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ORIGINAL RESEARCH

# Clinical Outcomes of First 100 Navigated Total Knee Arthroplasties at Duke University Medical Center

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## ABSTRACT

**Background:** Total knee arthroplasty (TKA) is one of the most clinically successful and cost-effective interventions in medicine. Implant malalignment can be a cause of early failure following total knee arthroplasty. Computer-assisted surgery has been employed to improve the precision of component alignment.

**Questions/purpose:** We asked: (1) What is the average coronal plane alignment of the first 100 patients undergoing computer-assisted total knee arthroplasty at our institution? (2) How do our clinical and radiographic results compare to those values reported in the literature? (3) Was a ‘learning curve’ present as evidenced by improvements in coronal plane alignment over time?

**Methods:** We retrospectively reviewed our first 100 patients undergoing computer navigated total knee arthroplasty. We calculated postoperative knee range of motion (ROM), coronal alignment as well as preoperative and postoperative Knee Society Scores. Minimum follow-up was 4.3 years (0.2-8.25 years).

**Results:** Of the 100 patients, average postoperative limb alignment was 0.9° varus compared to the mechanical axis. Seventy-nine percent of patients had coronal plane alignment of ±3°. Knee Society Scores improved on average from 60 preoperatively (52-67) to 85 postoperatively (56-97).

**Conclusion:** Computer-assisted total knee arthroplasty is potentially a way to improve component alignment and overall patient satisfaction. In our cohort, average coronal alignment was similar to literature reported values for navigated and conventional total knee arthroplasty. The benefit of this technology remains unproven.

**Level of evidence:** Level IV


**Keywords:** Total knee arthroplasty, Computer navigation, Outcomes.

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**Source of support:** Nil

**Conflict of interest:** None

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## INTRODUCTION

Accurate positioning and alignment of total knee arthroplasty (TKA) components has been the subject of controversy, particularly following the development of computer-navigated surgery.[1,2] Computer-navigated TKA is reported to improve the overall accuracy of tibial and femoral component positioning.[1,3-5] A mechanical axis within 3° of neutral has been used as the primary outcome measure in many clinical trials comparing computer-navigated and conventional TKA.[1,6-8] Evidence supporting this value has been limited by such factors as small sample size and inadequate radiographic follow-up;[9-11] however, it is believed that greater than 3° of deviation from the mechanical axis is associated with substantially higher long-term rates of loosening.[9,12,13]

Improving the accuracy of the alignment of TKA components has been the subject of several investigations. 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 survival.[1,14] However, some studies suggest that there is no substantial difference in the accuracy of alignment between computer-assisted and conventional TKAs and that use of this technology increases operative time with a potential increase in complications.[15,16] Furthermore, the current literature lacks studies that confirm that improved radiographic alignment achieved with computer-navigated TKA improves patients’ overall functional outcomes.[1]

The purpose of this study is to address the following questions: (1) What is the average coronal plane alignment of the first 100 patients undergoing computer-assisted TKA at our institution? (2) How do our clinical and radiographic results compare to those values reported in the literature? (3) Was a ‘learning curve’ present as evidenced by improvements in the coronal plane alignment over time?

## PATIENTS AND METHODS

### Demographics

The senior author (MPB) performed unilateral computer-assisted TKA in 100 consecutive patients. Our institutional review board approved the study and all patients signed and provided informed consent. All 100 patients received a cemented posterior cruciate sacrificing ultracongruent fixed-bearing knee prosthesis (Natural Knee II; Zimmer, Warsaw, Indiana) with an all polyethylene patellar component. There were 47 women and 53 men with a mean age of 57.1 years (37 to 76 years) at the time of the index arthroplasty. There were 51 right knees and 49 left knees. The mean duration of follow-up was 4.3 years (0.25-8.25 years).

### Surgical Technique

Zimmer Orthosoft (Zimmer, Warsaw, Indiana) computer navigation software was used for all TKAs performed in this study. Femoral and tibial tracking devices were established first prior to making an incision. 3.2 mm Steinman pins were placed unicortically, 2 each on the tibia and femur, and the tracking devices were secured to the pins. The hip was then taken through a range of motion to allow the computer software to document the center of rotation of the femoral head.

The arthroplasty procedure was then carried out through a standard midline incision with the knee slightly flexed and with use of a medial parapatellar arthrotomy. The pointer from the computer navigation system was then used to identify and reference multiple bony landmarks on the distal femur and the proximal tibia.

