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Complications following bilateral simultaneous versus staged total knee arthroplasty in the Japanese population: a propensity-matched case-control study

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Although bilateral simultaneous total knee arthroplasty (BSTKA) is an effective treatment for bilateral knee osteoarthritis, safety concerns and lack of precise patient selection criteria persist. This study aimed to determine the differences in perioperative parameters and complication rates between BSTKA and staged TKA in the Japanese population. We retrospectively reviewed 531 patients who underwent BSTKA or staged TKA between 2012 and 2021. Propensity score matching, performed on a 1:1 nearest neighbor basis for age, BMI, diagnosis, ASA score, and age-adjusted Charlson Comorbidity Index, yielded matched cohorts of 94 patients (188 knees) for each group. Outcome measures included operative time, perioperative blood loss, length of hospital stay, and nonmechanical complications after surgery. The BSTKA group had a shorter median operative time and hospital stay (111 min and 16 days) than the staged TKA group (159 min and 33 days) ($p < 0.001$). Overall complication rates were higher in the BSTKA group than in the staged TKA group (26% vs. 13%, $p = 0.026$), with anemia requiring transfusion being the most common. Cardiovascular complications were more frequent in the BSTKA group (4.3% vs. 0%, $p = 0.043$). These findings emphasize the importance of careful patient selection and risk assessment when considering BSTKA.

Keywords Total knee arthroplasty, Bilateral simultaneous, Complications, Propensity score matching

In a large Japanese cohort study, the prevalence of knee osteoarthritis (OA) in elderly Japanese was much higher than that in previous epidemiologic studies of elderly Western Caucasians[1–3]. Specifically, bilateral knee OA was observed in 50% of Japanese subjects over the age of 60 years, with the prevalence increasing with age[1]. A multicenter study conducted in the United States reported a cumulative incidence of contralateral TKA of 40% eight years after index TKA[4]. Bilateral simultaneous TKA (BSTKA) has emerged as a promising approach for the treatment of bilateral knee OA, offering potential advantages over staged TKA, including shorter cumulative hospital stays, a single anesthesia procedure, reduced overall rehabilitation requirements, earlier return to work, and importantly, reduced costs for both patients and the healthcare system[5–8]. Furthermore, in cases of severe contralateral knee deformity that complicates rehabilitation after initial arthroplasty, simultaneous surgery appears to be advantageous over staged TKA[9].

However, disadvantages of BSTKA include an increased need for allogeneic blood transfusions and increased physiologic stress induced by simultaneous surgery[10–12]. Despite numerous comparative studies between BSTKA and staged TKA, a consensus on their safety and efficacy remains elusive[6,13–15]. There are discrepancies between healthcare database-based studies and single-institution analyses, with database-based studies often suggesting an increased risk of complications with BSTKA compared to staged TKA[12,16,17]. However, they are plagued by confounding, selection, and measurement biases that undermine their credibility. Conversely, single-institution

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studies often report comparable morbidity and mortality rates between the two approaches[9,18,19], possibly due to surgeon expertise, advances in anesthesia, and process standardization in high-volume hospitals. In addition, many studies have predominantly used unilateral TKA comparison cohorts or analyzed staged TKA as two distinct surgical episodes, potentially misrepresenting its bilateral nature[10,11,20–22].

To the best of our knowledge, no study has compared the complication rates of BSTKA and staged TKA in Japanese subjects, especially after adjusting for background factors using propensity score matching. Therefore, the purpose of this study was to determine and compare the postoperative complication rates between BSTKA and staged TKA, with special emphasis on staged TKA as a single process consisting of two sequential episodes.

Patients and methods

This study was approved by the institutional ethical review board of the Faculty of Medicine, Saga University (No. 2022-07-R-04), and the requirement for informed consent of the participants was waived by the institutional ethical review board of the Faculty of Medicine, Saga University, due to the retrospective nature of the study.

