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Optimal timing for the second surgery in staged bilateral total knee arthroplasty: a patient-determined interval approach

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Abstract

Purpose The decision to perform a second surgery in staged bilateral total knee arthroplasty (BTKA) remains undetermined. While previous studies have investigated the timing of the second surgery, they have not reached a consensus on the optimal interval and lack self-controlled comparisons between the first and second surgeries to minimize bias. This study aimed to address these gaps by evaluating postoperative outcomes across patient-determined intervals and conducting internal comparisons between sequential surgeries to optimize the timing of the second procedure in staged BTKA.

Methods We retrospectively reviewed 528 patients (1,056 knees) who underwent staged BTKA between January 1, 2015, and December 31, 2019. Considering the different intervals, all patients were divided into 3 groups using 3 different cut-off points: group A (≤ 180 days), group B (> 180 days and ≤ 365 days), and group C (> 365 days). Comparison was done among the 3 groups for the second arthroplasties (A2 vs. B2 vs. C2). In each group, comparison was conducted between two surgeries (A1 vs. A2, B1 vs. B2, and C1 vs. C2, respectively).All data were retrieved retrospectively. This study utilized the propensity score matching (PSM)was performed to minimize confounding factors when comparing outcomes among groups.The matching variables included age, sex, BMI, height, comorbidities (hypertension, diabetes, coronary heart disease, chronic obstructive pulmonary disease, liver cirrhosis, and smoking status), ASA score (American Society of Anesthesiologists classification), and surgeon (C.X.W. or G.D.). Patients with same Kellgren-Lawrence (K-L) grades (grade 4)were included during the initial screening to ensure homogeneity in osteoarthritis severity. We evaluated demographics and clinical outcomes, major complications, and hospital adverse events.

Results There were no statistically significant differences in any of the clinical outcomes, major complications, and hospital adverse events among the 3 groups (A2 vs. B2 vs. C2)(all $P > 0.05$). When C1 and C2 were compared, LOS (12.23 ± 3.41 vs 10.12 ± 2.76, $P < 0.0001$), drainage volume (115.62 ± 45.67 vs 101.26 ± 49.28, $P = 0.003$), additional morphine analgesics consumption (131.52 ± 259.11 vs 69.78 ± 159.89, $P = 0.016$), and the rate of hospital adverse events (58.33% vs 46.15%, $P = 0.026$) were significantly better in group C2.

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Conclusion The time frame of staged BTKAs has no influence on postoperative outcomes when the intervals are determined by patients. However, prolonging the interval between the surgeries may be beneficial for a faster recovery after the second knee arthroplasty. Benefits such as reduced intraoperative blood loss, lower postoperative analgesic use, and shorter hospital stays are especially evident when the interval exceeds one year, showing statistically significant differences. Therefore, if patients are willing to wait, we recommend scheduling the second surgery at least one year after the first.

Trial registration number ZE2020-139–01, for retrospectively registered trials.

Level of Evidence Retrospective cohort study, LEVEL III.

Keywords Bilateral total knee arthroplasty, Optimal time for the second surgery, Major complications, Hospital adverse events, Perioperative outcomes

Introduction

Bilateral total knee arthroplasty (BTKA) may be required in patients with severe osteoarthritis of both knees. BTKA can be performed simultaneously during the same hospital stay, staggered within the same hospital stay, or staged over different hospital visits. Different BTKA procedures have been debated regarding the evaluations of complication rates, costs, length of stay (LOS), and outcomes.Potential benefts of simultaneous bilateral TKAs including decreased length of hospital stay, shorter rehabilitation period, and reduced medical expenses [1]. However, several studies have shown that simultaneous BTKA results in increased blood loss [2], mortality [3, 4], and perioperative systemic complications [5, 6], articularly acute cardiovascular events and pulmonary embolism [3], when compared with staged BTKA. In addition, simultaneous BTKA is not always possible, especially for patients with advanced age, high body mass index, preexisting pulmonary disorders, or other comorbidities [7–9]. Staged BTKA is performed as 2 separate procedures with considerable time between the index TKA and the second one to allow patients enough time to recover from the first operation. There is a delay in achieving optimal clinical outcomes until the second knee is replaced and the patient's satisfaction is influenced during the interval [10, 11]. The potential benefits of staged BTKA include decreasing the risk of complications [12, 13]. Only a few studies evaluated clinical outcomes and complications of staged BTKA and failed to identify the optimal timing for the second TKA [13–16].The results of a study involving 25,527 patients who undergoing staged bilateral TKA showed that the incidence of 2-year all-cause revision and 90-day major complications decreased significantly compared to the shortest fixed time interval (1–6 weeks) [17]. A systematic evaluation of 117,090 patients who underwent staged bilateral knee arthroplasty (BTKA) demonstrated an increased incidence of complications associated with a second knee arthroplasty if performed within 30 or 90 days of the procedure [18]. The retrospective study analyzed data from 281 patients, who divided the staging time into 3 groups by the interval between the second contralateral TKA: Group 1: 2 ~ 6 months, Group 2: 6 ~ 12 months, and Group 3: > 12 months. Patients with surgical intervals of 6 to 12 months were found to have shorter hospital stays compared to patients with intervals of 2 to 6 months [19]. Therefore, it is recommended that patients consider at least a 6 months interval when undergoing double knee replacement surgery to minimize complications and length of hospital stay.A study of 219 patients determined that the optimal interval for staging tka was 91–270 days [20]. These researchers have evaluated the clinical outcomes and complications of staged BTKA but have failed to determine the optimal timing of a second TKA. We aimed to gain insight into optimising the timing of the second operation in staged BTKA by comparing postoperative outcomes among patients with different surgical intervals.Additionally, we conducted a self-controlled comparison between knees to further evaluate the effects. A self-controlled design, not used in previous studies, avoids the bias caused by control selection in retrospective analysis and has been proven to have high statistical power [21], which was commonly used in studies of TKA [22]. We hypothesized that the clinical outcomes would be better in those second arthroplasties that performed closer to first contralateral arthroplasties.

