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Review Article

Hemiarthroplasty compared with total hip arthroplasty for displaced fractures of femoral neck in the elderly: a systematic review and meta-analysis of fourteen randomized clinical trials

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Abstract: The optimal choice for displaced femoral neck fracture (FNF) in the elderly remains controversial, with alternatives including hemiarthroplasty (HA) and total hip arthroplasty (THA). This study was performed to determine the effects of HA compared with THA on rates of mortality, revision, dislocation, infection, operating time, and hip function in elderly patients with a displaced FNF. Electronic databases were carefully searched for relevant publications. All prospective randomized controlled trials directly comparing mortality rate, revision rate, dislocation, or hip function assessment between HA and THA were retrieved. Fourteen studies involving 1523 patients were included in the analysis. There was no significant difference in 1-year mortality rate between groups. The revision rate after THA showed a slight decrease compared with that after HA. There was a significant risk of dislocation after treatment with THA. The risk of infection did not differ between HA and THA. The operating time for THA was greater than that for HA. Patients treated with THA had significantly higher Harris Hip Scores. In conclusion, THA for treatment of displaced FNF significantly reduces the risk of revision surgery and tends toward better hip functional outcome scores at the cost of greater dislocation rates, blood loss, and operating time.

Keywords: Displaced femoral neck fracture, hemiarthroplasty, total hip arthroplasty, dislocation, Harris hip score

Introduction

The proportion of elderly people is increasing as the world's population ages, which is predicted to result in a rise in the incidence of osteoporotic hip fractures. It is estimated that about 1.6 million hip fractures occurred in 2000 [1], and the incidence of hip fractures is expected to increase to more than six million worldwide by the year 2050 [2]. Treatment options for fractures of the femoral neck in elderly patients include internal fixation, hemiarthroplasty (HA), and total hip arthroplasty (THA). Internal fixation is recommended as the treatment of choice in young patients with displaced femoral neck fracture (FNF) [3] and in very elderly patients not medically fit for prosthetic surgery [4]. Arthroplasty (HA or THA) is a preferred treatment modality in the elderly population (> 60 years) [5]. The choice between HA and THA has always been difficult for elderly patients with displaced FNF.

Evidence suggests that THA leads to better functional outcome than HA [6], but HA has some advantages compared with THA, such as reduced dislocation rate, less complex surgery, shorter operation time, less blood loss, and lower initial costs [7]. The major long-term problem associated with HA is painful acetabular erosion, with reported rates ranging from 0-26% for bipolar designs and from 2.2-36% for unipolar designs [8, 9]. In one series, 38% of hips with a unipolar prosthesis required revision because of acetabular erosion [9]. In contrast, the major early complication of THA is dislocation, the rate of which increases in association with the use of a posterior approach and a smaller prosthetic head size [10]. The reported rates of dislocation after THA to treat displaced FNF have ranged from 0 to 20.2% [11-13]. Nevertheless, most orthopedic surgeons prefer HA in the management of this injury, reporting decreased operation time, blood loss, and risk of mortality because the procedure is quicker and often simpler than THA [14].

A number of recent randomized trials have compared the treatment of displaced FNF between HA and THA. These trials have overcome the limitations of earlier studies by decreasing bias through randomization. However, their small sample sizes (range, 40-252 patients) and wide confidence intervals (CI) surrounding the treatment effects have limited the inferences that can be made based on their results.

Previous systematic reviews have included few randomized trials. There have been several meta-analyses [15-18], and a limited number of studies have evaluated the optimal type of arthroplasty in properly designed RCTs. The overall conclusion is that there is inadequate evidence to support the choice between different types of arthroplasty. Given the recent increase in the number of published randomized trials evaluating alternative strategies for treatment of hip fractures, we conducted a meta-analysis of randomized trials to assess the clinical results with regard to the rates of mortality, revision surgery, dislocation, infection, and hip function of HA compared with those of THA in the treatment of displaced FNF. We hypothesized that HA may be associated with a greater risk of revision surgery but a decreased risk of mortality, and that THA may result in better hip function in follow-up.

Methods

This study was conducted strictly according to the methods established in the PRISMA 2015 checklist and the Cochrane Handbook for Systematic Reviews of Interventions 5.0.2 [19].

Literature search

We identified the articles that were published in electronic databases and met the following eligibility criteria: (1) the target population was patients ≥ 65 years of age with displaced FNF; (2) the intervention compared HA with THA; (3) the outcome measure was the available data including mortality or revision or dislocation rate or hip function assessment; (4) the follow-up period was ≥ 1 year; and (5) the study was a prospective randomized controlled trial.

Three independent investigators searched electronic databases (EMBASE, PubMed, ISI Web of Science, Cochrane Central Register of Controlled Trials, and China National Knowledge Infrastructure) with no restrictions in publication year or language. We identified the population (hip fracture or femoral neck fracture), intervention (hemiarthroplasty AND total hip arthroplasty), methodology (clinical trial), and used the keywords "femoral neck fracture" AND "arthroplasty". Results were last updated on August 31, 2017. We also manually searched the reference lists of manuscripts included to identify other reports not identified by our original search.

Two of the authors reviewed the titles and followed the eligibility criteria independently. Redundant publications were excluded by title review. We then chose potentially eligible studies for retrieval and reviewed the abstracts. Then, publications retrieved as full text were read in detail. All publications included fulfilled the eligibility criteria.

