



# Navigated Unicompartmental Knee Arthroplasty: A Different Perspective

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**Background:** Anteromedial osteoarthritis is a recognized indication for unicompartmental knee arthroplasty (UKA). Favorable postoperative outcomes largely depend on proper patient selection, correct implant positioning, and limb alignment. Computer navigation has a proven value over conventional systems in reducing mechanical errors in total knee arthroplasty (TKA). However, the lack of strong evidence impedes the universal use of computer navigation technology in UKA. Therefore, this study was proposed to investigate the accuracy of component positioning and limb alignment in computer navigated UKA and to observe the role of navigation in proper patient selection.

**Methods:** A total of 50 knees (38 patients) underwent computer navigated UKA between 2016 and 2018. All operations were performed by the senior surgeon using the same navigation system and implant type. The navigation system was used as a tool to aid patient selection: knees with preoperative residual varus  $> 5^\circ$  on valgus stress and hyperextension  $> 10^\circ$  were switched to navigated TKA. We measured the accuracy of component placement in sagittal and coronal planes on postoperative radiographs. Functional outcomes were also evaluated at the final follow-up (a minimum of 16 months).

**Results:** Nine patients had tibia vara and 14 patients had preoperative hyperextension deformity. We observed coronal outliers for the tibial component in 12% knees and for the femoral component in 10% knees. We also observed sagittal outliers for the tibial component in 14% knees and for the femoral component in 6% knees. There was a significant improvement in the functional score at the final follow-up. On multiple linear regression, no difference was found in functional scores of knees with or without tibia vara ( $p = 0.16$ ) and with or without hyperextension ( $p = 0.25$ ).

**Conclusions:** Our study further validates the role of computer navigation in desirable implant positioning and limb alignment. We encourage use of computer-assisted navigation as a tool for patient selection, as it allows intraoperative dynamic goniometry and provides real-time kinematic behavior of the knee to obviate pitfalls such as significant residual varus angulation and hyperextension that predispose early failure of UKA.

**Keywords:** Knee, Anteromedial osteoarthritis, Osteoarthritis, Computer assisted surgery, Unicompartmental knee arthroplasty

Anteromedial osteoarthritis of the knee is a specified entity.<sup>1)</sup> Mechanical risk factors such as tibia vara have been

attributed to its development.<sup>2,3)</sup> It is a recognized indication for unicompartmental knee arthroplasty (UKA).<sup>4)</sup> Proven benefits of UKA over total knee arthroplasty (TKA) include accelerated patient rehabilitation, shorter hospital stay, lower 45-day mortality and major complications rates, and higher functional performance with preservation of the normal knee kinematics.<sup>4,5)</sup> Several studies have shown better functional outcomes after UKA compared to TKA; furthermore, survival rates over 95% at 10 years and up to 91% at 20 years have been reported.<sup>6)</sup>

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Despite encouraging data, UKA is considered less reliable among knee surgeons, and this may be due to the higher overall revision rates compared with TKA in various national joint registries.<sup>7)</sup> Factors negatively affecting prosthesis survival in UKA include improper patient selection and technical reasons including excessive tibial slope, unbalanced flexion/extension gap, component malpositioning, limb malalignment, polyethylene impingement, and iatrogenic medial collateral ligament injury.<sup>8)</sup> The routine use of conventional instrumentation has been shown to lead to improper implant placement in as many as 30% of the cases. An intramedullary femoral guiding device can improve these results but does not allow reproducible optimal implantation.<sup>9)</sup>

Computer-assisted navigation allows higher precision of implant placement in TKA. Recent literature supports the use of navigation in UKA to improve accuracy and decrease variability in implant placement position and postoperative limb alignment when compared to the conventional technique.<sup>10)</sup> However, there is a paucity of strong evidence to validate the benefits of computer-assisted navigation in UKA. This study aimed to investigate navigation as a tool in patient selection and confirm purported benefits in terms of accuracy for desired implant positioning and limb alignment and their impact on clinical outcomes of UKA.