Materials and methods

Study design

This retrospective cohort study was approved by the ethics committee of Second Affiliated Hospital, Guangzhou University of Chinese Medicine (ethics number: ZE2020 - 139–01), and informed content from patients was waived due to the retrospective nature of the study. We retrospectively reviewed a consecutive series of 528 staged BTKA patients (1,056 knees) performed by 2 senior surgeons(C.X.W. and G.D.) between January 1, 2015, and December 31, 2019. Patients with simultaneous TKA and a rheumatoid arthritis diagnosis were excluded. Patients with different K–L grades were also

excluded. Patients requiring total knee replacement due to fracture were also excluded. All 510 patients underwent BTKA for severe osteoarthritis in both knees and all underwent the same surgical procedure. Baseline demographics and procedural details of the surgery were collected and accessed, including age, gender, height, body mass index (BMI), comorbidities, orthopedic surgeon, and American Society of Anesthesiologists (ASA) Physical Status Classification System score [23]. The intervals between the first and second TKA were calculated. The side for the first TKA was chosen by the patient. The timing of the second surgery was based on patient preference. Functional recovery after unilateral TKA can take approximately 6 months. Ryan et al. concluded that the time to recovery of quadriceps strength after total knee arthroplasty was approximately 6 months [24]. The study by Argenson concluded that the average time to return to sports for patients after total knee arthroplasty was 6 months [25]. At the same time, our case review showed that the majority of patients would prefer to have a second total knee arthroplasty after 6 months, so we chose the 6 months time-point as the minimum time interval. All patients were divided into 3 groups: group A (≤ 180 days), group B (> 180 days and ≤365 days), and group C (> 365 days). Comparison was performed among the 3 groups for the second arthroplasties (A2 vs. B2 vs. C2). Comparison between the first and second surgery (A1 vs. A2, B1 vs. B2, and C1 vs. C2, respectively) was also conducted (Fig. 1). In all surgeries, general anesthesia and standard TKA procedures were applied using posterior cruciate-substituting total knee prostheses (Zimmer®, Warsaw, IN). After prosthetic implantation, the same periarticular infiltration analgesia protocol was applied to all patients, the tourniquet was deflated, and hemostasis was achieved. All the patients underwent the same rehabilitation protocol.

Sample size justification

This retrospective cohort study aimed to evaluate clinically meaningful differences in outcomes of staged BTKA, with a focus on real-world patient-determined intervals. The sample size ($n = 528$ patients, 1,056 knees) was determined by the availability of complete clinical records within the study period (2015–2019). While no formal a priori power calculation was performed, our cohort size aligns with or exceeds those of similar studies investigating staged BTKA timing. For instance, Sun reported significant findings with 281 patients [19], and Villa included 419 patients in their analysis of surgical intervals [14]. Importantly, our study focused on patient-centered outcomes (e.g., LOS, analgesic use) with established clinical relevance, and the observed differences (e.g., reduced LOS in group C2) are consistent with prior literature on recovery trajectories after sequential arthroplasty. This suggests that our sample size was sufficient to detect clinically impactful variations in perioperative management.

