# Clinical Article

# Alignment in computer-navigated versus conventional total knee arthroplasty for valgus deformity

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## Abstract

### Introduction:
Significant improvement has been reported in limb alignment and component orientation with computer-navigated total knee arthroplasty (TKA) especially in varus deformities. Literature is lacking regarding the radiographic results of navigated TKA in valgus knees. This study aims to analyse the radiographic results of navigated TKAs in valgus knees and compare them with results of our conventional technique.

### Materials and methods:
We retrospectively analysed 120 primary TKAs done for valgus arthritic knees. Fifty-three computer-navigated TKAs (group N) were compared with a control group of 53 conventional TKAs (group C) for coronal and sagittal alignment of the femoral and tibial components on X-ray imaging at the end of two years after surgery.

### Results:
We found no significant difference in the postoperative coronal alignment of components between the two groups. The mean postoperative anatomic valgus angle in the group N was 5.48°±2.33° compared to 5.42° ±2.15° in group C (p=0.06). The percentage of outliers, from the acceptable range of 4° to 10° of anatomic tibiofemoral valgus, in group N was 13% (seven TKAs) compared to 17% (nine TKAs) in group C (p=0.78). Posterior femoral offset was restored more accurately in group N (p=0.047) compared to group C (p=0.68). A greater number of femoral components in group N (43%) was placed in extension relative to the distal femoral anatomic axis compared to group C (17%).

### Conclusion:
Sequential soft-tissue release and computer navigation for valgus TKA gives excellent overall alignment with few outliers. The component alignment between the two groups seems to be no different except for the sagittal femoral component orientation.

## Introduction

Long-term implant survival has been documented in several studies to be well correlated to postoperative limb and component alignment.[1-4] In contrast to the varus arthritic knee, restoration of optimal limb and component alignment after total knee arthroplasty (TKA) in valgus knees can be a formidable challenge in view of the associated lateral bone loss, metaphyseal remodelling, external rotation deformity of the distal femur, patellar maltracking and associated contracture of the lateral soft tissues.[5]

Computer navigation systems were introduced in TKA with the purpose of improving prosthesis alignment. Several studies have validated the accuracy and consistency of computer-assisted navigation and have reported significant improvement in component orientation and limb alignment in TKA with the use of computer navigation.[6-14] Mason *et al*[15] in a meta-analysis of alignment outcomes in conventional versus computer-assisted TKA, reported that computer-assisted surgery improved the precision and accuracy of component orientation outcome measures reported. Although most of these studies have included both varus and valgus knees, cases with valgus deformities formed a small portion of cases in these studies. We could not find any literature that specifically studied the alignment in valgus knees after computer-navigated TKAs.

The purpose of this study was to assess the alignment achieved with computer-navigated TKAs in valgus knees and compare them with valgus TKAs performed using conventional technique.

## Materials and methods

We retrospectively reviewed the medical records of 2 450 TKAs done between January 1996 to July 2007. A total of 120 primary TKAs were performed for cases of knee arthritis with valgus deformity using both conventional and computer-navigated techniques, by a single surgeon (AM), during this period. The indications for surgery included pain and disability due to arthritis, which was confirmed using plain radiographs. All knees with pre-operative anatomic valgus angulations of ≥10º, measured as the tibiofemoral angle on standing anteroposterior knee radiographs and a minimum postoperative follow-up of 12 months were included in the study. The exclusion criteria included cases with previous high tibial osteotomy (HTO), infection, and severe joint instability requiring constrained knee prosthesis.

