Computer Assisted Surgery Evaluation of Femoral Component Rotation in Well-Balanced and Well-Aligned Total Knee Arthroplasty Using Gap Technique

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Objective: *Using computer assisted surgery (CAS) to assess femoral component rotation in well-balanced, well-aligned total knee arthroplasty (TKA) implanted with Posterior Cruciate Ligament (PCL) excision type prosthesis using gap technique.*
Material and Method: *Using CAS, well-balanced TKA was defined by both flexion/extension and medial/lateral gap difference of less than 2 mm and well-aligned TKA was defined by final mechanical axis within ± 3 degrees deviation and flexion contracture of less than 5 degrees without hyper extension. Femoral component rotation was determined by posterior condylar axis versus proximal tibia resection plane. The present study analyzed data from January 1, 2009 to September 30, 2009.*
Results: *Out of 65 knees, 34 knees (14 fixed and 20 mobile bearing prosthesis) were considered well-balanced and well-aligned. Mean femoral component rotation was 2.12 ± 3.38 degrees. Seven knees were within 2-4 degrees external rotation. There was no statistically significant difference of femoral component rotation between fixed and mobile bearing.*
Conclusion: *Wide range of femoral component rotation occurred in well-aligned and well-balanced TKA using PCL excision type prosthesis.*

Keywords: *Computer assisted surgery, CAS, Femoral rotation, Well-balanced TKA*

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The major goals of total knee arthroplasty (TKA) are re-established mechanical axis, accurate bone cut and balanced flexion and extension gap. Proper surgical techniques are essential to achieve these goals. There are currently two distinct surgical theories in TKA operation, which resulted in two different surgical techniques. The first theory developed in conjunction with the design of cruciate-substituting prosthesis, is the Gap theory[1]. Gap theory resects tibial bone first then removes osteophytes and performs soft tissue release to bring hip-knee-ankle (H-K-A) axis to neutral in extension. Then surgeon determined femoral rotation according to tension of collateral ligaments and made anterior and posterior bone cut of distal femur. Finally an adjustment cut of distal femur was done to match extension gap with flexion gap[1]. And the second theory, which developed in conjunction with the design of cruciate-retaining prosthesis, is "Measured resection" or "Joint line" theory[2]. Measured resection theory, begins with the philosophy to maintaining joint line position. The technique allowed resection of tibia and femur independently; the thickness of bone to be removed is the same amount to be replaced by prosthesis[1]. Femoral component rotation could be determined by three commonly used methods, which consists of Posterior Condylar Axis (PCA) reference[3], trochlear groove[4], or the epicondylar axis[5]. Finally sequential soft tissue release was done to correct residual deformity[1]. Mechanical axis correction was generally accepted that it should be less than 3 degrees to improve longevity of prosthesis[6]. However, there was no consensus on definition of "well-balanced" gap. Although both theories and surgical techniques yielded excellent results, there are different in some details especially the degree of femoral rotation. Gap theory used tension of collateral ligament to determine femoral rotation, large variety of femoral rotation was observed[7,8]. While measured resection theory

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used fixed anatomic landmark to determine femoral rotation[3-5], less variety was expected. This variation became debate issue and research topics. There were studies showed gap technique achieved better coronal stability than measured resection[9,10]. And there was study using fixed references landmark achieved rectangular flexion gap[11].

Computer assisted surgery (CAS) was proved to be a reliable tool to reduce the possibility of inaccurate bone cut and achieve good gap balancing in total knee arthroplasty[12-14]. CAS has ability to detect real-time change of distance and angulations, so it is a useful tool to study knee kinematics *in vivo* during TKA[15]. With CAS data about gap and angle, the authors are able to characterize gap balancing and alignment of each patient. The authors defined "well-balanced and well-aligned" total knee arthroplasty and conducted study to assess femoral component rotation in this specific group.

Objective

To assess femoral component rotation in well-balanced and well-aligned TKA patients who underwent minimally invasive computer assisted (CAS) TKA.

