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Direct and indirect comparisons in network meta-analysis of SuperPATH, direct anterior and posterior approaches in total hip arthroplasty

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SuperPATH is a novel approach to the hip joint that needs to be compared to other known surgical approaches. To conduct a network meta-analysis (NMA) of randomized controlled trials (RCTs) comparing short-term outcomes of SuperPATH, direct anterior (DAA), and posterior/posterolateral approaches (PA) in total hip joint arthroplasty (THA). We performed a systematic review on PubMed, CNKI, Embase, The Cochrane Library, Clinical trials, and Google Scholar up to November 30th, 2021. We assessed treatment effects between SuperPATH, DAA, and PA by performing a frequentist NMA, including a total of 20 RCTs involving 1501 patients. SuperPATH showed a longer operation time (MD = 16.99, 95% CI 4.92 to 29.07), a shorter incision length (MD = -4.71, 95% CI -6.21 to -3.22), a lower intraoperative blood loss (MD = -81.75, 95% CI -114.78 to -48.72), a higher HHS 3, 6 and 12 months postoperatively (MD = 2.59, 95% CI 0.59–4.6; MD = 2.14, 95% CI 0.5–3.77; MD = 0.6, 95% CI 0.03–1.17, respectively) than PA. DAA showed a higher intraoperative blood loss than PA and SuperPATH (MD = 91.87, 95% CI 27.99–155.74; MD = 173.62, 95% CI 101.71–245.53, respectively). No other relevant differences were found. In conclusion, the overall findings suggested that the short-term outcomes of THA through SuperPATH were statistically superior to PA. DAA and PA as well as SuperPATH and DAA showed indifferent results.

Abbreviations

BMI	Body mass index
CNKI	China National Knowledge Infrastructure
CI	Confidence interval
DAA	Direct anterior approach
HHS	Harris Hip Score
MD	Mean difference
NMA	Network meta-analysis
PA	Posterior and posterolateral approach
RCT	Randomized controlled trial
SuperPATH	Supercapsular percutaneously assisted approach in total hip arthroplasty
THA	Total hip arthroplasty

Patient outcomes after hip arthroplasty have improved over the past few decades. SuperPATH was introduced by Chow in 2011 as a novel hip approach in an attempt to solve the remaining problems¹. Benefits of SuperPATH: Hip surgery in situ with the lower limb resting throughout the whole operation; tissue-sparing dissection through the interval between the gluteus medius and piriformis muscles; joint capsule preservation; unproblematic exposure

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of the acetabulum through accessory access. Two network meta-analyses (NMAs) comparing SuperPATH, the direct anterior approach (DAA), and conventional approaches showed some advantages of SuperPATH^{2,3}. The strong limitation of those two NMAs was that they summarized all conventional approaches, although these differ significantly in terms of surgical techniques and outcome^{4–6}. A different methodological approach is required to overcome this limitation. We performed another NMA of randomized controlled trials (RCTs) with the following PICO (Population, Intervention, Control, and Outcomes) question: In patients with hip disease or fracture, is the short-term outcome after total hip arthroplasty (THA) implanted through SuperPATH better compared to DAA and/or posterior/posterolateral (posterior/posterolateral approach = PA)?

Methods

Details on the SuperPATH technique. The SuperPATH technique is briefly described as follows: the incision of the capsule is performed through a 6–10 cm skin incision and a muscle-sparing approach between the piriformis and gluteus minimus muscles in lateral decubitus position. The femoral canal is then opened with a reamer, the femur is broached and osteotomy of the femoral neck is performed. Following exposure of the acetabulum, the acetabular reamers are inserted through the main incision and attached within the surgical field to the shaft of the motorized drill, which is inserted through a separate percutaneous portal passing adjacent to the posterior aspect of the proximal femur. After implantation of the cup, inlay, modular neck, and head, reposition is performed. Wound closure concludes the operation.

Search strategy and study selection. The PRISMA recommendations were followed when performing and presenting our NMA⁷. The review protocol was registered in PROSPERO on September 11th, 2021 (CRD42021272994). Our search strategy and methods were similar to our previous works^{2,3}. We searched the following databases and checked citations of screened studies and related meta-analyses for relevant manuscripts up to November 30th, 2021, without restrictions to publication date or language: PubMed, China National Knowledge Infrastructure (CNKI), Embase, The Cochrane Library, Clinical trials. We built a BOOLEAN search strategy for RCTs on SuperPATH and DAA as follows: [(SuperPATH OR supercapsular percutaneously assisted approach in total hip arthroplasty)] and [(THR OR THA OR total hip arthroplasty) AND (approach) AND (anterior OR posterior OR posterolateral)]. We adapted search terms to the syntax of the used databases. Furthermore, we searched Google Scholar for relevant RCTs. Titles, abstracts, and then full-text articles were independently reviewed by two reviewers (NR and PL). The decision on the inclusion of each study was determined by the consensus between the two reviewers. Cases of disagreement were resolved by discussion with a third reviewer (KL). Kappa coefficient was used to measure the agreement between the reviewers. The entire search and selection process was carried out separately for studies on DAA and studies on SuperPATH, using the same methods. A Chinese-speaking reviewer (KL) helped with the search in CNKI.

Inclusion/exclusion criteria. We included RCTs with human participants with hip disease or hip fracture, who had THA through either DAA or SuperPATH compared to PA. We excluded studies for the following reasons: no outcome of interest, employment of a computer navigation system, and hip replacement with hemiarthroplasty.

Types of outcome measures.

1. Surgical outcome
 - The operation time (in min.) was defined as the time interval from the skin incision to suture. It correlates with the operating skills and with the risk of infection.
 - The incision length (in cm) was measured on a graduated scale. It is one of several indicators of intraoperative trauma.
 - The intraoperative blood loss (in ml) was defined as the total amount of blood from the suction device. It is an indirect indicator of intraoperative trauma.
2. Functional outcome
 - The Harris Hip Score (HHS) was developed for the assessment of the results of hip surgery⁸. The hip joint function was periodically evaluated at 3, 6, and 12 months postoperatively. The score adds points from the evaluation of four categories: pain, function, degree of deformity, and hip range of motion. The best achievable score is 100 points.
3. Radiological outcome
 - The acetabular cup anteversion angle and the inclination angle (in degrees) have ideal values for positioning: anteversion angle from 10° to 25° and inclination angle from 40° to 50°⁹. A too large anteversion angle often leads to posterior impingement, resulting in anterior dislocation, and a too small anteversion angle leads to posterior dislocation.

Data extraction and quality assessment. Two reviewers (NR and PL) extracted the following relevant data into a data extraction form in a standard electronic spreadsheet and the Cochrane software program Review Manager Version 5.3: first author, year of publication, number of patients, patient characteristics, risk of bias and outcome. Cases of disagreement were resolved by discussion with a third reviewer (KL). The assessment of the risk of bias and the level of evidence was carried out independently by two reviewers (NR and KL) according to Cochrane's Risk of Bias 2 (RoB 2) tool¹⁰, respectively according to the recommendations of the GRADE system¹¹.

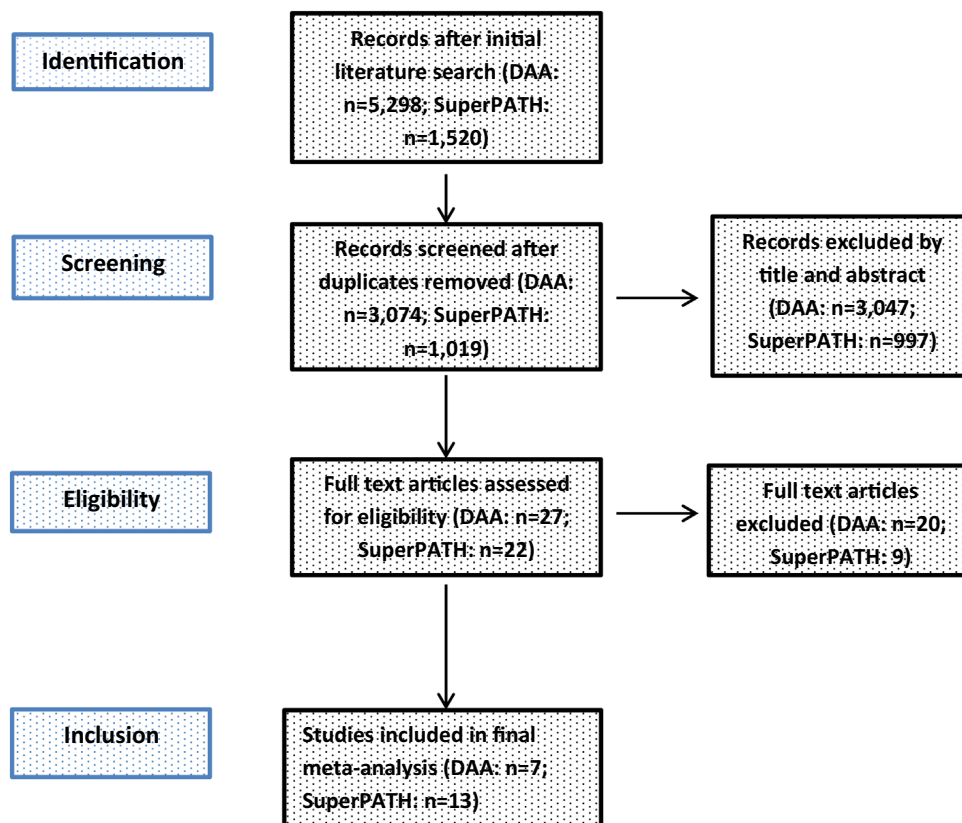


Figure 1. PRISMA flow diagram of the search results and selection according to our inclusion criteria.