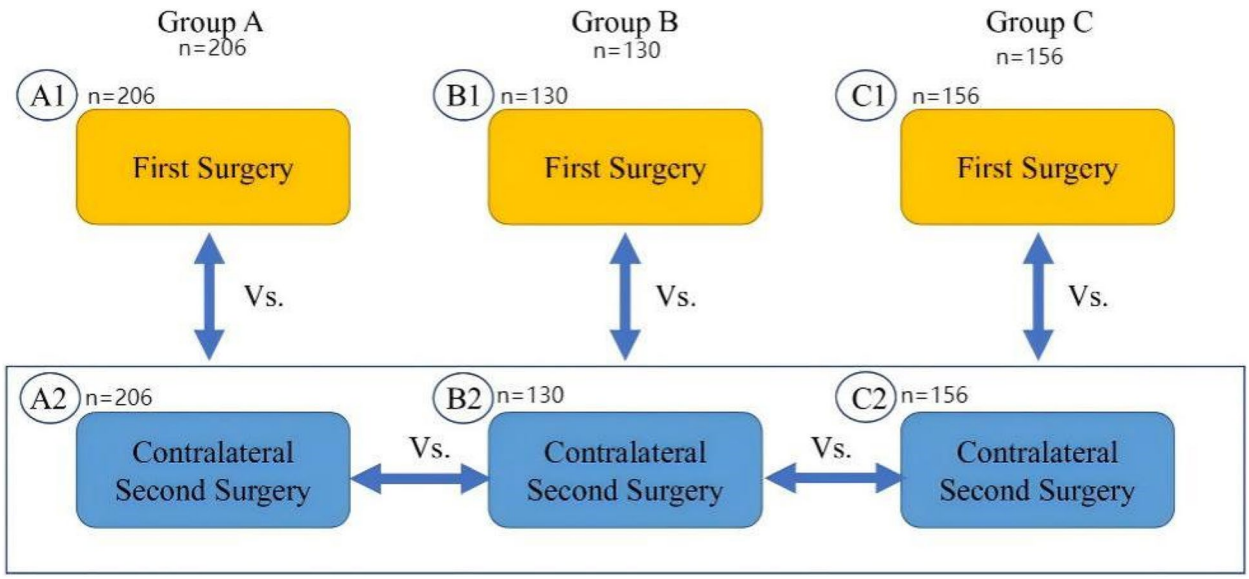

Fig. 1 All cases were set apart in 3 groups by the time between two arthroplasties using 2 different thresholds (180 and 365 days) named as group A(≤ 180 day), B(> 181 and ≤ 365 days) and C (> 365 days). Comparation was performed among 3 groups in second arthroplasties(A2 vs. B2 vs. C2). And in each groups, comparation was done between second surgery and their contralateral first surgery respectively(A1 vs. A2, B1 vs. B2 and C1 vs. C2, respectively)

Definitions of variables

The clinical outcomes analyzed included LOS (days), the rate of readmission within 3 months after the surgery, total hospital costs (in thousands RMB Yuan), drainage volume (mL), drainage-tube duration (h), additional morphine consumption, additional tranexamic acid consumption (mL), allogeneic transfusion rate, intraoperative blood loss (mL), and length of operation (min). The incidences of major complications and hospital adverse events were analyzed. Major complications were defined as events requiring surgical reintervention or intensive care within the first 3 months postoperatively (e.g., deep infection, thromboembolism) [26–28]. Hospital adverse events represent acute, procedure-related complications managed during the immediate postoperative period [27, 29]. A brief description of hospital events is summarized in Appendix Table A. The total rate of hospital adverse events was defined as the presence (yes) or not (no) of any event within the same hospital stay. For example, a patient who experienced postoperative anemia, nausea, and hypertension during hospitalization was counted for a"yes"only once. This method was also applied to the computation of major complications.

Statistical analyses

Propensity score matching

Propensity score matching (PSM) was performed to minimize confounding factors when comparing outcomes among groups. The matching variables included age, sex, BMI, height, comorbidities (hypertension, diabetes, coronary heart disease, chronic obstructive pulmonary disease, liver cirrhosis, and smoking status), ASA score (American Society of Anesthesiologists classification), and surgeon (C.X.W. or G.D.).

Patients with same Kellgren-Lawrence (K-L) grades (grade 4)were included during the initial screening to ensure homogeneity in osteoarthritis severity.The caliper value for coarsened exact matching (CEM) was initially set to 0.1 and iteratively adjusted to 0.01 to optimize balance between matching precision and sample retention. This process ensured that key covariates (e.g., age ± 5 years, BMI ± 2 kg/m^2) were balanced across groups. Propensity score matching was performed using the MatchIt package in R, version 1.3.1 (R Foundation for Statistical Computing, Vienna, Austria).

Data analysis

Continuous data are presented as the mean ± standard deviation. Categorical data are shown as the number of cases (percentage) or absolute number. An analysis of variance was used among the 3 groups (A2 vs. B2 vs. C2) for the second arthroplasty,and Fisher's least significant difference test was conducted to compare between-group differences. An analysis of categorical variables was performed using the Pearson chi- square test in R × 2 table, partitions of χ 2 method to compare between-group differences, and Pearson chi-square test to maintain specific *P* values. A paired t-test was performed between 2 operations (A1 vs. A2, B1 vs. B2, and C1 vs. C2). Categorical variables were analyzed using a matched chi-square test. All analyses were performed using SPSS (version 20.0; IBM Corp., Armonk, NY, USA). The significance level was set at $\alpha = 0.05$.

Results

Unmatched data

A total of 528 patients (1,056 knees) who underwent staged BTKA were identified. Sixteen patients with rheumatoid arthritis patients and two simultaneous TKA were excluded. A total of 510 patients (1,020 knees) were included in the analyses (Fig. 2). Table 1 summarizes the baseline characteristics of each group, without matching. Patients in group A were younger than the other 2 groups (69.44 ± 6.33 vs 70.71 ± 6.17 and 71.29 ± 7.05; $P = 0.018$). The other items were similar in each group ($P > 0.05$).

Matched data

After performing the CEM method, 492 patients were grouped (206 patients from group A, 130 patients from group B, and 156 patients from group C). The baseline covariates among the 3 groups (A2 vs. B2 vs. C2) were well matched, with similar perioperative characteristics ($P > 0.05$) (Table 1).

