Soler *et al.*
Journal of Orthopaedics and Traumatology (2026) 27:4
https://doi.org/10.1186/s10195-026-00904-y

Journal of Orthopaedics and Traumatology

SYSTEMATIC REVIEW Open Access

Simultaneous versus staged bilateral total hip arthroplasty: a meta-analysis

Francisco Soler[1], Javier Hernández[1], José María Lamo-Espinosa[2,3], María Benlloch[4*] and Gonzalo Mariscal[3,5]

Abstract

Background There is debate regarding the optimal timing of bilateral total hip arthroplasty (THA), with simultaneous or staged approaches considered. Cost-effectiveness is an important factor that influences resource allocation. The main aim of this study was to assess the cost implications of bilateral simultaneous (sim-THA) versus staged (st-THA) total hip arthroplasty. The secondary objective was to evaluate the efficacy and safety of sim-THA compared those with of st-THA.

Methods A systematic review and meta-analysis were conducted according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines. Studies comparing simultaneous and staged bilateral THA in terms of cost, complications, length of hospital stay, and patient outcomes were eligible. Odds ratios (ORs), mean differences (MD), and standard mean differences (SMD) with 95% confidence intervals (CIs) were calculated. The risk of bias was assessed using the Methodological Index for Non-randomised Studies (MINORS). Meta-analyses were performed using Review Manager version 5.4 (Cochrane, Oxford, United Kingdom).

Results A total of 20 observational studies including 13,984 patients were included. Sim-THA was associated with significantly lower total costs (SMD −0.54, 95% CI −0.92 to −0.16; $p=0.005$) and shorter hospital stay (MD −2.90, 95% CI −4.38 to −1.42; $p=0.0001$) than those in the st-THA group. Revisions were less frequent in the sim-THA group (OR 0.44, 95% CI 0.36–0.53; $p<0.00001$). No differences were observed in mortality (OR 1.01, 95% CI 0.31–3.28; $p=0.98$) or readmission rates (OR 0.58, 95% CI 0.23–1.44; $p=0.24$). The number of transfusions (OR 4.42, 95% CI 2.18–8.99; $p<0.0001$) was lower in st-THA. Functionality (SMD 0.37, 95% CI 0.20–0.53; $p<0.0001$) and pain scores (SMD 0.19, 95% CI 0.04–0.33; $p=0.01$) favored sim-THA.

Conclusions A meta-analysis of 20 studies demonstrated that sim-THA offers economical and clinical advantages, including reduced hospital expenses and improved patient quality of life, despite a higher number of transfusions, with comparable surgical blood loss to standard THA.

Keywords Total hip arthroplasty, Simultaneous bilateral, Staged bilateral, Cost-effectiveness, Complications, Length of stay, Patient-reported outcomes, Blood transfusion

*Correspondence:
María Benlloch
maria.benlloch@ucv.es
Full list of author information is available at the end of the article

© The Author(s) 2026. **Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by-nc-nd/4.0/.

Background

Total hip arthroplasty (THA) is one of the most effective interventions for restoring mobility and alleviating pain in patients suffering from severe hip joint damage [1]. Given the global trend of an aging population and the anticipated increase in the prevalence of conditions requiring THA, there is a growing interest in enhancing the efficiency and outcomes of this procedure [2, 3].

The likelihood of patients requiring a second surgery on the opposite hip is significant within 10 years of the initial surgery [4]. The dilemma of single versus staged bilateral total hip arthroplasty (st-THA) highlights the critical need for resource optimization and cost-effective surgical strategies in value-based healthcare [5]. The decision to perform simultaneous or staged THA is complex and depends largely on the surgeon's discretion, influenced by the patient's health status and the potential benefits and risks associated with each approach [6].

Research on whether simultaneous bilateral total hip arthroplasty (sim-THA) or staged surgeries should be conducted across two separate events has yielded mixed results. For instance, Brown et al. [7] reported cost savings of $4000 per hip arthroplasty with simultaneous surgery. However, Berend et al. [8], in 2007, noted higher complication rates with simultaneous surgeries, suggesting that there might be hidden costs related to these complications that were not analyzed in other studies. This was corroborated by observations of poorer physical state during hospital stay. Yakkanti et al. [9] observed a higher rate of patients needing to go to rehabilitation facilities after discharge from simultaneous surgery. However, the small sample sizes in many of these studies necessitate cautious interpretation of the data, suggesting the need for meta-analyses to combine the findings and provide more robust conclusions on costs. Moreover, these studies have more limitations apart from small sample sizes. For example, Tan et al. [10] found that total hospital costs and the incidence of complications were not significantly different between sim-THA and st-THA; however, they acknowledged limitations that are also present in other studies addressing the total direct or indirect costs of sim-THA and st-THA. These limitations included inconsistent follow-up at hospitals and missing information on complications, which complicated statistical analysis.

The need for a meta-analysis in the field of THA is evident when considering the varying focuses and findings of existing studies. For example, a meta-analysis by Ramezani et al. [11] primarily addressed clinical variables, such as complications and quality of life (QoL), noting lower overall costs with simultaneous surgeries. However, this study did not delve into the nuances of the different cost types that might affect financial outcomes. Similarly, Babis et al. [12] concentrated on the incidence of thromboembolic events and found no significant differences between the sim-THA and st-THA procedures. In contrast, Huang et al. focused on complications and reported a more favorable profile for simultaneous surgeries [13]. Notably, Tsiridis et al. analyzed different outcomes, such as length of stay and complications, but did not include a statistical cost analysis in their study [14].

On the basis of this literature, we hypothesized that sim-THA may result in lower overall healthcare costs due to a single hospital stay and a potentially shorter total length of stay, among others, without significantly increasing complications compared with st-THA.

Our meta-analysis aimed to synthesize the available evidence to provide a clearer understanding of cost differences, specifically addressing the lack of statistical power in individual studies. The primary objective of this study was to assess the cost implications associated with sim-THA compared with those associated with st-THA, focusing on total costs and overall healthcare expenses. As secondary objectives, we aimed to evaluate the efficacy and safety of sim-THA compared with those of st-THA.

Material and methods

Eligibility criteria

This meta-analysis was prospectively registered and followed a predefined protocol outlining the eligibility criteria and planned analyses (PROSPERO: CRD42024578225). It adhered to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) reporting guidelines [15]; the completed PRISMA checklist is provided as Additional File 1. The PICOS strategy was implemented as follows: P (population): adult patients who underwent bilateral THAs (simultaneous or staged) procedures; I (Intervention): the intervention group consisted of patients who underwent sim-THA at the time of surgery (at different follow-ups); C (Comparator): the comparator group comprised patients who underwent St-THA; and O (Outcome): the primary outcomes of interest were the direct and indirect costs of the procedures (such as length of stay), and the secondary outcomes were efficacy (through the assessment of quality of life using different functionality scores, such as the Harris Hip Score (HHS) or Japanese Orthopaedic Association (JOA) score, among others, and pain scales such as the Patient-Reported Outcome Measure (PROM) or Japanese Hip Disease-Specific Quality of Life Questionnaire (JHEQ)) and safety (through bleeding complications, readmissions, and revisions; discharge home dispositions; and other complications such as mortality). Observational cohort studies, including

prospective and retrospective cohort studies and case series, were included.

Noncomparative and duplicate studies were excluded from the study. Additionally, studies were excluded if they: (1) had missing data that prevented extraction of means or frequencies necessary for effect size computation or (2) did not report variables of interest in a comparable format (e.g., studies reporting only qualitative cost descriptions without quantifiable data or using incompatible outcome measurements that precluded pooled analysis).

Information sources

A comprehensive database search was conducted from 1 June 2024 to 31 October 2024 using multiple databases, including PubMed, EMBASE, Scopus, and The Cochrane Collaboration Library databases, without establishing a specific time or language filters. To maintain methodological consistency, the validated search strategy developed for PubMed was systematically applied to all database interfaces.

Search methods for identification of studies

The search terms used for the database search are listed in Supplementary File 2. An identical search strategy employing search terms and Boolean operators was developed for our primary PubMed search and systematically applied across all databases (PubMed, EMBASE, Scopus, and Cochrane Collaboration Library) to ensure methodological consistency.

Data extraction and data items

Two authors independently extracted data by consulting a third author in cases of disagreement to reach a consensus. Baseline characteristics including age, American Society of Anesthesiologists (ASA) classification, comorbidities, and surgical approach were extracted if reported. Some studies performed propensity score matching or multivariable adjustment to account for these confounders, whereas others provided only crude estimates. Comparable outcome measures of interest were total cost, specific costs such as nursing costs, length of stay (LOS), bleeding complications (blood loss, blood transfusion, and hemoglobin drop), complications (readmissions, revisions, and mortality), discharge home disposition, and quality of life. When studies did not specify whether events were counted per patient or per occurrence, data were included as reported. This approach was adopted to maximize data inclusion while acknowledging that some patients may have contributed multiple events to the pooled analysis, which could potentially introduce bias in the effect estimates.

