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One-Stage Versus Two-Stage Bilateral Total Knee Arthroplasty: A Systematic Review and Meta-Analysis

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ABSTRACT

Background: Bilateral total knee arthroplasty (B-TKA) represents an increasingly used option to address advanced bilateral knee osteoarthritis (OA). The aim of this study was to quantify and compare one-stage and two-stage B-TKA results in terms of clinical outcomes, perioperative parameters, complications, revisions, and mortality rates.

Methods: The literature search was conducted using three databases (PubMed, Cochrane, and Web of Science) in February 2024 according to the guidelines for Preferred Reporting Items for Systematic Reviews and Meta-Analysis. The inclusion criteria were as follows: comparative studies, English language, with no time filter on the comparison of one-stage and two-stage B-TKA for bilateral knee osteoarthritis treatment. The quality of each article was assessed using the Cochrane risk of bias in nonrandomized studies of interventions tool.

Results: Among the 2,130 articles retrieved, 69 studies (366,722 patients) were included. One-stage B-TKA showed lower rates of TKA-related complications ($P = 0.043$), deep infections ($P < 0.001$), and wound complications ($P = 0.033$), as well as lower operative time ($P = 0.028$), shorter length of hospital stay ($P < 0.001$), and higher improvements of Western Ontario and McMaster Universities Osteoarthritis Index score ($P = 0.013$) and Oxford Knee Score ($P = 0.004$), but higher mortality rates at the 1-month ($P < 0.001$), 3-month ($P < 0.001$), and 1-year ($P = 0.001$) follow-ups, as well as higher rates of neurological ($P = 0.013$) and gastrointestinal ($P < 0.001$) complications, deep vein thrombosis ($P = 0.016$), and pulmonary embolism ($P < 0.001$). The risk of bias was "low" in 26 studies, "moderate" in 36 studies, "serious" in six studies, and "critical" in one study.

Conclusions: One-stage B-TKA was associated with a higher mortality rate and thromboembolic risk while presenting lower TKA-related and infective complications compared to two-stage B-TKA. One-stage B-TKA also reduced hospital stay and total surgical time but provided only marginal improvement in clinical outcomes compared to two-stage B-TKA while showing a higher risk of neurologic and gastrointestinal complications. These results offer important information for both patients and surgeons in evaluating the most appropriate surgical approach, thereby contributing to optimize the management of patients undergoing B-TKA.

Level of evidence: Level I.

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Total knee arthroplasty (TKA) is one of the most common orthopaedic interventions, representing an increasingly applied solution for pain relief, functional restoration, and quality of life improvement in patients affected by advanced knee osteoarthritis (OA) [1–4]. Among patients undergoing TKA, 33% present with bilateral knee OA, with 10% of total patients requiring contralateral TKA during the first year and 20% after the second year [5]. In this scenario, bilateral TKA (B-TKA) represents an increasingly used option to address advanced bilateral knee OA [6], and the proportion of B-TKA to unilateral TKA is currently rising [7].

There are two surgical strategies available when performing B-TKA: one-stage and two-stage. They present some differences in terms of surgical technique, postoperative recovery, and potential complications. A one-stage B-TKA involves arthroplasty of both knees during a single surgical intervention. The proposed advantages of this approach include a single anesthesia and hospital admission, patient preference to undergo a single operation, shorter total hospital stay, and reduced perioperative costs [8–10]. Conversely, two-stage B-TKA entails two distinct surgical interventions, with each knee operated on separately. The main suggested benefit of this approach lies in its safety, with the advocates of this procedure claiming reduced complication and mortality rates compared to the one-stage approach [9–11]. Despite the growing body of literature on these two strategies, the choice of one-stage or two-stage B-TKA remains controversial.

Therefore, the aim of this systematic review and meta-analysis was to quantify and compare the results of one-stage and two-stage B-TKA in terms of clinical outcomes, perioperative parameters, complications, revisions, and mortality rates.

Materials and Methods

Literature Search

A literature search was conducted on the PubMed, Cochrane, and Web of Science databases on February 22, 2024, using the following criteria: bilateral AND (simultaneous OR sequential OR staged OR staggered OR 1-stage OR 2-stage) AND ((total knee AND (arthroplasty OR replacement OR prosthe*)) OR TKA OR TKR). The trial was registered on PROSPERO (ID CRD42024519050). The guidelines for Preferred Reporting Items for Systematic Reviews and Meta-Analysis were used (Figure 1) [12].

Studies Selection and Data Extraction

Screening process and data extraction were conducted separately by two independent observers (G.M. and L.B.P.), and any discrepancies between them were resolved by discussion and

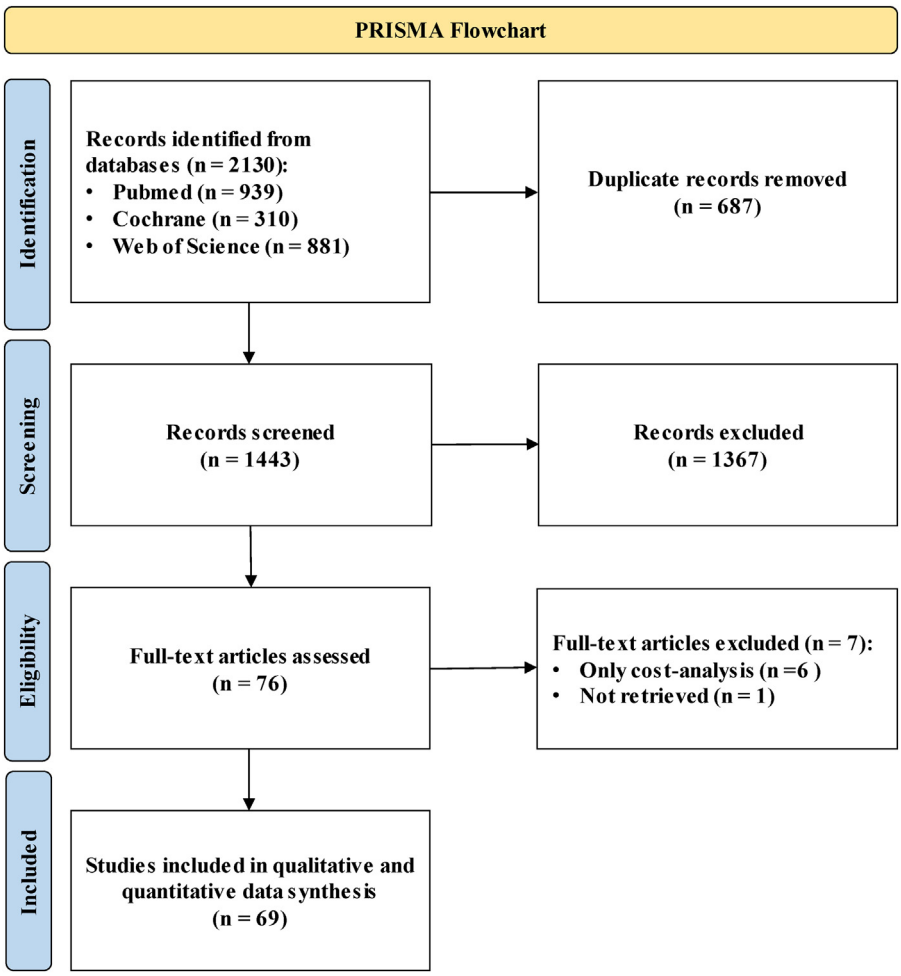

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) flow diagram.

consensus with a third author (A.B.). After the removal of duplicates, the articles were screened by title and abstract. The following inclusion criteria were used: comparative studies, written in the English language, with no time limitation on the comparison of one-stage and two-stage B-TKA for bilateral knee OA treatment. The exclusion criteria were articles written in other languages, systematic reviews, meta-analyses, narrative reviews, expert opinions, preclinical studies, studies not focusing on B-TKA, studies not reporting clinical outcomes, perioperative time parameters, complications, revisions, or mortality rates. In the second step, the full texts of the selected articles were screened with further exclusions according to the previously described criteria. Relevant data (title, author, year of publication, journal, country of the study, number of patients, sex, age, body mass index (BMI), follow-up time, clinical outcomes, perioperative parameters, complications, revisions, and mortality rates) were then extracted and collected in a database to be analyzed for the purposes of the present study. Complications were divided according to the following categories: TKA-related (including all the complications linked to the surgical intervention of TKA as reported by the included papers), cardiac, respiratory, neurological (such as nerve palsy, hemiparesis, altered mental status, nerve disorders, etc.), urinary, gastrointestinal (GI) (such as constipation, obstruction, diarrhea, GI hemorrhage, ulcers, GI infection, etc.), deep vein thrombosis (DVT), pulmonary embolism (PE), prosthesis-related (including all the complications linked to the prosthetic implant, such as periprosthetic fracture, components loosening, mechanical failure, dislocation, etc.), deep infection, wound complications, and other complications (encompassing all complications not included in the aforementioned categories, such as sepsis, fluid or electrolytes imbalance, hypoxia, skin ulcers, cellulitis, etc.).

