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Comparative study of the use of computer assisted navigation system for axial correction in medial unicompartmental knee arthroplasty

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Abstract The aim of our study was to compare the use of the Orthopilot Navigation system with conventional non-navigation technique for medial UKA with respect to the intraoperative mechanical limb alignment measurements and correlation with the postoperative radiological measurements. The postoperative mechanical limb alignment axes of 51 consecutive medial unicompartmental knee arthroplasty performed by a single surgeon over a 12-month period were measured. The cases were randomly assigned to two groups of which 21 cases were performed using conventional non-navigation based technique and 30 cases were performed using the Orthopilot Navigation System. Computed tomography (CT) scanogram was performed for all cases within the same hospitalization stay to assess the postoperative mechanical limb alignment. Our results showed that the non-navigated group had a more neutral mechanical axis with a narrower range compared to the navigation assisted group. The difference in the mean mechanical axis between the two groups was statistically not significant. There was poor correlation between the intraoperative navigation system measurements and the postoperative radiological measurements. In conclusion, the use of computer navigation in UKA is not as well validated as compared to TKA. We did not demonstrate any improvement in postoperative axial limb alignment measurement in using a computer navigation system compared to conventional non-navigation technique.

Keywords Knee · Arthroplasty · Unicompartmental · Navigation · Computer assisted

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Introduction

Computer assisted surgery (CAS) is gaining popularity in arthroplasty with numerous studies reporting improved accuracy and decreased variability in implant placement position and postoperative limb alignment when compared to conventional techniques [1, 7, 9, 17–19, 23]. Most of these studies were based on total knee arthroplasty. In comparison, there is limited literature evaluating the application of computer navigation for unicompartmental knee arthroplasty (UKA) [6, 11–13]. Apart from proper patient selection and implant design, implant position and limb alignment are important factors that affect the prosthetic survival rate in UKA [5, 14, 20, 24].

We hypothesized that computer navigation system provided a more accurate and reproducible intraoperative mean of assessing the mechanical axis in medial UKA surgery compared to conventional non-navigation technique.

The aim of our study was to compare the use of the Orthopilot Navigation system with conventional non-navigation technique for medial UKA with respect to the intraoperative mechanical limb alignment measurements and correlation with the postoperative radiological measurements.

Materials and methods

Over a 12-month period from October 2006 to September 2007, a prospective and randomized study was conducted on 51 consecutive cases of medial unicompartmental knee arthroplasty performed by the senior author (JB) using the FREEDOM Knee system. During the same period, the senior author had also performed 158 cases of primary and revision total knee arthroplasty; and was experienced in the use of the Orthopilot Navigation System. The knee system consisted of cemented polyethylene tibial monoblock and cobalt chrome femoral component. The study cohort was randomized based on the last digit of their hospital registration number. Odd number was assigned to the non-navigated group and Even number was assigned to the navigation assisted group. Of the 51 cases of UKA, 21 cases were performed without the aid of computer navigation system and 30 cases were performed with the use of the Orthopilot Navigation system. Pre- and post-operative mechanical limb alignment measurements were made during the procedure using the navigation system. We defined our desired postoperative mechanical axis to be within 1° of valgus–varus deviation in each case. The selection of patients for unicompartmental knee arthroplasty was based on the criteria as stated in Table 1.

The use of the Orthopilot Navigation System involved the insertion of femoral and tibial arrays to facilitate the registration of critical bony landmarks and joint movements. This allowed the user to evaluate the mechanical limb alignment pre- and post-operatively utilising varus or valgus stress if desired. In our study, the high tibial osteotomy software was used for the navigation process. An arthrotomy was performed by a conventional medial parapatellar incision. The guide pins were inserted over the medial distal femoral condyle and the medial proximal tibia within the incision. The trackers were attached and registration of the required landmarks and joint movements were made. The pre-operative limb alignment including whether the angular deformity can be corrected was then recorded.

For both groups, bony resection of the proximal tibia was made with a resection block and extramedullary tibial guide. The distal femur was sized and a trough was burred to place the femoral prosthesis. The thickness of the tibial implant was determined by the tension of the medial ligaments and joint stability. No soft tissue release was performed. The final postoperative alignment was achieved with restoration of the joint space. Intraoperative limb alignment was assessed based on the use of alignment rod or computer readout for the respective groups.

