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Systematic Review

Minimally Invasive versus Conventional Approaches in Total Hip Arthroplasty: A Systematic Review and Meta-Analysis of 47 Randomized Controlled Trials

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Abstract: Background: Recent meta-analyses have shown indifferent results between minimally invasive (MI) and conventional approach (CA) total hip arthroplasty (THA), not including the superior MI approach SuperPATH. The aim was to compare the surgical, functional and radiological outcomes and postoperative complications of MI THA, including SuperPATH, with CA THA in patients with hip disease or femoral neck fracture. Methods: PubMed, CNKI, The Cochrane Library, clinical trials, CINAHL and Embase were searched for randomized controlled trials (RCTs) comparing MI THA and CA THA up to 31 July 2023. Mean differences (MDs) with 95% confidence intervals (CIs) were calculated for continuous outcomes and odds ratios (ORs) with 95% CIs were calculated for dichotomous outcomes using a common effect/random effects model. The random effects model was used to present the results. Heterogeneity was assessed using the Cochrane Q test and the Higgins I^2 test. Results: A total of 47 RCTs with 4086 THAs in 4063 patients were included in our meta-analysis. MI THA showed better results than CA THA in 8 of 18 outcome parameters studied. MI THA showed a higher Harris Hip Score (HHS) than CA THA at 0–1.5, 3, 6 and ≥12 months postoperatively ($p < 0.01$; $p = 0.02$; $p = 0.01$; $p = 0.01$). MI THA showed an indifferent overall postoperative complication risk compared to CA THA ($p = 0.61$). Acetabular positioning angles were within the safe zone in all approaches. Conclusions: The results of the meta-analysis suggest that MI THA has several advantages over CA THA in terms of short-term surgical and functional outcomes, with equal postoperative complication rates. We cannot recommend a change in surgical approach based on our results, as the differences between the investigated approaches did not reach minimal clinically important differences. Level of evidence I: a systematic review of all relevant randomized controlled trials.

Keywords: MI approach; THA; conventional approach; minimally invasive approach; total hip arthroplasty; total hip replacement

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1. Introduction

Total hip arthroplasty (THA) is one of the most successful orthopedic procedures for restoring hip function and relieving pain. There has been an increasing trend in THA volumes in recent years and this is expected to continue in the future [1]. At the same time, there was a constant striving for even better surgical results. This improvement was to be achieved by introducing various minimally invasive (MI) approaches and surgical techniques. With the establishment and publicity of the procedure, the expectations of surgeons and informed patients of MI THA increased.

There are six conventional approaches (CAs) in hip arthroplasty: anterior, anterolateral, lateral, posterolateral, posterior and superior. MI surgical approaches to THA have been developed as modifications of known CAs to improve patient outcomes. The CAs were modified by trying to reduce the incision length and not incise the tendons and muscles in depth. Opponents have claimed that as a result of the limited view of the surgical field, MI THA could lead to misplacement of components or impaired fixation [2]. This is why MI THAs are considered potentially more prone to complications [2,3]. For this reason, some surgeons remain skeptical of improvement, resist switching and hold on to the good results of their CA THA. Proponents of MI THA claim that it results in less soft tissue trauma, which in turn leads to less blood loss and better functional outcomes. Other postoperative benefits include less pain, faster recovery and better cosmetic appearance [4,5].

The scientific discussion on the topic is still open and a final recommendation on the preference of MI THA cannot yet be given. It was assumed that MI approaches would result in a better THA outcome for the patient because they cause less tissue trauma compared to CAs. However, this assumption has not been scientifically proven [6–10]. The meta-analyses that have addressed this issue have a serious limitation in that they did not include the SuperPATH technique using a MI superior approach. Since SuperPATH has shown better initial short-term results compared to both CAs [11] and other MI approaches [12], it is reasonable to assume that including SuperPATH in the group of MI approaches would lead to different overall results compared to CAs. The aim of this study was to perform the first meta-analysis including SuperPATH in the MI THA group and comparing it with CA THA, using only randomized controlled trials (RCTs) as the primary data source.

The aim was to compare the surgical, functional and radiological outcomes and postoperative complications of MI THA, including SuperPATH, with CA THA in patients with hip disease or femoral neck fracture.

2. Materials and Methods

We formulated the following PICO (Population, Intervention, Control and Outcomes) question: In human participants with hip disorders such as osteoarthritis, femoral neck fracture, dysplasia, or femoral head avascular necrosis, is MI THA including SuperPATH superior to CA THA in terms of surgical, functional and radiological outcomes and postoperative complications?

We strictly followed the updated version of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines [13]. The PRISMA checklist is available in the Supplement (Table S1). The study protocol was registered in PROSPERO on 10 August 2022 (CRD42022350279). It should be noted that this meta-analysis was based on the same study protocol as a previously published meta-analysis by the same group of authors [14]. This is because the data extraction process found far too much interesting data on different outcome parameters to be summarized in a single article. The authors of this meta-analysis have some experience with meta-analyses in hip arthroplasty research. Similarities with previous publications are only due to the use of comparable high quality methods.

2.1. Data Sources and Search Strategies

PubMed, CNKI, The Cochrane Library, Clinical trials, CINAHL and Embase were searched up to 31 July 2023. Citations of related meta-analyses were screened for relevant articles. A BOOLEAN search strategy was constructed and adapted to the syntax of the databases used. No restrictions on publication language were applied. As MI approaches and techniques are constantly evolving, we arbitrarily excluded old studies published more than 15 years ago.

2.2. Study Screening and Selection

A stepwise screening process was carried out according to the PRISMA guidelines [13]. First, the titles and abstracts of the identified records were screened. The full texts of the screened articles were then assessed for eligibility. The decision to include each study was made by consensus between two reviewers (NR and PMK). The agreement between the reviewers was measured using the kappa coefficient (κ).

2.3. Inclusion Criteria

Types of studies:

- Only RCTs.

2.3.1. Types of Participants

- Human participants with hip disorders such as osteoarthritis, femoral neck fracture, dysplasia or avascular necrosis of the femoral head.

2.3.2. Types of Interventions

- MI THA or CA THA

Definition of MI THA: There is no uniform definition for MI approaches to THA. In general, the scientific community agrees on two conditions that must be met: an incision length $\leq$ 10 cm and, most importantly, preservation of muscles and tendons. In our meta-analysis, an approach with the related technique was defined as MI if it was known as MI per se in the literature or if it was explicitly referred to as MI in the individual RCTs. Mini-incision approaches that did not spare muscles or tendons were considered conventional rather than MI.

2.3.3. Types of Outcome Measures

I. Surgical outcome parameters: operation time, incision length, intraoperative blood loss, pain Visual Analogue Scale (VAS) [15];

II. Functional outcome: Harris Hip Score (HHS) [16];

III. Radiological outcome: acetabular cup abduction and anteversion angle;

IV. Postoperative complications: dislocation, infection, periprosthetic fracture, deep vein thrombosis, hematoma, and reoperation.

2.4. Exclusion Criteria

- Robotic assistance and computer navigation;
- Revision operation;
- Dual-mobility THA;
- Hemiarthroplasty;
- Comparison of MI and CA THA simultaneously in the same patients.

2.5. Data Extraction

Two reviewers (NR and PMK) independently extracted all relevant data on RCT characteristics, methods, quality assessment, participant characteristics, details of interventions, relevant outcomes and relevant additional information. The extracted data are available in the Supplement (Table S2). Disagreements were resolved by consensus between two reviewers (NR and PMK). The raw data extraction set available in the Supplement (Table S2).

2.6. Quality Assessment of RCTs

Two reviewers independently assessed the quality of the included RCTs. Risk of bias (RoB) was assessed using the Cochrane RoB 2 tool [17]. Level of evidence was assessed according to the recommendations of the GRADE system [18]. Disagreements were resolved by consensus between two reviewers (NR and PMK). In addition, publication bias was calculated using Begg's and Egger's tests.

2.7. Missing Data

The corresponding authors of the included RCTs were contacted to obtain missing primary data. If standard deviation information was missing, it was calculated by imputation [19]. If the RCTs provided different information for the intention to treat (ITT) and per protocol (PP) analyses, we used the numbers from the ITT analysis.

2.8. Measures of Treatment Effect

For continuous outcomes, mean differences (MDs) with 95% confidence intervals (CIs) were calculated using the Hartung–Knapp–Sidik–Jonkman method and a common effect/random effects model. For dichotomous outcomes, odds ratios (ORs) with 95% CIs were calculated using the Mantel–Haenszel method and a common effect/random effects model. The heterogeneity of the RCTs was measured by I^2 and τ^2 values. As these values indicated a high degree of heterogeneity for some parameters, we retained the random effects model in our presentation of the results. In cases where the included RCTs included primary data from patients with bilateral THA, the number of hips operated on was used in our calculations rather than the number of patients. Studies were weighted using inverse variance. The t-test was calculated to determine the differences between the means of the two groups. Statistical heterogeneity was assessed using the Cochrane Q test (p value < 10 indicates heterogeneity) and the Higgins test I^2 (low heterogeneity < 25%, moderate heterogeneity: 25–75% and high heterogeneity: >75%) [20]. A professional statistician (RH) performed all statistical calculations using the R packages meta and metafor. Meta results were analyzed using the Cochrane Handbook for Systematic Reviews of Interventions, Cochrane's Review Manager Version 5.3.

3. Results

The study selection process is presented in a flowchart (Figure 1). The initial literature search of the databases yielded 6908 records. A total of 50 RCTs [21–70] were screened for eligibility by full text analysis. Three RCTs [68–70] were excluded for the following reasons: one RCT evaluated hemiarthroplasty [68], another RCT compared two MI approaches [69] and another RCT evaluated MI and CA THA simultaneously in the same patients [70]. A total of 47 RCTs with 4086 THAs in 4063 patients [21–67] were included in this meta-analysis. The main characteristics of the patients and the included RCTs are listed in Table 1. It is important to note that two of the RCTs used identical patient cohorts, providing different outcome parameters with different follow-up periods [43,44]. In addition, two RCTs [42,62] included patients with bilateral THA (see Table 1). The risk of bias and the level of evidence are shown in Tables 2 and 3. The assessment of publication bias using Begg's and Egger's tests is shown in Table 4. The clinical characteristics for sex, age and BMI (Table 1) showed no relevant differences between the MI THA and CA THA groups. Table 5 shows the weighted means of the continuous outcome parameters and the weighted event percentages of the dichotomous outcome parameters.

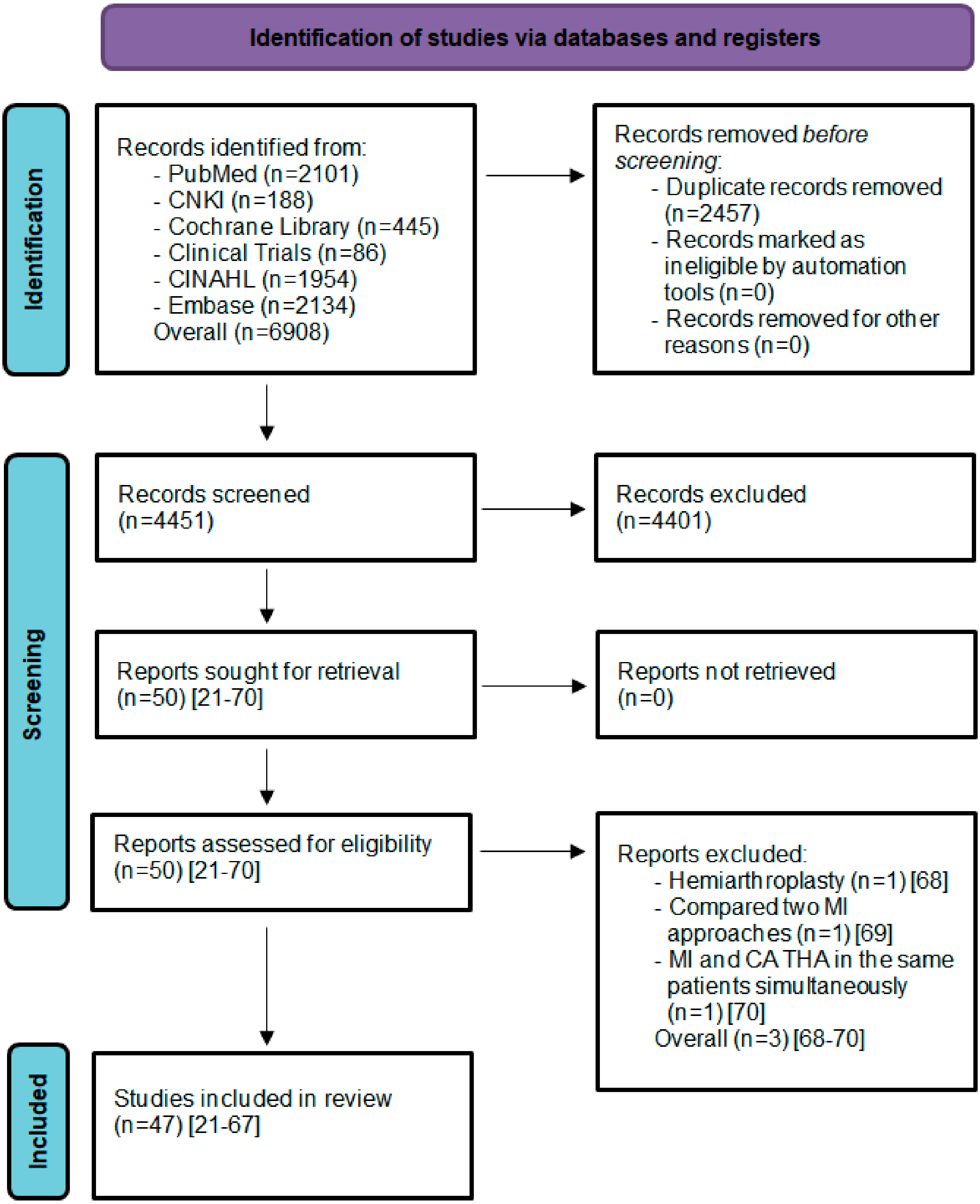

Figure 1. PRISMA flow diagram of the search results and selection process. MI: minimally invasive; CA: conventional approach; THA: total hip arthroplasty [21–70].