Patients

A retrospective analysis of the clinical data on bilateral TKA was conducted using a prospectively maintained arthroplasty database at our institution. Inclusion criteria for this study were patients undergoing either BSTKA or staged TKA for the treatment of bilateral OA or rheumatoid arthritis of the knee with persistent knee pain despite prolonged conservative treatment. BSTKA was defined as the replacement of both knees during a single hospitalization under a single anesthesia, whereas staged TKA was defined as patients being discharged after the first surgery and subsequently readmitted for the second knee surgery at varying intervals but within a timeframe of less than 12 months. No definitive selection criteria for BSTKA were established at our institution during the study period. Patients were informed about both BSTKA and staged TKA, with BSTKA being selected primarily on the basis of patient preference.

Between February 2012 and January 2021, 586 patients (1172 knees) underwent bilateral TKA (Fig. 1). Of these, 10 patients who underwent staged TKA with an interval > 12 months to the second TKA, and 45 patients without at least one year of follow-up were excluded. A total of 531 patients (1062 knees, 92%) were eligible for this study: 434 patients in the BSTKA group and 97 patients in the staged TKA group. The median interval between TKAs in the staged TKA group was 5 months (range 1–12 months).

Data collection and propensity score matching

We performed a comprehensive review of medical records to collect patient demographics, perioperative parameters, and any nonmechanical complications that occurred within 1 year of surgery. Preoperative demographics included age, sex, body mass index (BMI), diagnosis, American Society of Anesthesiologists (ASA) score, and age-adjusted Charlson Comorbidity Index (ACCI)[21,22]. Baseline characteristics of the prematched
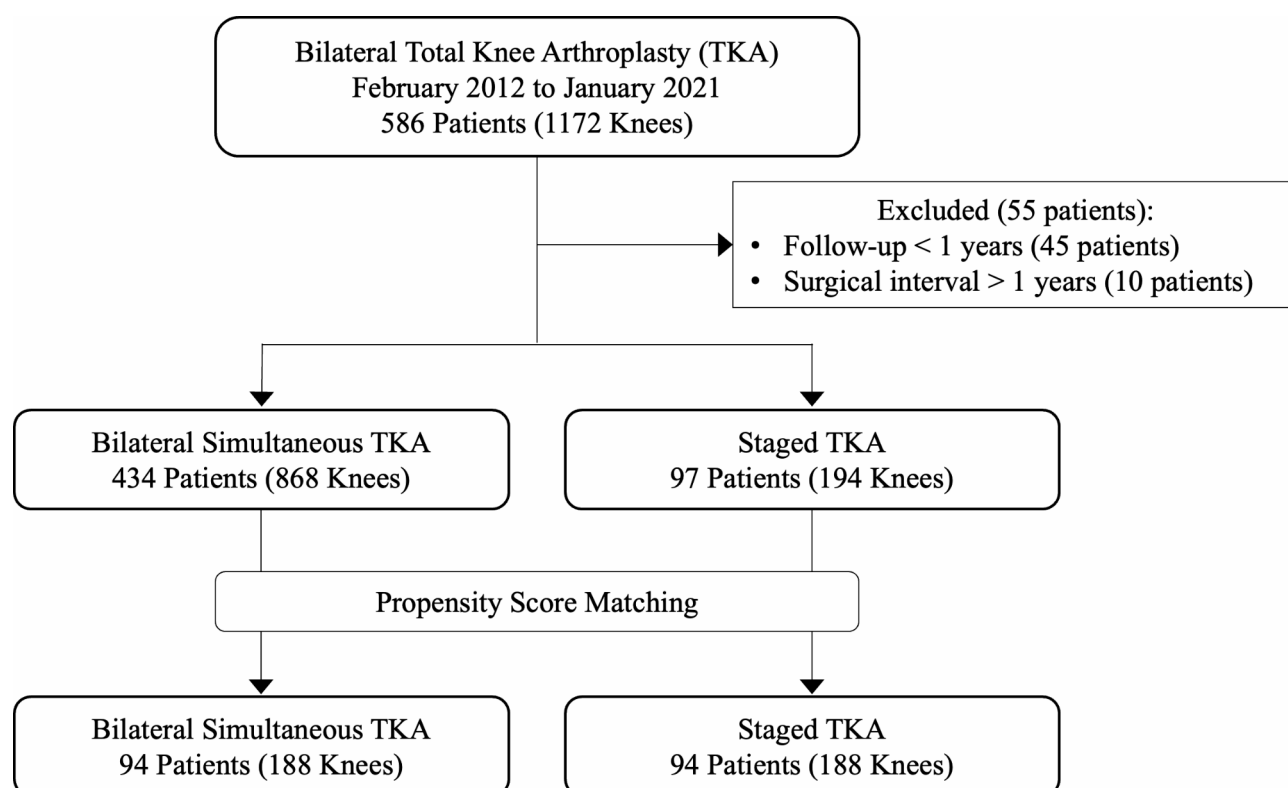