Quality assessment

Two investigators evaluated the methodological quality of each study using to a 12-item scale: randomized adequately, allocation concealed, patient blinded, care provider blinded, outcome assessor blinded, acceptable dropout rate, ITT analysis, avoided selective reporting, similar baseline, similar or avoided cofactor, patient compliance, and similar timing. [19] The kappa test was used to assess divergence, and consensus was obtained by discussion with the third investigator. According to the 12-item standard (**Table 1**), 12 studies were of high quality and the other two studies were of moderate quality. The weighted kappa for the agreement on study quality between the investigators was 0.87 (95% confidence interval (95% CI) = 0.81-0.93).

Data extraction

Two reviewers extracted relevant information regarding the study design, patient demograph-

Table 1. Methodological quality of the included studies based on the 12-items scoring system

Author & Year	Randomised adequately[a]	Allocation concealed	Patient blinded	Care provider blinded	Outcome assessor blinded	Acceptable drop-out rate[b]	ITT analysis[c]	Avoided selective reporting	Similar baseline	Similar or avoided cofactor	Patient compliance	Similar timing	Quality[d]
Sharma 2016	Yes	Yes	Unsure	Unsure	Unsure	Yes	No	Yes	Yes	Yes	Yes	Yes	High
Gao 2016	Yes	Yes	No	Unsure	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Tan 2015	Yes	No	No	Unsure	Unsure	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Cadossi 2013	No	No	No	Unsure	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Giannini 2011	No	No	Unsure	Unsure	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Hedbeck 2011	Yes	Yes	Unsure	Unsure	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Avery 2011	Yes	Yes	No	Unsure	No	Yes	No	Yes	Yes	Yes	Yes	Yes	High
Vanden 2010	Yes	Yes	Unsure	Unsure	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Mouzopoulos 2008	No	No	No	Unsure	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Moderate
Macaulay 2008	Yes	Yes	No	Unsure	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Keating 2006	Yes	Yes	No	Unsure	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Schleicher 2003	Yes	No	No	Unsure	No	Yes	No	Yes	Yes	Yes	Yes	Yes	High
Kasetti 2000	No	No	No	Unsure	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Moderate
Dorr 1986	No	No	No	Unsure	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High

[a]Only if the method of sequence made was explicitly introduced could get a "Yes"; sequence generated by "Dates of Admission" or "Patients Number" receive a "No". [b]Drop-out rate < 20% could get a "Yes", otherwise "No". [c]ITT = intention-to-treat, only if all randomised participants were analysed in the group they were allocated to could receive a "Yes". [d]"Yes" items more than 7 means "High"; more than 4 but no more than 7 means "Moderate"; no more than 4 means "Low".

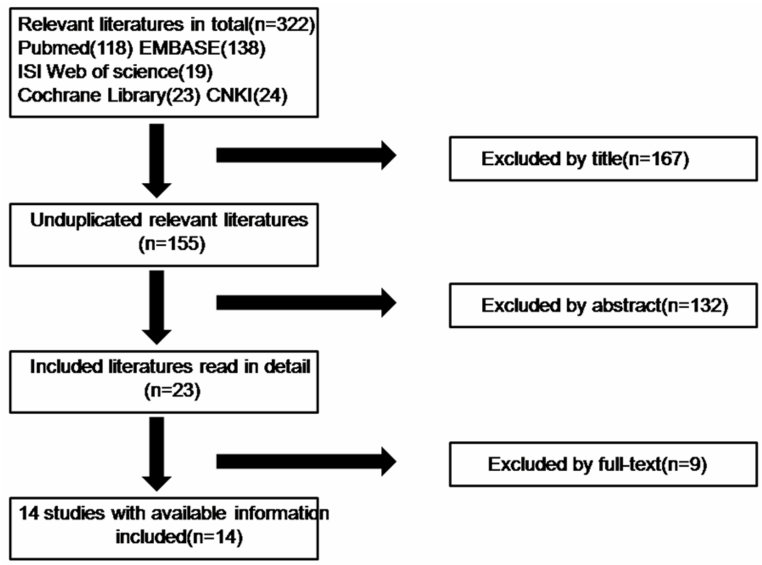

Figure 1. A PRISMA flowchart illustrated the selection of studies included in our systematic review.

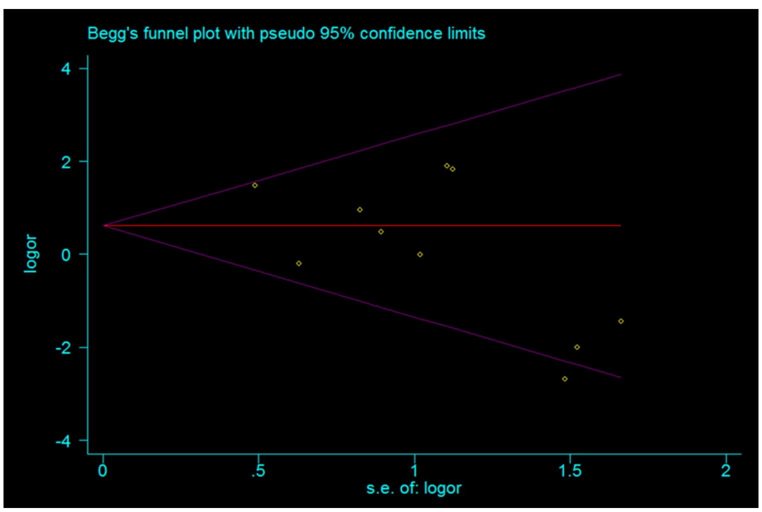

Figure 2. Publication bias assessed by begg's test.

ics (sample size, age, sex distribution), and mean follow-up time. In addition to the data on mortality rates, we abstracted data on revision rates, rates of wound infection (at the bone implant interface), rates of dislocation, postoperative hip function assessment, intraoperative blood loss, and surgical time. Intention-to-treat data from the trials were used. If relevant data were not reported, we attempted to obtain them from the accompanying graphs. We also attempted to contact the corresponding authors to request further data for our analysis if necessary.

