Navigation Did Not Improve the Precision of Minimally Invasive Knee Arthroplasty

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Abstract Potential advantages of minimally invasive total knee arthroplasty (TKA) include decreased pain, faster recovery, and increased quadriceps muscle strength. Computer-assisted navigation has been associated with more accurate component alignment. We evaluated two groups of 50 patients who had minimally invasive TKAs performed with and without navigation by two surgeons. A comparison of 50 previous TKAs by each of the two surgeons showed similar results. The mean operative times for the navigation and nonnavigation groups were 112 minutes (range, 63–297 minutes) and 54 minutes (range, 35–86 minutes), respectively. The mean estimated blood losses, mean Knee Society pain as well as functional scores and mean component alignments were similar. The number of knees that deviated by more than 3° from the normal anatomic axis was three and one in the navigated and nonnavigated groups, respectively. Complication rates were 6% and 4% in the navigated and nonnavigated groups, respectively. Our data demonstrate no distinct advantage of navigation when combined with a minimally invasive approach.

Level of Evidence: Level II, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

Introduction

The results of TKAs have been excellent with many reports describing a 90% to 100% success rate at 10 to 14 years [5, 10, 14, 28, 39]. However, failures and complications do occur so various techniques have been developed to try to minimize problems and improve patient outcomes. One technique is minimally invasive surgery, which is typically defined as a small incision (less than 14 cm), down-sized instruments, decreased dissection of soft tissues as well as avoidance of patellar eversion and tibiofemoral joint dislocation [2, 3, 33, 36, 38]. This technique may result in decreased pain, faster recovery, greater quadriceps muscle strength, improved cosmetic appearance, and higher patient satisfaction [12, 20, 21, 36, 37]. However, it also has been associated with longer operative times, less than optimal joint alignments as well as higher frequencies of malposition or loosening of the components [6, 12, 20, 36].

Another technique that has recently gained popularity is computer-assisted navigation surgery. Navigation systems have been associated with greater accuracy of component alignment, a higher frequency of normal tibiofemoral axes, and fewer radiographic outliers [1, 7, 22, 24, 25, 41]. However, they have also been associated with increased operative times [41], higher expenses [31], and higher complication rates, especially femur fractures [17]. In addition, some studies report no improvement in alignment with navigation [19, 29].

Recently, we compared minimally invasive with computer-assisted TKA and found the patients who underwent

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Each author certifies that his or her institution has approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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computer-assisted surgery had better alignment, but also had longer surgical times and more complications (unpublished data). Since conducting that study, we have increased our experience with both techniques and have modified the navigation procedure. We now use a minimally invasive midvastus approach [3]. Rather than use one large tracking pin anteriorly in the diaphysis of the femur and tibia, one or two thinner pins are placed laterally in the metaphyses. Navigation is used throughout the entire procedure, including cementing, to verify component position.

We determined whether this modified minimally invasive approach with navigation was associated with (1) improved perioperative parameters (surgery time and estimated blood loss), (2) better functional outcomes, (3) more accurate component alignment, or (4) reduced complications when compared with the same minimally invasive approach performed without navigation.

Materials and Methods

We prospectively followed two groups of patients who underwent TKA between January 1, 2005, and December 31, 2005. Thirty-five consecutive unselected patients (50 knees) had TKAs performed by one surgeon (DAD) using a computer-assisted minimally invasive technique (MIS-NAV) and another group of 40 consecutive unselected patients (50 knees) had TKAs performed by another surgeon (PMB) using the same minimally invasive technique without navigation (MIS). Inclusion criteria consisted of patients who had osteoarthritis of the knee and who failed nonoperative treatment. No patients who underwent TKAs during that time period were excluded, because none were lost to followup. A power analysis for a chi square test was performed with the number of alignment outliers as the primary outcome, an effect size of 0.3, and a total sample size of 50 patients per group. At an alpha level of 0.05, the

power was 0.851. All patients were followed for a minimum of 2 years (mean, 2.4 years; range, 2–3 years). The MIS-NAV group consisted of 19 men (26 knees) and 16 women (24 knees) who had a mean age of 67 years (range, 50–80 years) and a mean body mass index of 34 kg/m² (range, 22–53 kg/m²). The MIS group consisted of 11 men (13 knees) and 29 women (37 knees) who had a mean age of 70 years (range, 49–89 years) and a mean body mass index of 33 kg/m² (range, 23–52 kg/m²). Preoperative mechanical axis deviation in degrees of valgus as well as Knee Society knee and function scores [13] were also measured (Table 1). For the two groups, we compared perioperative variables (operative time, estimated blood loss, and hospital stay), radiographic and functional outcomes, and complications. Institutional Review Board approval was obtained for this study.