Fig. 1. A STROBE flow diagram of this study is shown.

cohort are shown in Table 1. Propensity score matching was performed on a 1:1 nearest neighbor basis with a caliper of 0.20, adjusting for age, BMI, diagnosis, ASA, and ACCI.

Outcome measures included operative time, perioperative blood loss, length of hospital stay, and nonmechanical complications that occurred within one year of surgery. The complication category included anemia requiring transfusion, symptomatic venous thromboembolism (VTE; includes deep vein thrombosis and pulmonary embolism), cardiovascular complications, prosthesis infection, delayed wound healing, renal complications, respiratory complications, gastrointestinal disorders, and delirium. The Knee Society Score (KSS) at the time of surgery and one year postoperatively was also obtained by reviewing medical records.

Surgical procedure

Both BSTKA and staged TKA were typically performed under spinal anesthesia; however, patients for whom spinal anesthesia was difficult (e.g., those with prior spinal surgery) received general anesthesia. BSTKA was performed by a team of two experienced surgeons, starting with the second knee after contralateral bone cutting. Using the medial parapatellar approach under tourniquet control, all procedures followed measured bone cuts guided by anatomical landmarks. The distal femur was cut perpendicular to its mechanical axis using intramedullary instruments to match the thickness of the femoral component. The proximal tibia was cut perpendicular to its mechanical axis in the coronal plane and with a 5-degree posterior tibial slope in the sagittal plane using extramedullary instruments. The posterior femoral condyles were cut parallel to the surgical epicondylar axis with 3–5-degree external rotation from the posterior condylar line, depending on the surgical epicondylar axis. Posterior stabilized implants were used in all TKAs, including Persona, LPS-Flex (ZimmerBiomet, Warsaw, IN, USA), Triathlon (Stryker, Mahwah, NJ, USA), BS5, Initia (Kyocera, Kyoto, JPN), and TriMAX (MDM, Tokyo, JPN). Patella replacement was performed selectively based on the severity of cartilage degeneration.

All patients received intravenous prophylactic antibiotics until postoperative day 1. Standard thromboprophylaxis was administered, and oral edoxaban tosilate hydrate was administered from postoperative days 1–14, with additional use of antiembolic stockings. A urinary catheter was placed in all patients before surgery and was typically removed on postoperative day 2, with no difference in catheterization duration between the BSTKA and staged TKA groups. Dysuria related to urinary catheterization was observed in three patients in the BSTKA group. Patients were allowed to begin range-of-motion and full-weight-bearing gait training on the day after surgery, with gradual progress. Patients were typically discharged 2 weeks after BSTKA, either home or to a rehabilitation hospital, depending on the need for postoperative rehabilitation.

