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REVIEW ARTICLE

Total hip arthroplasty: minimally invasive surgery or not? Meta-analysis of clinical trials

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Abstract

Background There exist a relevant number of clinical trials comparing the minimally invasive surgery to the standard-invasive approach in total hip arthroplasty (THA). Up to date, there are still debates concerning the most effective approach in THA.
Aim The purpose of this study is to compare the clinical outcomes concerning patients undergoing primary THA performed via the minimally invasive versus standard-invasive surgery incision.
Material and methods The search was performed in the main databases, evaluating both quantitative and qualitative results. All the randomised controlled trials (RCTs) and non-randomised controlled trials (nRCTs) comparing the minimally invasive versus the standard-invasive approach were enrolled in this study. We focused on the clinical and radiological outcomes and on the complication rate. Study methodological quality was assessed performing the PEDro critical appraisal scale. All meta-analyses were performed using the Review Manager software. To analyse the publication's bias, we performed the Funnel plot.
Result We enrolled in our study 4761 patients, undergoing to 4842 total hip arthroplasties. The mean follow-up was 22.26 months. In favour of the minimally invasive group, we reported less total estimated blood loss, shorter surgical duration, and a shorter length of stay. In favour of the standard-invasive group, we reported a higher value of the Harris hip score. Concerning the radiological outcomes, we did not report substantial differences across the two exposures. No difference was observed regarding the risk of femoral fractures, dislocation, and revision rates. We evidenced an increasing risk occurred in an iatrogenic nerve palsy during the minimally invasive approach.
Conclusion Based on currently available evidences concerning the outcomes following THA and the analysis of our results, we stated no remarkable benefits of the minimally invasive compared to the standard-invasive surgery.

Keywords Minimally · Mini · Standard · Exposure · Invasive · Approach · Total hip arthroplasty · Total hip replacement Hip prosthesis · osteoarthritis

Introduction

Degeneration of the hip joint can be result from several pathologies, presenting high incidence worldwide [1]. Furthermore, it presents also a significant economic impact on the health system, reducing considerably the quality of life of the affected patients.

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Total hip arthroplasty (THA) has been shown to be an effective treatment for advanced degenerative pathologies, restoring the physiological biomechanical function of the joint and providing substantial improvement in patient's quality of life [2]. The THA is believed to be one of the most successful orthopaedic surgical procedures [3]. In the past decades, we witnessed to a constant improvement and differentiation of the surgical techniques [4]. Minimally invasive surgery (MIS), especially for THA, is in the interest both of surgeons and patients. There are a relevant number of clinical trials comparing the MIS to the standard-invasive surgery (SIS) exposure. The most efficient outcome of both interventions remains still controversial and has not yet been fully clarified. The purpose of this study was to systematically review the available evidences and to perform a meta-analysis comparing clinical and functional outcomes among patients undergoing primary THA performed by the MIS versus SIS approach.

Material and methods

Search strategy

We conducted the meta-analysis referring to the standard methodology outlined in the Cochrane Handbook [5]. Published studies were included in the analysis if:

(1) The design was a trial clinical study;
(2) Patients underwent to a primary THA;
(3) One group received a MIS approach THA;
(4) Another group received a SIS approach THA; and
(5) Minimum one quantifiable pre-specified outcome measure was reported.

Data extraction

Two independent investigators (FM, JE) performed the research in the main databases, evaluating the results. The research was focused on the topic MIS versus SIS approach for THA. Data source were performed for publication available in a time frame ranging from 2000 to 2018. We conducted a comprehensive literature search in the main databases: PubMed, EMBASE, CINAHL, AMED, British Nursing Index, Scopus, Cochrane Systematic Reviews, and Google Scholar. We used exploded mesh terms and keywords to generate sets for the following themes: *minimally*, *mini*, *standard*, *exposure*, *invasive*, *approach*, *total hip arthroplasty*, *total hip replacement*, *hip prosthesis*, *osteoarthritis*.

The two authors independently examined titles and abstracts. Relevant review articles were obtained in full text. Additionally, the bibliography of all included studies was reviewed. The results from the literature search were divided and conducted an independent initial review for eligibility based on title and abstract. Studies that were clearly not related to the research question were immediately excluded. The remaining studies were then divided among the reviewers such that both reviewers independently assessed each to confirm final eligibility.

