Comparison of Accuracy between Side-Cutting Instruments and Front-Cutting Instruments in Minimally Invasive Total Knee Arthroplasty

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Background: *The specialized instrument system used in minimally invasive surgery (MIS) has been developed for reducing soft tissue trauma in total knee arthroplasty (TKA). Compared with front-cutting MIS instruments, side-cutting quadriceps sparing MIS instruments have the advantage of creating a smaller incision and causing fewer traumas to the quadriceps tendon. However, the accuracy of side-cutting instruments concerns surgeons in prosthesis malalignment.*
Objective: *To compare the accuracy of side-cutting quadriceps sparing instruments versus front-cutting instruments in MIS-TKA.*
Material and Method: *In this prospective randomized controlled study, we compared the accuracy of side-cutting quadriceps sparing instruments versus the front-cutting instruments used in MIS-TKA. Sixty knees were included in the study, with 30 knees in each group. All the operations were performed by single surgeon. Coronal alignment (tibiofemoral angle, lateral distal femoral angle, and medial proximal tibial angle), and sagittal alignment (femoral component flexion and tibial posterior slope) were measured and compared.*
Results: *Tibiofemoral angle, lateral distal femoral angle, and medial proximal tibial angle, all of which are considered in the assessment of acceptable coronal radiographic alignment, were not different between groups (p = 0.353, 0.500, and 0.177, respectively). However, side-cutting quadriceps sparing instruments produced less acceptable sagittal radiographic alignment, femoral component flexion (63% vs. 93%, p = 0.005), and tibial posterior slope (73% vs. 93%, p = 0.04).*
Conclusion: *Side-cutting quadriceps sparing MIS-TKA instruments had similar accuracy to front-cutting MIS-TKA instruments for coronal alignment but is less accurate for sagittal alignment.*

Keywords: *Total knee arthroplasty, Minimally invasive surgery, Instruments, Accuracy, Osteoarthritis*

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Total knee arthroplasty (TKA) is currently regarded as one of the most successful surgical procedures because of the early post-operative mobilization, early return to normal activities of daily living, and improved quality of life. Minimally invasive surgery (MIS) technique was developed to reduce soft tissue invasion, blood loss, and postoperative pain as well as promote an early recovery of quadriceps function, accelerated rehabilitation, and improved cosmetic outcome[1]. Different MIS-TKA systems have been developed that use different cutting jigs. Side-cutting Quadriceps-Sparing (QS) instruments were designed to minimize quadriceps exposure and reduce injury to the quadriceps tendon, as compare to front-cutting instruments. The potential disadvantage of side-cutting QS instruments that makes surgeons hesitant to use them is the accuracy of the cutting jigs[2,3]. Malalignment of the prosthesis due to limited exposure can lead to poor functional outcomes and early failure of the TKA[4].

The aim of this study was to investigate the accuracy of side-cutting QS instruments compared with front-cutting instruments in MIS-TKA.

Material and Method

This prospective randomized study was designed to compare the accuracy of side-cutting QS instruments with front-cutting instruments used in MIS-TKA, and all patients scheduled for TKA were invited to participate. Sixty knees were included in the study and randomized into two groups. Thirty knees (27 patients) were in the side-cutting QS instrumentation group (Group 1) and 30 knees (27 patients) were in the

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front-cutting instrumentation group (Group 2). Patient randomization was performed by computer randomization software. Patients who met the eligible criteria for TKA (40 to 80 years of age, diagnosed as primary osteoarthritis or inflammatory arthritis, and failed conservative treatment) were included in the study. Ten patients were excluded for the following reasons: MIS-TKA was deemed not appropriate (5 patients), limited range of motion with less than 90° of flexion (2 patients), flexion contracture more than 15° (1 patient), and prior knee surgery (2 patients). Three scheduled TKA patients were invited to participate, but declined to do so. One set of pre-numbered, sealed envelopes was prepared for each stratum and subjects were assigned to the group specified in the envelope.