Post-operatively, a drain was inserted and the patients were on antithrombotic prophylaxis and continuous passive movement regime. Postoperative ultrasound of the lower limb venous system was performed for all the cases. A Computed Tomography (CT) scanogram was performed within the same hospitalization stay to assess the postoperative mechanical limb alignment. The mechanical limb alignment is the angle subtended by a line from the centre of the femoral head to the centre of the knee joint and a line from the centre of the knee joint to the centre of the ankle mortise (Fig. 1). Using the Kennedy Protocol [14], a straight line was drawn from the centre of the femoral head to the centre of the ankle mortise. The area over the medial tibial plateau where the line crossed was recorded (Fig. 2). The frontal positioning of the tibial component was also measured on the CT scanogram. This is the angle subtended by frontal plane of the tibial component and a line from the central tibial intercondylar eminence to the centre of the ankle mortise (Fig. 3). The measurements were made on digital images using a DICOM viewer by a single observer (MHL) to minimize inter-observer variability.

Table 1 Indications for unicompartmental knee arthroplasty

Clinical criteria	
	1. Participate in low demand activities
	2. Good range of movement (115°) with <10° flexion contracture
	3. Minimal malalignment of <10° varus or valgus
	4. Stable knee joint with absence of subluxation, varus or valgus thrust on ambulation
Radiological criteria	
	1. Minimal involvement of contralateral tibiofemoral compartment and patellofemoral compartment
	2. Absence of underlying tibiofemoral osseous pathology eg. Cyst, lytic lesion

Fig. 1 Measurement of the limb mechanical axis on the CT scanogram

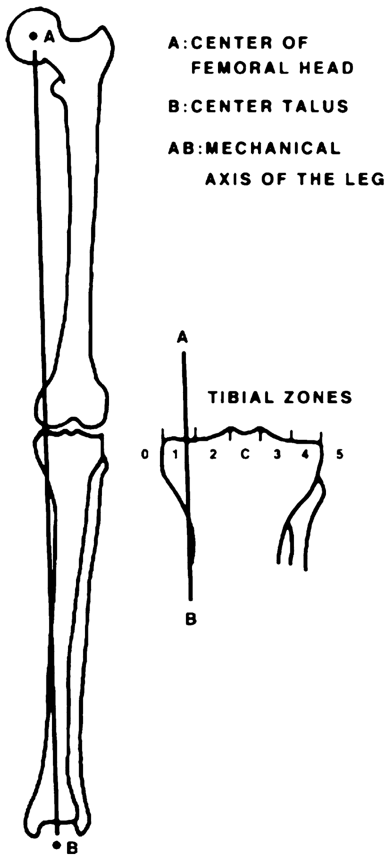

Fig. 2 Kennedy's protocol diagram

Fig. 3 Frontal alignment of tibial prosthesis

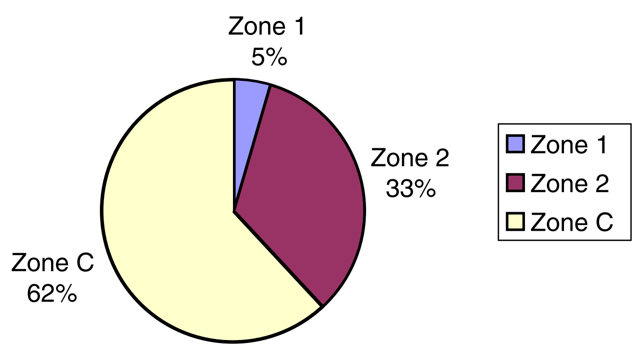

Fig. 4 Distribution of post-operative alignment based on Kennedy's protocol (non-navigation group). Total number of cases in non-navigated group = 21

Results

Non-navigation group

There were a total of 21 cases consisting of 52% females (11 cases) and a mean age of 72 years old (46–85 years old). The mean body mass index (BMI) of the group was 28.5 ± 6.0. The mean pre-operative clinical and functional Knee Society Score (KSS) were 28 (15–46) and 60 (45–70) respectively. Measurement of the limb mechanical axis on the CT scanogram revealed a mean axis of −2.8° ± 2.0° (−5.8° to 3.1°). 19% (4 cases) of the CT measurements were within the desired postoperative limb alignment assessed using the alignment rod. Based on the Kennedy Protocol [14], 95% of the cases had the mechanical axis passing through the desired tibial zones 2 and C (Fig. 4). Measurement of the frontal alignment of the tibial component on the CT scanogram revealed a mean alignment of 87.2° ± 1.5°.

Navigation assisted group

There were a total of 30 cases consisting of 50% females (15 cases) and a mean age of 60 years old (50–78 years old). The mean body mass index (BMI) of the group was 30.9 ± 6.3. The mean pre-operative clinical and functional Knee Society Score (KSS) were 29 (14–46) and 58.5 (50–70) respectively. Measurement of the limb mechanical axis on the CT scanogram revealed a mean axis of −3.3° ± 2.4° (−9.5° to 0.9°). 10% (3 cases) of the CT measurements were within the desired postoperative limb alignment based on the navigation system readings. Based on the Kennedy Protocol [14], 90% of the cases had the mechanical axis passing through the desired tibial zones 2 and C (Fig. 5). Measurement of the frontal alignment of the tibial component on the CT scanogram revealed a mean alignment of 87.0° ± 2.1°.

