

Intraoperative factors affecting conversion from cruciate retaining to cruciate substituting in total knee arthroplasty

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Abstract

Purpose The purpose of this study was to analyse the factors affecting the conversion from posterior cruciate ligament (PCL)-retaining (CR) to PCL-substituting (PS) prostheses during total knee arthroplasty (TKA).

Methods A total of 920 TKAs, which had been preoperatively planned to undergo implantation of CR-type prostheses, were reviewed retrospectively. Of these, 83 knees (9.0 %) were converted intraoperatively to PS prostheses. The clinical and radiological factors of the non-converted (CR) and converted (PS) groups were compared. Clinically, age, gender, body mass index, angle of flexion contracture, size of the femoral component, and thickness of the polyethylene insert were compared between the CR and PS groups. Radiologically, the severity of the varus deformity and the posterior tibial slope angle (PSA) were compared between the CR and PS groups.

Results No significant differences in age, gender, body mass index, range of motion, thickness of the polyethylene insert, or severity of varus deformity were identified. The average preoperative angle of flexion contracture was $5.9^\circ \pm 7.4^\circ$ in the CR group and $8.1^\circ \pm 9.1^\circ$ in the PS group ($p = 0.002$). The average preoperative PSA was $9.6^\circ \pm 4.0^\circ$ in the CR group and $11.0^\circ \pm 5.0^\circ$ in the PS group ($p = 0.018$). The conversion rates to a PS-type femoral component of size C, D, and E were 13.1, 7.0, and 6.3 %, respectively ($p = 0.004$).

Conclusion The conversion rate from CR- to PS-type prostheses was high in patients with severe flexion contracture, steep posterior slope, and a small femoral component size. These factors should be carefully considered for appropriate selection of prosthesis type.

Level of evidence IV.

Keywords Knee · Total knee arthroplasty · Total knee replacement · TKA · TKR · PCL retaining · PCL substituting · Conversion factor

Introduction

Two classic options for primary total knee arthroplasty (TKA) are available, namely posterior cruciate ligament (PCL) retaining (CR) and PCL substituting (PS) [35]. The decision as to whether to retain or sacrifice the PCL remains a controversial issue in TKA [1, 5, 6, 12, 16, 27]. Some authors prefer the CR type of prosthesis, believing that it confers theoretical advantages such as proprioceptive function, joint stability, and physiological kinematics [15, 17, 21, 38, 41]. A balanced flexion/extension gap is an important goal in TKA [4, 14, 33]. A flexion gap in CR-TKA is influenced by the tension of the PCL, the amount of resected posterior femoral condyle and tibia, and the angle of the resected tibial surface slope [3, 4, 14]. When the flexion gap is tight during a CR-TKA, additional procedures such as a partial release of the PCL [4, 40], increasing the resected tibial surface slope [16], and downsizing the femoral component [14, 29] are essential. However, the PCL is resected, and conversion to PS-TKA is required, when the flexion and extension gaps continue to appear inadequate despite the above-mentioned procedures [22].

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In general, CR-TKA can be difficult in severely deformed knees [28, 29, 32]. The decision to use CR-type prostheses in knees with relatively mild and moderate deformity is taken prior to surgery. However, intraoperative conversion to a PS-type prosthesis is unavoidable in several cases to achieve appropriate soft tissue balance. In a previous study, the conversion rate to PS-TKA was determined to be 17 % [20].

Most modern knee systems allow an intraoperative switch from CR type to PS type. However, there are no criteria relating to the retaining or resection of the PCL. The flexion and extension, and mediolateral gap situation, of each knee shows variation too wide to allow such a switch to be predicted prior to surgery [23]. Kaneyama et al. [23] argued that the decision of whether to preserve the PCL had to be made from the intraoperative gap measurements with an intact PCL to achieve adequate gap balancing. Ritter et al. [37] reported that the clinical difference between TKAs using CR- and PS-type prostheses may not be due solely to the difference in treatment of the PCL but also to more complex variables such as the surgeon, and also various patient factors. Therefore, it was necessary to study the affecting factors about the conversion to a PS-type prosthesis in knees that had been preoperatively planned to undergo implantation of a CR-type prosthesis. There have been a number of reports comparing the results between CR-type and PS-type prostheses [6, 9, 30]. However, to our knowledge, this is the first study to evaluate factors affecting the conversion from a CR-type to a PS-type prosthesis during CR-TKA.

The purpose of this study was to determine whether intraoperative conversion from a CR-type to a PS-type prosthesis during TKA is associated with certain underlying clinical or radiological factors.