Eligibility criteria

All the randomised controlled trials (RCTs) and non-randomised controlled trials (nRCTs) comparing the clinical and/or radiological outcomes and/or complications of THA using a MIS approach to a SIS were enrolled in this study. According to the Oxford Centre of Evidence-Based Medicine [6], level of evidence I and II articles have been considered for this work. According to the author's language capabilities, articles in English, Italian, German, Spanish, and French were included in this study. Missing data pertinent to MIS versus SIS in THA warranted exclusion from this meta-analysis. We referred to all types of surgical approaches [7]: lateral, posterolateral, anterolateral, anterior, and the two-incision standard approach [8]. Articles treating hip resurfacing, hemiarthroplasty, or revision surgery were excluded. Animal, cadaveric, and in vitro studies were also excluded.

Outcomes of interest

Two investigators (FM, JE) extracted the following data independently: author and year of the study, type of study, number of patients enrolled and of procedures performed, mean duration of the follow-up, percentage of patients suffering on OA, percentage of female patients, mean age of the included patients, mean incision length, type of approach, component positions (mean cup inclination and anteversion, mean stem alignment, mean limb length discrepancy), mean surgical duration, mean total estimated blood loss, mean length of hospital stay, mean body mass index (BMI), mean Harris hip score (HHS), post-operative complications (dislocations, fractures), and revision rates. Studies without quantitative data under the outcome of interest were excluded from this study.

Methodological quality assessment

Study methodological quality was assessed according to the PEDro critical appraisal score [9]. The PEDro score has been validated in many studies [10, 11] and is considered as a valid evaluating method for the methodological quality of clinical trials [12]. The PEDro score evaluates comparability between the study groups, method of randomisation, blinding, adequate eligibility criteria and follow-up, adequate analysis between baseline and groups, point estimates, and variability. Quality assessment was performed by two independent reviewers and any differences resolved by mutual agreement.

Statistical analysis

All meta-analyses were performed using the Review Manager software 5.3 (The Nordic Cochrane Centre, Copenhagen). We referred to the inverse variance method to evaluate continuous data, with 95% confidence intervals (CI). As concerns the binary data, they have been analysed through Mantel-Haenszel method, with 95% CI. In addition, a χ^2 and I^2 statistical tests were performed to evaluate the study heterogeneity. A p value with a threshold of $p = 0.05$ has been considered a discriminant for statistically significant. This parameter allows us to either use a fixed effect model or a random effect model if $p > 0.05$ or $p < 0.05$ respectively. A fixed model considers the differences as a just merely case, while a random fixed model also keeps in consideration the presence of an eventual other effect, as heterogeneity and publication bias. We performed the forest plot to have a visual representation of the overall effect and CI to respect to the no-effect line. We performed the funnel plot to have a visual representation of the publication's bias.

Results

Search results

A total of 1877 studies were obtained through the database research. A total of 212 articles were rejected because of duplicated. Another 1285 were excluded based on title and abstract review. A further 332 articles were excluded based on full-text review since they did not focus the topic or did not contain quantitative data under the outcomes of interest. This left 48 articles, 18 nRCTs, and 30 RCTs. The flowchart of the literature search is shown in Fig. 1.

Analysis of publication's bias

To analyse the publication bias, we inspected the most common reported outcome measure, the surgical duration (Fig. 2). The slightly asymmetrical funnel plot indicated, with respect to the no-effect line, that the overall result is acceptable. We conclude that the bias slightly affected the overall outcome.

