의학석사 학위논문

Comparison of Kinematics and Clinical Outcomes of Two Designs of Mobile Bearing Total Knee Arthroplasty : Ultracongruent vervus Posterior Stabilized

가동형 슬관절 전치환술에서 고도적합성 치환물과 후방안정형 치환물의 운동학 및 임상결과 비교

2013 년 10 월

서울대학교 대학원
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A thesis of the Degree of Master of Science in Medicine

가동형 슬관절 전치환술에서 고도적합성 치환물과 후방안정형 치환물의 운동학 및 임상결과 비교

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October, 2013

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지도 교수 성 상 철

이 논문을 의학석사 학위논문으로 제출함
2013년 10월

서울대학교 대학원
의학과 정형외과학 전공
김 태 우

김태우의 의학석사 학위논문을 인준함

2014년 1월

위 원 장 ______________________ (인)
부위원장 ______________________ (인)
위 원 ______________________ (인)

Comparison of Kinematics and Clinical Outcomes of Two Designs of Mobile Bearing Total Knee Arthroplasty : Ultracongruent vervus Posterior Stabilized

By

Tae Woo Kim

A thesis submitted to the Department of Medicine in partial fulfillment of the requirements for the Degree of Master of Science in Medicine (Orthopedic Surgery) at Seoul National University College of Medicine

October 2013

Approved by Thesis Committee:

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ABSTRACT

Introduction: There is no consensus as to whether to use posterior cruciate ligament sacrificing ultracongruent (UC)mobile TKA and posterior cruciate ligament substituting posterior stabilized(PS) mobile TKA. The purpose of this study is to assess kinematics and clinical outcomes of ultracongruent (UC) and posterior stabilized (PS) rotating-platform mobile bearing TKA.

Methods: Ninety primary osteoarthritis knees were randomized to undergo computer assisted TKA with UC (n=45) or PS (n=45) prostheses and eighty two knees (UC: 42 knees, PS: 40 knees) were followed up for a minimum 3-years. The passive kinematic evaluation was performed before and after the implantation with a navigation system. Three parameters of tibiofemoral relationship (anterior/posterior translation, varus/valgus alignment and rotation) were recorded from 0° to 120° of flexion. The patients were clinically and radiographically evaluated at the 3-year follow-up.

Results: Paradoxical anterior translation of the femur was observed from 0° to 82° of flexion in the UC knees (10.8mm) and 0° to 70° in the PS knees(8.7mm). The lengths of femoral roll-back in the UC knees and PS knees was 5.6mm and 6.7mm respectively, but never reached the starting point. Paradoxical internal rotation of the femur was found from 0° to 47° of flexion in the UC knees (5.8°) and 0° to 62° in the PS knees (9.9°). The femur of UC group was more externally rotated from 40° to 120° compared to the PS group. But, in regard to the coronal alignment, there was no significant difference between the groups. There was no significant difference in the maximal flexion(123°:125°, p=0.411), KS knee scores(91:94, p=0.221), KS function scores(81:84, p=0.588) and WOMAC index scores(15:15, p=0.540). There was no progressive radiolucent line or loosening in all knees.

Conclusions: With knee flexion, mobile UC TKA showed more anterior translation and external rotation of the femur when compared to the mobile PS TKA. Although the kinematic result of UC mobile TKA was different from that of PS mobile TKA, the range of knee motion and other clinical outcomes were similar to PS knees

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Keywords: total knee arthroplasty, ultracongruent, posterior stabilized, kinematics

Student number: 2012-21684

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INTRODUCTION

Posterior stabilized total knee arthroplasty (PS TKA) become more popular because it provides easier procedure, even in the severely deformed knee, and favorable long term outcomes[1] . In the PS TKA, post/cam mechanism substitutes for the function of the posterior cruciate ligament (PCL), and it is considered to provide reproducible femoral rollback and increased range of motion[2-4]. Post/cam mechanism, however, needs more bone cutting and can cause such complications as post breakage, dislocation, patellar clunk syndrome and intercondylar femur fracture[5-8]. Highly conforming ultracongruent insert in PCL sacrificing TKA(UC TKA) was developed to overcome these disadvantages of the post-cam type PCL-substituting TKA. The structural characteristics of ultracongruent inserts represented by increased anterior build-up and deep dish trough was expected to assured the stability of prosthesis without post-cam mechanism.