Materials and methods

This retrospective review was approved by the Institutional Review Board of Kyung Hee University Hospital (KMC IRB 1538-08).

As part of this study, we reviewed 920 primary TKAs (725 patients) where the original preoperative plan had been to use a NexGen® (Zimmer, Warsaw, IN) CR-type prosthesis. Patients initially enrolled in this study underwent TKA between 1998 and 2008. Among them, 83 knees (9.0 %) underwent intraoperative conversion to a PS-type prosthesis. Patients who met the following criteria were excluded from the retrospective review: knees that used another type of prosthesis, knees with a valgus or recurvatum deformity, knees with an extra-articular deformity, haemophilic arthropathy, or partial ankylosis with a range of motion (ROM) <90°. The inclusion criteria were:

moderate osteoarthritic knees (Kellgren–Lawrence grade 4) with a preoperative angle of flexion contracture <30° and varus deformity <15°. A total of 698 women and 27 men with an average age of 66 ± 7 years (range 31–90 years) were included in the study. The median body mass index (BMI) was 26.0 kg/m² (range 18.1–37.6 kg/m²).

Surgical technique

All TKAs were performed using a midline skin incision and medial parapatellar arthrotomy. Bone cuts were made using a measured resection technique. Rotation of the femoral component was determined with reference to the transepicondylar axis, and the size was selected using the anterior-referencing method. The tibial slope was usually set to 7° of the posterior slope in the sagittal plane [11]. Any contracted medial or lateral soft tissue was evaluated carefully with palpation and then selectively released. In cases of flexion tightness or lift-off and/or disturbance of rollback during flexion, the PCL was recessed carefully or the posterior slope of the tibia was increased as necessary. PCL recession was required in 258 cases, and an increase in posterior slope of the tibia was required in 142 cases. The tibial cut surface was trimmed and adjusted using a sharp electric saw. When flexion and extension and mediolateral gaps were still mismatched despite soft tissue balancing using a CR-type prosthesis, intraoperative conversion to a PS-type prosthesis was performed. The post-operative rehabilitation was similar to the general protocol [2]. No knees were required manipulation under anaesthesia because of post-operative limitation of ROM.

Measurement methods

The clinical and radiological factors affecting the non-converted (CR) and converted (PS) groups were compared. The CR group included 837 knees, and the PS group included 83 knees.

Clinically, age, gender, BMI, angle of flexion contracture, size of the femoral component, and thickness of the polyethylene insert were compared between the CR and PS groups. The sizes of the femoral components used in our study were C, D, and E, although the particular prosthesis is available in sizes A–H. The anteroposterior lengths of the femoral components C, D, and E were 53.5, 57.5, and 61.5 mm, respectively, with an increment of 4 mm [13]. The thicknesses of the polyethylene insert used in our study were 9, 10, and 12 mm.

Radiologically, the severity of the varus deformity and the posterior tibial slope angle (PSA) were compared between the CR and PS groups (Fig. 1). Preoperative weight-bearing anteroposterior and lateral radiographs of the knee were reviewed to assess the severity of the varus



Fig. 1 **a** The femorotibial angle for coronal plane alignment was defined as the angle between the femoral and tibial shaft axes on true anteroposterior radiograph. **b** The preoperative PSA was defined as the angle between the reference line of the medullary canal and a line connecting the anterior and posterior borders of the medial tibial plateau on true lateral radiograph

deformity and the PSA using a picture archiving and communication system (PACS) [2, 3]. Consistent films in the neutral position were obtained. The normality of all radiographs was checked, and to reduce observation bias, two independent investigators repeated all radiographic measurements. The intra- and interobserver reliabilities of all measurements were assessed using intraclass correlation coefficients (ICC) [24], which were >0.8 for all measures, for both intra- and interobserver reliabilities.

Statistical analysis

The distributions of continuous variables, such as age, BMI, angle of flexion contracture, femorotibial angle, and PSA, were compared between the CR and PS groups (Student's *t* test). The frequencies of the non-continuous variables, such as gender, size of the femoral component, and thickness of the polyethylene insert, were compared between the CR and PS groups (Chi-squared, χ^2 test). The continuous variables that were statistically significantly

different were categorized according to subgroups, and the frequency of conversion was also compared between the two groups (χ^2 test).

Univariate analysis was performed to establish the relationships between all independent factors and the conversion to a PS-type prosthesis from a CR-type prosthesis during TKA. Factors that were determined to have a significant relationship were included in multivariate analysis.

A post hoc power analysis was conducted to estimate the minimum sample size of patients needed to observe a significant difference between groups. The present study was adequate to detect a significant difference ($\alpha < 0.05$) with 80 % power. This degree of power would be achieved with study groups comprising at least 675 knees in the CR group and 61 knees in the PS group.