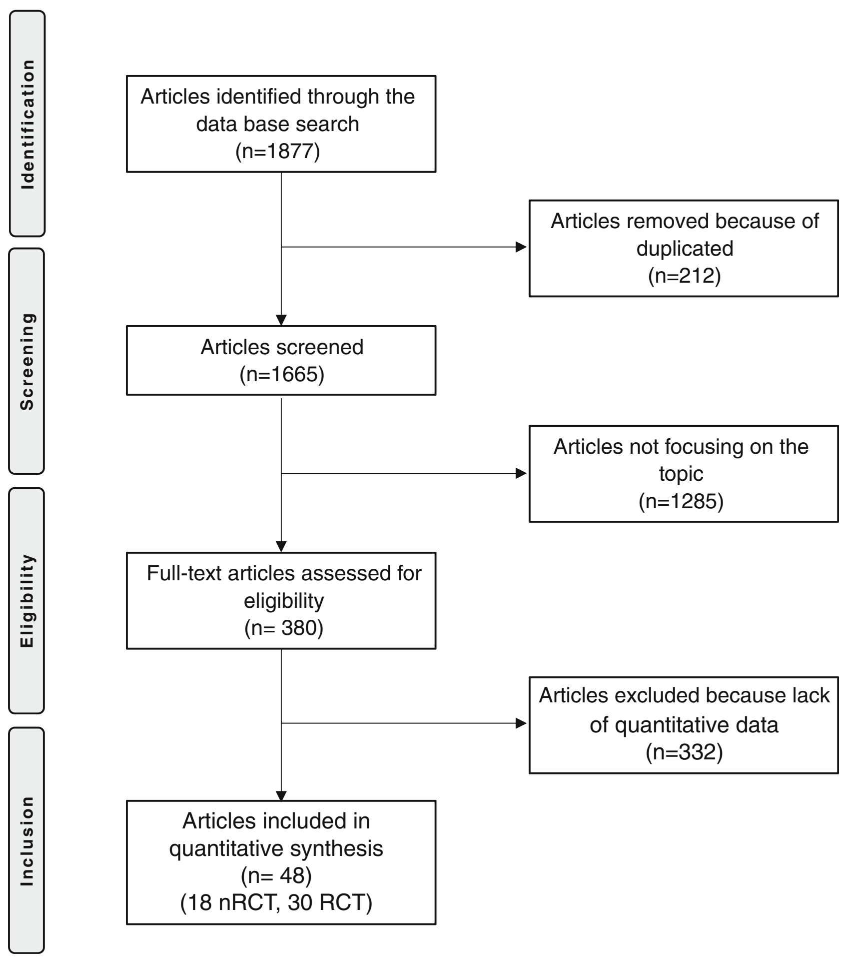
Methodological quality assessment

Concerning the methodological quality assessment, the overall result of the PEDro score was 5.98 points, attesting to this study a good quality. This score is strongly influenced by the randomisation and blinding methods. In this study, 37% articles did not provide any randomisation method. Furthermore, the 17% studies provided blinding methods. Eighty-seven percent of the included studies clearly describe inclusion and exclusion criteria, while 72% report adequate follow-up. Almost all the studies clearly reported intention to treat and a good between group and baseline analyses. The results of the PEDro score across the studies are shown in Table 1.

Patient's demographic

We enrolled in this study a total of 4649 patients, undergoing 4728 THA. The mean follow-up for both the groups was 22.75 months (SD 25.23). Regarding the MIS group, we enrolled in this study 2327 patients. The mean age of this cohort

Fig. 1 Flowchart of the literature search



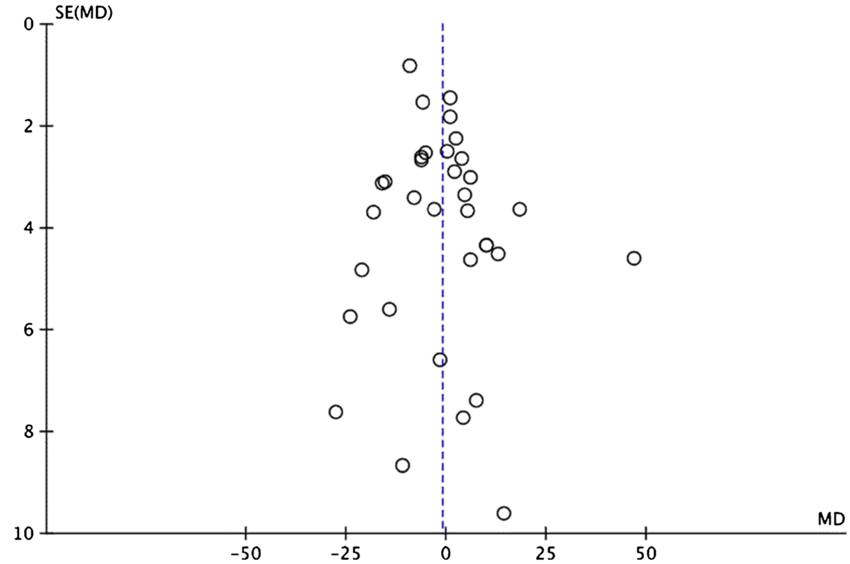


Fig. 2 Funnel plot of the most common reported outcome (surgical duration)