Assessment of risk of bias in included studies

Two independent authors evaluated the quality of the included studies using the Methodological Index for Non-Randomized Studies (MINORS) criteria [16]. Although MINORS scores were used to assess study quality, they were not employed as exclusion criteria. Studies with methodological limitations were included when they provided valuable data for analysis, acknowledging the limited availability of high-quality evidence in this specific field, which is consistent with the Cochrane recommendations for observational study inclusion in meta-analyses.

Assessment of results

Statistical analyses were performed using Review Manager 5.4 software (Cochrane, Oxford, United Kingdom). For binary outcomes (such as complications, revisions, and mortality), odds ratios (OR) with 95% confidence intervals (CI) were calculated. For continuous outcomes (such as costs, length of stay, and functional scores), mean differences (MD) with 95% CI were computed. When studies used different measurement scales, standardized mean differences (SMD) were applied to ensure comparability. Statistical heterogeneity between studies was evaluated using the I^2 statistic, with values of 25%, 50%, and 75% indicating low, moderate, and high heterogeneity, respectively [17]. A fixed-effects model was used when heterogeneity was low, and a random-effects model was applied when moderate or high heterogeneity was present. Data extraction from the graphs was performed using Web-PlotDigitizer version 13.1.4. Missing data were handled according to the established Cochrane Handbook guidelines [18].

Risk of bias across the studies

We assessed the possibility of publication bias by evaluating a funnel plot using the Review Manager 5.4 software package provided by Cochrane Collaboration (Cochrane, Oxford, United Kingdom).

Additional analyses

Sensitivity analysis was conducted by removing the study with the highest statistical weight to assess the stability of our findings. The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach was used to assess the quality of evidence for each outcome [19].

Results

Study selection

A systematic search of four databases identified 281 records that were screened. After screening and

eligibility assessment, 263 studies were excluded due to duplication, design, lack of relevant comparison, or incomplete data. The reference review added two studies, resulting in the inclusion of 20 studies in the meta-analysis comparing sim-THA and st-THA procedures [7, 8, 10, 20–36] (Fig. 1).

Risk of bias

The quality of the included studies, as assessed by the MINORS tool and deemed to have fair quality, is presented in Table 1.

Study characteristics

Table 2 summarizes the main characteristics of the 20 studies, including 13,984 patients; 19 were cohort studies and 1 was a case–control study, with follow-up ranging from 6 weeks to 17 years. The mean age ranged from 41.9 to 68.7 years. The studies originated mainly from America (30%) and Europe (35%). Intervention details appear in Table 2.

Outcomes

The first variable analyzed was the total cost of the procedures (depending on the study, it was in euros or dollars) to show the different costs between sim-THA and st-THA. sim-THA generated less general cost than st-THA, showing significant differences between both groups (SMD −0.54, 95% CI −0.92 to −0.16) (Fig. 2).

Many studies have divided costs into different components. Consequently, we were able to compare the different costs among the studies that shared this information. Regarding nursing cost and physical therapy cost, there were no significant differences (SMD −0.44, 95% CI −1.01 to 0.13 and SMD −0.74, 95% CI −2.39 to 0.91).

A condition that influences the cost of procedures is the patient's hospital stay duration. When comparing this variable, significant differences were obtained between the sim-THA and st-THA groups, with shorter stays in patients undergoing sim-THA (MD −2.90, 95% CI −4.38 to −1.42). (Fig. 3). Different complications are related not only to efficacy and safety, but also to the cost of the procedures. Complications related to bleeding and

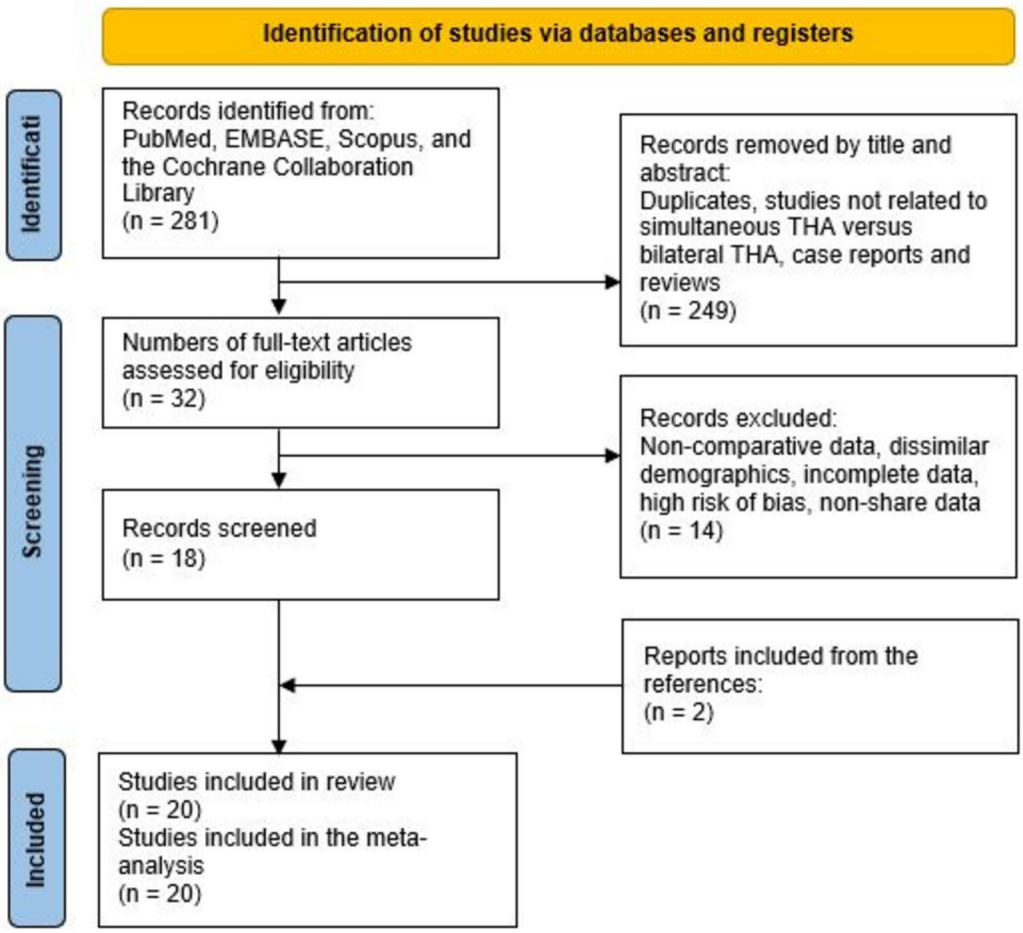

Fig. 1 Study selection flow diagram (Preferred Reporting Items for Systematic reviews and Meta-Analyses)

Table 1 Assessment of the quality of studies through methodological index for non-randomized studies (MINORS)

Study	Clearly stated aim	Consecutive patients	Prospective collection data	Endpoints	Assessment endpoint	Follow-up period	Loss less than 5%	Study size	Adequate control group	Contemporary group	Baseline control	Statistical analyses	MINORS
Berend et al. [8]	2	2	0	1	2	2	0	2	2	0	1	2	16
Brown et al. [7]	2	0	0	2	2	1	0	1	2	2	2	2	17
Calabro et al. [20]	2	0	0	1	2	2	0	2	1	0	2	2	14
Guo et al. [21]	2	2	0	2	2	1	0	2	2	1	2	2	18
Hoestlandt et al. [22]	2	0	0	2	2	2	0	1	2	2	2	2	17
Hou et al. [23]	2	0	0	2	2	0	0	2	2	2	2	2	16
Kamath et al. [24]	2	2	0	2	2	2	0	2	2	1	1	2	18
Kim et al. [25]	2	2	0	2	2	2	0	1	2	2	2	2	19
Kirschbaum et al. [26]	2	0	0	1	2	1	0	2	2	2	2	2	16
Lindberg-Larsen et al. [27]	2	0	0	1	2	1	0	2	2	1	1	2	14
Najfeld et al. [28]	2	0	0	2	2	0	0	1	2	2	2	2	15
Okazaki et al. [29]	2	0	0	1	2	2	0	1	2	2	2	2	16
Rajahraman et al. [30]	2	0	0	2	2	2	0	2	2	2	2	2	18
Reuben et al. [31]	2	0	0	1	2	0	0	1	2	2	2	2	14
Schlegelmilch et al. [32]	2	0	2	1	2	2	0	2	1	0	0	2	14
Seol et al. [33]	2	0	0	2	2	2	0	2	2	1	2	2	17
Shevenell et al. [34]	2	0	1	2	2	0	0	2	2	2	2	2	17
Tan et al. [10]	2	0	0	2	1	1	0	2	2	2	2	2	16
Verhaegen et al. [35]	2	0	0	2	2	2	0	2	2	1	2	2	17
Zampogna et al. [36]	2	2	0	2	2	2	0	1	2	0	2	2	17