The surgical technique consisted of a minimidvastus incision that was approximately 10 cm in length and used a modified vastus medialis obliquus muscle snip [3]. Extra-medullary alignment guides were used, and the cutting guides were placed using the computer. The Scorpio^{TM} Total Knee System (Stryker Orthopaedics, Mahwah, NJ) was used with the femoral, tibial, and patellar components cemented in all cases. All patellae were resurfaced.

The navigation procedure was performed using the Stryker Navigation System (Stryker Orthopaedics). The 4.5-mm tracker pins were placed bicortically in a medial-to-lateral direction in the femoral and tibial metaphyses. Navigation was used throughout the procedure to verify the component position before and after cementing as well as for placement of the cutting blocks. The femoral rotation alignment was checked using both the epicondylar and anteroposterior axes, and if they did not agree, the posterior condylar axis was used to confirm the alignment.

Venous thromboembolism prophylaxis for both groups consisted of subcutaneous enoxaparin in addition to sequential compression devices while in bed. This was

Table 1. Demographic and preoperative data of the study patients

Demographic information	MIS TKA	MIS-NAV TKA
Number of knees (patients)	50 (40)	50 (35)
Men	13 (11)	26 (19)
Women	37 (29)	24 (16)
Mean age in years (range)	70 (49–89)	67 (50–80)
Mean body mass index (range)	33 (23–52)	34 (22–53)
Mean preoperative mechanical axis deviation in degrees of valgus (range)	1 (–5–12)	0 (–15–20)
Mean preoperative Knee Society scores in points (range)		
Pain	28 (0–45)	37 (11–50)
Function	32 (0–60)	39 (0–60)
Mean preoperative range of motion in degrees (range)	92 (65–125)	108 (70–142)

MIS = minimally invasive total knee arthroplasty; MIS-NAV = minimally invasive total knee arthroplasty using computer-assisted navigation.

started immediately after the procedure and continued for the duration of the hospitalization. After discharge, each patient took 325 mg aspirin once daily for 21 days. The rehabilitation protocol for both groups was identical. A continuous passive motion machine was started in the recovery room. Patients began full weightbearing on the first postoperative day and were seen twice daily by physical therapists.

Operative times, estimated blood losses, and hospital stays for each patient were recorded in a database. We (PMB, DAD) evaluated the patients and assessed them for complications at 6 weeks, 6 months, 1 year, and annually thereafter. The Knee Society knee and functional scores [13] were collected independently by research staff. Passive range of motion was measured with a goniometer by physical therapists.

Postoperative anteroposterior and lateral weightbearing radiographs were taken at 6 weeks and afterward as needed. Two independent reviewers (LR, GZ) assessed each radiograph while blinded to the identities and cohorts of the patients. The interobserver variability was within 1° on 92% of the radiographs. If there was disagreement, they reexamined the radiograph with one of the authors (PMB) until a unanimous decision was reached. The method described by Ewald [9] was used to measure femoral and tibial angles on the anteroposterior and lateral radiographs. Radiolucencies were evaluated by dividing the tibial component into seven zones on the anteroposterior view and three zones on the lateral view, dividing the femoral component into seven zones on the lateral view, and dividing the patellar component into five zones on the Merchant view as described by Ewald [9]. The widths of the radiolucencies were added, and a sum greater than 10 mm or any progression of radiolucencies was considered to indicate component loosening.

A chart review was conducted of TKAs performed between January 1, 2002, and December 31, 2005, to evaluate 50 consecutive cases performed by each surgeon at a followup time that was similar to the two primary study groups. The minimum followup time was 2 years (mean, 3 years; range, 2–4 years). These TKAs were all performed using a conventional midvastus approach with an incision of 15 to 20 cm and navigation was not used. The perioperative variables (surgery time and estimated blood loss) and postoperative variables (Knee Society knee score, range of motion, and tibiofemoral axis) were examined to assess the comparability of the two surgeons as well as to compare the conventional methods with the techniques used in the present study.

The perioperative and postoperative variables (operative time, estimated blood loss, hospital stay, postoperative alignment, Knee Society scores, and range of motion) for the two groups were compared with a Student's *t*-test. The

complication rates and the number of alignment outliers in each group were compared with a chi square test with Yates' correction or a Fisher's exact test if any values in the comparison were less than five. The Statistical Package for the Social Sciences Version 13.0 (SPSS, Chicago, IL) was used for all analyses.