## METHODS

The first 50 knees (38 patients) that underwent navigated UKA in our institution between September 2016 and August 2018 were included in the present study. Institutional Ethics Committee of All India Institute of Medical Sciences (AIIMS) approval was obtained (IRB No. IEC-728/2017). All the patients suffering from anteromedial osteoarthritis of the knee and planned for navigated UKA were included while the patients with inflammatory arthritis, previous high tibial osteotomy, tibial plateau fracture, restricted range of motion (ROM), or severe deformities of the knee and patients who refused to participate were excluded. After obtaining informed consent, suitable patients underwent a preoperative clinical evaluation to observe correctable varus deformity, other deformities, and ROM of the knee. Preoperative radiological evaluation included plain radiographs: standing anteroposterior (AP) view, lateral view, skyline view, varus-valgus stress view of the knee, and standing scanogram of both lower limbs. Tibia vara was calculated on the standing scanogram using the metaphyseal-diaphyseal angle<sup>11)</sup> (Fig. 1). All patients were also evaluated for preoperative functional score using

Knee Injury and Osteoarthritis Outcome Score-Physical Function Shortform (KOOS-PS).

Each patient underwent medial compartmental mobile-bearing computer-assisted navigated UKA in the affected knee. All the cases were operated by the senior surgeon (RM) with more than 5 years of experience with the same navigation system for TKA. The patients were mobilized postoperatively with assistance on the same day. They followed the hospital standard physiotherapy protocol till discharge. The patients were followed up at 2 weeks after surgery for suture removal. The subsequent follow-up visits were scheduled at 6 weeks, 3 months, and 1 year (or latest follow-up). All the patients were evaluated clinically and radiologically. The functional outcomes were assessed using KOOS-PS scoring system.

Radiological assessment was done to examine limb alignment, implant positioning, loosening of the implants, and any complications such as bearing dislocation or infection. The zone of the tibial plateau, through which the mechanical axis traversed in the standing scanogram, was analyzed using the methods described by Kennedy and White<sup>12)</sup> (Fig. 2). Frontal positioning of the tibial and femoral components were examined on the AP radiograph of the knee. For the tibia, the component position was labelled as an outlier when the angle subtended by a frontal plane of the tibial component and the mechanical axis of the tibia was  $< 87^\circ$  (Fig. 3). For the femur, outliers meant

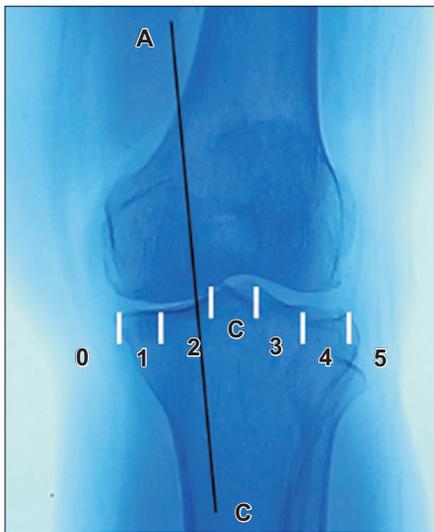


**Fig. 1.** Metaphyseal-diaphyseal angle. A line is drawn at the level of proximal tibial metaphysis (grey) parallel to the ankle joint line and a second line (continuous black) is drawn perpendicular to the line connecting the mid medullary points of the tibial diaphysis (interrupted black). Metaphyseal-diaphyseal angle is the angle formed by the metaphysis line and a line perpendicular to the diaphyseal line.

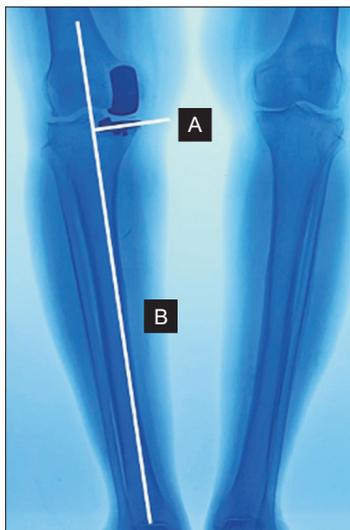
that the line along the long axis of the femoral component deviated  $> 3^\circ$  from the horizontal axis in either direction (Fig. 4). Sagittal positioning of the tibial component (tibial slope) and femoral component were examined on the lateral radiograph of the knee. For the tibia, these were labelled as outliers when not falling within the desired range of tibial slope,<sup>13</sup> i.e.,  $3^\circ$ – $8^\circ$  (Fig. 5). For the femur, the optimal position of the implant is perpendicular to the line along the anterior femoral cortex. The outliers were labelled when the angle between the distal femoral resection margin and the line along the anterior femoral cortex deviated  $> 3^\circ$  from the perpendicular in either direction (Fig. 6).