Table 2 Baseline characteristics of the included studies

Study	Region	Period	Type of study	Follow-up	*n* (patients) group 1/ group 2	Age group 1/group 2	Female group 1/ group 2	Study (kind of THA)	
								Group 1	Group 2/ group 3
Berend et al. [8]	USA	1997–2005	Retrospective cohort	28.5 months	167/110	52.7/57.3	67/63	Simultaneous	Staged
Brown et al. [7]	USA	2009–2015	Retrospective cohort	90 days	15/44	56.9/60.2	20/7	Simultaneous	Staged
Calabro et al. [20]	Australia	1999–2002	Retrospective cohort	17 years	2779/ 4790	NR	1434/2491	Simultaneous	Staged
Guo et al. [21]	China	2011–2015	Retrospective cohort	> 3 months	863/282	49/52.5	259/130	Simultaneous	Staged
Hoestlandt et al. [22]	France	NR	Retrospective cohort	58.18 months	53/77	50.13/47.34	9/19	Simultaneous	Staged
Hou et al. [23]	China	2013–2018	Retrospective cohort	NR	100/100	54/57	30/29	Simultaneous	Staged
Kamath et al. [24]	Switzerland	NR	Retrospective cohort	> 2 years	41/44	60.7/68.7	17/26	Simultaneous	Staged
Kim et al. [25]	Korea	2007–2013	Retrospective cohort	> 2 years	63/60	43.1/43.5	24/28	Simultaneous	Staged
Kirschbaum et al. [26]	Europe	2015–2020	Retrospective cohort	6 weeks	152/138	62.8/65	46.1/56.5	Simultaneous	Staged
Lind-berg-Larsen et al. [27]	Denmark	2010–2011	Retrospective cohort	30 days	103/514	55.7/66.8	42.7/55.4	Simultaneous	Staged
Najfeld et al. [28]	Germany and Belgium	2017–2020	Retrospective cohort	90 days	85/77	62.8/64	36/48	Simultaneous	Staged
Okazaki et al. [29]	Japan	2012–2020	Retrospective case–control	44/58 months	51/51	62.7/62.7	44/44	Simultaneous	Staged
Rajahraman et al. [30]	USA	2011–2021	Retrospective Cohort	> 1 year	139/1378	53.8/61.3	54/ 814	Simultaneous	Staged
Reuben et al. [31]	USA	1991–1994	Retrospective cohort	NR	7/8	49/57/55	3/7/72	Simultaneous	Staged
Schlegelmilch et al. [32]	Ecuador	2007–2011	Prospective cohort	1 year	26/6	NR	NR	Simultaneous	Staged
Seol et al. [33]	Korea	2004–2009	Retrospective cohort	1 year	147/59	41.9/46.3	35/14	Simultaneous	Staged
Shevenell et al. [34]	USA	2013–2020	Retrospective cohort	90 days	113/113	58.2/58.4	46/46	Simultaneous	Staged
Tan et al. [10]	China	2013–2016	Retrospective cohort	90 days	432/256	52/54.9	113/136	Simultaneous	Staged
Verhaegen et al. [35]	Belgium	2019	Retrospective cohort	1 year	223/119	60.5/63.0	256/142	Simultaneous	Staged
Zampogna et al. [36]	Italy	2017–2020	Retrospective cohort	> 2 years	43/156	58/65	24/84	Simultaneous	Staged

readmissions, revisions, and as a last term, mortality, were assessed.

When bleeding complications were evaluated, blood loss did not differ between the sim-THA and st-THA groups (SMD −31.01, 95% CI (−7327 to −11.224) (Fig. 4a). Nevertheless, there were significant differences in the case of blood transfusion analysis: the number of transfusions (42/559, 7,51% sim-THA versus 18/679, 2.65% st-THA, OR 4.42, 95% CI 2.18–8.99) (Fig. 4b) and cumulative units of packaged blood cells (MD 0.46, 95% CI 0.25–0.68) (Fig. 4c), where blood transfusion was lower in st-THA) (Fig. 4b).

Continuing with complications, we observed no differences in the case of readmissions when sim-THA was compared with st-THA (21/1238, 1.69% sim-THA versus 79/1181, 6.69% sim-THA, OR 0.58, 95% CI 0.23–1.44). In the case of revisions, there were significant differences, showing less revisions in sim-THA group (147/3401, 4.3% sim-THA versus 512/5272, 9.7% st-THA, OR 0.44, 95% CI 0.36–0.53). When mortality was analyzed, there

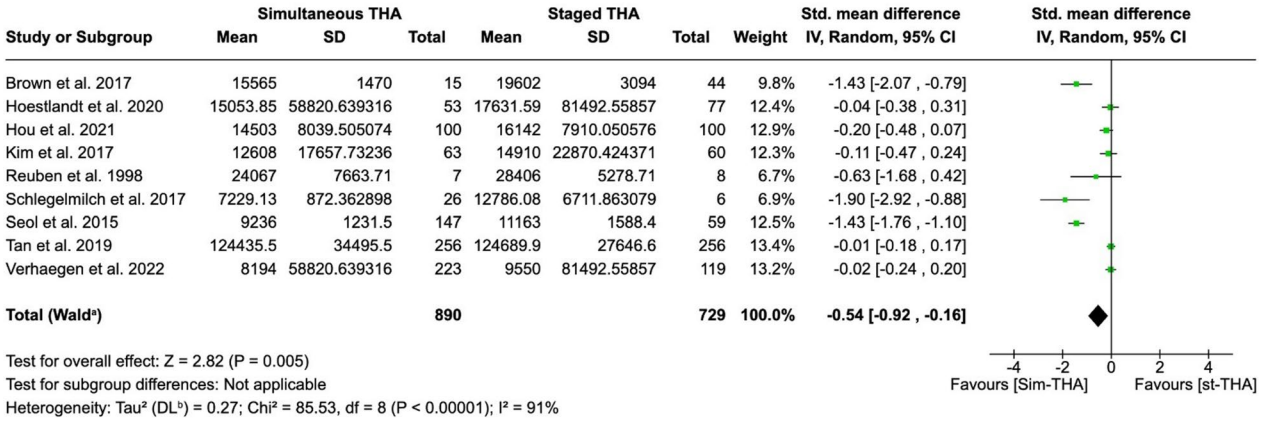

Fig. 2 Forest plot comparing the total cost of sim-THA versus st-THA. Sim-THA produced less total cost than st-THA, showing significant differences between both groups (SMD −0.54, 95% CI −0.92 to −0.16; participants = 1619; studies = 9; $I^2 = 91\%$; $p = 0.005$)

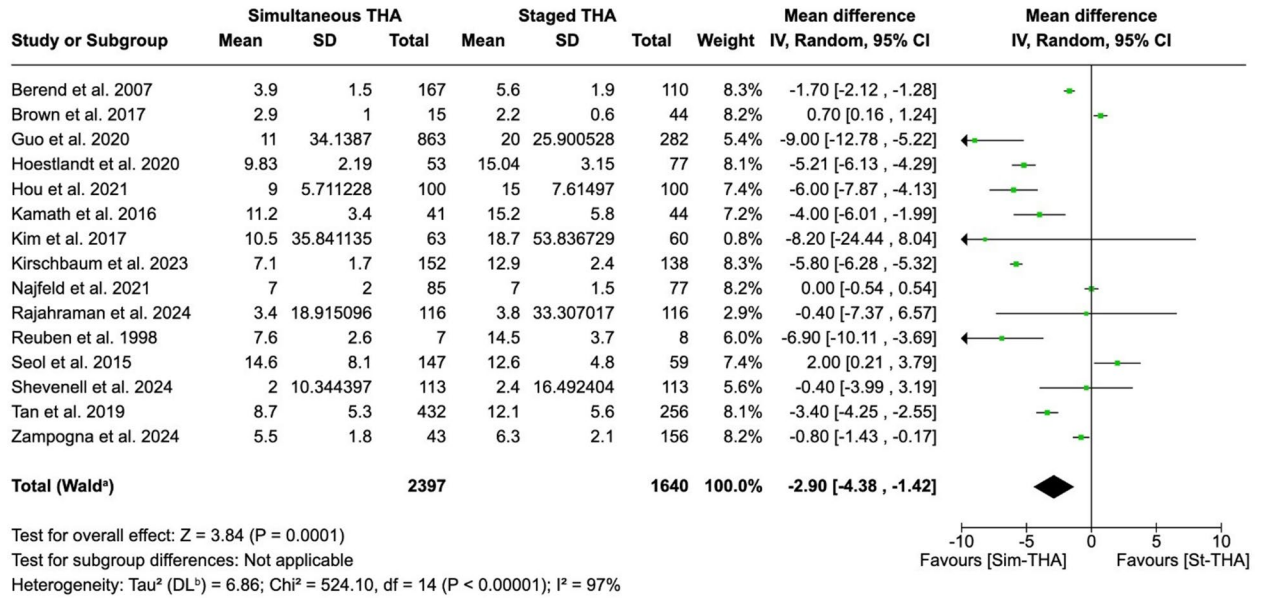

Fig. 3 Forest plot comparing LOS of sim-THA versus st-THA showing significant differences between the sim-THA and st-THA groups regarding LOS, with shorter stays in the case of patients undergoing sim-THA (MD −2.90, 95% CI −4.38 to −1.42; participants = 4037; studies = 15; $I^2 = 97\%$; $P = 0.0001$)

was no significant difference between sim-THA and st-THA (4/3092, 0.13% sim-THA versus 8/5423, 0.14% st-THA, OR 1.01, 95% CI 0.31–3.28) (Table 3).

