Comparative Study Between Computer Assisted-Navigation and Conventional Technique in Minimally Invasive Surgery Total Knee Arthroplasty, Prospective Control Study

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Background: *Both Minimally Invasive surgery (MIS) and Computer-Assisted Surgery (CAS) are useful in Total Knee Arthroplasty (TKA). Minimally invasive total knee arthroplasty was associated with decreased blood loss, shorter hospital stays, and increased range of motion. Computer-assisted surgery in total knee arthroplasty was developed to improve the positioning of implants during surgery.*
Objective: *To evaluate radiographic results relative to component position and limb alignment when using a navigation system compared with conventional technique in MIS-TKA.*
Material and Method: *A prospective control study was performed in 180 patients who underwent total knee arthroplasty by one surgeon. All patients were randomly divided into two groups, Conventional and Navigation TKA. Intra-, post-operative data, and postoperative limb alignment were recorded for comparison in both groups.*
Results: *The postoperative mechanical axis was within 3° of neutral mechanical alignment in 94% of the navigation group and 87% in conventional group (p = 0.13). Registration time of navigation group is 13.58 minutes. No statistical significant difference was found in tourniquet time and postoperative blood loss in both groups.*
Conclusion: *The use of navigation in total knee arthroplasty increases accuracy in limb and implants alignment, and does not increase complications and surgical times.*

Keywords: *Computer-assisted surgery, Minimally invasive surgery, Total knee arthroplasty*

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There has been an increasing interest in the use of minimally invasive techniques (MIS) for total knee arthroplasty. Tria evaluated the results of the minimally invasive total knee arthroplasty that this technique was associated with decreased blood loss, shorter hospital stays, increased range of motion, and similar implantation accuracy when compared with standard total knee replacement[1]. Kolisek reported the results of a minimally invasive midvastus approach were compared with a standard parapatellar approach. The author reported nearly equal Knee Society scores for the two groups and higher SF-12 scores for the minimally invasive group[2]. Laskin evaluated the results of 150 consecutive procedures that had been performed with use of the “mini-midvastus” approach and found an average increase of six minutes in operative time, with the patients more rapidly achieving 90° of flexion and stair-climbing postoperatively[3].

However, the minimally invasive surgery group had more complications (including patellar tendon injury and lateral femoral condyle fracture) and more radiographic outliers (varus tibiae)[4].

Similarly, Dalury compared TKA that were treated either with minimally invasive surgery or with a standard approach. While the knees in the minimally invasive surgery group were associated with a longer surgical time, increased minor wound-healing

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complications, and more frequent tibial component malalignment[5].

Incorrect positioning or orientation of the implant and improper alignment of the limb can lead to accelerated implant wear and loosening as well as suboptimal function performance. A number of studies have suggested that alignment errors of > 3° are associated with more rapid failure and less satisfactory functional results after total knee arthroplasty[6-8]. Jeffery et al[9] evaluated 115 patients radiographically and found a loosening rate of 24% with a postoperative mechanical alignment beyond 3° varus or valgus vs. a 3% loosening rate when mechanical alignment was within 3° of varus or valgus. Therefore, the target alignment is neutral mechanical alignment, with an acceptable range of 3° varus to 3° valgus. Berend et al[10] investigated tibial component failure mechanisms, noting that malalignment of the tibial component in more than 3° of varus increased the odds of failure. Intramedullary and extramedullary alignment systems have improved postoperative alignment results[11,12]. Unfortunately, there are limitations in the use of the systems in obesity, postfracture deformity, narrow canals, severe bowing, and after total hip arthroplasty, as well as continued difficulty in achieving consistently accurate alignment.

Computer-assisted surgery in total knee arthroplasty was developed to improve the positioning of implants during surgery. These systems include image-based and image-free navigation systems. Image-based systems use preoperative computed tomograph scans or operative fluoroscopic images to assist in implant positioning. Image-free navigation systems use information obtained in the operating suite with the aid of infrared probes. Early data on the use of these systems appear positive with improved mechanical alignment, frontal and sagittal femoral axis, and frontal tibial axis, and without increased complications compared with hand-guided techniques[13].