Statistical analysis. *Direct comparison: measures of treatment effect.* SuperPATH or DAA represented the “experimental group” and PA represented the “control group”. A direct comparison with both fixed and random effects models was applied to calculate the results for either SuperPATH or DAA and PA. We limited the presentation of statistical calculations to random effects model, as this method was more conservative and provided better estimates with wider confidence intervals. Mean differences (MDs) with 95% confidence intervals (CIs) were estimated for all outcomes. A common τ^2 was assumed for calculation of the estimates of the random effects, using the DerSimonian and Laird method. Study weighting was performed by inverse variance¹². In our NMA, we adhered to the Cochrane Handbook for Systematic Reviews of Interventions¹³.

Indirect comparison: network meta-analysis. A NMA using frequentist methods¹⁴ was performed, borrowing information from the direct comparisons mentioned above and using the PA group as a common comparator and reference node within the network. The following programs were used: meta and netmeta¹⁵. In addition, we calculated prediction intervals to estimate where to expect the results of future NMAs. We presented both direct comparison estimates and network estimates in a forest plot per outcome on a common scale. All statistic calculations were performed by a professional statistician (SB).

Assessment of heterogeneity. We assessed heterogeneity with a test on Cochran’s Q statistic, which followed a distribution with k-degrees of freedom (p-value < 0.10 is indicative of heterogeneity), and with a Higgins’ test I^2 (low heterogeneity, < 25%; moderate heterogeneity, 25–75%; and high heterogeneity, > 75%)¹⁶. Results were presented regardless of the detection of heterogeneity to maintain the informative value within the forest plots. We did not pool study data that were clinically too diverse.

Results

Study identification and selection. A description of the study selection process is presented in a PRISMA flow diagram (Fig. 1). A total of 1019 studies were identified in our initial literature search on SuperPATH, after removing 501 duplicates. After the first screening procedure by title and abstract ($\kappa = 1.0$) with total agreement by the reviewers, 22 RCTs were assessed for eligibility. After the second screening procedure by full-paper analysis ($\kappa = 1.0$), 13 RCTs on SuperPATH^{17–19,19–28} were included in the final NMA. A total of 3074 studies were identified in our initial literature search on DAA, after removing 2251 duplicates. After the first screening procedure by title and abstract ($\kappa = 0.96$) with disagreement between the reviewers concerning 1 RCT, 27 RCTs were assessed for eligibility. After the second screening procedure by full-paper analysis ($\kappa = 1.0$), 7 RCTs on DAA^{29–35} were included in the final NMA.

Characteristics of the RCTs. Thirteen RCTs, published between 2017 and 2021, compared SuperPATH with PA, altogether including 919 patients (with 923 operated hip joints). Of those patients, 459 were operated through SuperPATH and 460 through PA. The sample size of those RCTs ranged from 4 to 116 patients. Four RCTs were published in English language^{19–21,25}, five RCTs in Chinese with an English abstract^{22,23,26–28} and four RCTs only in Chinese^{17–19,24}. Seven RCTs, published between 2013 and 2020, compared DAA with PA, altogether including 582 patients. Of those patients, 291 were operated through DAA and 291 through PA. The sample size of those RCTs ranged from 46 to 120 patients. All RCTs on DAA were published in English language. Of the 7 RCTs included, 4 RCTs reported having used a traction table in THA through DAA^{29–32}. The main characteristics of the 20 RCTs on SuperPATH and DAA with an overall 1501 included patients are presented in Table 1.

Risk of bias and level of evidence. The quality of the included RCTs was assessed according to the Cochrane Collaboration's tool for risk of bias (Table 2) and according to the recommendations of the GRADE system (Table 3).

Clinical and statistical heterogeneity. The clinical characteristics for gender, age, and BMI (Table 1) showed no relevant differences between the patients in the experimental (either SuperPATH or DAA) and control group (PA). The statistical heterogeneity of all measured outcomes is shown in Figs. 2, 3, 4, 5, 6, 7, 8, 9.

Outcomes. 1. Surgical outcomes

Operation time: SuperPATH vs. PA

In a direct comparison between SuperPATH and PA, data on 711 patients were pooled from 10 RCTs ($I^2 = 99%$, $p < 0.01$, Fig. 2). The operation time of SuperPATH was 17 min. longer than the operation time of PA (MD = 16.99, 95% CI 4.92 to 29.07).

Operation time: DAA vs. PA

In a direct comparison between DAA and PA, data on 408 patients were pooled from 5 RCTs ($I^2 = 82%$, $p < 0.01$, Fig. 2). There was no difference in operation time (MD = 15.64, 95% CI -1.02 to 32.29).

Operation time: DAA vs. SuperPATH

In an indirect comparison between DAA and SuperPATH, data on 559 patients were pooled from 15 RCTs ($I^2 = 98%$, $p < 0.01$, Fig. 2). There was no difference in operation time (MD = -1.36, 95% CI -21.93 to 19.21).

Incision length: SuperPATH vs. PA

In a direct comparison between SuperPATH and PA, data on 805 patients were pooled from 11 RCTs ($I^2 = 98%$, $p < 0.01$, Fig. 3). The incision length of SuperPATH was 4.7 cm shorter than the incision length of PA (MD = -4.71, 95% CI -6.21 to -3.22).

Incision length: DAA vs. PA

In a direct comparison between DAA and PA, data on 207 patients were pooled from 2 RCTs ($I^2 = 100%$, $p < 0.01$, Fig. 3). There was no difference in incision length (MD = -1.54, 95% CI -4.98 to 1.91).

Incision length: DAA vs. SuperPATH

In an indirect comparison between DAA and SuperPATH, data on 505 patients were pooled from 13 RCTs ($I^2 = 99%$, $p < 0.01$, Fig. 3). There was no difference in incision length (MD = 3.18, 95% CI -0.58 to 6.93).

Intraoperative blood loss: SuperPATH vs. PA

In a direct comparison between SuperPATH and PA, data on 689 patients were pooled from 10 RCTs ($I^2 = 99%$, $p < 0.01$, Fig. 4). The intraoperative blood loss of SuperPATH was 81.8 ml less than the intraoperative blood loss of PA (MD = -81.75, 95% CI -114.78 to -48.72).

Intraoperative blood loss: DAA vs. PA

In a direct comparison between DAA and PA, data on 253 patients were pooled from 3 RCTs ($I^2 = 89%$, $p < 0.01$, Fig. 4). The intraoperative blood loss of DAA was 91.9 ml higher than the intraoperative blood loss of PA (MD = 91.87, 95% CI 27.99 to 155.74).

Intraoperative blood loss: DAA vs. SuperPATH

In an indirect comparison between DAA and SuperPATH, data on 470 patients were pooled from 13 RCTs ($I^2 = 99%$, $p < 0.01$, Fig. 4). The intraoperative blood loss of DAA was 173.6 ml higher than the intraoperative blood loss of SuperPATH (MD = 173.62, 95% CI 101.71 to 245.53).

2. Functional outcome: Harris Hip Score

HHS 3 months postoperatively: SuperPATH vs. PA

In a direct comparison between SuperPATH and PA, data on 559 patients were pooled from 9 RCTs ($I^2 = 95%$, $p < 0.01$, Fig. 5). The HHS 3 months postoperatively of SuperPATH was 2.6 points higher than the HHS 3 months postoperatively of PA (MD = 2.59, 95% CI 0.59 to 4.6).

