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ORIGINAL ARTICLE

Evidence-based computer-navigated total hip arthroplasty: an updated analysis of randomized controlled trials

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Abstract

Background Total hip arthroplasty (THA) has evolved over the years to be a reliable, reproducible, and successful orthopedic procedure. Nowadays, THA is increasingly performed on patients using less invasive, tissue-preserving techniques. Accordingly, the use of computer navigation in total joint arthroplasty has become more prevalent. However, there is still lack of high-quality evidence to verify the most effective technique for THA.

Methods A search was conducted in PubMed, Medline, Embase, Cochrane Central Register of Controlled Trials, and Google Scholar databases. Clinical trials published from 1966 to Feb 2012 that assess conventional techniques THA or computer-navigated techniques THA for placing the acetabular component. The main outcome measures included abduction angles, anteversion angles, percentage of acetabular outliers, operation time, decrease in Hb/24 h, and wound secretion/48 h.

Results The pooled analysis across all studies showed a significant difference in anteversion angles and acetabular outliers (difference −0.22, 95 % CI −0.67, 0.24; $p = 0.346$, $I^2 = 71.9$ %) and (difference 8.34, 95 % CI 4.15, 16.74; $p = 0.000$, $I^2 = 0.0$ %). However, no significant difference in abduction angle and decrease in Hb/24 h (difference −0.22, 95 % CI −0.67, 0.24; $p = 0.346$, $I^2 = 71.9$ %) and (difference 0.03, 95 % CI −0.36, 0.41; $p = 0.888$, $I^2 = 0.0$ %). For the operation time, computer-navigated THA was longer (difference −0.73, 95 % CI −1.32, −0.15; $p = 0.014$, $I^2 = 74.4$ %).

Conclusions This meta-analysis demonstrated computer-navigated THA was a more favorable method for placing the acetabular component and decreased the number of acetabular cups implanted outside the desired range of alignment. More high-quality RCTs were needed to support the evidence.

Keywords Total hip arthroplasty · Computer-navigated · Meta-analysis

Introduction

Total hip arthroplasty (THA) has evolved over the years to be a reliable, reproducible, and successful orthopedic procedure, with 10-year survival rates exceeding 90 % [1]. The position of the acetabular component is critical to the function and outcome of THA. Lewinnek et al. [2] recommended an abduction angle of 40 ± 10° and an anteversion angle of 15 ± 10° as the safe zone for cup orientation. However, recent studies have shown that even experienced surgeons often fail to place the acetabular component within Lewinnek's "safe zone" when using a freehand technique [3–5]. Malposition of the acetabular component in total hip arthroplasty restricts the range of movement, is the most common cause of dislocation and can lead to increased and premature wear [6, 7]. These problems have demonstrated a need to develop more reliable tools in order to prevent malposition of the implants

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and to improve the reproducibility of implant alignment in total hip arthroplasty [8].

Nowadays, total hip arthroplasty is increasingly performed on patients using less invasive, tissue-preserving techniques. Accordingly, the use of computer navigation in total joint arthroplasty has become more prevalent, and the method has proved to be reliable for acetabular component positioning [9]. Moreover, computer navigation system is not only aimed at an improved alignment of the hip prosthesis, it also provides instant information and feedback to the surgeon, which may make the surgical technique easier to perform and may result in better clinical outcomes [10]. However, due to the fact that computer navigation system resulted in longer operation times and surgeons cannot master the new technique, the computer navigation system is not applied broadly. Although the computer navigation system will result in better position of THA compared to conventional THA techniques, however, there is still lack of high-quality evidence to verify the most effective technique for THA. Consequently, we performed a meta-analysis to compare the conventional THA techniques with computer-navigated THA techniques.

Methods

Criteria for considering studies for this review

Studies included: We included randomized controlled trials.

Types of participants and interventions

The study population included adults who had primary osteoarthritis, subcapital fracture or avascular necrosis of the hip. All patients underwent the conventional techniques THA or computer-navigated techniques THA for placing the acetabular component.

Types of outcome measures

The main outcome measures included abduction angles, anteversion angles, percentage of acetabular outliers, operation time, decrease in Hb/24 h, and wound secretion/48 h. The second outcome measures included Harris Hip Score, limb length discrepancy, and WOMAC (Western Ontario and McMaster University Osteoarthritis Index).