The use of computer-assisted surgery by orthopedists experienced in total knee arthroplasty results in better overall limb and implant alignment and fewer outliers compared with the findings after manual total knee arthroplasty.

The first goal of the present study was undertaken to evaluate radiographic results relative to component position and limb alignment when using a navigation system as compared with conventional method when used by a high-volume surgeon. The second goal was to assess the intraoperative and postoperative data between both groups.

Material and Method

One hundred and eighty consecutive total knee arthroplasties were performed at Orthopedic Department, Phramongkutklao Hospital, Bangkok, Thailand between June 2006 and May 2007 by one surgeon (TC) who had extensive prior experience with both computer-assisted surgery and manual total knee arthroplasty. Of the one hundred and eighty, ninety-four were performed with manual instruments and eighty-six were performed with computer-assisted surgery. Demographic data were reviewed from the database and patient charts. Preoperative data included preoperative diagnosis, age, gender, and surgical technique. The patient characteristics are shown in Table 1.

Patients were excluded from the study if previous bony procedures about the knee had been performed or if complete or satisfactory radiographs for accurate measurements were unavailable for evaluation.

Intraoperative data included registration time for navigation and tourniquet time.

Postoperative blood loss was recorded from radivac drain content.

Surgical procedures

All patients underwent arthrotomy by 2 cm limited quadriceps exposure minimally invasive surgery total knee arthroplasty (2 cm Quad MIS TKA)[14].

PFC posterior-stabilized implants (DePuy Warsaw, IN) were used in all patients. The Brainlab navigation system (DePuy Warsaw, IN) was used for computer-assisted total knee arthroplasty. The conventional group underwent total knee arthroplasty with the use of an intramedullary femoral guide and extramedullary tibial guide.

Postoperative radiographic measurements of anterior-posterior mechanical axis and the sagittal tibial and femoral axes were evaluated by an observer (KT) who was blinded to the surgical technique.

Table 1. Demographic data of the patients

	Conventional	Navigation
No. of patients	94	86
Male	11 (64.7%)	6 (35.8%)
Female	83 (50.9%)	80 (49.1%)
Mean Age (yr)	67.8 $\pm$ 7.14 (47-81)	67.2 $\pm$ 6.46 (53-80)
Diagnosis		
OA	86 (51.2%)	82 (48.8%)
RA	8 (66.7%)	4 (33.3%)

Fig. 1 Full weight bearing alignment radiograph

Postoperative mechanical axis were determined from full-length weight-bearing radiographs (Fig. 1). The coronal alignment of the tibial and femoral components were evaluated by measuring the angle developed from a line tangential to the baseplate of the tibial component and the distal femoral condyles with respect to the mechanical axis (Fig. 2). Tibial slope and alignment of the femoral prosthesis were evaluated from lateral radiographs (Fig. 3).

Statistical analysis

Data were expressed as mean ± standard deviation (x ± SD) and range or percent with number. Student's two tailed test was used to compare between groups for continuous variables. Chi-square test and Fisher's exact test were used to analyze the differences between categorical variables. A p-value of < 0.05 was considered statistically significant.

Results

In the conventional group, nine patients were excluded because of unsatisfactory radiographs, resulting in 94 patients evaluated. Eighty-six patients had primary osteoarthritis and eight patients had rheumatoid arthritis. In the navigation group, six patients were excluded because of previous high tibial osteotomy or unsatisfactory radiographs, resulting in 86 patients evaluated. Eighty-two patients had primary

Fig. 2 Anteroposterior radiographic measurement of coronal alignment of tibial and femoral components

Fig. 3 Lateral radiographic measurement of sagittal alignment of tibial and femoral components