Discharge home dispositions were lower in the group undergoing sim-THA compared with st-THA (102/182, 56% sim-THA versus 131/154, 85% st-THA, OR 0.28, 95% CI 0.16–0.48) (Fig. 5).

Finally, quality of life was assessed using different functionality scores (such as the HHS or JOA score) and pain scales (such as PROM pain or JHEQ pain). The values of these scales were higher in the sim-THA group than in the st-THA group (SMD 0.37, 95% CI 0.20–0.53) at the different follow-up times of the studies (Fig. 6a). The same results were obtained when pain scores outcomes were compared (SMD 0.19, 95% CI 0.04–0.33) (Fig. 6b).

Sensitivity analyses

Sensitivity analysis revealed minimal result variations when excluding the highest-weighted study, only pain and revisions when sim-THA is compared with st-THA (Table 4).

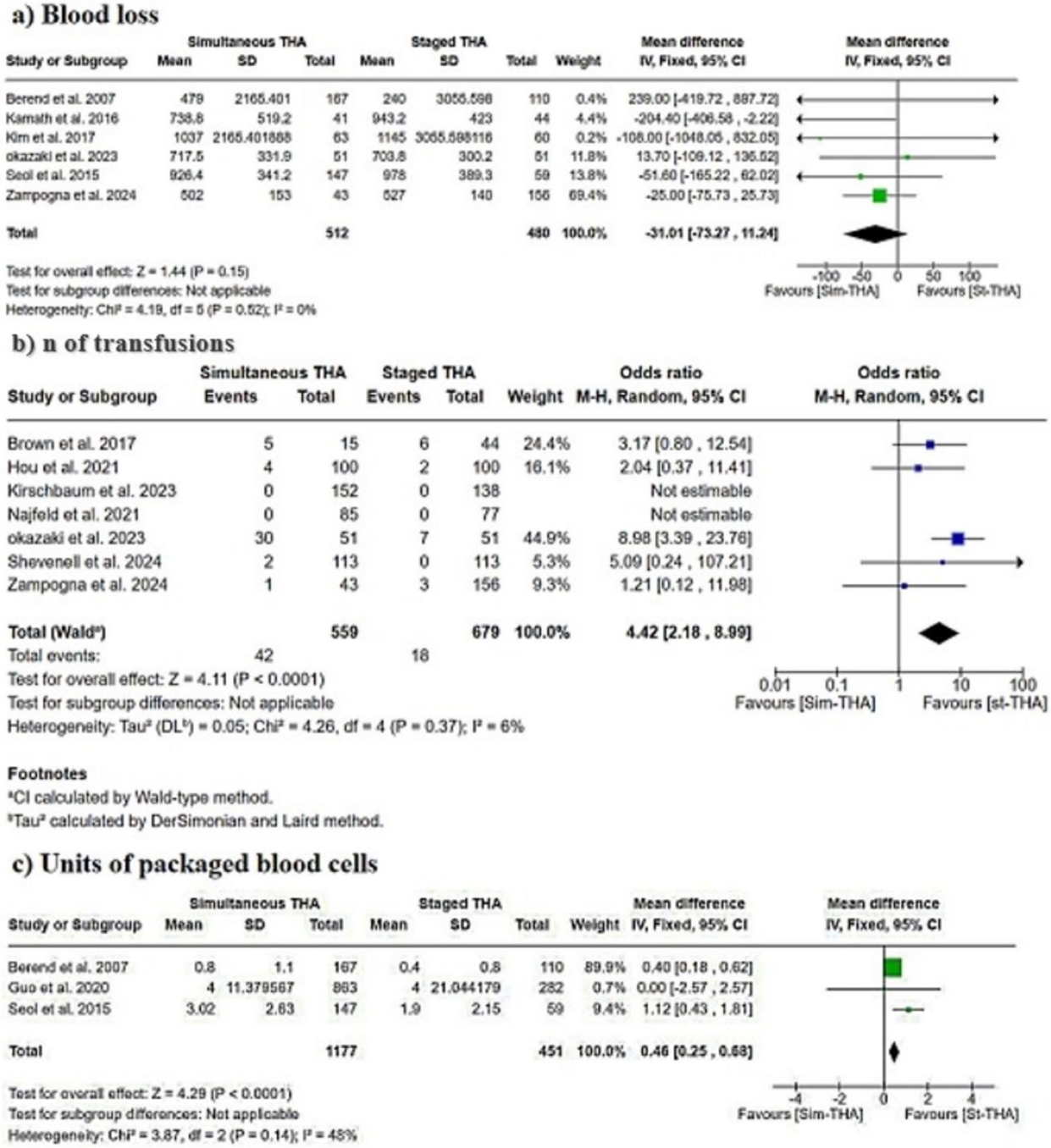

Fig. 4 Forest plot comparing bleeding complications of sim-THA versus st-THA. Blood loss **a** was not significant when sim-THA and st-THA groups were compared; there were significant differences in the case of blood transfusion analysis: in the case of number of transfusions, **b** (OR 4.42, 95% CI 2.18–8.99; participants = 1238; studies = 7; $I^2 = 6\%$; $p < 0.0001$) and units of packaged blood cells, **c** (OR 0.46, 95% CI 0.25–0.68; participants = 1628; studies = 3; $I^2 = 48\%$; $p < 0.0001$) with lower blood transfusion in st-THA

Table 3 Complications

Subgroup	*N* studies	*N* patients	Fixed effect model (OR 95% CI)	I_2 (%)	*p*-Value
Readmissions	5	2419	OR 0.58 (0.23–1.44)	36	$P=0.24$
Revisions	6	8673	OR 0.44 (0.36–0.53)	69	$p<0.00001$
Mortality	4	8515	OR 1.01 (0.31–3.28)	0	$p=0.98$

*CI, confidence interval; OR, odds ratio; THA, total hip arthroplasty

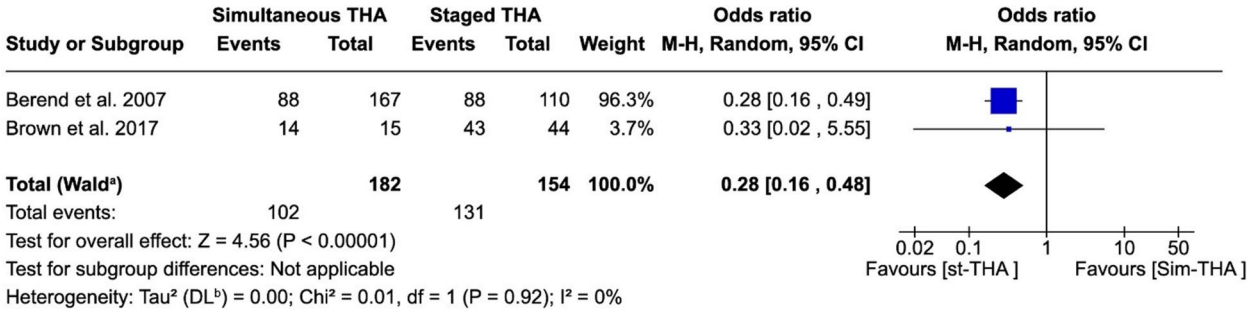

Fig. 5 Forest plot of home discharge dispositions. It was lower in the group undergoing staged bilateral THA (OR 0.28, 95% CI 0.16–0.48; participants = 338; studies = 2; $I^2=0\%$; $p<0.00001$) than in the case of simultaneous bilateral THA

