# ผลของการเปลี่ยนแปลงความชันของกระดูกทิเบียส่วนบนต่อการงอเข่าในการผ่าตัดเปลี่ยนข้อเข่าเทียมแบบอนุรักษ์เอ็นไขว้หลังโดยใช้คอมพิวเตอร์ช่วยผ่าตัด

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**บทคัดย่อ**

**บริบท** มีหลายการศึกษาพบว่าการใช้คอมพิวเตอร์ช่วยผ่าตัดสามารถหาความชันของกระดูกทิเบียส่วนบนหรือกระดูกหน้าแข้งขณะผ่าตัดเปลี่ยนข้อเข่าเทียมซึ่งส่งผลต่อการหาระยะสมดุลในท่างอเข่าและพิสัยการเคลื่อนไหวของข้อเข่าหลังการผ่าตัดข้อเข่าเทียมแบบอนุรักษ์เอ็นไขว้หลัง

**วัตถุประสงค์** เพื่อเปรียบเทียบความเปลี่ยนแปลงของความชันกระดูกหน้าแข้งระหว่างก่อนผ่าตัดและหลังผ่าตัดในผู้ป่วยที่ได้รับการเปลี่ยนข้อเข่าแบบอนุรักษ์เอ็นไขว้หลังโดยใช้คอมพิวเตอร์ช่วยผ่าตัด รวมถึงศึกษาผลของการเปลี่ยนแปลงความชันต่อการหาจุดสมดุลในท่างอเข่าหลังการผ่าตัด

**วิธีการศึกษา** ผู้วิจัยศึกษาข้อมูลผลการผ่าตัดเปลี่ยนข้อเข่าย้อนหลังแบบตัดขวาง โดยก่อนผ่าตัดผู้ป่วยมีอายุมากกว่า 60 ปีขึ้นไป ได้รับการวินิจฉัยเป็นข้อเข่าเสื่อม สามารถงอเข่าได้มากกว่า 100 องศา และแพทย์วางแผนการผ่าตัดเปลี่ยนข้อเข่าเทียมแบบวิธีอนุรักษ์เอ็นไขว้หลังโดยใช้คอมพิวเตอร์ช่วยผ่าตัด (computer-assisted surgery-cruciate retaining-total knee arthroplasty, CAS-CR-TKA) ที่ โรงพยาบาลวชิระพยาบาล ตั้งแต่เดือนกุมภาพันธ์ พ.ศ.2551 ถึง 31 มีนาคม พ.ศ.2554 ผู้วิจัยแบ่งข้อเข่าที่ได้รับการผ่าตัดเป็น 2 กลุ่ม ได้แก่ กลุ่มควบคุม คือ ข้อเข่าที่ได้รับการผ่าตัดแบบ CAS-CR-TKA และหลังผ่าตัดสามารถงอเข่าได้เท่ากับหรือมากกว่าก่อนการผ่าตัด กลุ่มศึกษา คือ ข้อเข่าที่จำเป็นต้องเปลี่ยนวิธีผ่าตัดในห้องผ่าตัดจากแบบ CAS-CR-TKA ไปเป็นการผ่าตัดแบบตัดเอ็นไขว้หลังออกหรือต้องเปลี่ยนเป็นข้อเข่าเทียมแบบทดแทนเอ็นไขว้หลัง (posterior stabilized-total knee arthroplasty, PS-TKA) เนื่องจากไม่สามารถหาระยะสมดุลในท่างอเข่าขณะผ่าตัดได้ หรือหลังผ่าตัดผู้ป่วยงอเข่าได้น้อยลงกว่าเดิม 15 องศา ผู้วิจัยศึกษาความชันของกระดูกหน้าแข้งทั้งก่อนและหลังการผ่าตัดที่ได้จากภาพคอมพิวเตอร์ช่วยผ่าตัด และภาพถ่ายทางรังสีที่ได้จากก่อนการผ่าตัด และที่ระยะ 1 เดือน 3 เดือน และ 6 เดือนหลังผ่าตัด

**ผลการศึกษา** ผู้ป่วยจำนวน 43 ราย มีจำนวน 46 ข้อเข่า แบ่งเป็นกลุ่มควบคุมจำนวน 11 ข้อเข่า และกลุ่มศึกษาจำนวน 35 ข้อเข่า ความชันของกระดูกหน้าแข้งระหว่างก่อนผ่าตัดและหลังผ่าตัดของทั้งสองกลุ่มคือ กลุ่มควบคุมและกลุ่มศึกษาไม่มีความแตกต่างกัน แต่พบว่าการเปลี่ยนแปลงความชันของกระดูกหน้าแข้งระหว่างในกลุ่ม