Results

The mean operative time for the MIS-NAV group was 112 minutes (range, 63–297 minutes), which was longer ($p < 0.0001$) than the mean 54-minute operative time for the MIS group (range, 35–86 minutes). The mean estimated blood loss and length of hospital stay were similar for the two groups (Table 2).

The functional outcomes for the two groups were similar. The mean Knee Society knee scores were 93 points (range, 64–100 points) for the MIS group and 93 points (range, 75–100 points) for the MIS-NAV group ($p = 0.223$). The mean Knee Society function scores were 93 points (range, 64–100 points) for the MIS group and 88 points (range, 50–100 points) for the MIS-NAV group ($p = 0.149$).

The mean anatomic axis for the MIS group was 5° of valgus (range, 2°–8° of valgus), and the mean axis for the MIS-NAV group was 4° of valgus (range, 2° of varus to 8° of valgus). Alignments in the coronal plane (femoral valgus angle, $p = 0.109$; tibial angle, $p = 0.160$) and the sagittal planes (femoral flexion, $p = 0.197$; tibial angle, $p = 0.248$) were similar (Table 2). One tibial component in each group was angled more than 3° from the tibial shaft axis. The number of knees that were angled more than 3° from the anatomic axis in the MIS and MIS-NAV groups were one (2%) and three (6%), respectively ($p = 0.367$). No progressive radiolucencies were found, and none of the knees had radiolucencies that added up to more than 4 mm.

Complication rates were also similar between the two groups ($p = 1.000$). In the MIS group, one patient had a deep venous thrombosis. He was treated with therapeutic anticoagulation and his thrombosis resolved with no sequelae. Three patients (6%) also developed postoperative knee stiffness. They were treated with manipulation under anesthesia and are currently doing well with Knee Society knee scores ranging from 88 to 100 points and function scores ranging from 89 to 99 points at a followup time of 1 year after the manipulations. In the MIS-NAV group, three patients developed hematomas in the knee and were treated with aspiration. In addition, two patients (4%) experienced postoperative knee stiffness and were treated with manipulation under anesthesia. All of the patients who developed hematomas are now doing well with Knee Society knee scores ranging from 92 to 100 points and function scores ranging from 95 to 100 points at followup times of 2 to

Table 2. Summary of results

Variable	MIS TKA	MIS-NAV TKA	p Value
Mean operative time in minutes (range)	54 (35–86)	112 (63–297)	< 0.001
Mean estimated blood loss in milliliters (range)	91 (0–400)	92 (0–350)	0.817
Mean length of hospital stay in days (range)	4 (2–9)	4 (2–6)	0.545
Postoperative alignment in degrees (range)			
Anteroposterior view			
Femoral valgus angle	95 (92–98)	94 (90–97)	0.109
Tibial angle	90 (86–93)	90 (86–92)	0.160
Lateral view			
Femoral flexion	12 (6–21)	13 (6–22)	0.197
Tibial angle	92 (85–99)	92 (85–97)	0.248
Mean Knee Society score in points (range)			
Pain	93 (64–100)	93 (75–100)	0.223
Function	93 (64–100)	88 (50–100)	0.149
Range of motion in degrees (range)	115 (92–128)	116 (90–130)	0.446

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3 years after the aspirations. The patients who underwent manipulation had fair outcomes with Knee Society knee scores ranging from 75 to 83 points and function scores ranging from 70 to 77 points at followup times of 6 months after the manipulations. There were no other reoperations.

A comparison of 50 conventional TKAs performed by each of the two surgeons revealed a higher mean surgical time for one surgeon but otherwise similar results at a minimum followup time of 2 years (mean, 3 years; range, 2–4 years). The surgical times for the two surgeons were 71 minutes (range, 50–111 minutes) and 87 minutes (range, 63–118 minutes) for the MIS and MIS-NAV surgeons, respectively ($p = 0.000007$). The mean estimated blood losses were 115 mL (range, 50–200 mL) and 98 mL (range, 50–350 mL), respectively ($p = 0.411$). The mean postoperative ranges of motion were 116° (range, 90° – 130°) and 113° (range, 80° – 130°), respectively ($p = 0.281$). The mean Knee Society knee scores were 95 points (range, 87–100 points) and 93 points (range, 72–100 points), respectively ($p = 0.610$). The reoperation rates of the two groups were 4% and 6%, respectively ($p = 0.441$). Component alignment of the two groups was similar, with five and six outliers in the groups performed by the MIS and MIS-NAV surgeons.

A comparison of the MIS-NAV results with the outcomes of conventional TKA performed without navigation by the same surgeon revealed an increased mean operative time but no other differences.