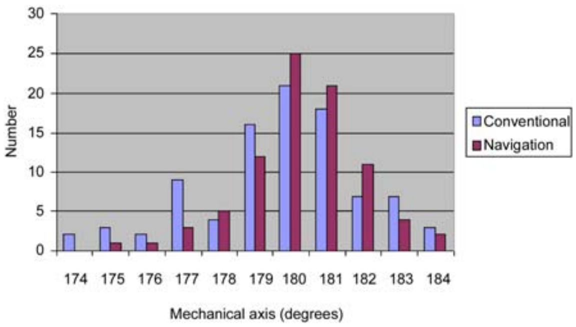

Fig. 4 Postoperative mechanical alignment

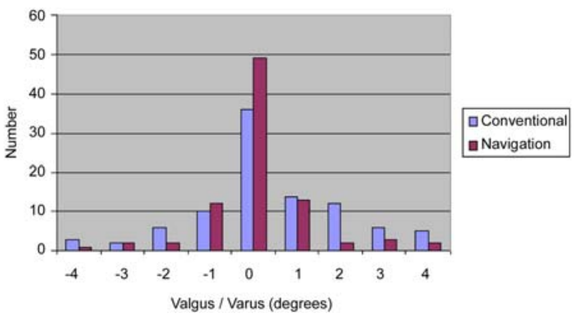

Fig. 5 Tibial component coronal alignment

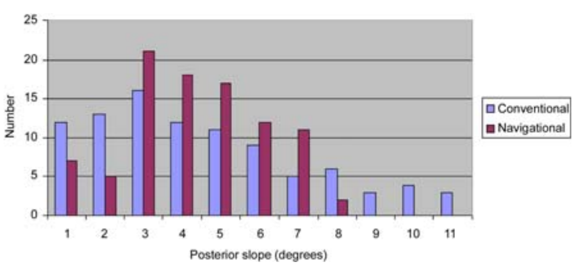

Fig. 6 Tibial component sagittal alignment (tibial slope)

osteoarthritis and four patients had rheumatoid arthritis.

With the numbers available, there was no statistical difference between the navigation group and the conventional group with regard to preoperative diagnosis, age and gender ($p < 0.05$).

The mean postoperative mechanical axis was 179° in the conventional group and 180.3° in the navigation group. The conventional group postoperative mechanical axis was within 3° of neutral alignment in 87% of cases compared with 94% of the navigation group (p = 0.131, Fisher's Exact test).

The postoperative tibial component alignment was 0.38° ± 1.74° valgus in the conventional group and neutral (0° ± 1.25°) in the navigation group (p = 0.199). Tibial posterior slope was 3.53° ± 2.75° in the conventional group and 3.10° ± 1.66° in the navigation group (p = 0.205).

The postoperative femoral component coronal alignment was 0.6° ± 2.13° valgus in the conventional group and 0.2° ± 1.55° varus in the navigation group ($p < 0.005$)*. The sagittal alignment of the femoral component was 1.52° ± 2.78° flexion in the conventional group and 1.10° ± 2.28° flexion in the navigation group (p = 0.272).

Intraoperative data, the tourniquet time was 100.46 minutes for the conventional group and 105.00 minutes for the navigation group (p = 0.44, two-tail t-test). Registration time for navigation was 13.58 minutes (range 11-20 mins). No intraoperative complications were noted in either group.

Postoperative blood loss (record from radivac drain content) was 361 ± 47.7 ml for the conventional group and 338 ± 121.2 ml for the navigation group (p = 0.212, two-tail t-test).

