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Optimal timing in staged bilateral total knee arthroplasty: A retrospective analysis of complications and functional outcomes

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ABSTRACT

Aim: To investigate the association between inter-stage timing and postoperative complications, hospital readmissions, and functional outcomes in staged bilateral TKA.

Methods: A retrospective analysis was performed on 815 staged bilateral TKA cases between March 2019 and April 2024. Patients were stratified into four groups based on inter-stage intervals: 3 weeks–90 days, 91–180 days, 181 days–1 year, and >1 year. Demographic data, complication rates, unplanned readmissions, length of hospital stay, and functional outcomes, as Knee Osteoarthritis Outcomes Score for Joint Replacement (KOOS JR) and the Lower Extremity Activity Scale (LEAS), were analyzed.

Results: A total of 645 patients (1,290 knees) met inclusion criteria. The 91–180 days group demonstrated the lowest complication rate (1.8%), significantly lower than the 3 weeks–90 days group (13.1%; $p<0.001$). Functional outcomes were superior in the 91–180 days group, with higher KOOS JR ($p=0.035$) and LEAS scores ($p=0.002$). Although hospital stay and readmissions were lower in this group, differences in readmission rates were not statistically significant.

Conclusion: Early reoperation within 90 days carries a substantially elevated complication risk. Our data strongly suggest that scheduling the second TKA between 91 and 180 days offers the most favorable balance of safety and functional recovery. These findings address a critical gap in surgical planning for bilateral TKA and warrant further validation through prospective multicenter trials.

Keywords: Staged bilateral total knee arthroplasty, optimal time interval, complication, functional outcomes, clinical outcomes, timing.

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1. Introduction

In recent decades, total knee arthroplasty (TKA) has become widely recognized as an exceptionally effective intervention for advanced osteoarthritis of the knee, particularly in terms of pain alleviation and improvements in functional capabilities and health-related quality of life [1]. The number of patients undergoing TKA has risen, and this trend is expected to continue in the coming decade due to the aging population and longer life expectancies [2]. Nevertheless, nearly one-third of patients undergoing TKA exhibit bilateral

osteoarthritis in the affected joint [3]. As a result, a growing number of patients are undergoing bilateral TKAs because of an elevated risk of experiencing bilateral knee osteoarthritis [4].

Bilateral TKAs can be performed at the same time during one hospital stay, spaced during the stay, or staged across multiple visits. The optimal approach for bilateral TKA is still widely debated, especially concerning complication rates, costs, and patient outcomes [5]. While simultaneous bilateral TKA offers patients multiple advantages, including having the surgery under one anesthesia and going through a single rehabilitation phase, it also raises significant concerns, such as heightened blood loss [5], cardiovascular issues [6], pulmonary embolism [7], and mortality risks [7, 8]. Conversely, earlier research indicates that the two procedures should be carried out in stages, separated by several months and conducted during two different admissions [9]. While this approach gives the patient time to recover from physiological stress of a simultaneous prior surgery, best clinical results are not realized until the contralateral knee is replaced [10].

In the context of staged bilateral TKAs, it is essential for both the patient and the physician to engage in a personalized discussion regarding the optimal timing for the second surgical procedure. Research indicates that intervals between the first and second surgeries can vary widely, ranging from one week to 120 months, depending on the specific indications for staging TKAs [11-13]. Nevertheless, the ideal timing for the subsequent surgery in the case of staged bilateral TKAs remains an area of uncertainty.

Therefore, the objective of this study is to examine the existing gap in the literature by evaluating whether there exists an optimal timing for the second TKA in staged bilateral procedures TKA.

2. Materials and methods

2.1. Study Design: We retrospectively reviewed 815 consecutive cases of primary staged bilateral TKAs that were performed at a single institution by five adult reconstruction orthopedic surgeons between March 2019 and April 2024. These bilateral procedures were selected from a total of 3739 TKAs carried out during the same timeframe. The local ethics committee (Ankara Bilkent City Hospital Ethical Committee, TABED 2-25-1178) approved the study, which was carried out in line with the ethical standards set forth in the Declaration of Helsinki. Before participating, patients provided their written informed consent. The findings of this study were reported following the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines [14].