is 62.26 years (SD 6.76), with a mean BMI of 26.53 kg/m^2 (SD 0.96). OA is the most frequent diagnose (85%), and female represent 63% of all enrolled patients. The mean incision length for the MIS group is 8.8 cm (SD 0.94). Concerning the SIS group, we enrolled 2448 patients. The mean age of this cohort is 64.13 years (SD 9.37), with a mean BMI of 25.77 kg/m^2 (SD 1.81). Patients affected by OA accounted 83% and 58% were female. The mean incision length for the SIS group is 15.7 cm (SD 3.03). The demographic baseline of the included patients is shown in Table 1.

Outcomes

In favour of the SIS approach, better outcomes of the HHS were reported (MD 1.00 points, 95% CI 0.140, 1.860, FM $p = 0.02$, Fig. 3). The MIS approach reported less total estimated blood loss (MD −52.59 mL, 95% Cl −68.660 −36.520, FM $p = 0.03$) and a faster surgical duration (MD −3.35 min, 95% CI −4.230 −2.460, FM $p = 0.58$). Furthermore, the MIS approach showed a shorter mean length of stay (MD −0.06 days, 95% CI −0.020, −0.080, $p = 0.4$). Concerning the implant positioning, in the MIS intervention group, a greater mean angle of cup inclination (MD −0.062°, 95% CI −1.890 −0.640, RM $p = 0.33$) and a lower mean angle of cup anteversion (MD 2.820°, 95% CI −0.390 −0.790, RM $p = 0.09$) have been evidenced. In the SIS group, a higher average leg-length discrepancy (MD 0.240 mm, 95% CI −1.640 2.13, FM $p = 0.8$) and a greater varus angle of the stem alignment (MD 0.060 grades, 95% CI −0.180 0.310, FM $p = 0.61$) were reported.

No differences were observed between the two groups, regarding the risk of incurring in femoral fractures (M-H 1.000, 95% CI 0.999 1.001, $p = 0.9$) and in the revision rates (M-H 1.000, 95% CI 0.999 1.001, $p = 0.75$). Regarding dislocations, a minimally increased risk in the SIS group was reported (M-H 1.001, 95% CI 0.999 1.020, $p = 0.46$). An increased risk to occur in an iatrogenic nerve palsy in the minimally invasive approach group (M-H 0.970, 95% CI 0.960 0.980, $p < 0.0001$) was evidenced. The overall results of the meta-analysis are shown in Table 2.

Discussion

Based on the currently available evidence and on the results of this study, we stated no relevant benefits of the minimally invasive compared to the standard-invasive approach for total hip arthroplasty during the follow-up duration. Minimally invasive compared to standard-invasive approach slightly reduced the surgical duration and the total estimated blood loss. On the other hand, it has been also observed a minimal increased risk to occur in iatrogenic nerve palsy and a very slight reduction of Harris hip score. Were also evidenced no relevant differences among the two approaches concerning the component positioning.

Between the approaches, very homogeneous data and a good quality of the results concerning the length of stay were reported, with an estimated total value of −0.06 days in favour of the MIS approach. The overall result of this comparison is not relevant in the clinical practice, since it represented a reduction of one hour and 25 minutes in favour of the MIS approach on an average of a week. Only the study of Sculco et al. [46] presented a longer length of stay, maybe due to the influence of some reported complications that have considerably prolonged the hospitalisation time up to 14 days.