### Surgical Technique

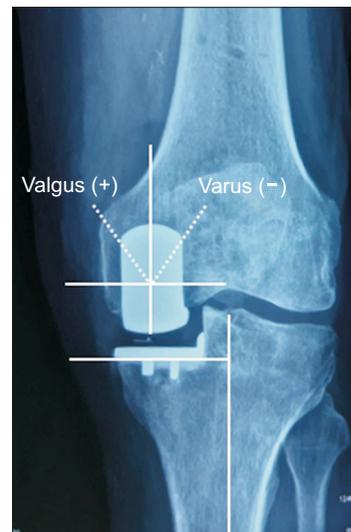
Combined spinal epidural anesthesia was administered in all cases. A thigh tourniquet was applied with the leg placed on an operating table with a lateral thigh support. The knee was kept free to flex and extend throughout the ROM. A computer navigation system (OrthoPilot; Aesculap, Tuttlingen, Germany) was used in all cases. The knee joint was exposed using a medial parapatellar approach and inspected for suitability of UKA. The notch osteophytes were removed. The femoral and tibial infrared tracers were secured on the femur and tibia, respectively.



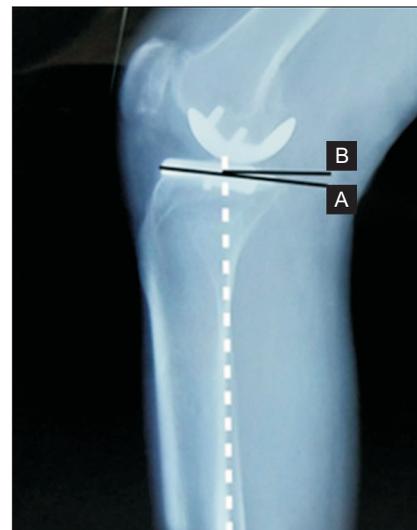
**Fig. 2.** Kennedy's zones. Optimal alignment: mechanical axis (AC) through zone C-2.



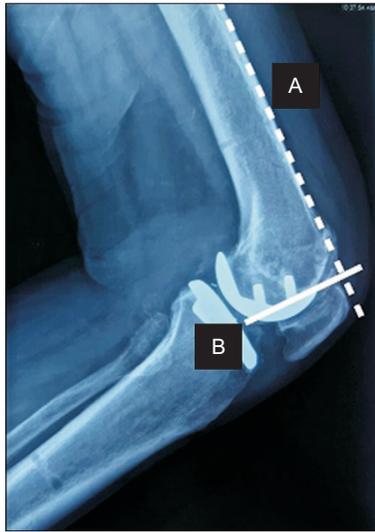
**Fig. 3.** Frontal positioning of tibial component. A: frontal plane of the tibial component, B: mechanical axis of tibia.



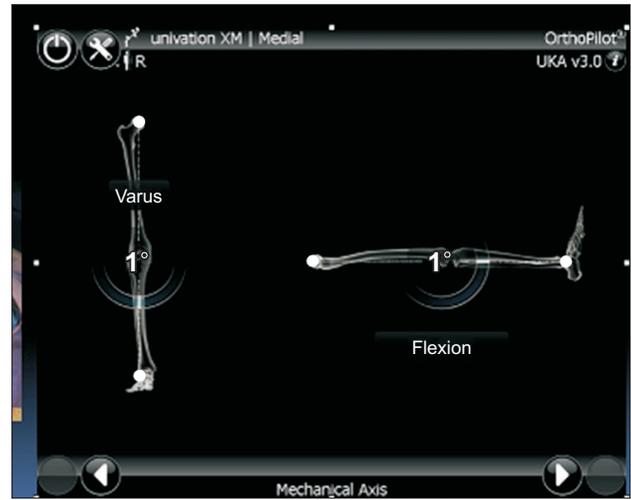
**Fig. 4.** Frontal positioning of femur (angle created by long axis of femur to horizontal axis).