Assessment of Risk of Bias and Quality of Evidence

The quality of each article was assessed independently by two independent observers (G.M. and L.B.P.) using the Cochrane non-randomized studies of interventions tool (ROBINS-I) [13], and any discrepancies between them were resolved by discussion and consensus with a third author (A.B.). This tool includes seven domains that can be classified as “low”, “moderate,” “serious,” or “critical” risk of bias. If a study is ranked low in all domains, it is considered to be at low risk of bias; if it is ranked moderate, serious, or critical in at least one domain, it is considered to be at moderate, serious, or critical risk of bias, respectively.

Data Analyses

The statistical analysis and the forest plotting were carried out according to Neyeloff et al. using the Meta XL tool for Microsoft Excel (Microsoft Corporation, Redmond, Washington) by an independent professional statistician [14]. The analysis was carried out using random effects (DerSimonian & Laird) for the weighted mean difference (MD) of continuous variables and the Peto method for the odds ratio (OR) of dichotomous variables. The 95% confidence intervals (CI) were then derived, and if the 95% CI excludes zero, evidence exists that the meta-analysis of interest has shown a significant treatment effect. Heterogeneity was evaluated using the I^2 statistical test. The presence of significant heterogeneity was considered with $I^2 \geq 25\%$. When no heterogeneity was found with $I^2 < 25\%$, a fixed-effect model was used to estimate the expected values and 95% CIs, otherwise, a random-effect model was applied, and an I^2 metric was evaluated for the random effect to check the correction of heterogeneity. A *P*-value of 0.05 was considered significant.

Results

Characteristics of the Included Studies and Patients

A total of 2,130 articles were retrieved; after the removal of duplicates, screening on the titles, abstracts, and full-texts, 69 studies were included according to the eligibility criteria (Table 1). Among the papers included, a total of 366,722 patients (40.4% men, 59.6% women, age 66 years, and BMI 29.3) were enrolled: 148,274 patients were part of the one-stage group (43.4% men, 56.6% women, age 65 years, and BMI 28.8) and 218,448 were in the two-stage group (38.3% men, 61.7% women, age 67 years, and BMI 29.9). The comparison of baseline characteristics showed that the one-stage group had a statistically higher men-to-women ratio ($P < 0.001$, OR = 1.2), younger age ($P < 0.001$, MD = 1.4), and lower BMI ($P = 0.004$, MD = 0.6). There were 26 studies that provided detailed information on the mean operative interval between the first and second TKA interventions in the two-stage group (overall mean interval time: 7.9 months), while 25 studies stratified the operative interval using different ranges or cutoffs, and 18 studies did not report details on the operative interval. Clinical outcomes included Western Ontario and McMaster Universities Arthritis Index (WOMAC), Knee Society Score (KSS), Oxford Knee Score (OKS), range of motion (ROM), and visual analog scale for pain (VAS). All clinical outcomes were evaluated in terms of improvement from preoperative to postoperative values. Perioperative parameters included operative time, intraoperative blood loss, and length of hospital stay (LHS).

Meta-Analysis

Among the outcome measures extracted, a meta-analysis was performed on the following parameters: in-hospital mortality, 1-month mortality, 3-month mortality, 1-year mortality, 2-year mortality, TKA-related complications, cardiac complications, respiratory complications, neurological complications, urinary complications, GI complications, others complications, DVT, PE, prosthesis-related complications, deep infections, wound complications, prosthesis revisions, surgery operative times, intraoperative bleeding, LHS, WOMAC, KSS, OKS, VAS pain, and ROM.

Mortality Outcomes

In-Hospital Mortality. The analysis of in-hospital mortality did not show a statistically significant difference between one-stage and two-stage B-TKA (0.233 versus 0.086%).

1-Month Mortality. The analysis of 1-month mortality showed a statistically significant difference, with a higher rate in the one-stage B-TKA group ($P < 0.001$, OR = 2.7, 0.319 versus 0.177%) (Figure 2).

3-Month Mortality. The analysis of 3-month mortality showed a statistically significant difference, with a higher rate in the one-stage B-TKA group ($P < 0.001$, OR = 2.1, 0.675 versus 0.433%) (Figure 2).

1-Year Mortality. The analysis of 1-year mortality showed a statistically significant difference, with a higher rate in the one-stage B-TKA group ($P = 0.001$, OR = 1.4, 1.327 versus 1.185%) (Figure 2).

2-Year Mortality. The analysis of 2-year mortality did not show a statistically significant difference between one-stage and two-stage B-TKA (3.711 versus 3.172%).

Table 1
Characteristics of the Included Studies.

Study	Year	Number of Patients		Men		Women		Age		Body Mass Index	
		One-Stage	Two-Stage	One-Stage	Two-Stage	One-Stage	Two-Stage	One-Stage	Two-Stage	One-Stage	Two-Stage
Abdelaal MS et al. [15]	2021	2,728	1,658	NR	NR	NR	NR	63	68	30.5	32.3
Abram SG et al. [16]	2016	66	172	29	84	49	166	65	66	NR	NR
Arslan A et al. [17]	2018	72	61	19	17	53	44	65	69	31.9 ± 3.9	32.1 ± 3.8
Ashkenazi I et al. [18]	2024	205	205	74	67	131	138	63	63	30.5	31.0
Ayekoloye C et al. [19]	2023	19	12	1	0	18	12	66	69	NR	NR
Bolognesi MP et al. [20]	2013	4,519	3,788	1,853	1,466	2,666	2,322	73	74	NR	NR
Borden LS et al. [21]	1999	8	5	3	1	5	4	70	64	29.8	39.3
Brotherton SL et al. [22]	1986	18	29	NR	NR	NR	NR	61	64	NR	NR
Bülbül M et al. [23]	2011	24	26	8	7	16	19	64	62	NR	NR
Çelen ZE et al. [24]	2023	168	63	26	12	142	51	67	67	33.2 ± 5.2	34.1 ± 4.5
Chou TA et al. [25]	2023	1,565	451	351	99	1,214	352	72	72	28.0 ± 4.2	28.6 ± 4.4
Chua HS et al. [26]	2018	23,136	12,951	12,449	6,557	10,687	6,394	NR	NR	NR	NR
Courtney PM et al. [27]	2014	103	131	38	30	65	101	59	64	31.7 ± 6.6	36.0 ± 9.2
Eke I et al. [28]	2022	225	51	34	12	191	38	67	70	NR	NR
Erossy M et al. [29]	2023	19,382	19,382	7,990	7,937	11,392	11,445	65	65	NR	NR
Follett MA et al. [30]	2022	87	72	29	18	58	54	66	64	31.0 ± 7.5	29.9 ± 6.9
Forster MC et al. [31]	2006	28	36	15	18	13	18	66	68	NR	NR
Ghadimi K et al. [32]	2022	60	59	15	10	45	49	63	69	NR	NR
Gill SD et al. [33]	2020	122	46	46	23	76	23	71	71	NR	NR
Goyal T et al. [34]	2020	250	210	110	95	140	115	68	67	25.3 ± 5.7	24.6 ± 4.5
Hadley S et al. [35]	2017	371	67	112	24	259	43	64	63	NR	NR
Hardaker WT, Jr et al. [36]	1978	12	14	4	8	8	6	61	62	NR	NR
Hernandez NM et al. [37]	2020	113	563	51	219	62	344	60	66	30.9 ± 5.4	32.2 ± 6.1
Hooper GJ et al. [38]	2009	506	680	NR	NR	NR	NR	65	69	NR	NR
Hou JF et al. [39]	2021	309	309	54	53	255	256	65	66	27.5 ± 4.1	27.5 ± 3.1
Hutchinson JR et al. [40]	2006	438	125	245	46	193	79	67	65	NR	NR
Ivory JP et al. [41]	1993	79	14	28	7	51	7	70	68	NR	NR
Jankiewicz JJ et al. [42]	1994	99	56	34	14	65	42	69	71	NR	NR
Kahlenberg CA et al. [43]	2021	152	61	84	24	68	37	63	65	29.9 ± 6.0	34.8 ± 7.2
Kirschbaum S et al. [44]	2024	53	74	31	33	22	41	70	68	28.1 ± 4.6	28.2 ± 4.7
Koh IJ et al. [45]	2015	519	181	30	14	489	167	NR	NR	27.2	26.8
Koh WU et al. [46]	2018	820	633	34	26	786	607	69	70	27.0 ± 3.4	27.1 ± 3.5
Kundu IK et al. [47]	2022	30	30	10	12	20	18	59	61	30.1 ± 4.8	30.7 ± 4.9
Lee WC et al. [48]	2016	29	38	3	3	26	35	63	68	NR	NR
Lin AC et al. [49]	2014	452	690	98	159	354	531	70	69	NR	NR
Lindberg-Larsen M et al. [50]	2015	157	628	74	269	83	359	64	67	NR	NR
Lindberg-Larsen M et al. [51]	2019	232	232	108	109	124	123	65	65	30.5	30.8
Macario A et al. [52]	2003	91	32	NR	NR	NR	NR	NR	NR	NR	NR
Mangaleshkar SR et al. [53]	2001	54	34	21	13	33	21	73	72	NR	NR
Mardani-Kivi M et al. [54]	2021	272	391	78	137	194	254	NR	NR	NR	NR
McLaughlin TP et al. [55]	1985	22	46	7	12	15	34	NR	NR	NR	NR
Meehan JP et al. [56]	2011	11,445	23,715	5,280	9,171	6,165	14,544	67	68	NR	NR
Minter JE et al. [57]	1995	23	41	15	21	8	20	66	66	NR	NR
Morrey BF et al. [58]	1987	145	231	56	71	89	160	63	62	NR	NR
Najfeld M et al. [59]	2021	53	64	31	27	22	37	70	70	28.1	28.4
Niki Y et al. [60]	2014	60	60	10	10	50	50	73	71	26.4 ± 3.5	25.6 ± 4.2
Phillips JLH et al. [61]	2018	391	168	NR	NR	NR	NR	69	72	29.4 ± 4.6	29.6 ± 5.3
Poultsides LA et al. [62]	2013	2,825	1,151	1,062	371	1,763	780	65	70	NR	NR
Pumo TJ et al. [63]	2022	198	396	113	209	85	187	62	63	32.1 ± 6.2	32.3 ± 5.9
Richardson SS et al. [64]	2019	1,637	6,110	723	2,241	914	3,869	NR	NR	NR	NR
Ritter MA et al. [65]	1997	12,922	50,108	4,988	16,595	7,934	33,513	73	73	NR	NR
Ritter MA et al. [66]	2003	2,050	152	906	35	1,144	117	70	69	NR	NR
Sarzaeem MM et al. [67]	2021	51	49	9	10	42	39	62	62	25.8 ± 2.5	26.1 ± 7.6
Seol JH et al. [68]	2016	759	315	43	25	716	290	68	66	25.3 ± 3.4	25.9 ± 3.3
Sliva CD et al. [69]	2005	26	306	14	106	12	200	59	66	NR	NR
Sobh AH et al. [70]	2018	225	337	108	128	117	209	61	66	31.3 ± 5.9	34.0 ± 7.2
Soudry M et al. [71]	1985	56	18	17	5	39	13	69	69	NR	NR
Stanley D et al. [72]	1990	32	18	8	4	24	14	62	58	NR	NR
Stefánsdóttir A et al. [73]	2008	1,139	3,432	465	1,287	674	2,145	70	71	NR	NR
Stubbs G et al. [74]	2005	61	38	NR	NR	NR	NR	NR	NR	NR	NR
Tsay EL et al. [75]	2019	27,304	45,419	11,807	16,980	15,494	28,439	66	67	NR	NR
Wan RCW et al. [76]	2021	95	80	26	22	69	58	66	69	NR	NR
Wilkie W et al. [77]	2022	19,334	19,334	8,184	8,162	11,150	11,172	65	64	NR	NR
Wilson L et al. [78]	2021	6,165	8,242	2,590	3,098	3,575	5,144	58	59	NR	NR
Wyatt MC et al. [79]	2019	3,220	13,745	1,973	6,320	1,247	7,425	NR	NR	NR	NR
Wyles CC et al. [80]	2019	188	242	79	88	109	154	61	72	31.7 ± 6.6	32.9 ± 7.0
Yoon HS et al. [81]	2010	119	119	7	7	112	112	70	70	26.4	26.5
Zhao YT et al. [82]	2015	54	39	6	5	48	34	67	67	24.5 ± 5.3	23.9 ± 4.9
Zhang S et al. [83]	2021	102	213	26	53	76	160	65	67	23.3	24.7