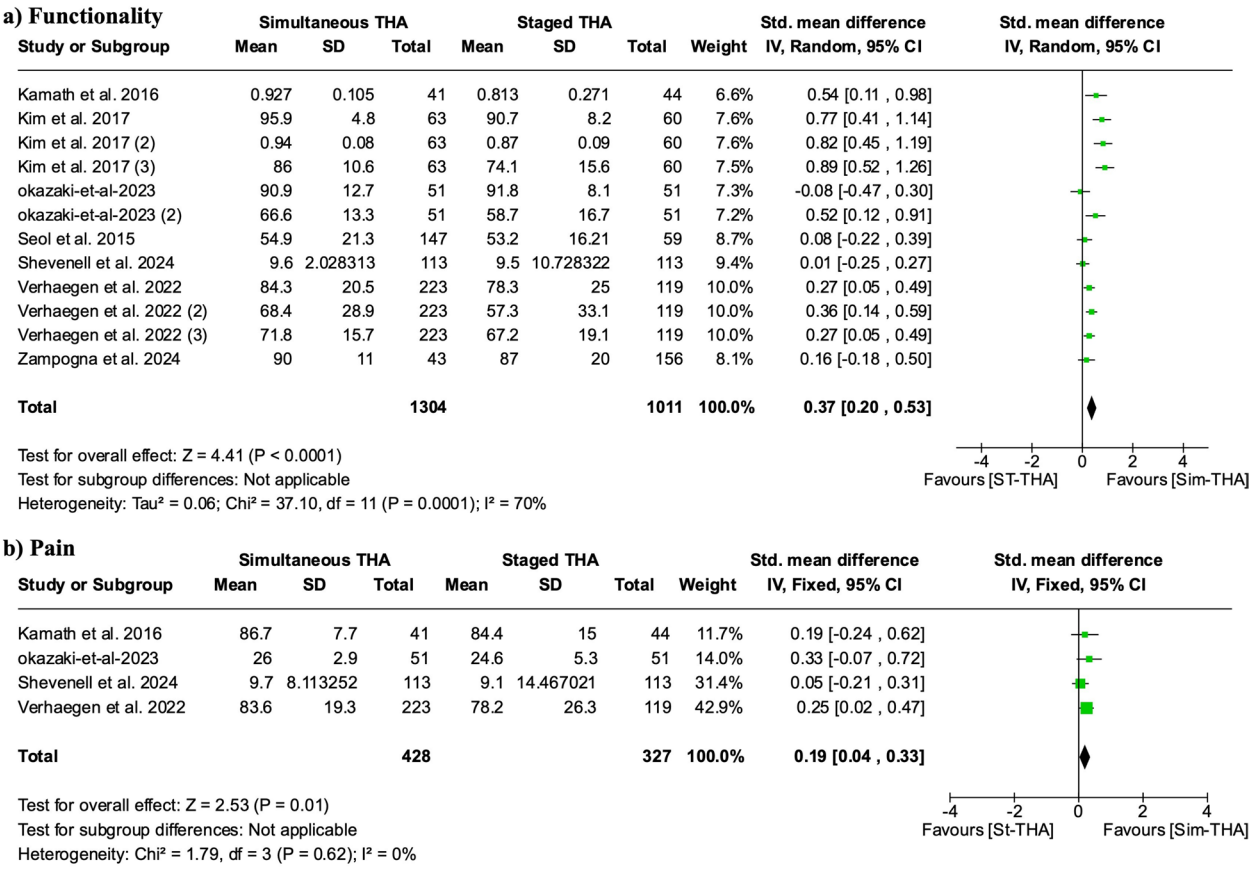

Fig. 6 Forest plot showing the assessment of quality of life. Values were significantly higher in the sim-THA group than in the st-THA group (SMD 0.37, 95% CI 0.20–0.53; participants = 1283; studies = 7; $I^2=70\%$; $p<0.0001$) for functionality (**a**) and pain scores (**b**) (SMD 0.19, 95% CI 0.04–0.33; participants = 755; studies = 4; $I^2=0\%$; $p=0.01$)

Table 4 Sensitivity analyses excluding the study with the highest weight

Effect size	*n* participants	Fixed effect model (SMD 95% CI; MD 95% CI; OR 95% CI)	I^2 (%)
Total cost	1107	SMD −0.64, 95%CI −1.09 to −0.18	91
LOS	3760	MD −3.04, 95%CI −4.80 to −1.28	97
Blood loss	793	MD −44.63, 95% CI 120.96–31.70	0
Blood transfusion (number of transfusions)	1136	OR 2.49, 95% CI 0.99–6.29	0
Blood transfusion (units of packaged blood cells)	1351	MD 1.04, 95% CI 0.37–1.71	0
Hb drop	349	MD 0.26, 95% CI −3.36 to 3.89	96
Readmissions	1274	OR 0.47, 95% CI 0.15–1.54	37
Revisions	1104	OR 1.72, 95% CI 0.85–3.47	44
Mortality	946	OR 0.97, 95% CI 0.12–7.62	0
Functionality	1289	SMD 0.40, 95% CI 0.15–0.65	78
Pain	413	SMD 0.15, 95% CI −0.05 to 0.34	0

*CI, confidence interval; LOS, length of stay; MD, mean difference; SMD, standardized mean difference; OR, odds ratio; THA, total hip arthroplasty

Publication bias

The efficacy, safety, and cost outcomes showed publication bias, as the funnel plots showed signs of asymmetry and a clustered distribution of studies at the top of the funnel shape (Supplementary Fig. 1).

GRADE

The certainty of the included effect sizes according to GRADE is presented in Table 5. In the case of total cost and functionality, the certainty was moderate, but LOS, readmissions, and revisions were low. The studies mainly presented a high risk of publication bias detected through funnel plots, and to a lesser extent, serious inconsistency.

Discussion

THA analysis revealed cost-effectiveness, shorter LOS, reduced revisions, higher functionality, and lower pain scores in sim-THA patients than in those undergoing st-THA.

The indications for simultaneous bilateral surgery have not been reported in most studies. Tan et al. [10] established criteria for simultaneous surgeries that included hemoglobin levels above 130 g/L in women and 150 g/L in men, American Society of Anesthesiologists (ASA) classification of I or II, and good nutritional status. However, the inclusion criteria for sim-THA were not specified in some studies, and baseline characteristics such as age and comorbidities varied, typically showing younger age and fewer comorbidities in patients undergoing bilateral surgery [28]. A higher percentage of these patients also had an ASA classification of I [35]. This suggests that sim-THA is often reserved for patients with better physical conditions. These restrictive selection criteria (ASA I–II and hemoglobin > 130–150 g/L) limit the generalizability of our findings by excluding many patients with comorbidities, anemia, and moderate surgical risk. This bias toward healthier patients may have enhanced the safety profile and outcomes of simultaneous THA, potentially overstating the benefits and underestimating the risks compared with real-world practice. Other studies, such as those by Seol et al. [33], which matched baseline characteristics to eliminate differences, showed no significant differences in functionality or complications but reported significantly lower costs in the simultaneous group.

Reuben et al. observed that patients with a higher ASA classification incurred higher costs, as did older patients [31].

The total costs were significantly lower in the simultaneous group than in the staged group, and several factors potentially explain these differences. Early initiation of rehabilitation due to a lower rate of home discharge in the simultaneous group and reduced overall hospital stays, leading to less resource consumption, are among the plausible reasons for this. Another cost-related factor is the reimbursement policy, as outlined by Berend et al., who advised against sim-THA because of reduced reimbursements for hospitals and surgeons stemming from medical complications [8]. Phillips et al. noted that the higher costs of staged surgeries could be attributed to fee discounts for surgeons if patients underwent simultaneous total joint arthroplasty [37]. Each surgical intervention represented a comprehensive 90-day care episode with complete associated costs. Each episode involves administrative expenses, facility usage, and potentially different hospitalization and rehabilitation periods.

Moreover, Phillips et al. observed that complications in the simultaneous group, although infrequent, were more costly [37]. Sim-THA showed comparable mortality and readmission rates, with slightly different home-discharge patterns. It has been suggested that sim-THA may lead to more thromboembolic problems; however, the type of antithrombotic treatment used is often not considered [12]. Wu et al. mentioned that erythropoietin (EPO) plus tranexamic acid reduces the need for transfusion and the risk of deep vein thrombosis and pulmonary embolism [38].