Landmarks on the femoral side included the intercondylar notch, medial and lateral epicondyles and the trochlear groove. On the tibial side, the landmarks included the entry hole, the medial third of the tibial tubercle, the PCL, and the most medial and lateral points of the tibial plateau. The medial and lateral malleoli were also referenced. Prior to the distal femoral cut the computer-generated data was used to establish the size of the femur. The femoral intramedullary canal was not entered at any point. Femoral resections were then made in the standard fashion.

Seven 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. Posterior slope of the tibial cut was matched to the patient's natural slope. Trial components were placed and computer navigation software was used to establish flexion, extension as well as overall component alignment and mechanical axis. Final components were then cemented into place. The knee was closed in a usual layered fashion over a suction drain.

### Rehabilitation

Starting with the first postoperative day, under the supervision of a physical therapist, all patients started active knee ROM exercises and began standing at the beside or walking with a walker twice daily for 30 minutes per period. Patients used a walker with full weight bearing for 6 weeks and a cane when needed thereafter.

### Clinical Evaluation

Clinical evaluations were done at 2 weeks, 6 weeks, 3 months, 1 year after the operation and yearly thereafter. All clinical data at the time of follow-up was obtained and recorded by the senior author. We calculated the Knee Society Score[17] for each knee based upon recorded data.

Active knee motion was determined with the patient in the supine position. The patient was asked to extend the knee fully while lying in the supine position so that any flexion contracture could be measured. The patient was then told to bend the knee maximally while in the supine position so that flexion could be measured.

### Radiographic Evaluation

Anteroposterior hip-to-ankle radiographs (made with the patient standing), lateral radiographs and sunrise patellar radiographs were made preoperatively and at each follow-up time point (except 2 weeks) and were assessed for alignment of the limb mechanical axis (Fig. 1), the position of the components, the posterior slope of the tibial component, and the presence and location of any radiolucent lines at the bone-cement interface in accordance with recommendations of the Knee Society.[17]

## RESULTS

### Clinical Results

Average estimated blood loss was 298 ml (175-500 ml) and tourniquet time was 84.8 minutes (39-123 minutes). Average preoperative knee range of motion was from 4° (0-15°) to 109° (75° to 125°). Average postoperative knee range of motion was from 0.5° (5 to 10°) to 116° (85° to 140°). The mean preoperative and postoperative Knee Society Scores were 60 (52-67) and 84 (56-91) respectively.


**Fig. 1:** Method of measuring limb mechanical axis from the center of the femoral head to the center of the trochlea the center of the ankle (values > 180° = valgus, values < 180° = varus)

### Radiographic Results

Mean coronal plane alignment compared to the mechanical axis was 0.9° varus (10° varus to 6° valgus). Seventy-nine percent of patients had coronal plane alignment of less than 3° varus or valgus (Table 1 and Graph 1)

### Complications

No intraoperative complications occurred. The overall post-operative complication rate was 15%. Eight knees (8.0%) were complicated by postoperative arthrofibrosis that were managed by manual manipulation under anesthesia after failing a sufficient course of physical therapy. Two knees (2.0%) were complicated by soft tissue impingement requiring both arthroscopic and open interventions. One knee (1.0%) sustained a patella fracture 1 week postoperatively that was managed nonoperatively. One knee (1.0%) was revised as a result of aseptic loosening of the femoral and tibial components at 15 months postoperatively.

One knee (1.0%) had a traumatic wound dehiscence secondary to a fall that was closed primarily without further incident. One knee (1.0%) had a deep wound infection 3 years postoperatively managed with open debridement, polyethylene liner exchange, and 6 weeks of intravenous antibiotics with no further evidence of infection. One knee (1.0%) had a deep wound infection managed with removal of the prosthesis and placement of an antibiotic spacer.

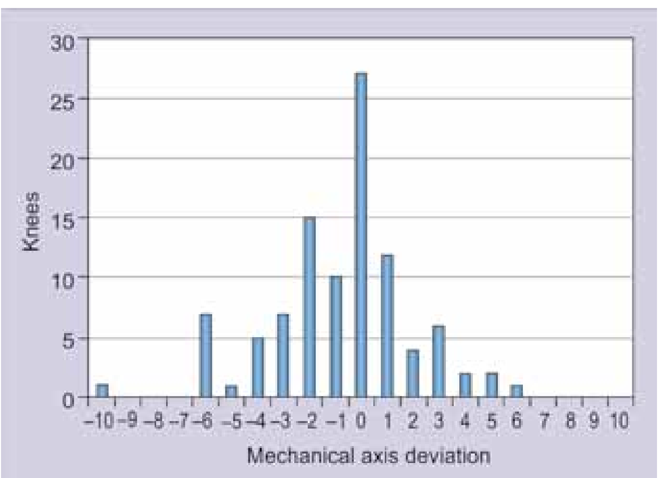
### Survival of the Implants

Survivorship of the implants at an average follow-up of 4.3 years was 98%.