Although UC TKA showed comparable clinical outcomes to PS TKA in many studies[9-11], there have been concerns whether high congruency of fixed insert can restrict rotational freedom of femur on tibia and increase shear stress on tibia-bone surface[12-14] resulting in early loosening.[15] In addition, unphysiologic femoral roll back and reduced axial rotation is reported in some kinematic studies[16,17].

Ultracongruent mobile bearing TKA was introduced to improve kinematics and wear characteristics of UC TKA and eventually make better clinical outcomes. However, to our knowledge, no study compared kinematics and clinical outcomes of UC TKA and PS TKA on the basis of mobile rotating platform bearing in the same prosthesis until now. The purpose of this study was to compare kinematics and clinical outcomes of mobile UC TKA and mobile PS TKA .We hypothesized that mobile UC TKA wound show comparable kinematic and clinical outcomes to mobile PS TKA.

MATERIALS AND METHODS

We performed a randomized controlled trial, and ethical approval for this study was received from the institutional review board of Seoul National University Hospital. The study was registered in the ClinicalTrials.Gov Protocol Registration System (trial number, KCT0000033). We prospectively enrolled 90 consecutive primary osteoarthritis knees (71 patients) which were scheduled to undergo primary total knee arthroplasty. Patients who have had previous open knee surgery or refused to participate in the study were excluded.

After obtaining informed consent for participation, ninety knees were randomly allocated to two groups according to permuted block randomization.: In the UC group, knees received the Ultracongruent e.motion® prosthesis (Aesculap, Tuttlingen, Germany). In the PS group, knees received the posterior stabilized e.motion® prosthesis.

Surgical procedures

All surgical procedure was performed by the senior author (M.C.L.), from March 2007 to June 2008. Identical surgical techniques were used in the two groups. An anterior midline skin incision and medial parapatellar arthrotomy were used, and both cruciate ligaments were resected. The OrthoPilot® imageless computer-assisted surgical navigation system (Aesculap, Tuttlingen, Germany) was used to perform the procedure. The patellae were resurfaced in all knees in both groups. A standardized clinical pathway was used for all patients throughout their hospitalization. Knee range-of-motion exercise was started on the first postoperative day. Patients began walking with a walker on the second postoperative day.

Measurement of the intraoperative kinematics

Knee kinematics was measured with OrthoPilot® navigation system. After inflating tourniquet with the knee flexed, passive optical reference frames were attached onto the distal femur and proximal tibia. The position and orientation of the reference frames were recorded by an optical tracking system. We used the anatomic coordinate systems established in the previous study[18]. The anterolateral edge of the PCL attachment was the origin of the femur reference frame, and the center of the anterior cruciate ligament attachment was the origin of the tibia reference frame.

Passive knee kinematics were recorded twice. The first kinematic evaluation was performed after minimal soft tissue dissection only to allow for the fixation of optical reference frames. The second evaluation was recorded after the implantation of all prostheses. At each evaluation stage, knee motions were recorded as the surgeon moved the knee through a range of flexion and extension. For the flexion movement of the hip and knee, the surgeon supported the foot with a palm and lifted the thigh. The reverse manipulation was used to extend the knee. We obtained three characteristics of the knee kinematics from the OrthoPilot® software: Anterior/posterior translation of the femur, varus/valgus alignment, and the internal/external rotation of the femur. We performed statistical analyses on the kinematics of UC knees and PS knees between 10° to 120 ° of flexion at the first evaluation, and 0° to 120 ° of flexion at the second evaluation. The first evaluation was performed from 10° because of flexion contracture of the knee. We compared the changes of kinematic data from 10° (at the first evaluation) or 0° (at the second evaluation) between UC and PS group.