Statistical analysis

We used Review Manager software (Version 5.3. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014) for statistical analysis and generating figures, and used the Mantel-Haenszel to analyze dichotomous outcomes and calculate the risk ratios between HA and THA. For continuous variables, we calculated means weighted by study size. We used the I^2 statistic to assess heterogeneity between studies; we considered I^2 values of 25%, 50%, and 75% to indicate low, medium, and high heterogeneity, respectively. We used the fixed-effects model when $I^2 < 50\%$; otherwise, we used the random-effects model. The results are expressed as risk ratio (RR) and 95% CI for dichotomous outcomes, and as weighted mean difference (WMD) and 95% CI for continuous outcomes. We used Begg's test to assess publication bias.

Results

Literature review

The literature search initially yielded 322 relevant citations, among which there were 167 duplicates leaving 155 trials. After scanning titles and abstracts according to the eligibility criteria, only 23 were retrieved as full text. Nine of these studies were excluded: two were nonrandomized comparisons, three were review articles, one was an observational study, and three were randomized trials that had been followed by publication of an article on the same trial with longer follow-up. Thus, 14 published studies [11, 12, 20-31] comparing HA with THA were ultimately eligible for the investigation (**Figure 1**). The weighted kappa for the agreement of eligibility between the investigators was 0.85 (95% CI, 0.78-0.92). No publication bias was

Table 2. Study characteristics and intervention of the trials

Author & Year	Study design	Surgical approach	Type	Sample size	Mean age (year)	Female/Male	Follow-up (mo)
Sharma 2016	Prospective, randomised	Modified Gibson	HA (bipolar)	40	73	29/11	48
			THA	40	78	26/14	48
Gao 2016	Prospective, randomised	Posterolateral	HA	74	73.4	33/41	12
			THA	74	72.9	36/38	12
Tan 2015	Prospective, randomised	N.R.	HA	40	72.9	23/17	12
			THA	40	72.7	22/18	12
Cadossi 2013	Prospective, randomised	Straight lateral	HA (bipolar)	41	84.2	28/13	28.6
			THA	42	82.3	34/8	30.1
Giannini 2011	Prospective, randomised	N.R.	HA (bipolar)	26	82.2	N.R.	12
			THA	26	80.7	N.R.	12
Hedbeck 2011	Prospective, randomised	Anterolateral	HA (bipolar)	60	80.7	54/6	48
			THA	60	80.5	47/13	48
Avery 2011	Multicenter, prospective, randomised	Transgluteal lateral	HA (unipolar)	41	75.8	32/9	103
			THA	40	74.2	32/8	106
Vanden 2010	Multicenter, prospective, randomised	Anterolateral posterolateral	HA (bipolar)	137	80.3	115/22	60
			THA	115	82.1	90/25	60
Mouzopoulos 2008	Multicenter, prospective, randomised	N.R.	HA	34	74.2	24/10	48
			THA	37	73.1	28/9	48
Macaulay 2008	Multicenter, prospective, randomised	Posterolateral direct lateral	HA	23	77	14/9	34
			THA	17	82	10/7	34
Keating 2006	Multicenter, prospective, randomised	Lateral posterior	HA	69	75	54/15	24
			THA	69	75.2	52/17	24
Schleicher 2003	Prospective, randomised	N.R.	HA (bipolar)	55	81	48/7	96
			THA	54	80.5	45/9	96
Kasetti 2000	Prospective, randomised	Posterolateral	HA (bipolar)	91	82.1	N.R.	156
			THA	89	81	N.R.	156
Dorr 1986	Prospective, randomised	Posterior	HA (bipolar)	50	70	35/15	> 24
			THA	39	69	23/16	> 24

HA: hemiarthroplasty. THA: total hip arthroplasty. N.R.: not record.