2.2. Inclusion and Exclusion Criteria: Any patients who received staged bilateral primary total knee arthroplasty (TKA) due to end-stage osteoarthritis and had at least one year since their last surgery qualified for inclusion. The exclusion criteria applied: 1) patients with posttraumatic osteoarthritis, 2) patients with hemophilic arthropathy for TKA, 3) patients who had revision after the first TKA, 4) patients who received different implant design in the first and second arthroplasty, 5) patients with missing perioperative laboratory data or incomplete medical records (Figure 1.).

Patients who met the inclusion criteria were divided into four groups according to the time interval from the first TKA and the second TKA: 3 weeks to 90 days (group 1), 91-180 days (group 2), 181 days to 1 year (group 3), and > 1 year (group 4).

2.3. Data Collection: Demographic characteristics, including age, sex, body mass index (BMI), and Charlson comorbidity index (CCI) [15] were extracted among the patients to conduct this study. An impartial observer conducted follow-up research that encompassed several key metrics, including the length of hospital stay, the occurrence of unanticipated readmissions within 90 days to both the emergency department and the outpatient clinic, as well as any medical complications that arose during the same period. Medical complications were defined as any condition that required additional treatment, such as extended hospitalization, an emergency room visit, or readmission. These complications may include cardiac events, renal failure, pulmonary issues, deep vein thrombosis (DVT), complications related to surgical wounds, and periprosthetic joint infection (PJI). Persistent wound drainage, wound dehiscence, skin erosion, and hematoma are defined as wound complications. PJI was delineated in accordance with the criteria established by the Musculoskeletal Infection Society [16].

Clinical and functional scores for patients were obtained by an independent researcher using the Knee Osteoarthritis Outcomes Score for Joint Replacement (KOOS JR) [17] and the Lower Extremity Activity Scale (LEAS) [18].

2.4. Operative procedure and Post-operative care: All surgeries were performed by one of five experienced arthroplasty surgeons under spinal or general anesthesia. All the patients in the study were operated with mechanical alignment technique, which is a standard of care for TKA in our institute. Although several total knee systems were available, every patient received the same implant in both knees, which was placed by the same surgeon. All the patients had a preoperative medical evaluation by a dedicated team of physicians of internal medicine prior to surgery. Patients who demonstrated satisfactory recovery and expressed a desire to proceed with surgery at an earlier date were permitted to do so. Provided that these individuals exhibited an adequate range of motion (ROM) in their knees and felt prepared to advance to surgery, they were granted approval based on the availability of the surgeon's schedule.

In this investigation, all patients received posterior-stabilized total knee arthroplasties utilizing fixed-bearing components. The surgeries followed a conventional protocol involving a midline skin incision and a medial parapatellar arthrotomy, with the patella being subluxated but not everted. Distal femoral cuts were executed using an intramedullary guide, while proximal tibial cuts were performed with an extramedullary alignment system. Patellar resurfacing was not conducted, and no constrained implant designs were utilized throughout the cohort. Prophylactic antibiotic administration included 1 or 2 grams of Cefazolin Sodium, adjusted for body weight, given within 30 to 45 minutes before the initial incision, with an additional intraoperative dose administered 10 to 15 minutes prior to tourniquet release. The posterior cruciate ligament was routinely excised in all cases, and final fixation of components was achieved using polymethyl methacrylate bone cement.

2.5. Statistical Analysis: Statistical power analysis was executed using G*Power software version 3.1.9.4. The primary endpoint for determining the required sample size was the Knee Injury and Osteoarthritis Outcome Score for Joint Replacement (KOOS JR), which served as the main outcome measure. Based on this variable, an effect size of 0.3576 was computed, and the analysis was conducted with a statistical power of 80%. All statistical