Table 1. Main characteristics of RCTs.

RCT	Year of Publication, Origin	Patients, N	Hips, N	Sex, Male, N	Approach	THA with Bone Cement, N	Table/ Patient Position	Mean Age, Years, SD	Mean BMI, kg/m^2, SD	Mean HHS Preoperatively, Points, SD	Osteoarthritis, N	Femoral Neck Fracture, N	Dysplasia, N	ANFH, N
Barrett WP et al. [21]	2013, USA	43	43	29	MI DAA	0	TT	61.4 ± 9.2	30.7 ± 5.4	57.6 ± 10.2	43	0	0	0
		44	44	19	CA PL	0	Lat	63.2 ± 7.7	29.1 ± 5	55.1 ± 9.1	44	0	0	0
Bon G et al. [22]	2019, France	50	50	21	MI DAA	7	TT	67.3 ± 10	26.5 ± 3.6	54 ± 15	50	0	0	0
		50	50	23	CA P	7	NR	69 ± 7.9	26.7 ± 3.1	52.3 ± 13.1	50	0	0	0
Brismar BH et al. [23]	2018, Sweden	50	50	18	MI DAA	0	Supine	66 ± 4	27 ± 1.3	NR	50	0	0	0
		50	50	17	CA L	0	Lat	67 ± 4	27 ± 1.5	NR	50	0	0	0
Cheng TE et al. [24]	2016, Australia	35	35	15	MI DAA	NR	TT	59 ± 3.8	27.7 ± 1.1	NR	35	0	0	0
		37	37	18	CA P	NR	Lat	62.5 ± 3.5	28.3 ± 1.6	NR	37	0	0	0
D'Arrigo C et al. [25]	2009, Italy	20	20	12	MI DAA	0	NR	64 ± 8	22.7 ± 1.5	37.7 ± 19	20	0	0	0
		149	149	81	CA L	0	NR	65 ± 9.8	28 ± 1.8	39 ± 10.2	149	0	0	0
De Anta-Diaz B et al. [26]	2016, Spain	49	49	26	MI DAA	8	NR	64.8 ± 10.1	26.6 ± 3.9	44.4 ± 13.6	49	0	0	0
		50	50	26	CA L	6	NR	63.5 ± 12.5	26.9 ± 3.1	42.9 ± 15.2	50	0	0	0
Dienstknecht T et al. [27] *	2013, Germany	42	42	14	MI MH	2	Lat	61 ± 13	26.1 ± 3	48 ± 15	42	0	0	0
		36	36	12	CA L	1	NR	62 ± 13	24.3 ± 3.6	46 ± 16	36	0	0	0
		41	41	24	MI MH	3	Lat	61 ± 11	34.3 ± 4.4	44 ± 15	41	0	0	0
		15	15	10	CA L	0	NR	61 ± 10	34.6 ± 4.1	46 ± 16	15	0	0	0
Fink B et al. [28]	2010, Germany	50	50	25	MI P	50	NR	71.9 ± 6.1	27 ± 4.8	NR	44	0	1	5
		50	50	23	CA PL	50	NR	71.5 ± 5.6	28 ± 3.8	NR	44	0	1	5
Gao P et Shi X [29]	2020, China	35	35	23	MI S	NR	Lat	69.3 ± 3.3	23.1 ± 2.6	15.4 ± 2.9	0	35	0	0
		35	35	20	CA P	NR	Lat	68.8 ± 3.5	23.2 ± 2.4	15.7 ± 2.7	0	35	0	0
Hou JZ et al. [30]	2017, China	20	20	13	MI S	NR	Lat	54.3 ± 13.7	24.5 ± 3.6	33.8 ± 5.4	6	0	0	14
		20	20	12	CA	NR	Lat	53.8 ± 12.9	23.9 ± 4.1	31.9 ± 6.1	5	0	0	15
Huang K et al. [31] **	2021, China	37	37	31	MI S	NR	Lat	56.2 ± 11.5	NR	47.3 ± 6.1	0	0	0	37
		58	58	50	CA L	NR	Lat	53 ± 10.4	NR	45.7 ± 8.1	0	0	0	58
		16	16	2	MI S	NR	Lat	78.1 ± 7.8	NR	40.6 ± 11.5	0	16	0	0
		18	18	8	CA L	NR	Lat	77.7 ± 10.1	NR	40.9 ± 11.6	0	18	0	0

Table 1. *Cont.*

RCT	Year of Publication, Origin	Patients, N	Hips, N	Sex, Male, N	Approach	THA with Bone Cement, N	Table/ Patient Position	Mean Age, Years, SD	Mean BMI, kg/m^2, SD	Mean HHS Preoperatively, Points, SD	Osteoarthritis, N	Femoral Neck Fracture, N	Dysplasia, N	ANFH, N
Iorio R et al. [32]	2021, Italy	29	29	14	MI DAA	0	Supine	62.7 ± 4.9	28.7 ± 3.4	49.2 ± 9.0	29	0	0	0
		31	31	14	CA L	0	Lat	67.2 ± 8.8	29.9 ± 3.1	46.4 ± 12.6	31	0	0	0
Khan RJK et al. [33]	2012, Australia	44	44	24	MI P	44	Lat	72.3 ± 1	28.5 ± 0.7	NR	42	0	0	2
		45	45	19	CA P	45	Lat	72.8 ± 1.1	28.9 ± 0.6	NR	43	0	0	2
Korytkin A et al. [34]	2023, Russia	20	20	10	MI S	0	NR	56.8 ± 12.9	28.2 ± 4.5	45.6 ± 11.3	NR	NR	NR	NR
		24	24	11	CA P	0	NR	57.0 ± 13.2	29.0 ± 4.9	46.0 ± 11.0	NR	NR	NR	NR
Landgraeber S et al. [35]	2013, Germany	36	36	12	MI AL	36	Lat	70.3 ± 4.1	27 ± 2.8	NR	36	0	0	0
		40	40	14	CA L	40	Supine	71 ± 5.4	26.7 ± 3.8	NR	40	0	0	0
Li L [36]	2020, China	30	30	16	MI S	NR	Lat	70.4 ± 4.3	NR	25.4 ± 2.4	NR	NR	NR	NR
		30	30	18	CA PL	NR	Lat	70.1 ± 4.8	NR	26.4 ± 2.5	NR	NR	NR	NR
Li X et al. [37]	2021, China	49	49	27	MI S	NR	Lat	75.5 ± 7.3	23 ± 2.9	NR	0	15	0	34
		47	47	24	CA PL	NR	Lat	77.2 ± 7.8	22.7 ± 3	NR	0	16	0	31
Ling Z et al. [38]	2020, China	50	50	31	MI S	NR	NR	89.1 ± 3.6	NR	46.1 ± 3.3	0	50	0	0
		50	50	29	CA PL	NR	NR	89 ± 3.7	NR	45.9 ± 3.7	0	50	0	0
Liu Y et al. [39]	2021, China	47	47	26	MI S	NR	Lat	68.3 ± 3.7	NR	67.7 ± 7.3	0	47	0	0
		47	47	24	CA PL	NR	Lat	68.6 ± 3.4	NR	68.7 ± 6.2	0	47	0	0
Liu W et al. [40]	2022, China	30	30	17	MI S	NR	Lat	58.6 ± 4.3	NR	58.7 ± 4.3	3	13	0	14
		30	30	18	CA	NR	Lat	58.3 ± 4.6	NR	58.8 ± 4.3	6	9	0	15
Martin R et al. [41]	2011, Belgium	42	42	12	MI AL	42	Lat	66.7 ± 10.1	30.6 ± 6.1	37.4 ± 15.5	37	0	0	5
		41	41	14	CA L	41	NR	63.1 ± 10.2	29.4 ± 5.5	40.2 ± 12.9	37	0	0	4
Meng W et al. [42]	2020, China	2	4	2	MI S	NR	Lat	51 ± 4.5	21.5 ± 1.7	37.9 ± 13.3	0	0	0	4
		2	4	2	CA PL	NR	Lat	51 ± 4.5	21.5 ± 1.7	37.7 ± 7	0	0	0	4
Mjaaland KE et al. [43] ***	2015, Norway	83	83	25	MI DAA	83	Supine	67.2 ± 8.6	27.7 ± 3.6	53.6 ± 13.7	83	0	0	0
		80	80	30	CA L	80	Lat	65.6 ± 8.6	27.6 ± 3.9	56 ± 11.2	80	0	0	0
Mjaaland KE et al. [44] ***	2018, Norway	83	83	25	MI DAA	83	Supine	67.2 ± 8.6	27.7 ± 3.6	53.6 ± 13.7	83	0	0	0
		80	80	30	CA L	80	Lat	65.6 ± 8.6	27.6 ± 3.9	56 ± 11.2	80	0	0	0

Table 1. *Cont.*

RCT	Year of Publication, Origin	Patients, N	Hips, N	Sex, Male, N	Approach	THA with Bone Cement, N	Table/ Patient Position	Mean Age, Years, SD	Mean BMI, kg/m², SD	Mean HHS Preoperatively, Points, SD	Osteoarthritis, N	Femoral Neck Fracture, N	Dysplasia, N	ANFH, N
Moerenhout K et al. [45]	2019, Canada	28	28	11	MI DAA	0	TT	70.4 ± 9.1	27.6 ± 4.4	52.1 ± 19.7	NR	0	0	NR
		27	27	18	CA P	0	Lat	69 ± 8.8	26.5 ± 4.3	48.2 ± 10.1	NR	0	0	NR
Müller M et al. [46]	2010, Germany	21	21	12	MI AL	0	NR	66 ± 6.8	28 ± 4.3	55.9 ± 8	21	0	0	0
		16	16	8	CA L	0	NR	64 ± 13.8	26 ± 2.5	55.6 ± 12	16	0	0	0
Nistor DV et al. [47]	2017, Romania	35	35	26	MI DAA	0	Supine	67 ± 4.8	27.5 ± 3.8	NR	35	0	0	0
		35	35	16	CA L	0	Supine	64 ± 3.3	28.6 ± 3.1	NR	35	0	0	0
Ouyang C et al. [48]	2018, China	12	12	8	MI S	NR	Lat	54 ± 6.5	23.1 ± 2.3	45.7 ± 5.9	5	0	0	7
		12	12	9	CA PL	NR	Lat	55 ± 5	23.9 ± 3.4	46.9 ± 8.9	6	0	0	6
Pan F et al. [49]	2020, China	58	58	34	MI S	NR	Lat	65.2 ± 6.8	22.2 ± 4.2	83.9 ± 2.7	12	26	NR	15
		58	58	33	CA PL	NR	Lat	65.6 ± 7	22.6 ± 4.2	84 ± 3.2	11	25	NR	18
Parvizi J et al. [50]	2016, USA	44	44	18	MI DAA	0	Supine	NR	NR	NR	44	0	0	0
		40	40	14	CA L	0	Supine	NR	NR	NR	40	0	0	0
Reichert et al. [51]	2018, Germany	77	77	45	MI DAA	4	Supine	63.2 ± 8.2	28.1 ± 3.7	54 ± 14.2	77	0	0	0
		71	71	39	CA L	5	Supine	61.9 ± 7.8	28.3 ± 3.4	53 ± 15.7	71	0	0	0
Ren D et al. [52]	2016, China	21	21	12	MI S	NR	NR	58 ± 6.9	NR	35.4 ± 4.9	0	0	0	21
		21	21	13	CA	NR	NR	58.5 ± 6.3	NR	36.3 ± 3.5	0	0	0	21
Restreppo C et al. [53]	2010, USA	50	50	17	MI DAA	0	Supine	62 ± 12.4	25.2 ± 11.1	51.9 ± 7.9	50	0	0	0
		50	50	22	CA L	0	Supine	59.9 ± 9	25.2 ± 2.5	55 ± 5.5	50	0	0	0
Rykov K et al. [54]	2017, Netherlands	23	23	8	MI DAA	23	Supine	62.8 ± 6.1	29 ± 5.6	52 ± 6.7	23	0	0	0
		23	23	11	CA PL	23	Lat	60.2 ± 8.1	29.3 ± 4.8	51 ± 9	23	0	0	0
Schwarze M et al. [55]	2017, Germany	22	22	13	MI AL	0	Supine	59 ± 9	26.7 ± 4.2	53 ± 12	22	0	0	0
		21	21	13	CA L	0	Supine	59 ± 9	26.7 ± 4.2	59 ± 15	21	0	0	0
Taunton M et al. [56]	2014, USA	27	NR	12	MI DAA	NR	Supine	62.1	27.7	55 ± 4.3	27	0	0	0
		27	NR	13	CA P	NR	Lat	66.4	29.2	51 ± 6	27	0	0	0
Taunton M et al. [57]	2018, USA	52	52	27	MI DAA	0	NR	65 ± 10	29 ± 22	57 ± 13	52	0	0	0
		49	49	25	CA P	0	NR	64 ± 11	30 ± 4	56 ± 12	49	0	0	0