Statistical analysis

All outcome measures were compared between the propensity score-matched cohorts. For patients undergoing BSTKA, continuous variables such as operative time, perioperative bleeding, and length of hospital stay were reported in the context of each surgical episode. Similarly, categorical variables for BSTKA were specific to each surgery. Conversely, for patients undergoing staged TKA, continuous variables were reported as an aggregate of both surgical episodes. Categorical variables in staged TKA were evaluated relative to both procedures, with percentages calculated based on the total number of patients. This approach allowed staged TKA to be evaluated as a single entity, although it consisted of two separate procedures. Student t-tests or Wilcoxon rank-sum tests were used to compare continuous parameters based on their distribution and homoscedasticity (Shapiro–Wilk test and f-test). Chi-square tests were used to compare categorical variables. The significance level was set at

Parameters	BSTKA ($n = 434$ patients)	Staged TKA ($n = 97$ patients)	p value
Age* (years)	76 (45–90)	76 (44–91)	0.694
Sex[†]			0.672
Male	77 (18)	19 (20)	
Female	357 (82)	75 (80)	
Body mass index* (kg/m²)	26 (13–49)	25 (14–38)	0.043
Diagnosis[†]			0.010
Osteoarthritis	416 (96)	86 (89)	
Rheumatoid arthritis	18 (4.1)	11 (11)	
American Society of Anesthesiologists score[†]			0.166
1	67 (15)	12 (12)	
2	341 (79)	83 (86)	
3	26 (6)	2 (2)	
Age-adjusted Charlson Comorbidity Index[†]			< 0.001
1–2	52 (12)	2 (2)	
3–4	267 (62)	42 (43)	
≤ 5	115 (26)	53 (55)	

Table 1. Comparison of baseline determinants between patients with bilateral simultaneous total knee arthroplasty (BSTKA) and staged TKA before propensity score matching. *Values are presented as median (range); [†]Values are presented as number of patients (%).

Parameters	BSTKA ($n = 94$ patients)	Staged TKA ($n = 94$ patients)	p value
Age* (years)	76 (50–90)	76 (44–91)	0.517
Sex†			
Male	21 (22)	18 (19)	0.710
Female	73 (78)	76 (81)	
Body mass index* (kg/m²)	25 (13–42)	25 (14–38)	0.366
Diagnosis†			
Osteoarthritis	87 (93)	86 (91)	0.788
Rheumatoid arthritis	7 (7.4)	8 (8.5)	
American Society of Anesthesiologists score†			
1	9 (10)	10 (12)	0.187
2	77 (82)	82 (86)	
3	8 (8)	2 (2)	
Age-adjusted Charlson Comorbidity Index†			
0–2	5 (5)	2 (2)	0.309
3–4	38 (42)	42 (43)	
≤ 5	51 (53)	50 (53)	

Table 2. Comparison of baseline determinants between patients with bilateral simultaneous total knee arthroplasty (BSTKA) and staged TKA after propensity score matching. *Values are presented as median (range); †Values are presented as number of patients (%).

Parameters	BSTKA ($n = 94$ patients)	Staged TKA ($n = 94$ patients)	p value
Perioperative parameters			
Operation time* (min)	111 (72–161)	159 (101–241)	< 0.001
Perioperative bleeding* (ml)	595 (90–1910)	640 (101–1870)	0.897
Length of stay* (days)	16 (12–29)	33 (20–56)	< 0.001
Total Complications†	24 (26)	12 (13)	0.026
Anemia requiring transfusion	6 (6.3)	4 (4.3)	0.514
Symptomatic thrombosis	5 (5.3)	1 (1.1)	0.097
Cardiovascular complication	4 (4.3)	0 (0)	0.043
Prosthetic joint infection	3 (3.2)	3 (3.2)	1.000
Delayed wound healing	2 (2.1)	4 (4.3)	0.402
Renal complication	1 (1.1)	0 (0)	0.316
Respiratory complication	0 (0)	0 (0)	1.000
Gastrointestinal disorder	3 (3.2)	0 (0)	0.081
Delirium	4 (4.3)	2 (2.1)	0.407

Table 3. Comparison of perioperative parameters and complications between patients with bilateral simultaneous total knee arthroplasty (BSTKA) and staged TKA. *Values are presented as medians (ranges); †Values are presented as number (%).