Outcomes compared among A2 vs B2 vs C2

There were no statistically significant differences in any of the perioperative outcomes among the 3 groups ($P > 0.05$) (Table 2). Perioperative outcomes compared between groups showed similar results (A2 vs B2, B2 vs C2, A2 vs C2) (Table 2). The incidences of major complications and hospital adverse events are shown in Table 3. There were 5 types of major complications that occurred within 3 months after the second TKA. The total major complication rates of the 3 groups were similar (3.88% vs. 3.08% vs. 2.56%, $P = 0.776$); and for each type of major complication, there was no significant difference among the 3 groups ($P > 0.05$). Thirty types of adverse events occurred within 3 months after surgery. The 2 most frequent adverse events were hypertension (10.57%) and anemia (8.94%). There was no statistically significant difference in the total adverse event rates among the 3 groups (53.39% vs. 56.92% vs. 46.15%, $P = 0.169$). The comparison of each adverse event showed no significant differences ($P > 0.05$) (Table 3).

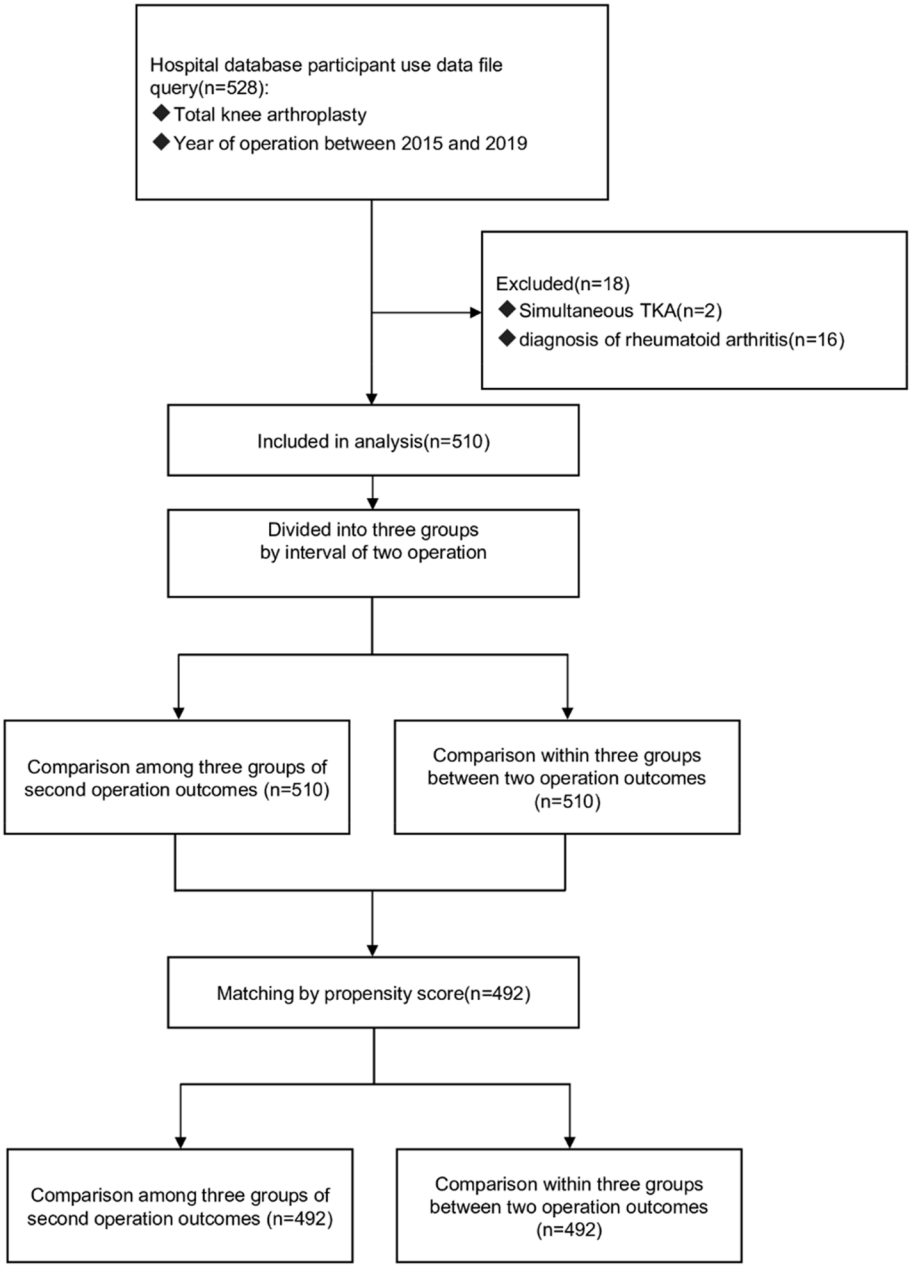

Fig. 2 CONSORT investigation

Outcomes compared between first and second TKA

A1 vs A2

The mean LOS compared between group A1 and A2 showed a statistically significant difference (11.71 ± 3.50 vs 10.07 ± 2.60, $P < 0.0001$). No significant difference was observed in any of the remaining outcomes between groups A1 and A2 *(all $P > 0.05$).* (Appendix Table B).

