



## Original research

# Posterior Cruciate Ligament Resection and Varus Correction in Total Knee Arthroplasty: A Study Using Computer-Assisted Surgery

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## ABSTRACT

**Background:** Alignment correction is crucial for sustaining longevity and function in total knee arthroplasty (TKA). Although the posterior cruciate ligament (PCL) is a secondary stabilizer in the coronal plane, there have been few reports on the effects of PCL resection on varus correction. The study aim was to assess the effect of PCL resection performed using computer-assisted surgery (CAS) on varus correction in TKA. **Methods:** From April 2019 through January 2021, patients with varus deformity of  $<20^\circ$  and grossly intact PCLs were included. We used CAS to measure varus correction and gap change after PCL resection during CAS-TKA.

**Results:** Twenty-four female and eight male patients (40 operated knees) were included. The mean age was  $68.7 \pm 9.0$  years, and the mean BMI was  $26.5 \pm 3.7$  kg/m<sup>2</sup>. The mean preoperative mechanical alignment was varus  $5.7^\circ \pm 2.5^\circ$ . We found that  $1.4^\circ \pm 0.6^\circ$  of varus correction occurred after PCL resection ( $P < .05$ ). The mean extension and flexion medial-side gap increases were 0.4 mm and 2.0 mm, respectively ( $P < .05$ ). The mean extension and flexion lateral-side gap increases were 0.4 mm and 1.6 mm, respectively ( $P < .05$ ).

**Conclusion:** PCL resection during TKA resulted in a small degree of varus correction. The flexion gap was larger when the PCL was resected. These effects were predictable, so surgeons should be aware of these findings while performing TKA.

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## Introduction

Total knee arthroplasty (TKA) provides long-term beneficial outcomes [1,2]. Survival of the TKA is typically 15 to 20 years; however, inappropriate soft-tissue balance and alignment restoration are important factors that could lead to instability and cause subsequent revision arthroplasty [1–4]. Posterior cruciate ligament (PCL) resection results in a joint-gap change during TKA as shown in previous studies, with some variation in results. Oshner and Johnson showed that there was an equal increase in both the flexion and extension gaps after PCL resection [5]. However, more studies have reported an increased flexion gap without extension gap change [5–10]. Mihalko and Krackow showed results of PCL resection which effected only flexion gap [6]. The mean flexion gap increased after PCL resection was  $5.3 \pm 1.9$  mm (range, 3.2–9.1 mm) [6]. Results from another recent study also showed significant

increase of flexion gap (1.3–2.1 mm) with minimal change of extension gap (0.2–0.3 mm) [10].

Since the PCL is a secondary coronal-plane stabilizer, PCL resection may result in coronal-alignment changes as well. Mihalko et al. studied the effect of PCL resection after medial soft-tissue release on deformity correction and showed that PCL resection was able to correct varus deformity, but that study used a cadaveric model [11,12].

The study aim was to examine the effect of PCL resection on coronal-alignment correction and gap change in TKA. We used computer-assisted surgery (CAS) to record data in this study because it could accurately detect small gap changes of 0.1 mm and angular changes of  $0.1^\circ$  [13–15]. The hypothesis of this study was PCL resection provides an increase in flexion gap with minimal degree of varus correction.

## Material and methods

This study was approved by the institutional ethics committee (COA 069/61) of our institution and followed the principles in the Declaration of Helsinki. Informed consent was obtained from all patients.

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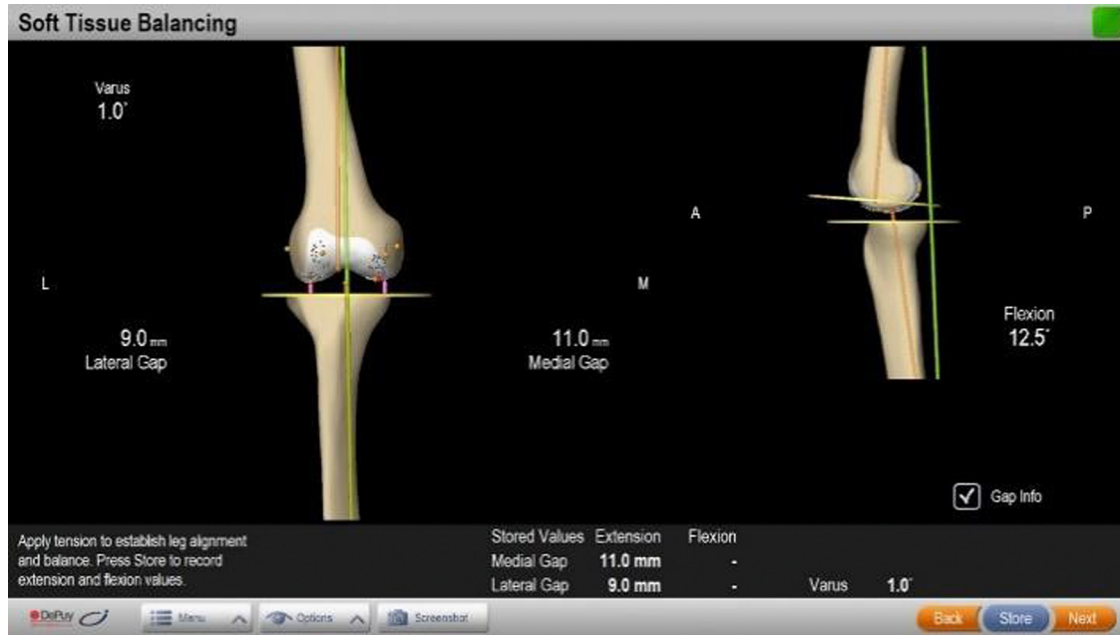