Table 1. *Cont.*

RCT	Year of Publication, Origin	Patients, N	Hips, N	Sex, Male, N	Approach	THA with Bone Cement, N	Table/ Patient Position	Mean Age, Years, SD	Mean BMI, kg/m^2, SD	Mean HHS Preoperatively, Points, SD	Osteoarthritis, N	Femoral Neck Fracture, N	Dysplasia, N	ANFH, N
Varela-Egocheaga JR et al. [58]	2013, Spain	25	25	12	MI L	0	NR	64.8 ± 10.5	28.3 ± 3.7	52.7 ± 12.9	21	0	0	4
		25	25	12	CA L	0	NR	63.8 ± 9.7	27.8 ± 3.2	51.3 ± 14.9	22	0	0	3
Wang Z et Ge W [59]	2021, China	43	43	26	MI S	NR	Supine	71.5 ± 3.8	22.5 ± 1.1	62.2 ± 5.2	0	43	0	0
		42	42	24	CA PL	NR	Lat	71.6 ± 3.8	22.5 ± 1.2	62.7 ± 6.6	0	42	0	0
Xiao C et al. [60]	2021, China	49	49	16	MI P	0	Lat	71.1 ± 10.9	26.7 ± 4.2	NR	0	49	0	0
		57	57	26	CA PL	0	Lat	73.9 ± 10	26.4 ± 4.6	NR	0	57	0	0
Xie J et al. [61]	2017, China	46	46	12	MI S	0	Lat	66.6 ± 11.9	23.6 ± 1.6	28.9 ± 11.3	46	0	0	0
		46	46	19	CA P	0	Lat	64.5 ± 12.1	24.1 ± 2.7	29.3 ± 17.4	46	0	0	0
Yan T et al. [62]	2017, China	64	70	29	MI S	NR	NR	66 ± 4	24.5 ± 3.5	33.5 ± 5.3	14	11	0	39
		90	103	42	CA L	NR	NR	65 ± 6.5	23.6 ± 3.6	30.7 ± 7.6	12	23	0	55
Yang C et al. [63]	2010, China	55	55	26	MI AL	0	Lat	59.5 ± 13.2	23.1 ± 3.2	25.9 ± 11.3	12	11	0	32
		55	55	30	CA PL	0	Lat	55.8 ± 13.9	22.4 ± 4	28.2 ± 13.7	19	13	0	23
Yuan H et al. [64]	2018, China	40	40	24	MI S	0	Lat	74.3 ± 3	22.7 ± 1.7	33 ± 1.9	5	21	4	10
		44	44	21	CA PL	0	Lat	75.7 ± 3.3	22.4 ± 2.7	32.7 ± 1.3	6	24	2	12
Zhang ZL et al. [65]	2019, China	27	27	10	MI S	NR	NR	62.4 ± 6.4	24.5 ± 5.3	35.6 ± 8.8	7	0	5	15
		27	27	12	CA PL	NR	NR	61.3 ± 6.7	23.9 ± 4.9	36.2 ± 9.2	9	0	4	14
Zhao HY et al. [66]	2017, China	60	60	24	MI DAA	NR	Supine	64.9 ± 12.1	24.4 ± 3.1	40.2 ± 9.2	41	0	6	13
		60	60	22	CA PL	NR	Lat	62.2 ± 14.7	25.6 ± 2.8	43.1 ± 15.6	40	0	7	13
Zhao S [67]	2021, China	48	48	28	MI S	NR	Lat	70.4 ± 1.5	22.6 ± 1.5	NR	0	48	0	0
		48	48	29	CA L	NR	Lat	70.5 ± 1.5	22.5 ± 1.5	NR	0	48	0	0

MI: minimally invasive; AL: anterolateral; DAA: direct anterior approach; L lateral; MH: MicroHip; P: posterior; PL: posterolateral; S: SuperPATH; CA: conventional approach; TT: traction table; Lat: lateral decubitus position; THA: total hip arthroplasty; BMI: Body Mass Index; SD: standard deviation; HHS: Harris Hip Score; ANFH: avascular necrosis of the femoral head; NR: not reported. * This RCT divided the patient cohort according to their BMI; ** this RCT divided the patient cohort according to their diagnosis; *** both RCTs used identical patient cohorts, giving different outcome parameters.

Table 2. Risk of bias assessment.

Study	Bias Arising from the Randomization Process	Bias Due to Deviation from Intended Interventions	Bias Due to Missing Outcome Data	Bias in Measurement of the Outcome	Bias in Selection of the Reported Result	Overall Risk of Bias
Barrett WP et al. [21]	+	–	?	?	+	–
Bon G et al. [22]	+	+	+	+	+	+
Brismar BH et al. [23]	+	+	–	+	+	–
Cheng TE et al. [24]	+	+	–	+	+	–
D'Arrigo C et al. [25]	+	+	+	+	+	+
De Anta-Diaz B et al. [26]	–	+	+	+	+	–
Dienstknecht T et al. [27]	–	+	+	+	+	–
Fink B et al. [28]	+	+	+	+	+	+
Gao P and Shi X [29]	+	?	–	+	+	–
Hou JZ et al. [30]	+	?	+	+	+	?
Huang K et al. [31]	–	?	+	+	+	–
Iorio R et al. [32]	+	?	?	?	+	?
Khan RJK et al. [33]	+	+	+	+	+	+
Korytkin A et al. [34]	+	?	+	+	+	?
Landgraeber S et al. [35]	+	?	+	+	?	?
Li L [36]	+	?	–	–	+	–
Li X et al. [37]	+	+	–	+	+	–
Ling Z et al. [38]	?	+	–	+	+	–
Liu Y et al. [39]	+	+	–	+	+	–
Liu W et al. [40]	+	+	+	+	+	+
Martin R et al. [41]	?	?	+	+	?	?
Meng W et al. [42]	+	+	+	+	+	+
Mjaaland KE et al. [43]	+	+	+	+	+	+
Mjaaland KE et al. [44]	+	+	+	+	+	+
Moerenhout K et al. [45]	+	+	+	+	+	+
Müller M et al. [46]	+	+	?	?	+	?
Nistor DV et al. [47]	–	+	+	+	+	–
Ouyang C et al. [48]	+	+	+	+	+	+
Pan F et al. 2020 [49]	+	?	–	+	+	–
Parvizi J et al. [50]	+	+	–	+	+	–
Reichert JC et al. [51]	–	+	+	+	+	–
Ren D et al. [52]	+	?	–	?	?	–
Restreppo C et al. [53]	+	+	+	+	+	+
Rykov K et al. [54]	+	+	–	+	+	–
Schwarze M et al. [55]	?	?	–	–	+	–
Taunton M et al. [56]	+	+	?	+	+	?
Taunton M et al. [57]	+	+	?	+	+	?
Varela-Egocheaga JR et al. [58]	–	–	+	+	+	–
Wang Z and Ge W [59]	+	?	–	+	+	–
Xiao C et al. [60]	?	+	+	+	+	?
Xie J et al. [61]	+	+	+	+	+	+
Yan T et al. [62]	+	?	?	+	+	?

Table 2. *Cont.*

Study	Bias Arising from the Randomization Process	Bias Due to Deviation from Intended Interventions	Bias Due to Missing Outcome Data	Bias in Measurement of the Outcome	Bias in Selection of the Reported Result	Overall Risk of Bias
Yang C et al. [63]	+	+	+	+	+	+
Yuan H et al. [64]	+	?	−	+	+	−
Zhang ZL et al. [65]	+	+	?	+	+	?
Zhao HY et al. [66]	+	+	+	+	+	+
Zhao S [67]	−	?	+	+	+	−

(+): low risk of bias; (?): some concerns; (−): high risk of bias.

Table 3. Level of evidence assessment according to GRADE recommendations.

No. of Studies	Design	Risk of Bias	Inconsistency	Indirectness	Imprecision	Other Considerations	Quality of Evidence
I. Surgical outcome							
1. Operation time							
39	RCT	Serious	Serious	No serious indirectness	Serious	In some cases SD was calculated via imputation	Very low
2. Incision length							
28	RCT	Serious	No serious inconsistency	No serious indirectness	Serious	In some cases SD was calculated via imputation	Very low
3. Intraoperative blood loss							
26	RCT	Serious	Serious	No serious indirectness	Serious	In some cases SD was calculated via imputation	Very low
4. VAS 1 day postoperatively							
9	RCT	Serious	No serious inconsistency	No serious indirectness	No serious imprecision	-	Low
5. VAS 3 days postoperatively							
8	RCT	Serious	No serious inconsistency	No serious indirectness	No serious imprecision	-	Low
II. Functional outcome							
1. HHS 0–1.5 months postoperatively							
26	RCT	Serious	No serious inconsistency	No serious indirectness	Serious	In some cases SD was calculated via imputation	Very low
2. HHS 3 months postoperatively							
22	RCT	Serious	Serious	No serious indirectness	No serious imprecision	-	Very low
3. HHS 6 months postoperatively							
13	RCT	Serious	No serious inconsistency	No serious indirectness	No serious imprecision	-	Low
4. HHS 12 months postoperatively							
16	RCT	Serious	No serious inconsistency	No serious indirectness	Serious	In some cases SD was calculated via imputation	Very low
III. Radiological outcome							
1. Acetabular cup anteversion angle							
17	RCT	Serious	Serious	No serious indirectness	Serious	In some cases SD was calculated via imputation	Very low
2. Acetabular cup inclination angle							
22	RCT	Serious	Serious	No serious indirectness	Serious	In some cases SD was calculated via imputation	Very low

Table 3. *Cont.*

No. of Studies	Design	Risk of Bias	Inconsistency	Indirectness	Imprecision	Other Considerations	Quality of Evidence
IV. Postoperative complications							
1. Overall postoperative complications							
34	RCT	Serious	Serious	No serious indirectness	No serious imprecision	-	Very low
2. Dislocation							
31	RCT	Serious	No serious inconsistency	No serious indirectness	No serious imprecision	-	Low
3. Infection							
31	RCT	Serious	No serious inconsistency	No serious indirectness	No serious imprecision	-	Low
4. Periprosthetic fracture							
31	RCT	Serious	No serious inconsistency	No serious indirectness	Serious	-	Very low
5. Deep vein thrombosis							
31	RCT	Serious	No serious inconsistency	No serious indirectness	No serious imprecision	-	Low
6. Hematoma							
27	RCT	Serious	No serious inconsistency	No serious indirectness	No serious imprecision	-	Low
7. Reoperation							
25	RCT	Serious	No serious inconsistency	No serious indirectness	No serious imprecision	-	Low

RCT: randomized controlled trial; HHS: Harris Hip Score; VAS: Visual Analogue Scale.

Table 4. Publication bias evaluation.

	Number of RCTs	Egger.*p*.Value	Begg.*p*.Value
I. Surgical outcome			
1.Operation time	39	0.0038 **	0.5779
2.Incision length	28	0.5494	0.7670
3.Intraoperative blood loss	26	0.1562	0.4806
4.Pain VAS 1 day postoperatively	9	0.7491	0.7545
5. Pain VAS 3 days postoperatively	8	0.9212	0.7105
II. Functional outcome			
1. HHS 0–1.5 months postoperatively	26	0.4812	0.0778 *
2. HHS 3 months postoperatively	22	0.1843	0.6118
3. HHS 6 months postoperatively	13	0.4700	0.7603
4. HHS $\geq$ 12 months postoperatively	16	0.2160	0.2604
III. Radiological outcome			
1. Cup anteversion	17	0.3168	0.5923
2. Cup inclination	22	0.0057 **	0.6519

Table 4. *Cont.*

	Number of RCTs	Egger.*p*.Value	Begg.*p*.Value
IV. Postoperative complications			
1.Overall postoperative complications	34	0.8312	0.7098
2. Dislocation	31	0.5516	0.6404
3. Infection	31	0.1585	0.3359
4. Periprosthetic fracture	31	0.2566	0.7603
5. Deep vein thrombosis	31	0.8549	0.2758
6. Hematoma	27	0.2438	1.0000
7. Reoperation	25	0.0244 *	0.0375 *

* Significant result; ** highly significant result; VAS: visual analog scale; HHS: Harris Hip Score.

Table 5. The weighted mean values of the continuous outcome parameters and the weighted event percentages of the dichotomous outcome parameter.

