Original Article

Investigation of the effect of intraoperative mediolateral stability on postoperative sagittal stability after bi-cruciate stabilized total knee arthroplasty

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ABSTRACT

Purpose: This study investigated the effect of mediolateral stability on sagittal stability in bi-cruciate stabilized total knee arthroplasty.

Method: This study included 59 patients. We intraoperatively assessed the component gap with a joint distraction force of 60 N for each compartment. Immediately after surgery, sagittal stability was assessed using an arthrometer.

Result: The intraoperative medial joint laxity at 30° of flexion was significantly correlated with postoperative anteroposterior translation ($r = 0.276$, $p < 0.05$).

Conclusion: This study demonstrated the effect of intraoperative mediolateral stability effect on postoperative sagittal stability. Improving medial stability may enhance postoperative sagittal stability.

1. Introduction

Total knee arthroplasty (TKA) is one of the world standard surgical procedure performed in older patients to treat pain and functional limitation associated with osteoarthritis, rheumatoid arthritis or osteonecrosis. However, in questionnaire-based evaluations of patient satisfaction to examine the outcomes of hip and knee arthroplasty, patients undergoing primary TKA reported inferior outcomes than those undergoing primary total hip arthroplasty.¹ The percentage of patients who reported satisfaction with TKA ranged 65–100% (median, 88.9%), with most patients reporting >80% satisfaction.²

Factors previously reported to affect patient satisfaction following TKA include gender, age, high preoperative expectations, patient's personality, severity of arthropathy and postoperative alignment.³ Moreover, the postoperative stability of TKA has also been reported to be associated with patient-reported outcome measures (PROMs),^{4–6} and we believe that stability after TKA is important for improving patient satisfaction. In particular, sagittal stability is associated with complex interactions such as prosthetic design and intraoperative soft tissue balancing.

The bi-cruciate-stabilized (BCS) knee system (Journey2 BCS; Smith

and Nephew, Memphis, TN, USA) was developed to address sagittal instability by introducing both anterior and posterior cams to prevent excessive anterior and posterior translation of the femur on the tibia.⁷ Regarding sagittal stability in BCS TKA, Inui reported the effect of medial stability.⁸ They measured sagittal stability using a navigation system intraoperatively and revealed that sagittal stability after BCS TKA had a positive relationship with intraoperative medial stability. They concluded the medial stability of the knee is an important factor for determining the sagittal stability of the BCS system. However, their intraoperative measures of sagittal stability were performed manually. To our knowledge, no previous report has revealed the relationship between anteroposterior stability measured using an arthrometer immediately after operation and intraoperative medial–lateral stability in BCS TKA. We hypothesized that intraoperative the medial stability in BCS TKA reduces the anteroposterior translation in mid-flexion range.

We evaluated sagittal stability after BCS TKA using an arthrometer and investigated the effect of mediolateral stability on sagittal stability.

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2. Material and methods

2.1. Patients

This retrospective study examined patients who underwent primary TKA performed by two surgeons between January 2018 and April 2020. Eighty-eight primary TKAs were performed using the Journey2 BCS system. Patients with valgus deformity (eight knees) and those for whom complete data were not recorded (21 knees) were excluded. The study population finally included 45 females and 14 males (mean age, 75.3 ± 7.7 years). The preoperative hip–knee–ankle angle was 169.1 ± 5.3° (range, 153–178°). The preoperative passive knee flexion angle was 121.7 ± 12.5°, and the passive knee extension angle was −9.1 ± 8.1°. The preoperative demographic data of the patients are shown in Table 1.

2.2. Surgical procedure

All patients underwent surgery via a medial parapatellar approach. The distal femur was resected using an intramedullary rod. We aimed the femoral alignment at 90° to the mechanical axis in the frontal plane. The tibia was resected using an extramedullary guide. We aimed the tibial alignment at 90° to the mechanical axis in the frontal plane and 3° of posterior slope in the sagittal plane. We determined the femoral rotation to be parallel to the surgical epicondylar axis.