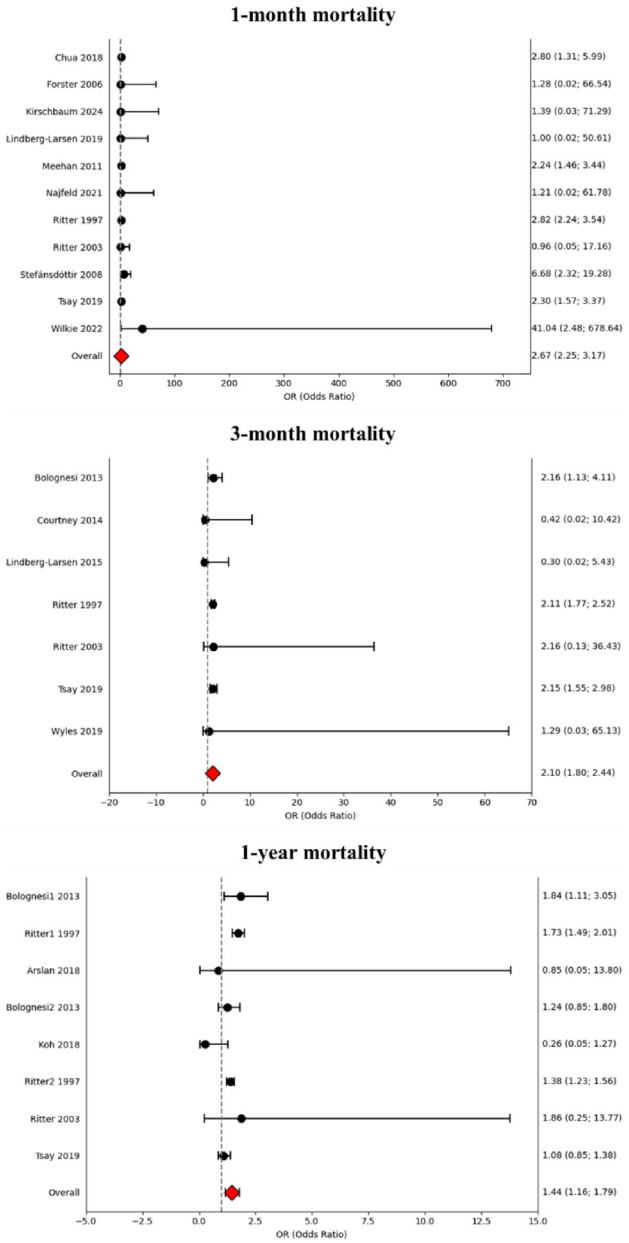

Figure 2. Forest plots of the individual studies and odds ratios (OR) for the 1-month, 3-month, and 1-year mortality, including 95% confidence intervals (CIs). One-stage bilateral total knee arthroplasty (B-TKA) showed higher mortality rates at all 3 follow-ups compared to two-stage B-TKA.

Complications and Revisions

TKA-Related Complications. The analysis of TKA-related complications showed a statistically significant difference, with a higher rate in the two-stage B-TKA group ($P = 0.043$, OR = 0.8) (Figure 3).

Cardiac Complications. The analysis of cardiac complications did not show a statistically significant difference between one-stage and two-stage B-TKA.

Respiratory Complications. The analysis of respiratory complications did not show a statistically significant difference between one-stage and two-stage B-TKA.

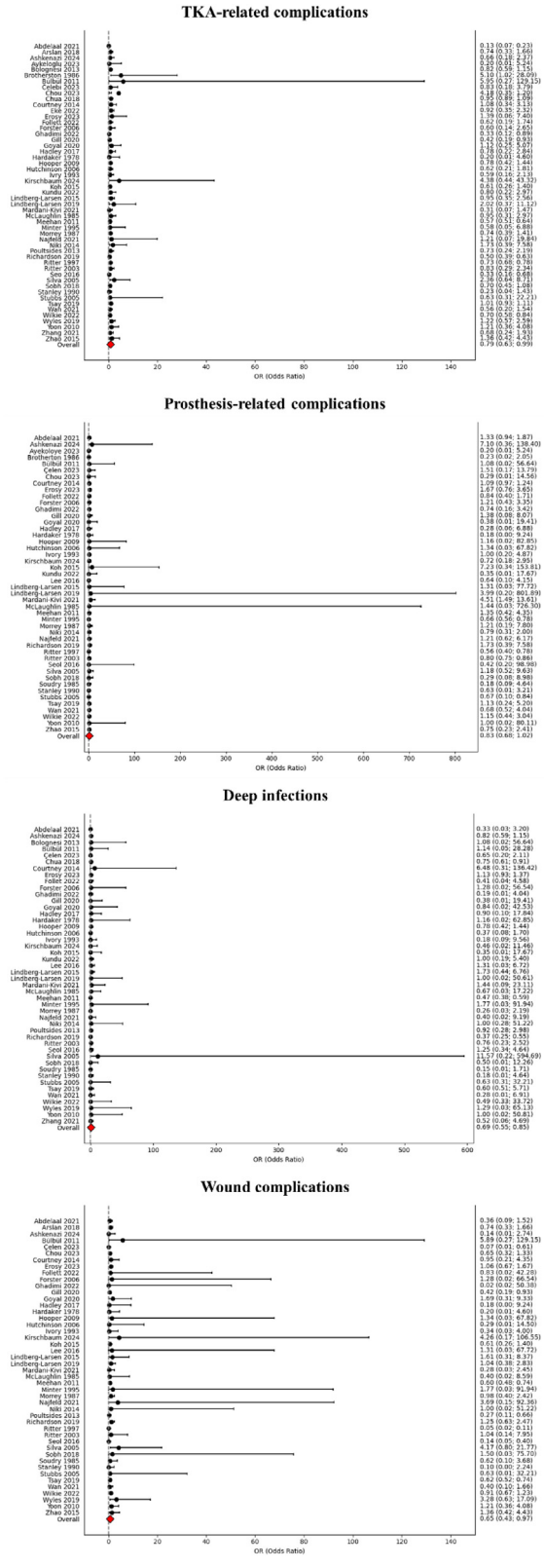

Figure 3. Forest plots of the individual studies and pooled OR for TKA-related complications, prosthesis-related complications, deep infections, and wound complications, including 95% CIs. B-TKA showed lower rates of TKA-related and prosthesis-related complications, deep infections, and wound complications compared to two-stage B-TKA.