Figure 1. Actual screen of varus alignment and full extension gap measurement.

Patients

We prospectively collected data from patients who underwent primary CAS-TKA at our institution from April 2019 to January 2021. The inclusion criteria were an intact PCL determined from the patients' histories and physical examinations. The exclusion criteria included intraoperative varus deformity >20° measured by CAS or intraoperative findings of partial or complete PCL tear. Patients with valgus osteoarthritis of the knee or secondary osteoarthritis of the knee were also excluded from this study.

Statistical analysis

Comparisons of the continuous variables were made by performing the paired *t*-test. *P* values of <.05 were considered to be

indicative of statistical significance. Analyses were performed by using IBM SPSS Statistics for Windows software, version 26 (IBM Corp., Armonk, New York).

Surgery and measurement

All operations were performed by one senior joint specialist by using computer-assisted TKA and the mid-vastus approach. A computer navigation system version 2.6 (Brainlab, Munich, Germany) was used in every case. After the mid-vastus approach, followed by anterior cruciate ligament resection, minimal medial soft-tissue release, and osteophyte removal for adequate exposure, one intra-incisional femoral pin and 2 extra-incisional tibial pins were inserted for CAS trackers. References of bone resection with CAS

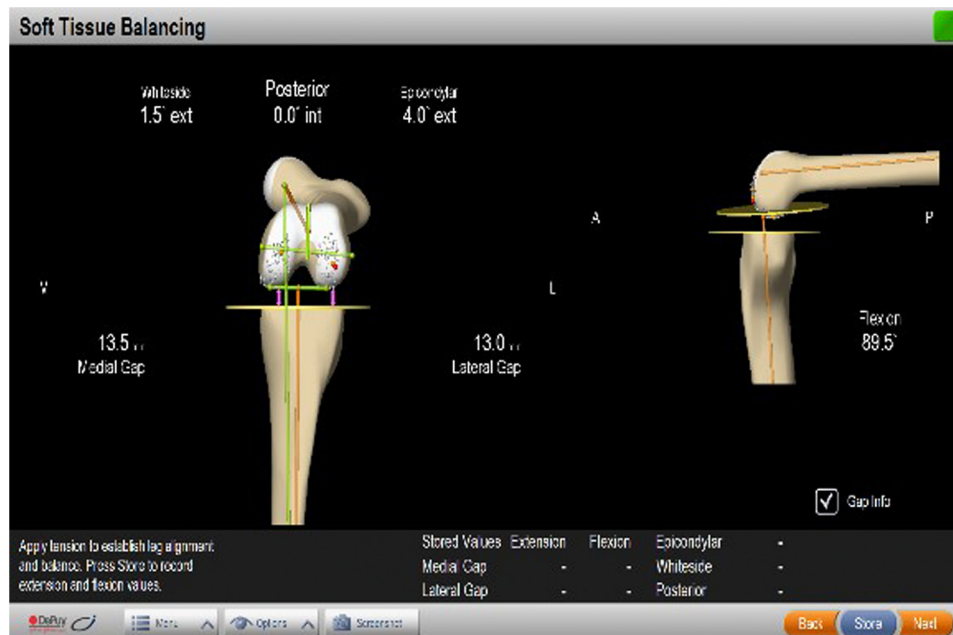


Figure 2. Actual screen of flexion gap at 90° measurement.