Based on these criteria, 106 primary TKAs (13 bilateral TKAs) performed in 93 patients were included in the study. Four patients were excluded due to previous HTO (five knees), three patients were excluded due to use of constrained knee prosthesis (three knees), and five patients were lost to follow-up (six knees). The computer-navigated group (Group N) included 53 computer-navigated TKAs performed on 46 patients (seven bilateral TKAs) out of which 35 were females and 11 were males. The primary diagnosis was primary osteoarthritis in 39 patients (85%) and rheumatoid arthritis in seven patients (15%). The average age of these patients at the time of surgery was 65 years (range, 48-85 years). Two patients had had ipsilateral uncemented total hip replacement, and one patient had had an intramedullary nailing done for an ipsilateral tibial shaft fracture. The control group consisted of 53 conventional TKAs (Group C) performed on 47 patients (six bilateral TKAs). Thirty-six of these patients were female and 11 were male. The average age of the patients at the time of surgery was 67 years (range, 42-79 years). The primary diagnosis was primary osteoarthritis in 40 patients (85%), rheumatoid arthritis in six patients (13%), and post-traumatic arthritis in one patient (2%). Two patients had had surgery for previous fractures (intramedullary nailing for shaft fracture of femur and tibia); one patient had had a bilateral total hip replacement. The recorded height (cm) and weight (kg) were used to calculate the body mass index (BMI) in all patients.

### Radiographic evaluation

Pre-operative radiographic evaluation was done using standing anteroposterior (AP) and lateral knee radiographs. The anatomic valgus deformity at the knee was calculated using the tibiofemoral angle, which was the angle between the medullary axis of the distal femur and the medullary axis of the proximal tibia (*Figure 1a*). The radiographs were also scrutinised for medial-lateral joint opening, tibial subluxation, and osteophytes. Postoperatively, the tibial and femoral components were assessed using the Knee Society roentgenographic evaluation system[16] as follows:

1. Postoperative tibiofemoral angle on AP radiographs as described above.
2. Medial femoral angle on AP radiographs measured as the angle between the medullary axis of the distal femur and the line drawn tangential to the medial femoral condyle of the prosthesis (*Figure 1b*).
3. Medial tibial angle on AP radiographs measured as the angle between the medullary axis of the proximal tibia and the line drawn along the base of the tibial component (*Figure 1b*).
4. Femoral flexion angle on lateral radiographs measured as the angle between the medullary axis of the distal femur and the line drawn perpendicular to the femoral prosthesis (*Figure 1c*).
5. Tibial slope on lateral radiographs measured as the angle between the medullary axis of the proximal tibia and the line drawn along the base of the tibial component (*Figure 1c*).

The pre-operative and postoperative posterior femoral offset was measured using the standing true lateral knee radiographs as the maximum thickness of the posterior femoral condyle (*Figure 1c*), projected posterior to the tangent of the posterior cortex of the femoral shaft.[17]