Table 5 GRADE assessment of the quality of the evidence and the strength of the recommendations

Certainty assessment							Number of patients		Effect		Certainty	Importance
Number of studies	**Study design**	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other considerations**	**Simultaneous THA**	**Staged THA**	**Relative (95% CI)**	**Absolute (95% CI)**		
Total cost												
9	Nonrandomized studies	Not serious[a]	Not serious	Not serious	Not serious	Publication bias strongly suspected Strong association[b]	8900	729	–	SMD **0.54 SD lower** (0.92 lower to 0.16 lower)	⨁⨁◯◯ Low[a,b]	CRITICAL
Length of stay												
15	Nonrandomized studies	Not serious	Not serious	Not serious	Not serious	Publication bias strongly suspected[b]	2394	1640	–	MD **2.9 lower** (4.38 lower to 1.42 lower)	⨁◯◯◯ Very low[b]	CRITICAL
Functionality												
7	Nonrandomized studies	Not serious	Not serious	Not serious	Not serious	Publication bias strongly suspected Strong association[b]	1304	1011	–	SMD **0.37 SD higher** (0.2 higher to 0.53 higher)	⨁⨁◯◯ Low[b]	IMPORTANT
Readmissions												
5	Nonrandomized studies	Not serious	Serious[c]	Not serious	Not serious	Publication bias strongly suspected[b]	21/1238 (1.7%)	79/1181 (6.7%)	**OR 0.58** (0.23–1.44)	**27 fewer per 1000** (from 51 fewer to 27 more)	⨁◯◯◯ Very low[b,c]	IMPORTANT
Revisions												
6	Nonrandomized studies	Not serious	Serious[c]	Not serious	Not serious	Publication bias strongly suspected[b]	147/3401 (4.3%)	512/5272 (9.7%)	**OR 0.88** (0.72–1.06)	**11 fewer per 1000** (from 25 fewer to 5 more)	⨁◯◯◯ Very low[b,c]	IMPORTANT

[a] Medium risk of bias assessed by MINORS

[b] Publication bias detected through the Funnel Plots

[c] Serious inconsistency assessed by the Forest Plot

*CI, confidence interval; MD, mean difference; OR, odds ratio; SMD, standardized mean difference

Verhaegen et al. observed that the economic compensation for performing simultaneous surgeries does not balance out, as a 50% reduction applies to the second intervention [35].

Additionally, a higher number of transfusions during simultaneous surgeries could potentially lead to increased costs [10]. Tan et al. also discussed that being accustomed to the procedure from the first intervention could influence expectations and thus patient satisfaction for the second intervention, even though staged surgery showed worse pain and functionality outcomes [10]. Potential reasons for more complications in simultaneous surgeries could include a longer LOS, as observed by Goh et al., who noted a higher LOS and more transfusions in sim-THA [39].

Sim-THA showed significantly better outcomes in terms of functionality and lower pain than st-THA. Sim-THA offers significant advantages by minimizing anesthetic exposure risks, particularly for elderly [40] or high-risk patients, and enabling comprehensive rehabilitation through a single recovery period, potentially reducing complications and improving overall functional outcomes [41]. From a psychological perspective, patients undergoing a single surgery and recovery might experience less anxiety [42] and a better mood than those anticipating a second surgical procedure, which can significantly influence their pain perception and motivation during rehabilitation. However, the findings of this study were limited by the inclusion of different follow-up durations.

Another factor influencing the results is surgical expertise and institutional volume. Kirschbaum et al. [26] demonstrated that outcomes for sim-THA were comparable to staged procedures only when performed by high-volume surgeons. Because sim-THA is concentrated in specialized centers, the generalizability of our findings to lower-volume institutions is limited.

In sim-THA, there were no significant differences in blood loss between the groups; however, the number of transfusions was significantly higher in that group than in the staged group. Sim-THA showed comparable blood loss despite higher transfusion rates, with potential variations influenced by cementation techniques. Cemented prostheses tend to bleed less, subside less, and have fewer periprosthetic fractures than noncemented prostheses. In cases of bilateral procedures that cause increased bleeding, for example, in patients with transfusion-related issues or those affected by hematologic diseases, one possible option to consider is whether the use of cemented prostheses could reduce blood loss, as described by Lamo-Espinosa et al. [43].

A different meta-analysis of simultaneous bilateral arthroplasties demonstrated lower infection rates and shorter hospital stays but an increased risk of thromboembolism, neurological complications, and mortality [11]. However, this analysis did not consider the costs. Thès et al. [44] found greater cost-effectiveness of simultaneous total knee arthroplasty for patients with hemophilia, suggesting that indications might need to be more individualized. Hou et al. noted lower costs when evaluating THA and total knee arthroplasty together than with the staged approach [22].

Baseline differences between sim-THA and st-THA patients, particularly age, ASA class, and comorbidities, likely influenced pooled outcomes. Although some included studies adjusted or matched for these characteristics, others did not, which restricts interpretation of the relative effectiveness of the two procedures.

Our meta-analysis employed systematic approaches to evaluate the quality of evidence; however, several important methodological considerations warrant discussion. Risk of bias assessment using funnel plot analysis revealed publication bias across multiple outcomes, particularly for cost and functional measures, suggesting the potential overrepresentation of positive findings. This publication bias was systematically factored into our GRADE quality assessments, resulting in moderate certainty for the primary outcomes and low certainty for the secondary outcomes.

Sensitivity analysis demonstrated remarkable consistency in the primary findings, with pooled effect estimates remaining stable when individual studies were excluded. However, significant heterogeneity ($I^2 > 75\%$) across several outcomes reflected substantial between-study variability, which may limit interpretation. The predominance of observational studies in this clinical area fundamentally constrains the quality of evidence, necessitating cautious interpretation of pooled estimates and emphasizing the need for future randomized controlled trials to confirm these preliminary findings.

The clinical implementation of our findings requires careful consideration of individual patient factors and broader health system contexts. From a practical standpoint, sim-THA offers compelling advantages for appropriately selected patients, particularly those meeting strict criteria (ASA I–II, hemoglobin > 13 g/dL), who can benefit from reduced overall costs, and enhanced functional outcomes through a single surgical episode. However, clinical decision-making must account for individual patient risk profiles, with particular attention to transfusion requirements and thromboembolic risks, which may be increased during simultaneous procedures.

Variations in the health system significantly influence the feasibility and economic advantages of sim-THA. Different financing models across countries substantially impact cost-effectiveness calculations, as reimbursement

policies, facility fees, and physician compensation structures vary considerably across countries. Health systems with bundled payment models may find sim-THA more economically attractive because of reduced administrative overhead and comprehensive care episodes, whereas fee-for-service systems might favor staged approaches given the current reimbursement structures that often penalize simultaneous procedures with reduced payments for secondary interventions. Additionally, infrastructure requirements differ between approaches, with sim-THA demanding higher-capacity operating rooms, specialized post-anesthesia care units, and coordinated rehabilitation services that may not be available in all healthcare settings. These health system considerations must be integrated with patient-specific factors to optimize clinical decision-making and ensure the sustainable implementation of simultaneous bilateral procedures.

This meta-analysis has several limitations. First, the included studies lacked uniform inclusion criteria, leading to inconsistencies in participant selection. Additionally, the absence of standardized follow-up measures for PROMs complicates outcome comparisons. An important limitation of this meta-analysis is the low-to-very-low certainty of evidence for most outcomes according to our GRADE assessment. This primarily reflects the observational study designs, suspected publication bias, and inconsistencies in outcomes. These limitations significantly reduce our confidence in the effect estimates and highlight the need for high-quality randomized controlled trials.

A critical limitation of our meta-analysis is the inherent patient-selection bias in studies comparing simultaneous and staged bilateral THA. Sim-THA is often preferentially selected for healthier and younger patients, with many included studies employing restrictive inclusion criteria, particularly ASA classification I–II and hemoglobin levels > 13 g/dL, which systematically excluded patients with comorbidities, anemia, or elevated surgical risk. This selection bias toward healthier patients with lower ASA classifications and fewer comorbidities may partly explain the favorable outcomes observed for sim-THA in terms of cost, functionality, and complication rates. Consequently, this selection bias significantly limits the external validity of our findings to the general population requiring bilateral THA, and these differences must be carefully considered when interpreting pooled estimates. It should be noted that our definition of "complications" was limited to readmissions, revisions, and mortality, as specified in the Methods section. This differs from the broader orthopedic literature definition, which typically includes clinical adverse events, such as deep vein thrombosis, infections, and periprosthetic fractures. Our analysis was constrained by the complications consistently reported across the included studies, and the absence of data on other traditional orthopedic complications represents a limitation when interpreting our safety findings. The retrospective nature of the data, including older studies, may reduce the relevance of the findings to current clinical practice owing to the evolving practices and technologies. The reliance on retrospective studies rather than randomized controlled trials (RCTs) increases the potential for bias and confounding variables in the results. Many studies did not separate the results by approach or adjust for confounding factors, hindering a thorough sensitivity analysis. Furthermore, the influence of the surgical approach and surgeon experience has not been adequately considered in previous studies. Some studies failed to report the time intervals between staged surgeries, and inconsistencies regarding the impact of surgical approaches on outcomes remain unclear. Another limitation of our study is the lack of standardized inclusion criteria across the included studies, which limited comparability and introduced heterogeneity into the pooled analysis. Furthermore, only four studies reported the perioperative use of tranexamic acid (TXA), a widely adopted strategy for reducing blood loss during THA. The underreporting of TXA use may have contributed to the higher transfusion rates observed in the sim-THA group. Future research incorporating standardized perioperative blood management protocols, including TXA administration, is warranted to provide a more accurate comparison of transfusion rates between sim-THA and st-THA groups. None of the studies assessed return-to-work data to provide valuable insights into indirect costs or patient recovery. Moreover, the costs of the studies were unclear. Due to that, they have to be standardized using SMD, trying to minimize potential biases related to variations in the specific cost components considered in each study, and as a consequence, mean or median cost of the surgeries has not been provided. In the analysis of dichotomous variables, it was assumed that events were related to specific patients, but some patients may have experienced multiple events. The heterogeneous reporting of dichotomous outcomes across studies represents a significant methodological limitation. The inability to standardize whether events were counted per patient or per occurrence limited the precision of our pooled estimates for complications, readmissions, and revisions. Additionally, subgroup analyses stratified by key variables, such as age, ASA classification, comorbidity, and surgical approach, could not be systematically performed due to heterogeneity in reporting and limited availability of these stratified data across the included studies. This limitation affects the generalizability of our findings to specific patient subgroups and represents an important area for future studies. As indicated in the discussion,

