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Original article

Posterior condylar offset and flexion in posterior cruciate-retaining and posterior stabilized TKA

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Abstract

Background. Anterior tibial translation associated with posterior impingement has been reported to be one of the factors limiting flexion after posterior cruciate-retaining (CR) total knee arthroplasty (TKA), especially when posterior condylar offset is decreased postoperatively. On the other hand, its effect on postoperative motion in posterior-stabilized (PS) TKA remains unknown. It has been demonstrated that PS TKA exhibits a consistent posterior femoral rollback during flexion. Thus, we hypothesized that the problem of posterior impingement can be avoided by use of PS TKA. In this study, we examined the relationship between postoperative posterior condylar offset and knee flexion in CR and PS TKAs.

Methods. In this study, analysis was performed for 20 subjects who underwent bilateral TKAs (one CR and one PS TKA) as well as another group of 50 PS TKAs. All patients could be tracked for a minimum of 2 years. The range of flexion was measured before operation and at follow-up. Preoperative and postoperative posterior condylar offset was evaluated on true lateral radiographs.

Results. At the follow-up examination, the mean flexion angle was 123° in the CR knees and 131° in the PS knees with a significantly greater improvement observed for the latter group. In the roentgenographic measurement of the posterior condylar offset, no significant difference was observed between the preoperative and postoperative values both in the CR and PS knees. We divided the patients into two groups according to the change of posterior condylar offset. The first group (Group I) showed a decrease in the posterior condylar offset after surgery and the second group (Group II) showed no change or an increase. Subsequently, postoperative change in flexion was compared between Groups I and II for the CR and PS knees. A significant difference between Groups I and II was observed in the CR knees, while no difference was observed in the PS knees. The magnitude of postoperative posterior condylar offset did not correlate with an improvement in maximum flexion angle in the 50 PS knees.

Conclusions. It was shown that the magnitude of posterior condylar offset correlated with a postoperative change in flexion angle in CR knees, while no such correlation was observed in PS knees.

Introduction

Several crucial factors have been shown to influence knee flexion after total knee arthroplasty (TKA), including preoperative range of motion, surgical technique, prosthetic design, and postoperative rehabilitation.[1–9] Among those potentially influential factors, whether the posterior cruciate ligament is retained or sacrificed has been a focus of investigation, and there have been several clinical and biomechanical studies.[3–5,10–14]

We conducted a prospective comparative study of posterior cruciate-retaining (CR) and posterior stabilized (PS) TKAs in 20 patients who underwent bilateral surgeries for osteoarthritis. In this comparative study, it was shown that postoperative improvement in range of motion was significantly superior in PS TKA patients.[15]

In attempting to clarify the difference between CR and PS TKAs, flexion kinematics has been investigated through fluoroscopic analysis.[10,11,13,14,16,17] We also compared the flexion kinematics between CR and PS knees in the same group of 20 patients.[18] Our kinematic results agreed with those of the previous studies,[11,13,16,17] demonstrating anterior femoral translation in CR knees and posterior femoral rollback in PS knees during flexion.

Bellemans et al.[19] reported that the anterior tibial translation during flexion can be a factor to limit maximum flexion by posterior impingement of the tibial insert against the back of the femur. Bellemans et al.[19] defined a parameter termed "posterior condylar offset

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(amount of posterior projection of the femoral implant to the tangent of the posterior femoral cortex)," and showed that a decreased posterior condylar offset in a CR TKA could be a causative factor in limiting flexion after surgery. Considering a kinematic difference was demonstrated between CR and PS knees as shown in the previous studies as well as our own,[10,11,17,18] the effect of posterior condylar offset on the postoperative flexion in knees implanted with PS TKA can be different from that of CR TKA-implanted knee. To date, no study has examined the significance of this issue in PS knees.

We hypothesized that the problem of posterior impingement can be avoided even in knees with decreased posterior condylar offset by use of PS TKA, thus achieving improved postoperative flexion. Therefore, in this study, we examined the relationship between postoperative posterior condylar offset and knee flexion in patients who received bilateral paired CR and PS TKAs as well as 50 consecutive patients who had undergone primary PS TKAs.

Materials and methods

Our study consisted of two parts. The first study included 20 patients (12 women and 8 men) who underwent bilateral TKAs for osteoarthritis between January 1998 and July 2000. Inclusion criteria were as follows: (1) bilateral osteoarthritic knees with similar roentgenographic grades, (2) bilateral TKAs (CR type in one knee and PS type in the contralateral knee) performed with a time interval of less than 2 years, and (3) correction of deformity was achieved with retention of the posterior cruciate ligament (PCL). A CR TKA was implanted in one knee, and a PS TKA in the contralateral knee. The side (left or right) for each of the two different TKAs was randomly alternated among the 20 subjects. Prostheses of both types were of PFC Σ Series (DePuy, Warsaw, IN, USA). Both CR and PS components possessed basically the same surface geometry except a cam-post mechanism was added to the PS type.