Discussion

The present study was undertaken to evaluate early outcomes of the use of an image-free navigation

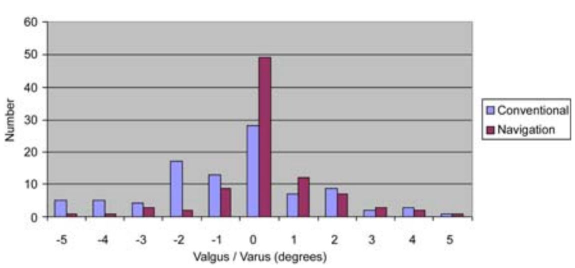

Fig. 7 Femoral component coronal alignment

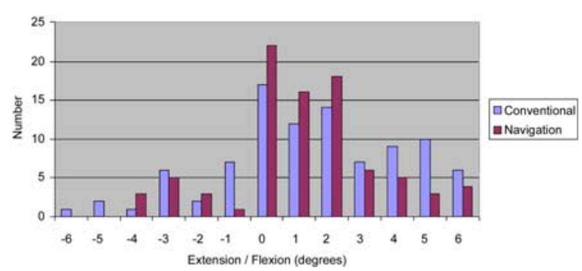

Fig. 8 Femoral component sagittal alignment

system compared with conventional methods when used by a high-volume total joint surgeon. There were no statistically significant differences noted between the control group that used conventional intramedullary femoral guides with extramedullary tibia guides and the navigation group relative to the overall postoperative mechanical alignment. However, the navigation system narrowed the range of alignment measures, that is, more uniform and consistent placement within 3° of neutral. In addition, the desired postoperative alignment of the individual components with the exception of femoral component coronal alignment was different with statistical significance.

A limitation of the present study was the accuracy of radiographic measurements. Variations in rotation of the lower extremity and orientation of the x-ray beam may alter the true projections. The quality of radiographs was similar among the navigation and conventional groups. Any radiograph that appeared rotated was eliminated from the data to improve the accuracy of measurements. The relatively large sample size and identical technique of measurement in both groups contribute to the validity of these data.

The present study does not include functional outcomes and clinical outcomes, so may be different in both groups of study. However, the long-term success of total knee arthroplasty is highly dependent on proper limb and implant alignment.

Navigation did not increase tourniquet time. Registration time for navigation was 13.58 minutes. Importantly, no complications were noted to be related to the use of the navigation system.

The duration of stay in hospital was not different in both groups because the authors used the same clinical practice guideline for 5 days.

The navigation system provided more reliable and reproducible mechanical alignment within 3° of neutral alignment. These data showed fewer outliers and increased accuracy of alignment in the navigation group. The improved alignment of the components may influence the longevity of the implants.

Most reports have demonstrated that total knee replacements implanted with computer-assisted navigation have more accurate component alignment, on the basis of plain radiographs, than those implanted conventionally[15,16]. The improvement of accuracy through computer assistance has been shown to be a few degrees, which is within the range of inaccuracy produced by projection-related errors in standing radiographs. Kai Bauwens showed that the alignment of the mechanical axis did not differ between the navigated and conventional surgery group (weighted mean difference, 0.2°; 95% confidence interval, -0.2° to 0.5°). Patients managed with navigated surgery had a lower risk of malalignment at critical thresholds of > 3° (risk ratio, 0.79; 95% confidence interval, 0.71 to 0.87) and > 2° (risk ratio, 0.76; 95% confidence interval, 0.71 to 0.82)[17]. Georg Matziolis showed that overall mechanical axis has a range between 4.8° valgus and 6.6° varus alignment in the frontal plane for conventionally implanted arthroplasty components compared with a significantly smaller range between 2.9° valgus and 3.1° varus alignment for computer-assisted implantations ($p = 0.004$)[18].

The fact that the authors do not know the association between implant alignment and early postoperative range of motion and Knee Society scores may be explained by the considerably low deviation from the designated axis in the collective group of patients. In fact, a slight component malalignment may only be a cofactor beside instability and soft-tissue trauma, leading to restricted range of motion and function[19], but it still may promote early loosening through increased wear caused by suboptimal implant loading[20]. It remains for future investigations to determine the extent to which these results raise hopes of improving the long-term outcome of total knee arthroplasties.