Material and Method

The authors collected data from all patients underwent TKA with CAS (CAS-TKA) and using either Posterior Cruciate Ligament (PCL) substitute fixed bearing (PFC sigma, CS femur and Modular fixed bearing tibial tray, Depuy, Johnson and Johnson) or LCS Rotating Platform mobile bearing knee prosthesis (Depuy, Johnson and Johnson) from January 1, 2009 to September 30, 2009. Patients underwent TKA with PCL retaining (CR femur) were excluded from the present study to reduce deviation of data which may causes by retention of PCL. All patients were operated by single surgeon (PC) using Ci™ MITKR software, optimized gap and tibial first workflow. This workflow based on gap theory, which means variation of femoral rotation may occurs in order to balance flexion gap. General data such as age, sex, height, weight, body mass index (BMI) and type of prosthesis were recorded. The authors also recorded clinical data, which consisted of pre-operative and post-operative Knee Society score and Functional score and complications. Pre-operative and post-operative long standing hip-knee-ankle AP film, 18-inches knee AP and lateral films were taken for radiographic evaluation. The authors evaluated coronal alignment of femoral and tibial component using radiographic evaluation of the Knee Society[16]. The manual measurement method which describe by Petersen and Engh in 1988[17] was used to evaluate the radiographs. Trained personnel and one of co-authors did the measurement. The authors used consensus agreement for recorded data. After operation, all patients went through the same protocol of post-operative and rehabilitation.

The authors defined well-balanced TKA as a TKA with medial/lateral gap difference of less than 2 mm in extension and flexion at 90 degrees from intra-operative CAS measurement. And also the difference between extension gap and flexion gap on both sides must be less than 2 mm. A well-aligned TKA was defined by final mechanical axis within $\pm$ 3 degrees from neutral and flexion contracture of less than 5 degrees without hyperextension, as determined by intra-operative CAS and post-operative long film standing radiographic evaluation.

From CAS data, femoral component rotation was analyzed and reported in term of rotation of posterior condylar axis versus proximal tibial resection axis. The authors also compared the difference of femoral component rotation between fixed and mobile bearing prosthesis using student t-test and p-values of less than 0.05 was considered statistically significant.

Results

There were 65 patients with underwent CAS-MIS-TKA during that period. After the authors applied well-balanced and well-aligned criteria, there were 34 knees (34 patients, 31 female and 3 male) considered well balanced and well aligned. Regarding prosthesis type, this group consisted of 14 fixed bearing TKA and 20 mobile bearing TKA prosthesis. Average age was 66.5 $\pm$ 8.6 years with range of 47 to 83 years. Average pre-op deformity using CAS measurement in all patients was 10.73 $\pm$ 8.39 degrees of mechanical axis varus (varus 31.1-valgus 3.5). Average pre-op deformity in fixed bearing group was 14.77 $\pm$ 8.85 degrees of mechanical axis varus (varus 31.1-varus 2.5). Average pre-op deformity in mobile bearing group was 7.9 $\pm$ 6.94 degrees of mechanical axis varus (varus 20-valgus 3.5). There was statistically significant difference of pre-operative deformity between groups (p-value 0.02). After operation, mean post-operative mechanical axis from CAS was 1.09 $\pm$ 1.02 degrees of varus (varus 3 degrees-valgus 0.9 degrees). Average post-operative mechanical axis in fixed bearing group was 1.58 $\pm$ 1.03 degrees of varus. Average post-operative mechanical axis in mobile bearing group was 0.75 $\pm$ 0.88 degrees of

varus. Although the difference between bearing type was small (0.83 degree), there was statistically significant difference (p-value 0.02). Mean post-operative mechanical axis from long film standing view was 1.5 ± 1.46 degrees of varus (varus 3 degrees-valgus 2 degrees).

Mean femoral component rotation from all patients was 2.12 ± 3.38 degrees of external rotation (internal rotation 5.5 degrees-external rotation 8 degrees). Mean femoral component rotation in fixed bearing group was 1.3 ± 4.12 degrees of external rotation (internal rotation 5.5 degrees-external rotation 8 degrees). Mean femoral component rotation in mobile bearing group was 2.69 ± 2.73 degrees of external rotation (internal rotation 2.5 degrees to external rotation 7.7 degrees). There was no statistically significant difference when comparing femoral component rotation of fixed and mobile bearing group (p-value 0.28).