Table 3. Details of outcome measurements of the trials

Author & Year	Type (Sample)	Mean operative time (min)	Blood loss (ml)	Hospital day (day)	Dislocation	Infection	Revision	1 year mortality	1 year HHS
Sharma 2016	HA (40)	35	200	14	0% (0)	0% (0)	N.R.	0% (0)	80
	THA (40)	45	300	14	0% (0)	2.5% (1)	N.R.	2.5% (1)	90
Gao 2016	HA (74)	125.3	236.5	16.4	4.1% (3)	0% (0)	N.R.	N.R.	89.2
	THA (74)	158.6	325.8	16.2	2.7% (2)	0% (0)	N.R.	N.R.	90.4
Tan 2015	HA (40)	88.96	327.0	N.R.	7.5% (3)	N.R.	N.R.	2.5% (1)	N.R.
	THA (40)	101.36	463.9	N.R.	7.5% (3)	N.R.	N.R.	5% (2)	N.R.
Cadossi 2013	HA (41)	81	643.9	12.3	0% (0)	N.R.	0% (0)	19.5% (8)	74.7
	THA (42)	75.4	571.4	12.8	4.8% (2)	N.R.	14.3% (6)	7.1% (3)	73.1
Giannini 2011	HA (26)	71.6	380	10.5	N.R.	N.R.	N.R.	N.R.	75.5
	THA (26)	76.7	460	12.8	N.R.	N.R.	N.R.	N.R.	80.7
Hedbeck 2011	HA (60)	N.R.	320	N.R.	0% (0)	0% (0)	0% (0)	5% (3)	79.4
	THA (60)	N.R.	460	N.R.	0% (0)	1.7% (1)	5% (3)	6.7% (4)	87.2
Avery 2011	HA (41)	N.R.	N.R.	N.R.	0% (0)	2.4% (1)	14.6% (6)	N.R.	N.R.
	THA (40)	N.R.	N.R.	N.R.	7.5% (3)	7.5% (3)	2.5% (1)	N.R.	N.R.
Vanden 2010	HA (137)	68	283.6	17.1	0% (0)	N.R.	4.4% (6)	13.1% (18)	73.9
	THA (115)	80.7	381.6	18.4	7.0% (8)	N.R.	1.7% (2)	13.9% (16)	76
Mouzopoulos 2008	HA (34)	N.R.	N.R.	9.1	N.R.	N.R.	14.7% (5)	17.6% (6)	77.8
	THA (37)	N.R.	N.R.	8.3	N.R.	N.R.	2.7% (1)	16.2% (6)	81.6
Macaulay 2008	HA (23)	82	N.R.	5.4	0% (0)	4.3% (1)	0% (0)	21.7% (5)	80.6
	THA (17)	89.1	N.R.	7.7	5.9% (1)	0% (0)	5.9% (1)	5.9% (1)	84.2
Keating 2006	HA (69)	58.5	N.R.	N.R.	2.9% (2)	4.3% (3)	7.2% (5)	N.R.	76.5
	THA (69)	79.7	N.R.	N.R.	4.3% (3)	4.3% (3)	8.7% (6)	N.R.	79.4
Schleicher 2003	HA (55)	72	400	N.R.	1.8% (1)	1.8% (1)	3.6% (2)	10.9% (6)	N.R.
	THA (54)	84	600	N.R.	1.9% (1)	0% (0)	3.7% (2)	18.5% (10)	N.R.
Kasetti 2000	HA (91)	N.R.	N.R.	N.R.	13.2% (12)	3.3% (3)	24.2% (22)	27.5% (25)	N.R.
	THA (89)	N.R.	N.R.	N.R.	20.2% (18)	2.2% (2)	6.7% (6)	22.5% (20)	N.R.
Dorr 1986	HA (50)	N.R.	N.R.	N.R.	4% (2)	0% (0)	8% (4)	N.R.	N.R.
	THA (39)	N.R.	N.R.	N.R.	17.9% (7)	0% (0)	5.1% (2)	N.R.	N.R.

HA: hemiarthroplasty. THA: total hip arthroplasty. N.R. = not record. HHS: Harris hip score.

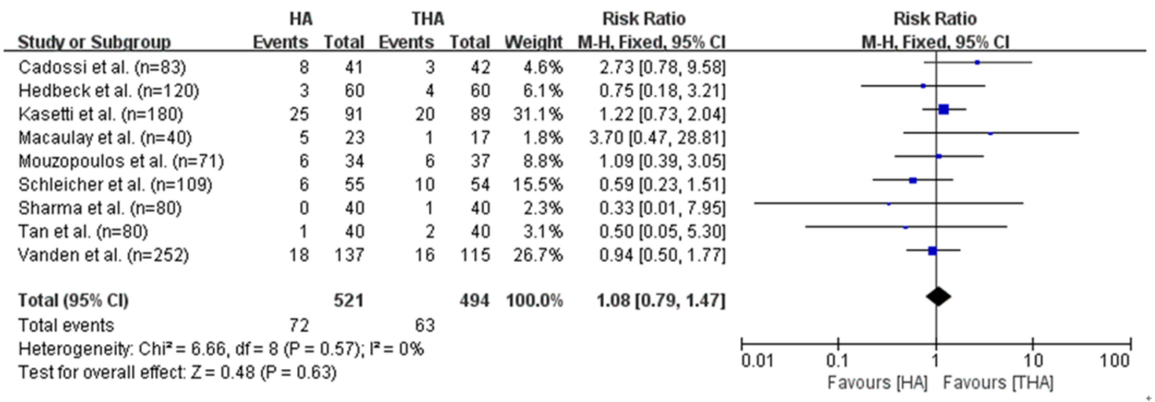

Figure 3. 1-year mortality. Forest plot comparing risk ratios of 1-year mortality after hemiarthroplasty versus total hip arthroplasty in displaced femoral neck fractures in the healthy elderly. Mantel-Haenszel statistical method was used with the 'fixed-effects' analysis method for dichotomous data. M-H: Mantel-Haenszel, THA: total hip arthroplasty, HA: hemiarthroplasty.