There was no significant difference exhibited in the rates of major complications and total hospital adverse events between groups A1 and A2 (2.91% vs 3.88%, $P = 0.791$; 59.71% vs 53.40%, $P = 0.154$) (Appendix Table C).

B1 vs B2

The mean LOS was significantly shorter in group B2 than group B1 (11.31 ± 2.90 vs 9.62 ± 2.36, $P = 0.001$). The tranexamic acid consumption was significantly lower in group B1 than in group B2 (65.38 ± 69.00 vs. 87.69 ± 79.74%, $P = 0.013$). There were no significant differences

Table 1 The baseline characteristics of included patients in each group in original data without matched and matched data

Variable	Total cohort(unmatched data)*				PSM matched cohort*			
	No.(*n*)				No.(*n*)			
	Group A (220)	Group B (130)	Group C (160)	*P* value	Group A (206)	Group B (130)	Group C (156)	*P* value
Age, year	69.44 ± 6.33	70.71 ± 6.17	71.29 ± 7.05	0.018[*b]	70.00 ± 5.74	70.71 ± 6.16	71.13 ± 6.90	0.225 [b]
Height, cm	156.03 ± 7.33	155.49 ± 7.05	155.92 ± 7.27	0.794 [b]	156.13 ± 7.32	155.49 ± 7.05	155.84 ± 7.15	0.733 [b]
BMI, g/m2	27.33 ± 3.90	28.07 ± 4.06	28.02 ± 4.12	0.139 [b]	27.37 ± 3.90	28.07 ± 4.06	28.11 ± 4.12	0.144 [b]
Gender				0.971[c]				0.522[c]
Female	188(85.5%)	112(86.2%)	138(86.3%)		174(84.5%)	112(86.2%)	138(88.5%)	
Male	32(14.5%)	18(13.8%)	22(13.7%)		32(15.5%)	18(13.8%)	18(11.5%)	
COPD	0	1(0.8%)	0	0.231 [c]	0	1(0.8%)	0	0.248[c]
HT	148(67.3%)	84(64.6%)	96(60.0%)	0.343[c]	144(69.9%)	84(64.6%)	94(60.3%)	0.157[c]
DM	44(20.0%)	34(26.2%)	40(25.0%)	0.334[c]	44(21.4%)	34(26.2%)	38(24.4%)	0.579[c]
CHD	30(13.6%)	16(12.3%)	12(7.5%)	0.164[c]	30(14.6%)	16(12.3%)	12(7.7%)	0.130[c]
CHF	2(0.9%)	0	0	0.266[c]	2(0.9%)	0	0	0.248[c]
LC	2(0.9%)	0	0	0.266[c]	2(0.9%)	0	0	0.248[c]
Smoke	4(1.8%)	6(4.6%)	2(1.3%)	0.134[c]	4(1.9%)	6(4.6%)	2(1.3%)	0.159[c]
ASA[a]				0.739[c]				0.893[c]
I	24(10.9%)	12(9.2%)	18 (11.3%)		24(11.7%)	12(9.2%)	18(11.5%)	
II	150(68.2%)	86(66.2%)	100(62.5%)		138(66.9%)	86(66.2%)	100(64.1%)	
III	46(20.9%)	32(24.6%)	42(26.3%)		44(21.4%)	32(24.6%)	38(24.4%)	
Surgeon(C/G)				0.137[c]				0.245[c]
CXW	130(59.1%)	64(49.2%)	82(51.2%)		118(57.3%)	64(49.2%)	78(50.0%)	
GD	90(40.9%)	66(50.8%)	78(48.8%)		88(42.7%)	66(50.8%)	78(50.0%)	

[*] Mean ± standard deviation or number of cases(percentages). Missing data not included

[a] *Abbreviation*: *PSM* Propensity score matching, *COPD* Chronic obstructive pulmonary disease, *HT* Hypertension, *DM* Diabetes mellitus, *CHD* Coronary heart disease, *CHF* Congestive heart failure, *LC* Liver cirrhosis, *ASA* American Society of Anesthesiologists, *cm* centimeter, *Kg* kilogram, m meter

[b] Comparison among three groups using analysis of variance

[c] Comparison among three groups using Pearson chi-square test in R × C table

in the remaining outcomes between the 2 surgeries (all P > 0.05) (Appendix Table D).

The incidences of different types of major complications and hospital adverse events in the 2 operations showed no significant difference ($P > 0.05$) (Appendix Table E).

C1 vs C2

The comparison between groups C1 and C2 is presented in Table 4. LOS was significantly shorter in group C2 (12.23 ± 3.41 vs 10.12 ± 2.76, $P < 0.0001$). The drainage volume, and additional morphine analgesics consumption were significantly lower in group C2 (115.62 ± 45.67 vs 101.26 ± 49.28, $P = 0.003$; 131.52 ± 259.11 vs 69.78 ± 159.89, $P = 0.016$). Additional tranexamic acid consumption in group C2 was significantly higher than that in group C1 (46.15 ± 61.58 vs. 106.41 ± 112.84, $P < 0.0001$). There were no significant differences in the other clinical outcomes.