Clinical and radiographic evaluations

Clinical and radiographic evaluations were performed at six weeks, three months, and one year after the operation and annually thereafter. The active range of motion of the knee was measured using a goniometer with the patient in the supine position. Functional status of each knee was rated according to the systems of the Knee Society and the Hospital for Special Surgery, and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) health status questionnaire. All data were compiled by a physician assistant who had no knowledge of the current study. Radiographic parameters were measured on standard weight-bearing anteroposterior and long leg radiographs, supine lateral radiographs (30° flexed) and merchant radiographs. We assessed tibiofemoral angle, posterior tibial slope ,changes in the posterior condylar offset and existnedce of radiolucent line.

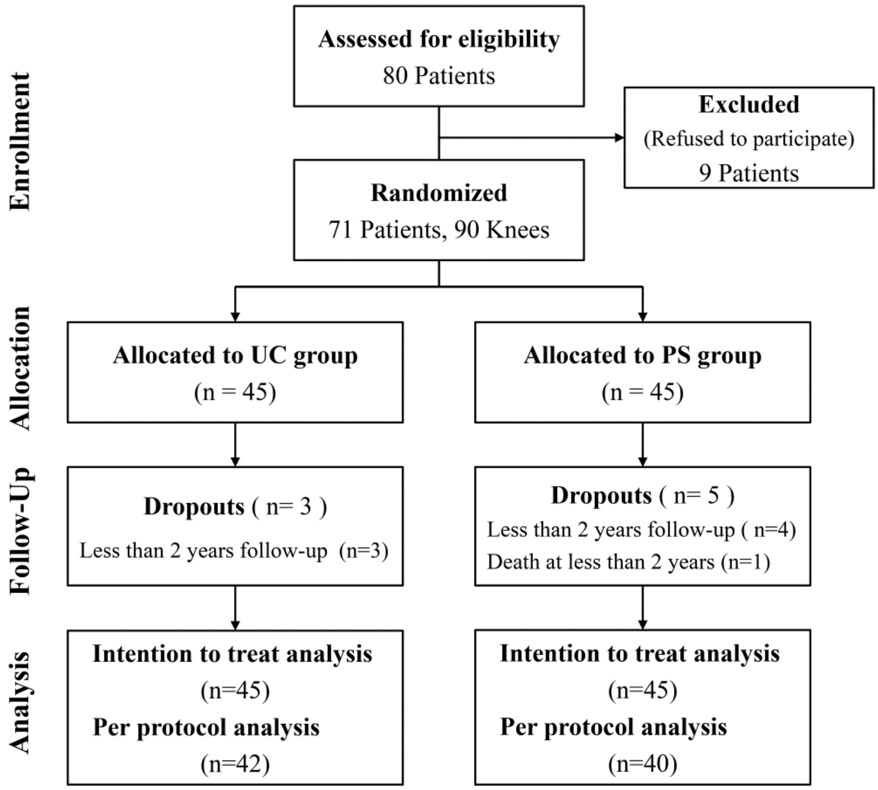
Statistical Analysis

Previous study indicated that 14 subjects in each group were required to detect a difference in anterior/posterior translation ($\alpha = 0.05$, $\beta = 0.8$)[19]. With consideration of possible losses and additional evaluation including range of motion, forty-five knees were enrolled in each group.

Categorical variables were analyzed using Pearson chi-square or Fisher exact test, and continuous variables were examined by Student t- test. Kinematic differences between the two groups were analyzed with Student t test at every 10° of flexion. All statistical analyses were performed using two-tailed tests, and the significance was set at p-value < 0.05.

The data analysis was performed in accordance with an intention-to-treat principle, and the “last observation carried forward” principle was applied. Per-protocol analysis, which excluded the dropouts, was also performed.

Figure 1. A flow diagram according to the CONSORT (Consolidated Standards of Reporting Trials) guidelines



(UC : ultracongruent, PS: posterior stabilized)

RESULTS

Study Population

There was no significant difference between UC group and PS group with regard to the demographics and preoperative measurements (Table I). First and second intraoperative kinematic data were obtained in 90 knees. However, three knees in the UC group and five knees in the PS group were withdrawn during the follow-up period. One knee in the PS group was lost due to the death during the three-year follow-up period, and the others were lost because of unknown reason (Fig. 1). The UC group and PS group were followed-up for a mean of 39.2±6.5 months (range, 20 to 48 months) and 38.7±6.0months (range, 23 to 48 months).