All surgeries were performed by the same surgeon (MK) with standardized instrumentation attached to the PFC Σ Series. Surgeries were performed with a basically identical technique except for the type of prosthesis. In the bony resection, the distal femoral cut was performed at a right angle to the mechanical axis of the femur. An anterior–posterior cutting block was placed with anterior referencing with the rotational alignment of 3° external rotation in reference to the posterior condylar line. The intramedullary guide was used for the tibial cut with a posterior inclination of 5°. Prosthetic components were cemented in all knees. Intraoperatively, tight collateral structures were released to achieve symmetrical joint gap. In the majority of the CR TKAs (18 of 20 knees), the PCL was judged to be tight in flexion and recession of the PCL was performed off the tibia until the tension appeared to be appropriate. Postoperatively, the operated knee was not immobilized and range of motion exercises at the physical therapy department were begun 3 days after surgery. Weight bearing was allowed at 2 weeks with gradual progression to full weight bearing.

The mean age at the time of surgery was 74.3 years (range 65 to 84 years). The time interval between surgeries for both knees ranged from 1 month to 23 months and all patients could be tracked for a minimum of 2 years after the second surgery with the average follow-up period of 31.7 months (range 24 to 53 months) for the CR TKA knees and 30.6 months (range 24 to 38 months) for PS TKA knees. All patients had successful results with a knee score of 85 or more and a function score of 80 or more, according to the Knee Society Scoring System.[11] Size of the implant selected for bilateral knees (range #1.5 to 3) was different in two subjects and the polyethylene insert of different thickness (range 8 to 15 mm) was used in three knees. Maximum differences of implant size and insert thickness were #0.5 and 3 mm, respectively.

In the second part of our study, we followed 50 consecutive patients who had undergone a PS TKA for osteoarthritis of the knee including the 20 knees examined in the first part of the study. All knees had been operated on between 1997 and 2000 by the same surgeon (MK) using the same implant (PFC Σ) and same technique as mentioned above. The mean age at the time of surgery was 72.1 years (range 52 to 86 years). All patients could be tracked for a minimum of 2 years with the average follow-up period of 31.5 months (range 24 to 57 months). The size of the implant ranged from #1.5 to 3 and the thickness of the polyethylene insert ranged from 8 to 15 mm. Informed consent for participation in the study was obtained from each patient.

The follow-up evaluation included clinical and fluoroscopic roentgenographic examinations, and all the assessments were performed by the principal author (MA). The range of flexion was measured using a standard clinical goniometer before operation and at follow-up. Preoperative and postoperative posterior condylar offset was evaluated on true lateral radiographs as described by Bellemans et al.[19] (Fig. 1). In order to obtain an accurate lateral view, direction of the roentgenographic projection was adjusted under fluoroscopic control.

The results were analyzed statistically using the two-way analysis of variance (ANOVA) for the comparison between preoperative and postoperative data as well as that between the two prosthetic types. Pearson's regression analysis was utilized for assessment of the correlation. StatView for Windows was used for statistical analysis with a significance level set at $P < 0.05$.

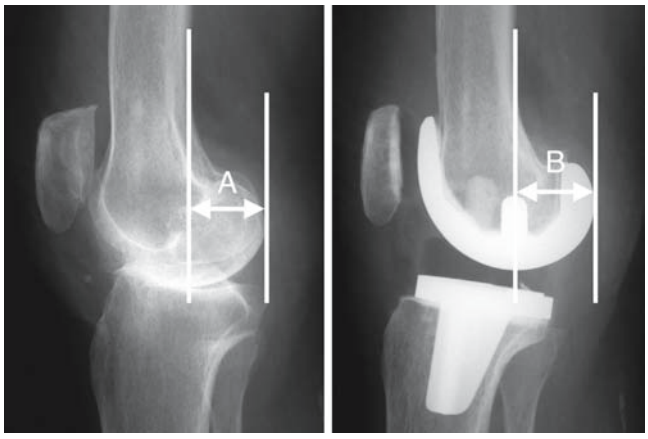

Fig. 1. Assessment of posterior condylar offset was made preoperatively (*A*) and postoperatively (*B*)