The incidences of major complications and hospital adverse events between C1 and C2 are shown in Table 5. There was no significant difference in the total rate of major complications between the 2 operations (0 vs. 2.56%, $P = 0.125$) and each type of complication (0 vs. 1.28%, $P = 0.500$). Twenty-nine hospital adverse events were observed, and the total hospital adverse event rate was significantly lower in group C2 (58.33% vs. 46.15%, $P = 0.026$). The most common event was hypertension, followed by anemia. The rates of each adverse event were similar between the 2 surgeries (Table 5).

Discussion

We attempted to verify our hypothesis based on multiple aspects, including clinical outcomes, major complications, and adverse hospital events, however, the optimal time frame for staged bilateral TKA remains undetermined. We also conducted a self- controlled comparison between the knees of patients as their internal controls. To the best of our knowledge, no study has estimated the

Table 2 Comparison of perioperative outcomes of second total knee arthroplasty among three groups(A2 vs B2 vs C2)

Perioperative outcomes	No (*n*)*			*P* value
	Group A2(206)	Group B2 (130)	Group C2(156)	
Length of stay/d	10.07 ± 2.60	10.07 ± 2.60	10.12 ± 2.76	0.196[a]
Total hospital costs/thousand	67.00 ± 12.30	67.78 ± 15.54	69.30 ± 30.02	0.562[a]
Additional morphine analgesics consumption/mL	108.22 ± 232.03	125.39 ± 304.46	69.78 ± 159.89	0.114[a]
Length of operation/min	99.81 ± 21.87	99.75 ± 21.67	102.65 ± 22.80	0.409[a]
Intraoperative blood loss/mL	63.88 ± 45.88	68.46 ± 30.94	73.33 ± 63.27	0.192[a]
Drainage volume/mL	113.73 ± 66.89	111.91 ± 65.05	101.26 ± 49.28	0.137[a]
Drainage-tube Duration/h	19.96 ± 5.14	19.92 ± 4.63	20.16 ± 4.42	0.900[a]
Additional tranexamic acid consumption/mL	91.26 ± 86.23	87.69 ± 79.74	106.41 ± 112.84	0.183[a]
Transfusion rate	3(1.5%)	0	0	0.123[b]
Readmission rate	12(5.8%)	6(4.6%)	6(3.8%)	0.679[b]
Total major complication rate*	8(3.9%)	4(3.1%)	4(2.6%)	0.776[b]
Total adverse event rate*	110(53.4%)	74(56.9%)	72(46.2%)	0.169[b]

Abbreviation: *d* day, *h* hour, *min* minute, *mL* milliliter

* Mean ± standard deviation or number of cases (percentages). Missing data not included. The second arthroplasties were set apart in 3 groups based on the interval to their first arthroplasty using 3 different cut-off points named as group A2(≤ 180 days), group B2(> 180 days and ≤ 365 days) and group C2(> 365 days)

[a] Comparison among three groups using analysis of variance.

[b] Comparison among three groups using Pearson chi-square test in R × 2 table

perioperative outcomes between the first and second surgeries of staged BTKA. We believe that this study with combined self-controlled comparisons and parallel comparisons offered more convincing evidence. Our data showed that the LOS was similar among the three second TKA groups. Our results agree with the results of Villa et al. who found that there was no significant difference in LOS of second TKA among groups when using cutoff points of 90, 180, and 365 days [14]. Ritter et al. reported a slight increase in LOS when the interval time of 2 procedures increased. However, they only estimated LOS when a second surgery was performed within 1 year, and rheumatoid arthritis patients were included in the analysis [30]. We also found that the LOS of the second TKA was significantly shorter than that of the first TKA. Risk factors for increased LOS include increased age, female sex, high BMI, higher ASA score, and higher functional outcomes [31, 32]. A previous investigation showed that procedure location and surgeon are the main factors influencing LOS for patients [32]. The time of the second arthroplasty was determined by the patients'own wishes and the ability to undergo another surgery. The successful experience of the first operation played a positive role in the rapid recovery from the second operation. The rate of hospital adverse events was similar among the three second arthroplasty groups. Perioperative hospital adverse events affect various organ systems and cause different events of varying discomfort. It has been reported that hospital adverse events are associated with worse postoperative clinical outcomes [33] which, to some extent, affect patient satisfaction and lead to increased LOS, higher hospital costs, and decreased hospital revenue [29, 34]. However, only a few orthopedic studies have focused on minor clinical events. Yeh et al. evaluated 306 patients who underwent staged bilateral TKA divided into 4 groups according to the timing of the second surgery and found that the rate of hospital adverse events did not show a significant difference [15]. Chen et al. reported that patients were grouped into 21–90, 91–180,181–270, and 270–360 days after the first TKA, and hospital complication rates did not present significant differences [13]. Courtney et al. compared outcomes between patients who underwent staged bilateral TKA and those who underwent unilateral TKA and found no significant difference in complications and 90-day readmission rates between the 2 groups [10]. Our findings agree with those previous studies. We also found that the rate of hospital adverse events was significantly lower in the second TKA when performed 365 days after the first TKA. Similarly, Villa et al. found that second arthroplasties performed at or less than 1 year apart from the first one had significantly higher rates of hospital adverse events [14]. They concluded that staging the second arthroplasty more than 1 year after the first one offered less LOS and hospital adverse event rates. We speculate that a closer interval to the first might result in easier decompensation of some patients with baseline comorbidities. They might have insufficient time to create an adequate physiologic reserve to enable them to withstand the trauma and/or stressors associated with the second arthroplasty. The