Neurological Complications. The analysis of neurological complications showed a statistically significant difference, with a higher rate in the one-stage B-TKA group ($P = 0.013$, OR = 1.2) (Figure 4).

Urinary Complications. The analysis of urinary complications did not show a statistically significant difference between one-stage and two-stage B-TKA.

Gastrointestinal Complications. The analysis of GI complications showed a statistically significant difference, with a higher rate in the one-stage B-TKA group ($P < 0.001$, OR = 1.6) (Figure 4).

Others Complications. The analysis of other complications did not show a statistically significant difference between one-stage and two-stage B-TKA.

Deep Vein Thrombosis. The analysis of DVT showed a statistically significant difference, with a higher rate in the one-stage B-TKA group ($P = 0.016$, OR = 1.3) (Figure 4).

Pulmonary embolism. The analysis of PE showed a statistically significant difference, with a higher rate in the one-stage B-TKA group ($P < 0.001$, OR = 1.8) (Figure 4).

Prosthesis-Related Complications. The analysis of prosthesis-related complication showed a statistical trend, with a higher rate in the two-stage B-TKA group ($P = 0.074$, OR = 0.7) (Figure 3).

Deep Infections. The analysis of deep infections showed a statistically significant difference, with a lower rate in the one-stage B-TKA group ($P < 0.001$, OR = 0.7) (Figure 3).

Wound Complications. The analysis of wound complications showed a statistically significant difference, with a lower rate in the one-stage B-TKA group ($P = 0.033$, OR = 0.6) (Figure 3).

Prosthesis Revisions. The analysis of other complications did not show a statistically significant difference between one-stage and two-stage B-TKA.

Perioperative Parameters

Operative Time. The analysis of operative time showed a statistically significant difference, with higher values in the two-stage B-TKA group ($P = 0.028$, MD = 25.1) (Figure 5).

Intraoperative Bleeding. The analysis of intra-operative bleeding showed a statistical trend, with higher values in the two-stage B-TKA group ($P = 0.053$, MD = 320.4) (Figure 5).

Length of Hospital Stay. The analysis of LHS showed a statistically significant difference, with higher values in the two-stage B-TKA group ($P < 0.001$, MD = 4.8) (Figure 5).

Clinical Outcomes

Western Ontario and McMaster Universities Osteoarthritis Index. The analysis of the WOMAC score showed a statistically significant difference, with a higher improvement in the one-stage B-TKA group ($P = 0.013$, MD = 2.5) (Figure 6).

Knee Society Score. The analysis of KSS did not show a statistically significant difference between one-stage and two-stage B-TKA.

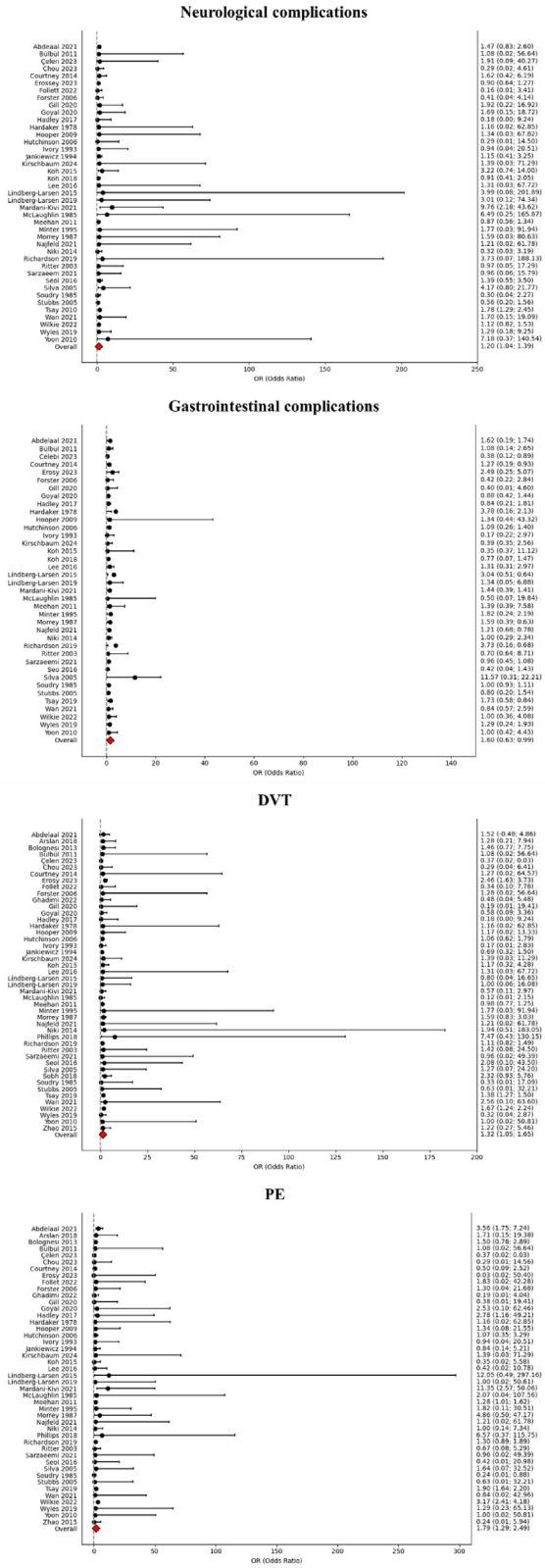

Figure 4. Forest plots of the individual studies and pooled OR for neurological complications, gastrointestinal complications, deep vein thrombosis (DVT), and pulmonary embolism, including 95% CIs. B-TKA showed higher rates of neurological and gastrointestinal complications, DVT, and pulmonary embolism compared to two-stage B-TKA.

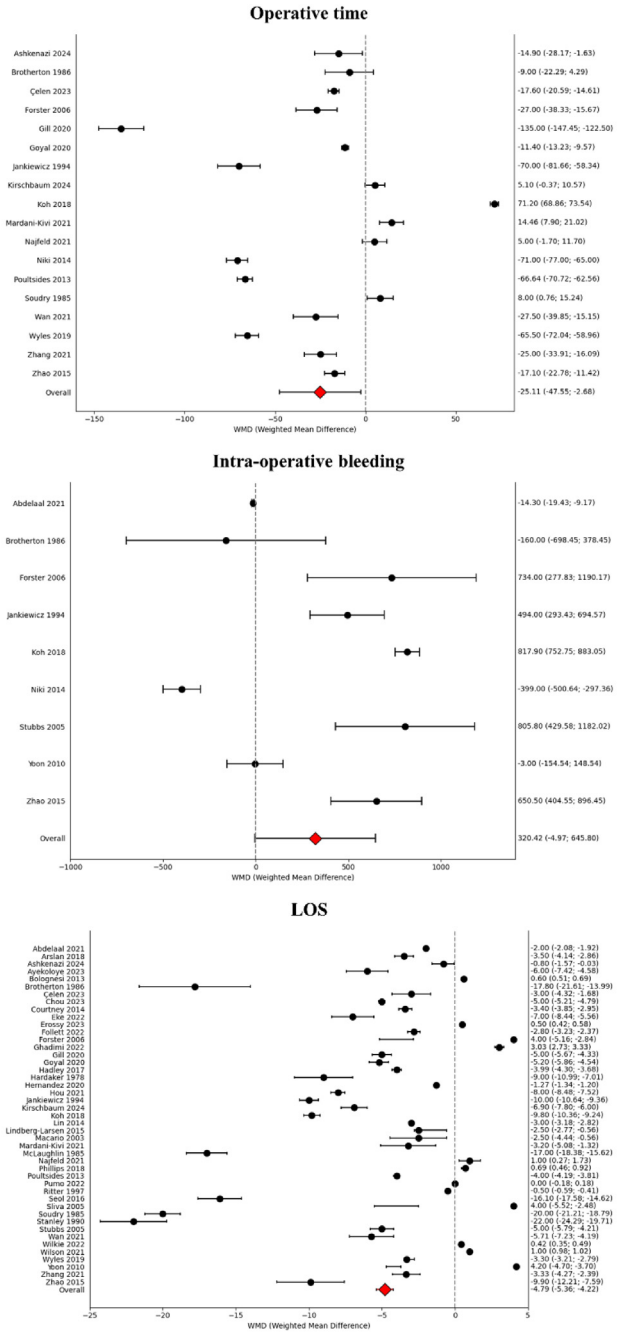

Figure 5. Forest plots of the individual studies and weighted mean differences or OR for operative time, intraoperative bleeding, number of transfusions, and length of hospital stay, including 95% CIs. B-TKA showed lower operative time, intraoperative bleeding, and length of hospital stay, but a higher number of transfusions compared to two-stage B-TKA.