Results

In univariate analysis, no significant differences were identified in age, gender, BMI, range of motion, or thickness of the polyethylene insert (Table 1). The mean preoperative angle of flexion contracture was $5.9^\circ \pm 7.4^\circ$ in the CR group and $8.1^\circ \pm 9.1^\circ$ in the PS group ($p = 0.002$). Flexion contracture was classified as follows: $<5^\circ$, 5° – 10° , 10° – 15° , 15° – 20° , and $>20^\circ$. The conversion rates to a PS-type prosthesis were 7.8, 7.4, 10.3, 12.5, and 14.3 %, respectively, depending on the degree of flexion contracture ($p = 0.025$).

No significant difference was found radiographically in the severity of preoperative varus deformity (Table 2). The average preoperative PSA varied, with values of $9.6^\circ \pm 4.0^\circ$ in the CR group and $11.0^\circ \pm 5.0^\circ$ in the PS group ($p = 0.018$). The conversion rates to a PS-type prosthesis in patients with preoperative PSA $<3^\circ$, 3° – 6° , 6° – 9° , 9° – 12° , 12° – 15° , and $>15^\circ$, were 7.7, 7.9, 6.7, 8.5, 10.9, and 13.6 %, respectively ($p = 0.02$).

The conversion rates to a PS-type femoral component of size C, D, and E were 13.1, 7.0, and 6.3 %, respectively ($p = 0.004$) (Table 1).

Multivariate analysis revealed three significant variables: preoperative angle of flexion contracture ($p = 0.045$), preoperative PSA ($p = 0.032$), and size of the femoral component ($p = 0.011$).

Discussion

The most important finding was that the conversion rate from a CR prosthesis to a PS prosthesis was high in patients with severe flexion contracture, steeper posterior tibial slope, and a smaller femoral component. There is ongoing debate regarding the most appropriate selection criteria for PCL-retaining or PCL-substituting procedure in

Table 1 Comparison of clinical factors between CR and PS groups

	CR ^a	PS ^b	PS %	<i>p</i> value
Age (year)	66 ± 7	65 ± 8		n.s.
Gender (female/male)	806/31	77/6		n.s.
Body mass index (kg/m ²)	26.2 ± 3.3	26.9 ± 3.2		n.s.
Diagnosis (OA/RA/2° OA/others)	824/7/1/5	75/3/2/0		n.s.
Flexion contracture (°)	6 ± 7	8 ± 9		0.002
Range of motion (°)	126 ± 18	122 ± 23		n.s.
Femoral component				0.004
Size C	271	41	13.1	
Size D	491	37	7.0	
Size E	75	5	6.3	
Thickness of polyethylene insert (9/10/12/14 mm)	158/438/214/27	10/44/24/5		n.s.

^a CR, knees in which the posterior cruciate ligament (PCL)-retaining prostheses were implanted as it was planned

^b PS, knees which were converted to the PCL-substituting prostheses

Table 2 Comparison of radiological factors between CR and PS groups

	CR ^a	PS ^b	<i>p</i> value
Femorotibial angle (°)	Varus 3.8 ± 5.2	Varus 4.7 ± 5.8	n.s.
Tibial posterior slope angle (°)	9.6 ± 4.0	11.0 ± 5.0	0.018

^a CR, knees in which the posterior cruciate ligament (PCL)-retaining prostheses were used as it was planned

^b PS, knees which were converted to the PCL-substituting prostheses

TKA [1, 15, 16, 21, 26, 27, 42]. At present, the surgeon's preference and the intraoperative status of the PCL and soft tissue determine whether or not a PCL should be resected [28]. Lombardi et al. [28] recommended CR-TKA only for patients without severe coronal deformity and flexion contracture. They also recommended PS-TKA for patients with inflammatory arthritis, a history of previous patellectomy or tibial osteotomy, coronal deformity >15°, moderate to severe flexion contracture, and severe contracture or dysfunction of the PCL [25, 36]. Pereira et al. [36] argued that PCL resection should be considered in knees requiring extensive soft tissue release and complex ligament balancing.

Although the selection criteria for a CR-type prosthesis differ depending on the author, a CR-type prosthesis is preferred in knees with mild varus deformity and flexion contracture. In the present study, CR-TKA was prepared preoperatively in patients with varus deformity <15° and

flexion contracture <30°. The conversion rate to a PS-type prosthesis was 9.0 %. The factors that affected the conversion to PS from a CR-type prosthesis were the severity of preoperative flexion contracture, the steepness of the posterior tibial slope, and the size of the femoral component.