Table 3 Incidence of major complication and hospital adverse events of total knee arthroplasty within 3 months after operation among three 392 groups(A2 vs B2 vs C2)

Event	Detail	No.(*n*)*			
		Group A2(206)	Group B2 (130)	Group C2(156)	*P* value a
Major complication*	Tachyarrhythmia	2	0	0	0.248
	Cerebrovascular accident	4	0	2	0.286
	Anaphylactic shock	2	0	0	0.248
	Deep wound infection	2	2	2	0.896
	Returning to the operation room	0	3	2	0.112
Adverse event*	Anemia	26	8	10	0.053
	Transfusion	3	0	0	0.123
	Nausea	8	2	4	0.438
	Vomiting	18	8	8	0.376
	Dizziness	8	10	8	0.313
	Hypertension	20	16	16	0.743
	Electrolyte imbalance	18	11	8	0.389
	Constipation	2	2	0	0.334
	Headache	0	2	0	0.061
	Hypotension	8	2	4	0.438
	Low oxygen saturation	2	0	0	0.248
	Tachycardia	8	2	2	0.209
	Insomnia	6	0	2	0.111
	Cough	4	4	4	0.800
	Skin blisters	2	3	0	0.152
	Dermatitis	6	4	4	0.964
	Itch of skin	6	6	8	0.534
	Throat discomfort	2	2	4	0.492
	Dysuresia	2	2	0	0.334
	Diarrhea	6	0	4	0.156
	Hypercoagulable states	0	2	0	0.061
	Hematoma	2	2	2	0.896
	Allergy	2	0	0	0.248
	Pneumonia	2	0	0	0.248
	Hyperplastic scar	0	0	2	0.115
	Poor appetite	3	3	0	0.192
	Chest tightness	2	4	5	0.273
	Hyperglycemia	4	6	2	0.159
	Persistent wound drainage	0	0	2	0.115
	Dyspnea	0	0	2	0.115

*Showed as number of cases within groups. The second arthroplasties were set apart in 3 groups based on the interval to their first arthroplasty using 3 different cut-off points named as group A2(≤ 180 days), group B2(> 180 days and ≤365 days) and group C2(> 365 days)

[a] Comparison among three groups using Pearson chi-square test in R× 2 table

second operation showed some advantages over the first operation when performed after 365 days of the first one. We considered that the significant decrease in LOS after the second arthroplasty may have been related to the success of the first arthroplasty, which played a positive role in the rapid recovery of the second operation. To a certain extent, a shorter LOS may be related to the fact that the additional morphine analgesics consumption was significantly lower in the second arthroplasty. Previous studies found that increased postoperative morphine consumption is a risk factor associated with prolonged LOS [35, 36]. Our data showed that the significant decrease in the drainage blood loss in the second arthroplasty was seemingly associated with a significant increase in the amount

Table 4 Comparison of perioperative outcomes between primary and second total knee arthroplasty in group that second total knee arthroplasty done more than 365 days(C1 vs C2)

Perioperative outcomes	No.(*n*)*		*r* value
	Primary TKA(156)	Second TKA(156)	
Length of stay/d	12.23 ± 3.41	10.12 ± 2.76	< 0.0001[a]
Total hospital costs/thousand	66.06 ± 9.68	69.30 ± 30.02	0.179[a]
Additional morphine analgesics consumption/mL	131.52 ± 259.11	69.78 ± 159.89	0.016[a]
Length of operation/min	101.40 ± 21.82	102.65 ± 22.80	0.582[a]
Intraoperative blood loss/mL	65.77 ± 47.24	73.33 ± 63.27	0.225[a]
Drainage volume/mL	115.62 ± 45.67	101.26 ± 49.28	0.003[a]
Drainage-tube Duration/h	20.95 ± 4.72	20.16 ± 4.42	0.101[a]
Additional tranexamic acid consumption/mL	46.15 ± 61.58	106.41 ± 112.84	< 0.0001[a]
Transfusion rate	0	0	-
Readmission rate	6(3.8%)	6(3.8%)	1[b]
Total major complication rate*	0	4(2.6%)	0.125[b]
Total adverse event rate*	91(58.3%)	72(46.2%)	0.026[b]

Abbreviation: *d* day, *h* hour, *min* minute, *mL* milliliter

* Mean ± standard deviation or number of cases (percentages). Missing data not included.

[a] Paired t-test

[b] Matched chi-square test

of additional intravenous tranexamic acid. Perioperative tranexamic acid can effectively decrease postoperative blood loss in TKA [37, 38]. Wu et al. reported that the amount of 48- hour blood drainage decreased with an increased dose of intravenous tranexamic acid [39]. Lei et al. reached a conclusion that a multiple-dose intravenous TXA regimen can reduce blood loss following TKA [40]. The difference in the amount of intravenous tranexamic acid In our study might have explained the difference in our findings for drainage blood loss.