Overall results

The overall mechanical limb alignment for the study cohort was −3.1° ± 2.2°. Analysis of the difference in the mean mechanical alignment measurement using the Student's *T* test revealed no statistical significance ($P = 0.2$) between the mean differences in alignment between the two groups at 95% confidence level. The navigation-assisted group was found to have a wider range and increased outliers (Fig. 6).

The overall frontal alignment of the tibial component for the study cohort was 87.1 ± 1.9 degrees. Analysis of the difference in the frontal alignment of the tibial component using the Student's *T* test revealed no statistical significance ($P = 0.4$) between the mean differences in alignment between the two groups at 95% confidence level.

There was no post-operative complication such as infection, deep vein thrombosis and pin tract fracture in our series.

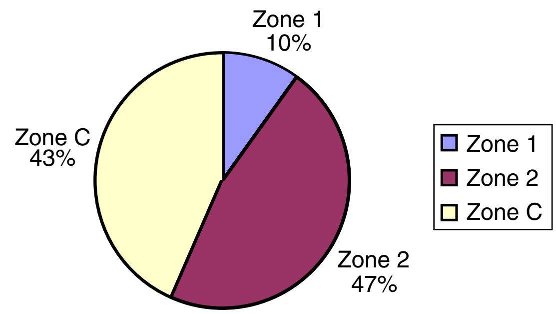

Fig. 5 Distribution of post-operative alignment based on Kennedy's protocol (navigation assisted group). Total number of cases in navigation assisted group = 30

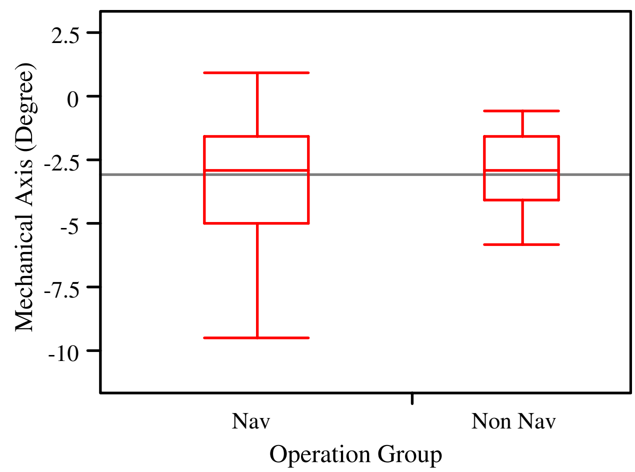

Fig. 6 Comparison of mechanical axis distribution between non-navigation and navigation assisted group

Discussion

Unicompartmental knee arthroplasty (UKA) is indicated in isolated medial or lateral compartment arthrosis with good functional range of movement and absence of significant knee deformity. It aims to resurface the diseased articulating surface and thereby enhancing the knee function. Various registries had consistently demonstrated that the survival rate of UKA is lower than total knee arthroplasty (TKA). Based on the Norwegian Arthroplasty Register from January 1994 to December 2004, Furnes et al. [8] reported a 10-year survival probability of 80.1% for UKA compared with 92% for TKA. Similar 10-year survival outcome for UKA of 73% based on the Finnish Arthroplasty Register from 1985 to 2003 was also reported by Koskinen et al. [16]. Likewise, the Australian Orthopaedic Association National Joint Replacement Registry [2] reported that UKA had a 5-year cumulative percent revised of 8.9% compared to 3.6% for primary TKA based on data from September 1999 to December 2006. The Swedish Registry [22] reported that the cumulative revision rate for UKA was more than two times that of TKA based on data from 1994 to 2004.

Bearing in mind the lower survival rate of UKA, it is therefore critical to have proper patient selection and sound surgical techniques. Alignment, ligament balance and implant fixation were identified by Whiteside [24] as essential areas in UKA surgery. Collier et al. [5] studied the factors associated with revision of medial compartment unicondylar arthroplasty and concluded that varus angulation of the medial tibial plateau and knee at surgery is associated with a higher revision rate. Undercorrection in varus and overcorrection in valgus of the preoperative deformity (hip–knee–ankle angle) is associated with a higher rate of polyethylene wear and degenerative changes in the opposite compartment [10]. Therefore, improved alignment after arthroplasty is associated with better function and longevity.