HHS 3 months postoperatively: DAA vs. PA

In a direct comparison between DAA and PA, data on 362 patients were pooled from 4 RCTs ($I^2 = 53%$, $p = 0.09$, Fig. 5). There was no difference in HHS 3 months postoperatively (MD = 1.95, 95% CI -1.8 to 5.7).

HHS 3 months postoperatively: DAA vs. SuperPATH

In an indirect comparison between DAA and SuperPATH, data on 459 patients were pooled from 13 RCTs ($I^2 = 94%$, $p < 0.01$, Fig. 5). There was no difference in HHS 3 months postoperatively of DAA (MD = -0.64, 95% CI -4.89 to 3.61).

HHS 6 months postoperatively: SuperPATH vs. PA

In a direct comparison between SuperPATH and PA, data on 482 patients were pooled from 8 RCTs ($I^2 = 84%$, $p < 0.01$, Fig. 6). The HHS 6 months postoperatively of SuperPATH was 2.1 points higher than the HHS 6 months postoperatively of PA (MD = 2.14, 95% CI 0.5 to 3.77).

HHS 6 months postoperatively: DAA vs. PA

Study	Sample size, n		Surgical approach		Mean age, y (SD or range)		Gender (M/F), n		BMI, kg/m ² (SD or range)		Imaging procedure for acetabular cup positioning	Hip pathology			
	Pts	Hips	S	PA	S	PA	S	PA	S	PA		S/PA	Osteoarthritis	ANFH	Dysplasia
SuperPATH															
Gao and Shi ¹⁷	70	70	35	35 P	69.26 ± 3.28	68.81 ± 3.45	23/12	20/15	23.09 ± 2.57	23.21 ± 2.44	Not reported	-	-	-	70
Li ¹⁸	60	60	30	30 PL	70.35 ± 4.26	70.12 ± 4.78	16/14	18/12	Not reported	Not reported	Not reported	Not reported			
Li et al. ¹⁹	96	96	49	47 PL	75.53 ± 7.34	77.21 ± 7.84	27/22	24/23	22.99 ± 2.87	22.7 ± 3	Not reported	Not reported			
Liu et al. ²⁰	94	94	47	47 PL	68.27 ± 3.71	68.55 ± 3.4	26/21	24/23	Not reported	Not reported	Not reported	-	-	-	94
Meng et al. ²¹	4	8	4	4 PL	51.00 ± 4.54		4/0		21.49 (19.60–23.04)		Conv. X-Rays	-	8	-	-
Meng et al. ²²	40	40	20	20 Mini-PL	64.55 ± 9.06	65.25 ± 10.33	8/12	9/11	23.36 ± 2.55	22.82 ± 2.61	Conv. X-Rays	40	-	-	-
Ouyang et al. ²³	24	24	12	12 PL	54 (45–71)	55 (47–67)	8/4	9/3	23.1 (17.5–26.7)	23.9 (16.9–30.4)	Conv. X-Rays	11	13	-	-
Pan et al. ²⁴	116	116	58	58 PL	65.23 ± 6.84	65.62 ± 6.96	34/24	33/25	22.24 ± 4.15	22.56 ± 4.22	Not reported	23	33	9	51
Wang and Ge ²⁵	85	85	43	42 PL	71.53 ± 3.76	71.58 ± 3.79	26/17	24/18	22.47 ± 1.12	22.51 ± 1.15	Not reported	-	-	-	85
Xie et al. ²⁶	92	92	46	46 P	66.6 ± 11.88	64.47 ± 12.09	12/34	19/27	23.62 ± 1.63	24.06 ± 2.72	Conv. X-Rays	-	-	-	92
Yuan et al. ²⁷	84	84	40	44 PL	74.3 (67–79)	75.7 (69–82)	24/16	21/23	22.73 ± 1.71	22.36 ± 1.89	Not reported	11	22	6	45
Zhang et al. ²⁸	54	54	27	27 PL	62.41 ± 6.44	61.28 ± 6.7	10/17	12/15	24.53 ± 5.31	23.93 ± 4.89	Not reported	16	29	9	-
Zunlong et al. ²⁹	100	100	50	50 PL	89.14 ± 3.6	88.95 ± 3.71	31/19	29/21	Not reported	Not reported	Not reported	-	-	-	-
DAA															
Barrett et al. ³⁰	87	87	43TT	44 PL	61.4 ± 9.2	63.2 ± 7.7	29/14	19/25	30.7 ± 5.4	29.1 ± 5	Conv. X-Rays	87	-	-	-
Bon et al. ³¹	100	100	50 TT	50 PL	67.26 ± 10	68.98 ± 7.93	21/29	23/27	26.46 ± 3.58	26.69 ± 3.12	Conv. X-Rays	100	-	-	-
Cheng et al. ³²	73	73	35TT	38 P	59	62.5	15/20	18/20	27.7	28.3	Conv. X-Rays	73	-	-	-
Moerenhout et al. ³³	55	55	28 TT	27 P	70.4 ± 9.1	68.9 ± 8.8	11/17	18/9	27.6 ± 4.4	26.5 ± 4.3	Conv. X-Rays	55	-	-	-
Rykov et al. ³⁴	46	46	23	23 PL	62.8 ± 6.1	60.2 ± 8.1	8/15	11/12	29 ± 5.6	29.3 ± 4.8	Not reported	46	-	-	-
Taunton et al. ³⁵	101	101	52	49 Mini-P	65 ± 10	64 ± 11	27/25	25/24	29 ± 22	30 ± 4	Conv. X-Rays	101	-	-	-
Zhao et al. ³⁶	120	120	60	60 PL	64.88 ± 12.13	62.18 ± 14.72	24/36	26/34	24.35 ± 3.1	25.58 ± 2.83	Conv. X-Rays	81	26	13	-

Table 1. Main characteristics of RCTs included in network meta-analysis. DAA: direct anterior approach; S: SuperPATH; TT: traction table PL: posterolateral approach; P: posterior approach; Pts: patients; Conv. = conventional.

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
SuperPATH vs. PA						
Gao and Shi ¹⁷	+	?	-	+	+	-
Li ¹⁸	+	?	-	-	+	-
Li et al. ¹⁹	+	+	-	+	+	-
Liu et al. ²⁰	+	+	-	+	+	-
Meng et al. ²¹	+	+	+	+	+	+
Meng et al. ²²	+	+	+	+	+	+
Ouyang et al. ²³	+	+	+	+	+	+
Pan et al. ²⁴	+	?	-	+	+	-
Wang and Ge ²⁵	+	?	-	+	+	-
Xie et al. ²⁶	+	+	+	+	+	+
Yuan et al. ²⁷	+	?	-	+	+	-
Zhang et al. ²⁸	+	+	-	+	+	-
Zunlong et al. ²⁹	+	?	-	+	+	-
DAA vs. PA						
Barrett et al. ³⁰	+	-	?	?	+	-
Bon et al. ³¹	+	+	+	+	+	+
Cheng et al. ³²	+	+	+	+	+	+
Moerenhout et al. ³³	+	+	+	+	+	+
Rykov et al. ³⁴	+	+	-	+	+	-
Taunton et al. ³⁵	+	+	?	+	+	?
Zhao et al. ³⁶	+	+	+	+	+	+

Table 2. Risk of bias assessment. DAA: direct anterior approach; PA: posterior and posterolateral approaches; (+): low risk of bias; (?): some concerns; (-): high risk of bias.