**Figure 3.** Tensioning device.

were based on intact articular surfaces. We used balance-gap workflow because it allowed us to measure (1) varus alignment, (2) the full extension joint gap, and (3) the flexion joint gap at any degree. Preoperative data, including knee alignment and flexion contracture, were recorded. A proximal tibial cut was made perpendicular to mechanical axis with 3° of tibial slope. At this point, if an inadvertent PCL injury was found, the patient was then excluded from the study.

After PCL competency was assessed, we inserted a tensioning device (Knee Balancer; DePuy, Johnson and Johnson, IN), which consistently maintained a distraction force (Fig. 1) of 220 N to create equal tension space for data recording. Next, we recorded the alignment and gap of the knee at full extension, 30°, 60°, and 90° of flexion by using CAS (Figs. 2 and 3).

After measurement, we completely resected the PCL from the femoral origin and tibial insertion. Completeness of resection was confirmed by palpation of the PCL on knee extension and flexion under tension. Measurement of the alignment and gap were repeated by using the same technique as described previously. After that, soft-tissue release to correct the coronal deformity was

performed, and coronal alignment was checked using the tensioning device. Then, femoral rotation was determined using a soft-tissue tension guide, and femoral preparation was carried out. Trial prostheses were inserted, and final alignment was checked using CAS. The patella was resurfaced in all patients. The tourniquet was only used during cementation, which took several minutes. Finally, a drain was not used, and soft-tissue closure was performed in a layered fashion. All patients went through the same standard rehabilitation program after the operation.

## Results

There were 40 knees of 32 patients included in this study. Staged bilateral TKA was performed in 5 female and 3 male patients. The mean patient age was 68.7 years (59.0–78.0 years), the mean weight was 65.1 kg (54.9–75.2 kg), the mean height was 156.5 cm (149.9–163.1 cm), and the mean BMI was 26.54 kg/m<sup>2</sup> (22.9–30.2 kg/m<sup>2</sup>). The mean preoperative varus deformity relative to the mechanical axis measured by CAS was 5.7° (3.1°–8.2°), the mean range of motion was 5.7°–110.0°, and the mean flexion contracture was 9.0°

**Table 1**  
Demographic data (32 patients, 40 knees).

Age (y)	68.7 (59.0 to 78.0)	Mean (range)
Gender		
Male	8/32 (25.0%)	
Female	24/32 (75.0%)	
BMI (kg/m <sup>2</sup> )	26.5 (22.9 to 30.2)	Mean (range)
Kellgren and Lawrence stage		
III	13/40 (32.5%)	
IV	27/40 (67.5%)	
Side		
Right	21/40 (52.5%)	
Left	19/40 (47.5%)	
Preoperative HKA angle <sup>a</sup> (degree)	5.7° ± 2.5° (2.5° to 13.5°)	Mean ± SD (range)
Range of motion (degree)	103.5° ± 7.9° (90.0° to 120.0°)	Mean ± SD (range)
Flexion contraction (degree)	9.0° ± 3.7° (2.0° to 15.0°)	Mean ± SD (range)
Postoperative HKA angle <sup>a</sup> (degree)	2.2° ± 2.1° (–2.1° to 6.5°)	Mean ± SD (range)
Postoperative HKA outlier <sup>b</sup>	4/40 (10%)	

HKA, hip-knee-ankle.

<sup>a</sup> Positive value refers as varus alignment.

<sup>b</sup> Outlier determine by deviation of HKA axis more than 3 degrees.

**Table 2**  
Results prior and following posterior cruciate ligament resection.

	Full extension			30° flexion		60° flexion		90° flexion	
	Alignment (degree)	Medial gap (mm)	Lateral gap (mm)	Medial gap (mm)	Lateral gap (mm)	Medial gap (mm)	Lateral gap (mm)	Medial gap (mm)	Lateral gap (mm)
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Pre-PCL resection	5.7° (2.5°)	7.6 (2.0)	9.2 (2.0)	8.9 (2.0)	11.0 (2.4)	7.3 (2.1)	9.9 (2.2)	6.3 (2.0)	9.2 (2.1)
Post-PCL resection	4.3° (2.6°)	8.0 (1.7)	8.8 (2.1)	9.3 (1.9)	11.1 (2.3)	8.3 (2.1)	10.5 (2.3)	8.3 (2.3)	10.8 (2.2)
Difference	1.4° (0.6°)	0.4 (0.9)	0.4 (1.0)	0.4 (0.5)	0.1 (0.9)	1.0 (0.8)	0.6 (0.9)	2.0 (1.7)	1.6 (1.2)
P value	<.05	<.05	<.05	<.05	.387	<.05	<.05	<.05	<.05

$\pm 3.5^\circ$ . All demographic data and preoperative data of the patients are shown in Table 1.