There were 7 knees from 34 knees (20.58%) that femoral component rotation was within the range of 2 to 4 degrees of external rotation. If the authors extend to range of 1 to 5 degrees of external rotation, 17 knees from 34 knees (50%) will be in this range. The summary of overall femoral component rotation was shown in Fig. 1. Pre-operative knee score and functional score were improved gradually as shown in Fig. 2. There were no post-operative complications in this group of patients.

Figure 1 : Range of femoral component rotation

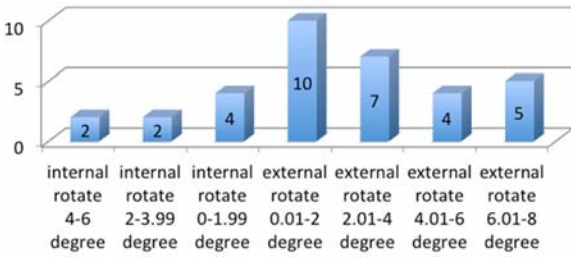

Fig. 1 Column chart shows numbers of patients and range of femoral component rotation observed in well-balanced and well-aligned total knee arthroplasty patients

Figure 2: Knee score and Functional score

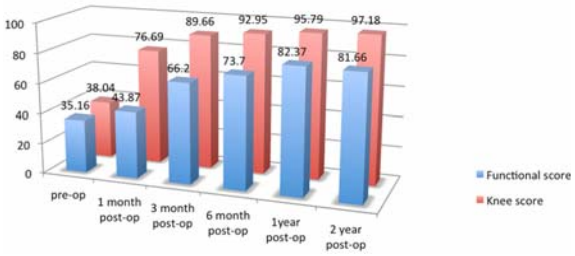

Fig. 2 Column chart shows average Knee score and Functional score of all patients at each time point

Discussion

Femoral component rotation is a major factor to determine flexion gap balancing in TKA. In appropriate femoral component rotation may leads to trapezoidal flexion gap, which causes condylar lift off in flexion and abnormal knee kinematics. Nevertheless, determination of femoral component rotation becomes difficult situation because of it is one of the major differences between gap theory and measured resection theory[9,18]. Surgical techniques using gap theory resulted in large variety of femoral component rotation but using measured resection resulted in relatively fixed amount of femoral rotation. There were publications used CAS to study appropriate femoral component rotation[8,13] and reported wide range of femoral component rotation in relation to proximal tibial bone cut from internal rotation 7 degrees to external rotation 10.5 degrees. However the inclusion criteria are different from the present study.

There were at least 3 methods using nowadays to identify femoral component rotation, which consisted of epicondylar axis[5], trochlear groove (Whiteside's line)[4] and posterior condylar axis[3]. In the preset study, the authors determined femoral component rotation using posterior condylar axis versus proximal tibial resection axis because less variation was observed when compared with epicondylar axis or Whiteside's line[8].

There was general acceptance for well-aligned TKA, which should be within 3-degree deviation, but there was no consensus about well-balanced TKA[13,19]. The authors choose more strict criteria to define well-balanced and well-aligned in order to define femoral rotation in this specific group. And due to the authors strict criteria, the percentage of well-balanced knees in the present study was less than previous reported study[13]. Although we used different prosthesis type, PCL was excised in both types; moreover the surgical techniques including CAS workflow were identical. Finally there was no statistically difference between range of femoral component rotation of fixed and mobile bearing group so the authors believe that bearing type does not affect femoral component rotation on condition that PCL was excised and gap technique was

applied.