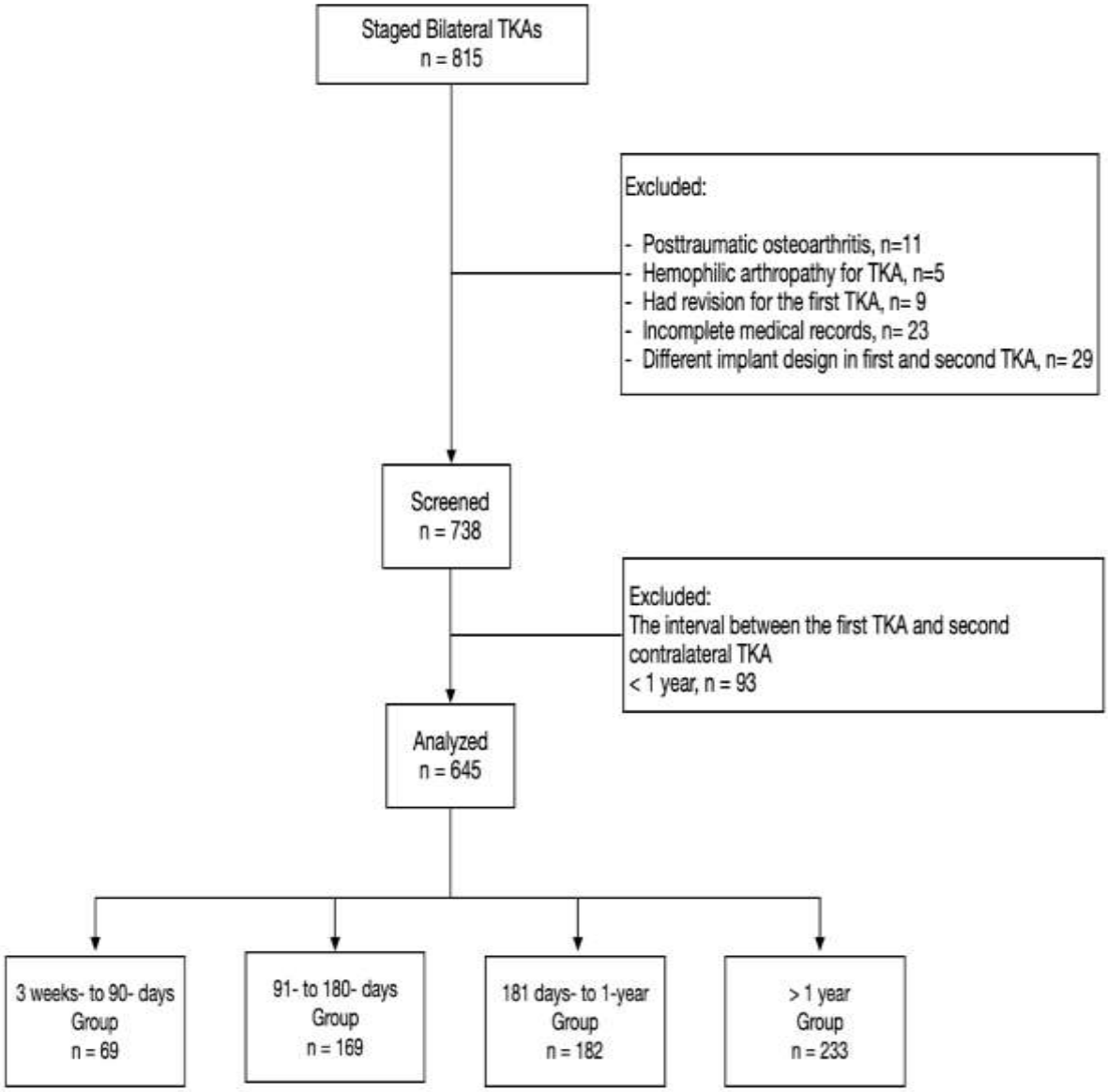

Figure 1. Patient enrollment flowchart.

evaluations were carried out with IBM SPSS Statistics, version 22.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics included metrics such as frequencies, percentages, means, standard deviations, medians, and the full range (minimum to maximum), expressed numerically. The Shapiro-Wilk test confirmed a normal distribution for both age and KOOS JR scores; therefore, comparisons between groups for these parameters utilized the Independent Samples T-test. For other continuous variables that did not follow a normal distribution, non-parametric methods were applied. Specifically, the Mann-Whitney U test was used to compare parameters such as Body Mass Index (BMI), hospital length of stay, and the Lower Extremity Activity Scale (LEAS).

A confidence level of 95% was maintained throughout the analyses, and statistical significance was defined as a *p*-value below 0.05.