Oxford Knee Score. The analysis OKS showed a statistically significant difference with a higher improvement in the one-stage B-TKA group ($P = 0.004$, MD = 1.3) (Figure 6).

Visual Analogue Scale. The analysis of VAS did not show a statistically significant difference between one-stage and two-stage B-TKA.

Range of Motion. The analysis of ROM did not show a statistically significant difference between one-stage and two-stage B-TKA.

Risk of Bias

The evaluation using the ROBINS-I tool showed a heterogeneous quality of the studies, with 26 papers falling in the “low” risk category, 36 in the “moderate” risk category, 6 in the “serious” risk category, and 1 in the “critical” risk category (Figure 7).

Discussion

The main finding of this meta-analysis is that one-stage B-TKA was associated with a higher mortality rate and thromboembolic risk while presenting lower TKA-related and infective complications compared to two-stage B-TKA. One-stage B-TKA was also able to reduce the hospital stay and total surgical time but provided only marginal improvement in clinical outcomes compared to two-stage TKA while showing higher risk of neurologic and GI complications.

The number of B-TKA performed to address end-stage bilateral knee OA is currently rising [6], but the choice between the one-stage and the two-stage approach for this type of intervention remains a subject of debate. Among the several aspects to be considered when weighing the advantages and drawbacks of these two approaches, the mortality risk represents one of the decisive factors. Previous smaller systematic reviews and meta-analyses unanimously reported increased mortality rates in patients treated with one-stage B-TKA compared to the two-stage approach [8,9,11,84]. The present meta-analysis confirmed those findings in a larger body of literature, documenting a superior mortality risk in the one-stage group at the 1-month, 3-month, and 1-year follow-ups. This difference was not statistically significant considering the in-hospital mortality, confirming the results of a smaller meta-analysis addressing this aspect [8]. Hospitalization could be a factor contributing to reducing mortality due to the fast access to life-saving procedures and facilities possibly leveling the difference between the approaches [85]. When considering the subsequent follow-ups going beyond the hospitalization period, the one-stage approach showed a higher mortality rate. This difference was lost only at the 2-year follow-up. There are some relevant aspects warranting attention in the interpretation of these results. When staged procedures are performed over longer periods of time, patients may die between the two procedures. As a result, these patients would fall under the unilateral TKA category despite the presence of bilateral knee OA and even having a scheduled intervention to address this pathology in the second knee after the first TKA procedure. Furthermore, surgeons may decide not to perform the second staged procedure on patients who experienced major complications following the first procedure. These considerations underpin the complexity of the interpretations of these results and show the need for new studies focusing specifically on the factors contributing the most to the risk of mortality after B-TKA.

Perioperative complications and revision rates represent other decisive aspects in the outcome of B-TKA. The present meta-analysis showed some differences between one-stage and two-stage B-TKA across various complication categories. One-stage B-TKA demonstrated lower rates of TKA-related complications, deep infections, and wound complications but higher rates of neurological and GI complications, DVT, and PE compared to two-stage B-TKA. No differences between the two approaches were detected in terms of cardiac, respiratory, and urinary complications as well as revision rates. The analysis of prosthesis-related complications showed a statistical tendency with a higher rate in the two-stage group. These results build upon the finding of previous smaller meta-analyses, investigating a larger body of literature and offering a deeper analysis of complication subtypes. Two meta-analyses reported lower deep infection rates and higher risk of PE in the one-stage approach [9,84], while another

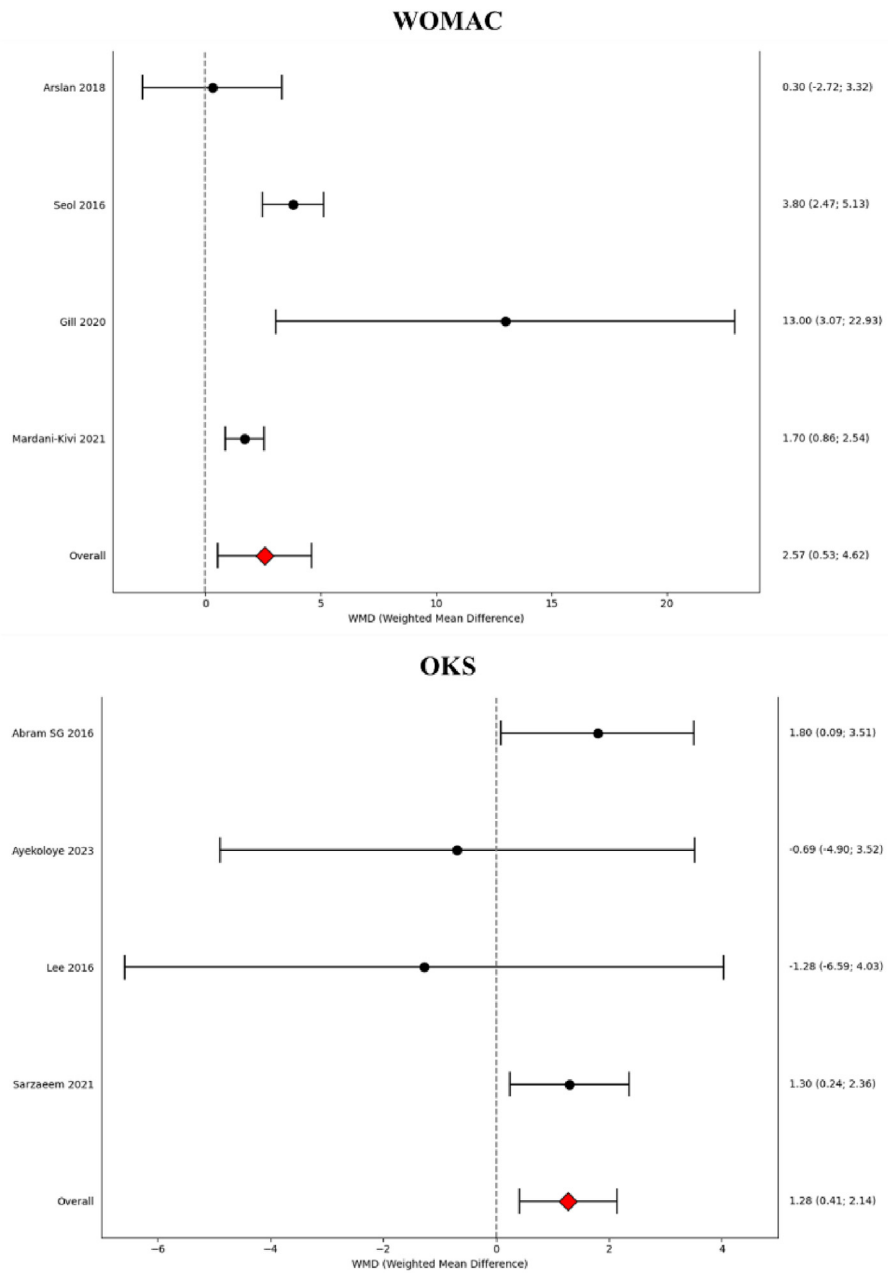

Figure 6. Forest plots of the individual studies and weighted mean differences for Western Ontario and McMaster Universities Arthritis Index and Oxford Knee Score, including 95% CIs. B-TKA showed a higher improvement of both Western Ontario and McMaster Universities Arthritis Index and Oxford Knee Score compared to two-stage B-TKA.

meta-analysis showed no difference between the two groups in both analyses [8]. A meta-analysis reported higher risk of DVT in the one-stage approach [84], while two meta-analyses showed no difference between the two groups [8,9]. A meta-analysis reported lower revision rates in the one-stage approach [9], while another meta-analysis showed no difference between the two groups [84]. Future studies are needed to investigate the factors contributing the most to the development of certain complications in both the one-stage and the two-stage approaches in order to develop targeted strategies to anticipate and prevent the development of such complications and optimize the management of patients undergoing B-TKA.

Complications and revisions are not the only perioperative factors contributing to the final outcome of B-TKA. Other relevant perioperative parameters include operative time, LHS, and intra-operative bleeding. The present meta-analysis showed that one-stage B-TKA required shorter overall operative time (25 minutes) and LHS (approximately 5 days) with a statistical tendency toward lower intra-operative blood loss compared to the two-stage approach, representing a considerable advantage compared to the two-stage approach. These benefits should be carefully weighed with the potential risks of the one-stage procedure, especially in terms of mortality and possible complications, when choosing the optimal approach for B-TKA, tailoring the therapeutic approach to the specific patient's characteristics to maximize both safety and effectiveness.