Limitations

The study had several limitations. First, the main limitation of the single-center retrospective design is the limited sample representativeness, which usually reflects only the characteristics and treatment outcomes of patients from a specific region or institution, resulting in low external validity. Since the data were collected retrospectively, there is a risk of information bias and confounding factors, making it difficult to establish causal relationships. In our study, the interval between the two procedures was determined by the patients. To mitigate these issues, we used Propensity Score Matching (PSM), which helps reduce differences in confounding factors between the exposed and control groups by matching individuals with similar characteristics, thereby enhancing group comparability and internal validity. However, the sample size ($n = 528$) may limit the statistical power to detect differences in rare adverse events (e.g., major complications with incidences < 5%). Second, key clinical functional outcomes, such as the Short-Form 12 or the Hospital for Special Surgery Score, were not collected or analyzed due to missing data in the administrative system, which limits the scope of the conclusions. However, the timing of the second arthroplasty in our study was determined by the patients'assessed ability and rehabilitation status. A previous investigation [15] reported that preoperative functional outcomes did not show a significant difference between staged groups when time intervals were patient-determined. Third, the time intervals we used for group division may not have been adequate. We divided cases into four groups (0–90, 90–180, 180–270, and 270–365 days) to allow more comparisons among groups, but this caused the sample size to be scattered and may have introduced bias. Additionally, the follow-up period for major complications was restricted to 3 months postoperatively, which may not capture long-term adverse events such as prosthetic loosening, late infections, or chronic pain. Future studies with extended follow-up durations are needed to comprehensively evaluate the safety profile of staged BTKA. Fourth, there may have been variations in the timing of surgery due to the attending surgeon's assessment of the patient's recovery and postoperative complications, which could have affected the final conclusions. This flexibility in timing may also have influenced the reliability of the findings. Therefore, a multicenter, prospective cohort trial is necessary to obtain a higher level of evidence and confirm our findings. Nevertheless, our rigorous matching approach and focus on patient-determined intervals

Table 5 Comparison of incidence of major complication and hospital adverse events between primary and second total knee arthroplasty in group that second total knee arthroplasty done more than 365 days(C1 vs C2)

Event	Detail	No.(*n*)*		*P* value a
		Primary TKA(156)	Second TKA(156)	
Major complication*	Cerebrovascular accident	0	2	0.5
	Deep wound infection	0	2	0.5
	Returning to the operation room	0	2	0.5
Adverse event*	Anemia	18	10	0.077
	Nausea	6	4	0.754
	Vomiting	8	8	1
	Dizziness	10	8	0.815
	Hypertension	18	16	0.855
	Electrolyte imbalance	14	8	0.18
	Constipation	4	0	0.125
	Hypotension	6	4	0.754
	Tachycardia	0	2	0.5
	Insomnia	6	2	0.125
	Cough	8	4	0.388
	Dermatitis	8	4	0.125
	Itch of skin	18	8	0.078
	Throat discomfort	8	4	0.388
	Diarrhea	4	4	1
	Hematoma	0	2	0.5
	Hyperplastic scar	0	2	0.5
	Poor appetite	4	0	0.125
	Chest tightness	6	5	1
	Hyperglycemia	2	2	1
	Persistent wound drainage	0	2	0.5
	Dyspnea	0	2	0.5
	Card symptoms	4	0	0.125
	Ecchymosis	4	0	0.125
	Metabolic alkalosis	2	0	0.5
	Fever	2	0	0.5
	Asynodia	1	0	1
	Gastric hypomotility	4	0	0.125
	Sustained Wound Exudation	2	0	0.5

* Showed as number of cases within groups

[a] Matched chi-square test

provide robust insights into the safety of staged BTKA timing.

Conclusions

There is no statistically significant difference in postoperative outcomes, major complication rates, hospital adverse events, or overall adverse event rates when the time interval between staged bilateral total knee arthroplasties (BTKAs) is determined by the patients. However, prolonging the interval between the surgeries may be beneficial for a faster recovery after the second knee arthroplasty. Benefits such as reduced intraoperative blood loss, lower postoperative analgesic use, and shorter hospital stays are especially evident when the interval exceeds one year, showing statistically significant differences. Therefore, if patients are willing to wait, we recommend scheduling the second surgery at least one year after the first.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12893-025-02915-8.

Supplementary Material 1
Supplementary Material 2
Supplementary Material 3
Supplementary Material 4

Authors' contributions

Yang Lv and Zhijian Pan contributed to study conception and design and wrote the manuscript.Xiaojie Zheng and Da Guo performed the implementation and feasibility analysis of the study. Chunjian Zi collated the data. Xin Li conducted statistical analysis and proofreading of the text for language. Dingkun Lin analyzed and interpreted the results. Dingkun Lin revised the manuscript. Yang Lv was responsible for quality control and review of articles, as well as the overall supervision and management of articles.

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Data availability

Data is provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Second Affiliated Hospital, Guangzhou University of Chinese Medicine (ethics number: ZE2020 - 139–01), and informed content from patients was waived due to the retrospective nature of the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.3

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