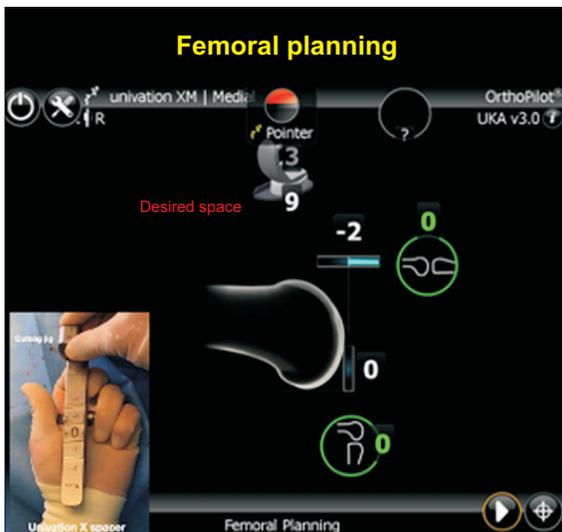
**Fig. 5.** Sagittal positioning of tibial component. A: horizontal axis of tibial component, B: a line perpendicular to a line drawn along posterior tibial cortex.



**Fig. 6.** Sagittal positioning of femoral component. Ideally, an implant is placed perpendicular to the line drawn along anterior femoral cortex. A: a line along the anterior femoral cortex, B: a line along distal femoral resection.



**Fig. 8.** Final limb alignment.



**Fig. 7.** Femoral planning on computer screen to achieve equal flexion and extension space. To achieve desired space of 9, computer is prompting to decrease distal femoral resection by 2 mm.

The registration of points inside the knee joint, hip center, and knee center was done as prompted by the computer. The extent of deformity and its correction could be demonstrated on a computer screen and recorded. The knees with residual varus angulation  $> 5^\circ$  on valgus stress and hyperextension  $> 10^\circ$  were switched to navigated TKA and excluded from the study. This was followed by securing a tibial cutting jig on the tibia under navigation guidance in neutral varus/valgus angulation and desired slope and

depth. The tibial cut was completed using a saw and confirmed with navigation. The flexion and extension spaces were registered into the computer using the tensor device. This was followed by femoral planning to obtain equal flexion and extension spaces (Fig. 7). The femur was cut through the jig guide secured on the femur under navigation. The medial meniscus and impinging osteophytes were removed. This was followed by the preparation of the tibial plateau and femoral condyle. The trial implants were placed and knee was assessed for stability, ROM, and limb alignment on a computer screen (Fig. 8). After a thorough wash and drying of bone surfaces, implants were cemented in an appropriate position, followed by the insertion of the meniscal bearing. The arthrotomy was closed in layers. All the patients received the same mobile-bearing unicompartmental knee implant, i.e., Univation (Aesculap).

### Statistical Analysis

Data were entered in Excel and analyzed using Stata 15.1 (StataCorp., College Station, TX, USA). Descriptive analysis of demographic and clinical characteristics was done using means (standard deviation [SD]) and number (percentage) as appropriate. Presence of residual varus angulation was considered significant if the angle was  $\geq 3^\circ$ . The clinical characteristics were analyzed based on the operated knee, while functional scores were analyzed at the patient level. Differences in mean (SD) functional scores at preoperative, 3-month postoperative, and final follow-up across patients with postoperative hyperextension and significant residual varus angulation were analyzed using *t*-tests. Multiple linear regression was done to analyze whether residual varus angulation and postoperative hyperextension were significantly associated with follow-up

KOOS-PS scores, after adjusting for age, sex, and bilateral surgery. A  $p < 0.05$  was considered statistically significant.

## RESULTS

A total of 50 knees (38 patients; 24 women and 14 men) were included in the study. The average time of follow-up was 29.4 months (range, 1–42; SD, 6.7 months). There were 12 bilateral knees (31.6%) and 26 unilateral knees (68.4%). The mean age of patients was 63.9 years (range, 51–84; SD, 10.9 years) (Table 1).