The final clinical outcome after arthroplasty of both knee joints represents another relevant aspect of B-TKA. The present meta-analysis showed overall similar results for the two approaches in the scores evaluated. Only the WOMAC and OKS scores reached statistical significance with higher improvements in the one-stage

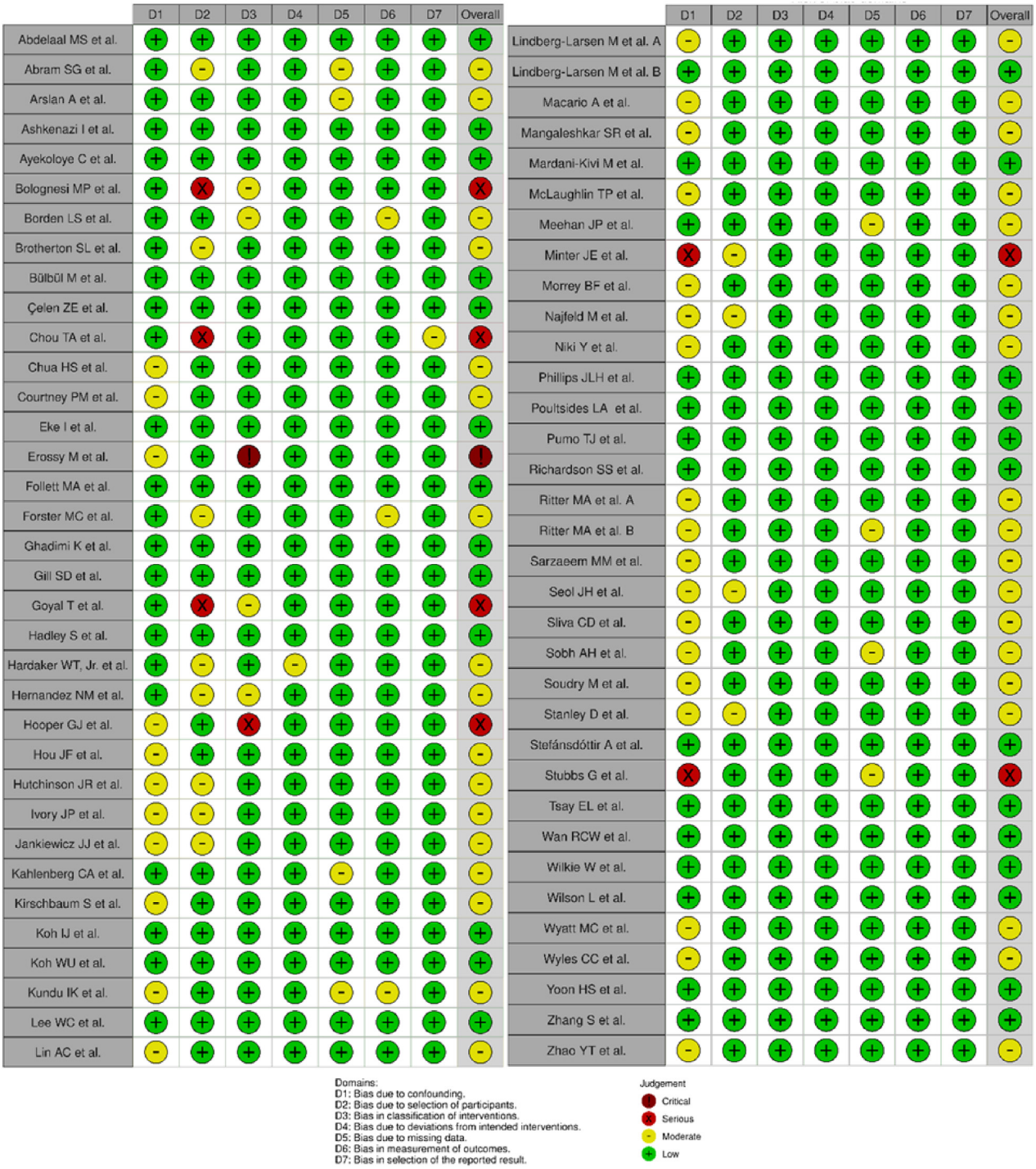

Figure 7. Cochrane ROBINS-I (Risk Of Bias In Non-randomised Studies - of Interventions) evaluation.

group. However, the differences were very limited between the two groups and therefore of negligible clinical relevance. These results supporting the overall equivalence of the one-stage and two-stage approaches in terms of clinical outcomes should be interpreted with caution, especially in light of the delicate comparison between procedures having considerably different timeframes. In fact, the final results of the two-stage approach do not consider the patient's outcomes after the first TKA procedure and therefore may not reflect the full course of the patient's clinical condition. This may mask possible periods of clinical improvement or deterioration between the two procedures that can have a considerable impact on the global clinical outcome. Still, these findings represent important evidence for both patients and physicians choosing the best approach B-TKA, offering important information to appropriately evaluate all the pros and cons of the two procedures in the clinical practice.

This meta-analysis presents some potential limitations that require consideration. Variations in surgical technique, preoperative and post-operative care protocols across different institutions, as well as the variability of the timespan between the first and the second TKA procedures in the two-stage group may be factors influencing the pooled results. Additionally, the studies analyzed

presented a considerable heterogeneity of designs, with both prospective and retrospective studies included. Due to the lack of randomization and the retrospective nature of most studies, selection and recall bias cannot be completely excluded. Even if majority of the included studies presented a “low” or “moderate” risk of bias, the overall heterogeneity in terms of ROBINS-I evaluation is another element deserving attention when interpreting the results of this meta-analysis. Moreover, the baseline demographic characteristics presented some statistically significant differences between the one-stage and two-stage groups. However, the modest entity of these differences is of questionable clinical relevance, as it could hardly have any effect on the results of this meta-analysis, with a slight difference in terms of male-to-female ratio, a minor age difference of 1.4 years, and a negligible BMI difference of 0.6. Finally, the selected studies lacked standardization in data collection and reporting, hindering the possibility of performing a subanalysis comparing the sequential (one surgeon) or simultaneous (two surgeons) techniques in the one-stage B-TKA group. Despite these limitations, this meta-analysis provided important findings by quantifying the advantages and drawbacks of the one-stage and two-stage approaches for B-TKA. Future studies should aim at producing an even superior level of evidence, possibly with high-level randomized controlled trials, as well as at evaluating resource implications and cost-analysis data in order to tailor the therapeutic approach to the individual characteristics while optimizing the overall management of patients undergoing B-TKA in the clinical practice.

Conclusions

One-stage B-TKA was associated with a higher mortality rate and thromboembolic risk while presenting lower TKA-related and infective complications compared to two-stage B-TKA. One-stage B-TKA also reduced hospital stay and total surgical time but provided only marginal improvement in clinical outcomes compared to two-stage B-TKA while showing higher risk of neurologic and GI complications. These results offer important information for both patients and surgeons in evaluating the most appropriate surgical approach, thereby contributing to optimizing the management of patients undergoing B-TKA.

CRediT authorship contribution statement

Alessandro Bensa: Writing – original draft, Visualization, Validation, Investigation, Data curation, Conceptualization. **Marco Delcogliano:** Writing – review & editing, Writing – original draft, Visualization, Validation, Investigation, Data curation. **Giacomo Moraca:** Writing – original draft, Visualization, Investigation, Data curation. **Luca Bianco Prevot:** Writing – original draft, Visualization, Investigation, Data curation. **Gae Fattini Fellini:** Writing – original draft, Visualization, Investigation, Data curation. **Giuseppe Filardo:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Conceptualization.

References

[1] Price AJ, Alvand A, Troelsen A, Katz JN, Hooper G, Gray A, et al. Knee replacement. Lancet 2018;392:1672.

[2] Carr AJ, Robertsson O, Graves S, Price AJ, Arden NK, Judge A, et al. Knee replacement. Lancet 2012;379:1331.

[3] De Marziani L, Boffa A, Di Martino A, Andriolo L, Reale D, Bernasconi A, et al. The reimbursement system can influence the treatment choice and favor joint replacement versus other less invasive solutions in patients affected by osteoarthritis. J Exp Orthop 2023;10:146.

[4] Perdisa F, Bordini B, Salerno M, Traina F, Zaffagnini S, Filardo G. Total knee arthroplasty (TKA): when do the risks of TKA overcome the benefits? Double risk of failure in patients up to 65 years old. Cartilage 2023;14:305.

[5] Walmsley P, Murray A, Brenkel IJ. The practice of bilateral, simultaneous total knee replacement in Scotland over the last decade. Data from the Scottish Arthroplasty Project. Knee 2006;13:102.

[6] Kop M, Kim N, Shimoda B, Unebasami E, Weldon RH, Nakasone CK. The prevalence of bilateral and ipsilateral radiographic osteoarthritis is high in White, Asian and Native Hawaiian/Pacific Islanders presenting for unilateral knee or hip arthroplasty. Arch Orthop Trauma Surg 2024;144:1565–73.

[7] Vulcano E, Memtsoudis S, Della Valle AG. Bilateral total knee arthroplasty guidelines: are we there yet? J Knee Surg 2013;26:273.

[8] Hussain N, Chien T, Hussain F, Bookwala A, Simunovic N, Shetty V, et al. Simultaneous versus staged bilateral total knee arthroplasty: a meta-analysis evaluating mortality, peri-operative complications and infection rates. HSS J 2013;9:50.