Search methods for identification of studies

We searched the PubMed, Medline, Embase, Cochrane Central Register of Controlled Trials, and Google Scholar databases. Two authors independently searched for relevant studies from 1966 to Feb 2012. The search strategy was created with the assistance of a librarian using a combination of terms including computer, computer navigation, navigation, hip arthroplasty, joint replacement, joint prosthesis, arthroplasty, total hip arthroplasty, THA, prospective, meta, review, and random. We limited searches to randomized controlled trials, systematic reviews, and meta-analyses and imposed no language or other limitations. Figure 1 gives details of the search strategy.

Selection of studies

The study selection was performed in two stages. First, two reviewers independently screened the titles and abstracts of studies identified by the search strategy and discarded clearly irrelevant studies. Then consensus was used to resolve disagreements concerning selection and inclusion of RCTs, and a third reviewer was consulted if disagreements persisted.

Methodological quality assessment

Two reviewers assessed the quality of the studies independently; revised Jadad Scale was used to perform the quality assessment. This scale includes the random sequence production (2 points), allocation concealment (2 points), appropriateness of blinding (2 points), and description of dropouts and withdrawals (1 point). The total score is 7 points, 0–3 points means poor quality and 4–7 points means high quality. And Consolidated Standards on Reporting Trials (CONSORT) checklist and scoring system were used to evaluate the quality of included trials: Scores

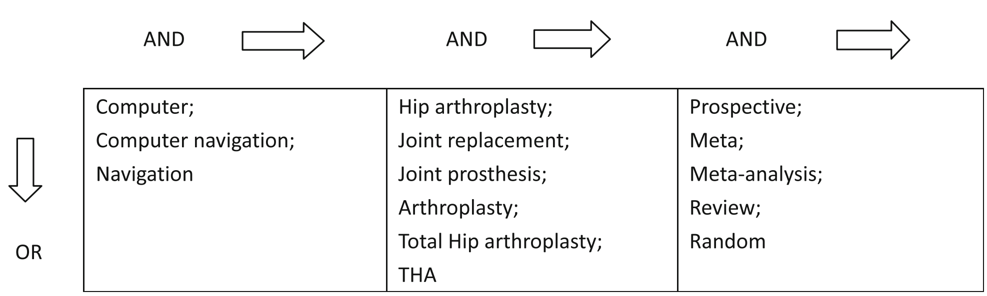

Fig. 1 Keywords and boolean (logical) operators used in the database searches

of 18–22 are considered excellent study quality; 13–17, good; 8–12, fair; and less than 7, poor.

Data extraction

Two reviewers independently extracted the data using a standardized form regarding inclusion criteria (study design, participants, interventions, and outcomes). A consensus method was used to resolve disagreements, and a third reviewer was consulted if disagreements persisted.

Data analysis

For dichotomous variables, we derived the relative risks and 95 % confidence intervals for each outcome. For continuous variables, we calculated the mean differences and 95 % confidence intervals for each outcome. We performed the meta-analysis using a fixed-effect model if no significant heterogeneity was present. To assess heterogeneity between studies, we performed a Chi-square test and estimated the I^2 statistic. A random effects model was selected to account for heterogeneity in the design and patient selection among included studies. And the subgroup analyses were conducted for different outcomes.

Results

Description of studies

Search results

A search of the PubMed, Embase, Cochrane Central Register of Controlled Trials, and Google Scholar databases retrieved 993 articles. We excluded 239 duplicate articles after we reviewed the titles and abstracts. Then reading the whole paper, we included 7 papers [8, 9, 11–15]. These studies included a total population of 473 participants with 235 in the conventional techniques THA group and 238 in or computer-navigated techniques THA group. Figure 2 summarizes the study selection process.

