degree in the navigation group (p=0.019 and 0.007 respectively) (Table 3). Interestingly, the femoral component coronal alignment in conventional group TKA was also improved during the period of usage of navigation system (p=0.008), but not for the tibial component coronal angle (p=0.899) (Table 4).

Medical status and early complications

There was no significant difference in either the tourniquet time or the decrease in hemoglobin levels on the first postoperative day. However, when compared with the conventional group, the patients who underwent navigation-assisted TKA experienced less blood loss ($p = 0.032$), needed fewer blood transfusions ($p < 0.01$) and required fewer hospitalization days ($p < 0.01$) (Table 5). The complications that arose within 90 days after surgery are shown (Figure 2). There were 2 cases of delayed wound healing and 1 case of upper gastrointestinal bleeding in the navigation-assisted group. In the conventional TKA group, there were 3 cases of superficial infection, 2 cases of cerebral infarction, 2 cases of periprosthetic fracture, 2 cases of upper gastrointestinal bleeding, and 1 case each of angina pectoralis and deep infection.

Table 1 Clinical Summary of Patients in Both Groups

	Conventional group	Navigation group	*p*-value
Number	125	125	1.00
Age (years)	67.25 ± 8.95	66.3 ± 10.88	0.449
Gender Male:Female	25:100	25:100	1.00
Laterality (left:right)	61:64	60:65	0.90
Body mass index (kg/M^2)	28.33 ± 4.85	27.97 ± 4.63	0.559
Cause of operation OA: RA:other	113:9:3	110:12:3	0.842
ASA grade 1:2:3	2:85:38	0:75:50	0.141

Table 2. Comparative data of Component Alignment in Both Groups

		Conventional group (n = 125)	Navigation group (n = 125)	*p*-value
Mechanical axis (degree)		2.01 ± 2.76	0.39 ± 2.15	<0.01
Femoral component				
Coronal angle (degree)		88.95 ± 2.15	89.58 ± 1.69	0.22
	within 3° deviation	109 (85.8%)	118 (93.7%)	0.04
	within 1° deviation	50 (39.4%)	65 (51.6%)	0.05
Sagittal angle	(degree)	93.3 ± 3.7	90.5 ± 2.4	<0.01
	within 3° deviation	73 (57.5%)	103 (81.7%)	<0.01
	within 1° deviation	28 (22%)	59 (46.8%)	<0.01
Tibia component				
Coronal angle (degree)		89.34 ± 1.73	90.01 ± 1.26	<0.01
	within 3° deviation	112 (88.2%)	125 (100%)	<0.01
	within 1° deviation	55 (43.3%)	84 (66.7%)	<0.01
Sagittal angle	(degree)			
	83–90°	116 (91.3%)	111(88.1%)	0.396

Table 3 Comparative Data of Component Alignment within the Overlap Period

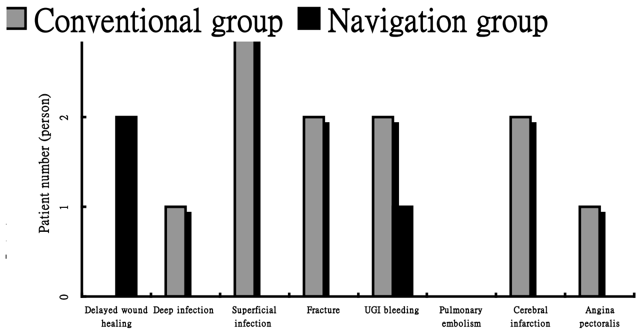
	Conventional group (n = 50)	Navigation group (n=34)	*p*-value
Femoral component			
Coronal angle (degree)	89.07 ± 2.55	89.92 ± 1.84	0.019
Tibia component			
Coronal angle (degree)	89.16 ± 1.73	90.19 ± 1.06	0.007

Table 4 Comparative Data of Conventional Group Before and After the Usage of Navigation System

	Before (n = 75)	After (n = 50)	*p*-value
Femoral component			
Coronal angle (degree)	88.87 ± 1.84	89.07 ± 2.55	0.008
Tibia component			
Coronal angle (degree)	88.94 ± 1.73	89.16 ± 1.73	0.899