[9] Fu D, Li G, Chen K, Zeng H, Zhang X, Cai Z. Comparison of clinical outcome between simultaneous-bilateral and staged-bilateral total knee arthroplasty: a systematic review of retrospective studies. J Arthroplasty 2013;28:1141.

[10] Ghasemi SA, Rashidi S, Rasouli MR, Parvizi J. Staged bilateral total knee arthroplasty: when should the second knee be replaced? Arch Bone Jt Surg 2021;9:633.

[11] Alshaikh AM, Alshaeri NM, Jamal R, Almaghthawi OF, Al Eid MM, Alfageeh ZS, et al. Mortality following simultaneous versus staged bilateral total knee arthroplasty: a systematic review and meta-analysis. Cureus 2023;15:e50823.

[12] Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Int J Surg 2010;8:336.

[13] Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ 2016;355:i4919.

[14] Neyeloff JL, Fuchs SC, Moreira LB. Meta-analyses and forest plots using a microsoft excel spreadsheet: step-by-step guide focusing on descriptive data analysis. BMC Res Notes 2012;5:52.

[15] Abdelaal MS, Calem D, Sherman MB, Sharkey PF. Short interval staged bilateral total knee arthroplasty: safety compared to simultaneous and later staged bilateral total knee arthroplasty. J Arthroplasty 2021;36:3901.

[16] Abram SG, Nicol F, Spencer SJ. Patient reported outcomes in three hundred and twenty eight bilateral total knee replacement cases (simultaneous versus staged arthroplasty) using the Oxford Knee Score. Int Orthop 2016;40:2055.

[17] Arslan A, Utkan A, Ozkurt B. Are unilateral or staged bilateral total knee arthroplasty really safer than simultaneously bilateral TKA, or is it a myth? Acta Orthop Belg 2018;84:192.

[18] Ashkenazi I, Rajahraman V, Lawrence KW, Lajam CM, Bosco JA, Schwarzkopf R. The financial feasibility of bilateral total knee arthroplasty: a matched cohort analyses of revenue and contribution margin between simultaneous and staged procedures. J Arthroplasty 2024;39:1645.

[19] Ayekoloye C, Balogun M, Oyewole G, Ogunlade S, Alonge T, Adeoye S. Staged versus simultaneous approach in complex bilateral total knee replacement: experience from tertiary institution in Nigeria. Ann Ib Postgrad Med 2023;21:17.

[20] Bolognesi MP, Watters TS, Attarian DE, Wellman SS, Setoguchi S. Simultaneous versus staged bilateral total knee arthroplasty among Medicare beneficiaries, 2000-2009. J Arthroplasty 2013;28(8 Suppl):87.

[21] Borden LS, Perry JE, Davis BL, Owings TM, Grabiner MD. A biomechanical evaluation of one-stage versus two-stage bilateral knee arthroplasty patients. Gait Posture 1999;9:24.

[22] Brotherton SL, Roberson JR, Robin de Andrade J, Fleming LL. Staged versus simultaneous bilateral total knee replacement. J Arthroplasty 1986;1:221.

[23] Bülbül A, Ayanoğlu S, Imren Y, Dedeoğlu S, Esenyel C, H G. Assessment of functional outcomes of either simultaneous or staged bilateral total knee arthroplasty at year one. Nobel Med 2011;26:2011.

[24] Çelen Z, Özkurt B, Aydin Ö, Akalan T, Gazİ O, Utkan A. Comparison of safety and efficiency between sequential simultaneous bilateral and staged bilateral total knee arthroplasty at a high-volume center: a retrospective cohort study. Acta Orthop Belg 2023;89:455.

[25] Chou TA, Ma HH, Tsai CW, Tsai SW, Chen CF, Chiu FY, et al. The safety and cost-analysis of simultaneous versus staged bilateral total knee arthroplasty in a Taiwan population. J Chin Med Assoc 2023;86:494.

[26] Chua HS, Whitehouse SL, Lorimer M, De Steiger R, Guo L, Crawford RW. Mortality and implant survival with simultaneous and staged bilateral total knee arthroplasty experience from the Australian Orthopedic Association National Joint Replacement Registry. J Arthroplasty 2018;33:3167.

[27] Courtney PM, Melnic CM, Alosh H, Shah RP, Nelson CL, Israelite CL. Is bilateral total knee arthroplasty staged at a 1-week interval safe? A matched case control study. J Arthroplasty 2014;29:1946.

[28] Eke I. Total knee arthroplasty: unilateral, simultaneous bilateral or staged bilateral in advanced age? Turk J Geriatrics 2022;25:441.

[29] Erossy M, Emara AK, Zhou G, Kourkian S, Klika AK, Molloy RM, et al. Simultaneous bilateral total knee arthroplasty has higher in-hospital complications than both staged surgeries: a nationwide propensity score matched analysis of 38,764 cases. Eur J Orthop Surg Traumatol 2023;33:1057.

[30] Follett MA, Arora P, Maloney WJ, Goodman SB, Huddleston 3rd JI, Amanatullah DF. Staging bilateral total knee arthroplasties reduces alignment outliers. J Arthroplasty 2022;37:694.

[31] Forster MC, Bauze AJ, Bailie AG, Falworth MS, Oakeshott RD. A retrospective comparative study of bilateral total knee replacement staged at a 1-week interval. J Bone Joint Surg Br 2006;88:1006.

[32] Ghadimi K, Motififard M, Mohammadi R, Rafiee Zadeh A. Complete bilateral knee arthroplasty in staged or simultaneous surgeries in patients with osteoarthritis. Int J Burns Trauma 2022;12:59.