Included studies

Seven RCTs [8, 9, 11–15]were included that all were published in English. Four studies [8, 9, 11, 14] had included a homogeneous population of patients who had primary osteoarthritis, and three studies [12, 13, 15] did not report the patients' details. Three studies [11–13] compared the CT-based computer navigation to free-hand method, and four studies [8, 9, 14, 15] compared the imageless

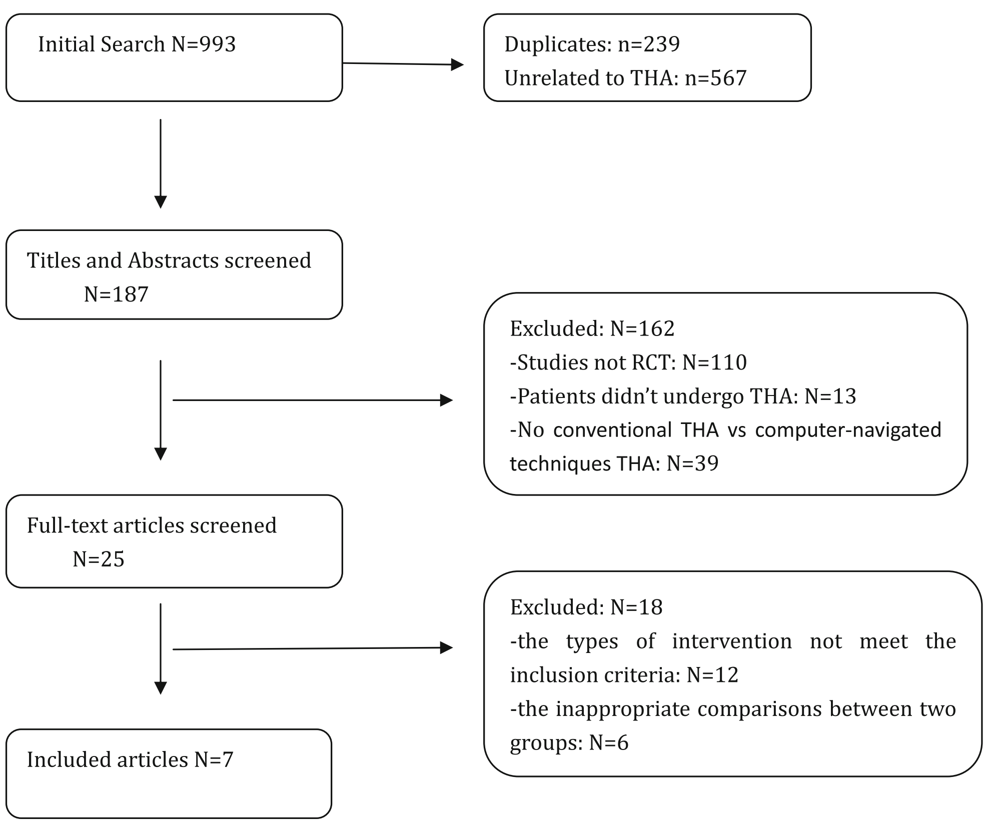

Fig. 2 Flowchart of trial selection process

computer-assisted surgical system to free-hand method. Characteristics of the 7 studies are described in Table 1.

Methodological quality

Of all the 7 trials, all studies were level II evidence (Table 1). For the revised Jadad Scale, all studies were 4–7 points with a high quality. Seven RCTs were evaluated by Consolidated Standards on Reporting Trials (CONSORT) checklist and scoring system, 4 studies [11–13, 15] were 8–12 scores; 3 studies [8, 9, 14] were 13–17 scores; and no studies were 18–22 scores, all the RCTs had satisfied methodological quality. The details are described in Table 2.

Outcomes

In all the trials, subgroup analysis was performed by different measure outcomes. All the data are summarized in Table 3.

Abduction angle

Five studies [8, 9, 12–14] reported the abduction angle, and the pooled analysis across all studies showed no evidence of a significant difference in abduction angle between control and navigation groups (difference −0.22, 95 % CI −0.67, 0.24; $p = 0.346$, $I^2 = 71.9$ %) (Fig. 3). Evidence showed notable heterogeneity, however, none of the covariables could explain heterogeneity by meta-regression.

Anteversion angles

Five studies [8, 9, 12–14] reported the anteversion angles, and significant differences between the two groups were detected (difference 0.47, 95 % CI 0.12, 0.82; $p = 0.009$, $I^2 = 53.1$ %) (Fig. 4). The result showed a moderate heterogeneity and prompted that computer-navigated techniques can place the acetabular component more exactly and safely.