the inclusion criteria for sim-THA were not specified in some studies, and baseline characteristics such as age and comorbidities varied, typically showing younger age and fewer comorbidities in patients undergoing bilateral surgery. This creates a limitation that should be considered in future research. Finally, the lack of consideration of country-specific differences in surgical implementation and outcomes limits the generalizability of our findings to other countries.

Conclusions

The findings revealed that sim-THA is associated with lower overall costs and shorter hospital stays, alongside enhanced quality-of-life outcomes characterized by higher functionality and reduced pain scores. Notably, the analysis indicated that sim-THA resulted in fewer revisions than st-THA. Nevertheless, the number of transfusions was notably higher in the sim-THA group. However, these findings should be interpreted with caution, given the restrictive patient selection criteria (ASA I–II, Hb > 13 g/dL) employed in many studies, which limit generalizability to higher-risk patients commonly encountered in clinical practice, the heterogeneity of patients across the studies, and limited reporting of TXA use that reduces comparability.

Abbreviations

ASA	American Society of Anesthesiologists
CI	Confidence interval
EPO	Erythropoietin
GRADE	Grading of Recommendations Assessment, Development, and Evaluation
HHS	Harris Hip Score
JOA	Japanese Orthopaedic Association
JHEQ	Japanese Hip Disease-Specific Quality of Life Questionnaire
MD	Mean difference
MINORS	Methodological Index for Non-Randomized Studies
OR	Odds ratio
PROM	Patient-Reported Outcome Measure
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses
SMD	Standardized mean difference
st-THA	Staged bilateral total hip arthroplasty
sim-THA	Simultaneous bilateral total hip arthroplasty
THA	Total hip arthroplasty
TXA	Tranexamic acid

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s10195-026-00904-y.

Additional file1 (DOCX 32 kb)

Additional file2 (DOCX 17 kb)

Additional file3 (DOCX 1094 kb)

Acknowledgements

Not applicable.

Author contributions

Conceptualization: F.S., J.H., J.M.L.-E., M.B., and G.M.; data curation: F.S., J.H., J.M.L.-E., M.B., and G.M.; formal analysis: F.S., J.H., J.M.L.-E., M.B., and G.M.; funding acquisition: N.A.; investigation: F.S., J.H., J.M.L.-E., M.B., and G.M.; methodology: F.S., J.H., J.M.L.-E., M.B., and G.M.; project administration: N.A.; resources: F.S., J.H., J.M.L.-E., M.B., and G.M.; software and supervision: F.S. and G.M.; validation: F.S., J.H., J.M.L.-E., M.B., and G.M.; visualization: F.S., J.H., J.M.L.-E., M.B., and G.M.; roles/writing—original draft: F.S., J.H., J.M.L.-E., M.B., and G.M.; and writing—review and editing: F.S., J.H., J.M.L.-E., M.B., and G.M.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Availability of data and materials

The data in the study were obtained from PubMed, EMBASE, Scopus, and the Cochrane Collaboration Library.

Declarations

Ethics approval and consent to participate

Not applicable. This systematic review and meta-analysis does not include individual person's data, images, or videos requiring consent for publication.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Soler Trauma Clinic, Elche, Spain. [2]Tumor and Hip Surgery Unit, Vithas 9 de Octubre Hospital, Valencia, Spain. [3]Institute for Research on Musculoskeletal Disorders, Catholic University of Valencia, Valencia, Spain. [4]Department of Basic Medical Sciences, Catholic University of Valencia San Vicente Mártir, 46001 Valencia, Spain. [5]La Fe University and Polytechnic Hospital, Valencia, Spain.

Received: 29 May 2025 Accepted: 23 December 2025
Published online: 19 January 2026

References

1. Borsinger TM, Chandi SK, Puri S, Debbi EM, Blevins JL, Chalmers BP (2023) Total hip arthroplasty: an update on navigation, robotics, and contemporary advancements. HSS J 19:478–485. https://doi.org/10.1177/15563316231193704
2. Xi JY, Lin X, Hao YT (2022) Measurement and projection of the burden of disease attributable to population aging in 188 countries, 1990–2050: a population-based study. J Glob Health 12:04093. https://doi.org/10.7189/jogh.12.04093
3. Park JW, Won SH, Moon SY, Lee YK, Ha YC, Koo KH (2021) Burden and future projection of revision total hip arthroplasty in South Korea. BMC Musculoskelet Disord 22:375. https://doi.org/10.1186/s12891-021-04235-3
4. Sayeed SA, Johnson AJ, Jaffe DE, Mont MA (2012) Incidence of contralateral THA after index THA for osteoarthritis. Clin Orthop Relat Res 470:535–540. https://doi.org/10.1007/s11999-011-2110-9
5. Capra R, Bini SA, Bowden DE, Etter K, Callahan M, Smith RT et al. (2019) Implementing a perioperative efficiency initiative for orthopedic surgery instrumentation at an academic center: a comparative before-and-after study. Medicine (Baltimore) 98:e14338. https://doi.org/10.1097/MD.0000000000014338
6. Fong AJ, Smith M, Langerman A (2016) Efficiency improvement in the operating room. J Surg Res 204:371–383. https://doi.org/10.1016/j.jss.2016.04.054
7. Brown ML, Plate JF, Holst DC, Bracey DN, Bullock MW, Lang JE (2017) A retrospective analysis of the merits and challenges associated with simultaneous bilateral THA using the direct anterior approach. Hip Int 27:169–174. https://doi.org/10.5301/hipint.5000449