Outcome Parameter	MI THA	CA THA
I. Surgical outcome		
1. Operation time (min.)	82.3	72.8
2. Incision length (cm)	9.0	13.1
3. Intraoperative blood loss (mL)	262.3	435.3
4. VAS 1 day postoperatively (points)	3.5	4.9
5. VAS 3 days postoperatively (points)	2.6	3.7
II. Functional outcome		
1. HHS 0–1.5 months postoperatively (points)	83.2	79.1
2. HHS 3 months postoperatively (points)	88.6	86.3
3. HHS 6 months postoperatively (points)	91.5	89.9
4. HHS 12 months postoperatively (points)	93.5	92.4
III. Radiological outcome		
1. Acetabular cup anteversion angle (degrees)	20.4	20.5
2. Acetabular cup inclination angle (degrees)	42.3	42.6
IV. Postoperative complications		
1. Overall postoperative complications (%)	5.72	4.21
2. Dislocation (%)	0.68	0.76
3. Infection (%)	0.53	0.90
4. Periprosthetic fracture (%)	1.06	0.62
5. Deep vein thrombosis (%)	0.38	1.18
6. Hematoma (%)	0.09	0.61
7. Reoperation (%)	1.47	1.04

MI: minimally invasive; CA: conventional approach; THA: total hip arthroplasty.

3.1. Surgical Outcome

3.1.1. Operation Time: MI THA vs. CA THA

Data on 3370 THAs from 39 RCTs were pooled (I^2 = 98%, $p < 0.01$, Figure 2). The operation time for MI THA was 10.6 min. longer than that for CA THA (MD = 10.64, 95% CI 5.29 to 15.99).

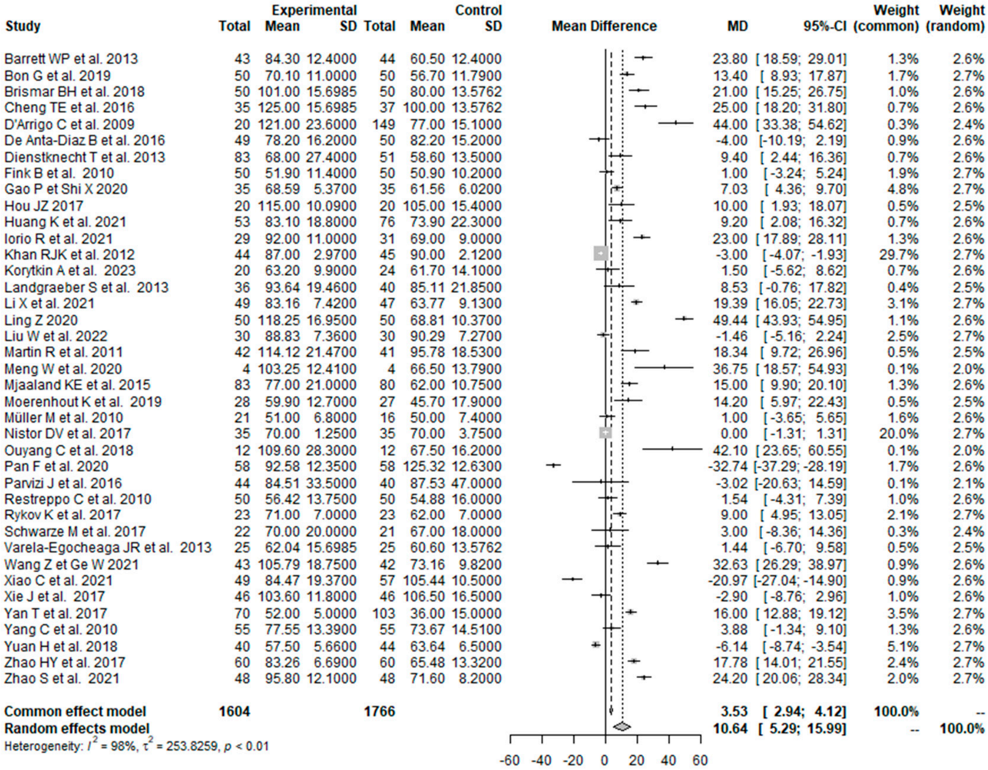

Figure 2. Comparison of the operation time (min.). SD: standard deviation; MD: mean difference; CI: confidence interval [21–35,37,38,40–43,45–50,53–55,58–64,66,67].

3.1.2. Incision Length: MI THA vs. CA THA

Data on 2513 THAs from 28 RCTs were pooled (I^2 = 99%, p = 0, Figure 3). The incision length for MI THA was 4.1 cm. shorter than that for CA THA (MD = −4.12, 95% CI −5.26 to −2.98).

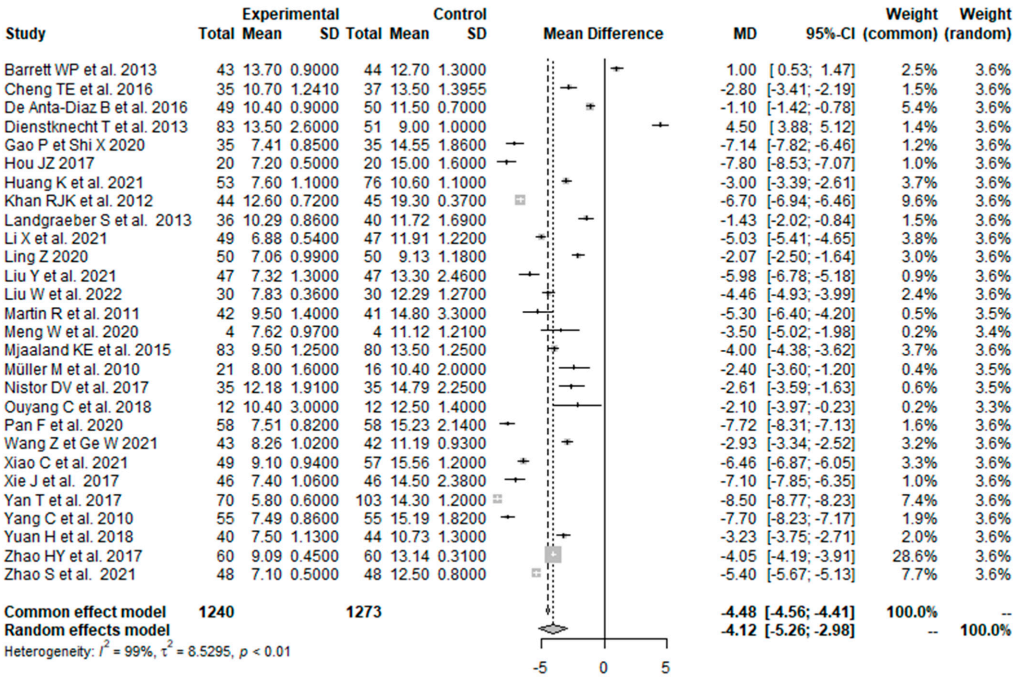

Figure 3. Comparison of the incision length (cm). SD: standard deviation; MD: mean difference; CI: confidence interval [21,24,26,27,29–31,33,35,37–43,46–49,59–64,66,67].

3.1.3. Intraoperative Blood Loss: MI THA vs. CA THA

Data on 2321 THAs from 26 RCTs were pooled ($I^2 = 99\%$, $p = 0$, Figure 4). The intraoperative blood loss for MI THA was indifferent compared to that for CA THA (MD = −43.58, 95% CI −94.76 to 7.61).

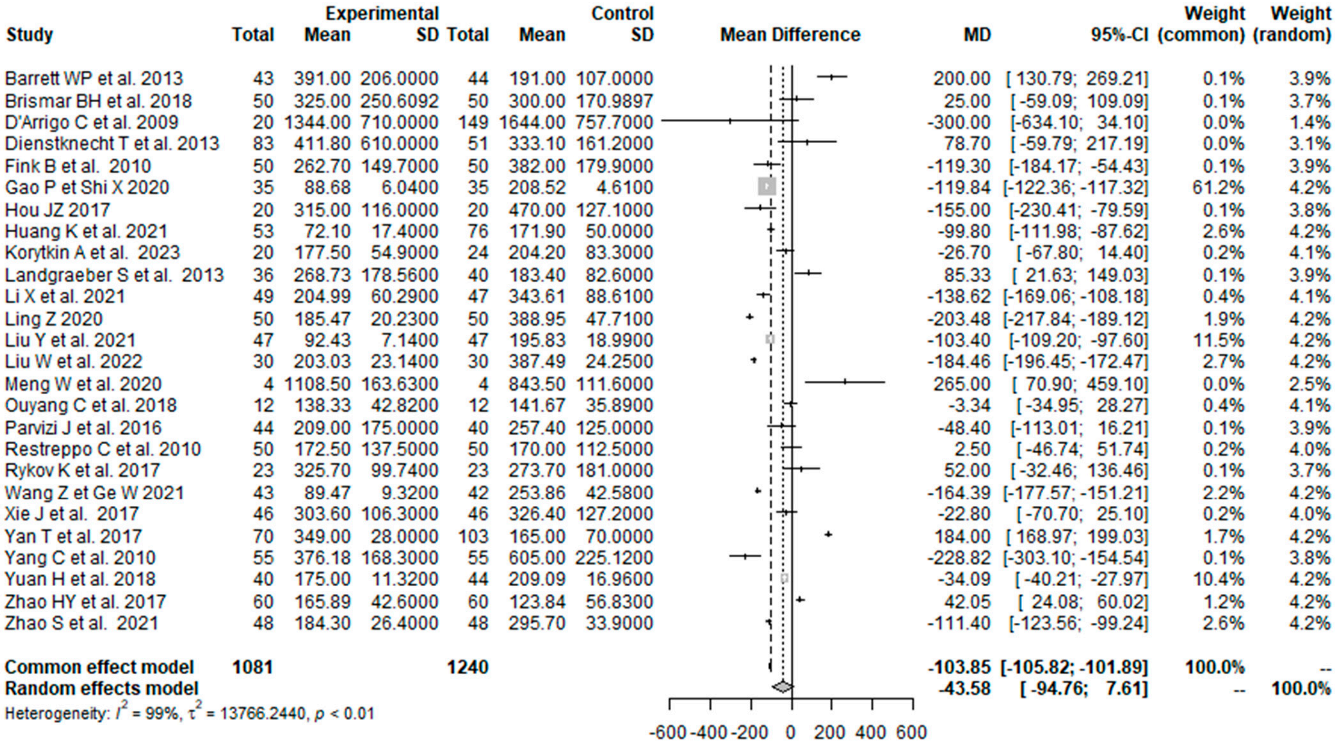

Figure 4. Comparison of the intraoperative blood loss (mL). SD: standard deviation; MD: mean difference; CI: confidence interval [21,23,25,27–31,34,35,37–40,42,48,50,53,54,59,61–64,66,67].

3.1.4. Pain VAS 1 Day Postoperatively: MI THA vs. CA THA

Data on 800 THAs from 9 RCTs were pooled ($I^2 = 96\%$, $p < 0.01$, Figure 5). The pain VAS 1 day postoperatively for MI THA was 1.1 points lower than that for CA THA (MD = −1.06, 95% CI −1.74 to −0.37).

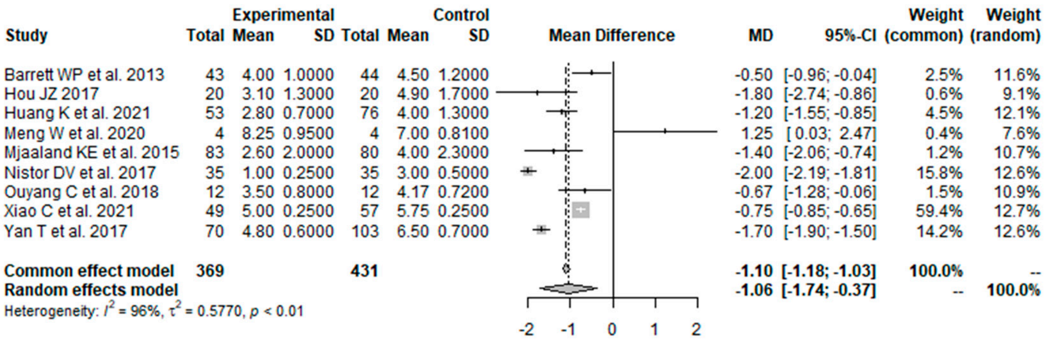

Figure 5. Comparison of the pain VAS 1 day postoperatively (points). SD: standard deviation; MD: mean difference; CI: confidence interval [21,30,31,42,43,47,48,60,62].

3.1.5. Pain VAS 3 Days Postoperatively: MI THA vs. CA THA

Data on 644 THAs from 8 RCTs were pooled ($I^2 = 96\%$, $p < 0.01$, Figure 6). The pain VAS 3 days postoperatively for MI THA was 0.8 point lower than that for CA THA (MD = −0.82, 95% CI −1.38 to −0.25).

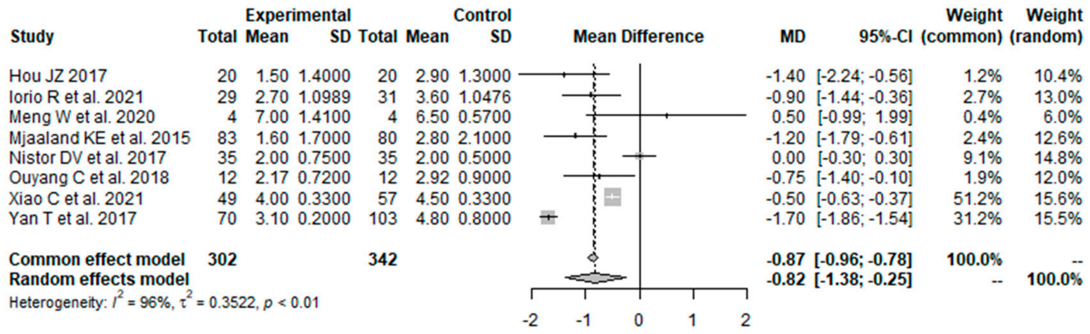

Figure 6. Comparison of the pain VAS 3 days postoperatively (points). SD: standard deviation; MD: mean difference; CI: confidence interval [30,32,42,43,47,48,60,62].