$p < 0.05$ for all tests. Statistical analyses were performed using JMP® version 17.0 (SAS Institute Inc., Cary, NC, USA).

Results

Before propensity score matching, significant differences in baseline characteristics were observed between patients undergoing BSTKA and staged TKA, particularly in terms of BMI, diagnosis, and ACCI (Table 1). Propensity score matching yielded a matched cohort of 94 patients (188 knees) in both the BSTKA and staged TKA groups, effectively mitigating the differences in the baseline characteristics between the original cohorts (Table 2).

Perioperative parameters and complications for each group are shown in Table 3. Median operative time and length of hospital stay were shorter in the BSTKA group (111 min and 16 days) compared to the staged TKA group (159 min and 33 days) ($p < 0.001$). However, there was no difference in perioperative bleeding between the two groups (595 ml vs. 640 ml, $p = 0.897$).

The overall complication rate was higher in the BSTKA group than in the staged TKA group (26% vs. 13%, $p = 0.026$). Patients with an ASA score ≥ 3 had significantly more complications than those with an ASA score of 1 or 2 in the BSTKA group (100% vs. 18%, $p < 0.001$), whereas the prevalence of complications did not differ

in the staged TKA group (13% vs. 0%, $p = 0.585$). Anemia requiring transfusion (6.3%) was the most common complication in the BSTKA group, followed by symptomatic thrombosis (5.3%), cardiovascular complications (4.3%), and delirium (4.3%). Similarly, in the staged TKA group, anemia requiring transfusion (4.3%) was the most common, followed by delayed wound healing (4.3%), prosthetic joint infection (3.2%), and delirium (2.1%). The incidence of cardiovascular complications was significantly higher in the BSTKA group than in the staged TKA group (4.3% vs. 0%, $p = 0.043$), whereas other complications did not differ between the two groups. Specifically, cardiovascular complications in the BSTKA group included postoperative heart failure in three patients and postoperative arrhythmia in one patient. The median (range) days after surgery for each complication was as follows: anemia requiring transfusion, 1 day (0–4); symptomatic thrombosis, 8 days (1–34); cardiovascular complications, 3 days (0–5); prosthetic joint infection, 60 days (20–120); gastrointestinal ulcers, 14 days (10–18); and delirium, 2 days (1–3).

There were no differences in KSS at the time of surgery and one year postoperatively between the BSTKA and staged TKA groups, indicating comparable functional outcomes (Table 4).

Discussion

BSTKA offers compelling advantages such as shorter cumulative hospital stay, accelerated functional recovery, earlier return to work, and reduced healthcare costs[5–7,9]. The present study confirmed that BSTKA has a shorter cumulative operative and hospitalization time compared with staged TKA, which is consistent with previous studies. However, BSTKA may also be associated with increased susceptibility to postoperative complications due to greater physiologic stress compared to staged TKA[10–12,23]. Despite extensive comparative studies on the outcomes of BSTKA versus staged TKA[6,12–20,23], a consensus on the safety of BSTKA remains elusive. Recent studies highlight the variability in TKA practice, with shifts toward outpatient TKA and personalized protocols based on institutional preferences and patient needs. This variety underscores the need for standardized, evidence-based approaches, especially for high-risk procedures such as BSTKA[24,25]. Many previous studies comparing the complication rates of BSTKA and staged TKA may have been confounded by differences in patient baseline characteristics and institutional variables[13,15]. To our knowledge, this study represents the first attempt to investigate postoperative complications between BSTKA and staged TKA in the Japanese population while adjusting for these potential confounders using propensity score matching.