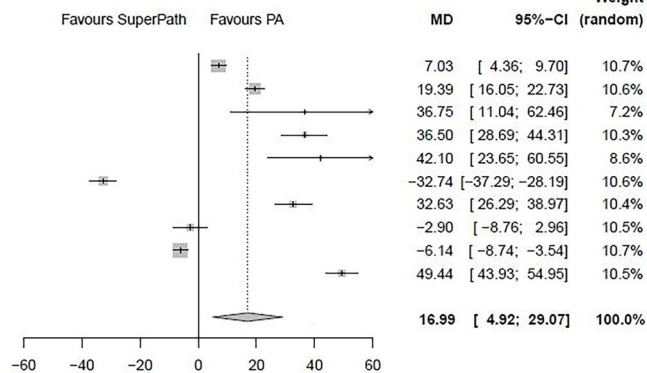
No. of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Quality of evidence
SuperPATH vs. PA							
<i>HHS 3 months postoperatively</i>							
9	RCT	Serious	Serious	No serious indirectness	Serious	All studies were from China	Very low
<i>HHS 6 months postoperatively</i>							
8	RCT	Serious	No serious inconsistency	No serious indirectness	Serious	All studies were from China	Very low
<i>HHS 12 months postoperatively</i>							
6	RCT	Moderate	No serious inconsistency	No serious indirectness	Serious	All studies were from China	Low
<i>Acetabular cup anteversion angle</i>							
4	RCT	Moderate	Serious	No serious indirectness	Serious	All studies were from China	Very low
<i>Acetabular cup inclination angle</i>							
5	RCT	Moderate	No serious inconsistency	No serious indirectness	No serious imprecision	All studies were from China	Moderate
<i>Intraoperative blood loss</i>							
10	RCT	Serious	No serious inconsistency	No serious indirectness	Serious	All studies were from China	Very low
<i>Operation time</i>							
10	RCT	Serious	Serious	No serious indirectness	Serious	All studies were from China	Very low
<i>Incision length</i>							
11	RCT	Serious	No serious inconsistency	No serious indirectness	No serious imprecision	All studies were from China	Low
DAA vs. PA							
<i>HHS 3 months postoperatively</i>							
4	RCT	Moderate	Serious	No serious indirectness	Serious	–	Very low
<i>HHS 6 months postoperatively</i>							
3	RCT	Moderate	No serious inconsistency	No serious indirectness	Serious	–	Low
<i>HHS 12 months postoperatively</i>							
3	RCT	Moderate	No serious inconsistency	No serious indirectness	No serious imprecision	–	Moderate
<i>Acetabular cup anteversion angle</i>							
5	RCT	Serious	Serious	No serious indirectness	Serious	–	Very low
<i>Acetabular cup inclination angle</i>							
6	RCT	Moderate	No serious inconsistency	No serious indirectness	Serious	–	Low
<i>Intraoperative blood loss</i>							
3	RCT	Serious	No serious inconsistency	No serious indirectness	No serious imprecision	–	Low
<i>Operation time</i>							
5	RCT	Serious	Serious	No serious indirectness	No serious imprecision	–	Very low
<i>Incision length</i>							
2	RCT	Serious	No serious inconsistency	No serious indirectness	Serious	–	Very low

Table 3. Level of evidence assessment according to GRADE recommendations. RCT: randomized controlled trial; HHS: Harris Hip Score; VAS: Visual Analog Scale.

Direct comparisons

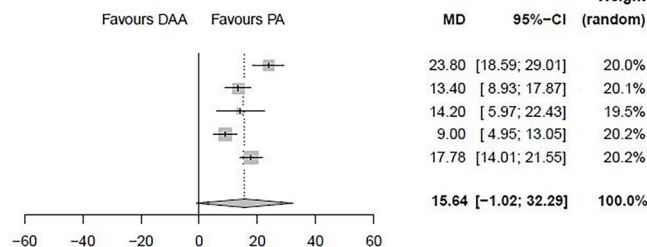
Study	SuperPath			PA			MD	95%-CI (random)	Weight
	Total	Mean	SD	Total	Mean	SD			
Gao 2020	35	68.59	5.3700	35	61.56	6.0200	7.03	[4.36; 9.70]	10.7%
Li et al. 2020	49	83.16	7.4200	47	63.77	9.1300	19.39	[16.05; 22.73]	10.6%
Meng 2019	2	103.25	12.4100	2	66.50	13.7900	36.75	[11.04; 62.46]	7.2%
Meng 2020	20	102.72	13.5500	20	66.22	11.5900	36.50	[28.69; 44.31]	10.3%
Ouyang 2018	12	109.60	28.3000	12	67.50	16.2000	42.10	[23.65; 60.55]	8.6%
Pan 2020	58	92.58	12.3500	58	125.32	12.6300	-32.74	[-37.29; -28.19]	10.6%
Wang 2021	43	105.79	18.7500	42	73.16	9.8200	32.63	[26.29; 38.97]	10.4%
Xie 2017	46	103.60	11.8000	46	106.50	16.5000	-2.90	[-8.76; 2.96]	10.5%
Yuan 2018	40	57.50	5.6600	44	63.64	6.5000	-6.14	[-8.74; -3.54]	10.7%
Zunlong 2020	50	118.25	16.9500	50	68.81	10.3700	49.44	[43.93; 54.95]	10.5%
Random effects model	355			356			16.99	[4.92; 29.07]	100.0%

Heterogeneity: $I^2 = 99\%$, $\tau^2 = 353.5981$, $\chi^2_3 = 819.16$ ($p < 0.01$)



Study	DAA			PA			MD	95%-CI (random)	Weight
	Total	Mean	SD	Total	Mean	SD			
Barrett 2013	43	84.30	12.4000	44	60.50	12.4000	23.80	[18.59; 29.01]	20.0%
Bon 2019	50	70.10	11.0000	50	56.70	11.7900	13.40	[8.93; 17.87]	20.1%
Moerenhout 2020	28	59.90	12.7000	27	45.70	17.9000	14.20	[5.97; 22.43]	19.5%
Rykov 2017	23	71.00	7.0000	23	62.00	7.0000	9.00	[4.95; 13.05]	20.2%
Zhao 2017	60	83.26	6.6900	60	65.48	13.3200	17.78	[14.01; 21.55]	20.2%
Random effects model	204			204			15.64	[-1.02; 32.29]	100.0%

Heterogeneity: $I^2 = 82\%$, $\tau^2 = 353.5981$, $\chi^2_4 = 21.96$ ($p < 0.01$)



Indirect comparison

DAA vs SuperPath

Random effects Network estimate

Prediction interval

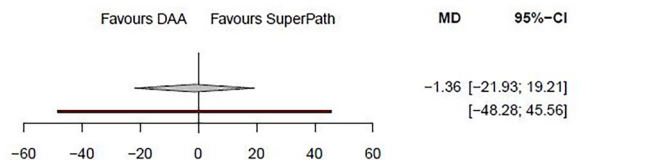
Network Heterogeneity: $I^2 = 98\%$, $\tau^2 = 353.5981$, $\chi^2_3 = 841.12$ ($p < 0.01$)

Figure 2. Comparison of the operation time in min. DAA: direct anterior approach; PA: posterior and posterolateral approaches; SD: standard deviation; MD: mean difference; CI: confidence interval.

In a direct comparison between DAA and PA, data on 262 patients were pooled from 3 RCTs ($I^2 = 0\%$, $p = 0.67$, Fig. 6). There was no difference in HHS 6 months postoperatively (MD = 0.66, 95% CI -2.69 to 4.0).

HHS 6 months postoperatively: DAA vs. SuperPATH

In an indirect comparison between DAA and SuperPATH, data on 370 patients were pooled from 11 RCTs ($I^2 = 80\%$, $p < 0.01$, Fig. 6). There was no difference in HHS 6 months postoperatively (MD = -1.48, 95% CI -5.2 to 2.24).

HHS 12 months postoperatively: SuperPATH vs. PA

In a direct comparison between SuperPATH and PA, data on 330 patients were pooled from 6 RCTs ($I^2 = 0\%$, $p = 0.87$, Fig. 7). The HHS 12 months postoperatively of SuperPATH was 0.6 points higher than the HHS 12 months postoperatively of PA (MD = 0.6, 95% CI 0.03 to 1.17).

HHS 12 months postoperatively: DAA vs. PA

In a direct comparison between DAA and PA, data on 243 patients were pooled from 3 RCTs ($I^2 = 0\%$, $p = 0.46$, Fig. 7). There was no difference in HHS 12 months postoperatively of DAA (MD = 1.28, 95% CI -0.28 to 2.84).