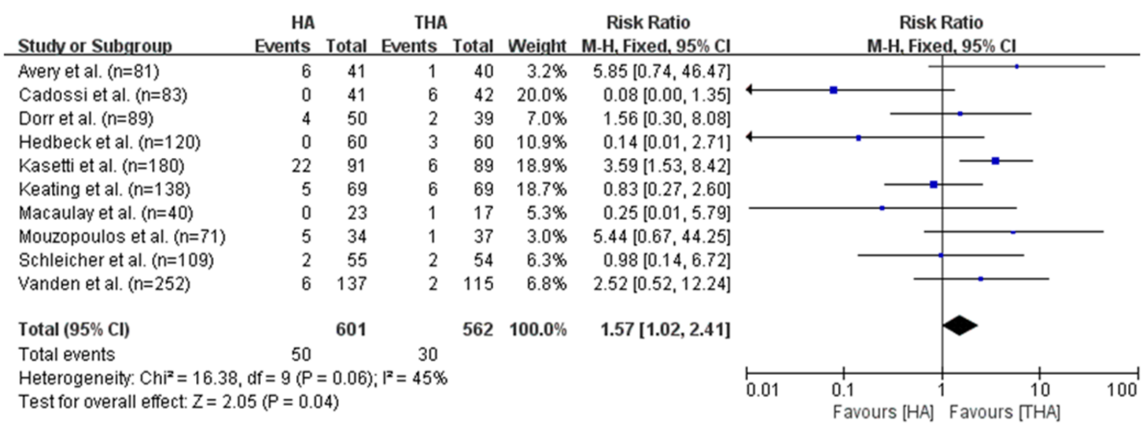

Figure 4. Revision. Forest plot comparing risk ratios of revision after hemiarthroplasty versus total hip arthroplasty in displaced femoral neck fractures in the healthy elderly. Mantel-Haenszel statistical method was used with the 'fixed-effects' analysis method for dichotomous data. M-H: Mantel-Haenszel, THA: total hip arthroplasty, HA: hemiarthroplasty.

found in the Begg's test (Begg's bias = 1.25, p = 0.21; **Figure 2**).

Characteristics and interventions

Table 2 lists the characteristics and interventions of the 14 trials. They were all prospective randomized controlled trials, among which five trials were multicenter prospective studies. A total of 1523 patients were included: 781 in the HA group and 742 in the THA group. The mean age was 77.7 years in the HA group and 77.8 years in the THA group. The majority of patients were female (female/male = 938/346). The surgical approach was recorded in 10 studies [11, 12, 20, 21, 23, 24, 26, 27, 29, 30]. The mean length of follow-up was more than 57.6 months. All trials had an acceptable dropout rate (< 20%).

Mortality

Nine reports [12, 20, 22-24, 27-29, 31] including a total of 1015 patients provided one-year mortality rates (**Table 3**), which ranged from 0 to 27.5% after HA and from 2.5% to 22.5% after THA. The 1-year mortality rate was 13.8% (72/521) in the HA group versus 12.7% (63/494) in the THA group. There was no evidence of heterogeneity (I^2 = 0%, P = 0.57). The pooled 1-year mortality data did not differ significantly between patients that had undergone

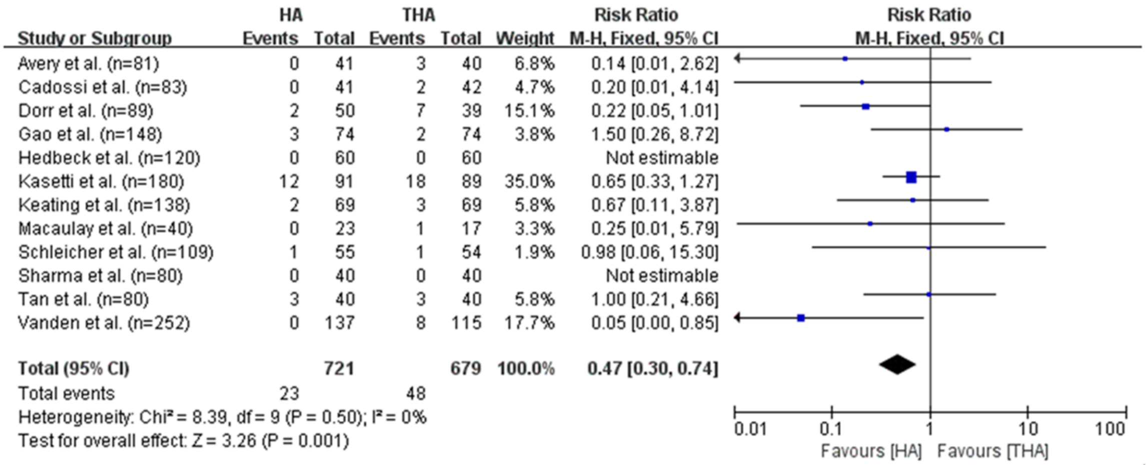

Figure 5. Dislocation. Forest plot comparing risk ratios of dislocation after hemiarthroplasty versus total hip arthroplasty in displaced femoral neck fractures in the healthy elderly. Mantel-Haenszel statistical method was used with the 'fixed-effects' analysis method for dichotomous data. M-H: Mantel-Haenszel, THA: total hip arthroplasty, HA: hemiarthroplasty.

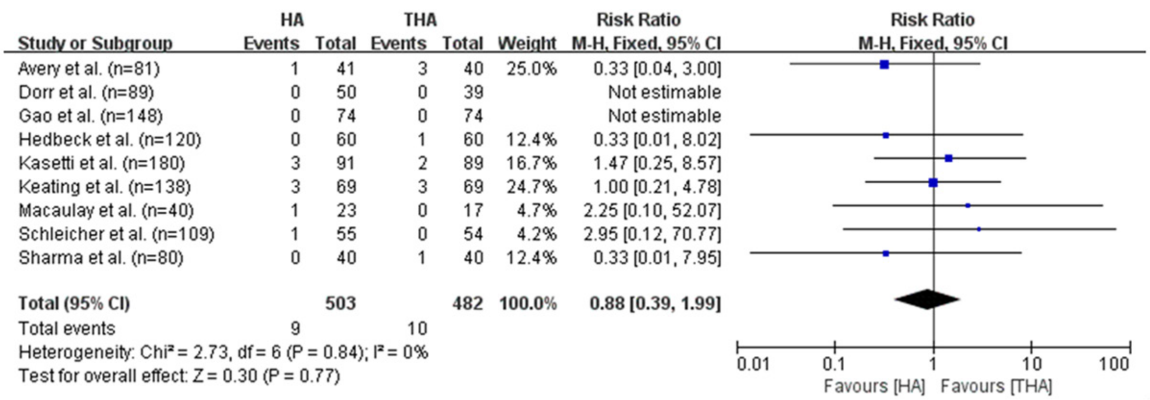

Figure 6. Infection. Forest plot comparing risk ratios of infection after hemiarthroplasty versus total hip arthroplasty in displaced femoral neck fractures in the healthy elderly. Mantel-Haenszel statistical method was used with the 'fixed-effects' analysis method for dichotomous data. M-H: Mantel-Haenszel, THA: total hip arthroplasty, HA: hemiarthroplasty.