We found small but consistent changes in varus angulation after PCL resection. Varus alignment was reduced after PCL resection from a mean of  $5.7^\circ \pm 2.5^\circ$  to  $4.3^\circ \pm 2.6^\circ$ . The mean varus alignment reduction was  $1.4^\circ \pm 0.6^\circ$ . The difference between varus angulation before and after PCL resection was statistically significant ( $P < .05$ ) (Table 2). Both the flexion gap and extension gap increased after PCL resection. There were significant increases in the flexion gaps after PCL resection on both the medial and lateral sides at  $90^\circ$  knee flexion ( $2.0 \pm 1.7$  mm,  $P < .05$ , and  $1.6 \pm 1.2$  mm,  $P < .05$ , respectively). The extension gaps also significantly increased after PCL resection on both the medial ( $0.4 \pm 0.9$  mm,  $P < .05$ ) and lateral sides ( $0.4 \pm 1.0$  mm,  $P < .05$ ). Nevertheless, the flexion gap increased more than the extension gap (Table 2). The mean postoperative hip-knee-ankle angle was varus  $2.2^\circ$  as shown in Table 1.

## Discussion

Gap balance and alignment correction are essential factors that determine long-term successful outcomes in TKA. Although various alignment correction techniques have been reported, PCL resection, which is commonly performed, has not been widely discussed. Thus, we conducted this study to determine the effect of PCL resection on gap and alignment from April 2019 through January 2021. Our study results showed consistent varus alignment correction after PCL resection, and our mean varus correction of  $1.4^\circ \pm 0.6^\circ$  was similar to that of a previous study, which reported that PCL resection decreased varus angulation by about  $1.7^\circ$  in full extension [11]. The effect of varus correction from PCL resection is similar to previous results from downsizing and lateralizing the tibial tray [12,16,17] but is smaller than the effect of medial soft-tissue release [18]. Based on the results of this study, PCL resection alone could be useful to correct only a mild degree of varus alignment with predictable results. However, if combined with other methods, PCL resection could be used to correct more severe varus deformities. As shown in our study, varus alignment could be corrected from  $5.7^\circ \pm 2.5^\circ$  (mean  $\pm$  SD) to  $2.2^\circ \pm 2.1^\circ$  (mean  $\pm$  SD).

Apart from alignment correction, gap change was an additional effect from PCL resection. Our study showed that PCL resection increased the mean flexion gap more than the extension gap, which is similar to the findings of previous reports, although the change in the flexion gap was smaller because of the different protocols used [10]. Resection of PCL after soft-tissue balance, especially superficial medial collateral ligament release, could result in a larger degree of flexion gap change [19,20]. We noticed a change in the femoral rotation after PCL resection as well with a larger increase in the flexion gap on the medial side. In our practice, we also observed a cumulative effect of varus correction when PCL resection was combined with other techniques, such as downsizing and lateralizing the tibial tray and posteromedial soft-tissue release. A lesser

percentage of superficial medial collateral ligament release was needed for correction of moderate to severe varus when all aforementioned techniques were combined. As polyethylene insert (ultracongruent insert) with a higher level of constraint was available for cruciate retaining design with favorable outcomes [21–23], PCL resection may be useful to correct varus deformity even in the case of cruciate retaining TKA implanted with ultracongruent insert.

This study had several strengths. Although the correction of varus deformity was small, it was consistent and statistically significant. All the cases in our series showed some degree of varus correction after PCL resection. Few clinical studies have focused on alignment after PCL resection. The study was also conducted in primary varus osteoarthritis knee patients who had undergone TKA, so they were better subjects than cadavers. Furthermore, we used CAS to record the change in alignment and gap to provide high accuracy. Hence, we believe that PCL resection could be useful in correcting varus deformity in TKA.

## Conclusions

PCL resection during TKA resulted in a small degree of varus correction. Although PCL resection alone to correct moderate to severe varus deformity was not justified, it is a viable option in conjunction with other varus correction procedures to achieve a cumulative effect. PCL resection also caused a larger flexion gap, so surgeons should be aware of this effect when performing TKA.

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## Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests.

## References

- [1] Fang DM, Ritter MA, Davis KE. Coronal alignment in total knee arthroplasty: just how important is it? *J Arthroplasty* 2009;24(6 Suppl):39.