Table 5. Hemodynamic Status and Hospitalization Days in Both Groups

	Conventional group	Navigation group	*p*-value
Tourniquet time (minutes)	121.9 ± 21.5	118.1 ± 22.6	0.182
Hemoglobin level decrease on the first postoperative day (mg/dl)	2.13 ± 0.98	1.97 ± 0.98	0.193
Blood loss in drainage bottle (cc)	525.6 ± 323.1	277.1 ± 205.6	0.032
Blood transfusion number (%)	29 (23.2%)	9 (7.2%)	<0.01
Hospitalization(days)	7.42 ± 3.67	5.77 ± 2.18	<0.01



Most investigators have found that navigation-assisted TKA achieves more accurate component alignment than that obtained using conventional implantation [11-13]. In addition to better alignment, we demonstrate a more stable perioperative hemodynamic status and fewer complications when using navigation-assisted TKA. Improvement of the component alignment by a single experienced surgeon was also observed in this study.

No definite association between implant alignment and early postoperative range of motion or knee function has previously been demonstrated. However, a misaligned component promotes early loosening through increased wear caused by suboptimal implant loading [14-18]. Using an improved computed tomography protocol, higher accuracy of implant alignment could be obtained through the use of a navigation system [19]. Surgeons need to define the rotation of the femoral component through a compromise between different landmarks [20]. With collaboration of navigation systems and surgeon's experience on the rotation determination, bony cut, and soft tissue balancing outcome of TKA can be improved even the optimum rotational alignment of the femoral component has not been clearly defined [8,21,22]. We observed that after usage of navigation system, surgeons can improve the bone cutting and placement of femoral component even in the conventional procedure. Computer navigation system can be a tool in modifying the surgical technique and surgical outcome in an experienced surgeon.

In contrast to the conventional surgical procedure, the navigation system presents a real-time intraoperative mechanical axis and soft tissue gap evaluation. With precise bone cutting, soft tissue release can be minimized. Our study demonstrates that the avoidance of intramedullary violation and limited soft tissue release during navigation-guided balancing of the prosthesis produces a less invasive surgical environment. This less invasive environment might be a factor contributing to the lower blood loss, fewer blood transfusions, hospitalization days, and complications. The increased blood loss in conventional TKA may be due to intramedullary jigging of the femur and more soft tissue dissection during balancing of the prosthesis[23,24]. The navigation-assisted operation saves blood, lessens the risks of transfusion, and may be useful in patients for whom blood products are not acceptable.

Systemic emboli phenomena during preparation of the femur and tibia are well-recognized complications associated with TKA [25]. They are widely believed to be the cause of intraoperative hypotension and reduced cardiac output, which may lead to circulatory collapse, change of mental status, or cerebral infarction [26]. Navigation-assisted TKA significantly reduced systemic emboli as detected by transcranial Doppler ultrasonography [27]. Computer-assisted TKA resulted in the release of significantly fewer systemic emboli than the conventional procedure using intramedullary alignment[19]. In conventional group, there were 2 cases of cerebral infarction and 1 case of angina pectoralis. One cerebral infarction occurred during the operation and the other developed 2 days after the surgery. However, no infarction or cardiac attack incident was noted in our navigation group.

In addition to systemic emboli, there were 2 cases of upper gastrointestinal bleeding, 1 case of periprosthetic fracture, and 1 case of deep infection in the conventional TKA group. By comparison, there was just a single case of upper gastrointestinal bleeding in the navigation-assisted TKA. No previous reports, however, have suggested possible explanations to account for these differences. Less bone marrow and soft tissue damage in the navigation-assisted TKA and pain management [28,29] might reduce the need for anti-inflammatory medication. This might explain the less frequent occurrence of upper gastrointestinal bleeding. The undistorted metaphyseal intramedullary canal may contribute to decreased prosthesis infection during sepsis[30,31] or decreased incidence of periprosthesis fracture.

In conclusion, using navigation-assisted system by an experienced knee surgeon also contributes to the better outcome of TKA. Better alignment, less invasion and preservation of the microarchitecture of the distal femur through the avoidance of intramedullary violation contribute to the better hemodynamic status and fewer early complications.

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