The data were gleaned from navigation machine to quantify preoperative deformities and postoperative limb alignment. The mechanical frontal limb alignment improved from mean preoperative varus  $7.6^\circ \pm 3.5^\circ$  (range,  $2^\circ$ – $14^\circ$ ) to mean postoperative varus  $1.24^\circ \pm 1.48^\circ$  (range,  $0^\circ$ – $5^\circ$ ;  $p \leq 0.001$ ). There was  $6.36^\circ \pm 2.4^\circ$  average improvement in varus after surgery. Forty-one knees had optimal frontal limb alignment of  $\leq 2^\circ$  varus. In 9 knees with tibia vara (range,  $4^\circ$ – $7^\circ$ ), postoperative frontal mechanical limb alignment varied from  $3^\circ$  to  $5^\circ$  varus (mean,  $3.77^\circ$ ; SD,  $0.83^\circ$ ).

The preoperative sagittal limb alignment ranged

from  $6^\circ$  hyperextension to  $9^\circ$  flexion. No sagittal plane deformity was present in 3 knees (6%). Thirty-three knees (66%) had mean preoperative flexion deformity of  $5.12^\circ \pm 2.20^\circ$  (range,  $1^\circ$ – $9^\circ$ ), which improved to mean postoperative flexion deformity of  $0.3^\circ \pm 0.81^\circ$  (range,  $0^\circ$ – $2^\circ$ ;  $p \leq 0.001$ ). Fourteen knees (28%) had mean preoperative hyperextension deformity of  $3.14^\circ \pm 1.6^\circ$  (range,  $1^\circ$ – $6^\circ$ ), which improved to mean postoperative hyperextension deformity of  $0.79^\circ \pm 0.8^\circ$  (range,  $0^\circ$  to  $2^\circ$ ;  $p \leq 0.001$ ). Neutral sagittal alignment was achieved in 27 knees (54%) postoperatively.

On the postoperative radiological assessment for Kennedy and White tibial zones, out of 41 knees (with optimal frontal alignment intraoperatively), 24 knees (48%) had the mechanical axis through zone C, in 13 knees (26%) mechanical axis passed to zone 2, and 2 knees (4%) in each zone 1 and zone 3. All 9 (18%) knees with tibia vara had the mechanical axis in zone 1.

Coronal placement of the tibial component ( $< 90^\circ$ , varus) averaged  $88.42^\circ$  (range,  $84^\circ$ – $90^\circ$ ; SD,  $1.57^\circ$ ), and there were 6 outliers (12%). The average sagittal placement (tibial slope) of the tibial component was  $5.10^\circ$  (range,  $0^\circ$ – $9^\circ$ ; SD,  $2.06^\circ$ ), and there were 7 outliers (14%). Coronal placement of the femoral component was on average  $1.16^\circ$  (range,  $-2^\circ$  varus to  $6^\circ$  valgus; SD,  $1.76^\circ$ ), and there were 5 outliers (10%). In 47 knees, the femoral component was implanted optimally in the sagittal plane. The component placement ranged from  $5^\circ$  flexion to  $4^\circ$  extension (mean,  $0.12^\circ$  extension; SD,  $1.98^\circ$ ), and 3 outliers (6%) were observed.

On the functional score assessment, KOOS-PS was calculated at 3 months and at final follow-up (minimum 16 months). The mean preoperative score was 77.02 (SD, 6.41), which improved to 64.92 (SD, 5.11) at 3 months and 40.77 (SD, 8.00) at the final follow-up. On univariate analysis, there was a statistically significant difference at 3 months ( $p = 0.024$ ) and the final follow-up ( $p = 0.045$ ) for residual varus angulation, with lower scores among patients with residual varus angulation. No significant difference was found for postoperative hyperextension at 3 months ( $p = 0.72$ ) and final follow-up ( $p = 0.25$ ). On multiple linear regression, residual varus angulation, postoperative hyperextension, and bilateral knee disease were not associated with 3-month or final follow-up KOOS-PS functional scores after adjusting for age, sex, and preoperative KOOS-PS functional scores.