HA or THA (RR = 1.08, 95% CI = 0.79-1.47, P = 0.63, **Figure 3**).

Revision

Ten reports [11, 12, 23, 24, 26-31] including a total of 1163 patients provided revision rates (**Table 3**), which ranged from 0 to 24.2% after HA and from 1.7% to 14.3% after THA. The revision rate was 8.3% (50/601) in the HA group versus 5.3% (30/563) in the THA group. There was little evidence of heterogeneity across the studies (I^2 = 45%, P = 0.06). There was a trend toward decreased revision after THA compared with that after HA (RR = 1.57, 95% CI = 1.02-2.41, P = 0.04; **Figure 4**).

Dislocation

Twelve [11, 12, 20-24, 26, 27, 29-31] of the included studies provided data on dislocation; two studies [20, 24] reported no cases of dislocation in either treatment group (**Table 3**). Another two studies [25, 28] did not report dislocation. The risk of dislocation was 3.2% (23/721) in the HA group versus 7.1% (48/679) in the THA group. There was no evidence of heterogeneity across the studies (I^2 = 0%, P =

Study or Subgroup	HA Mean	HA SD	HA Total	THA Mean	THA SD	THA Total	Weight	Mean Difference IV, Random, 95% CI
Cadossi et al. (n=83)	81	23.75	41	75.4	17.25	42	11.5%	5.60 [-3.35, 14.55]
Gao et al. (n=148)	125.3	22.5	74	158.6	32.7	74	11.5%	-33.30 [-42.34, -24.26]
Giannini et al. (n=52)	71.6	20	26	76.7	17.25	26	10.8%	-5.10 [-15.25, 5.05]
Hedbeck et al. (n=120)	78	22	60	102	20.25	60	12.4%	-24.00 [-31.57, -16.43]
Keating et al. (n=138)	58.5	21	69	79.7	26	69	12.2%	-21.20 [-29.09, -13.31]
Macaulay et al. (n=40)	82	35.1	23	89.1	35.8	17	5.2%	-7.10 [-29.36, 15.16]
Schleicher et al. (n=109)	72	27	55	84	51	54	7.9%	-12.00 [-27.36, 3.36]
Sharma et al. (n=80)	35	2.5	40	45	3.75	40	15.0%	-10.00 [-11.40, -8.60]
Tan et al. (n=80)	88.96	10.87	40	101.36	13.97	40	13.5%	-12.40 [-17.89, -6.91]
Total (95% CI)			**428**			**422**	**100.0%**	**-13.77 [-20.03, -7.52]**

Heterogeneity: Tau² = 67.42; Chi² = 57.97, df = 8 (P < 0.00001); I² = 86%

Test for overall effect: Z = 4.32 (P < 0.0001)

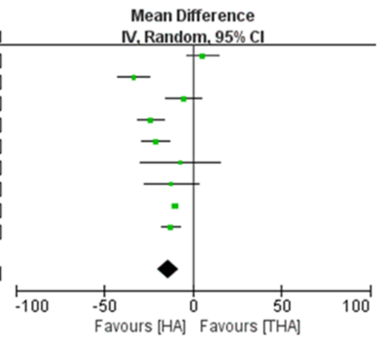

Figure 7. Operating time. Forest plot comparing risk ratios of total operating time after hemiarthroplasty versus total hip arthroplasty in displaced femoral neck fractures in the healthy elderly. Inverse variance statistical method was used with the 'random effects' analysis method for continuous data. IV inverse variance, THA total hip arthroplasty, HA hemiarthroplasty.

0.50). The pooled data indicated a significant risk of dislocation after treatment with THA for displaced FNF (RR = 0.47, 95% CI = 0.30-0.74, P = 0.001; **Figure 5**).

Infection

Infection, which was reported in nine studies [11, 12, 20, 21, 24, 26, 29-31] including a total of 985 patients (**Table 3**), developed in 0-4.3% of patients treated with HA and in 0-4.3% of those treated with THA. The risk of dislocation was 1.8% (9/503) in the HA group versus 2.1% (10/482) in the THA group. There was no evidence of heterogeneity across the studies (I^2 = 0%, P = 0.84). The risk of infection did not differ between HA and THA groups (RR = 0.88, 95% CI = 0.39-1.99, P = 0.77; **Figure 6**).

Blood loss and surgical time

Blood loss was estimated in eight studies [20-25, 27, 31] that included a total of 924 patients, and surgical time was reported in nine studies [20-23, 25, 27, 29-31] that included a total of 850 patients (**Table 3**). Patients that underwent THA had more blood loss than those treated with HA. However, because the values were in various formats, we could not calculate whether the difference was significant. The operating time for THA was longer than that for HA (WMD, 13.77 minutes; 95% CI, 7.52-20.03, P < 0.0001; **Figure 7**).

Functional outcome

The Harris Hip Score (HHS) ranges from 0-100 points and includes function, pain, deformity, and range of motion. Nine studies [20, 21, 23-25, 27-30] reported the HHS after 1-year follow-up (**Table 4**). A difference was observed in HHS total scores: patients treated with THA scored significantly higher than those treated with HA (WMD = 4.06; 95% CI = 0.68-7.43, P = 0.02; **Figure 8**).