3.2. Functional Outcome

3.2.1. HHS 0–1.5 Months Postoperatively: MI THA vs. CA THA

Data on 2190 THAs from 26 RCTs were pooled (I^2 = 95%, $p < 0.01$, Figure 7). The HHS 0–1.5 months postoperatively for MI THA was 5.2 points higher than that for CA THA (MD = 5.22, 95% CI 3.18 to 7.26).

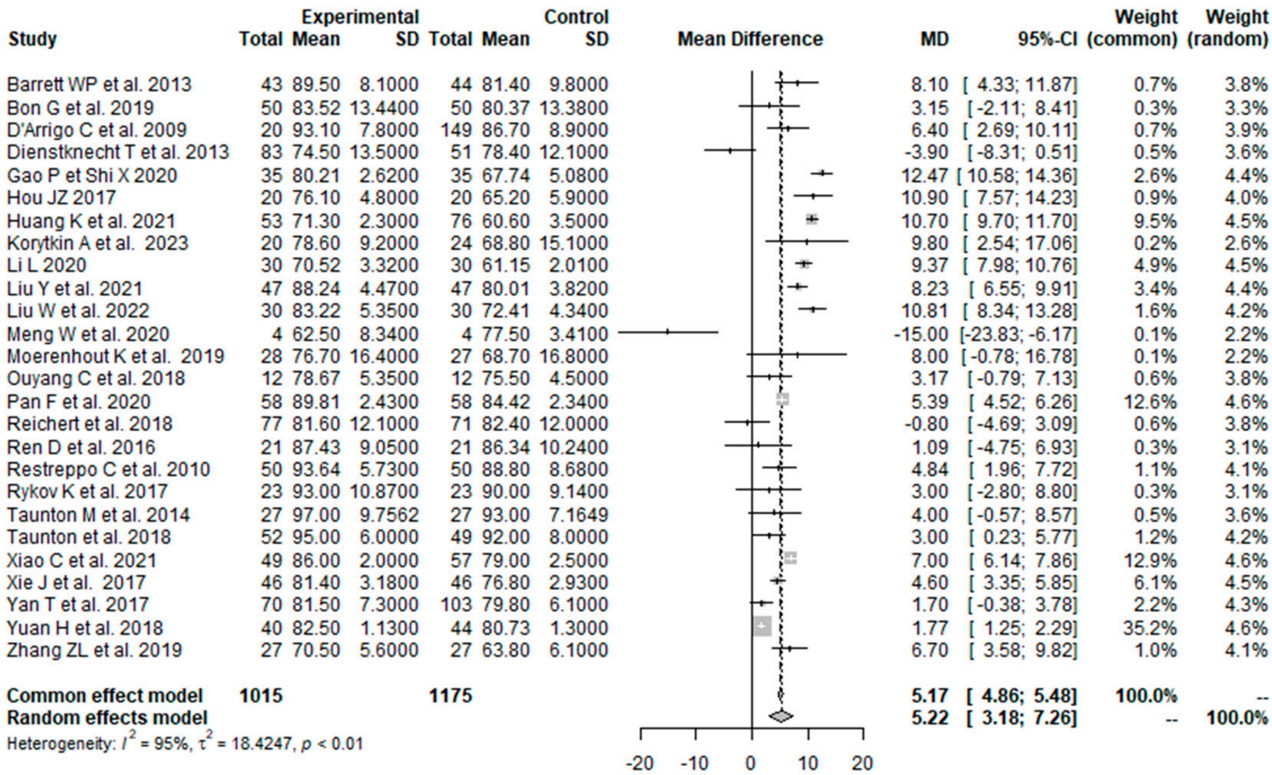

Figure 7. Comparison of the HHS 0–1.5 months postoperatively (points). SD: standard deviation; MD: mean difference; CI: confidence interval [21,22,25,27,29–31,34,36,39,40,42,45,48,49,51–54,56,57,60–62,64,65].

3.2.2. HHS 3 Months Postoperatively: MI THA vs. CA THA

Data on 1827 THAs from 22 RCTs were pooled (I^2 = 91%, $p < 0.01$, Figure 8). The HHS 3 months postoperatively for MI THA was 2.2 points higher than that for CA THA (MD = 2.15, 95% CI 0.31 to 3.99).

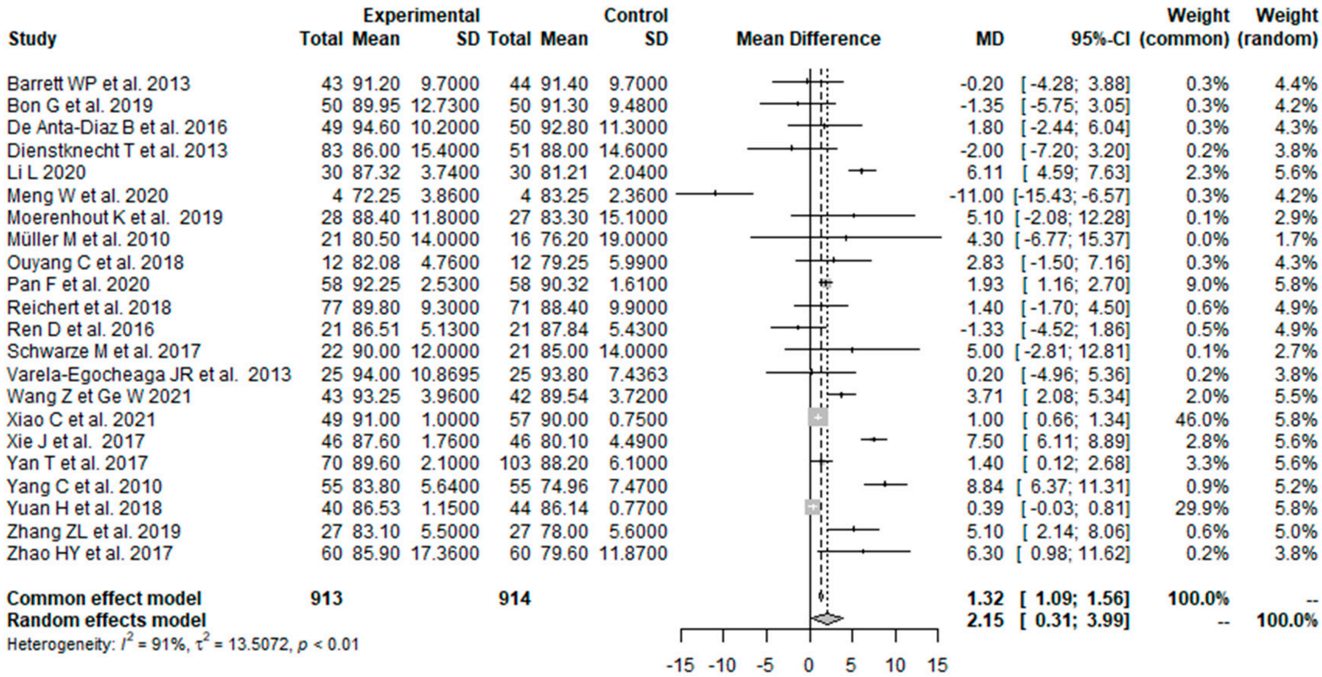

Figure 8. Comparison of the HHS 3 months postoperatively (points). SD: standard deviation; MD: mean difference; CI: confidence interval [21,22,26,27,36,42,45,46,48,49,51,52,55,58–66].

3.2.3. HHS 6 Months Postoperatively: MI THA vs. CA THA

Data on 1072 THAs from 13 RCTs were pooled (I^2 = 76%, p < 0.01, Figure 9). The HHS 6 months postoperatively for MI THA was 1.9 points higher than that for CA THA (MD = 1.88, 95% CI 0.48 to 3.29).

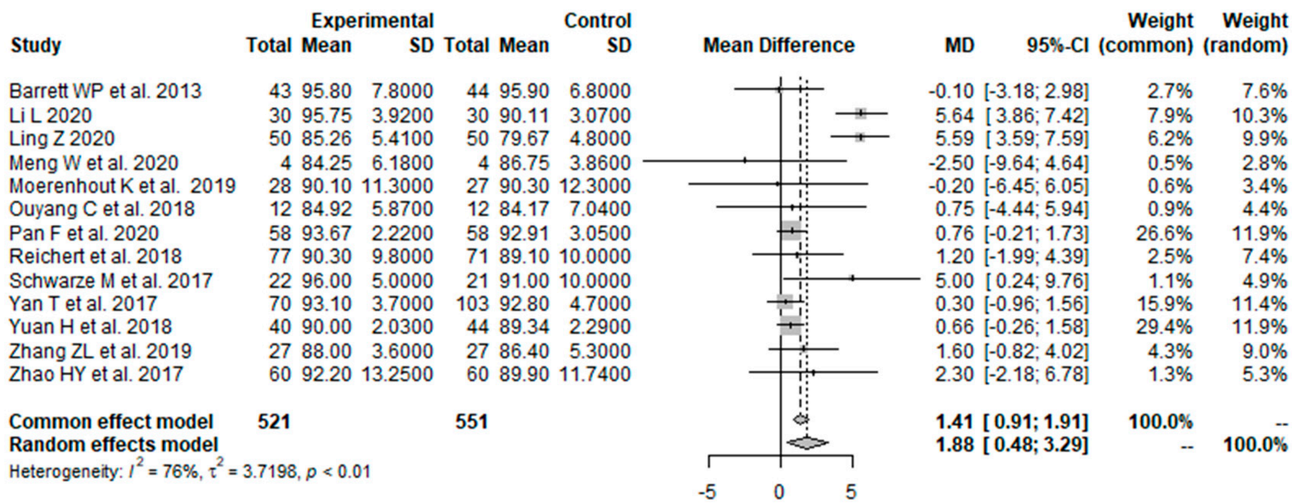

Figure 9. Comparison of the HHS 6 months postoperatively (points). SD: standard deviation; MD: mean difference; CI: confidence interval [21,36,38,42,45,48,49,51,55,62,64–66].

3.2.4. HHS ≥12 Months Postoperatively: MI THA vs. CA THA

Data on 1161 THAs from 16 RCTs were pooled (I^2 = 12%, p = 0.32, Figure 10). The HHS ≥ 12 months postoperatively for MI THA was 0.9 point higher than that for CA THA (MD = 0.85, 95% CI 0.27 to 1.43).

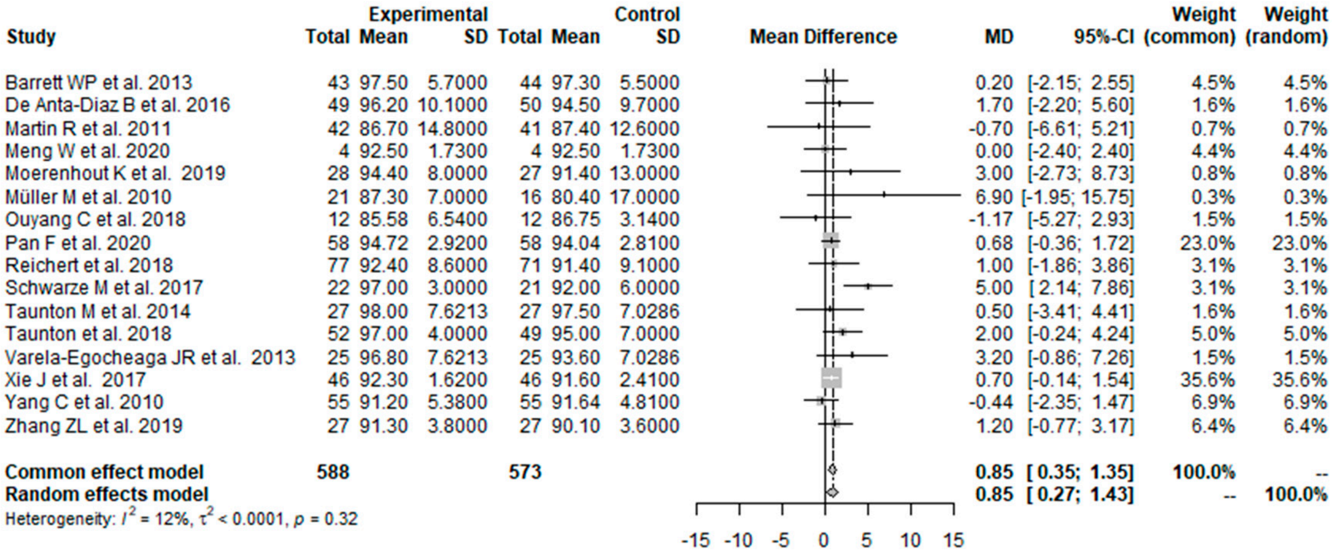

Figure 10. Comparison of the HHS ≥12 months postoperatively (points). SD: standard deviation; MD: mean difference; CI: confidence interval [21,26,41,42,45,46,48,49,51,55–58,61,63,65].

3.3. Radiological Outcome

3.3.1. Acetabular Cup Anteversion Angle: MI THA vs. CA THA

Data on 1341 THAs from 17 RCTs were pooled (I^2 = 97%, $p < 0.01$, Figure 11). The acetabular cup anteversion angle for MI THA was indifferent compared to that for CA THA (MD = −0.46, 95% CI −2.05 to 1.13).