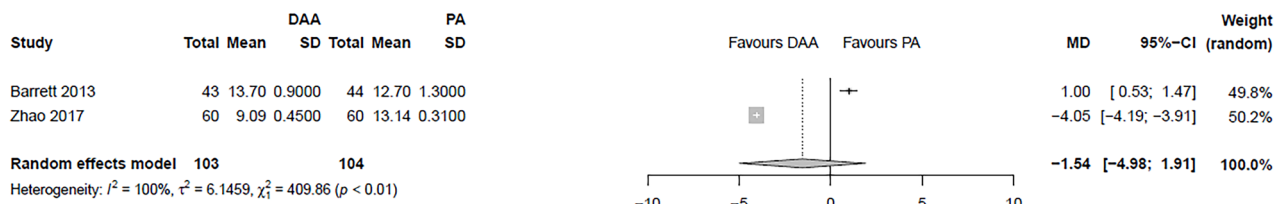
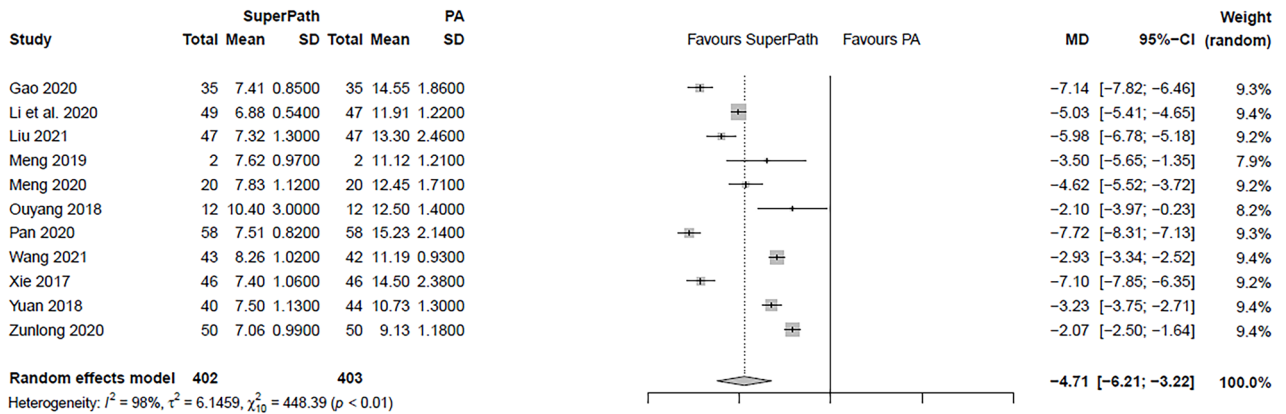
HHS 12 months postoperatively: DAA vs. SuperPATH

In an indirect comparison between DAA and SuperPATH, data on 288 patients were pooled from 9 RCTs ($I^2 = 0\%$, $p = 0.85$, Fig. 7). There was no difference in HHS 12 months postoperatively (MD = 0.68, 95% CI -0.98 to 2.35).

3. Radiological outcome**Acetabular cup anteversion angle: SuperPATH vs. PA**

In a direct comparison between SuperPATH and PA, data on 160 patients were pooled from 4 RCTs ($I^2 = 0\%$, $p = 0.75$, Fig. 8). There was no difference in acetabular cup anteversion angle (MD = -0.51, 95% CI -3.04 to 2.01).

Direct comparisons



Indirect comparison

DAA vs SuperPath

Random effects Network estimate

Prediction interval

Network Heterogeneity: $I^2 = 99\%$, $\tau^2 = 6.1459$, $\chi^2_{11} = 858.24$ ($p < 0.01$)

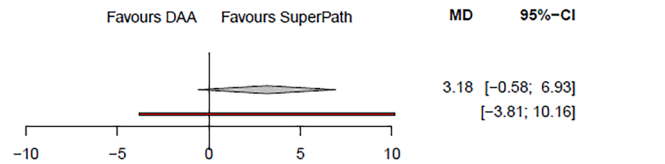


Figure 3. Comparison of the incision length in cm. DAA: direct anterior approach; PA: posterior and posterolateral approaches; SD: standard deviation; MD: mean difference; CI: confidence interval.

Acetabular cup anteversion angle: DAA vs. PA

In a direct comparison between DAA and PA, data on 436 patients were pooled from 5 RCTs ($I^2 = 85\%$, $p < 0.01$, Fig. 8). There was no difference in acetabular cup anteversion angle (MD = -1.78, 95% CI -4.09 to 0.53).

Acetabular cup anteversion angle: DAA vs. SuperPATH

In an indirect comparison between DAA and SuperPATH, data on 298 patients were pooled from 9 RCTs ($I^2 = 75\%$, $p < 0.01$, Fig. 8). There was no difference in acetabular cup anteversion angle (MD = -1.27, 95% CI -4.69 to 2.15).

Acetabular cup inclination angle: SuperPATH vs. PA

In a direct comparison between SuperPATH and PA, data on 256 patients were pooled from 5 RCTs ($I^2 = 26\%$, $p = 0.25$, Fig. 9). The acetabular cup inclination angle of SuperPATH was 3.0° lower than the acetabular cup inclination angle of PA (MD = -2.96, 95% CI -5.24 to -0.67).

Acetabular cup inclination angle: DAA vs. PA

In a direct comparison between DAA and PA, data on 536 patients were pooled from 6 RCTs ($I^2 = 78\%$, $p < 0.01$, Fig. 9). There was no difference in acetabular cup inclination angle (MD = 0.14, 95% CI -1.67 to 1.95).

Acetabular cup inclination angle: DAA vs. SuperPATH

In an indirect comparison between DAA and SuperPATH, data on 397 patients were pooled from 11 RCTs ($I^2 = 68\%$, $p < 0.01$, Fig. 9). The acetabular cup inclination angle of SuperPATH was 3.1° lower than the acetabular cup inclination angle of DAA (MD = 3.09, 95% CI 0.18 to 6.01).

Direct comparisons

Study	SuperPath				PA	
	Total	Mean	SD	Total	Mean	SD
Gao 2020	35	88.68	6.0400	35	208.52	4.6100
Li et al. 2020	49	204.99	60.2900	47	343.61	88.6100
Liu 2021	47	92.43	7.1400	47	195.83	18.9900
Meng 2019	2	1108.50	163.6300	2	843.50	111.6000
Meng 2020	20	1007.38	174.2200	20	844.55	161.1600
Ouyang 2018	12	138.33	42.8200	12	141.67	35.8900
Wang 2021	43	89.47	9.3200	42	253.86	42.5800
Xie 2017	46	303.60	106.3000	46	326.40	127.2000
Yuan 2018	40	175.00	11.3200	44	209.09	16.9600
Zunlong 2020	50	185.47	20.2300	50	388.95	47.7100

Random effects model 344 345
 Heterogeneity: $I^2 = 99\%$, $\tau^2 = 2301.1882$, $\chi^2_9 = 976.81$ ($p < 0.01$)

Study	DAA				PA	
	Total	Mean	SD	Total	Mean	SD
Barrett 2013	43	391.00	206.0000	44	191.00	107.0000
Rykov 2017	23	325.70	99.7400	23	273.70	181.0000
Zhao 2017	60	165.89	42.6000	60	123.84	56.8300

Random effects model 126 127
 Heterogeneity: $I^2 = 89\%$, $\tau^2 = 2301.1882$, $\chi^2_2 = 18.74$ ($p < 0.01$)

Indirect comparison

DAA vs SuperPath

Random effects Network estimate
 Prediction interval
 Network Heterogeneity: $I^2 = 99\%$, $\tau^2 = 2301.1882$, $\chi^2_{11} = 995.56$ ($p < 0.01$)

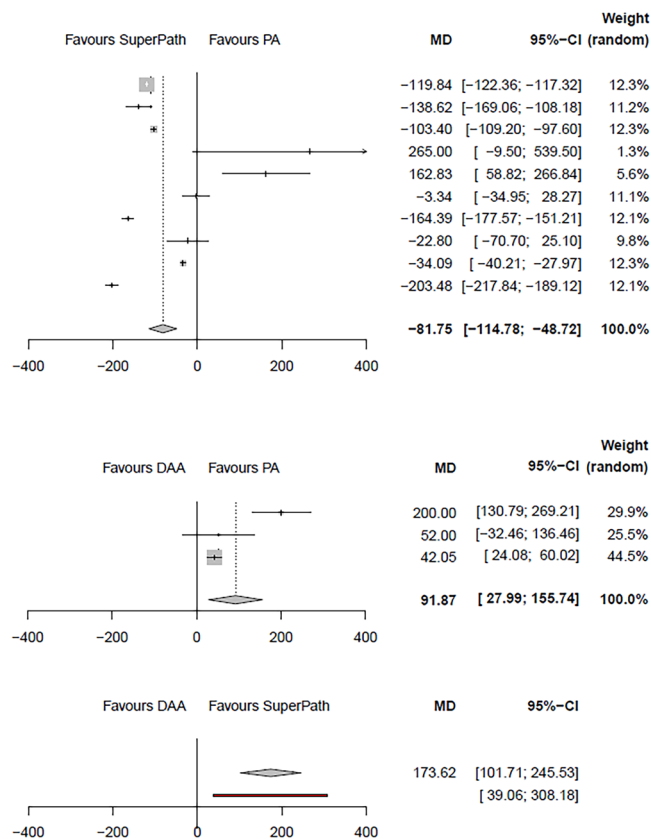


Figure 4. Comparison of the intraoperative blood loss in ml. DAA: direct anterior approach; PA: posterior and posterolateral approaches; SD: standard deviation; MD: mean difference; CI: confidence interval.