The difference of post-operative correction between fixed and mobile bearing in the present study may reflect the difference of pre-operative deformity between groups. Wide range of pre-operative deformity may represent wide variety of TKA patients which normally seen in operating theater. Homogeneous post-operative coronal alignment correction result from our strict inclusion criteria, but generally using CAS in TKA gives higher accuracy of coronal alignment correction[14]. Even though there have been several studies on femoral component rotation using various methods[7-10,18,20], the criteria of well-balanced TKA were different from the present study. The present study used relatively more strict criteria but even with this, the authors found wide range of femoral rotation in this specific group. Therefore, gap technique is more preferable in order to achieve well-balanced and well-aligned TKA when PCL excision type prosthesis was used.

Conclusion

Wide range of femoral component rotation occurred in well-balanced and well-aligned total knee arthroplasty implanted with PCL excision knee prosthesis, either substitution with post and cam mechanism or deep-dished polyethylene insert. Using fixed-angle anatomical landmarks as references may increase the risk of flexion gap imbalance in this situation.

Potential conflicts of interest

None.

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การศึกษาการหมุนของข้อเทียมบริเวณกระดูกต้นขาส่วนปลายในการผ่าตัดเปลี่ยนข้อเข่าเทียมที่มีการจัดตำแหน่งและความตึงของเส้นเอ็นรอบเข่าได้สมดุลด้วยวิธีผ่าตัด Gap theory และใช้คอมพิวเตอร์นำร่อง

พฤกษ์ ไชยกิจ, สุรพจน์ เมฆนาวิน

วัตถุประสงค์: *วิเคราะห์การหมุนของข้อเทียมบริเวณกระดูกต้นขาส่วนปลาย ที่พบในกลุ่มผู้ป่วยที่ทำการผ่าตัดเปลี่ยนข้อเข่าเทียมชนิดที่มีการตัดเส้นเอ็นไขว้หลังโดยการใช้คอมพิวเตอร์นำร่องและมีการจัดตำแหน่งและความตึงของเส้นเอ็นรอบเข่าได้สมดุล (well-balanced and well-aligned)*

วัสดุและวิธีการ: *ผู้นิพนธ์ได้ทำการเก็บข้อมูลจากผู้ป่วยที่ทำการผ่าตัดตั้งแต่ เดือนมกราคม พ.ศ. 2552 ถึง เดือนกันยายน พ.ศ. 2552 พบว่ามีการผ่าตัด 65 เข่า ที่ทำการผ่าตัดเปลี่ยนข้อเข่าเทียม ชนิดที่มีการตัดเส้นเอ็นไขว้หลัง แต่พบว่ามี 34 เข่า ที่มีการจัดตำแหน่งและความตึงของเส้นเอ็นรอบเข่าได้สมดุล*

ผลการศึกษา: *พบว่าการหมุนของข้อเทียมบริเวณกระดูกต้นขาส่วนปลายมีค่าเฉลี่ย 2.12 $\pm$ 3.38 องศา และมีเพียง 7 เข่า (20.58%) มีค่าการหมุนของข้อเทียมบริเวณกระดูกต้นขาส่วนปลายเป็น external rotation 2-4 องศา โดยผลการศึกษาพบว่า ไม่มีความแตกต่างอย่างมีนัยสำคัญทางสถิติระหว่างข้อเข่าเทียมชนิดแผ่น รองรับน้ำหนักยึดติดแน่น (fixed bearing) และชนิดแผ่นรองรับน้ำหนักหมุนได้ (mobile bearing)*

สรุป: *ในการผ่าตัดเปลี่ยนข้อเข่าเทียมชนิดที่มีการตัดเส้นเอ็นไขว้หลัง และมีการจัดตำแหน่งและความตึงของเส้นเอ็นรอบเข่าได้สมดุล (well-balanced and well-aligned) พบว่ามีค่าการหมุนของข้อเทียมบริเวณกระดูกต้นขาส่วนปลายมีความแปรปรวนค่อนข้างมาก ดังนั้นการผ่าตัดโดยยึดค่าการหมุนของข้อเทียมบริเวณกระดูกต้นขาส่วนปลายให้มีค่าคงที่ อาจทำให้ความตึงของเส้นเอ็นรอบเข่าไม่สมดุลได้*