Operation time

Three studies [12, 13, 15] reported the operation time, and significant differences between the two groups were detected (difference −0.73, 95 % CI −1.32, −0.15; $p = 0.014$, $I^2 = 74.4$ %) (Fig. 5). Evidence showed notable heterogeneity, however, sensitivity analysis demonstrated that the result is stable. The computer-navigated techniques resulted in a longer operation time.

Decrease in Hb/24 h

There were two studies [12, 13] reported the decrease in Hb/24 h, and the pooled analysis across two studies showed no evidence of a significant difference in decrease in Hb/24 h between control and navigation groups (difference 0.03, 95 % CI −0.36, 0.41; $p = 0.888$, $I^2 = 0.0$ %) (Fig. 6). No heterogeneity was detected.

Table 1 Description of Included Trials

Author	Study design	Mean age (years)		Male/female	Number of patients		Outcome	Level of evidence
		Control	Navigation		Control	Navigation		
Leenders et al. [11]	RCT	64.9	64.1	42/58	50	50	Abduction angle; percentage of acetabular outliers	II
Kalteis et al. [12]	RCT	62.4	63.5	17/28	22	23	Abduction angle; anteversion angles; operation time; decrease in Hb/24 h; wound secretion/48 h; percentage of acetabular outliers	II
Kalteis et al. [13]	RCT	64.7	63.9	31/29	30	30	Abduction angle; operation time; decrease in Hb/24 h; blood loss/48 h; percentage of acetabular outliers	II
Parratte and Argenson [8]	RCT	62.6	61.2	32/28	30	30	Abduction angle; anteversion angles; percentage of acetabular outliers	II
Sendtner et al. [9]	RCT	70	68	24/38	30	32	Abduction angle; anteversion angles	II
Lin et al. [14]	RCT	63.5	62.1	28/22	25	25	Abduction angle; anteversion angles	II
Manzotti et al. [15]	RCT	71.98	72.23	44/52	48	48	Harris Hip Score; limb length discrepancy; WOMAC; operation time	II

WOMAC Western Ontario and McMaster University Osteoarthritis Index

Table 2 Quality assessment of included randomized controlled trials with revised Jadad scale and CONSORT statement

Author	Random sequence production	Allocation concealment	Blind method	Withdrawal	Revised Jadad's scale score	CONSORT statement
Leenders et al. [11]	1	1	1	1	4	11
Kalteis et al. [12]	1	1	1	1	4	10
Kalteis et al. [13]	1	1	1	1	4	11
Parratte and Argenson [8]	1	1	1	1	4	13
Sendtner et al. [9]	2	1	1	1	5	14
Lin et al. [14]	1	1	1	1	4	13
Manzotti et al. [15]	1	1	1	1	4	12

Table 3 Data extraction of outcomes for assessing the knee

Authors	Control group			Navigation group		
	N	Mean	SD	*N*	Mean	SD
Abduction angle						
Kalteis et al. [12]	22	42.3	7.0	23	45.0	2.8
Kalteis et al. [13]	30	43.7	7.3	30	43.2	4.0
Parratte and Argenson [8]	30	38.0	8.0	30	40.0	5.0
Sendtner et al. [9]	30	37.9	6.3	32	42.3	3.8
Lin et al. [14]	25	42.5	6.3	25	40.0	3.4
Anteversion angles						
Kalteis et al. [12]	22	24.0	15.0	23	14.4	5.0
Kalteis et al. [13]	30	22.2	14.2	30	15.2	5.5
Parratte and Argenson [8]	30	20.6	10.0	30	14.8	4.6
Sendtner et al. [9]	30	23.8	10.1	32	24.5	6.0
Lin et al. [14]	25	20.3	7.6	25	18.7	5.5
Operation time (min)						
Kalteis et al. [12]	22	77.0	21.8	23	85.3	13.9
Kalteis et al. [13]	30	75.1	22.5	30	82.6	11.8
Manzotti et al. [15]	48	73.17	15.26	48	89.39	9.68
Decrease in Hb/24 h(mg/dl)						
Kalteis et al. [12]	22	3.3	0.8	23	3.1	1.3
Kalteis et al. [13]	30	3.1	0.9	30	3.2	1.3