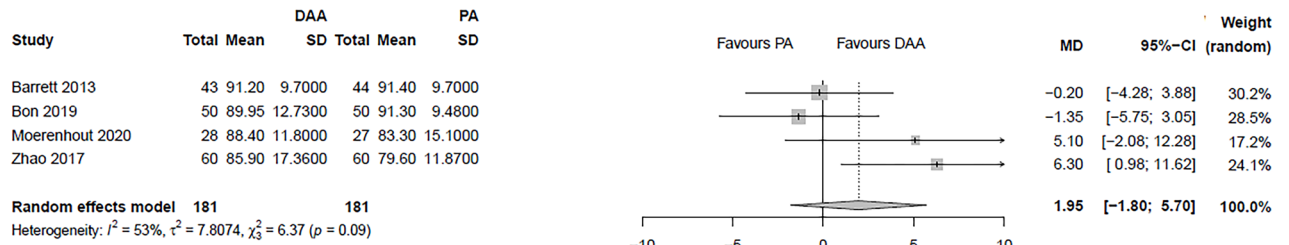
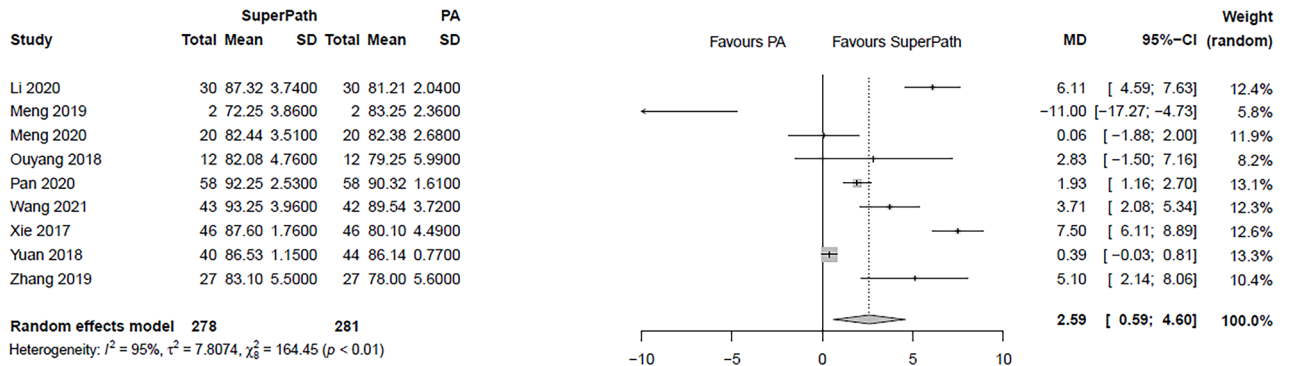
Discussion

Main and new findings. Our NMA included 20 RCTs with 1501 patients. Of these, 7 RCTs involving 592 patients compared DAA with PA, and 13 RCTs involving 919 patients compared SuperPATH with PA. Our NMA indicated that the results of THA through SuperPATH were statistically superior to THA through PA regarding the investigated outcomes. SuperPATH showed statistically better results on incision length, intraoperative blood loss, and HHS than PA. SuperPATH showed statistically worse results in operation time than PA. DAA showed statistically worse results in intraoperative blood loss than PA. The other outcomes in THA through DAA and PA were indifferent. SuperPATH showed statistically better results in intraoperative blood loss than DAA. The other outcomes in THA through SuperPATH and DAA were indifferent. All approaches showed sufficient results in acetabular cup positioning.

The value of this NMA comes from the inclusion of RCTs and the employment of high-quality statistical methods. We performed the NMA with both a fixed and a random effects model. Our NMA is an attempt to overcome the limitations of our previous NMAs^{2,3} by systematically and quantitatively reviewing literature comparing SuperPATH, DAA, and PA.

SuperPATH vs. DAA vs. PA. The mean operation time in our NMA ranged from 57 to 118 min. for SuperPATH, from 60 to 84 min. for DAA, and from 46 to 125 min. for PA. SuperPATH had a 17 min. longer operation time than PA. There was no difference in operation time between DAA vs. PA and SuperPATH vs. DAA. A prolonged operation time was found in other meta-analyses comparing SuperPATH with conventional approaches³⁷⁻³⁹. A 2018 meta-analysis by Wang et al.⁴⁰ with 9 RCTs and 754 THAs showed no difference in operation time between DAA and PA. Wills et al. found that an operation time > 90 min. in THA leads to increased rates of superficial infections⁴¹. Surace et al. determined in an analysis of 89,802 THA cases that an optimal

Direct comparisons



Indirect comparison

DAA vs SuperPath

Random effects Network estimate
 Prediction interval
 Network Heterogeneity: $I^2 = 94\%$, $\tau^2 = 7.8074$, $\chi^2_{11} = 170.82$ ($p < 0.01$)

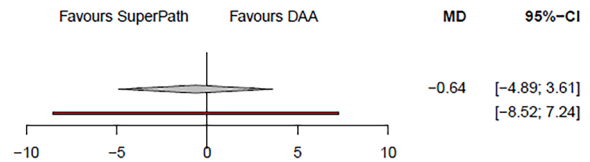


Figure 5. Comparison of the HHS 3 months postoperatively. DAA: direct anterior approach; PA: posterior and posterolateral approaches; SD: standard deviation; MD: mean difference; CI: confidence interval.

operation time of around 80 min. leads to a lower risk of perioperative complications⁴². The operational technique through SuperPATH and DAA is somewhat more complicated than through the conventional approaches. Because of this, SuperPATH and DAA have an extended learning curve for operating surgeons^{43,44}. SuperPATH may have the potential for a shorter operation time as it is a novel approach.

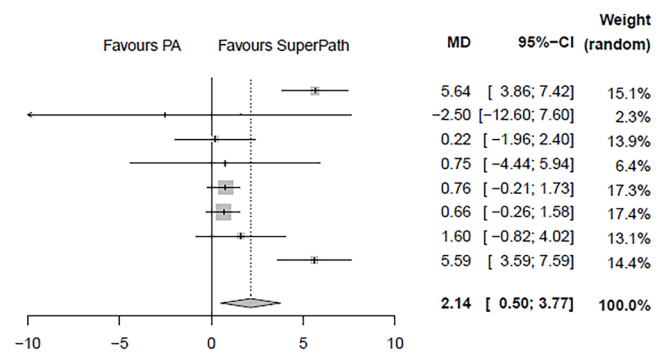
The mean incision length in our NMA ranged from 6.9 to 10.4 cm for SuperPATH, from 9.1 to 13.7 cm for DAA, and from 9.1 to 15.2 cm for PA. SuperPATH had a 4.7 cm shorter incision length than PA. There was no difference in incision length between DAA vs. PA and SuperPATH vs. DAA. Several recent meta-analyses found a shorter incision length for SuperPATH compared to conventional approaches^{37–39,45}, other meta-analyses found a shorter incision length for DAA compared to conventional approaches^{40,46}. Both SuperPATH and DAA should aim for incision lengths of < 10 cm, as this is a requirement for minimally invasive hip surgery. As can be seen in the corresponding Forest plot, SuperPATH is more likely to meet this requirement. Nevertheless, a 2013 meta-analysis by Xu et al. with 14 RCTs and 1174 patients did not come to a definite overall conclusion on whether there is a relevant difference between mini-incision or standard incision in THA outcome⁴⁷. On the other hand, a 2013 meta-analysis by Moskal et al. with 30 studies and 3548 THAs concluded that shorter incisions had a better short-term outcome after THA, compared to standard incisions⁴⁸.