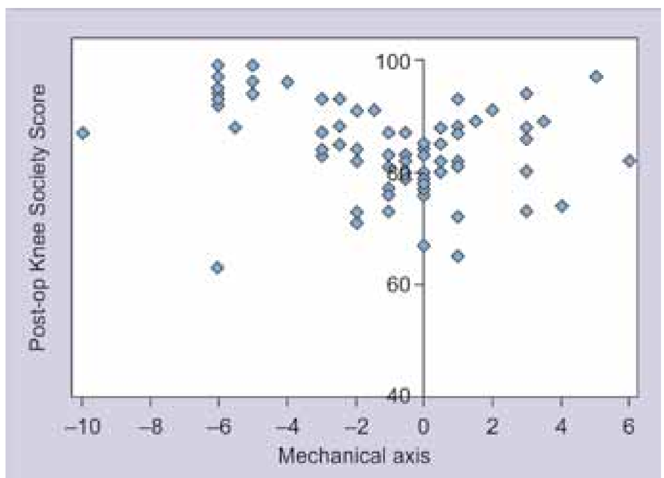
## DISCUSSION

Proper alignment of the components during total knee arthroplasty is believed to be critical in maximizing implant survival.[1,10,12,18,19] It has been claimed that computer-navigated total knee arthroplasty allows a higher degree of accuracy in component alignment.[3-5] Restoring the mechanical axis of the lower extremity, especially in the coronal plane, is a major factor contributing to the mid-term and long-term outcomes of total knee arthroplasty.[9] Choong et al 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.[20] 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 term.[15,21-25]

In looking at our cohort of 100 patients, we sought to answer the following questions: (1) What is the average coronal plane alignment of the first 100 patients undergoing computer-assisted total knee arthroplasty at our institution? (2) How do our clinical and radiographic results compare to those values reported in the literature? (3) Was a ‘learning




**Graph 1:** Overall knee malalignment in the coronal plane in relation to the mechanical axis. Mechanical axis deviation in degrees. Negative values = varus, positive values = valgus




**Graph 2:** Scatterplot of limb mechanical axis (X-axis) *vs* postoperative Knee Society Scores (Y-axis)

**Table 1:** Degrees of mechanical axis deviation (0°= neutral) by case number

| *Patient number* | *0-1°* | *1-2°* | *2-3°* | *>3°* |
|---|---|---|---|---|
| 0-25 | 13 | 6 | 3 | 3 |
| 26-50 | 15 | 2 | 1 | 7 |
| 51-75 | 9 | 5 | 5 | 6 |
| 76-100 | 10 | 3 | 7 | 5 |
| Total | 47 | 16 | 16 | 21 |

**Table 2:** Literature review of computer-navigated TKA

| | *Stulberg et al*[29] | *Matzolis et al*[3] | *Quoc Dutton et al*[27] | *Kim et al*[24] | *Zhang et al*[28] | *Kim et al*[1] |
|---|---|---|---|---|---|---|
| Number of knees | 35 | 32 | 52 | 160 | 32 | 520 |
| Coronal alignment (mean) | 2.6° varus | 1.4° valgus | 0.5° varus | — | — | — |
| Percentage of outliers (>3°) | — | 3% | 8% | 13% | 0% | 11% |
| Range | | 2.9° valgus to 3.1° varus (6° total) | | 5.1° valgus to 4.8° varus (9.9° total) | | 4.8° valgus to 5.3° varus (10.1° total) |
| KSS | | | 84 | 92 | | 93 |

**Table 3:** Literature review of conventional TKA

| | *Parratte et al*[18] | *Matzolis et al*[3] | *Quoc Dutton et al*[27] | *Kim et al*[24] | *Zhang et al*[28] | *Kim et al*[1] |
|---|---|---|---|---|---|---|
| Number of knees | 398 | 28 | 56 | 160 | 32 | 520 |
| Coronal alignment (mean) | — | 2.6° valgus | 0.6° valgus | — | — | — |
| Percentage of outliers (>3°) | 27% | 25% | 32% | 19% | 28% | 13% |
| Range | | 4.8° valgus to 6.6° varus (11.4° total) | | 4.7° valgus to 4.9° varus (9.6° total) | | 5.1° valgus to 5.1° varus (10.2° total) |
| KSS | | | 85 | 93 | | 92 |

curve' present as evidenced by improvements in coronal plane alignment over time?