## DISCUSSION

Various technical factors have been attributed to failed

**Table 1.** Demographic Profile of Patients

Variable	Total (n = 38)
Age (yr)	63.9 ± 10.9
Sex	
Male	14 (36.8)
Female	24 (63.2)
Side operated	
Bilateral	12 (31.6)
Unilateral	26 (68.4)
ASA classification	
I	12 (31.6)
II	16 (42.1)
III	10 (26.3)
Comorbidity	
Type II diabetes mellitus	14 (36.8)
Hypertension	21 (55.3)
Hypothyroidism	8 (21)
Coronary artery disease	5 (13.2)

Values are presented as mean ± standard deviation or number (%). ASA: American Society of Anesthesiologists.

UKA. Notable among these are component malposition and limb alignment-related errors.<sup>8)</sup> The conventional jig-based system is not reproducible in terms of implant positioning and limb alignment.<sup>9,10,14,15)</sup> So, we need an approach to avoid the technical errors associated with UKA failure. Computer navigation has a proven value to reduce mechanical errors in TKA.<sup>16-18)</sup> However, a lack of strong evidence impedes the universal use of computer navigation technology in UKA.<sup>19,20)</sup>

Song et al.<sup>21)</sup> compared outcome and survival after UKA between navigation and conventional techniques with an average 9-year follow-up. They reported a significantly higher number of outliers in final limb alignment and implant positioning in the conventional group. However, the navigated group also reported 16% outliers in final limb alignment, 10% and 30% outliers in the coronal and sagittal placement of the femoral component respectively, and 3.2% and 13.3% outliers in the coronal and sagittal placement of tibial component, respectively. In the present study, outliers in limb alignment and implant positioning ranged 6%–14% with imageless computer-assisted navigation. Other previous studies have also reported 0%–20% outliers in component positioning with navigation. Although various definitions exist for outliers, in general, deviation more than 3° from desired component placement is considered an outlier.<sup>14,15,21,22)</sup> Even after executing optimal bone cuts in the present study, there was a deviation of component orientation on postoperative radiographs. Computer navigation utilizes advance technology for the planning process but depends on the conventional oscillating saw system for execution of bone cuts. Previous studies have reported that significant errors can occur at bone resection and implant cementing steps even with the navigation system.<sup>23-25)</sup> The computer navigation used in the present study allowed us to crosscheck the accuracy of bony cuts only. The outliers in the present study can be attributed to error introduced during cementation and impaction of the final components, regardless of how accurately the bony resection was performed.<sup>25)</sup> Similarly, there was a discrepancy between radiological and computer navigation measurements of postoperative coronal plane limb alignment in the present study. This variation can be attributed to the supine and weight-bearing status of the patient during computer navigation and radiography, respectively.<sup>26-28)</sup>

Extra-articular deformity (tibia vara) contributed to all outliers in frontal mechanical limb alignment after

UKA in our study. The previous studies have reported that the patients with extra-articular deformity present with significantly larger preoperative frontal deformity. They advised avoiding UKA in patients with preoperative frontal deformity > 15° since the postoperative residual varus will exceed 7°–10°. This will affect long-term clinical and implant survival outcomes.<sup>2,3,29)</sup> In the present study, navigation enabled us to precisely quantify preoperative deformity and correctability before committing to UKA. Patients with residual varus angulation of > 5° on valgus stress were switched to navigated TKA on the table. This can be the reason for the lower percentage of tibia vara in the current study compared to Asian literature.<sup>29,30)</sup>

Genu recurvatum (hyperextension) is a predictor of poorer outcome after UKA.<sup>31)</sup> Proper intraoperative management of this deformity can improve clinical outcomes.<sup>15)</sup> In the present study, there was a significant reduction of hyperextension deformity after surgery and no difference in functional outcome was found among patients with or without hyperextension. The patients with preoperative hyperextension > 10°, confirmed intraoperatively with navigation, were switched to TKA.<sup>31)</sup>

Limitations of this study include the small sample size and absence of a control group. To conclude, present study further validates the role of computer-assisted navigation in accurate implant positioning and final limb alignment in UKA. We encourage use of computer-assisted navigation as a tool for patient selection, as it allows intraoperative dynamic goniometry and provides real-time kinematic behavior of the knee to obviate pitfalls such as significant residual varus angulation and hyperextension that predispose early failure of UKA. We encourage studies with larger cohorts to investigate the use of computer navigation in aforesaid propositions.

## CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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