Discussion

Both computer-assisted navigation and minimally invasive approaches have potential advantages when used for

TKAs. Computer-assisted navigation may result in greater accuracy of component position and joint alignment [1, 7, 19, 22, 29]. However, it has been associated with increased complication rates, including femoral fractures [17]. Minimally invasive approaches may lead to decreased blood loss, shorter rehabilitation time, greater quadriceps muscle strength, and improved function [12, 20, 21, 36, 37]. However, this technique may also result in malalignment of the components as a result of decreased visibility [6, 12, 20, 36]. Proper alignment (within 3° of the normal anatomic axis) has been associated with better long-term survival rates of the prosthesis, and varus angulation of greater than 3° has been associated with higher rates of loosening and failure [15, 32]. Because of the varied results in the literature, we undertook this study to examine functional and radiographic outcomes after merging the two technologies and after modifying the navigation technique to assess whether navigation improved alignment and outcomes of minimally invasive TKA.

Some limitations were present in this study. The two procedures were each performed by different surgeons, although the results of conventional TKAs performed by each surgeon without navigation were comparable, and the surgeons attempted to keep approaches and perioperative treatments similar except for the use of navigation. Another limitation is the short followup time, but we believe a minimum followup time of 2 years is sufficient to assess the short-term prognosis of the two procedures.

The navigation procedure was associated with a longer mean operative time, but the estimated blood losses and hospital stays of the two groups were similar. The functional and radiographic outcomes as well as complication rates were also similar. The navigation procedure had a

higher incidence of postoperative bleeding complications, possibly as a result of the tracker pins, but these were treated by aspiration and the final outcomes were excellent. The manipulation rates of 4% and 6% were lower than the manipulation rates reported in some studies of conventional TKAs [8, 18, 23, 26, 27, 30, 40], which range from 2% to 14%, but similar to rates reported in some studies of MIS-TKA [2, 11, 27], which ranged from 2% to 4%. The decreased soft tissue disruption of MIS-TKA might lead to decreased scarring, which could result in fewer stiff knees and less need for manipulation. The number of outliers that deviated by more than 3° from the normal axis was similar in the two groups. Also, a comparison of the navigation group with a nonnavigated group that used conventional 15- to 20-cm approaches, performed by the same surgeon, showed no advantages of navigation.

Some studies have examined short-term results of minimally invasive knee arthroplasties using navigation. Buckup et al. [4] examined 23 patients who underwent MIS unicompartmental knee arthroplasty (UKA) and 15 patients who underwent MIS-NAV UKA. Both groups had similar improvements of the mechanical leg axis with mean improvements of 5.23° and 4.18° for the MIS and MIS-NAV groups, respectively. Jenny et al. [16] reported 49 UKAs implanted using an MIS-NAV technique had better mean implant orientations than a comparison group of 87 patients who underwent conventional TKA. Seon and Song [34] compared 49 MIS-NAV knees with 53 conventional TKAs and reported a lower mean operative blood loss as well as a lower mean pain score during the first postoperative week, but found no differences in range of motion, pain, or radiographic alignment between the two groups at 2 weeks postoperatively. Seon et al. [35] compared an MIS-NAV technique with conventional TKA in bilateral knees of 42 patients. They reported the MIS-NAV TKAs had better HSS as well as WOMAC scores at 6- and 9-month followup times but that the scores were similar at 1 year. The MIS-NAV knees also had better alignment than the conventional knees. Range of motion was similar for the two techniques. Lampe et al. [21] compared MIS-NAV with navigated conventional TKA and found similar functional results in both groups at 3- to 6-month followup but decreased pain and earlier return to function in the MIS-NAV group. Thus, the published studies suggest some advantages of MIS-NAV over conventional TKA and no differences between MIS-NAV and MIS at short-term followup. Our results confirm there is no distinct advantage of MIS-NAV when compared with a minimally invasive approach without navigation.

Minimally invasive TKA and computer-assisted navigation are both new techniques that have recently been combined by some authors in an attempt to improve patient outcomes with mixed results. We found the operative time

was longer for the arthroplasties that used navigation, but the functional and radiographic outcomes were similar to minimally invasive TKA without navigation 2 to 3 years postoperatively. The complication rates of the two groups were also similar, indicating the modifications to the navigation technique may decrease the incidence of femoral fractures. However, the possible increased risks and costs of the longer surgical time (by a mean of 58 minutes) do not appear to justify the results of navigation in this study. More experience with the techniques and longer followup may reveal further information about the usefulness of these procedures.

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