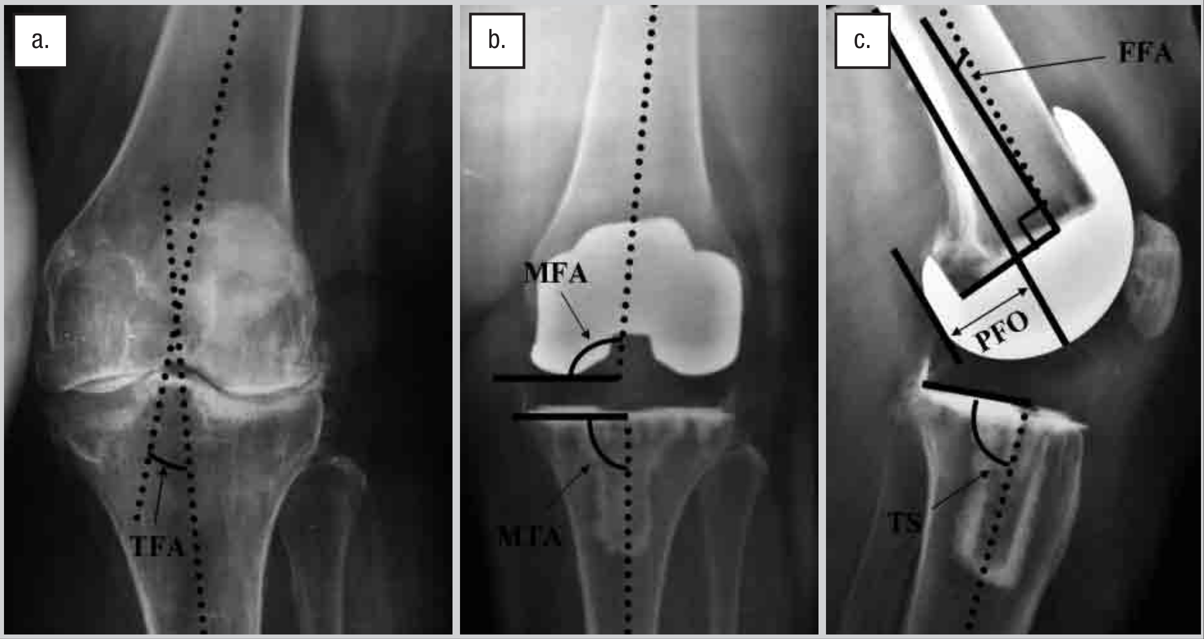


**Figure 1**

a: Pre-operative standing anteroposterior radiograph showing the tibiofemoral angle (TFA) measured as the angle between the medullary axis of the distal femur and the medullary axis of the proximal tibia

b: Post-operative standing anteroposterior radiograph showing the medial femoral angle (MFA) and the medial tibial angle (MTA)

c: Post-operative lateral radiograph showing the measured femoral flexion angle (FFA), tibial slope (TS) and the posterior femoral offset (PFO). Note that the femoral component is placed in approximately 6° extension with respect to the distal femoral anatomic axis in this case of navigated total knee arthroplasty.

These posterior femoral offset measurements were corrected for magnification using a reference measurement of the diameter of the femoral shaft 10 cm proximal to the femoral articular surface. In addition to component position, all radiographs were assessed for signs of osteolysis, defined as an expanding area of focal radiolucency measuring ≥1 cm in diameter. All radiographs were analysed by one surgeon (GMS) blinded to the surgical technique used.

Radiologically, all patients were assessed pre-operatively and at six weeks, three months, six months and one year postoperatively. Thereafter all patients were assessed radiologically at one-year intervals. Clinically all patients were assessed during the same intervals using the Knee Society score for pain, stability, range of motion and ambulation.

## Surgical technique

All TKAs were performed by a single surgeon (AM) with an experience of 12 years of using conventional technique and an experience of three years of using the computer-navigated technique. All procedures were performed with the tourniquet inflated, which was deflated after the cement had hardened. An anterior longitudinal incision and a medial parapatellar arthrotomy were used. All patients underwent TKA using a cemented, posterior cruciate substituting design and all patients had resurfacing of the patella. Three designs of the PFC Sigma implant (DePuy Orthopaedics, Warsaw, Indiana) was used in all patients: PFC Sigma fixed bearing with metal-backed tibia (18 knees in Group N and 49 knees in Group C), PFC Sigma fixed-bearing all-polyethylene tibia (36 knees in Group N and 21 knees in Group C) and PFC Sigma RP mobile bearing (one knee in Group N and three knees in Group C). The surgical aim in both the groups was to align both femoral and tibial components perpendicular to the respective mechanical axes, femoral rotation aligned to the epicondylar axis, and to achieve a neutral lower limb mechanical axis. The same set of instruments were used in both groups to perform all bone cuts.

### Computer-navigation technique (Group N)

In the navigated group, registration was performed in the standard fashion after insertion of two pins in the proximal tibia and distal femur to which arrays with three reflector spheres were affixed. We used the Ci navigation system with its software (BrainLab, Munich, Germany).

The mechanical axis of the lower limb was obtained by navigation, using the centre of femoral rotation, the malleoli, and the centre of the intercondylar notch. The severity of deformity was recorded. The line joining the prominence of the lateral epicondyle and the groove distal to the medial epicondyle determined the epicondylar axis. Conventional cutting blocks were navigated into position; the size and alignment of the prosthesis was usually that recommended by the computer. The surgeon made appropriate changes, when deemed necessary, to the recommendations made by the computer at various stages. The distal femoral cut was made perpendicular to the femoral mechanical axis, initially resecting no more than 6-8 mm from the medial side and no more than 2 mm from the lateral side. Extension and flexion gaps were determined using spacer blocks of different thicknesses. Soft-tissue balancing was achieved sequentially by releasing the iliotibial band from the Gerdy's tubercle, posterolateral capsule intra-articularly using electrocautery and freeing the popliteus tendon from its surrounding adhesions. The anterior and posterior femoral cuts were then performed after confirming the rotational alignment by referencing the cutting block with respect to the epicondylar axis. Trial components were inserted after the box and chamfer cuts and the final alignment of the limb were confirmed. Stability and patellar tracking were also checked through a full range of knee motion.