Kinematic Results

First kinematic data were not significantly different between the two groups in anterior/posterior translation, internal/external rotation and varus/valgus alignment (Fig. 2). Paradoxical anterior translation of the femur was observed from 10° to 41°±16.0° (range, 10° -90°) of knee flexion (UC: 43°, PS: 39°; p=0.173). Then femoral roll-back was occurred. The distance of paradoxical anterior translation was 5.3mm±3.9mm (UC: 5.8mm, PS: 4.8mm; p=0.250), and distance of femoral roll-back was 8.5mm±3.0mm (UC: 9.0mm, PS: 8.0mm; p=0.121). External rotation of the femur was occurred after 49°±19.3° (range, 10° -90°) of knee flexion (UC: 46°, PS: 52°; p=0.158), and the magnitude of external rotation was 16.6°±9.2° (UC: 16.1°, PS: 17.1°; p=0.614). With regard to the coronal alignment, 3.5°±2.3° of varus rotation (UC: 3.8°, PS: 3.2°; p=0.295) was observed from 10° to 62°±27.3° (range,10°-110°) of knee flexion(UC:60°, PS:63°; p=0.613), and then 3.9°±3.0° of valgus rotation (UC:3.9°, PS:3.8°; p=0.805) was found until 120° of knee flexion.

In the second kinematic evaluation after implantation, two groups showed different kinematic patterns in anterior/posterior translation and internal/external rotation (Fig. 3). Paradoxical anterior translation of the femur was observed from 0° to 82°±16.2° of knee flexion in the UC group and 0° to 70°±14.2° in the PS group ($p<0.001$). The length of anterior translation of the femur was 10.8mm±5.2mm in the UC and 8.7±3.0mm in the PS group (p=0.027). Femoral rollback was occurred after anterior translation of the femur. The length of femoral roll back was 5.6mm±3.3mm in the UC knees and 6.7mm±2.8mm in the PS knees (p=0.100). The femur of UC group was more anteriorly translated from 80° to 120° of knee flexion compared to the PS group. With knee flexion, the femur was internally rotated relative to the tibia at first, and externally rotated (i.e. screw home movement) thereafter. UC knees showed smaller magnitude of internal rotation (5.8° ±5.1° versus 9.9°±7.2°; p=0.003) and earlier onset of external rotation of femur (47° ±16.9° versus 62°±23.8°; p=0.002). The amount of screw home movement was 16.6°±10.1° in the UC knees and 15.6°±12.4° in the PS knees (p=0.683). The femur of UC group was more externally rotated from 40° to 120° of knee flexion when compared to the PS group. There was no significant difference between the two groups in the coronal alignment.

Clinical Results

At the end of 2-year follow-up period, there were no significant differences in the flexion contracture (0° versus 1°; p=0.261) or active maximal flexion angle (123° versus 125°; p=0.411) between the UC and PS groups (Table II). The average postoperative Knee Society knee score (91 versus 94 points; p=0.221), Knee Society function score (81 versus 84 points; p=0.588), HSS score (89 versus 90 points; p=0.440) and WOMAC scores (15 versus 15 points; p=0.540) were also similar between the two groups (Table III).

Radiographic Results

There were no significant differences between UC and PS groups in the radiographic parameters. Mean postoperative tibiofemoral angles were 5.5° ± 2.5° of valgus in the UC group, 5.9° ± 3.3° of valgus in the PS group (p=0.557). Posterior tibial slope averaged 2.9° ± 2.1° in the UC group, 2.4° ± 1.8° in the PS group (p=0.242). The changes in the posterior condylar offset were also similar in the two groups(UC: 1.5mm ± 5.8mm, PS: 0.1mm ±5.4mm; p=0.173). There was no progressive radiolucent line or loosening in all knees.