Despite propensity score matching to control for baseline differences, including comorbidities, our results indicate a higher incidence of postoperative complications in the BSTKA group (26%) compared to the staged TKA group (13%) ($p = 0.026$). Although the BSTKA group consisted of relatively fitter patients with fewer baseline comorbidities, this increased complication rate suggests that BSTKA inherently carries a higher risk, likely due to the greater physiologic stress of the simultaneous procedure. In addition, complications were more common in patients with higher ASA scores, underscoring the importance of individualized risk assessment when considering BSTKA. Although direct comparisons are challenging due to differences in patient demographics, surgical techniques, and complication definitions, the complication rates observed after BSTKA in our study are consistent with those reported in previous studies, where rates have ranged from 13 to 32%[17,21–23,26]. Currently, the predominant literature evaluating the safety of BSTKA versus staged TKA consists of retrospective studies, with a limited number of prospective or propensity score matching studies[6,12–15,23]. In a study by Lindberg et al.[23], which examined a propensity score-matched cohort of 232 BSTKA and 232 staged TKA cases, BSTKA had a higher incidence of in-hospital complications (15.5%) compared to staged TKA (7.3%), which is consistent with our findings. In addition, Erossy et al.[12]. also reported increased in-hospital complications after BSTKA compared to staged TKA in a nationwide propensity score-matched analysis of 38,764 cases, highlighting the need for future investigation to further establish patient selection for BSTKA. Conversely, Sheth et al.[13] found similar complication rates between BSTKA and staged TKA using the Total Joint Registry and adjusting for differences in patient, surgeon, and hospital characteristics. Therefore, the evidence for the superiority of either BSTKA or staged TKA remains inconclusive, and further prospective studies are needed to reach a definitive conclusion.

In this study, the incidence of cardiovascular complications was significantly higher in the BSTKA group than in the staged TKA group (4.3% vs. 0%, $p = 0.043$), whereas other complications did not differ between the two groups. This finding is consistent with Erossy et al.[12] who also reported a higher prevalence of cardiovascular complications in BSTKA compared to staged TKA (9.2% vs. 5.6%, $p < 0.001$). In addition, Bolognesi et al.[16] reported a higher 90-day risk of myocardial infarction with BSTKA compared to staged TKA (0.5% vs. 0.2%, $P = 0.02$) in a study of Medicare beneficiaries over 65 years of age. Conversely, other studies have reported no significant differences in cardiovascular complications between the two procedure cohorts[15,19,27]. The

Parameters	BSTKA (*n* = 94 patients)	Staged TKA (*n* = 94 patients)	*p* value
Perioperative parameters			
Knee score	44 (31–53)	45 (33–54)	0.512
Functional score	45 (30–55)	40 (30–50)	0.511
On year after surgery			
Knee score	94 (91–100)	96 (94–100)	0.105
Functional score	80 (53–90)	80 (55–90)	0.215

Table 4. Comparison of Knee Society Score between patients with bilateral simultaneous total knee arthroplasty (BSTKA) and staged TKA. Values are presented as the median (interquartile range).

pathophysiology of BSTKA differs from that of unilateral TKA and has a greater impact on the cardiopulmonary system[10–12]. As a result, orthopaedic surgeons often use conservative risk stratification methods when evaluating candidates for BSTKA to reduce patient risk, such as avoiding patients with cardiopulmonary disease or advanced age[10,11,14,20–22,28,29]. Specifically, Koh et al.[21]. demonstrated that patients aged ≥ 75 years with ASA score ≥ 3 and concomitant cardiovascular disease are at increased risk of postoperative complications after BSTKA. However, further studies are warranted to establish validated risk stratification models specifically tailored to facilitate patient selection for BSTKA.