3. Results

This study included a total of 645 individuals (comprising 1,290 knees) who underwent staged bilateral total knee arthroplasty (TKA). The timing of the second procedure varied among patients: 61 individuals (9.4%) had their contralateral TKA between 3 weeks and 90 days following the initial surgery (Group 1); 169 patients (26.2%) underwent the second procedure between 91 and 180 days (Group 2); 182 patients (28.2%) between 181 days and one year (Group 3); and 233 patients (36.2%) more than one year after the first operation (Group 4). The cohort consisted of 518 women (80.3%) and 127 men (19.7%), with a mean age of 64.7 ± 9.8 years. Detailed demographic data are provided in Table 1. Patients in Group 1 were notably younger and had significantly lower body mass index (BMI) values compared to the other groups (p = 0.036). No statistically significant differences were observed among the groups in terms of sex distribution or Charlson Comorbidity Index (CCI) scores (p = 0.658 and p = 0.283, respectively).

BMI, body mass index; CCI, Charlson comorbidity index; SD, standard deviation. Group 1 (3 weeks- 90 days), group 2 (91 days-180 days), group 3 (181 days- 1 year), group 4 (> 1 year). There were 20 overall complications identified after the second TKA, including 1 case of PJI, 8 cases of wound complications, 4 cases of cardiac complications, 4 cases of pulmonary complications, and 5 cases of DVT. The most prevalent complication observed across all groups was wound complications. Group 1 reported the highest overall complication rate of 13.1%, whereas Group 2 exhibited a significantly lower complication rate of 1.8% ($p < 0.001$) (Table 2).

Comprehensive information on 90-day hospital readmission rates and postoperative length of stay is presented in Table 3. Within 90 days of undergoing the second total knee arthroplasty (TKA), 29 patients experienced unplanned readmissions. The highest incidence was observed in Group 1 (n = 4, 6.5%), followed by Group 3 (n = 8, 4.3%), Group 4 (n = 10, 4.3%), and Group 2 (n = 7, 4.1%). However, the differences among groups did not reach statistical significance (p = 0.215). Patients in Group 1 demonstrated a notably longer hospital stay compared to other cohorts (p = 0.015) (Table 3.).

Table 1. Patient characteristics.

Characteristic	**Group 1 (n = 61)**	**Group 2 (n = 169)**	**Group 3 (n = 182)**	**Group 4 (n = 233)**	***P-value***
Age (years)	61.1 ± 8.5	65.3 ± 7.7	66.4 ± 7.2	66.9 ± 7.6	*0.036*
Gender Male Female	 12 (19.7%) 49 (80.3%)	 34 (21.4%) 135 (79.8%)	 35 (17.1%) 147 (80.7%)	 46 (17.6%) 187 (80.2%)	*0.658*
BMI (kg/m^2)	26.1 ± 4.5	28.7 ± 4.6	28.9 ± 4.8	29.1 ± 4.3	*0.015*
CCI	2.4 ± 0.9	2.6 ± 1.1	2.7 ± 1.2	2.8 ± 1.2	*0.283*

Data are given in Mean±SD.

Table 2. Complications of second total knee arthroplasty.

Complication	**Group 1 (*n* = 61)**	**Group 2 (*n* = 169)**	**Group 3 (*n* = 182)**	**Group 4 (*n* = 233)**	***P-value***
Periprosthetic Infection, **n (%)**	0	0	1 (0.05)	0	*0.537*
Wound complications, **n (%)**	4 (6.5%)	1 (0.06%)	1 (0.05%)	2 (0.09%)	*0.002*
Cardiac, **n (%)**	1 (1.6%)	1 (0.06%)	2 (1.1%)	0	*0.672*
Pulmonary, **n (%)**	2 (3.2%)	0 (0.06%)	1 (0.05%)	1 (0.05%)	*0.378*
Deep vein thrombosis, **n (%)**	2 (3.2%)	1 (0.06%)	0	2 (0.09%)	*0.330*
Overall complications, **n (%)**	8 (13.1%)	3 (1.8)	5 (2.7%)	4 (2.1%)	*<0.001*

Table 3. The 90-day unplanned readmission rate and length of stay (LOS).

Variable	**Group 1 (*n* = 61)**	**Group 2 (*n* = 169)**	**Group 3 (*n* = 182)**	**Group 4 (*n* = 233)**	***P-value***
Readmission, **n (%)**	4 (6.5%)	7 (4.1%)	8 (4.3%)	10 (4.3%)	*0.215*
LOS, **n (%)**	6.7 ± 1.9	3.6 ± 2.1	4.2 ± 1.8	4.1 ± 1.9	*0.015*

Data are given in Mean ± SD.