8. Berend KR, Lombardi AV Jr, Adams JB (2007) Simultaneous vs staged cementless bilateral total hip arthroplasty: perioperative risk comparison. J Arthroplasty 22:111–115. https://doi.org/10.1016/j.arth.2007.03.043
9. Yakkanti RR, Syros A, Reddy GB, D'Apuzzo MR (2024) In-hospital complications and costs of simultaneous bilateral total hip arthroplasty: the case for selection and potential cost savings. Arthroplast Today 25:101294. https://doi.org/10.1016/j.artd.2023.101294
10. Tan Z, Cao G, Wang G, Zhou Z, Pei F (2019) Total hospital cost, length of stay, and complications between simultaneous and staged bilateral total hip arthroplasty: a nationwide retrospective cohort study in China. Medicine (Baltimore) 98:e14687. https://doi.org/10.1097/MD.0000000000014687
11. Ramezani A, Ghaseminejad Raeini A, Sharafi A, Sheikhvatan M, Mortazavi SMJ, Shafiei SH (2022) Simultaneous versus staged bilateral total hip arthroplasty: a systematic review and meta-analysis. J Orthop Surg Res 17:392. https://doi.org/10.1186/s13018-022-03281-4
12. Babis GC, Sakellariou VI, Johnson EO, Soucacos PN (2011) Incidence and prevention of thromboembolic events in one stage bilateral total hip arthroplasty: a systematic review. Curr Vasc Pharmacol 9:24–32. https://doi.org/10.2174/157016111793744751
13. Huang L, Xu T, Li P, Xu Y, Xia L, Zhao Z (2019) Comparison of mortality and complications between bilateral simultaneous and staged total hip arthroplasty: a systematic review and meta-analysis. Medicine 98:e16774. https://doi.org/10.1097/MD.0000000000016774
14. Tsiridis E, Pavlou G, Charity J, Tsiridis E, Gie G, West R (2008) The safety and efficacy of bilateral simultaneous total hip replacement: an analysis of 2063 cases. J Bone Joint Surg Br 90:1005–1012. https://doi.org/10.1302/0301-620X.90B8.20552
15. Migliorini F, Randelli F, Di Martino A, Rivera F (2025) Writing for JOOT: raising standards in clinical research and evidence synthesis. J Orthop Traumatol 26:52. https://doi.org/10.1186/s10195-025-00868-5
16. Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, Chipponi J (2003) Methodological index for non-randomized studies (MINORS): development and validation of a new instrument. ANZ J Surg 73:712–716. https://doi.org/10.1046/j.1445-2197.2003.02748.x
17. Lorente A, Pelaz L, Palacios P, Benlloch M, de la Rubia Ortí JE, Barrios C et al. (2024) Predictive factors of functional outcomes and quality of life in patients with ankle fractures: a systematic review. J Clin Med 20:1188. https://doi.org/10.3390/jcm13051188
18. Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ et al. (2023) Cochrane Handbook for Systematic Reviews of Interventions version 6.4 (updated August 2023). www.training.cochrane.org/handbook . Accessed 18 July 2024
19. Guyatt GH, Thorlund K, Oxman AD, Walter SD, Patrick D, Furukawa TA et al. (2013) GRADE guidelines: 13. Preparing summary of findings tables and evidence profiles—Continuous outcomes. J Clin Epidemiol 66(2):173–183. https://doi.org/10.1016/j.jclinepi.2012.08.001
20. Calabro L, Yong M, Whitehouse SL, Hatton A, de Steiger R, Crawford RW (2020) Mortality and implant survival with simultaneous and staged bilateral total hip arthroplasty: experience from the Australian Orthopedic Association National Joint Replacement Registry. J Arthroplasty 35:2518–2524. https://doi.org/10.1016/j.arth.2020.04.027
21. Guo SJ, Shao HY, Huang Y, Yang DJ, Zheng HL, Zhou YX (2020) Retrospective cohort study comparing complications, readmission, transfusion, and length of stay of patients undergoing simultaneous and staged bilateral total hip arthroplasty. Orthop Surg 12:233–240. https://doi.org/10.1111/os.12617
22. Hoestlandt A, Dartus J, Delay C, Martinot P, Girard J (2020) Is the economic and social cost of one-stage bilateral hip resurfacing lower than two-stage procedures? Retrospective case-control study of 260 hips. Orthop Traumatol Surg Res 106:535–542. https://doi.org/10.1016/j.otsr.2020.01.011
23. Hou JF, Hu C, Zhang Y, Tian LQ, Liu YZ, Zhang C et al. (2021) Cost analysis of staged versus simultaneous bilateral total knee and hip arthroplasty using a propensity score matching. BMJ Open 11:e041147. https://doi.org/10.1136/bmjopen-2020-041147
24. Kamath AF, Monteiro EL, Spranger A, Impellizzeri F, Leunig M (2016) Simultaneous versus staged bilateral direct anterior total hip arthroplasty: are early patient-centered outcomes equivalent? Acta Orthop Belg 82:497–508
25. Kim SC, Lim YW, Jo WL, Park DC, Lee JW, Kang WW et al. (2017) Surgical accuracy, function, and quality of life of simultaneous versus staged bilateral total hip arthroplasty in patients with osteonecrosis of the femoral head. BMC Musculoskelet Disord 18:266. https://doi.org/10.1186/s12891-017-1605-2
26. Kirschbaum S, Hube R, Perka C, Ley C, Rosaria S, Najfeld M (2023) Bilateral simultaneous hip arthroplasty shows comparable early outcome and complication rate as staged bilateral hip arthroplasty for patients scored ASA 1–3 if performed by a high-volume surgeon. Int Orthop 47:2571–2578. https://doi.org/10.1007/s00264-023-05871-1
27. Lindberg-Larsen M, Joergensen CC, Husted H, Kehlet H (2013) Simultaneous and staged bilateral total hip arthroplasty: a Danish nationwide study. Arch Orthop Trauma Surg 133:1601–1605. https://doi.org/10.1007/s00402-013-1829-z
28. Najfeld M, Kalteis T, Spiegler C, Ley C, Hube R (2021) 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 10:4507. https://doi.org/10.3390/jcm10194507
29. Okazaki T, Imagama T, Tanaka H, Shiigi E, Hirata K, Kaneoka T et al. (2023) Comparison of simultaneous versus staged bilateral total hip arthroplasty via the direct anterior approach: a propensity score matched analysis. J Orthop Surg (Hong Kong) 31:10225536231180328. https://doi.org/10.1177/10225536231180328
30. Rajahraman V, Ashkenazi I, Thomas J, Bosco J, Davidovitch R, Schwarzkopf R (2024) Simultaneous versus staged bilateral total hip arthroplasty: a matched cohort analysis of revenue and contribution margin. J Arthroplasty S0883–5403(24):00413–00415. https://doi.org/10.1016/j.arth.2024.04.065
31. Reuben JD, Meyers SJ, Cox DD, Elliott M, Watson M, Shim SD (1998) Cost comparison between bilateral simultaneous, staged, and unilateral total joint arthroplasty. J Arthroplasty 13:172–179. https://doi.org/10.1016/S0883-5403(98)90095-X
32. Schlegelmilch M, Rashiq S, Moreau B, Jarrín P, Tran B, Chuck A (2017) Cost-effectiveness analysis of total hip arthroplasty performed by a Canadian short-stay surgical team in Ecuador. Adv Orthop 2017:5109895. https://doi.org/10.1155/2017/5109895
33. Seol JH, Park KS, Yoon TR (2015) Postoperative complications and cost-effectiveness of simultaneous and staged bilateral total hip arthroplasty using a modified minimally invasive two-incision technique. Hip Pelvis 27:77–82. https://doi.org/10.5371/hp.2015.27.2.77
34. Shevenell BE, Mackenzie JA, Tanasijevic K et al. (2024) Bilateral total hip arthroplasty: outcomes of staged versus simultaneous procedures performed using an anterior-based muscle-sparing approach. J Arthroplasty 39:979-984.e3. https://doi.org/10.1016/j.arth.2023.10.048
35. Verhaegen JCF, Schreiber A, Balust C, Menon A, Dille J, Corten K (2022) Perioperative operating room efficiency can make simultaneous bilateral total hip arthroplasty cost-effective: a proposal for a value-sharing model. Arthroplasty Today 18:202-211.e1. https://doi.org/10.1016/j.artd.2022.09.009
36. Zampogna B, Papalia GF, Laudisio A, Berton A, Zampoli A, Buccolieri L et al. (2024) Simultaneous vs staged bilateral hip arthroplasty: monocentric analysis of satisfaction rate and complications. Eur J Orthop Surg Traumatol. https://doi.org/10.1007/s00590-024-03958-y
37. Phillips JLH, Rondon AJ, Gorica Z, Fillingham YA, Austin MS, Courtney PM (2018) No difference in total episode-of-care cost between staged and simultaneous bilateral total joint arthroplasty. J Arthroplasty 33:3607–3611. https://doi.org/10.1016/j.arth.2018.08.035
38. Wu YG, Zeng Y, Shen B, Si HB, Cao F, Yang TM et al. (2016) Combination of erythropoietin and tranexamic acid in bilateral simultaneous total hip arthroplasty: a randomised, controlled trial. Hip Int 26:331–337. https://doi.org/10.5301/hipint.5000356
39. Goh GS, Sutton RM, D'Amore T, Baker CM, Clark SC, Courtney PM (2022) A time-driven activity-based costing analysis of simultaneous versus staged bilateral total hip arthroplasty and total knee arthroplasty. J Arthroplasty 37:S742–S747. https://doi.org/10.1016/j.arth.2022.01.048
40. Sato K, Hatta T, Shinagawa K, Okuno H, Nobuta S (2022) Simultaneous reverse shoulder arthroplasty and open reduction with internal fixation for bilateral proximal humerus fractures in the elderly: a report of two cases. Cureus 14:e28777. https://doi.org/10.7759/cureus.28777

41. Tokuhiro T, Urita A, Kameda Y, Motomiya M, Watanabe N, Iwasaki N (2022) Simultaneous bilateral proximal humerus fractures treated with single-stage bilateral reverse shoulder arthroplasty. Case Rep Orthop 2022:2162331. https://doi.org/10.1155/2022/2162331
42. Accatino G, Monzio Compagnoni A, Grassi FA, Castelli A, Pasta G, Benazzo F et al. (2024) Bilateral total knee arthroplasty (TKA) in a one-stage procedure versus two-stage procedure: a retrospective study. Healthcare 12:1902. https://doi.org/10.3390/healthcare12181902
43. Lamo-Espinosa J, Troncoso S, Valentí-Azcárate A, de Díaz Rada P, Valentí-Nín JR (2015) Clinical and radiological short-term complications after single-stage bilateral uncemented total hip arthroplasty. Musculoskelet Surg 99:67–73. https://doi.org/10.1007/s12306-014-0342-z
44. Thès A, Molina V, Lambert T (2015) Simultaneous bilateral total knee arthroplasty in severe hemophilia: a retrospective cost-effectiveness analysis. Orthop Traumatol Surg Res 101:147–150. https://doi.org/10.1016/j.otsr.2014.12.0

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.