[33] Gill SD, Hill-Buxton LM, Gwini SM, Morrison S, Moreira B, Beattie S, et al. Simultaneous (two-surgeon) versus staged bilateral knee arthroplasty: an observational study of intraoperative and post-operative outcomes. ANZ J Surg 2020;90:826.
[34] Goyal T, Azam MQ, Syed A, Paul S. Simultaneous single-stage versus two-staged bilateral total knee arthroplasty: a prospective comparative study. Int Orthop 2020;44:1305.
[35] Hadley S, Day M, Schwarzkopf R, Smith A, Slover J, Zuckerman J. Is simultaneous bilateral total knee arthroplasty (BTKA) as safe as staged BTKA? Am J Orthop (Belle Mead NJ) 2017;46:E224.
[36] Hardaker Jr WT, Ogden WS, Musgrave RE, Goldner JL. Simultaneous and staged bilateral total knee arthroplasty. J Bone Joint Surg Am 1978;60:247.
[37] Hernandez NM, Ryan SP, Wu CJ, Hinton ZW, Wellman SS, Bolognesi MP, et al. Same-day bilateral total knee arthroplasty did not increase 90-ds hospital returns. J Orthop Surg (Hong Kong) 2020;28:2309499020918170.
[38] Hooper GJ, Hooper NM, Rothwell AG, Hobbs T. Bilateral total joint arthroplasty: the early results from the New Zealand National Joint Registry. J Arthroplasty 2009;24:1174.
[39] Hou JF, Hu C, Zhang Y, Tian LQ, Liu YZ, Zhang C, et al. Cost analysis of staged versus simultaneous bilateral total knee and hip arthroplasty using a propensity score matching. BMJ Open 2021;11:e041147.
[40] Hutchinson JR, Parish EN, Cross MJ. A comparison of bilateral uncemented total knee arthroplasty: simultaneous or staged? J Bone Joint Surg Br 2006;88:40.
[41] Ivory JP, Simpson AH, Toogood GJ, McLardy-Smith PD, Goodfellow JW. Bilateral knee replacements: simultaneous or staged? J R Coll Surg Edinb 1993;38:105.
[42] Jankiewicz JJ, Sculco TP, Ranawat CS, Behr C, Tarrentino S. One-stage versus 2-stage bilateral total knee arthroplasty. Clin Orthop Relat Res 1994;94.
[43] Kahlenberg CA, Krell EC, Sculco TP, Katz JN, Nguyen JT, Figgie MP, et al. Differences in time to return to work among patients undergoing simultaneous versus staged bilateral total knee arthroplasty. Bone Joint J 2021;103-b(6 Supple A):108.
[44] Kirschbaum S, Hube R, Perka C, Najfeld M. Bilateral simultaneous knee arthroplasty shows comparable early outcome and complication rate as staged bilateral knee arthroplasty for patients scored ASA 1-3 if performed by a high-volume surgeon: a retrospective cohort study of 127 cases. Arch Orthop Trauma Surg 2024;144:417.
[45] Koh IJ, Kim GH, Kong CG, Park SW, Park TY, In Y. The patient's age and American Society of Anesthesiologists status are reasonable criteria for deciding whether to perform same-day bilateral TKA. J Arthroplasty 2015;30:770.
[46] Koh WU, Kim HJ, Park HS, Jang MJ, Ro YJ, Song JG. Staggered rather than staged or simultaneous surgical strategy may reduce the risk of acute kidney injury in patients undergoing bilateral TKA. J Bone Joint Surg Am 2018;100:1597.
[47] Kundu IK, Chowdhury AZ, Faisal A, Arefin KN, Rahman MN, Paul MS, et al. Functional outcome of bilateral total knee replacement in advanced osteoarthritis in simultaneous versus staged procedure. Mymensingh Med J 2022;31:165.
[48] Lee WC, Kwan YH, Yeo SJ. Severe bilateral fixed flexion deformity-simultaneous or staged total knee arthroplasty? J Arthroplasty 2016;31:128.
[49] Lin AC, Chao E, Yang CM, Wen HC, Ma HL, Lu TC. Costs of staged versus simultaneous bilateral total knee arthroplasty: a population-based study of the Taiwanese National Health Insurance Database. J Orthop Surg Res 2014;9:59.
[50] Lindberg-Larsen M, Jorgensen CC, Husted H, Kehlet H. Early morbidity after simultaneous and staged bilateral total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 2015;23:831.
[51] Lindberg-Larsen M, Pitter FT, Husted H, Kehlet H, Jørgensen CC. Simultaneous versus staged bilateral total knee arthroplasty: a propensity-matched case-control study from nine fast-track centers. Arch Orthop Trauma Surg 2019;139:709.
[52] Macario A, Schilling P, Rubio R, Goodman S. Economics of one-stage versus two-stage bilateral total knee arthroplasties. Clin Orthop Relat Res 2003:149.
[53] Mangaleshkar SR, Prasad PS, Chugh S, Thomas AP. Staged bilateral total knee replacement–a safer approach in older patients. Knee 2001;8:207.
[54] Mardani-Kivi M, Leili EK, Torfeh N, Azari Z. Bilateral total knee arthroplasty: simultaneous versus staging in the same or in twice hospitalization. J Clin Orthop Trauma 2021;14:59–64.
[55] McLaughlin TP, Fisher RL. Bilateral total knee arthroplasties. Comparison of simultaneous (two-team), sequential, and staged knee replacements. Clin Orthop Relat Res 1985:220.
[56] Meehan JP, Danielsen B, Tancredi DJ, Kim S, Jamali AA, White RH. A population-based comparison of the incidence of adverse outcomes after simultaneous-bilateral and staged-bilateral total knee arthroplasty. J Bone Joint Surg Am 2011;93:2203.
[57] Minter JE, Dorr LD. Indications for bilateral total knee replacement. Contemp Orthop 1995;31:108.
[58] Morrey BF, Adams RA, Ilstrup DM, Bryan RS. Complications and mortality associated with bilateral or unilateral total knee arthroplasty. J Bone Joint Surg Am 1987;69:484.
[59] Najfeld M, Kalteis T, Spiegler C, Ley C, Hube R. The safety of bilateral simultaneous hip and knee arthroplasty versus staged arthroplasty in a high-volume center comparing blood loss, peri- and postoperative complications, and early functional outcome. J Clin Med 2021;10:4507.
[60] Niki Y, Katsuyama E, Takeda Y, Enomoto H, Toyama Y, Suda Y. Comparison of postoperative morbidity between simultaneous bilateral and staged bilateral total knee arthroplasties: serological perspective and clinical consequences. J Arthroplasty 2014;29:504.
[61] Phillips JLH, Rondon AJ, Gorica Z, Fillingham YA, Austin MS, Courtney PM. No difference in total episode-of-care cost between staged and simultaneous bilateral total joint arthroplasty. J Arthroplasty 2018;33:3607.
[62] Poultsides LA, Memtsoudis SG, Vasilakakos T, Wanivenhaus F, Do HT, Finerty E, et al. Infection following simultaneous bilateral total knee arthroplasty. J Arthroplasty 2013;28(8 Suppl):92.
[63] Pumo TJ, Emara AK, Jin Y, Klika AK, Piuzzi NS. Staged versus simultaneous bilateral knee arthroplasty: does minimal cost difference justify risks? J Arthroplasty 2022;37:1776.
[64] Richardson SS, Kahlenberg CA, Blevins JL, Goodman SM, Sculco TP, Figgie MP, et al. Complications associated with staged versus simultaneous bilateral total knee arthroplasty: an analysis of 7747 patients. Knee 2019;26:1096.
[65] Ritter M, Mamlin LA, Melfi CA, Katz BP, Freund DA, Arthur DS. Outcome implications for the timing of bilateral total knee arthroplasties. Clin Orthop Relat Res 1997:99.
[66] Ritter MA, Harty LD, Davis KE, Meding JB, Berend M. Simultaneous bilateral, staged bilateral, and unilateral total knee arthroplasty. A survival analysis. J Bone Joint Surg Am 2003;85:1532.
[67] Sarzaeem MM, Amoozadeh Omrani F, Omidian MM, Sahebalzamani MA, Maniei E. Clinical outcome comparison between staged -bilateral versus simultaneous bilateral total knee replacements. Arch Bone Jt Surg 2021;9:641.
[68] Seol JH, Seon JK, Song EK. Comparison of postoperative complications and clinical outcomes between simultaneous and staged bilateral total knee arthroplasty. J Orthop Sci 2016;21:766.
[69] Sliva CD, Callaghan JJ, Goetz DD, Taylor SG. Staggered bilateral total knee arthroplasty performed four to 7 days apart during a single hospitalization. J Bone Joint Surg Am 2005;87:508.
[70] Sobh AH, Siljander MP, Mells AJ, Koueiter DM, Moore DD, Karadsheh MS. Cost analysis, complications, and discharge disposition associated with simultaneous versus staged bilateral total knee arthroplasty. J Arthroplasty 2018;33:320.
[71] Soudry M, Binazzi R, Insall JN, Nordstrom TJ, Pellicci PM, Goulet JA. Successive bilateral total knee replacement. J Bone Joint Surg Am 1985;67:573.
[72] Stanley D, Stockley I, Getty CJ. Simultaneous or staged bilateral total knee replacements in rheumatoid arthritis. A prospective study. J Bone Joint Surg Br 1990;72:772.
[73] Stefánsdóttir A, Lidgren L, Robertsson O. Higher early mortality with simultaneous rather than staged bilateral TKAs: results from the Swedish Knee Arthroplasty Register. Clin Orthop Relat Res 2008;466:3066.
[74] Stubbs G, Pryke SER, Tewari S, Rogers J, Crowe B, Bridgfoot L, et al. Safety and cost benefits of bilateral total knee replacement in an acute hospital. ANZ J Surg 2005;75:739.
[75] Tsai SW, Chang WL, Pai FY, Chou TFA, Chen CF, Wu PK, et al. Combination of enoxaparin and low-dose aspirin for thromboprophylaxis in selective patients after primary total joint arthroplasty in a Taiwanese population. J Chin Med Assoc 2023;86:923.
[76] Wan RCW, Fan JCH, Hung YW, Kwok KB, Lo CKM, Chung KY. Cost, safety, and rehabilitation of same-stage, bilateral total knee replacements compared to two-stage total knee replacements. Knee Surg Relat Res 2021;33:17.
[77] Wilkie W, Mohamed N, Remily E, Pastore M, Nace J, Delanois RE. Same day versus staged total knee arthroplasty: do cost savings justify the risk? J Knee Surg 2022;35:288.
[78] Wilson L, Fiasconaro M, Liu J, Poeran J, Poultsides L, Memtsoudis SG. Risk of chronic opioid use after simultaneous versus staged bilateral knee arthroplasty. Reg Anesth Pain Med 2021;46:405.
[79] Wyatt MC, Hozack J, Frampton C, Hooper GJ. Safety of single-anaesthetic versus staged bilateral primary total knee replacement: experience from the New Zealand National Joint Registry. ANZ J Surg 2019;89:567.
[80] Wyles CC, Robinson WA, Maradit-Kremers H, Houdek MT, Trousdale RT, Mabry TM. Cost and patient outcomes associated with bilateral total knee arthroplasty performed by 2-surgeon teams versus a single surgeon. J Arthroplasty 2019;34:671.
[81] Yoon HS, Han CD, Yang IH. Comparison of simultaneous bilateral and staged bilateral total knee arthroplasty in terms of perioperative complications. J Arthroplasty 2010;25:179.
[82] Zhao YT, Chu HJ, Heng DF, Lei J. Comparison of the effectiveness and safety of one-stage versus two-stage bilateral total knee arthroplasty. Acta Orthop Belg 2015;81:784.
[83] Zhang S, Wang F, Wang C, Wang C, Xu Y, Long X, et al. Comparison of the effect and complications of sequential bilateral arthroplasty at different time intervals and simultaneous bilateral total knee arthroplasty: a single-centre retrospective cohort study. Adv Ther 2021;38:5191.
[84] Liu L, Liu H, Zhang H, Song J, Zhang L. Bilateral total knee arthroplasty: simultaneous or staged? A systematic review and meta-analysis. Medicine 2019;98:e15931.
[85] Roshanov PS, Chan MTV, Borges FK, Conen D, Wang CY, Xavier D, et al. One-year outcomes after discharge from noncardiac surgery and association between predischarge complications and death after discharge: analysis of the VISION prospective cohort study. Anesthesiology 2024;140:8.