Discussion

The primary findings of this meta-analysis were: relative to HA, THA substantially reduced the prevalence of surgical revision with very tight confidence intervals, suggesting that the reduction in relative risk is at least 50%. However, this benefit appears to come at the price of a substantially increased risk of dislocation, more surgical blood loss, and a longer operation time. THA and HA do not appear to differ with regard to their effects on the risk of infection and 1-year mortality, but patients in the THA group are more likely to have better hip function.

A recent meta-analysis by Zhao *et al.* [18] explored similar data, but we found major errors in their data extraction procedure. They recorded mean hospital days as mean blood loss in the study of Macaulay *et al.*, [18, 29], ignored dislocation and revision cases in the study of Cadossi *et al.*, [18, 23] and changed the HHS in HA and THA groups in the study of Cadossi *et al.* [18, 23]. These data represent the main outcomes to assess treatment, so errors in data extraction make the outcomes of this meta-analysis unreliable. Our study updated the previous review with an additional six studies, and included a total of 14 studies (1523 fractures) without language restriction,

Table 4. Summary of HHS in the studies

Author & Year	Method	Type	< 6 mo. (mo.)	1 year	2 year	3 year	4 year	5 year	> 5 year (year)
Sharma 2016	HHS	HA	N.R.	80	N.R.	N.R.	N.R.	N.R.	N.R.
		THA	N.R.	90	N.R.	N.R.	N.R.	N.R.	N.R.
Gao 2016	HHS	HA	N.R.	89.2	N.R.	N.R.	N.R.	N.R.	N.R.
		THA	N.R.	90.4	N.R.	N.R.	N.R.	N.R.	N.R.
Tan 2015	HHS	HA	91.2 (6)	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
		THA	92.1 (6)	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
Cadossi 2013	HHS	HA	72.3 (3)	74.7	75	78.7	N.R.	N.R.	N.R.
		THA	74 (3)	73.1	71.9	71.3	N.R.	N.R.	N.R.
Giannini 2011	HHS	HA	71.6 (3)	75.5	N.R.	N.R.	N.R.	N.R.	N.R.
		THA	74.5 (3)	80.7	N.R.	N.R.	N.R.	N.R.	N.R.
Hedbeck 2011	HHS	HA	77.5 (4)	79.4	77.9	75.2	N.R.	N.R.	N.R.
		THA	82.5 (4)	87.2	87.2	89	N.R.	N.R.	N.R.
Avery 2011	Oxford hip score	HA	N.R.	N.R.	N.R.	22.3	N.R.	N.R.	22.5 (9)
		THA	N.R.	N.R.	N.R.	18.8	N.R.	N.R.	23.1 (9)
Vanden 2010	HHS	HA	N.R.	73.9	N.R.	N.R.	N.R.	72	N.R.
		THA	N.R.	76	N.R.	N.R.	N.R.	75	N.R.
Mouzopoulos 2008	HHS	HA	N.R.	77.8	N.R.	N.R.	80	N.R.	N.R.
		THA	N.R.	81.6	N.R.	N.R.	84	N.R.	N.R.
Macaulay 2008	HHS	HA	77.1 (6)	80.6	81.1	N.R.	N.R.	N.R.	N.R.
		THA	76.1 (6)	84.2	84	N.R.	N.R.	N.R.	N.R.
Keating 2006	Hip Rating Questionnaire	HA	73.4 (4)	76.5	73.8	N.R.	N.R.	N.R.	N.R.
		THA	75.9 (4)	79.4	79.9	N.R.	N.R.	N.R.	N.R.
Schleicher 2003	Nach Melzer u. Sniezynski	HA	N.R.	62.5	N.R.	N.R.	N.R.	N.R.	50 (8)
		THA	N.R.	65	N.R.	N.R.	N.R.	N.R.	75 (8)
Kasetti 2000	HHS	HA	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	55 (13)
		THA	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	80 (13)
Dorr 1986	N.R.	HA	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
		THA	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

HA: hemiarthroplasty. THA: total hip arthroplasty. N.R. = not record. HHS: Harris hip score.

Study or Subgroup	HA Mean	HA SD	HA Total	THA Mean	THA SD	THA Total	Weight	Mean Difference IV, Random, 95% CI
Cadossi et al. (n=83)	74.7	10.5	33	73.1	14.3	36	9.7%	1.60 [-4.29, 7.49]
Gao et al. (n=148)	89.2	3.69	74	90.4	2.46	74	13.5%	-1.20 [-2.21, -0.19]
Giannini et al. (n=52)	75.5	9.33	26	80.7	9.33	26	10.5%	-5.20 [-10.27, -0.13]
Hedbeck et al. (n=120)	79.4	12.3	60	87.2	9.4	60	11.6%	-7.80 [-11.72, -3.88]
Keating et al. (n=138)	76.5	13	69	79.4	17	69	10.5%	-2.90 [-7.95, 2.15]
Macaulay et al. (n=40)	80.6	14.3	23	84.2	12	17	7.6%	-3.60 [-11.77, 4.57]
Mouzopoulos et al. (n=71)	77.81	9.6	34	81.6	4.9	37	11.9%	-3.79 [-7.38, -0.20]
Sharma et al. (n=80)	80	4.5	39	90	2	39	13.3%	-10.00 [-11.55, -8.45]
Vanden et al. (n=252)	73.9	19.25	137	76	14	115	11.4%	-2.10 [-6.22, 2.02]
Total (95% CI)			**495**			**473**	**100.0%**	**-4.06 [-7.43, -0.68]**