2.3. Intraoperative component gap measurement

After bone resection, the femoral trial component was placed. Then, the surgeon measured the gap using a tensor device after reducing the patellorofemoral joint (Fig. 1). The tensor device consisted of three parts: the upper compartment-specific plates, a lower platform plate and an extra-articular main body. The upper plates had identical shapes as the medial and lateral compartments of the polyethylene trial surface of the Journey2 BCS system (Fig. 2). This device is designed to allow surgeons to measure the joint component gap of the medial and lateral compartments respectively. Using this tensor device, we assessed the component gap of each compartment at 0, 30, 60, 90 and 120° of flexion with a joint distraction force of 60 N for each compartment after the reduction of patellarfemoral joint.^{9,10} In our study, the medial and lateral joint ‘laxity’ was defined as the ‘component gap minus the selected thickness of the polyethylene insert’ as described previously.⁸

Table 1
Characteristics of the cohort.

Parameter	Mean (SD), or n (%)
Age (year)	72.3 (7.7)
Female	45 (76)
Height (cm)	153.1 (9.7)
Body weight (kg)	62.2 (11.5)
Body mass index (kg/m ²)	26.5 (4.2)
Diagnosis	
OA	56 (95)
RA	3 (5)
Preoperative ROM	
Flexion (degree)	121.7 (12.5)
Extension (degree)	−9.1 (8.1)
KOOS	
pain score	39.8 (21.5)
function score	51.2 (17.3)
Pain score (VAS) (mm)	70.6 (26.8)
Preoperative FTA (degree)	185.7 (5.8)
Preoperative HKA angle (degree)	169.1 (5.3)
Postoperative FTA (degree)	174.7 (2.4)
Postoperative HKA angle (degree)	179.5 (2.2)

SD; Standard Deviation, OA; osteoarthritis, RA; rheumatoid arthritis, ROM; range of motion, KOOS; Knee Injury and Osteoarthritis Outcome Score, VAS; visual analog scale, FTA; femorotibial angle, HKA; hip-knee-ankle.

Fig. 1. Photographs showing our using ligament tensor device.

Fig. 2. Photographs showing the medial and lateral upper plate of ligament tensor device. The shapes of medial and lateral upper plates was identical shapes of each compartments of the polyethylene trial surface of the Journey2 BCS TKA.

2.4. Postoperative anteroposterior translation

Immediately after surgery, sagittal stability of the knee was assessed in all patients using a KNEELAX-3 arthrometer (Monitored Rehab Systems, Haarlem, The Netherlands) with an anterior and posterior force of 132 N applied to the proximal tibia at 30° of flexion. We determined the anterior and posterior force based on previous study.⁸ The measurement was performed twice under general anaesthesia by the chief surgeons, and the average values were used.

2.5. Statistical analyses

Statistical analyses were conducted using JMP software version 14.0 (SAS Institute Japan Ltd, Tokyo, Japan). All values are expressed as the mean $\pm$ standard deviation. Comparisons between the study groups were performed using the Wilcoxon sum rank test for continuous variables. The correlations between the intraoperative medial and lateral component gap and postoperative anteroposterior translation were assessed using Pearson's correlation coefficients.

All tests were two-sided, and $P < 0.05$ was considered statistically significant.

This study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by our Institutional Review Board. Informed consent was obtained from all patients included in the study.

3. Results

There were significant differences between the medial component gap and lateral component gap at 0–120° of flexion (Table 2). Postoperative anteroposterior translation was 11.3 ± 2.9 mm at 30° of flexion. The intraoperative medial joint laxity at 30° of flexion was significantly correlated with postoperative anteroposterior translation ($r = 0.276$, $p = 0.034$). There was no significant correlation between the intraoperative lateral joint laxity and postoperative anteroposterior translation (Table 3).

4. Discussion

The most important finding of the present study was the relationship between intraoperative medial joint laxity and postoperative anteroposterior translation at 30° of flexion. To our knowledge, this is the first report to describe the relationship between mediolateral stability and sagittal stability after BCS TKA using an arthrometer under general anaesthesia.

A significant correlation was noted between the intraoperative medial joint laxity at 30° of flexion and postoperative anteroposterior translation. Inui et al. also reported that a correlation of medial stability with the intraoperative anteroposterior translation of BCS TKA using a navigation system.⁸ In BCS TKA, control of the medial laxity may reduce sagittal instability in the mid-flexion range.