ควบคุม คือ 4.16 องศา และกลุ่มศึกษา คือ 7.64 องศา ซึ่งมีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ ($p = .01$) และ พบว่ากลุ่มศึกษาที่มีการเปลี่ยนแปลงความชัน 7.64 องศา เป็นกลุ่มที่ไม่สามารถหาจุดสมดุลในท่างอเข่าด้วยวิธีผ่าตัดเปลี่ยนข้อเข่าเทียมแบบอนุรักษ์เอ็นไขว้หลังได้

**สรุป** การเปลี่ยนแปลงความชันของกระดูกหน้าแข้งระหว่างก่อนและหลังผ่าตัดที่มากเกินไป (ในการศึกษานี้คือมากกว่า 7.64 องศา) จะทำให้ไม่สามารถหาระยะสมดุลในท่างอเข่าขณะผ่าตัด จึงจำเป็นต้องเปลี่ยนแปลงการผ่าตัดเข่าเทียมแบบอนุรักษ์เอ็นไขว้หลังไปเป็นวิธีอื่นแทน

**คำสำคัญ** ข้อเข่าเสื่อม คอมพิวเตอร์ช่วยผ่าตัด การผ่าตัดเปลี่ยนข้อเข่าเทียม อนุรักษ์เอ็นไขว้หลัง ความชันกระดูกหน้าแข้ง (ทิเบียส่วนบน)

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# Effects of posterior tibial slope restoration difference in cruciate retaining total knee arthroplasty using computer-assisted surgery

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## Abstract

**Context:** Studies have shown that the presence of a posterior tibial slope after total knee arthroplasty(TKA), affects both flexion gap balancing and the patient's range of motion after surgery, especially in cruciate-retaining, computer-assisted total knee arthroplasty surgery.

**Objective:** To compare changes in the position of the posterior tibial slope, pre and post operation, on patients having received CR-TKA (cruciate-retaining total knee arthroplasty). The effects of a change in the posterior slope on flexion gap balancing and knee bending were also studied.

**Materials and Methods:** This was a cross-sectional, retrospective study, performed on computer-assisted cruciate-retaining total knee arthroplasty (CAS-CR-TKA) patients at Vajira Hospital, from February of 2008 to March 31st of 2011. Patients with a degree of knee flexion less than 100 degrees were not included in this study. After performing the CAS-CR-TKA, we classified the patients into two groups, as determined by comparing the changes in their posterior tibial slope before and after operation. Changes to the tibial slope were observed via computer and x-ray film. The study group of patients were those needing to either retain their posterior cruciate ligament (PCL), needing to change from CAS-CR-TKA to PS-TKA (posterior stabilized-TKA); or, whose degree of knee bending was less than 15 degrees. The control group of patients were those with an equal or improved degree of knee flexion before taking their CAS-CR-TKA.

**Results**: Slope restoration differences between the study and control groups were statistically significant (7.64 degrees in the study group, and 4.16 degrees in the control group) with p-value at 0.01. The pre and postoperative posterior tibial slope was not different statistically between groups.

**Conclusions:** Posterior tibial slope restoration (changing between pre-operative and post-operative tibial slope) greater than 7.64 degrees will result in inability to find a balance gap during knee flexion and decrease range of motion of the knee after the cruciate-retaining, computer-assisted total knee arthroplasty surgery.

**Keywords:** Osteoarthritis knee, Computer assisted surgery, Total knee arthroplasty, Cruciate retaining, Tibial slope

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**Introduction**

Osteoarthritis refers to losing parts of the joint articular cartilage surface along with the regeneration of osteophyte. The regeneration of osteophyte makes the knee joint abnormal, resulting in painful knee deformities and knee stiffness. These effects reduce the quality of the patient's life.[1]

Total knee arthroplasty (TKA) is normally performed when conservative treatment is unsuccessful. Generally, replacing the knee joint can be classified into several kinds and types. To opt for this kind of operation depends on each patient's symptoms, pre-operation disorders, intra-operation situations as well as the expertise of the doctor and post-operation management, rehabilitation and the patient's resolution

Upon the treatment of osteoarthritis includes replacing the patient's knee joint using cruciate-retaining total knee arthroplasty (CR–TKA), we found that the range of motion of knee joints was less than 100 degrees in some patients. Moreover, some patients needed to release their posterior cruciate ligaments, or needed to change the type of operation to a posterior stabilization (PS) during surgery because there was an unbalanced flexion and extension gap (tight flexion gap) during surgery.[2] Normally, TKA have to resected the bone on both distal femur and proximal tibia for created gap and need to balance the gap on both flexion and extension knee before inserting the prosthesis for the good result (longevity prosthesis and better range of motion function).