Authors	Percentage of acetabular outliers			
	Control group		Navigation group	
	Yes	No	Yes	No
Leenders et al. [11]	13	37	2	48
Kalteis et al. [12]	11	11	2	21
Kalteis et al. [13]	16	14	2	28
Parratte and Argenson [8]	17	13	6	24
Lin et al. [14]	2	23	0	25

Acetabular outliers

Five studies [8, 11–14] reported the percentage of acetabular outliers; pooled analysis showed significant differences between the two groups (difference 8.34, 95 % CI 4.15, 16.74; $p = 0.000$, $I^2 = 0.0$ %) (Fig. 7). No heterogeneity was detected. The results demonstrated that the accuracy of cup placement was significantly improved by using the computer navigation system.

Discussion

In this meta-analysis, we assessed the evidence from randomized controlled trials that compared outcomes with conventional techniques THA or computer-navigated techniques THA for placing the acetabular component. Our review suggested computer-navigated techniques can place the acetabular component more exactly and decrease the percentage of acetabular outliers. However, the computer-navigated techniques resulted in a longer operation time. For blood lose, there was no significant difference between two techniques.

There was a meta-analysis published in 2009 by Gandhi et al. [16], which included 3 RCTs and reported a consistent result that navigation in hip arthroplasty improves the precision of acetabular cup placement by decreasing the number of outliers from the desired alignment. However, the study did not summarize the abduction angle, anteversion angles, operation time, and blood loss between two kinds of techniques. In our study, results showed no significant differences in abduction angles, but a significant difference was detected in anteversion angles, and the percentage of acetabular outliers was lower in computer-navigated groups. It showed more favorable results in computer-navigated groups, although a longer operation time was displayed.

Our review has several strengths; we used an exhaustive search strategy, including great amount of high-quality RCTs. All included studies were assessed rigorously by revised Jadad Scale and Consolidated Standards on Reporting Trials (CONSORT) checklist and scoring system. When coming heterogeneity, Meta-regression analysis and sensitivity analysis were performed to control the veracity and stability of pooled results.