All procedures were performed by a single orthopedic surgeon (Pinsornsak P) who had extensive experience in MIS-TKA. All operations were performed at Thammasat University Hospital, Thailand. The 30 knees in Group 1 were operated on using side-cutting MIS Quad-Sparing™ instrumentation (Zimmer, Warsaw, IN, USA) with the Zimmer Nexgen® Complete Knee Solution Legacy® Posterior-Stabilized (LPS)-Flex Fixed Bearing Knee System (Zimmer, Warsaw, IN, USA). The 30 knees in Group 2 were treated using the front-cutting MIS-TKA instrument (Smith & Nephew Inc., Memphis, TN, USA) with Genesis™ II posterior-stabilized knee system (Smith & Nephew Inc., Memphis, TN, USA). Palacos G bone cement without antibiotics (Biomet Orthopedics, Warsaw, IN, USA) was used for cemented fixation in all cases. The protocol for this study was approved by the Institutional Review Boards.

Surgical technique

After sterile draping and tourniquet inflation, a limited medial parapatellar skin incision (~10 cm length) was used to expose the knee joint. The visible osteophyte was removed, and the Anterior Cruciate Ligament (ACL) and Posterior Cruciate Ligament (PCL) were cut at their femoral origin. No patellar eversion was performed. The measure resection technique for TKA was used in both group of patient. Intramedullary femoral drilling was performed 1 cm above the PCL insertion. In Group 1, the side-cutting MIS Quad-Spaing™ instrument (Zimmer, Warsaw, IN, USA) was used to perform the distal femoral cut. The valgus angle was set and cut at 5° from anatomical axis in all cases, cutting from the medial to lateral side of the distal femur (Fig. 1). The tibial cut was performed perpendicular to the mechanical axis of the tibia, with aiming of 6° posterior slope. The MIS tibial cutting jig with extramedullary alignment guide was used to cut the tibial articular surface from the anteromedial tibial plateau to the lateral side (Fig. 1). Extension gap balancing was performed, followed by the AP femoral cut aiming external rotation 3° from posterior condylar axis and flexion gap balancing. The finishing cut for femoral and tibial implantation was then performed. The cemented Zimmer Nexgen® Complete Knee Solution Legacy® Posterior-Stabilized knee was inserted using bone cement without antibiotics. In Group 2, the front-cutting MIS-TKA instrument (Smith & Nephew Inc., Memphis, TN, USA) was used for distal femoral cut. The cutting was performed aiming for 5° valgus from anatomical axis and cut from the superior to inferior surface of the femur (Fig. 2) The tibial cut, using MIS extramedullary tibial alignment guide, was made perpendicular to the mechanical axis with aiming for 3° posterior slope (the polyethylene insert of Genesis™ II posterior-stabilized prosthesis has 3° built in posterior slope) by using the extramedullary MIS tibial cutting guide from anteromedial to the lateral tibial plateau (Fig. 2). Extension gap balancing was performed and followed

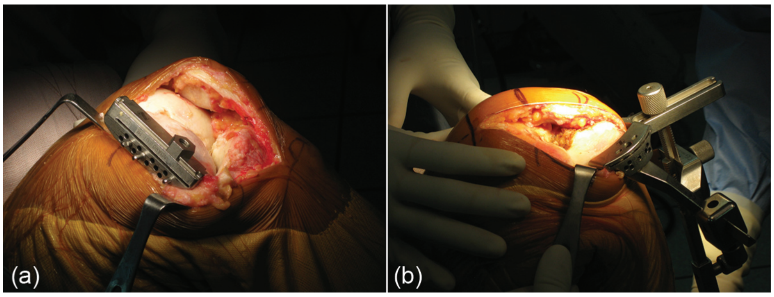

Fig. 1 (a) Distal femoral cut from the medial to lateral side of the distal femur using a side-cutting MIS Quad-Sparing™ instrument. (b) Tibial cut from the anteromedial tibial plateau to the lateral side using an MIS extramedullary tibial alignment guide.

by the anteroposterior (AP) femoral cut 0° external rotation from posterior condylar axis (the Genesis™ II posterior-stabilized femoral component has 3° build in external rotation) with flexion gap balancing as in the first group. The cemented Genesis™ II posterior-stabilized prosthesis was then inserted using bone cement without antibiotics.