Recently,[3] computers have been used to improve the accuracy of slope and position measurements during TKA, i.e., "Computer assisted surgery in total knee arthroplasty (CAS-TKA)." As a result, CAS-TKA had better accuracy, especially with bone cutting. However, there were some patients whose post-operation knee flexion was less than 100°. As mentioned earlier, this problem is caused by an instability due to a tight flexion gap. To the best of our knowledge, there is no literature available recommending the specific degree of posterior tibial slope, when performing CR-TKA.

Consequently, we began studying the changes of the posterior slope in patients undergoing CR-TKA, if changes in the posterior slope caused an unbalanced flexion and extension gap, then the type of surgery must be changed to a posterior stabilized (PS) design. It should be noted that an unbalanced flexion and extension gap may decrease the slope of knee bending in some patients.

The purpose of this study was to compare changes in the posterior slope before and after performing operation on patients receiving CR-TKA. The effect and correlation of the change in posterior slope to the flexion gap, as well as balancing and knee bending was also studied.

**Materials and Methods**

This research was conducted on osteoarthritis patients receiving surgery at

the Faculty of Medicine of Vajira Hospital, Navamindradhiraj University, Bangkok Thailand. The findings were based on a cross-sectional, retrospective study from February of 2008 to the 31st of March of 2011. Moreover, the treatment of these osteoarthritis patients needed to be performed using CAS-CR-TKA.

Inclusion criteria:

1. The patient is more than 60 years old
2. Posterior drawer tests negative

Exclusion criteria:

1. Inflammatory joint disease
2. Post-infectious arthritis
3. A previous major knee injury
4. The presence of a lower extremity fracture after CAS-CR-TKA
5. Pre-operative range of motion (ROM) < 100 degrees
6. An inability to continually follow up with the patient
7. Inadequate Radiograph
8. Serious medical illness

Following the above criteria, 26 of the 69 CAS-CR-TKA patients were excluded from our research due to pre-operation risks such as inadequate knee flexion (ROM less than 100 degrees), rheumatoid arthritis, severe medical illness; post-operation risks such as surgical knee infection, knee flexion decreased less than 14 degrees after operation, and a problem with the x-ray films. Therefore, only 46 post operation patient's knees from 43 patients were separated into two groups, the control group and the study group for evaluating their posterior tibial slope. The control group was the 11 patients' knees whose degree of knee flexion were better or the same as before operation. The study group included 35 patients' knees with knee flexion decreased more than 15 degrees after operation or patients needing posterior cruciate ligament (PCL) release to tighten their flexion gap – or even patients needing to change their knee prosthesis to a posterior stabilized-TKA (PS-TKA) design intraoperation because of further complications with their flexion gap.