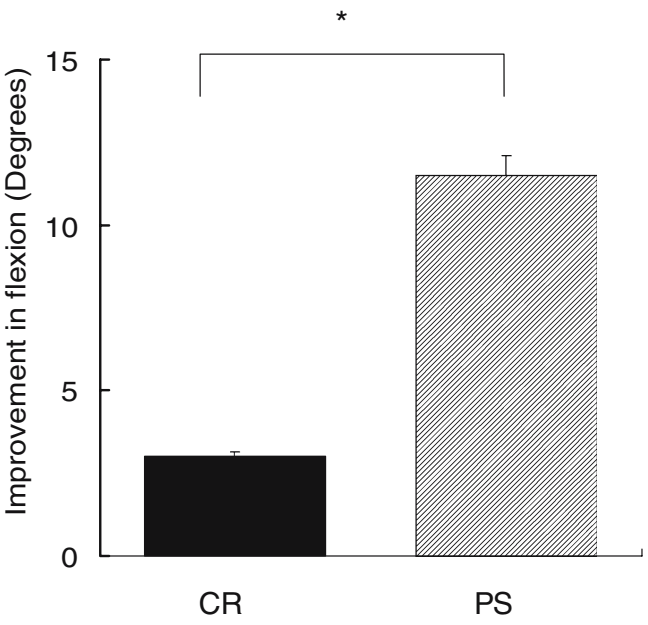

Fig. 2. Postoperative improvement in flexion angle of the posterior cruciate-retaining (*CR*) knees and posterior-stabilized (*PS*) knees. *Asterisk* indicates significant difference between the groups ($P < 0.05$)

Results

Comparison between the CR and PS TKAs

In the comparison of clinical results between the groups, postoperative recovery as assessed by hospitalization period was not significantly different between the groups. In the overall clinical outcome, no significant difference was detected both preoperatively and postoperatively between the two TKA designs. On the other hand, the mean flexion angles were 120° ± 18° in the CR knees and 120° ± 18° in the PS knees before surgery, while those values increased to 123° ± 15° in the CR knees and 131° ± 13° in the PS knees at the follow-up. The improvement in flexion angle was significantly higher in the PS knees than that in the CR knees ($P < 0.05$) (Fig. 2).

In roentgenographic examination, the preoperative mean posterior condylar offset was 25.0 mm in the PS knees and 25.3 mm in the CR knees, while the corresponding values were 24.5 mm and 24.3 mm, respectively, at the follow-up. Thus, both preoperative and postoperative posterior condylar offset values were basically identical in both groups. In order to evaluate the relationship between the change of posterior condylar offset and the postoperative improvement in range of flexion, we divided the patients into two groups according to the change of posterior condylar offset. The first group (Group I) showed a decrease in the posterior condylar offset after surgery (CR: 10 knees, PS: 11 knees). The second group (Group II) showed no change or increase in the posterior condylar offset after surgery (CR: 10 knees, PS: 9 knees). Subsequently, postoperative change in flexion was compared between Group I (subjects with reduction of posterior condylar offset) and Group II (subjects without reduction of posterior condylar offset) in each of the CR and PS knees. Then a significant difference between Group I and Group II (effect of change in posterior condylar offset on postoperative flexion) was observed in the CR knees ($P < 0.05$), while no difference was observed in the PS knees (Fig. 3).

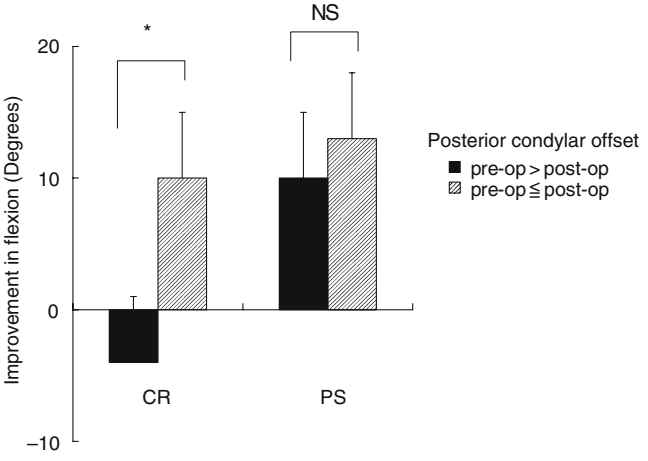

Fig. 3. Relationship between postoperative change in flexion angle and the posterior condylar offset was assessed in the CR and PS knees. When the knees with reduction in posterior condylar offset and those without the reduction were compared, a significant difference in the mean postoperative change of flexion angle was observed only in the CR knees (*asterisk*, $P < 0.05$)