Radiographic evaluation

Pre-operative and 3-month follow-up radiographs were compared and evaluated for limb alignment and prosthesis position using three feet weight bearing standing radiographs. The AP and lateral radiographs were used for evaluation and measured by a single doctor (Harnroongroj T). In AP radiograph, tibiofemoral angle, lateral distal femoral angle (LDFA), and medial proximal tibial angle (MPTA) were measured. In lateral radiograph, tibial posterior slope and femoral component alignment were evaluated (Fig. 3). Acceptable alignment was considered to be within ±3° of ideal alignment on all planes.

Statistical analysis

All statistical analyses were performed using SPSS software version 18.0 (SPSS Inc., Chicago, IL, USA). Differences in categorical variables were analyzed by Chi-squared test and continuous variables were analyzed by unpaired t-test. Data were presented as mean ± standard deviation or number and percentage. The data were collected from both patient medical charts and radiographs. We focused on the difference between the radiographic alignment and the acceptable radiographic alignment (within 3° of anticipated angle) data of groups 1 and 2. A p-value <0.05 was considered statistically significant.

Results

Pre-operative demographic and clinical data of all patients are shown in Table 1. Postoperative radiographic alignment and number of patients within acceptable alignment are shown in Table 2 and 3.

Coronal alignment parameters

For the tibiofemoral angle, postoperatively, we anticipated a valgus angle of 5°. The average valgus angle was 5.3°±2.1° in Group 1, and 5.9°±2.4° in Group 2. There was no difference in acceptable alignment between groups (90% vs. 83%, respectively, $p = 0.35$).

For the LDFA, we anticipated a valgus angle of 95°. There was very little difference between mean

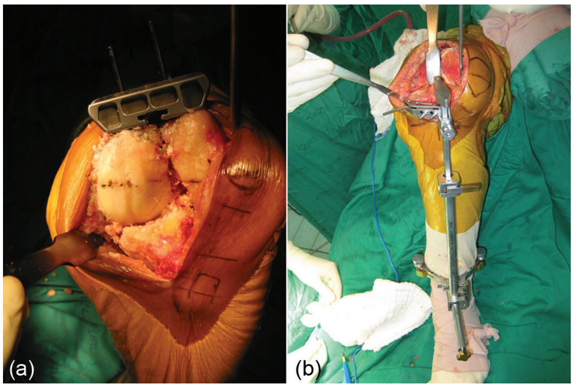

Fig. 2 (a) Front-cutting MIS-TKA instrument cutting from the superior to inferior surface of the femur. (b) MIS extramedullary tibial alignment guide for cutting tibia from anteromedial to lateral side of the tibial plateau.

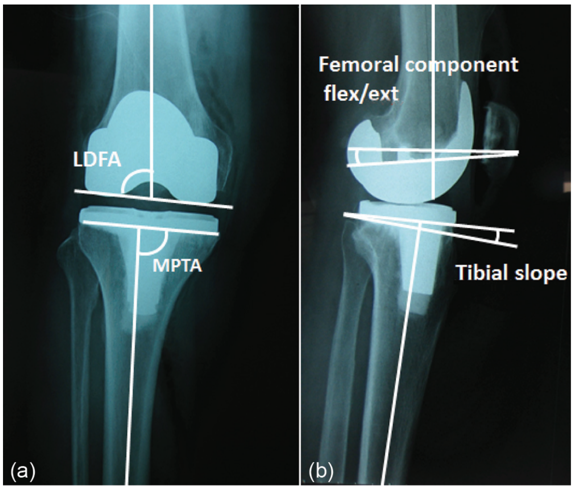

Fig. 3 (a) LDFA and MTPA were measured from the 3 feet AP weight bearing radiograph while (b) femoral component flexion and tibial posterior slope were measured from the lateral radiograph.

LDFA in Group 1 (95.1°±1.8°) and 2 (95.3°±2°) regarding within acceptable alignment (100% vs. 97%, respectively; $p = 0.5$).

For the MPTA, MPTA was set at 90°. Mean MPTA in Group 1 and 2 was 90.6°±1.4° and 91°±1.9°, respectively. Acceptable alignment was not significantly different (97% vs. 87%, respectively; $p = 0.177$).