- [2] Tay KS, Lo NN, Yeo SJ, et al. Revision total knee arthroplasty: causes and outcomes. *Ann Acad Med Singap* 2013;42(4):178.
- [3] Scuderi GR. Complications after total knee arthroplasty: how to manage patients with osteolysis. *J Bone Joint Surg Am* 2011;93(22):2127.
- [4] Shan L, Shan B, Suzuki A, et al. Intermediate and long-term quality of life after total knee replacement: a systematic review and meta-analysis. *J Bone Joint Surg Am* 2015;97(2):156.
- [5] Ochsner Jr JL, Johnson WD. Flexion and extension gap measurements in total knee arthroplasty after sacrifice of posterior cruciate ligament. *J South Orthop Assoc* 1994;3(4):290.
- [6] Mihalko WM, Krackow KA. Posterior cruciate ligament effects on the flexion space in total knee arthroplasty. *Clin Orthop Relat Res* 1999;(360):243.
- [7] Whiteside LA, Saeki K, Mihalko WM. Functional medial ligament balancing in total knee arthroplasty. *Clin Orthop Relat Res* 2000;(380):45.
- [8] Kennedy NI, Wijdicks CA, Goldsmith MT, et al. Kinematic analysis of the posterior cruciate ligament, part 1: the individual and collective function of the anterolateral and posteromedial bundles. *Am J Sports Med* 2013;41(12):2828.
- [9] Kadoya Y, Kobayashi A, Komatsu T, et al. Effects of posterior cruciate ligament resection on the tibiofemoral joint gap. *Clin Orthop Relat Res* 2001;(391):210.
- [10] Chaiyakit P, Meknavin S, Hongku N. Effects of posterior cruciate ligament resection in total knee arthroplasty using computer assisted surgery. *J Med Assoc Thai* 2009;92:S80.
- [11] Mihalko WM, Miller C, Krackow KA. Total knee arthroplasty ligament balancing and gap kinematics with posterior cruciate ligament retention and sacrifice. *Am J Orthop (Belle Mead NJ)* 2000;29(8):610.
- [12] Hongku N, Chaiyakrit P, Senwiruch C. Gap and angulation change in total knee arthroplasty after Tibia component undersizing and lateralization in flexion gap and extension gap in cruciate retaining total knee arthroplasty using computer-assisted surgery: cadaveric study. *Vajira Med J* 2021;65(2):117.
- [13] Delp SL, Stulberg SD, Davies B, et al. Computer assisted knee replacement. *Clin Orthop Relat Res* 1998;(354):49.
- [14] Jenny JY, Boeri C, Picard F, et al. Reproducibility of intra-operative measurement of the mechanical axes of the lower limb during total knee replacement with a non-image-based navigation system. *Comput Aided Surg* 2004;9(4):161.
- [15] Mason JB, Fehring TK, Estok R, et al. Meta-analysis of alignment outcomes in computer-assisted total knee arthroplasty surgery. *J Arthroplasty* 2007;22(8):1097.
- [16] Dixon MC, Parsch D, Brown RR, et al. The correction of severe varus deformity in total knee arthroplasty by tibial component downsizing and resection of uncapped proximal medial bone. *J Arthroplasty* 2004;19(1):19.
- [17] Mullaji AB, Shetty GM. Correction of varus deformity during TKA with reduction osteotomy. *Clin Orthop Relat Res* 2014;472(1):126.
- [18] Mullaji AB, Padmanabhan V, Jindal G. Total knee arthroplasty for profound varus deformity: technique and radiological results in 173 knees with varus of more than 20 degrees. *J Arthroplasty* 2005;20(5):550.
- [19] Krackow KA, Mihalko WM. The effect of medial release on flexion and extension gaps in cadaveric knees: implications for soft-tissue balancing in total knee arthroplasty. *Am J Knee Surg* 1999;12(4):222.
- [20] Mullaji A, Sharma A, Marawar S, et al. Quantification of effect of sequential posteromedial release on flexion and extension gaps: a computer-assisted study in cadaveric knees. *J Arthroplasty* 2009;24(5):795.
- [21] Lutzner J, Firmbach FP, Lutzner C, et al. Similar stability and range of motion between cruciate-retaining and cruciate-substituting ultracongruent insert total knee arthroplasty. *Knee Surg Sports Traumatol Arthrosc* 2015;23(6):1638.
- [22] Lutzner J, Beyer F, Dixel J, et al. No difference in range of motion between ultracongruent and posterior stabilized design in total knee arthroplasty: a randomized controlled trial. *Knee Surg Sports Traumatol Arthrosc* 2017;25(11):3515.
- [23] Song EK, Lim HA, Joo SD, et al. Total knee arthroplasty using ultra-congruent inserts can provide similar stability and function compared with cruciate-retaining total knee arthroplasty. *Knee Surg Sports Traumatol Arthrosc* 2017;25(11):3530.