A higher value in favour of the standard approach concerning the Harris hip score was reported. Because of the small difference (1%), this data was considered clinically not relevant. By analysing the forest plot graphic of the HHS (Fig. 3), it is evident

Table 1 Demographic data of the patients and results of the PEDro score. *RCT*, randomised clinical trial; *nRCT*, non-randomised clinical trial; *A*, anterior approach; *AL*, anterolateral approach; *L*, lateral approach; *PL*, posterolateral approach; *P*, posterior approach; *2-Inc*, two-incision technique; *OA*, number of patients affected by osteoarthritis; *PAT*, patients; *APP*, approach

Generalities						Minimally invasive approach							Standard-invasive approach						
Author (years)	Type of study	Patients (*n*)	Hips (*n*)	Follow-up (months)	PEDro score	Patients (*n*)	OA	Female gender	BMI	Mean age (years)	Mean incision length (cm)	APP	Patients (*n*)	OA	Female gender	BMI	Mean age (years)	Mean incision length (cm)	APP
Abdel et al. [13]	RCT	71	71	102	6	36		47%	30.2	66	8.25	P	35		47%	28.7	67		2-Inc
Bennett et al. [14]	RCT	95	95	0.2	6	43		58%	29.59	66.1		P	52		46%	29.17	64.6	16	P
Biau et al. [15]	RCT	209	209		4	105	90%	59%	25	68	9	P	102	92%	61%	25	66	12	P
Chen et al. [16]	nRCT	166	166	24	5	83		45%		53.5	9.8	AL	83		51%		55	19.9	AL
Chimento et al. [17]	RCT	60	60	24	7	28	100%	43%	25.2	67.2	8	P	32	100%	59%	24	65.6	15	L
Chung et al. [18]	nRCT	120	120	14	3	60	100%	60%		61	9.2	P	60	100%	53%		64	20	P
Della Valle et al. [19]	RCT	72	72	12	7	35	100%	69%	27.3	63.8		P	37	100%	68%	27.6	61.2		2-Inc
Dienstknecht et al. [20]	nRCT	143	143	3	3	55	100%	75%	27.6	61.9	9.3	A	88	100%	60%	30.1	61.3	13.4	L
DiGioia et al. [21]	nRCT	66	70	12	3	35	100%	58%		65	11.7	P	35	100%	58%		65	20.2	P
Dorr et al. [22]	RCT	60	60	6	6	30		43%	27.6	70.3	9.8	P	30		53%	30.2	63.9	19.78	P
Dutka et al. [23]	RCT	120	120	9.75	7	60	68%	85%		46		L	60	68%	84%		44		L
Farr et al. [24]	RCT	216	216	12	8	97						P	119						P
Fink et al. [25]	nRCT	100	100	1.5	5	70	88%	54%		65		P	70	88%	50%		71.5		P
Goosen et al. [26]	RCT	120	120	12	8	30	90%	50%	26.7	60	8	AL	30	97%	55%	26.1	62	18	AL
					8	30	90%	50%	26.4	60	7.7	PL	30	97%	45%	26.8	62	18	PL
Hart et al. [27]	RCT	120	120	39	9	60	100%	67%		72.4	9.5	PL	60	100%	67%		72.4	20	PL
Howell et al. [28]	nRCT	107	107		4	50	78%	32%	26.2	59.8	7.8	AL	57	35/57	53%	28.8	62.3		AL
Khan et al. [29]	RCT	100	100	38	9	48	91.7%	50%		72.3	12.6	P	52	96.2%	64%		72.8	19.3	P
Kim et al. [30]	RCT	70	140	26	8	70		43%		70.3	8	PL	70		53%		63.9	17.5	PL
Kiyama et al. [31]	RCT	20	20	6	8	10	80%	90%	23.4	65	7.3		10	90%	80%	23.5	63.8	14	
Krych et al. [32]	nRCT	21	21	3	3	10	100%				8.25	P	11	100%					2-Inc
Kubeš et al. [33]	nRCT	80	80	24	5	40		65%		67		AL	40		65%		66.1		AL
Laffosse et al. [34]	nRCT	100	100	6	3	42		43%		57.4		AL	58		40%		59.7		P
Lawlor et al. [35]	RCT	219	219	1.2	8	109		55%		67.4		P	110		47%		65.9	16	P
Leuchte et al. [36]	nRCT	32	32	7	4	16	100%		26.7	59.7		AL	16	100%		28.6	62.6		L
Lichmann et al. [37]	RCT	255	255	24	6	113	94.5%	47%		70		A	142	95.5%	47%		70		L
Martin et al. [38]	RCT	79	83	12	9	42	88%	71%	30.6	66.7	9.5	AL	41	90%	66%	29.4	63.1	14.8	L
Mazoochian et al. [39]	RCT	51	52	3	6	26	67%	54%			8.9	L	26		65%			14	L
Ogonda et al. [40]	RCT	219	219	1.5	9	109	98%	55%	28.22	67.42	9.21	P	110	97%	47%	28.94	65.85	16	P
Pflüger et al. [41]	nRCT	100	100		2	50	76%	64%		68	8	AL	50	76%	64%		68	17.5	AL
Pospischill et al. [42]	RCT	40	40	3	9	20	100%	60%	25.7	61.9	9	AL	20	100%	40%	25.7	60.6	12	AL