Sagittal alignment parameters

For the femoral component alignment, the anticipated angle of femoral flexion was 0° (no flexion

Table 1. Preoperative demographic data

	Group 1: side-cutting instrument	Group 2: front-cutting instrument	*p*-value
Age (years)	67.0±8.8	68.0±7.3	0.526
Sex (male:female)	4:26	0:30	0.056
Tibiofemoral angle			
Mean ± SD	Varus 4.8°±5.7°	Varus 3.2°±4.8°	0.280
Range	Varus 15° to Valgus 10°	Varus 13° to Valgus 6°	
Lateral distal femoral angle			
Mean ± SD	82.9°±4.2°	81.5°±2.2°	0.122
Range	75° to 96°	78° to 86°	
Medial proximal tibial angle			
Mean ± SD	82.9°±3.9°	83.1°±3.1°	0.824
Range	69° to 87°	77° to 89°	

$p<0.05$ considered significant

Table 2. Postoperative radiographic data

	Group 1: side-cutting instrument	Group 2: front-cutting instrument	*p*-value
Tibiofemoral angle			
Mean ± SD	Valgus 5.3°±2.1°	Valgus 5.9°±2.4°	0.330
Range	Valgus 1° to Valgus 10°	Valgus 2° to Valgus 11°	
Lateral distal femoral angle			
Mean ± SD	95.1°±1.8°	95.3°±2.0°	0.110
Range	92° to 99°	92° to 101°	
Femoral component flexion			
Mean ± SD	-1.2°±3.0°	0.5°±2.0°	0.043
Range	-6° to 6°	-3° to 5°	
Medial proximal tibial angle			
Mean ± SD	90.6°±1.4°	91.0°±1.9°	0.500
Range	88° to 94°	86° to 95°	
Tibial posterior slope			
Mean ± SD	4.7°±2.5°	3.1°±2.1°	0.051
Range	0° to 10°	0° to 8°	

$p<0.05$ considered significant

Table 3. The number of knee with acceptable radiographic alignment (within 3° of anticipated angle) (n = 30)

	Group 1: side-cutting instrument	Group 2: front-cutting instrument	*p*-value
Tibiofemoral angle	27 (90%)	25 (83%)	0.353
Lateral distal femoral angle	30 (100%)	29 (97%)	0.500
Femoral component flexion	19 (63%)	28 (93%)	0.005
Medial proximal tibial angle	29 (97%)	26 (87%)	0.177
Tibial posterior slope	22 (73%)	28 (93%)	0.040

$p<0.05$ considered significant

and extension of the component). The femoral component had an average extension of 1.2°±3° in Group 1 and a flexion of 0.5°±2° in Group 2, which was significantly different between the groups ($p = 0.043$). The number of the knees with acceptable alignment was significantly less in Group 1 than in Group 2 (63% vs. 93%, respectively; $p = 0.005$).

About the last parameter, mean tibial posterior slope was 4.7°±2.5° in Group 1 with the anticipation of 6° and 3.1°±2.1° degrees in Group 2 with the anticipation of 3°, but the number of knees with acceptable alignment (within ±3° of anticipated angle) was significant lower in Group 1 than in Group 2 (73% vs. 93%, respectively; $p = 0.04$).

Discussion

TKA is a well-established and highly successful surgical procedure that is performed worldwide. Problems associated with TKA include postoperative pain, massive blood loss and an extended recovery time. MIS has become a widely used approach in TKA, because it decreases soft tissue invasion, blood loss, and pain, while allowing for faster rehabilitation and enhanced functional outcome[5-8]. The main concern regarding the MIS-TKA is the limited exposure and less accurate alignment placement of prosthesis[9]. Error in alignment placement may lead to early component loosening and failure, especially of the tibial component in coronal alignments greater than 3° of varus and overall limb alignment with less valgus[10]. Quad-Sparing™ MIS-TKA instruments (side-cutting instruments) were designed to reduce damage to the quadriceps tendon, decrease soft tissue trauma, and shorten the incision; all as compared with front-cutting MIS instrumentation.