Table I. Preoperative Demographics and Clinical Status Between the groups

	UC Group	PS Group	P value§
Number of knees	45	45	
Gender (M/F)	2 / 43	3 / 42	0.645‡
Mean age (yr) *	69.0 ± 5.0	69.4 ± 5.9	0.774§
Body-mass index (kg/m^2) *	26.6 ± 4.0	26.9 ± 3.4	0.698§
Laterality (right/left)	21/24	22/23	0.833#
Range of knee motion* (degrees)			
Flexion contracture	10.9 ± 8.0	10.7 ± 8.0	0.896§
Active maximal flexion	130.0 ±13.7	128.1 ± 15.5	0.542§
Range of motion	119.1 ± 17.7	117.4 ± 19.5	0.672§
Tibiofemoral angle* (degrees)	Varus 3.1 ± 6.4	Varus 4.4 ± 5.0	0.323§
KS – Knee score*† (points)	47.3 ± 18.4	52.0 ± 20.6	0.323§
KS – Function score*† (points)	37.5 ± 14.0	39.4 ± 16.5	0.608§
HSS total score*† (points)	60.9 ± 10.9	62.9 ± 12.8	0.454§
WOMAC score*† (points)	52.9 ± 19.5	48.3 ± 16.3	0.281§

* The values are reported as the mean and the standard deviation. † HSS = Hospital for Special Surgery, KS = Knee Society, and WOMAC Index= Western Ontario and McMaster Universities Osteoarthritis Index. ‡Fisher exact test. §Student t test. #Chi-square test.

Table II. Comparison of ranges of knee motion between the groups at 2-year follow-up

	UC Group	PS Group	P value
Intention to treat analysis			
Number of knees	45	45	
Flexion contracture * (degrees)	0.3±1.3	0.8±2.4	0.261†
Active maximal flexion* (degrees)	123.0 ± 12.1	124.9 ± 9.2	0.411†
Total range of motion* (degrees)	122.7±12.6	124.1±10.0	0.556†
Per protocol analysis			
Number of knees	42	40	
Flexion contracture* (degrees)	0.4±1.3 (0-5)	0.8±2.4 (0-10)	0.359†
Active maximal flexion* (degrees)	123.6 ± 12.0	124.9 ± 9.5	0.588†
Total range of motion* (degrees)	123.2 ± 12.5	124.1 ± 10.2	0.281†

* The values are reported as the mean and the standard deviation. †Student t test.

Table III. Comparison of knee scores between the groups at two years follow-up

	UC Group	PS Group	P value
Intention to treat analysis			
Number of knees	45	45	
KS score*† (points)			
Knee	91.3±12.5	94.3±8.8	0.221‡
Function	81.4±19.6	83.7±18.9	0.588‡
HSS score*† (points)	89.2±7.3	90.3± 5.7	0.440‡
WOMAC score*†			
Pain	1.9±2.4	1.1±1.8	0.091‡
Stiffness	1.1±1.3	1.0±0.9	0.790‡
Function	12.5±7.0	12.8±7.6	0.836‡
Per protocol analysis			
Number of knees	42	40	
KS score*† (points)			
Knee	91.6±12.4	94.3±9.0	0.281‡
Fuction	80.3±19.9	83.0±19.5	0.553‡
HSS score*† (points)	89.2±7.3	90.3±6.0	0.453‡
WOMAC score*†			
Pain	1.9±2.3	1.0±1.8	0.084‡
Stiffness	1.0±1.3	0.9±0.9	0.622‡
Function	1.0±1.8	12.5±7.8	0.807‡

* The values are reported as the mean and the standard deviation. † HSS = Hospital for Special Surgery, KS = Knee Society, and WOMAC Index= Western Ontario and McMaster Universities Osteoarthritis Index. ‡Student t test

Figure 2. First kinematic data were not significantly different between two groups in anterior/posterior translation, internal/external rotation and varus/valgus alignment.