### Conventional technique (Group C)

The conventional technique involved use of intramedullary femoral and extramedullary tibial guides. The proximal tibia was cut at 90° to its mechanical axis. An intramedullary rod was used to aid in placement of the distal femoral cutting block at 3-5° of valgus, resecting no more than 6-8 mm from the medial side and no more than 2 mm from the lateral side. The knee was then fully extended and using appropriate spacer blocks, the mediolateral stability of the knee was assessed using varus and valgus stress. Soft-tissue balancing was achieved sequentially by releasing lateral structures similar to the navigated group. The soft-tissue balance in extension was then confirmed using a spacer block when a valgus and varus stress gave a springy gap of 2 mm on both the medial and lateral side. The knee was then put in 90° flexion and an anteroposterior cutting block was placed on the distal femur parallel to the cut tibial surface. This was corroborated with a soft-tissue tensioner placed in the flexion gap to measure the medial and lateral flexion gaps. We aimed for the flexion gap to be same as the extension gap. Flexion stability was assessed using the spacer block.

Maltracking of the patella after trial implantation was dealt with when necessary by pie-crusting of the lateral retinaculum or an inside-out lateral retinacular release. In patients with severe, rigid valgus deformity, the lateral collateral ligament and popliteus tendon were released from their femoral attachment by performing a lateral epicondylar osteotomy in flexion. The epicondylar fragment was reattached at 90° flexion, after cementation, using cancellous screws. Subperiosteal fibular head excision was performed in some cases of severe stiff valgus deformities to decompress the peroneal nerve. Any flexion deformity was dealt with sequentially by the posterolateral capsular and iliotibial band release, removal of posterior osteophytes and stripping of the head of gastrocnemius off the distal femur. When a bone defect more than 1 cm in depth was encountered on the tibial plateau, a step cut defect was created which was then built up with autologous bone graft (taken from the intercondylar notch bone block) fixed with Kirschner wires and protected with a longer tibial stem extension. One patient in group N (76-year-old female) had presented with an ununited stress fracture-dislocation of the ipsilateral ankle for which an ankle arthrodesis was performed using corticocancellous screws. One patient in group C (72-year-old male) presented with an ipsilateral acute stress fracture involving the middle-distal 1/3 junction of the tibial shaft which was treated with patellar tendon bearing cast and partial weight-bearing for six weeks. The two groups did not differ in the type of postoperative physical rehabilitation protocol, which remained standard.

**Table I: Demographic details of both groups**

| Parameter | Navigated | Conventional | p-value |
|---|---|---|---|
| Number (patients) | 53 | 53 | NS |
| Age (years)* | 65.4±7.3 | 67.9±6.3 | NS (p=0.08) |
| Gender (% male) | 23.9% | 23.4% | NS (p>0.05) |
| Diagnosis (%Osteoarthritis) | 85% | 85% | NS |
| BMI * | 29.45±2.05 | 28.33±3.74 | NS (p=0.07) |

*Data presented as Mean±SD
BMI – Body mass index
NS – Not significant

The two groups were identical in terms of age, diagnosis, gender, BMI, implants and peri-operative management (*Table I*). In view of the difference in the mean follow-up periods between the two groups, we compared the alignment and clinical data from group N with the data from group C at the end of 24 months of follow-up. Data from the two groups were compared using Student's t-test and Fisher's exact test and a p-value of <0.05 was taken to be statistically significant.