Flexion contracture can be resolved by removal of osteophytes located at the posterior section of the distal femur and the proximal tibia, release of the posterior capsule, additional resection of the distal femur, decreasing the slope of the tibial cut surface, and careful release of the PCL during CR-TKA [7, 28, 29]. Conversion to a PS-type prosthesis is necessary in cases with flexion tightness despite application of these techniques [7]. Berend et al. [7] performed TKA using this algorithm for conversion to a PS-type prosthesis, and 31 of 52 (59.6 %) knees were implanted with a CR-type prosthesis in patients with flexion contracture >20°. However, Mihalko et al. [34] performed TKA in 103 knees with flexion contracture >20°; the PCL was not resected in any of these knees. The PCL was partially released in only 25 knees, and the majority of the flexion contracture was resolved with careful release of the collateral ligament. In the present study, the conversion to a PS-type prosthesis was necessary in a small number of knees with flexion contracture <10°, and the conversion rate increased as the flexion contracture increased ($p = 0.025$). In addition, we implanted a converted PS-type prosthesis in 13 knees (14.3 %) in patients with flexion contracture of 20°–30°. These results suggest that adequate flexion and extension gaps can be acquired using a CR-type prosthesis in a large number of patients with moderate to severe flexion contracture >20°.

In the present study, the average preoperative PSA was 9.6° in the CR group and 11.0° in the PS group (Fig. 2). The recommended slope of the tibial cut surface for the NexGen® CR-type prosthesis is 7° in the sagittal plane [11]. Limited resection of the bone at the posterior aspect of the tibial plateau is anticipated in patients with excessive preoperative PSA. Flexion tightness and flexion/extension gap mismatch can also occur in these patients [3, 19]. It is important, therefore, not to excessively resect the distal femur, especially in patients with a greater PSA.

The conversion rates to a PS type of femur component of size C, D, and E were 13.1, 7.0, and 6.3, respectively, in the present study. The conversion rate increased with the use of smaller femoral components ($p = 0.004$). These results were considered to be due to the morphological characteristics of the distal femur and the aspect ratio (AP/ML ratio) in Asian populations [10, 18]. Numerous morphological studies have demonstrated that Asians have a small and narrow width of femoral condyles [10, 39]. Hitt et al. [18] reported mismatches in both size and aspect ratio and found that the prostheses do not account for the changes in aspect ratio across the femoral condylar size, and that the mediolateral



Fig. 2 Pre- and post-operative radiographs of total knee arthroplasties (TKA) converted to a NexGen® LPS prosthesis from a NexGen® cruciate-retaining (CR) prosthesis during TKA in patients with a unilateral steep tibial slope. **a** A 66-year-old female had osteoarthritic knees. The range of motion was 0°–130° on both sides. The tibial

posterior slope angle was 9.5° in the right knee and 16.9° in the left knee. **b** A CR-TKA could be performed in the right knee with a small tibial posterior slope. The conversion to a PS prosthesis from a CR prosthesis was required to achieve accurate gap balancing in the left knee with a large tibial slope angle

sizing of the contemporary femoral components tends to be too large and thus overhang for smaller knees. The medialateral overhang can result in irritation of the soft tissue or overstuffing of the joint space [8, 31]; it also increases the incidence of femoral component downsizing [13]. Both findings could make accurate flexion/extension balancing difficult and may have increased the incidence of conversion to a PS-type prosthesis in the present study.

This study had several limitations. First, it was a retrospective study from a consecutive series using a single prosthesis. Most of the patients were female, and all had osteoarthritic knees with varus deformities. This female predominance in the distributions of varus deformity is common in Asian populations because of differences in disease demographics among ethnic groups and gender differences in the incidence of bowed legs. Other limitations were that the femoral component size, final slope of the tibial cut surface, and the decision for conversion to the PS-type prosthesis were determined by the planning and experience of a single surgeon. Last, the clinical and radiographic results were not compared between the CR and PS groups. However, this was not necessary to evaluate the aims of the present study.

In general, the use of a CR-type prosthesis was predicted prior to surgery in patients with radiologically mild deformity. There were several knees in which the conversion to a PS-type prosthesis was required intraoperatively for balanced flexion and extension gaps, even in patients with mild deformity. Anticipating the possibility of converting the prosthesis aided the operation team in dealing appropriately with the conversion. The back table could be prepared, and operation time could be shortened.

Conclusion

The conversion rate from a CR- to a PS-type prosthesis was high in patients with severe flexion contracture, steep posterior slope, and a small femoral component size. These factors should be carefully considered for appropriate selection of prosthesis type.

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