Table 1 (continued)

Generalities						Minimally invasive approach							Standard-invasive approach						
Author (years)	Type of study	Patients (*n*)	Hips (*n*)	Follow-up (months)	PEDro score	Patients (*n*)	OA	Female gender	BMI	Mean age (years)	Mean incision length (cm)	APP	Patients (*n*)	OA	Female gender	BMI	Mean age (years)	Mean incision length (cm)	APP
	RCT	40	40	3	8	20	100%	60%		61.9	9	AL	20	100%	40%		60.6	12	L
Pour et al. [43]	RCT	100	100	1.5	8	50		55%	26	61.6	10	L	50		43%	26	60.1	14	L
Rittmeister et al. [44]	nRCT	152	152	0.2	4	76	70%%	70%	28	60		P	76	65%	45%	27	65		AL
Roy et al. [45]	RCT	56	56	24	6	25	0%	72%		79.5	8	P	31	0%	87%		84	16	P
Sculco et al. [46]	nRCT	84	84	60	4	42	100%	75%	25.2	67.2	8.8	AL	42	100%	31%	24	65.6	23	
Sershon et al. [47]	RCT	63	63	98	5	35	100%	68%	28.2	73.4		P	37	100%	72%	28.7	70.9		2-Inc
Shitama et al. [48]	RCT	70	70	6	8	15	85%	85%	23.2	61.7	9	TL	8	86%	86%	23.0	53.4	13.1	TL
					8	19	85%	85%	23.2	58.3	9	PL	28	86%	86%	23.0	61.3	14.7	PL
Speranza et al. [49]	RCT	100	100	6	5	50		52%		65	8	L	50		42%		66.2	13	L
Szendrõi et al. [50]	nRCT	59	59	3	4	38			26	64	8.8	L	21			29.5	57		L
Taunton et al. [51]	RCT	54	54	30	7	27	100%	55%	27.7	66.4	10	P	27	100%	55%	29.2	62.05		A
Varela et al. [52]	RCT	50	50	60	8	25	84%	50%		64.8	9.5	L	25	88%	50%		63.8		L
Varela-Egocheaga et al. [53]	RCT	50	50	12	8	25	88%	44%	27.04	65		P	25	84%	56%	29.56	61.3		P
Vicente et al. [54]	nRCT	76	76	6	3	34	35.3%	38%	27	50	9.7	P	42	31%	38%	27	57	17	
Wohlrab et al. [55]	nRCT	50	50	3	3	27	96%	96%	27.2	58.8		P	23	100%	52%	29.3	61.9		L
Wright et al. [56]	nRCT	84	84	60	4	42	88%		24.4	64.2	8.8	PL	42	93%		28.3	65.0	23.0	PL
Yang et al. [57]	RCT	110	110	36	8	55	28%	53%	23.12	59.47	7.49	AL	55	13%	44%	22.42	55.82	15.19	PL
Zawadsky et al. [58]	nRCT	100	100	0.5	4	50		72%	28.6	56.0	11	P	50		56%	27.9	60.8		A
Zhang et al. [59]	RCT	120	120	20.4	6	60		75%			7.9	A	60		60%			16	PL