The development of a computer navigation system as a tool to aid the surgeon in achieving ideal implant position and post-operative limb alignment is a logical and attractive adjunct. Numerous studies [1, 7, 9, 17–19, 23] had reported the enhanced accuracy for implant placement in total knee arthroplasty using a computer navigation system with the aim of improving clinical outcome. In comparison, there is limited literature evaluating the application of computer navigation for UKA [6, 11–13]. Cossey et al. [6] demonstrated in 30 consecutive patients that UKA performed with computer assisted surgical navigation resulted in a more accurate and reproducible limb alignment than UKA performed without surgical navigation. Keene et al.

[13] also reported similar findings in 20 patients who underwent bilateral medial UKA.

Despite the promising evidence of enhanced implant positioning using computer navigation system in arthroplasty, it has not conclusively translated to good clinical outcome. In a meta-analysis by Bauwens et al. [3], 33 studies involving 3,423 patients who underwent navigated total knee replacement were reviewed. The alignment of the mechanical axes did not differ between the navigated and conventional surgery group. Patients managed with navigated surgery had a lower risk of malalignment. However, no conclusive inferences could be drawn on functional outcome or complication rate. Spencer et al. [21] reported that the clinical outcome of patients with computer-navigated knee replacement appears to be no different to that of a more conventional jig-based technique at 2 years post-operatively, despite the better alignment achieved with computer navigated surgery.

We hypothesized that computer navigation system provided a more accurate and reproducible intraoperative mean of assessing the mechanical axis in UKA surgery compared to conventional non-navigation technique. However, contrary to majority of the current literature, the use of computer navigation in our study did not enhance the accuracy and variability of the limb alignment. There was poor correlation between the intraoperative navigation readings and the postoperative limb alignment measurement. This was similarly reported by Kim et al. [15] that computer assisted navigated TKA did not result in more accurate orientation and alignment than that achieved by conventional TKA. The possible causes of these conflicting results could be due to the navigation registration process, system accuracy or software incompatibility. The study outcome highlights the need to review the software to be designed specifically for UKA, regular system calibration and most importantly, a good foundation and knowledge in conventional surgical techniques. We agree with Bejek et al. [4] that the computer navigated technique does not substitute professional skills and experience, since it merely transmits information for the surgeon. The decision is in the hands of the doctor during the entire procedure.

Kennedy et al. [14] had reported that superior results were obtained when the mechanical axis fell in Zone C or 2 and concluded that final limb alignment of a medial compartment arthroplasty will be a major factor in the long-term success of the operation. Zone C was defined as the area between the tibial spines and Zone 2 was defined as the area between the lateral half of the medial tibial plateau and the medial tibial spine. After surgery, the femorotibial angles averaged 3° and 6° of valgus in Zone 2 and C respectively. Our case selection and surgical techniques aimed to achieve the desired zones of post-operative mechanical axis alignment. We defined our desired post-operative mechanical axis to be within 1° of valgus–varus deviation. Most of the cases had postoperative mechanical axes that fell into Zones 2 and C.

The aim of our study was to compare the use of the Orthopilot Navigation system with conventional non-navigation technique for medial UKA with respect to the intraoperative mechanical limb alignment measurements and correlation with the postoperative radiological measurements. The bony resections for both groups were performed with conventional jigs. The navigation system was utilised primarily to demonstrate the limb alignment. Therefore, the absolute positioning of the femoral and tibial implants was not the focus of our study. Moreover, the CT scan protocol performed for our study was not suitable for measuring sagittal alignment of the tibial implant as well as position of the femoral implant. This was because the protocol consisted of a scanogram and localised view of the knee joint. The detailed scan did not extend to the hip joint or ankle mortise. Nonetheless, we were able to measure the frontal positioning of the tibial component on the CT scanogram. Analysis of the mean difference in the frontal alignment of the tibial component of the two groups revealed no statistical significance.

Computed tomography scan is the investigation of choice as it provides a better evaluation of the cement–polyethylene interface when a polyethylene tibial monoblock is used compared to plain radiograph. The concern for the use of non-weightbearing CT scan is negated by the fact that the computer calculations are obtained in a non-weightbearing situation which is reproduced with the CT scan. Our results showed that under the same CT scan condition, a higher percentage of cases using the conventional technique had a more neutral mechanical axis compared to those using computer navigation. However, there was no statistical significance in the difference between the two groups. There was poor correlation between the intraoperative navigation system measurements and the post-operative radiological measurements.

In conclusion, the use of computer navigation in UKA is not as well validated as compared to TKA. We did not demonstrate any improvement in postoperative axial limb alignment in using a computer navigation system compared to the non-navigation technique.

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