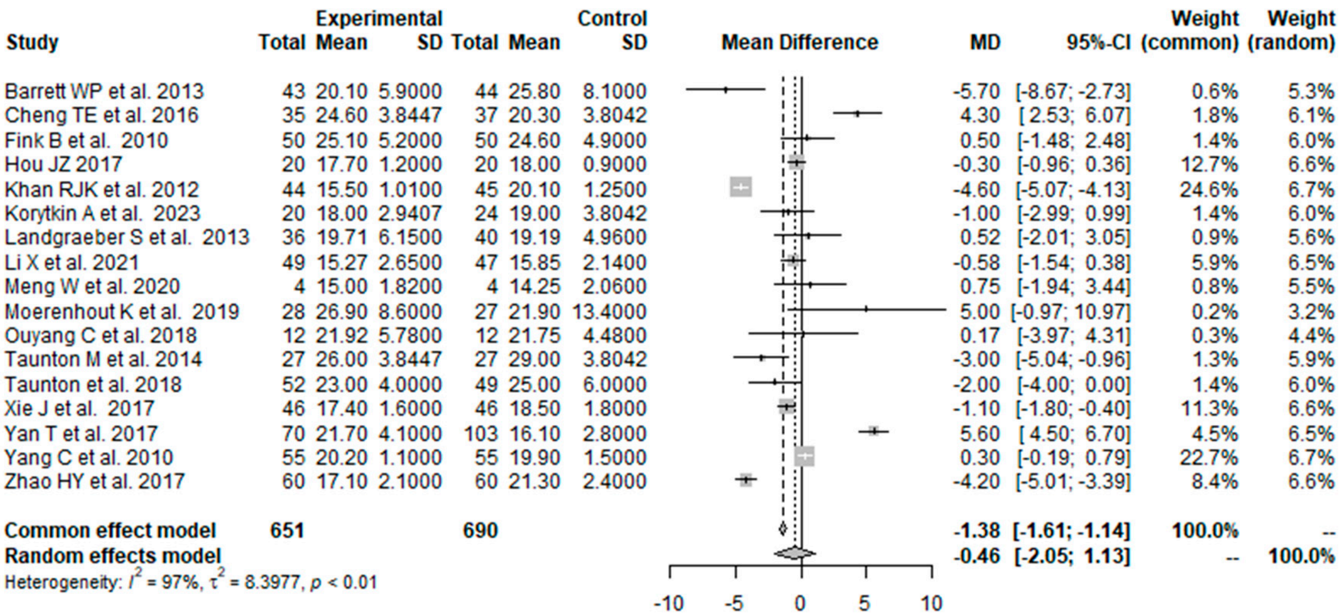

Figure 11. Comparison of the acetabular cup anteversion angle (degrees). SD: standard deviation; MD: mean difference; CI: confidence interval [21,24,28,30,33–35,37,42,45,48,56,57,61–63,66].

3.3.2. Acetabular Cup Inclination Angle: MI THA vs. CA THA

Data on 1843 THAs from 22 RCTs were pooled (I^2 = 86%, $p < 0.01$, Figure 12). The acetabular cup inclination angle for MI THA was indifferent compared to that for CA THA (MD = −0.79, 95% CI −1.73 to 0.15).

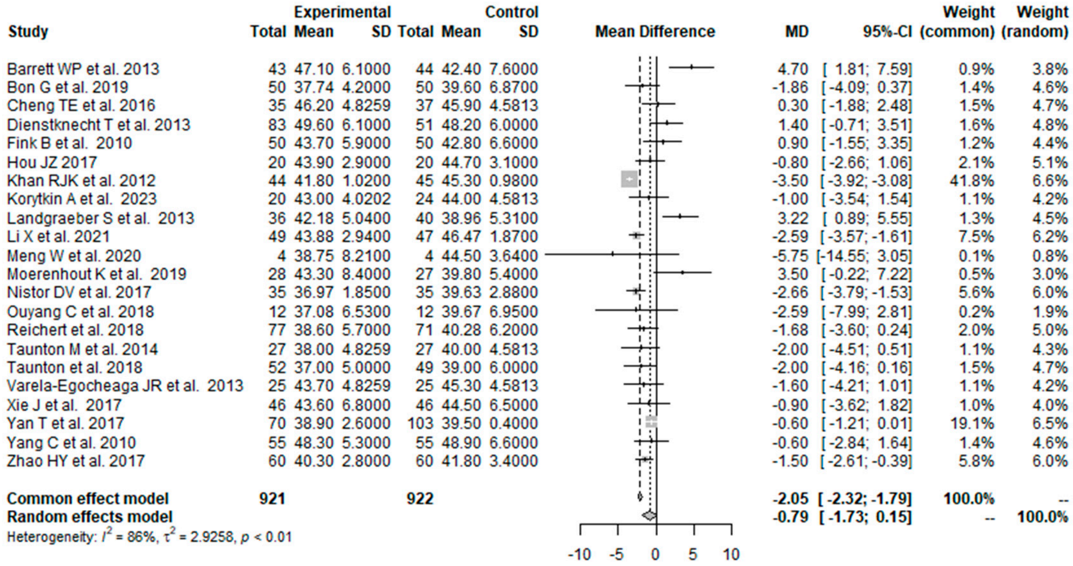

Figure 12. Comparison of the acetabular cup inclination angle (degrees). SD: standard deviation; MD: mean difference; CI: confidence interval [21,22,24,27,28,30,33–35,37,42,45,47,48,51,56–58,61–63,66].

3.4. Postoperative Complications

3.4.1. Overall Postoperative Complications: MI THA vs. CA THA

Data on 2959 THAs from 34 RCTs were pooled (I^2 = 64%, p < 0.01, Figure 13). The overall postoperative complication risk for MI THA was indifferent compared to that for CA THA (OR = 1.20, 95% CI 0.58 to 2.49).

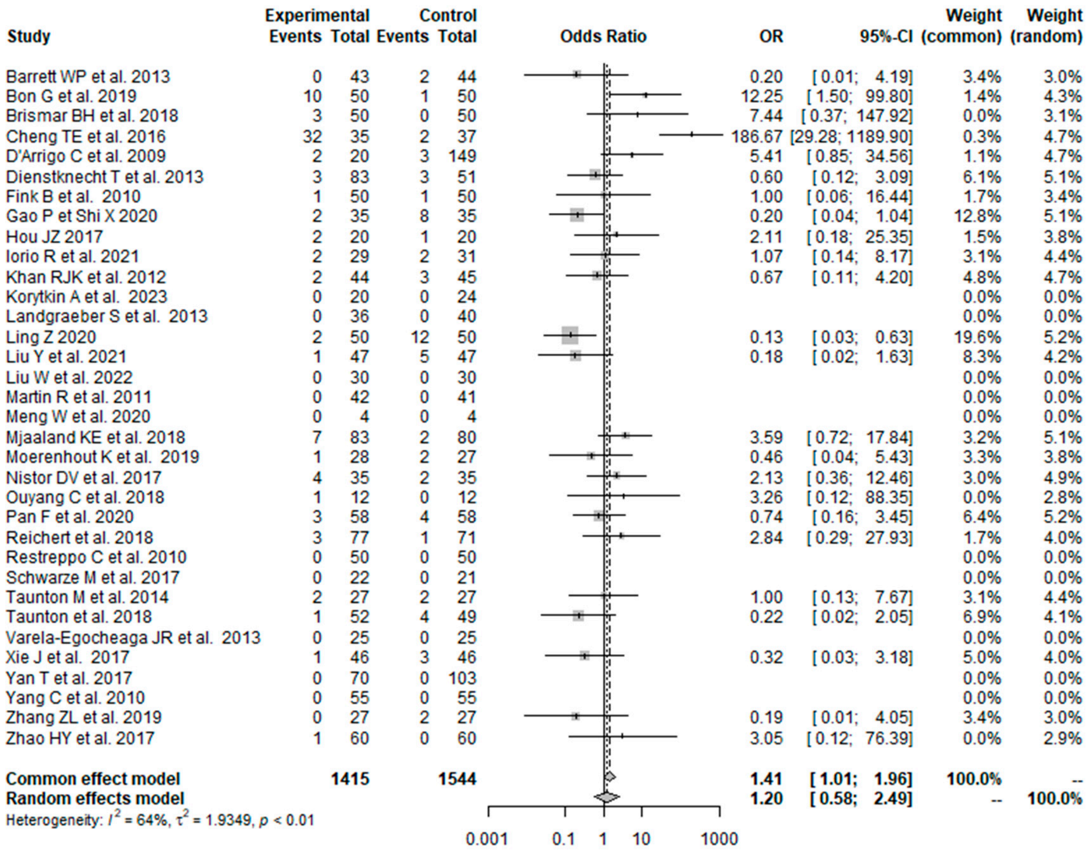

Figure 13. Comparison of the overall postoperative complication rate. OR: odds ratio; CI: confidence interval [21–25,27–30,32–35,38–42,44,45,47–49,51,53,55–58,61–63,65,66].

3.4.2. Dislocation: MI THA vs. CA THA

Data on 2755 THAs from 31 RCTs were pooled (I^2 = 0%, p = 0.91, Figure 14). The dislocation risk for MI THA was indifferent compared to that for CA THA (OR = 0.85, 95% CI 0.43 to 1.66).

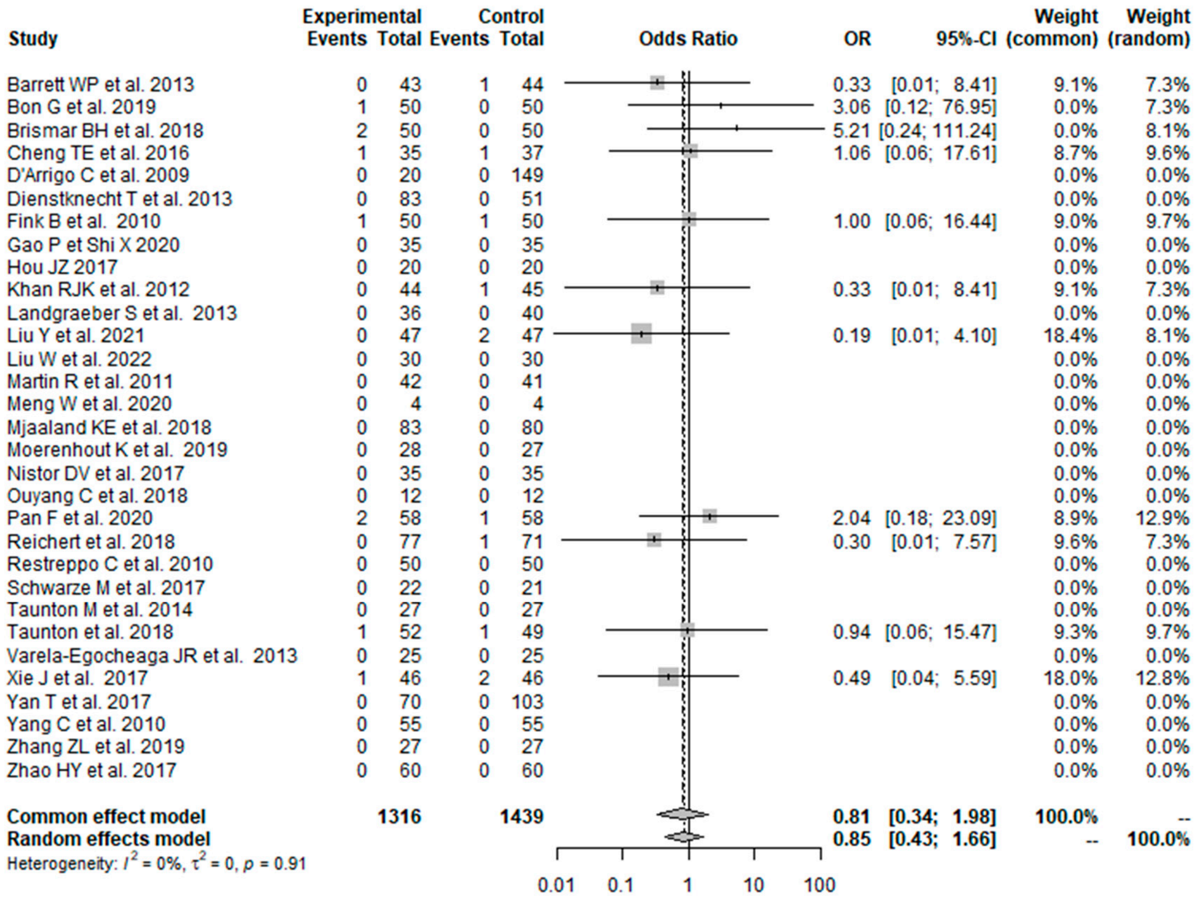

Figure 14. Comparison of the dislocation rate. OR: odds ratio; CI: confidence interval [21–25,27–30,33,35,39–42,44,45,47–49,51,53,55–58,61–63,65,66].

3.4.3. Infection: MI THA vs. CA THA

Data on 2755 THAs from 31 RCTs were pooled (I^2 = 0%, p = 0.95, Figure 15). The infection risk for MI THA was indifferent compared to that for CA THA (OR = 0.71, 95% CI 0.39 to 1.29).