Previous reports measured anteroposterior translation after TKA using an arthrometer, and the average values were 4.5–10 mm.^{5,8,11–15} The average anteroposterior translation was 11.3 mm in the present

Table 3

Pearson correlation coefficients intraoperative medial and lateral joint laxity and postoperative anteroposterior translation.

Joint laxity	postoperative anteroposterior translation	
	r	P value
Medial		
0°	−0.110	0.256
30°	0.276	0.034*
60°	0.087	0.511
90°	−0.063	0.637
120°	−0.166	0.214
Lateral		
0°	0.076	0.567
30°	0.167	0.207
60°	−0.041	0.760
90°	−0.174	0.189
120°	−0.080	0.556

*Significant.

study, exceeding previous findings. As a possible explanation for this discrepancy, anteroposterior translation was measured more than 3 months after surgery in other reports, whereas the present study conducted the evaluations immediately after surgery and under general anaesthesia. We believe these differences affected the results for anteroposterior translation. Second, the surgical technique may have been the cause of the large amount of anteroposterior translation. Inui and co-workers reported good results with an average anteroposterior translation of 5.9 mm in BCS TKA.⁸ They performed minimum release of medial soft tissues for bone resection. The balancing techniques focused on medial compartment stability, such as the 'medial preserving gap technique'.¹⁶ The anteroposterior translation in the present study was larger than that in previous reports, but we observed a significant correlation between medial laxity and anteroposterior instability. This finding was in line with previous results.⁸ We believe that medial soft tissue tension plays an important role in anteroposterior stability in BCS TKA. Additionally, several reports described the importance of sagittal stability after TKA. In prior research, TKA with more than 10 mm of anteroposterior translation at 75° had significantly less flexion and lower Knee Society Scores than knees with 5–10 mm of anteroposterior translation.¹⁷ Meanwhile, Mochizuki et al. measured sagittal stability postoperatively using an arthrometer and clarified the association between subjective instability and anteroposterior translation after TKA. They concluded that >7 mm of anteroposterior translation at 30° of flexion was an independent risk factor for perceived instability after TKA.¹⁴ Moreover, Matsumoto et al. also measured anteroposterior translation after TKA using an arthrometer. They reported that the Knee injury and Osteoarthritis Outcome Score pain score was significantly correlated with anteroposterior translation at 60° of flexion.⁵ To our knowledge, the association between sagittal stability and PROMs after BCS TKA has not been previously reported. We will investigate the relationship between sagittal stability and PROMs in BCS TKA in a future study.

Our study had several limitations. First, the upper plate of the tensor for measuring joint component gaps had the same shape as the medial and lateral compartments of the Journey2 BCS polyethylene trial surface, but the tibial post construct was excluded. However, the tibial post has little effect on the component gap. Second, this cohort included patients with rheumatoid arthritis (RA). However, patients with RA who had knee valgus were excluded from this study. In the long term, RA synovitis may increase joint laxity, but it is considered to have little effect immediately after surgery. Third, there is a possibility that this slight change of the thickness of cement mantle might have influenced the results of the component gap, which was measured before cementing.

Table 2

Intraoperative component gap.

	Medial, mm	Lateral, mm	P value
	Mean (SD)	Mean $\pm$ SD	
0°	11.0 (1.7)	16.2 (2.3)	<0.001
30°	11.6 (1.7)	16.1 (2.3)	<0.001
60°	11.7 (2.0)	16.0 (2.7)	<0.001
90°	12.4 (2.0)	16.6 (3.1)	<0.001
120°	12.2 (2.2)	15.8 (3.3)	<0.001

SD; Standard Deviation.

5. Conclusion

In BCS TKA, there was a significant correlation between the intra-operative medial stability and anteroposterior translation using an arthrometer under general anaesthesia. We concluded that improving medial stability may enhance postoperative sagittal stability in the mid-flexion range in BCS TKA.

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Ethical approval

The study protocol was reviewed and approved by the Institutional Review Board of Yamaguchi University.

Informed consent

Written informed consent for publication was obtained from all patients.

Authors' contribution

KS acquired the raw data, conceived the study and wrote the paper. TS, YM, and KY acquired data. HO, TS, TI and TS provided clinical expertise and commentary. All authors contributed comments and edits to the final report.

Submission declaration

This manuscript has not been published elsewhere, nor is it under consideration by another journal.

Declaration of competing interest

The authors declare that they have no competing interests.

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