Table 4. Functional outcome: Knee Osteoarthritis Outcomes Score for Joint Replacement (KOOS JR) and Lower Extremity Activity Scale (LEAS).

Outcomes	**Group 1 (*n* = 61)**	**Group 2 (*n* = 169)**	**Group 3 (*n* = 182)**	**Group 4 (*n* = 233)**	***P-value***
	Mean ± SD				
KOOS JR	78.4 ± 13.5	83.1 ± 14.2	77.1 ± 12.6	79.3 ± 15.4	*0.035*
LEAS	11.3 ± 3.7)	13.5 ± 7.2	11.1 ± 2.9	11.4 ± 2.8	*0.002*

Data are given in Mean ± SD.

Additionally, individuals in Group 2 achieved significantly better scores on both the KOOS JR and LEAS functional outcome scales (p = 0.035 and p = 0.002, respectively). A summary of functional outcome data is provided in Table 4.

4. Discussion

The most important finding of the study was that patients who underwent staged bilateral TKA with a time interval of 91 to 180 days exhibited significantly lower complication rates

and superior clinical and functional outcomes. Additionally, while there was no significant difference, patients in Group 2 experienced lower 90-day unplanned readmission rates and shorter lengths of stay.

TKA is recognized as one of the most successful procedures for enhancing the overall quality of life within the field of orthopedic surgery. In light of the considerable rise in average life expectancy, recent projection studies indicate that the incidence of primary TKA is expected to increase by 43% by 2050 [2]. Several studies have explored the likelihood of requiring a contralateral TKA following the initial procedure. In a study by Ritter et al., it was found that 37% of patients with pre-existing osteoarthritis in the opposite knee went on to have a second TKA within ten years of their first surgery [19]. Similarly, Mont et al. observed that 23% of individuals scheduled for unilateral TKA already presented with significant symptoms in the contralateral joint [20]. Notably, over a minimum five-year follow-up period, 93% of these symptomatic patients ultimately underwent a second TKA. These findings underscore the critical need for patients and clinicians to carefully plan long-term management strategies for those undergoing staged bilateral TKA procedures.

Currently, the high prevalence of perioperative complications and the substantial physiological burden associated with simultaneous bilateral TKA have resulted in a reluctance to perform this procedure [21]. Thus, numerous studies have been conducted to determine the optimal time interval for mitigating complications in the setting of staged bilateral TKA [4, 22, 23]. A recent systematic review highlighted an increased incidence of serious complications, such as pneumonia, myocardial infarction (MI), and deep vein thrombosis (DVT), when the second TKA was carried out within 90 days of the initial procedure in patients undergoing staged bilateral TKA [9]. In a related study, Sliva et al. reported that spacing the two surgeries several months apart significantly reduced complication rates compared to both simultaneous procedures and staged TKAs performed with only a one-week interval between operations [23]. A prolonged duration between stages of bilateral TKA, specifically exceeding 90 days but less than 270 days, has been recommended by Maltenfort et al. to mitigate the risk of complications [4]. Our findings are consistent with the previous recommendations from the consensus group and the widely accepted belief that undergoing a second TKA within three months of the first TKA is associated with an increased risk of significant complications, including mortality [22]. The findings can likely be explained by the inflammatory or tissue response process. Surgical tissue trauma triggers various inflammatory reactions, resulting in both localized and systemic release of cytokines, interleukins, and other mediators of inflammation. Staging bilateral BTKA in patients with comorbidities aims to minimize the physiological stress and inflammation associated with performing two TKAs simultaneously. Notably, the increased incidence of serious complications, including MI and other cardiac events, when two TKAs are conducted closely together is linked to the ongoing inflammatory or catabolic state in these patients [24].

In an extensive analysis of an insurance database involving 7,747 patients, Richardson et al. observed that individuals who underwent staged TKA within 90 days exhibited a significantly elevated rate of readmission necessitating additional treatment, with an odds ratio of 2.14 (p = 0.004) [25]. In this study, we

found significantly higher unplanned readmission rates and longer lengths of stay in patients who underwent a second TKA within a three-month period. These findings also confirm the increase in complication rates. It is hypothesized that the rising occurrence of adverse hospital events noted in subsequent arthroplasties conducted in close temporal proximity to the initial procedure may be partially attributable to the more rapid decompensation of certain patients with preexisting comorbidities. These patients may not have had adequate time to establish a sufficient physiological reserve, thereby impairing their ability to endure the trauma and/or stressors associated with the second arthroplasty. The duration of recovery may vary among patients; however, inadequate recovery periods could help elucidate some of our findings.