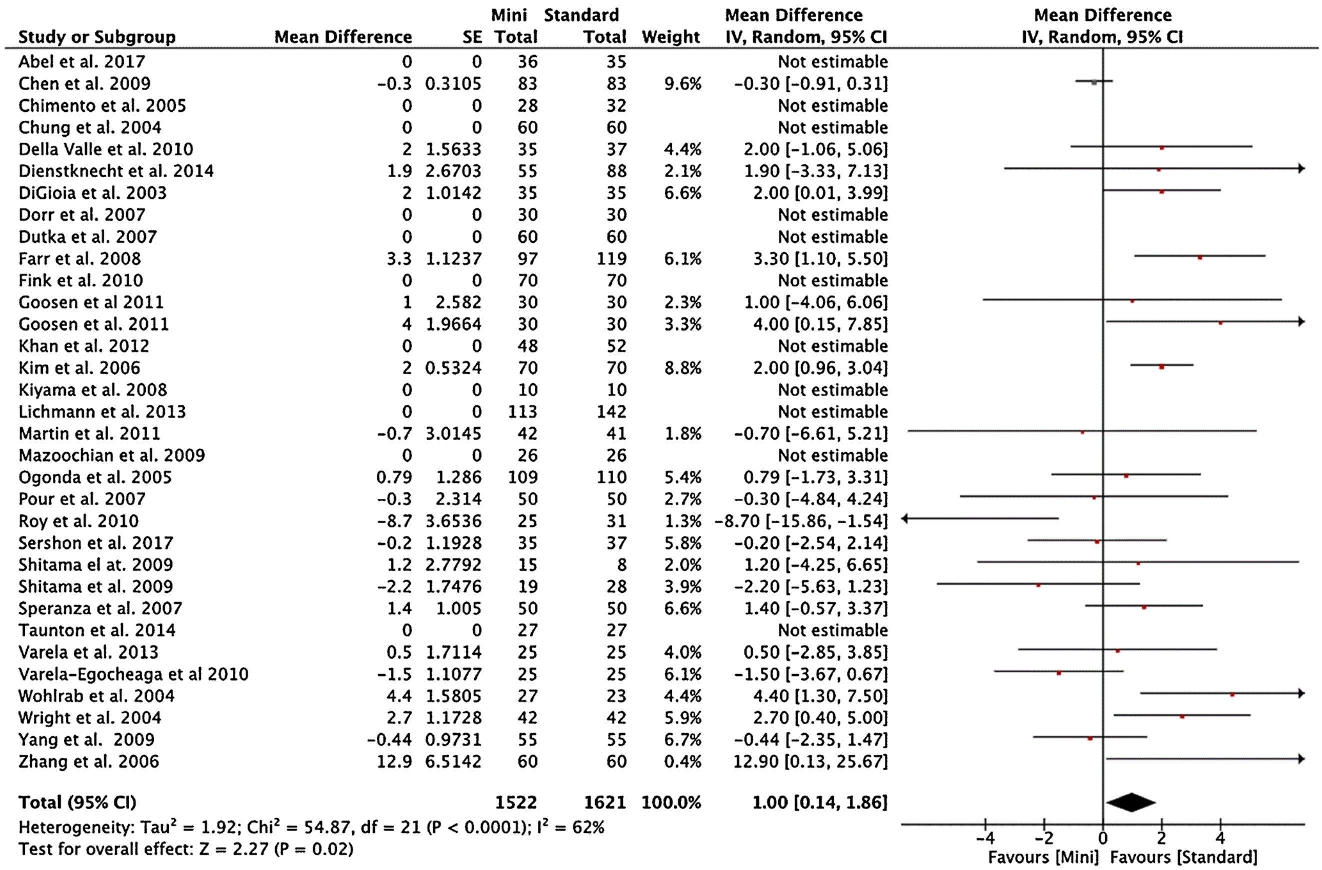


Fig. 3 Meta-analysis of the comparison HHS

that all results are closed to the no-effect line, presenting also a very good homogeneity. Moreover, it is also evident that the confidence interval is narrow, index of very statistically significance. Analysing data dispersion under this outcome, the study of Zang et al. [59] and Roy et al. [45] presented very heterogenic value of MD and SD. Due to their data heterogeneity, both have an imperceptible influence on the overall effect. In a recent retrospective study, Capuano et al. [60] compared the evolution of HHS between MIS and SIS. According to our findings, they also stated no relevant differences across the two approaches after four year follow-up.