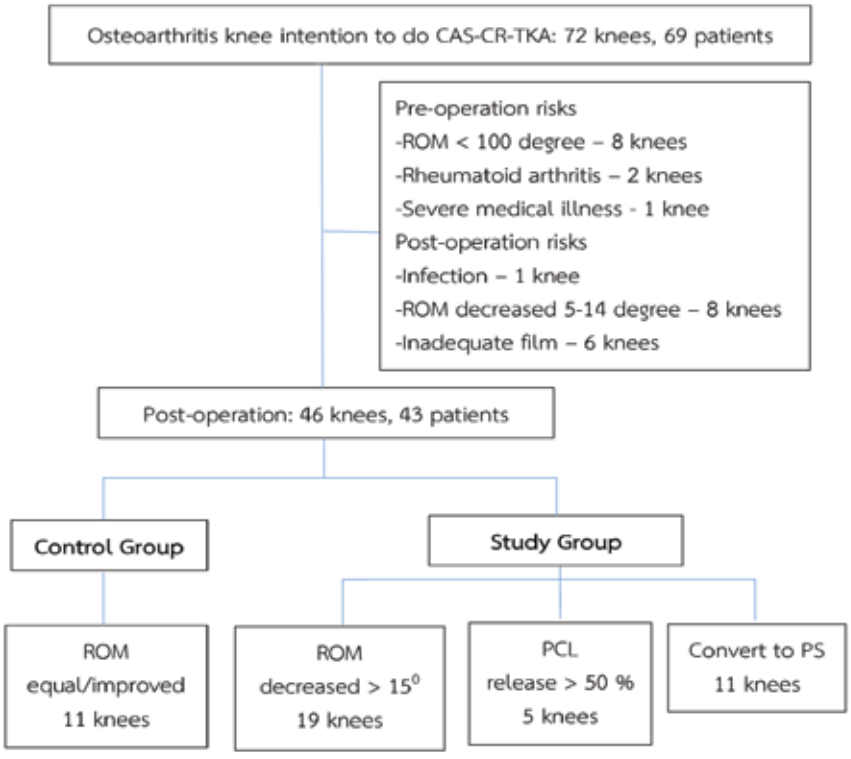



**Figure** 1 Overview of the number of patients receiving operations at Vajira Hospital
**Note**: CAS-CR-TKA = Computer-assisted cruciate-retaining total knee arthroplasty; ROM = Range of motion; PCL = Posterior cruciate ligament; PS = Posterior stabilized

Measurements of the degrees of each patient's knee flexion were taken before and the first, third and sixth month after operation by two medical assistants who were trained to measure the slope using a goniometer. However, the medical assistants had no other contribution in this research.

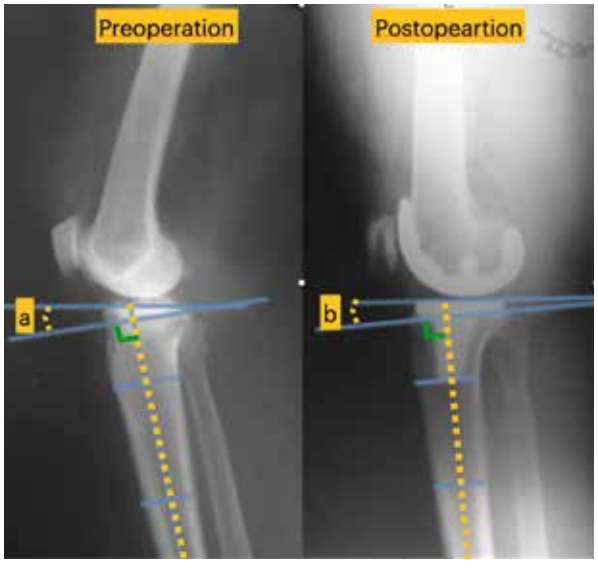



**Figure 2** The method of measuring the posterior tibial slope with radiography

**Note**: Dot line - proximal anatomical axis of the tibia: created by a line drawn proximal to middle in the intramedullary canal bisecting the tibial in half; a - preoperative tibial slope; b - postoperative tibial slope

X-rays were taken by two doctors. The first doctor performs the x-ray while the second doctor evaluates any error in measurement. In this research, we used the proximal anatomical axis of the tibia (Figure 2) to measure the tibial slope.[4-6] From the method of posterior tibial slope measuring (Yoo[6]), the proximal anatomical axis of the tibia was used for best accuracy.

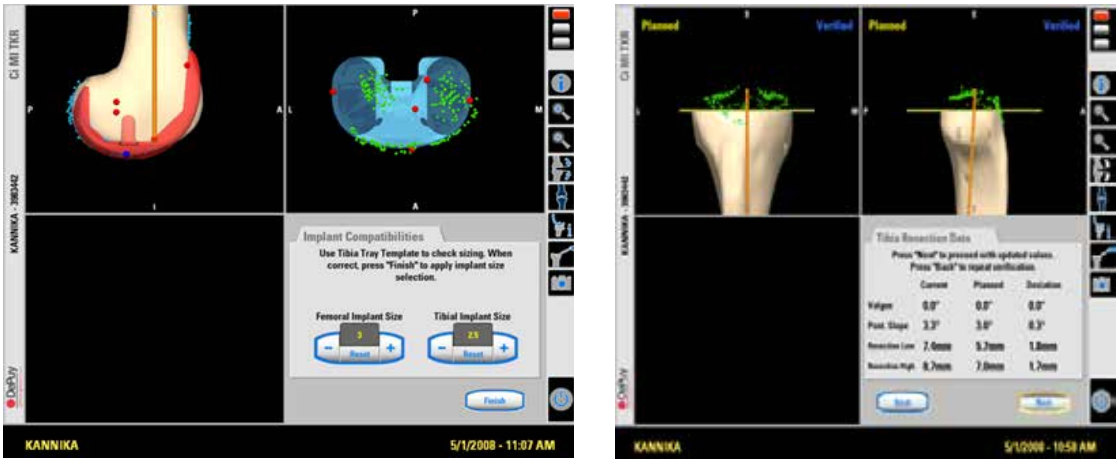
Results from the x-rays are as follows:

1. Posterior Tibial Slope before and after operation.

2. Anatomical axis of knee.

The differences in slope before and after operation was used to evaluate the success of the restoration.

The operation was done by using a medial parapatellar approach. There was a posterior cruciate ligament (PCL) examination in the operation. If PCL insufficiency was detected, the Posterior Stabilized (PS) design is implemented. In patients whose posterior cruciate ligament function was normal, the operation was ongoing to the computer-assisted surgery (CAS-TKA). As shown in Figure 3, there was an evaluation of the knee's tightness after cutting the bone and inserting a trial prosthesis. If there was tightness of the knee flexion, the PCL release was performed. If the PCL release results in more than 50% flexion, the type of knee prosthesis was then changed to a PS design.




a b

**Figure 3** Computer-assisted surgery in total knee arthroplasty monitor a Showed method to template for selected tibial tra b Planning for tibial resection data and intraoperative posterior tibial slope

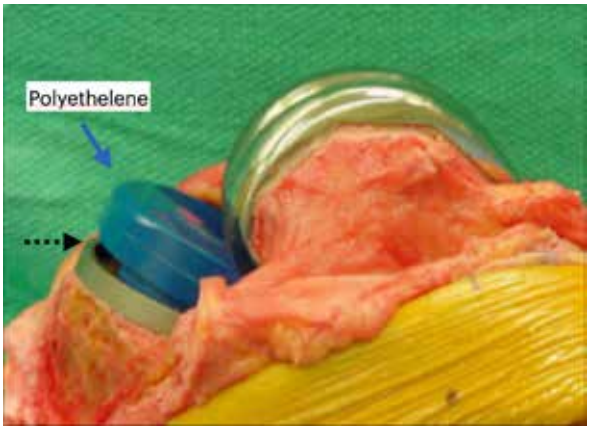



**Figure 4** The flexion gap tightness after the full prosthesis trial. The polyethylene (blue arrow) was lifted off during knee flexion (black dot arrow) – flexion gap tightness was the cause of the condition.

Statistical evaluations from our analysis complied with the Mann-Whitney test. The parameters in this research were set as *p*-value less than 0.05 and size of population was 72.9.

**Results**

Forty-six post operation patient's knees consisted of 11 patient's knees made up a control group, with a study group of 35 patient's knees for evaluating their posterior tibial slope. However, the basic information as shown in Table 1 between the two groups. (average age, BMI, tourniquet time and the amount of blood lost) were not different.

**Table 1** Basic demographic data between control and study groups

| Basic Demographic Data | Control Groups | Study Groups |
|---|---|---|
| Number (knee) | 11 | 35 |
| Average age (yr) (SD) | 71.53 (8.06) | 68.66 (3.55) |
| Gender | | |
| - Male | 2 | 1 |
| - female | 9 | 34 |
| BMI (kg/m$^2$) (SD) | 27.011 (5.09) | 27.16 (5.06) |
| Tourniquet time (min) (SD) | 72.5 (13.2) | 91.66 (20.1) |
| Amount of blood lost (cc.) | 680 | 580 |

A knee's anatomical axis is calculated as either varus or valgus knees, and both anatomical axes affect operation and a balanced flexion-extension gap. As a result, we found that the anatomical axes of our two groups of patients were not different (Table 2).