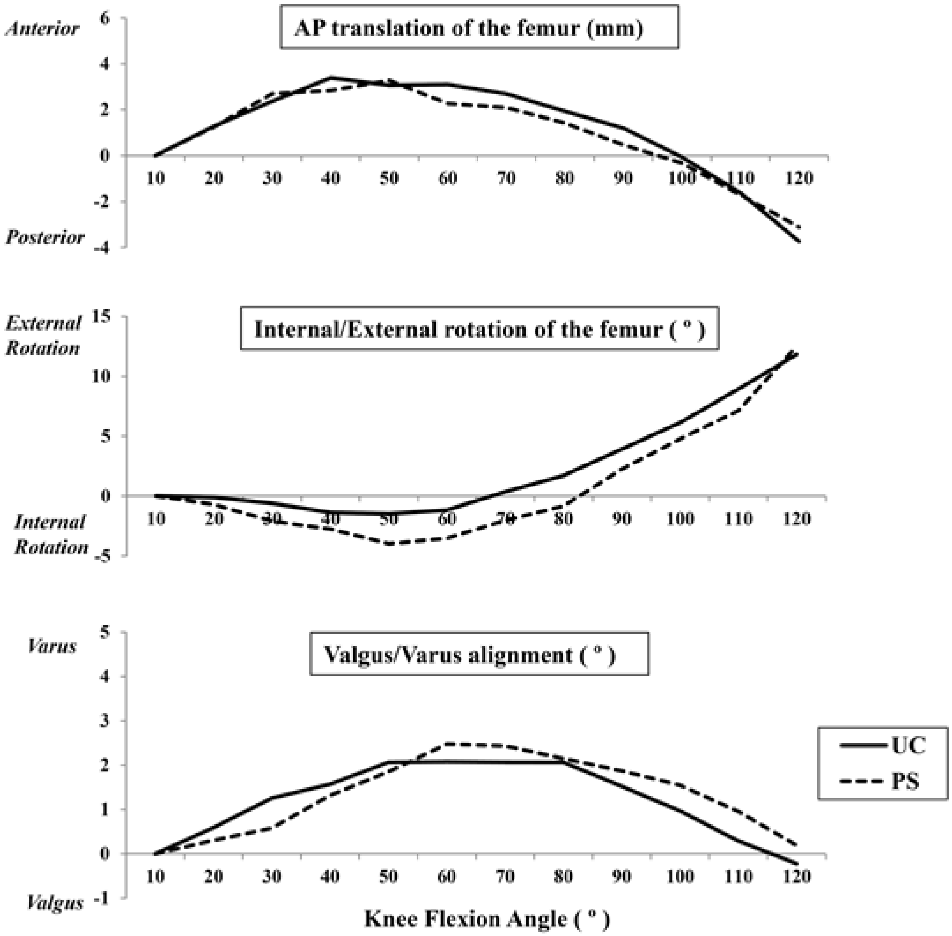
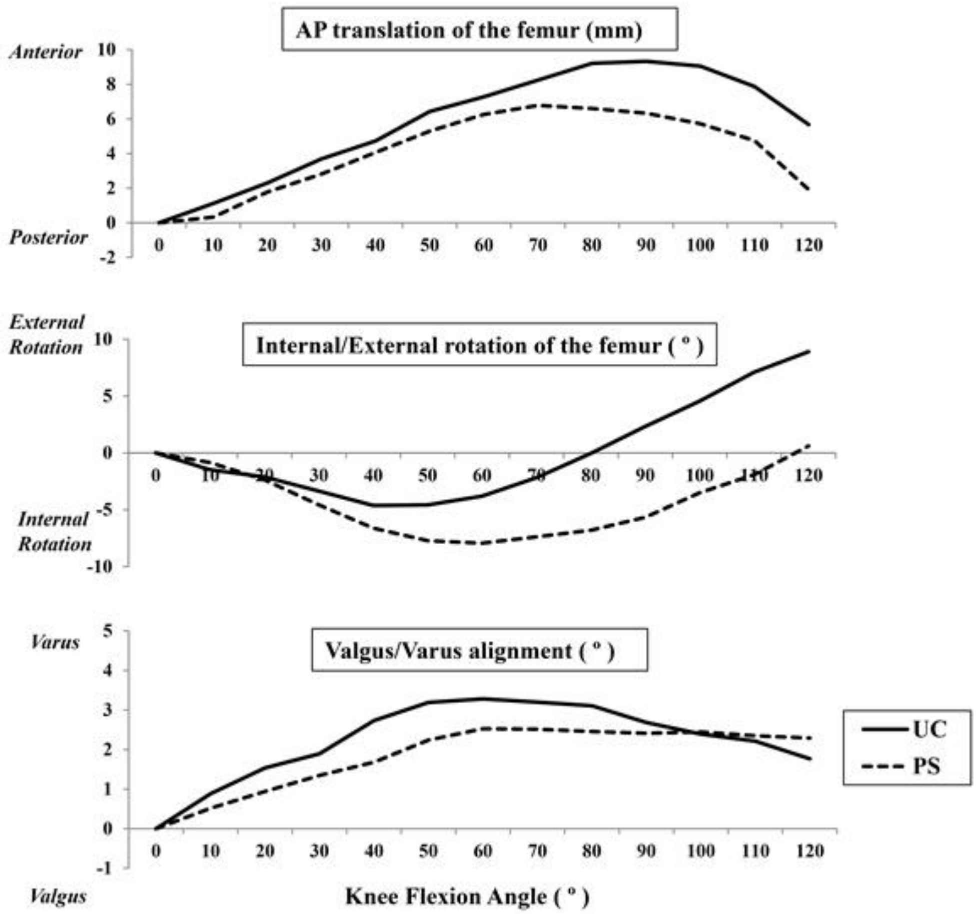