The mean intraoperative blood loss in our NMA ranged from 89 to 1108 ml for SuperPATH, from 166 to 391 ml for DAA, and from 123.8 to 844.6 ml for PA. SuperPATH had 82 ml lower intraoperative blood loss than PA. DAA had 92 ml higher intraoperative blood loss than PA and 174 ml higher intraoperative blood loss than SuperPATH. A lower blood loss for SuperPATH compared to conventional approaches was already found in earlier meta-analyses^{37,39}. However, in our NMA DAA showed a higher blood loss than PA. A possible explanation

Direct comparisons

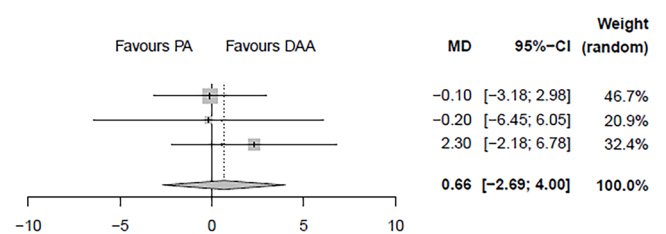
Study	SuperPath		PA	
	Total Mean	SD	Total Mean	SD
Li 2020	30 95.75	3.9200	30 90.11	3.0700
Meng 2019	2 84.25	6.1800	2 86.75	3.8600
Meng 2020	20 87.77	3.4700	20 87.55	3.5600
Ouyang 2018	12 84.92	5.8700	12 84.17	7.0400
Pan 2020	58 93.67	2.2200	58 92.91	3.0500
Yuan 2018	40 90.00	2.0300	44 89.34	2.2900
Zhang 2019	27 88.00	3.6000	27 86.40	5.3000
Zunlong 2020	50 85.26	5.4100	50 79.67	4.8000
Random effects model	239		243	

Heterogeneity: $I^2 = 84%$, $\tau^2 = 3.7693$, $\chi^2_3 = 44.09$ ($p < 0.01$)



Study	DAA		PA	
	Total Mean	SD	Total Mean	SD
Barrett 2013	43 95.80	7.8000	44 95.90	6.8000
Moerenhout 2020	28 90.10	11.3000	27 90.30	12.3000
Zhao 2017	60 92.20	13.2500	60 89.90	11.7400
Random effects model	131		131	

Heterogeneity: $I^2 = 0%$, $\tau^2 = 3.7693$, $\chi^2_2 = 0.81$ ($p = 0.67$)



Indirect comparison

DAA vs SuperPath
 Random effects Network estimate
 Prediction interval
 Network Heterogeneity: $I^2 = 80%$, $\tau^2 = 3.7693$, $\chi^2_3 = 44.90$ ($p < 0.01$)

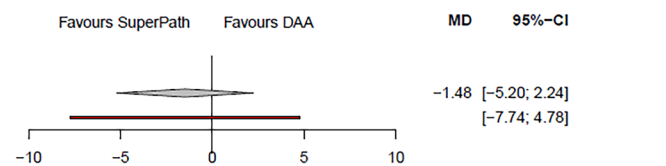


Figure 6. Comparison of the HHS 6 months postoperatively. DAA: direct anterior approach; PA: posterior and posterolateral approaches; SD: standard deviation; MD: mean difference; CI: confidence interval.

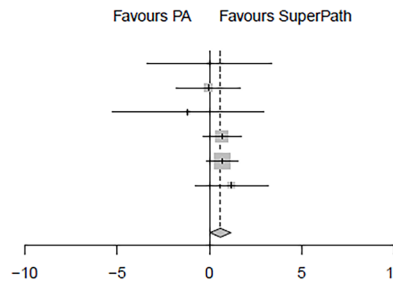
is bleeding of branches of the lateral circumflex femoral artery, the ligation of which is sometimes problematic. Besides the approaches to the hip joint, other known factors that influence blood loss in hip surgery are the use of tranexamic acid and intraoperative active warming^{49–51}.

The mean HHS 3 months postoperatively in our NMA ranged from 72.3 to 93.3 points for SuperPATH, from 85.9 to 91.2 points for DAA, and 78.0 to 91.4 points for PA. The mean HHS 6 months postoperatively in our NMA ranged from 84.3 to 95.8 points for SuperPATH, from 90.1 to 95.8 points for DAA, and from 79.7 to 95.9 points for PA. The mean HHS 12 months postoperatively in our NMA ranged from 85.6 to 94.7 points for SuperPATH, from 94.4 to 97.5 points for DAA, and from 86.6 to 97.3 points for PA. With regards to the postoperative functional outcome (HHS 3, 6, and 12 months postoperatively) SuperPATH demonstrated statistically superior results to PA. The difference in HHS decreased over time after surgery. SuperPATH had a 2.6 point higher HHS 3 months postoperatively, a 2.1 points higher HHS 6 months postoperatively, and a 0.6 points higher HHS 12 months postoperatively. This means that the strength of SuperPATH lies in the early functional outcome. However, when interpreting the results it is important to emphasize that differences in functional outcomes are not clinically relevant. The highest HHS difference noted in our NMA was 2.6 points at 3 months postoperatively. Although in the literature the minimal clinically important difference (MCID) for HHS varies according to different types of hip surgery^{52–55}, it has been reported as no less than 7.9 points on the 0–100 HHS scale. There was no difference in HHS 3, 6, and 12 months postoperatively between DAA vs. PA and SuperPATH vs. DAA. Several meta-analyses on SuperPATH vs. conventional approaches came to similar conclusions^{37–39,45}. In contrast to our findings, several meta-analyses showed better early functional results for DAA compared to

Direct comparisons

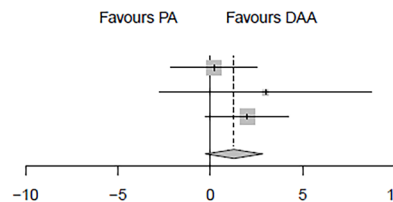
Study	SuperPath		PA		MD	95%-CI (random)	Weight
	Total Mean	SD	Total Mean	SD			
Meng 2019	2 92.50	1.7300	2 92.50	1.7300	0.00	[-3.39; 3.39]	2.8%
Meng 2020	20 92.61	2.7600	20 92.66	2.8000	-0.05	[-1.77; 1.67]	10.9%
Ouyang 2018	12 85.58	6.5400	12 86.75	3.1400	-1.17	[-5.27; 2.93]	1.9%
Pan 2020	58 94.72	2.9200	58 94.04	2.8100	0.68	[-0.36; 1.72]	29.9%
Xie 2017	46 92.30	1.6200	46 91.60	2.4100	0.70	[-0.14; 1.54]	46.1%
Zhang 2019	27 91.30	3.8000	27 90.10	3.6000	1.20	[-0.77; 3.17]	8.3%
Random effects model	165		165		0.60	[0.03; 1.17]	100.0%

Heterogeneity: $I^2 = 0\%$, $\tau^2 = 0$, $\chi^2_5 = 1.81$ ($p = 0.87$)



Study	DAA		PA		MD	95%-CI (random)	Weight
	Total Mean	SD	Total Mean	SD			
Barrett 2013	43 97.50	5.7000	44 97.30	5.5000	0.20	[-2.15; 2.55]	44.0%
Moerenhout 2020	28 94.40	8.0000	27 91.40	13.0000	3.00	[-2.73; 8.73]	7.4%
Taunton 2018	52 97.00	4.0000	49 95.00	7.0000	2.00	[-0.24; 4.24]	48.6%
Random effects model	123		120		1.28	[-0.28; 2.84]	100.0%

Heterogeneity: $I^2 = 0\%$, $\tau^2 = 0$, $\chi^2_2 = 1.55$ ($p = 0.46$)



Indirect comparison

DAA vs SuperPath

Random effects Network estimate
 Prediction interval
 Network Heterogeneity: $I^2 = 0\%$, $\tau^2 = 0$, $\chi^2_1 = 3.36$ ($p = 0.85$)

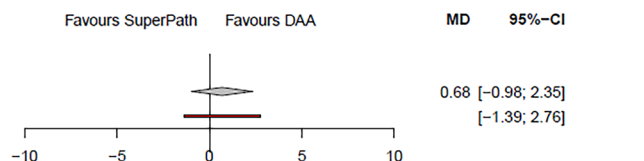


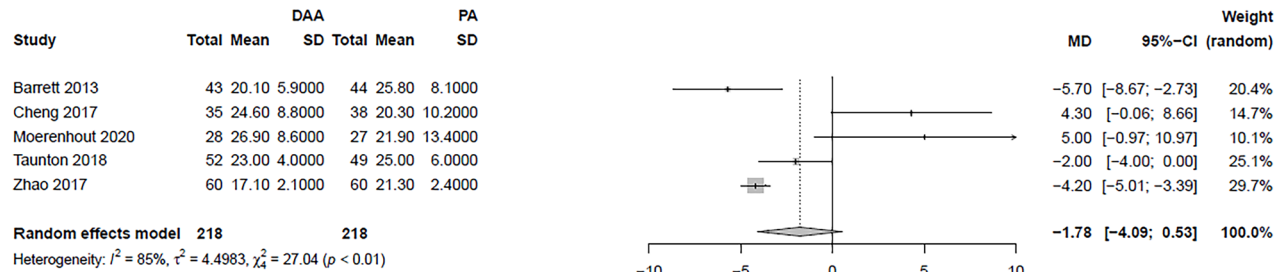
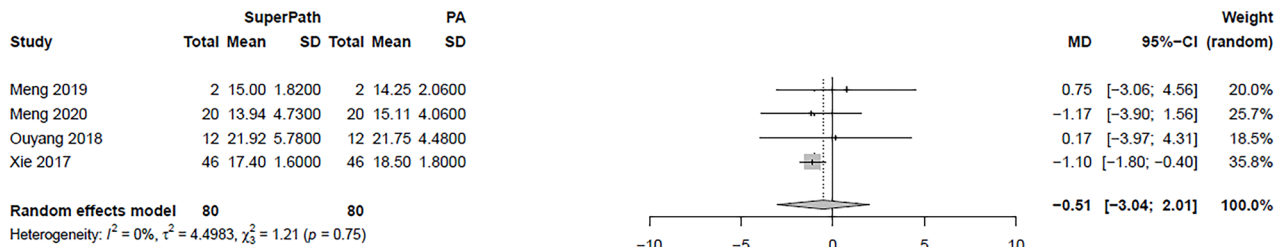
Figure 7. Comparison of the HHS 12 months postoperatively. DAA: direct anterior approach; PA: posterior and posterolateral approaches; SD: standard deviation; MD: mean difference; CI: confidence interval.