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การศึกษาเปรียบเทียบระหว่างเทคนิคการใช้คอมพิวเตอร์ช่วยผ่าตัด และการผ่าตัดแบบปกติ ในการผ่าตัดข้อเข่าเทียมแบบมีการบอบช้ำต่อเนื้อเยื่อน้อย

ธไนนิธย์ โชตนภูติ, พิพัฒน์ องค์น้ำทิพย์, กฤกษ์ ธีรลีกุล, เฉลิมฤทธิ์ กระตุกฤกษ์

ภูมิหลัง: *เทคนิคการผ่าตัดที่มีความบอบช้ำกับเนื้อเยื้อน้อย (minimally invasive surgery) และเทคนิคการใช้คอมพิวเตอร์ช่วยในการผ่าตัด (computer assisted surgery) ต่างมีประโยชน์เมื่อนำมาใช้ในการผ่าตัดข้อเข่าเทียม เทคนิคการผ่าตัดที่มีความบอบช้ำกับเนื้อเยื้อน้อยช่วยลดการสูญเสียเลือด ลดระยะเวลาการอยู่ในโรงพยาบาล และทำให้การเคลื่อนไหวของข้อได้ดี การผ่าตัดโดยการใช้คอมพิวเตอร์ช่วยผ่าตัดในการผ่าตัด ช่วยทำให้การวางตำแหน่งของข้อเทียมได้แม่นยำมากขึ้น การใช้เทคนิคทั้งสองอย่างร่วมกันจะทำให้ การผ่าตัด ได้ผลดียิ่งขึ้น*

วัตถุประสงค์: *เพื่อประเมินแนวแกนของขา (mechanical axis) และตำแหน่งของข้อเทียมจากภาพถ่ายรังสีภายหลังการผ่าตัดข้อเข่าเทียม เปรียบเทียบกันระหว่างกลุ่มที่ผ่าตัดแบบปกติ และกลุ่มที่ใช้คอมพิวเตอร์ช่วยผ่าตัดในการผ่าตัด นอกจากนี้ยังประเมินระยะเวลาของการผ่าตัดและปริมาณของเลือดที่ออกหลังการผ่าตัดด้วย*

วัสดุและวิธีการ: *เป็นการศึกษาเปรียบเทียบการผ่าตัดข้อเข่าเทียมเทคนิคที่มีความบอบช้ำกับเนื้อเยื่อน้อย จำนวน 180 ข้อ โดยแบ่งเป็นสองกลุ่ม ได้แก่กลุ่มที่ใช้การผ่าตัดแบบปกติ (conventional) และการผ่าตัดโดยการใช้คอมพิวเตอร์ช่วยผ่าตัดในการผ่าตัด โดยแพทย์ที่มีความชำนาญเพียงท่านเดียว โดยเก็บรวบรวม ข้อมูลก่อน ระหว่าง และหลังการผ่าตัด*

ผลการศึกษา: *หลังการผ่าตัดแนวแกนของขา ที่อยู่ภายใน 3 องศาจากแนวกลาง เท่ากับ 94% ในกลุ่มการใช้คอมพิวเตอร์ช่วยผ่าตัดในการผ่าตัดและเท่ากับ 87% ในกลุ่มที่ใช้การผ่าตัดแบบปกติ ซึ่งไม่มีความแตกต่างอย่างมีนัยสำคัญทางสถิติ เวลาที่ใช้ในการป้อนข้อมูล (registration time) ของการใช้คอมพิวเตอร์ช่วยผ่าตัดคือ 13.58 นาที ไม่มีความแตกต่างกันของระยะเวลาของการผ่าตัดและปริมาณของเลือดที่ออกหลังการผ่าตัดของทั้งสองกลุ่ม*

สรุป: *การใช้คอมพิวเตอร์ช่วยผ่าตัดในการผ่าตัดข้อเข่าเทียมจะสามารถเพิ่มความแม่นยำในการวางตำแหน่งของข้อเทียมและแนวของขาได้ดีขึ้น โดยไม่เพิ่มภาวะแทรกซ้อนและเวลาในการผ่าตัด*