## Results

The patients in the computer-navigated group (Group N) were followed up for a mean of 25 months (range, 24-40 months) compared to a mean follow-up of 61 months (range, 33-132 months) in the conventional group (Group C). In group N, at the end of 24 months of follow-up, the mean postoperative knee score was 92 (range, 85-100) and the functional score was 86 (range, 50-100) postoperatively. In group C, at the end of 24 months of follow-up, the mean postoperative knee score was 90 (range, 80-100) and the functional score was 84.6 (range, 40-100) postoperatively. There was no difference in the mean clinical and functional scores between the two groups at the end of the last follow-up (p>0.05). The overall component alignment in each group and the comparison between the two groups is summarised in *Table II*.

The mean pre-operative and postoperative anatomic valgus angles in both groups were not significantly different. The percentage of outliers, from the acceptable range of 4° to 10° of anatomic tibiofemoral valgus, in group N was 13% (7 TKAs) with a mean anatomic valgus angle of 1.5° (range, 0°-3°) compared to 17% (9 TKAs) with a mean anatomic valgus angle of 1.5° (range, 0°-3.5°) in group C. This difference was found to be statistically not significant (Fisher's exact test, p=0.78). The overall alignment of femoral and tibial components in both groups was not significantly different except for the femoral component sagittal alignment. The femoral component was placed in extension with respect to the distal femoral anatomic axis in 43% of knees (23 out of 53 knees) in group N compared to 17% (nine out of 53 knees) in group C. This difference in femoral sagittal component alignment was found to be statistically significant (Fisher's exact test, p=0.005). The posterior femoral offset was found to be more accurately restored postoperatively when compared to pre-operative values in group N (p=0.68) than in group C (p=0.047).

Lateral epicondylar osteotomy was performed in ten knees in group N (18%) compared to two knees in group C (4%) whereas fibular head excision was performed in two knees in group C.

**There was no difference in the mean clinical and functional scores between the two groups at the end of the last follow-up**

**Table II: Comparison of radiographic findings of both groups**

| Parameter | Navigated† | | Conventional§ | | p-value |
|---|---|---|---|---|---|
| | Mean±S.D | 95% CI | Mean±S.D | 95% CI | |
| Pre-operative TFA (degrees) | 16.05±5.93 | 14.46-17.64 | 18.27±6.31 | 16.58-19.96 | 0.06 |
| Postoperative TFA (degrees) | 5.48±2.33 | 4.85-6.11 | 5.42±2.15 | 4.83-6.0 | 0.06 |
| Pre-operative PFO (mm) | 20.55±4.48 | 19.34-21.76 | 18.83±4.30 | 17.67-19.99 | 0.89 |
| Postoperative PFO (mm) | 20.88±3.28 | 20.0-21.76 | 20.54±4.07 | 19.45-21.63 | 0.65 |
| MFA (degrees) | 95.85±1.77 | 95.38-96.32 | 95.67±2.42 | 95.02-96.32 | 0.66 |
| MTA (degrees) | 89.81±1.01 | 89.54-90.08 | 89.58±1.55 | 85.16-90 | 0.38 |
| FFA (degrees)* | -1.47±4.66 | -2.75 to -0.18 | +1.51±3.36 | +0.58 to +2.44 | 0.0003 |
| Tibial slope (degrees) | 1.66±1.44 | 1.29-2.03 | 1.95±1.87 | 1.45-2.45 | 0.38 |

TFA – Tibiofemoral angle
PFO – Posterior femoral offset
MFA – Medial femoral angle
MTA – Medial tibial angle
FFA – femoral flexion angle
† All data obtained at last follow-up
§ All data obtained at 24 months of follow-up
*Negative values indicate femoral component extension and positive values indicate flexion
p-value <0.05 statistically significant

All patients who underwent lateral epicondylar osteotomy showed complete union at last follow-up. One patient in group C had delayed infection (at 1.5 years after the index surgery) for which a two-staged revision TKA was performed. None of the patients in either group had any instability, or evidence of loosening or lysis radiographically at the end of 24 months of follow-up. There were no cases with peroneal nerve palsy and patellar dislocation.