conventional approaches^{40,46,56}. However, HHS is a very important outcome parameter as it gives a comprehensive impression of the function of the operated hip.

The mean acetabular cup anteversion angle in our NMA ranged from 13.9° to 21.9° for SuperPATH, from 17.1° to 26.9° for DAA, and from 14.3° to 25.8° for PA. Each in another RCT, DAA³³ and PA³⁰ showed a slightly too large angle with 26.9° and 25.8°, respectively. The mean acetabular cup inclination angle in our NMA ranged from 36.9° to 43.9° for SuperPATH, from 37.0° to 47.1° for DAA, and from 39.6° to 46.5° for PA. In general, all approaches stayed within the widely accepted values for acetabular cup positioning: anteversion angle from 10° to 25° and inclination angle from 40° to 50°⁹. None of the included studies evaluated the restoration of the center of rotation of the native acetabulum, which could be affected during minimally invasive approaches, due to potential upward deviation of the acetabular reamers by the soft tissue tension. Furthermore, the assessment of the anteversion angle, in particular, is questionable, as none of the included RCTs used computed tomography (Table 1). In addition, both acetabular inclination and anteversion change between standing and supine conventional radiographs. Nevertheless, there was no relevant difference between SuperPATH, DAA, and PA in acetabular cup positioning.

Intra- and postoperative fractures, especially trochanteric fractures, infections, and hip dislocations are important complications that seem to show different patterns in certain approaches. Surgical revision rates, leg length discrepancies, and postoperative pain are also parameters often taken into consideration in comparisons of THA. Nevertheless, postoperative complications could not be compared due to the lack of consistent data in the RCTs included.

Direct comparisons



Indirect comparison

DAA vs SuperPath

Random effects Network estimate

Prediction interval

Network Heterogeneity: $I^2 = 75\%$, $\tau^2 = 4.4983$, $\chi^2_7 = 28.25$ ($p < 0.01$)

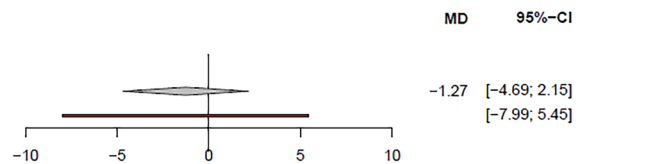


Figure 8. Comparison of the acetabular cup anteversion angle in degrees. DAA: direct anterior approach; PA: posterior and posterolateral approaches; SD: standard deviation; MD: mean difference; CI: confidence interval.

Limitations. In this NMA we addressed an important limitation of our previous NMAs^{2,3}: we distinguished between each conventional approach and compared SuperPATH, DAA, and PA. The other restrictions remain unchanged: First, due to the lack of RCTs that directly compare SuperPATH and DAA, we provided an indirect comparison of both approaches, which offers weaker evidence. Second, the long-term outcomes of THA were not considered. Third, due to insufficient data, important outcome parameters such as hospitalization time, postoperative drainage volume, postoperative pain, and complications could not be considered. Fourth, this NMA did not consider the possible influence of the surgeon operating skills, the utilization of tranexamic acid and anticoagulants, bone cement, or the types of implants for hip replacement. Fifth, part of the RCTs did not give any information on what exact hip pathology was treated with THA. Sixth, since the SuperPATH approach is a 2-incision approach, it remains unclear whether the included RCTs reported the added incision length or the length of the larger incision, ignoring the smaller additional incision. Lastly, in some cases of the outcomes investigated, the heterogeneity of the included RCTs was high.

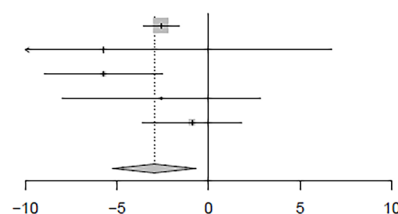
Conclusion

Our overall findings suggested that the short-term outcomes of THA through SuperPATH were statistically superior to PA. SuperPATH showed statistically better results in incision length, intraoperative blood loss, and functional outcome than PA. DAA and PA as well as SuperPATH and DAA showed overall indifferent short-term outcomes.

Direct comparisons

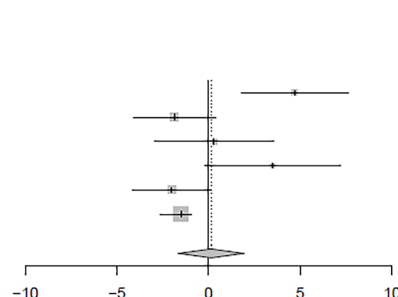
Study	SuperPath		PA		MD	95%-CI (random)	Weight	
	Total Mean	SD	Total Mean	SD				
Li et al. 2020	49	43.88	2.9400	47	46.47	1.8700	-2.59 [-3.57; -1.61]	36.9%
Meng 2019	2	38.75	8.2100	2	44.50	3.6400	-5.75 [-18.20; 6.70]	3.1%
Meng 2020	20	36.94	6.3700	20	42.66	3.5800	-5.72 [-8.92; -2.52]	22.3%
Ouyang 2018	12	37.08	6.5300	12	39.67	6.9500	-2.59 [-7.99; 2.81]	12.4%
Xie 2017	46	43.60	6.8000	46	44.50	6.5000	-0.90 [-3.62; 1.82]	25.4%

Random effects model 129 127
Heterogeneity: $I^2 = 26%$, $\tau^2 = 3.4398$, $\chi^2_4 = 5.37$ ($p = 0.25$)



Study	DAA		PA		MD	95%-CI (random)	Weight	
	Total Mean	SD	Total Mean	SD				
Barrett 2013	43	47.10	6.1000	44	42.40	7.6000	4.70 [1.81; 7.59]	15.2%
Bon 2019	50	37.74	4.2000	50	39.60	6.8700	-1.86 [-4.09; 0.37]	18.0%
Cheng 2017	35	46.20	6.1000	38	45.90	8.0000	0.30 [-2.95; 3.55]	13.8%
Moerenhout 2020	28	43.30	8.4000	27	39.80	5.4000	3.50 [-0.22; 7.22]	12.1%
Taunton 2018	52	37.00	5.0000	49	39.00	6.0000	-2.00 [-4.16; 0.16]	18.3%
Zhao 2017	60	40.30	2.8000	60	41.80	3.4000	-1.50 [-2.61; -0.39]	22.6%

Random effects model 268 268
Heterogeneity: $I^2 = 78%$, $\tau^2 = 3.4398$, $\chi^2_5 = 23.03$ ($p < 0.01$)



Indirect comparison

DAA vs SuperPath

Random effects Network estimate

Prediction interval

Network Heterogeneity: $I^2 = 68%$, $\tau^2 = 3.4398$, $\chi^2_9 = 28.40$ ($p < 0.01$)

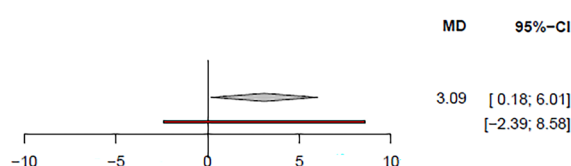


Figure 9. Comparison of the acetabular cup inclination angle in degrees. DAA: direct anterior approach; PA: posterior and posterolateral approaches; SD: standard deviation; MD: mean difference; CI: confidence interval.

Data availability

The data are available from the corresponding author upon reasonable request.

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Author contributions

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Additional information

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