Figure 3. In the second kinematic evaluation after implantation, two groups showed different kinematic patterns in anterior/posterior translation and internal/external rotation. UC group showed late onset of femoral roll back, and the femur of UC group was more anteriorly translated from 80° to 120° of knee flexion when compared to the PS group. External rotation of the femur started earlier in the UC group, and the femur of UC group was more externally rotated from 40° to 120° of knee flexion. But, in regard to the coronal alignment, there was no significant difference between the groups



DISCUSSION

The debate regarding the management of the PCL in TKA is ongoing, with the options including posterior cruciate retaining(CR), posterior stabilized (PS), and posterior cruciate sacrificing with highly conforming ultracongruent insert(UC). There have been large volume of literature on CR or PS TKA , but studies comparing UC and PS TKA was limited relatively, especially on the basis of mobile rotating platform bearing. We intended to investigate whether mobile UC TKA can show comparable kinematics and clinical outcomes to mobile PS TKA in the same prosthesis.

In the normal knee, femur rolls and slips on the tibia in the posterior direction (postror femoral rollback) during flexion motion. Paradoxical anterior translation of femur and decreased femoral rollback, usually observed after TKA reduce quadriceps moment arm that result in decrease of quadriceps efficiency[20,21] and induce posterior impingement that decrease range of motion.[22,23] Daniilidis et al.[17] reported non-physiological roll back of UC insert in fluoroscopic study, because of centralization of the tibiofemoral contact point by its nature and Heyse et al.[16] observed higher patella-femoral pressure in UC TKA compared with PS TKA that implies better reproducible femoral rollback of PS by cadevaric study. Roh,Y.W et al.[24] also observed paradoxical anterior translation of femur in intraoperative navigational kinematics of mobile UC TKA. On the other hand, Uvehammer et al.[10] reported no difference in tibia rotation, maximum femorl A-P motion and lift off between UC and PS TKA in radiostereometry and Dennis et al.[25] showed similar femoral anterior translation between mobile PCL sacrificing TKA and mobile PCL substituting TKA in fluoroscopic multicenter study. We observed paradoxical anterior translation of the femur in both UC and PS group . But, femur of UC group was more anteriorly translated from 80° to 120° of knee flexion compared to the PS group. The starting point of this angle (80 °) is similar with post-cam engagement angle in many kinematic studies.[26-28] This result implies that on the basis of mobile rotating plarform, post-cam mechanism in PS TKA reduced paradoxical anterior translation of femur and reproduced more physiologic femoral roll-back compared to high congruency of ultracongruent insert in UC TKA.