Side-cutting instruments, which cut the femur and tibia in a medial to lateral direction, can cause errors in the coronal and sagittal plane alignment as compared to front-cutting MIS instruments. From our study, the total coronal limb alignment (tibiofemoral angle) in both systems showed good overall limb alignment with similar outliers. Our results were different from those of a previous study by Chin et al[11], who performed a single-blind, prospective, randomized controlled study of three techniques, conventional, MIS mini-incision mid-vastus, and MIS side-cutting techniques in TKA. The percentage of overall limb alignment within ±3° of varus/valgus (mechanical axis of the femur and mechanical axis of the tibia) for each of the three techniques was 83.3% (25/30), 83.3% (25/30), and 56.7% (17/30), respectively. In the study, the side-cutting group performed significantly poorer than the control and mini-incision groups[11].

Lin et al[2] conducted a comparative study of side-cutting MIS-TKA instruments and minimal incision medial parapatellar approach with downsized traditional TKA cutting instruments. The authors found that the coronal alignment of the femoral component had significant less valgus and the tibial component had more varus when the side-cutting instruments were used. More tibial and femoral component outliers were observed in the side-cutting instrument group. The authors proposed that errors occurred in the side-cutting group because the blade was too short to access the lateral compartment with the cutting guide in place. To complete the final cut, the cutting guide was removed, and a free hand technique was used, which resulted in less bone cut from the lateral compartment[2]. Regarding coronal alignment in our study, mean LDFA and MPTA of both side-cutting and front-cutting instruments had good alignment. The LDFA of the component in the side-cutting instrument group revealed fewer outliers (±3° varus/valgus) compared with the front-cutting group but the difference was not statistically significant. We devised a technique using a long thick blade to perform the distal femoral cut from the medial to lateral condyle. This technique can reduce errors associated with using a blade that is too short and free-hand cutting of the lateral compartment. For pin fixation of the cutting jig, we secured the cutting jig by using three pins instead of the usual two pins, which allowed for a more precise cut. We believe that this technique can eliminate errors associated with side-cutting instruments used to make the distal femoral cut in the coronal plane.

Martin et al[3] found the side-cutting mini-incision instruments had significantly lower accuracy in terms of the mechanical axis of the limb, MPTA and tibial posterior slope, when compared with the anterior-posterior cutting instruments. The authors hypothesized that the error was caused by the greater length of the medial to lateral cut compared with the anterior to posterior cut, as well as the insufficiency of the cutting jig fixation technique[3]. We found the results with no difference in acceptable alignment of tibiofemoral angle and MPTA. We believed that this accuracy resulted from the improvement of instrument and technique. Our results reveal the extramedullary guide tibial cut made by both mini-instrument systems had good accuracy in coronal alignment.

For sagittal alignment, the side-cutting instruments demonstrated less accuracy for controlling femoral component flexion. The lower degree of accuracy regarding sagittal femoral alignment may be attributable to the thickness of medial soft tissue which can push the component guide in the sagittal plane out of its proper position.

This study has some mentionable limitations. First, it is difficult to measure and compare objectively the accuracy of two different prosthesis designs and surgical instrumentation systems. But with the availability of the side-cutting MIS Quad-Sparing™ instrumentation, which decreases soft tissue invasion and facilitates a smaller incision, we have abandoned the use of front cutting instrumentation when using Zimmer Nexgen® Complete Knee Solution Legacy®

Posterior-Stabilized knee system prosthesis. Second, errors in final prosthesis alignment could result from several factors, not only instrument-related error, such as blade lengths and thicknesses, presence of sclerotic bone that deflects and misdirects the cutting blade, and cement impaction technique. Any attempt to definitely conclude that an error was instrument-related would be confounded by many factors.

Conclusion

The results of this study found side-cutting QS MIS-TKA instruments have similar accuracy to front-cutting MIS-TKA instruments for coronal alignment, but less accuracy for sagittal alignment. When using side-cutting QS instruments, special care and attention are recommended to ensure proper coronal and sagittal alignment.

What is already known on this topic?

Side-cutting Instruments for MIS-TKA had the potentially benefit of less soft tissue invasion, decrease postoperative pain and faster rehabilitation compared with Front-cutting Instruments for MIS-TKA. There was a concern of error in misalignment of the components due to limitation of the exposure. The difference of an incidence of the outliers between "side-cutting" MIS instrument and "front-cutting" MIS instrument was still a controversial issue.

What this study adds?

MIS-TKA had similar coronal alignment accuracy compared with the front-cutting MIS instrument. However, it caused greater outlier in the sagittal component alignment.