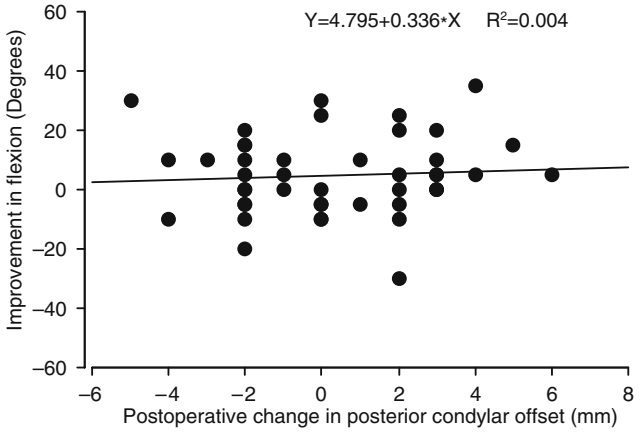

Fig. 4. Correlation between postoperative improvement in flexion and change in the posterior condylar offset in the PS knees

Correlation between the posterior condylar offset and the postoperative flexion in PS TKAs

In order to confirm the findings obtained in the study for the subjects with bilateral TKAs, we conducted a second study for a larger group of 50 consecutive patients who had undergone primary PS TKAs, including the 20 subjects examined in the first part of the study. In this part of the study, the mean preoperative and postoperative flexion values were 122° ± 10° and 127° ± 13°, respectively, while the mean preoperative posterior condylar offset was 25.5 ± 2.0 mm, and it was measured as 25.8 ± 2.7 mm after operation. The magnitude of postoperative posterior condylar offset did not correlate with an improvement in maximum flexion angle ($R^2 = 0.004$) (Fig. 4).

Discussion

There have been a number of studies comparing results of CR and PS TKAs.[3–5,10–14] Among those studies, Hirsch et al.[4] reported that superior postoperative flexion was attained in a PS TKA and our clinical comparative study also showed the advantage of a PS TKA over a CR TKA in terms of postoperative flexion.[15]

A potential disadvantage of a CR TKA is that physiological function (pattern of change in tension through range of motion) cannot always be reproduced after surgery. Kim et al.[12] performed a radiographic analysis for CR TKA and stated that if the PCL was too tight, excessive femoral rollback resulted in anterior lift-off of the tibial trial in flexion, leading to a limitation of flexion. On the other hand, it was also shown that if the PCL was too loose, anterior sliding of the femur during flexion led to a limitation of flexion.[3,11,12] In 2002, Bellemans et al.[19] investigated the mechanism limiting the maximum knee flexion in vivo after a CR TKA, and reported that the maximum degree of active flexion was determined by direct impingement of the posterior aspect of the tibial insert against the shaft of the femur in 72% of the knees investigated. They further showed that a mechanical block caused by the impingement was associated with a forward sliding of the femur during flexion, resulting in limitation of flexion after CR TKA when the decreased posterior condylar offset was present. However, in PS TKA, the significance of this parameter has not been clarified.

In the present study, the influence of the posterior condylar offset on the postoperative knee flexion angle was compared between CR TKA and PS TKA for patients who underwent bilateral TKAs. Consequently, it was demonstrated that in the CR TKA, the magnitude of the posterior condylar offset was found to correlate with a change in the final knee flexion angle, as shown by Bellemans et al.,[19] while the measured values had no correlation with postoperative flexion in the PS TKA. Thus, it is demonstrated that the postoperative decrease in the posterior condylar offset affects flexion gains in the CR TKA but not in the PS TKA.

Previous three-dimensional fluoroscopic analyses of TKA reported that the PS knee consistently exhibited posterior femoral rollback with flexion, while an anterior femoral translation with flexion was observed in the CR knees.[11,18,20] Therefore, in contrast to the CR TKA, the post-cam mechanism of the PS knee can theoretically prevent an anterior femoral translation during flexion causing posterior impingement even with the presence of the decreased posterior condylar offset.

Theoretically, restoration of normal PCL function and posterior condylar offset in the use of a CR TKA can restore normal knee kinematics. However, the actual surgical procedure does not always accomplish this ideal situation, resulting in nonphysiological knee kinematics and geometry. In these circumstances, excessive PCL tension or posterior impingement associated with PCL dysfunction can limit postoperative flexion in CR TKA. In this study, a decrease in the posterior condylar offset in the CR knee was shown to be associated with flexion limitation, while in the PS knees, a decreased posterior condylar offset did not affect the postoperative improvement in flexion. Difference in flexion kinematics as shown in our separate study[18] for the same group of patients is thought to account for the difference in clinical performance between the CR and PS TKAs. However, the number of subjects is not high enough and the reliability of our analytical method has not been validated. Thus, a conclusive statement cannot be drawn from the data obtained in this study. Further study to test the reliability of our assessment and a more comprehensive analysis with a larger group of patients will be required.

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