In this study, the most common complication was anemia requiring blood transfusion, with comparable rates between BSTKA and staged TKA (6.3%, vs. 4.3%, $p = 0.514$). However, previous studies have documented transfusion rates ranging from 35 to 58% in BSTKA[17,30], suggesting a relatively lower transfusion rate in this study. Several studies have suggested an increased perioperative risk of VTE after BSTKA compared to staged TKA[12,16]. However, in this study, the incidence of VTE was not significantly different between the two groups (5.3% vs. 1.1%, $p = 0.097$). This discrepancy could be attributed to the lower susceptibility of Asian patients to VTE complications, possibly due to a lower prevalence of clinical prothrombotic risk factors such as obesity, venous disease, and hyperlipidemia, as well as a lower frequency of susceptibility genes such as the factor V Leiden mutation and prothrombin promoter G20210A mutation[9,31,32]. Regarding prosthesis infection, the results of the current study showed no significant difference between the BSTKA and staged TKA groups (3.2% vs. 3.2%, $p = 1.000$). Several previous studies have also reported no significant difference in the incidence of infection between BSTKA and staged TKA[16,19]. However, Richardson et al.[17]. analyzed 7747 patients undergoing BSTKA or staged TKA and reported a higher incidence of postoperative infection in staged TKA patients. Conversely, some studies have reported a higher incidence of postoperative infection in BSTKA patients[12]. Variations in patient demographics, surgical techniques, and perioperative management may have influenced these discrepancies in study results.

Limitations
Despite the contributions of this study, its limitations should be acknowledged. First, the major weakness of our study was its retrospective design based on the database of our institute. However, the standardized 14-day postoperative hospital stay for all BSTKA patients in our health care system, which is significantly longer than typical stays in Western countries, facilitated the early detection of most complications occurring during this period. The timing of complications underscores the challenges for high-volume centers that discharge patients within 2–3 days, as events such as symptomatic thrombosis and cardiovascular events may require outpatient follow-up. Second, although this study includes short-term functional outcomes using the KSS, it was designed primarily to assess perioperative parameters and short-term complications rather than long-term outcomes. Therefore, a comprehensive survival analysis was beyond the scope of this study. Future studies should include survival analysis with longer follow-up to evaluate the long-term durability and efficacy of BSTKA compared with staged TKA. Lastly, the sample size may not be sufficient. Sample size and power were not analyzed in our study; however, this study represents robust data available from a single institution, which avoids the bias resulting from confounding variables such as differences in surgical technique, surgeon experience, and management protocol, as in studies using multicenter or registry data.

Conclusion
Our study using propensity-matched Japanese cohorts demonstrated that BSTKA, while offering advantages such as shorter operative time and hospital stay, is associated with a higher overall complication rate than staged TKA, particularly an increased incidence of cardiovascular complications. These findings underscore the importance of careful patient selection and risk assessment when considering BSTKA. Future research should focus on refining patient selection criteria and surgical techniques to improve the safety and efficacy of BSTKA, ultimately improving outcomes and optimizing patient care.

Data availability
The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Author contributions

Y.M., M.F., and Y.Y. contributed to the conception and design, acquisition or analysis of data, interpretation of data, drafting of the article, and critical revision of the article for important intellectual content. S.N., T.S., S.I., T.T., T.S., S.E., and M.M. contributed to the acquisition or analysis of data and critical revision of the article for important intellectual content. All authors have read and approved the final submitted manuscript.

Declarations

Competing interests

The authors declare no competing interests.

Ethical approval

Each author certifies that his/her institution approved the human subject protocol for this investigation and that all investigations were conducted in conformity with the 1964 Helsinki Declaration. Ethical approval for this study was obtained from the institutional ethical review board of the Faculty of Medicine, Saga University (No. 2022-07-R-04), and the requirement for informed consent of the participants was waived by the

institutional ethical review board of the Faculty of Medicine, Saga University, due to the retrospective nature of the study.

Consent to participate

 Ethical approval for this study was obtained from the Faculty of Medicine, Saga University (No. 2022-07-R-04).

Additional information

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