3.4.4. Periprosthetic Fracture: MI THA vs. CA THA

Data on 2755 THAs from 31 RCTs were pooled (I^2 = 0%, p = 0.56, Figure 16). The periprosthetic fracture risk for MI THA was indifferent compared to that for CA THA (OR = 1.76, 95% CI 0.75 to 4.13).

3.4.5. Deep Vein Thrombosis: MI THA vs. CA THA

Data on 2755 THAs from 31 RCTs were pooled (I^2 = 0%, p = 0.98, Figure 17). The deep vein thrombosis risk for MI THA was 0.39 times smaller than that for CA THA (OR = 0.39, 95% CI 0.23 to 0.66).

3.4.6. Hematoma: MI THA vs. CA THA

Data on 2287 THAs from 27 RCTs were pooled (I^2 = 0%, p = 0.79, Figure 18). The hematoma risk for MI THA was indifferent compared to that for CA THA (OR = 0.26, 95% CI 0.05 to 1.47).

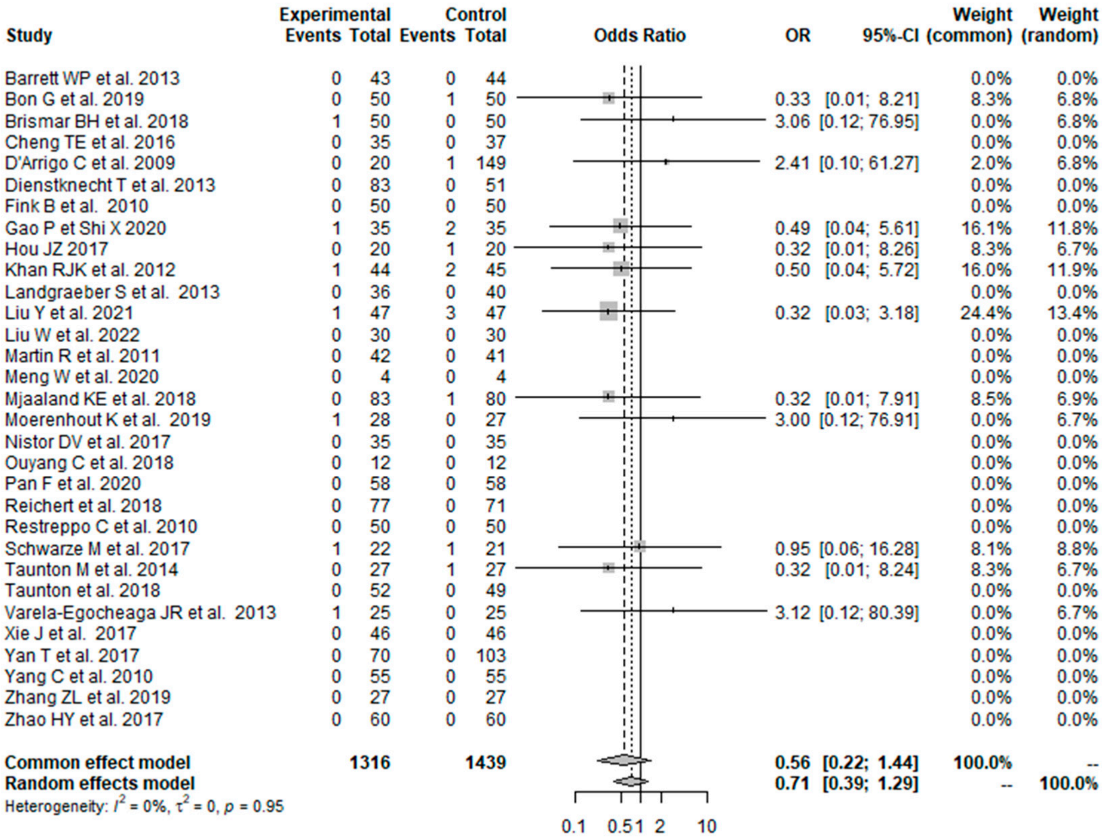

Figure 15. Comparison of the infection rate. OR: odds ratio; CI: confidence interval [21–25,27–30,33,35,39–42,44,45,47–49,51,53,55–58,61–63,65,66].

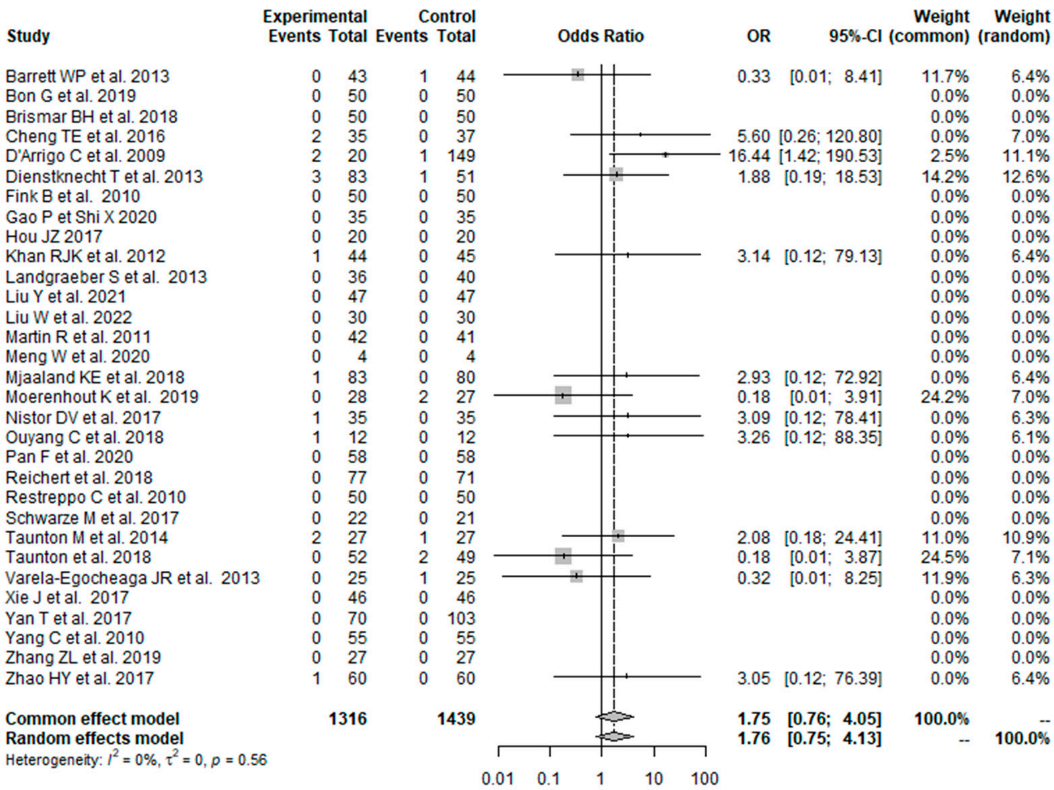

Figure 16. Comparison of the periprosthetic fracture rate. OR: odds ratio; CI: confidence interval [21–25,27–30,33,35,39–42,44,45,47–49,51,53,55–58,61–63,65,66].

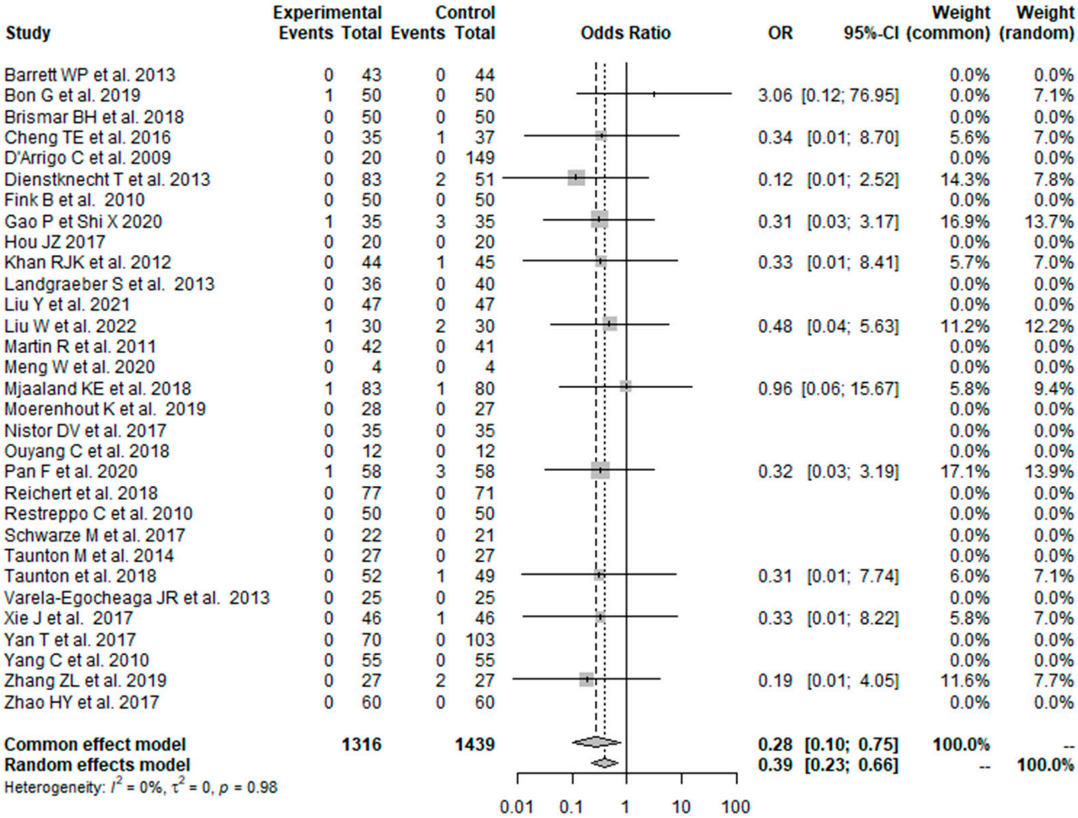

Figure 17. Comparison of the deep vein thrombosis rate. OR: odds ratio; CI: confidence interval [21–25,27–30,33,35,39–42,44,45,47–49,51,53,55–58,61–63,65,66].

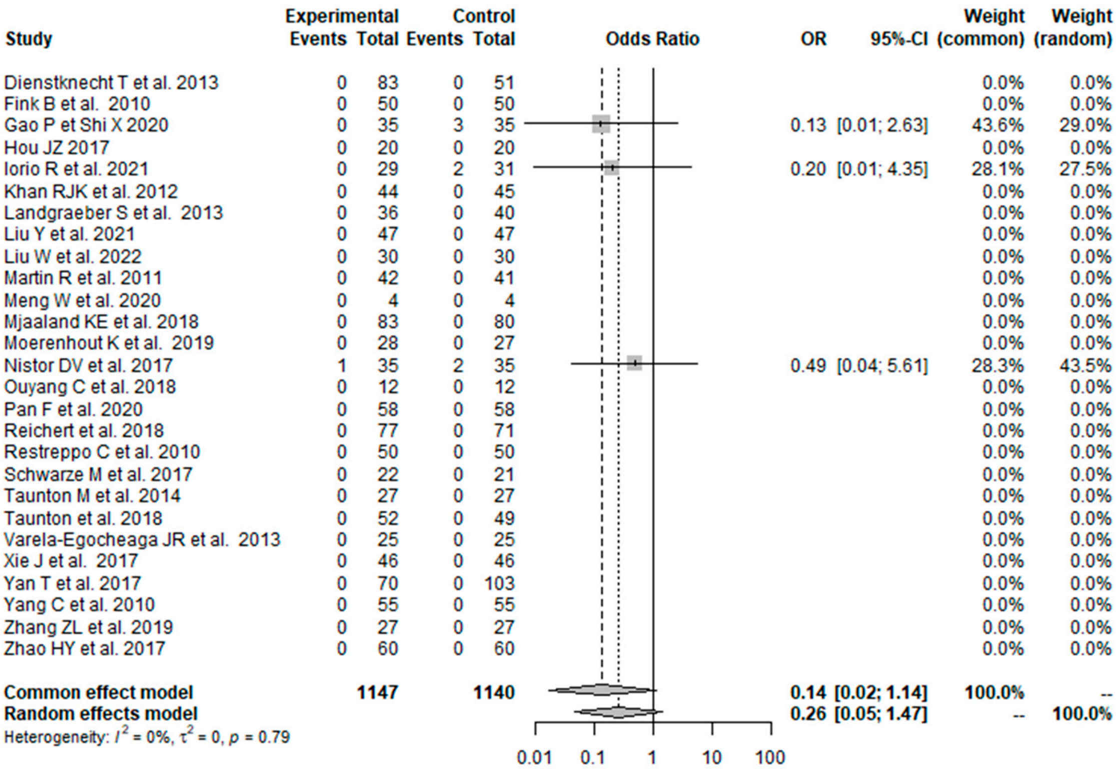

Figure 18. Comparison of the hematoma rate. OR: odds ratio; CI: confidence interval [27–30,32,33,35,39–42,44,45,47–49,51,53,55–58,61–63,65,66].

3.5. Reoperation: MI THA vs. CA THA

Data on 2314 THAs from 25 RCTs were pooled ($I^2 = 0\%$, $p = 0.81$, Figure 19). The reoperation risk for MI THA was indifferent compared to that for CA THA (OR = 1.35, 95% CI 0.69 to 2.61).