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Potential conflicts of interest

None.

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การศึกษาเปรียบเทียบความแม่นยำของอุปกรณ์ side-cutting กับ front-cutting ในการผ่าตัดเปลี่ยนข้อเข่าเทียมแบบแผลขนาดเล็ก

ปิยะ ปิ่นศรศักดิ์, ทศ หาญรุ่งโรจน์

ภูมิหลัง: *ปัจจุบันมีการพัฒนาอุปกรณ์ที่ถูกออกแบบเพื่อช่วยในการผ่าตัดข้อเข่าเทียมแบบแผลขนาดเล็ก มีวัตถุประสงค์หลักเพื่อลดความบอบช้ำต่อเนื้อเยื่อรอบข้างขณะทำการผ่าตัด อุปกรณ์ side-cutting มีข้อได้เปรียบอุปกรณ์ front-cutting คือ สามารถทำได้ในแผลที่มีขนาดเล็กกว่าและมีการบาดเจ็บต่อเอ็น quadriceps ที่น้อยกว่า แต่ข้อเสียของอุปกรณ์ side-cutting ที่ใช้ร่วมกับแผลขนาดเล็กคือมีผลต่อทัศนวิสัยที่ทำการผ่าตัดลดลงและทำให้ศัลยแพทย์มีความกังวลเกี่ยวกับการจัดวางข้อเทียมที่อาจมีแนวการจัดวางที่ผิดพลาดมากขึ้นได้*

วัตถุประสงค์: *เปรียบเทียบความแม่นยำในการตัดกระดูกของอุปกรณ์ side-cutting quadriceps sparing กับอุปกรณ์ front-cutting ในการผ่าตัดเปลี่ยนข้อเข่าเทียมแบบแผลขนาดเล็ก*

วัสดุและวิธีการ: *เป็นการศึกษาไปข้างหน้าแบบสุ่ม เปรียบเทียบความแม่นยำในการตัดกระดูกระหว่างอุปกรณ์ 2 กลุ่ม คือ side-cutting quadriceps sparing กับ front-cutting ในการผ่าตัดเปลี่ยนข้อเข่าเทียมแบบแผลขนาดเล็กในประชากรศึกษาทั้งสิ้น 60 ราย (กลุ่มละ 30 ราย) โดยประเมินการวางตัวของข้อเข่าเทียมในภาพถ่ายรังสีด้านหน้า ได้แก่ tibiofemoral angle, lateral distal femoral angle และ medial proximal tibial angle และการวางตัวของข้อเข่าเทียมในภาพถ่ายรังสีด้านข้าง ได้แก่ femoral component flexion และ tibial posterior slope*

ผลการศึกษา: *ความแม่นยำของแนวการวางตัวของข้อเข่าเทียมที่อยู่ในเกณฑ์ยอมรับได้จากภาพถ่ายรังสีด้านหน้าระหว่าง 2 กลุ่ม ไม่มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ จากการประเมิน tibiofemoral angle, lateral distal femoral angle และ medial proximal tibial angle (p = 0.353, 0.500 และ 0.177 ตามลำดับ) แต่ความแม่นยำของการวางข้อเข่าเทียมที่อยู่ในเกณฑ์ยอมรับได้ของภาพถ่ายรังสีด้านข้าง พบว่ากลุ่มอุปกรณ์ side-cutting quadriceps sparing มีความแม่นยำน้อยกว่ากลุ่มอุปกรณ์ front-cutting อย่างมีนัยสำคัญทางสถิติ เมื่อเปรียบเทียบกันในด้าน femoral component flexion (63% เทียบกับ 93%, p = 0.005) และ tibial posterior slope (73% เทียบกับ 93%, p = 0.04)*

สรุป: *อุปกรณ์ side-cutting quadriceps sparing มีความแม่นยำในการตัดกระดูกใกล้เคียงอุปกรณ์ front-cutting ในเรื่องการวางตัวของข้อเข่าเทียมในภาพถ่ายรังสีด้านหน้า แต่มีความถูกต้องน้อยกว่าในด้านการวางตัวของข้อเข่าเทียมในภาพถ่ายรังสีด้านข้าง*