## Discussion

Proper alignment of components and the limb is crucial to the success of TKA. Proper alignment and gap balancing in valgus knees during conventional TKA is achieved by sequentially releasing the lateral soft tissue structures, which is effective, reproducible and is said to provide excellent long-term results in most cases.[5,18]

Computer-assisted navigation aims to restore optimal component orientation and limb alignment in TKA. Literature review suggests that the number of outliers for overall femoral and tibial component alignment is significantly lower in navigated TKA compared to conventional TKA.[15] However, all of these studies have reported mainly on varus knees with no reports specifically reporting the results of navigated TKA in valgus knees. The aim of our study was to assess the component alignment achieved with computer-navigated TKAs in valgus knees and compare them with valgus knees operated using conventional technique.

There was no significant difference in the mean postoperative anatomic valgus angle and the percentage of outliers from the acceptable anatomic valgus angle of 4° to 10° between the two groups in our study at the end of 24 months of follow-up. The mean postoperative anatomic valgus angle of 5.42°±2.15° in our conventional group and 5.48±2.33 in the navigated group is similar to results of conventional valgus TKAs reported in literature. Elkus *et al*[5] in their series of 42 conventional TKAs done for valgus knees had reported a mean postoperative anatomic valgus angle of 5° whereas Lombardi *et al*[19] in their review of 97 conventional TKAs done for valgus knees reported a mean postoperative anatomic valgus angle of 5.8°. In the current study, the percentage of outliers for postoperative tibiofemoral anatomic angle for navigated TKAs was 13% compared to 17% in the conventional group. Stern *et al*[20] in their results of 134 conventional valgus TKAs reported the outliers for an anatomic valgus range of 5°-9° to be 24%. Elkus *et al*[5] and Miyasaka *et al*[18] reported the outliers for an anatomic valgus range of 2°-7° to be 12% (for 42 conventional valgus TKAs) and 25% (for 108 conventional valgus TKAs) respectively. This difference in the percentage of outliers between the current study and the ones mentioned above could be due to the smaller range of acceptable anatomic valgus angle taken by the previous investigators.

There was no statistical difference between the postoperative femoral and tibial component alignment parameters such as coronal femoral and tibial component alignment, sagittal tibial component alignment, and posterior femoral offset. The sagittal femoral component alignment (femoral flexion angle) was however different in the two groups with up to 43% of the components in the navigated knees placed in extension compared to 17% in the conventional group. This could be due to the computer navigation system giving a true mechanical axis of the entire limb in the sagittal plane, which is in hyperextension relative to the apparent mechanical axis that is determined using intramedullary non-navigated instruments.[21] The degree of femoral flexion measured using lateral knee radiographs measures it only with respect to the distal femoral anatomic axis and not the entire sagittal mechanical axis of the femur. Hence, the exact sagittal orientation of the femoral component needs to be confirmed using lateral full-length radiographs of the limb. The posterior femoral offset in the navigated group was found to be more accurately restored postoperatively compared to the conventional group. However, this improved accuracy in restoration of the posterior femoral offset and placement of femoral component in extension does not seem to have made any clinical difference in terms of function and range of motion between the two groups at the end of 24 months of follow-up.

The major drawbacks of our study include the retrospective nature of the study, and relative short mean follow-up of the navigated group. Despite the difference in the percentage of outliers for postoperative tibiofemoral anatomic angle between the two groups (13% in group N and 17% in group C), it failed to reach statistical significance in view of the relatively small number of patients in both groups.

## Conclusion

In conclusion, sequential soft-tissue release and computer navigation during TKA for valgus knees gives excellent overall component alignment with few outliers. Our study results show no difference in the overall postoperative anatomic valgus angle and femoral and tibial component alignment between the navigated and conventional groups. Navigation may result in more accurate restoration of posterior femoral offset and tends to place the femoral component in extension with respect to the distal femoral sagittal anatomic axis, but the clinical consequence of these needs to be validated separately with a longer follow-up study.

*No benefits or funds were received in support of this study/article.*

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