A recent study evaluated early clinical and functional outcomes, such as the University of California, Los Angeles (UCLA) activity score, based on the timing of staged bilateral TKAs [26]. There was no significant difference in functional scores among patients. Yeh et al. conducted a comparative analysis of the Short Form-36 (SF-36) and the Oxford Knee Scores (OKS) across four groups, categorized by the time intervals among patients undergoing staged bilateral TKA [27]. The study resulted in no statistically significant differences observed between the groups. In contrast, we found superior KOOS JR and LEAS scores in patients who underwent staged bilateral TKA with a time interval of 91 to 180 days. When interpreting these results, it is important to consider their clinical relevance. Prior studies have reported the minimal clinically important difference (MCID) to be approximately 6–8 points for KOOS JR and 1–2 points for LEAS after TKA [17, 18, 31]. In our cohort, the observed differences in KOOS JR between groups (~5–6 points) approached but did not consistently surpass the MCID threshold, suggesting a trend toward clinical benefit. Conversely, the differences in LEAS scores (~2–2.5 points) exceeded the MCID, indicating a clinically meaningful improvement in functional activity levels for patients undergoing their second TKA between 91 and 180 days. It should also be noted that the relatively wide standard deviation in LEAS scores observed in Group 2 (13.5 ± 7.2) indicates variability in patient-reported activity levels. This heterogeneity may reflect differences in baseline functional capacity, rehabilitation engagement, or comorbidity burden. Although the mean improvement exceeded the MCID threshold, these findings suggest that functional recovery trajectories after staged bilateral TKA can differ substantially among individuals, underscoring the importance of tailored rehabilitation strategies. We propose that the discrepancy observed in relation to previous literature may be partially elucidated by the fact that the majority of activity measurement instruments, such as the UCLA and OKS scores, were specifically designed for individuals participating in high-activity sports. These instruments typically evaluate maximum activity levels at a single instance rather than capturing the actual activity levels over time [28-30]. A previous study evaluating activity levels through the UCLA scale in arthroplasty patients demonstrated a correlation between pedometer readings and activity ratings [30]. Nevertheless, the average daily step count among patients with identical UCLA scores exhibited considerable variability. Conversely, the KOOS JR and LEAS scores have demonstrated reliability, clinical validity, and ease of interpretation, whereas the SF-36 is not

readily applicable in the routine clinical care of patients [17, 18, 31].

This study is subject to some limitations. Primarily, it carries inherent selection and observer biases due to the single-center nature of the patient cohort. Additionally, the retrospective study design presents limitations, including potential selection and information biases. One notable source of selection bias lies in the clinical decision-making process for short-interval staged bilateral TKA, as surgeons tend to prefer younger, lower-risk individuals for such procedures. This is reflected in the data, where Group 1 patients were younger and had lower BMI values. Moreover, the relatively small sample size in Group 1 (3 weeks–90 days) compared with the other groups may limit the statistical power of some comparisons, particularly regarding complication rates, and findings related to this subgroup should therefore be interpreted with caution. Nevertheless, despite being older and having higher BMI, patients in the longer-interval groups demonstrated similar rates of complications and functional recovery. To address these limitations, future prospective studies involving multiple centers are essential for generating more generalizable and unbiased findings. Lastly, there may exist a cohort of patients who were scheduled for staged bilateral procedures but for whom the second surgery was canceled due to complications or medical comorbidities. Unfortunately, we were unable to account for this potential cohort in our dataset.

4.1. Conclusion: The staging of the second arthroplasty with a time interval ranging from 91 to 180 days appears to yield improved clinical and functional outcomes, as well as enhanced complication rates. Patients may be counseled regarding this optimal timing between staged surgeries when confronted with bilateral procedures TKA. Additionally, our data suggest that both patients and surgeons should be aware of the increased risk of complications when undergoing two surgeries within a 90-day period. However, further studies with a multicenter and prospective design are needed to confirm our results.

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