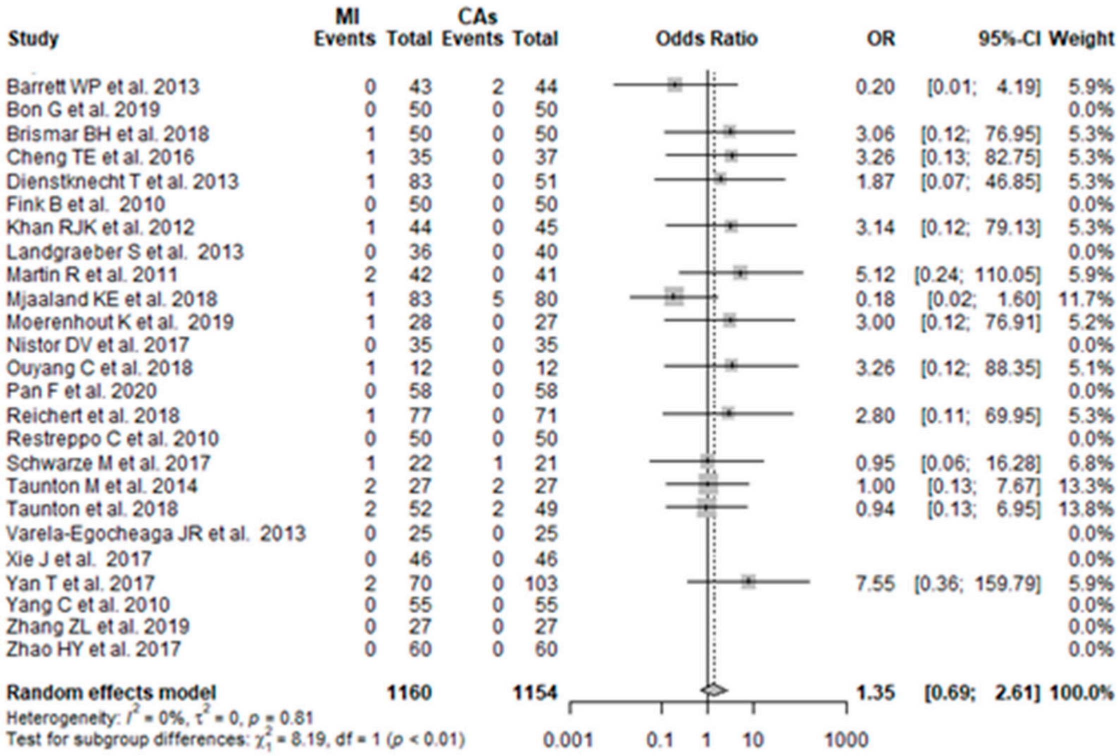

Figure 19. Comparison of the reoperation rate. OR: odds ratio; CI: confidence interval [21–24,27,28,33,35,41,44,45,47–49,51,53,55–58,61–63,65,66].

4. Discussion

The main finding of this study is that MI THA gives statistically better results overall than CA THA. This finding is based on a meta-analysis of 47 RCTs with 4086 THAs in 4063 patients, which allowed us to look at a large number of outcome parameters. For 8 of the 18 outcome parameters examined, MI THA showed better results than CA THA. For 9 of the 18 outcome parameters examined, MI THA showed indifferent results compared with CA THA, and in 1 case worse results than CA THA. However, the differences in outcome parameters between the two approaches do not reach the minimum clinically important difference (MCID). Therefore, we recommend that the choice of surgical approach should continue to be left to the experience and preference of the surgeon, in the knowledge that even better results might be achieved with MI THA.

A 2019 meta-analysis by Migliorini et al. [4], which included 4761 patients from 48 RCTs and non-RCTs, found no significant advantages of MI THA compared with CA THA. In particular, MI THA had a lower estimated total blood loss, shorter operation time and shorter hospital stay. In contrast, CA THA had a higher HHS score. Radiological results showed no significant differences between the two approaches. There was no difference in the risk of femoral fracture, dislocation or reoperation. Migliorini et al. [4] found an increased risk of iatrogenic nerve palsy with the MI approach. A 2022 meta-analysis by Clesham et al. [2] of 2633 THAs from 20 RCTs and non-RCTs found that MI THA was equivalent to CA THA in terms of all-cause revision, aseptic revision, infection, dislocation, fracture rates and functional outcomes. A 2010 meta-analysis by Smith et al. [5] of 2849 THAs from 28 RCTs and non-RCTs reached similar conclusions. There was little difference in clinical and radiological outcomes between MI and CA THA, while MI approaches were associated with an increased risk of lateral femoral cutaneous nerve palsy. These meta-analyses [2,4,5] did not include primary data from studies of the SuperPATH superior MI approach.

4.1. Surgical Outcomes

In our meta-analysis, MI THA showed a 10.6 min. longer operation time than CA THA (Figure 2). This was the only outcome parameter where MI THA showed statistically worse results. A recent analysis of 35 articles by Cantrell et al., reporting on 630,675 THAs, found a mean operation time of approximately 95 min., which remained relatively stable over two decades between 1996 and 2016 [71]. In a 2019 analysis of 89,802 THAs, Surace et al. [72] suggested an operation time of approximately 80 min. with a lower risk of perioperative complications. Longer operation times are known to be associated with perioperative complications [72,73]. The mean operation time for MI THA was 82.3 min and the mean operative time for CA THA was 72.8 min. This means that the operation time for MI THA was well within the recommendation of Surace et al. [73].

MI THA had a 4.1 cm shorter incision length than CA THA (Figure 3). The mean incision length for MI THA was 9.0 cm, ranging from 5.8 cm to 13.7 cm, and the mean incision length for CA THA was 13.1 cm, ranging from 9.0 cm to 15.6 cm. Incision length must always be considered in relation to other outcome parameters. A very short incision must not be forced at the expense of functional outcome and complication rate. Apart from the obvious cosmetic benefit of a short incision, the importance of mini-incision approaches for THA outcomes is questionable [10,74].

There was no difference in intraoperative blood loss between MI THA and CA THA (Figure 4). However, the mean intraoperative blood loss for MI THA was 262.3 mL, ranging from 72.1 mL to 1344.0 mL, and the mean intraoperative blood loss for CA THA was 435.3 mL, ranging from 123.84 mL to 1644.0 mL. The correlation between blood loss and intraoperative trauma is well established. However, there is no information in the literature on the level of blood loss at which an MCID is present in THA. Logically, any blood loss requiring transfusion should be considered clinically relevant. In some cases, this insignificant difference in blood loss between MI THA and CA THA might be the amount of blood required to avoid the need for blood transfusion. Then there is the hidden blood loss, which can only be measured using laboratory parameters. The first meta-analysis investigating postoperative serum biomarkers of MI THA versus CA THA was recently published by the authors of this study [14]. Based on 13 included RCTs with 1186 THA patients, this 2023 meta-analysis found no statistically significant differences in postoperative hemoglobin levels of MI THA compared to CA THA [14]. In addition to the choice of surgical approach, there are other measures to reduce blood loss in THA. Systemic and local application of tranexamic acid [75] and intraoperative warming of the patient have a positive effect on blood loss [76]. The cell saver device offers the possibility of autotransfusion. The use of iron supplements and erythropoietin is considered a postoperative option to avoid transfusions [77].

MI THA had a 1.1 points lower pain VAS 1 day postoperatively and a 0.8 point lower pain VAS 3 days postoperatively than CA THA (Figures 5 and 6). However, these differences do not appear to be of clinical significance. A recent comparative study by Danoff et al. [78] found that a pain improvement of 18.6 mm for THA patients, measured on a VAS-P scale of 100, is one MCID. Applied to our 10-point pain VAS, this would be a difference of 1.9 points. This is a difference that could not be achieved by the MI THA compared to the CA THA. Low pain in the postoperative period is important for patient comfort. A very simple and effective way to reduce short-term postoperative pain and hospital stay in THA patients is intraoperative infiltration with local anesthetics [79].

4.2. Functional Outcome

Probably the most important outcome parameter is the HHS, as it provides information on the function of the operated hip. At 0–1.5 months postoperatively, MI THA had a HHS

5.2 points higher than CA THA (Figure 7). At 3 months postoperatively, MI THA had a HHS 2.2 points higher than CA THA (Figure 8). At 6 months postoperatively, MI THA had a 1.9 point higher HHS than CA THA (Figure 9). At ≥12 months postoperatively, MI THA had a 0.9 point higher HHS than CA THA (Figure 10). The lowest MCID reported in the literature is not less than 7.9 points on the 0–100 HHS scale [80]. Therefore, we can state that the short-term functional outcome of MI THA is statistically superior to that of CA THA without reaching the MCID. Most impressively, the difference in functional outcome between MI HTA and CA THA gradually almost disappears over 12 months. This reinforces the finding that MI THA has a particular advantage in early short-term functional outcome.

4.3. Radiological Outcome

There were no significant differences in cup positioning between MI THA and CA THA or in the subgroup analysis. The ideal anteversion angle for cup positioning is 15° ± 10° and the ideal inclination angle for cup positioning is 40° ± 10° [81]. The ideal anteversion angle is particularly important as it correlates with the risk of dislocation. The mean anteversion angle of the MI THA was 20.4° (range: 15.0–26.9°) (Figure 11). The mean inclination angle of the MI THA was 42.3° (range: 37.0–49.6°) (Figure 12). The mean anteversion angle of the CA THA was 20.5° (range: 14.3–29°) (Figure 11). The mean inclination angle of the CA THA was 42.6° (range: 39.0–48.9°) (Figure 12). However, the acetabular positioning angles were within the safe zone for MI THA and CA THA.

4.4. Overall Postoperative Complications

In addition to HHS, postoperative complications are probably the most important parameters that allow us to draw conclusions about the outcome of THA patients. We evaluated the following complications: dislocation, infection, periprosthetic fracture, deep vein thrombosis, hematoma and reoperation. MI THA showed indifferent postoperative complication rates compared with CA THA (Figure 13). In 12 RCTs, MI THA resulted in 86 complications out of 1415 THAs compared to 65 complications out of 1544 THAs with CA THA. The well-known alleged disadvantage of MI approaches, that they lead to significantly higher complication rates because the operative field is impaired for the surgeon, seems to be only an assumption without scientific evidence.

The risk of deep vein thrombosis was 0.39 times lower with MI THA than with CA THA (Figure 17). In 31 RCTs, there were 5 cases of deep vein thrombosis with MI THA out of 1316 THAs compared to 17 cases of deep vein thrombosis with CA THA out of 1439 THAs. MI THA had similar rates of dislocation, infection, periprosthetic fracture, hematoma and reoperation compared with CA THA (Figures 14–16, 18 and 19).

When assessing the quality of trials, it is striking that a large proportion of RCTs are of low quality (Table 2). Nevertheless, the RCT has been shown to be the most reliable scientific form in the hierarchy of evidence in medical research. The RCT is considered the best study design for making a clear statement with a clear question and for proving causality. Meta-analyses of RCTs are increasingly used for evidence-based practice and guideline development. It is important to note that only RCTs were included in our meta-analysis.

Finally, the fact that the differences between the approaches did not reach minimal clinical significance must be put into perspective. The outcome parameters for which MI THA showed better results but did not reach an MCID were very numerous and, taken together, may still be of clinical importance.

Our study contributes to daily clinical practice. The mean values of relevant outcome parameters such as operating time, incision length, intraoperative blood loss, pain VAS, HHS, acetabular cup positioning angles and postoperative complication rates can be used for self-critical comparison with the results of the reader’s orthopedic department. In addition, our findings may encourage some orthopedic surgeons to try MI THA in an attempt to achieve even better patient outcomes, although perhaps without reaching an MCID.

5. Limitations

We identified the following strengths and limitations of our meta-analysis: (1) We only included RCTs in our systematic review and meta-analysis. This is the top of the pyramid of evidence and ensures that our conclusions are reliable and meaningful. (2) We used high-quality statistical methods to conduct the meta-analysis. (3) The RCTs and patients included were of substantial size. (4) Significant heterogeneity was found among the included studies for several outcome parameters. (5) The included studies combined different surgical indications in one meta-analysis: osteoarthritis, femoral neck fracture, dysplasia and avascular necrosis of the femoral head. (6) For some outcomes, the sample size and number of included RCTs were small. (7) Long-term THA outcomes were not included. (8) Surgeon skill, learning curve, perioperative management or type of implant probably influenced the results and must be considered as confounding factors.

6. Conclusions

Our meta-analysis suggests that MI THA has several advantages over CA THA in terms of short-term surgical and functional outcomes, with equal postoperative complication rates. However, a general recommendation for orthopedic surgeons to change their surgical approach to hip THA based on our results cannot be made, as the differences between the investigated approaches did not reach the MCID.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/prosthesis5030067/s1, Table S1: PRISMA Checklist; Table S2: Raw data extraction set.

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Informed Consent Statement: Not applicable.

Data Availability Statement: Raw data extraction set available in Supplement.

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Abbreviations

CA	conventional approach
CI	confidence interval
CNKI	China National Knowledge Infrastructure
HHS	Harris Hip Score
ITT	intention to treat
MCID	minimal clinically important difference
MD	mean difference
OR	odds ratio
MI	minimally invasive
PP	per protocol
RCT	randomized controlled trials
THA	total hip arthroplasty

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