Axital femorotibial rotation is important in patella-femoral tracking and abnormal rotation can occur patella-femoral complications such as dislocation, wear and anterior knee pain. Dennis et al.[21] and Wasieleski[29] et al. reported decreased external rotation and increased paradoxical reverse rotation of femur during the knee flexion in mobile PCL sacrificing TKA compared to mobile PS TKA by fluoroscopic study. In our study, however, we found different rotational kinematic outcome compared with previous kinematic studies. Mobile UC TKA group showed more external rotation of femur and decrease reverse rotation from 40° to 120° of knee flexion. Wolterbeek et al.[30] explained reduced reverse axial rotaion of femur by the presumption that femoral component might be obstructed by highly congruent insert in mobile UC TKA. We also assume that highly congruent geometry of insert restricted axial rotation of femur, resulting in reduced reverse axial rotation and increased external rotation. Although neither UC nor TKA group reproduced physiologic rotational kinematics, mobile UC TKA showed lesser paradoxical rotational pattern. There was no significant difference between the two groups in the coronal alignment. To summarize the kinematic results, mobile PS TKA reproduced more physiologic femoral rollback and mobile UC TKA showed lesser paradoxical axial rotation of femur. So we could not decide the superiority of one prosthesis in kinematic assessment.

Despite the different kinematic patterns of UC TKA and PS TKA, there was no significant difference in the clinical outcomes including flexion angle, HSS/KSS/WOMAC score and radiographic evaluation including coronal/ sagittal alignment and radiolucent at post operative 3 year. This clinical result is the same way with other studies[31,32] comparing clinical outcomes including KSS/HSS score , range of motion and survival rate between mobile UC TKA and mobile PS TKA.

There are some limitations in our study. Follow up period was not sufficient to compare the late complication such as looseing or polyethylene wear. A further limitation is the kinematic measurement method. Many kinematic studies of total knee arthroplasty evaluate post operative state under weight bearing condition by fluoroscopy.[25,33,34] In our study, navigation assisted kinematic assessment was performed intraoperatively in passive motion. Although passive kinematics can assess the effect of implant geometry on the motion of joint without influence of external factor or muscle activation, it cannot reflect active kinematics under weight bearing.[18] Discrepancy between the kinematic data and the actual clinical outcomes could be affected by this kinematic setting. Additional in vivo kinematic study under weight bearing motion or gait analysis after the intraoperative navigation assisted kinematic study is required in the future.

Conclusion

With knee flexion, UC mobile TKA showed more paradoxical anterior translation and external rotation of the femur when compared to the PS mobile TKA. Although the kinematic result of UC mobile TKA was different from that of PS mobile TKA, the range of knee motion and other clinical outcomes were similar to PS knees.

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국문 초록

가동형 인공슬관절 전치환술에서 고도적합성 치환물과 후방안정형 치환물 중 어느것을 사용하는 것이 좋을지에 대해서는 아직 정해진 바가 없다. 이 연구의 목적은 가동형 인공슬관절 전치환술에서 고도적합성 치환물과 후방안정형 치환물간의 운동학 및 임상결과를 비교하는데 있다. 퇴행성관절염으로 인공슬관절 전치환술 예정인 90 례의 무릎이 고도적합성 치환물군과 후방안정형 치환물군으로 각각 45 명씩 무작위배정되었고 수술 후 3 년간 임상결과의 추시가 이루어졌다. 수동 운동학적 평가는 수술중 컴퓨터 네비게이션을 이용하여 치환물 삽인 전과 후 두차례에 시행되었고 평가 항목은 굴곡각도 0 도부터 120 도까지에서 대퇴골의 전후방 전이,내반/외반정렬, 그리고 축회전 정도였다. 운동학적 평가상 고도적합성 치환물은 후방안정형 치환물 보다 증가된 역설적 대퇴골 전방전이소견(10.8 mm >8.7 mm)과 감소된 대퇴골 역설적 축회전(5.8° <9.9°) 소견을 보였으며 관상면상의 정렬에는 두 군 간에 큰 차이가 없었다. 수술후 3 년째 시행한 임상평가에서 두 군간의 굴곡각도(123° :125°)와 KSS 점수, KSFA 점수, WOMAC 점수, 방사선학 적변화에는 유의한 차이가 없었다. 가동형 인공슬관절 전치환술에서 고도적합성 치환물은 운동학적 평가에서 후방안정형 치환물보다 증가된 역설적 대퇴전방전위소견과 감소된 역설적 대퇴축회전 소견을 보였지만 임상적으로는 두 군간에 유의한 차이가 없었다.

주요어 : 슬관절 전치환술, 고도적합성, 후방안정형, 운동학

학 번 : 2012-21684