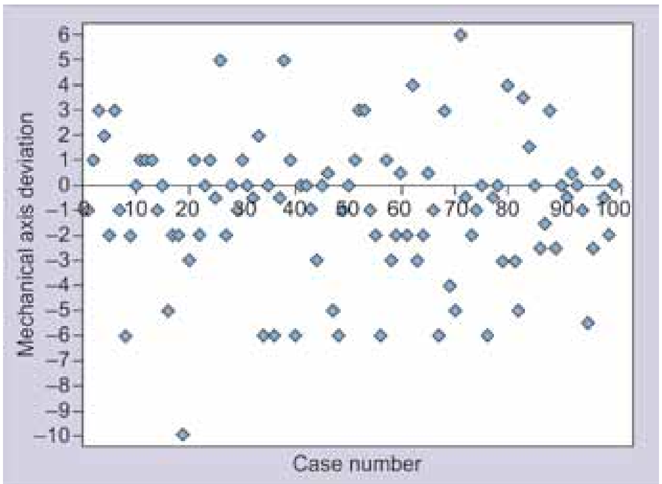
In the current study, the average coronal plane alignment of the limb did not differ significantly from literature reported values with either computer-assisted or conventional TKA[8,16,26-28] (Tables 2 and 3). However, we did note a greater percentage of outliers (>3° from the neutral mechanical axis) in our study compared literature reported values for computer-assisted TKA (*see* Table 2). Our findings are not in agreement with the results of other investigators who have demonstrated that, in comparison with conventional TKA, computer-navigated TKA is associated with more accurate alignment on radiographs.[4,29-31] In addition, we did not notice a trend of improved postoperative Knee Society Scores with a more neutral mechanical axis (Graph 2).

Recent studies have demonstrated that computer navigation may play a role in reducing the learning curve in joint replacement surgery. Jenny et al concluded that, after 30 computer-assisted TKAs, all outcome parameters including alignment, operating time and complications leveled off between beginning and experienced orthopaedic surgeons.[32] In our study, we did not observe an improvement in accuracy over time in alignment of the limb mechanical axis (Graph 3).

The cost effectiveness of computer-navigated TKA is an issue that must be addressed. It has been previously shown that computer-assisted surgery has an increased incremental cost of $871 over conventional TKA.[33] This does not take into account the capital expenditures that are accrued with the purchase of a navigation system. However, it was also demonstrated that when the cost per operation decreases below $629, as possibly achievable in larger joint arthroplasty centers, cost-savings over the entire lifespan of a TKA are reachable.[33,34]

Computer-assisted navigation may be associated with complications. Authors of clinical studies have reported that fracture at the pin-track site on the femur and tibia.[35-37] Causes of fracture included large pin diameter (4 to 5 mm), an improperly positioned pin, repeated drilling of pins, obesity, osteoporosis and postoperative trauma. In our series, pin diameter was 3.2 mm and was placed uneventfully in all knees without intraoperative complication.

There are several strengths of this study. First, drawing a large series of patients from a single surgeon at a single




**Graph 3:** Scatterplot of limb mechanical axis deviation (X-axis) *vs* case number (Y-axis)

center allows for accurate comparisons across a time continuum given the consistency of surgical technique and implants. Second, the follow-up was long enough to allow for determination of knee scores, survivorship of the implants and prevalence of osteolysis or aseptic loosening at a mean follow-up of 4.3 years.

There are limitations to this study as well. First, we report only on a series of patients who underwent computer-assisted TKA without a matched control or comparative group for conventional TKA. Secondly, we only had sufficient follow-up information to calculate a Knee Society Score and not a functional score. Thirdly, our postoperative radiographic assessment was limited to determination of coronal limb alignment and did not take into account individual alignments of the tibial and femoral components. We note that there is a margin of error produced by projection-related errors in standing radiographs and therefore CT evaluation may give us more accurate data regarding not only limb alignment but also component positioning.[38]

Our data demonstrated that there was no difference in mean coronal alignment or postoperative Knee Society Scores for our cohort of patients undergoing computer-assisted TKA when compared to literature reported values of patients undergoing conventional TKA. The clinical and functional benefit of computer-assisted TKA remains unproven.

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