Reducing the blood loss is typically one of the most important reasons that encourage a surgeon to perform a MIS approach [61]. In favour of the MIS approach, it was observed a

Table 2 Overview of the overall results of the meta-analysis

Clinical outcome	Patients (*n*)		Overall effect			
	MIS	SIS	Effect estimate	95% CI		*p*
Total estimated blood lost	1405	1472	− 70.380	− 132.900	− 7.860	0.03
Length of stay	1275	1350	− 0.060	− 0.020	0.080	0.4
Harris hip score	1522	1621	1.000	0.140	1.860	0.02
Surgical duration	1977	2041	− 0.960	− 4.340	2.410	0.58
Leg-length discrepancy	212	212	0.240	− 1.640	2.130	0.8
Mean inclination	919	969	− 0.062	− 1.890	0.640	0.33
Mean anteversion	597	630	2.820	− 0.390	6.040	0.09
Stem alignment	416	453	0.060	− 0.180	0.310	0.61
Femur fractures	19	23	1.000	0.999	1.001	0.9
Iatrogenic nerve damage	36	3	0.990	0.970	1.010	0.35
Dislocations	14	20	1.001	0.999	1.020	0.46
Revision	9	12	1.000	0.999	1.001	0.75

lower volume of total estimated blood loss. Unfortunately, the clinical relevance of this observation is fair, since we are referring to a small variation between the two approaches (about 70 mL), on a total average of approximately 500 mL. Moreover, also, the statistical relevance of this outcome is fair, since it presented a high level of heterogeneity and data dispersion. In the analysis, only two studies are strongly in favour of the MIS, but they presented a slight statistical weight, influencing minimally the overall result [49, 52].

A shorter surgical duration in favour of the MIS approach was observed, with a mean time saving of 3.35 minutes. This data has been considered not relevant in the clinical practice because of its low expressiveness, considering that to perform a THA the surgeon needs an average 111 minutes [62]. This comparison is also affected by high level of data heterogeneity, reducing considerably the statistical significance. A possible explanation for data dispersion could be the longer learning curve of the MIS [63]. For a surgeon with few experiences, the MIS could take longer to be performed. According also with previous studies [64], it is deductible that the surgical duration of this approach strictly depends on the operator's experience.

To investigate the component positions, were referred to cup inclination and anteversion, stem alignment, and limb length discrepancy. The statistical analysis of these outcomes evidenced any relevant variations across the two approaches. This data is very important, since component positioning influences the biomechanics and the duration of the implants [65]. Assuming that both techniques have the purpose and the ability to restore the physiological joint biomechanics [66], it appears obvious that the component position should be not conditioned by any different approaches.

In this meta-analysis, a higher risk to occur in an iatrogenic nerve palsy in the MIS group was evidenced. A possible explanation for this result could be the path of the nerve more hidden, determining more difficulties to identify the nerve during the MIS exposure [67]. Defining additional reference points to identify the nerve path can represent a valid solution to reduce the incidence of this complication [68]. We hypothesised that this outcome can be negatively affected by the long learning curve as well and can be potentially avoided by expert surgeons [69, 70]. Further studies should be addressed to clarify the impact of the learning curve on the outcomes.

The meta-analysis results concerning the intra- and post-operative fractures, dislocations, and revision rates between the two surgical techniques evidenced very homogeneous data and weight distributions, with a 95% confidence interval overlapping near to the no-effect line in all the comparisons. To prove it, we performed a hypothesis test of significance at 5% that confirms that this meta-analysis has been carried out correctly.

The strength point of this meta-analysis is the comprehensive nature of the literature search and rigorous assessment of methodological quality of the current available data. A limitation of this study is represented by the relatively shortly duration of the follow-up. Another important point of weakness of this study was to not consider the different surgical positions as separated, to ensure a larger pool of enrolled patients for this study, but representing a selection bias of this work.

Conclusion

Minimally invasive compared to the standard-invasive approach slightly reduced the surgical duration and the total estimated blood loss. On the other hand, it reported a very slightly increased risk to occur in iatrogenic nerve palsy and a very slight reduction of Harris hip score. No relevant differences were evidenced among the two approaches concerning the component positioning. Based on the currently available evidences and on the results of this study, we stated no relevant benefits of the minimally invasive compared to the standard-invasive approach.

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