**Table 2** Anatomical axes before and after operation across both groups

| Types | Degree of Varus (SD) | |
|---|---|---|
| | Control Group | Study Group |
| Pre-op Mechanical Axis (X-ray) | 9.90 (6.05) | 10.99 (6.31) |
| Post-op Mechanical Axis (X-ray) | 2.90 (1.51) | 2.88 (2.89) |

Furthermore, when we compared posterior tibial slope differences from both groups, both pre- and post-operation, in the control group, knee flexion is the same or better (the difference is 4.16 degrees); and, in the study group, the slope difference was 7.46 degrees. These values were further calculated through a statistical model to reveal there was significant difference ($p < 0.01$) (Table 3)

**Table 3** Compare posterior tibial slopes, pre-operative, post-operative and the differences in slope between pre and post-operative

| Groups | Pre-operative slope (degree) | Post-operative slope (degree) | Difference in Posterior Tibial Slope (degree) |
|---|---|---|---|
| Control Group<br>- ROM equal or increase | 10.63 | 6.59 | 4.16 |
| Study Group<br>- ROM decrease<br>- PCL release 50%<br>- Change to PS-TKA | 12.11 | 4.65 | 7.46 |

## Discussion

The problem of a decrease in the degree of knee flexion after operation is caused by a tight flexion gap. As mentioned in previous studies,[7-11] the posterior slope affects the flexion gap balancing. In the literature of Bellemans et al., studies were carried out on cadavers. To cut the tibia along different slopes would change the degree of knee flexion (when the posterior tibial slope was increased by 1 degree, the degree of knee flexion increased to 1.7 degrees). However, Massin et al. found that when studying real patients, cutting the posterior slope at an increase of five degrees resulted in a five degree decrease in knee flexion, as compared with the patient's preoperative degree of knee flexion. It should be noted too that the study above was a PS-TKA operation.[12.] Kansara et al., found the difference in posterior slope did not affect the degree of knee flexion.[13] It should be noted that that study used a PS-TKA operation. Pruk et al., found there was a 0 - 3 mm increase in flexion gap after the PCL is removed in total knee arthroplasty.[14] Lombardi et al. reported that, If the degree of posterior tibial slope was less than 3 degrees, a PCL release would be required – but not in patients with a posterior tibial slope more than 3 degrees.[15]

It can be seen from the CR total knee arthroplasty group, that the posterior cruciate ligament will affect a patient's flexion gap more than in patients from the PS total knee arthroplasty group. This means that the posterior tibial slope cut must be in the desired value to avoid the problem of balancing the flexion and extension gap.

However, the posterior tibial slope in each patient is different, according to the research of Chiu et al., having studied on

cadavers, that the average posterior tibial slope was 14.7 degrees (SD = 3.7 degrees; Range = 5-22 degrees). In patients with osteoarthritis the slope was significantly more than in patients without osteoarthritis.[16] Kansaral and colleagues have measured the posterior tibial slope was in the range of 0 - 15 degrees.[13] Matsuda et al, found that patients with normal functioning knees exhibited a posterior tibial slope within the range of 5 - 15 degrees, while in the varus knee the range was 1.5 - 1.9 degrees.[17] In this study it was found that the posterior tibial slope of the patients was in the range of 3 - 18 degrees.

This research found no statistically significant difference in the posterior tibial slope of the patient before or after surgery. However, when we take the original patient before surgery and after surgery, and take the differences of the slope's change before and after surgery, we found a decrease in knee flexion, a necessity to cut the PCL or the need to change the type of prosthesis, resulting in a knee flexion the same or better after surgery (7.46 degrees and 4.16 degrees respectively). The calculations showed that there was a significant difference ($p$ = 0.01).

The hypothesis of this research confirms that the posterior tibial slope changed from the patient's own, affecting the balance, flexion and extension gap of the patient, leading to the need to release the PCL due to a problem with the flexion gap tightness.

Thus, in the pre-operative stage when the surgeon measures the posterior tibial slope and finds it necessary to cut the slope more than 7 degrees from the original position, the type of prosthesis should be considered; because, if using a CR prosthesis, it may necessitate cutting the PCL or later changing the type of prosthesis during surgery. However, note that the weakness of this study is its retrospection (though taking a patient to trial and cutting the posterior tibial slope with various differing degrees is unethical). Additionally, X-ray measurements made by only one doctor may result in errors in measurement. We solved this problem by having a second doctor reevaluate the accuracy of the measurements (without knowing which patients are in which group to reduce any bias).

## Conclusion

Changes in the posterior tibial slope affect the balance of the flexion gap and knee flexion after surgery, in patients having undergone cruciate retaining total knee arthroplasty (CR-TKA).

The degree of pre-operative posterior tibial slope is one important factor in choosing the type of prosthesis, to reduce the problems of not being able to balance the flexion and extension gap during operation.

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