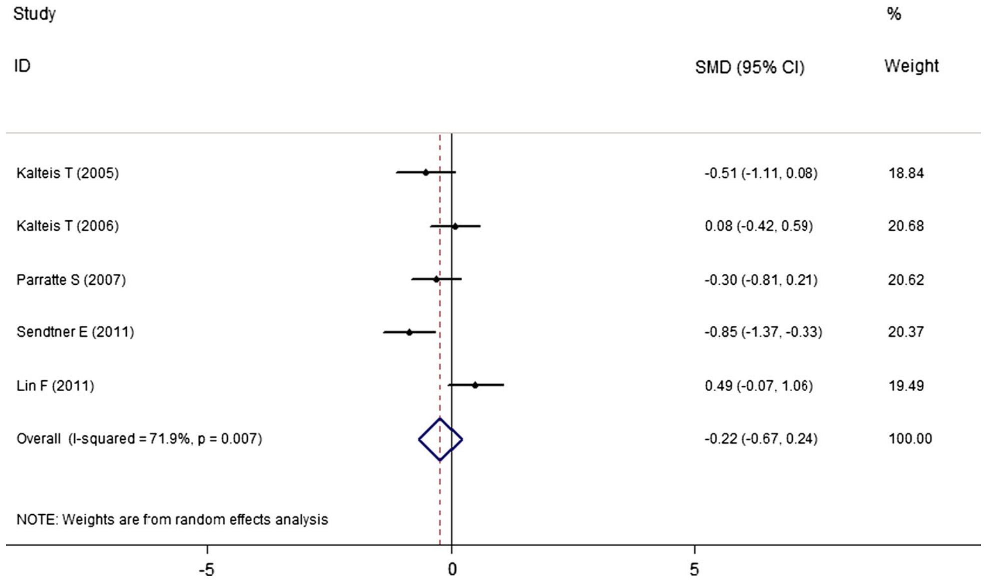

Fig. 3 Forest plots of pooling abduction angle between two groups

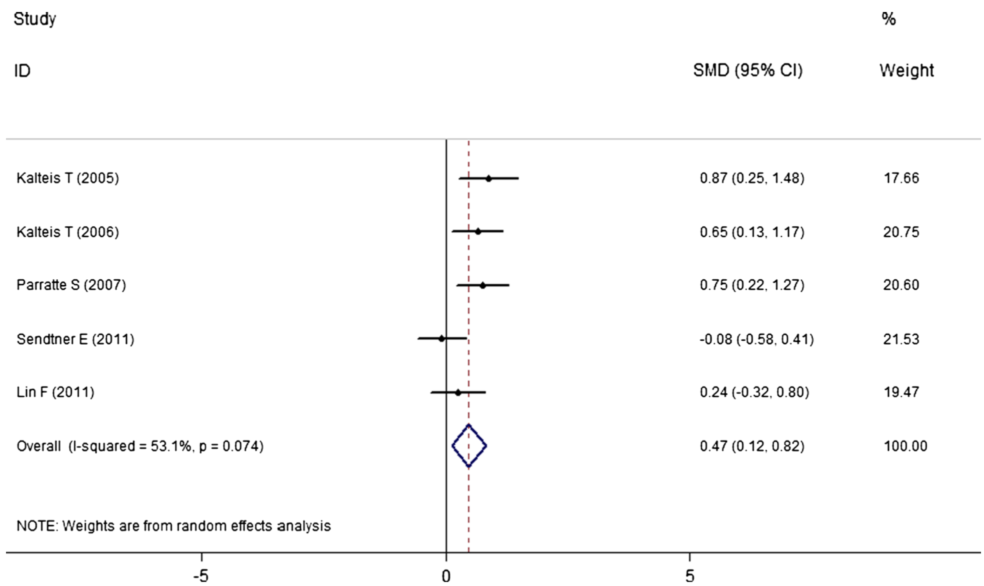

Fig. 4 Forest plots of pooling anteversion angles between two groups

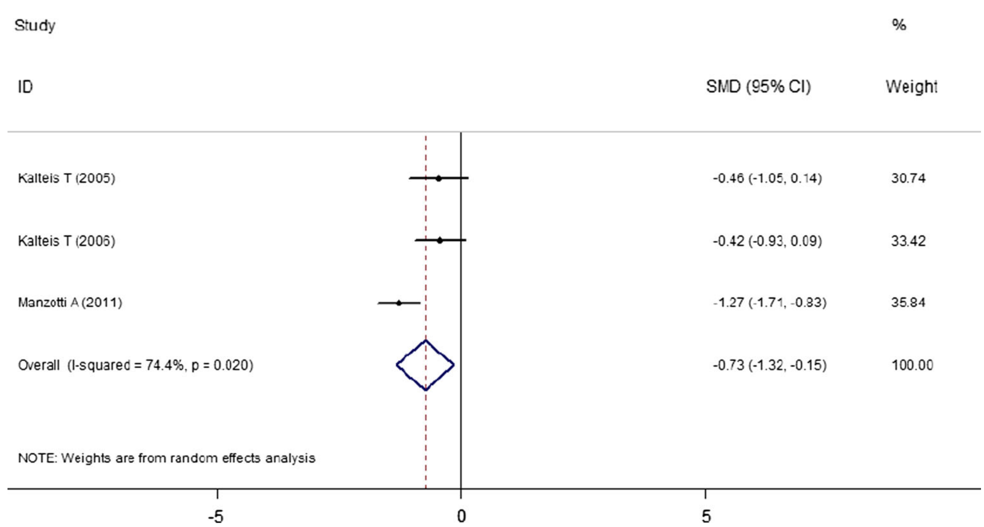

Fig. 5 Forest plots of pooling operation time between two groups

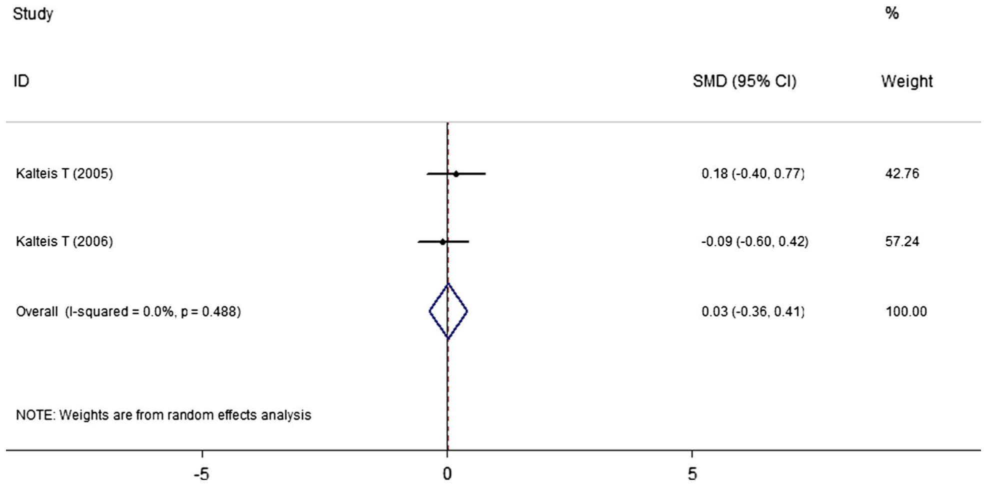

Fig. 6 Forest plots of pooling the decrease in Hb/24 h between two groups

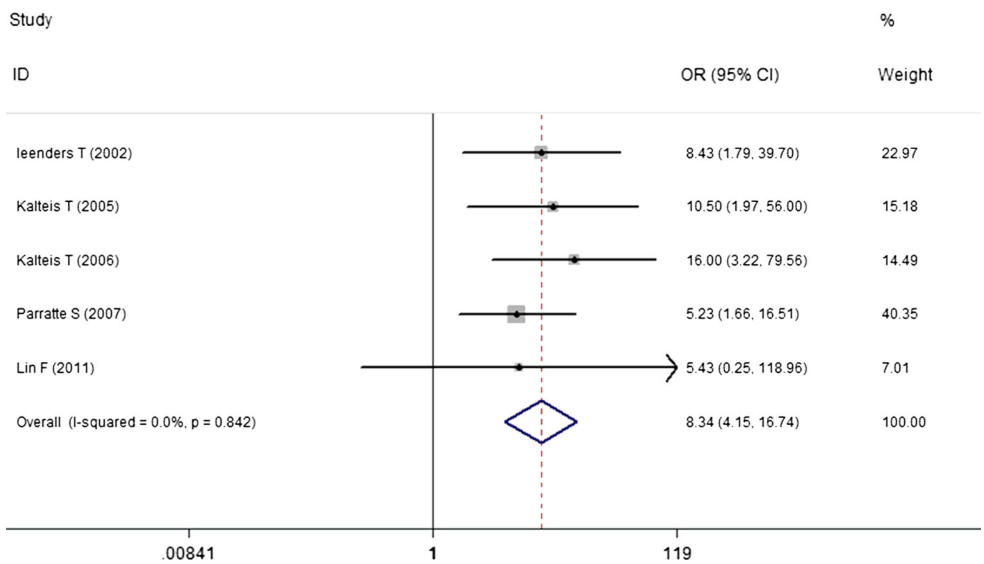

Fig. 7 Forest plots of pooling the acetabular outliers between two groups

Although we believe this to be the most comprehensive meta-analysis of RCT-based evidence for the comparisons between conventional techniques THA and computer-navigated techniques THA for placing the acetabular component, we acknowledge that this study has a number of limitations. The general lack of allocation concealment methods in the included RCTs made it difficult to assess their methodological quality, thereby the risk of bias and potential to overestimate the effect may be existent. Our evidence showed considerable statistical heterogeneity for several outcomes across the trials; however, the regression analysis and sensitivity analysis suggested the results were stable. It is reassuring that our findings were generally consistent across various sensitivity analyses undertaken to explore this heterogeneity.

In conclusion, this meta-analysis demonstrated computer-navigated THA was a more favorable method for placing the acetabular component and decreased the number of acetabular cups implanted outside the desired range of alignment. More high-quality RCTs were needed to support the evidence.

Conflict of interest The authors declare that they have no conflict of interest.

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