Heterogeneity: $Tau^2 = 21.66$; $Chi^2 = 95.56$, df = 8 ($P < 0.00001$); $I^2 = 92\%$
Test for overall effect: Z = 2.35 (P = 0.02)

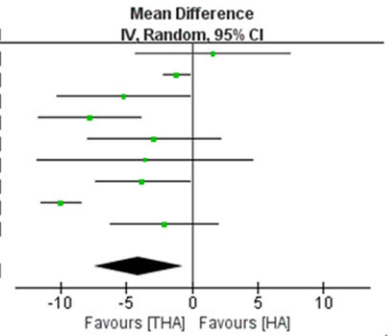

Figure 8. Harris hip score. Forest plot comparing risk ratios of total Harris hip score after hemiarthroplasty versus total hip arthroplasty in displaced femoral neck fractures in the healthy elderly. Inverse variance statistical method was used with the 'random effects' analysis method for continuous data. IV inverse variance, THA total hip arthroplasty, HA hemiarthroplasty.

so it is the most comprehensive evaluation of the available evidence to date. The 14 trials included in our study were all prospective, randomized control trials; regardless of the integrity and care with which they are conducted, randomized trials reduce the risk of bias by randomization, concealment of allocation, blinding, and complete follow-up.

The validity of our findings was further strengthened by strictly following the Cochrane Handbook for Systematic Reviews of Interventions 5.0.2 and the PRISMA 2015 checklist. We developed explicit eligibility criteria, thoroughly assessed the methodological quality of the studies, demonstrated the reproducibility of study selection and assessment criteria, performed quantitative analysis, explored possible reasons for differences in results between studies, and performed statistical analysis of the revision rate, 1-year mortality rate, dislocation rate, infection rate, operation duration, blood loss, and hip function postoperatively.

Despite these advantages of our review, some limitations should be acknowledged. First, we may have failed to identify all relevant randomized trials as a result of a publication bias against studies that did not demonstrate a significant difference in effect between two treatments. To counter this, we used Begg's test to investigate the potential influence of publication bias on our results. Second, the inclusion of prospective studies was inadequately randomized. Five trials included in our analysis were not randomized adequately; they generated randomization by alternation or hospital registration number (odd or even), which could lead to bias and reduce the level of evidence in our analysis. Third, several eligible trials had a short follow-up of 1 year. Although some studies indicated general complications and HHS within the first year, we feel that long-term follow-up would be more comprehensive and valuable to evaluate the effectiveness of arthroplasty after displaced FNF.

Recently, Paul *et al.* [17] performed a meta-analysis of eight studies including a total of 986 patients. They found that THA decreased the rate of revision but increased the rate of dislocation, and found no significant differences in mortality rate; but their estimates of function, pain, and quality of life were less clear. Hopley *et al.* [32] conducted an extensive analysis with four randomized, three quasi-randomized, and eight retrospective cohort studies, and concluded that patients treated with THA for displaced FNF may obtain better outcomes than those treated with HA. Nevertheless, they found that dislocation was more common with THA, which is consistent with our findings.

Dislocation is the major concern after primary THA for treatment of displaced FNF. Blomfeldt and Hedbeck *et al.* [24, 33] reported no dislocations in any patients in their research using an anterolateral approach. It is interesting to contrast this with other reports on primary THA in patients with FNF using the posterolateral approach, where the dislocation rate ranges from between 7-20% [11, 12, 26, 29, 34]. Two studies confirmed that dislocation is not a major problem when an appropriate surgical approach is used [35, 36]. Sharma *et al.* [20]

reported that placing the acetabular cup in about 20-25° anteversion, using short external rotators, and choosing a large head size [37] could circumvent dislocation.

The results of our analysis indicate that THA was associated with a longer operation time and greater number of hospital days, but it did not increase the number of general complications or the mortality rate. Conversely, THA significantly decreased the rates of revision and tended to yield better hip functional outcome scores compared with HA. Function improved with time after THA in some studies [12, 24, 28, 30, 31]. Ravikumar and Schleicher [12, 31] found that HHS remained stable in 75 and 80 patients treated with THA after 8 and 13 years of follow-up, respectively. Acetabular erosion following HA may explain the relatively poor hip function in HA patients [24, 26]. However, the revision rate for acetabular erosion after HA was low [26, 38]. Additionally, the rates of infection and mortality did not differ significantly between the two groups, similar to previous results [16, 17]. Patients in the HA group had shorter surgical times and less blood loss. HA may be sufficient for elderly patients with comorbidities.

Age appeared to be an important factor in the requirement for revision surgery. Kannan *et al.* [39] reviewed national registry data in Australia and Italy and found that the revision rate did not differ significantly in patients less than 75 years but was significantly lower after HA in those older than 75 years. Skoldenberg *et al.* [40] designed a randomized controlled trial comparing mortality, complications, reoperation, HHS, and quality of life after THA versus HA in patients aged ≥ 80 years with a displaced FNF over a study period of 10 years. In previous studies, the age groups were obscure, and we could not analyze the results in different age groups. Future studies should subdivide patients into age groups, i.e., < 70 years, 70-75 years, 75-80 years, and ≥ 80 years old, so that the respective outcomes can be assessed.

The results of our analysis indicate that, in comparison with HA, THA to treat displaced FNF significantly reduces the risk of revision surgery and tends toward better hip functional outcome score at the cost of greater dislocation rate, blood loss, and operation time. Dislocation could be circumvented in THA by using an anterolateral approach and choosing a large head size. HA is associated with reduced surgical time and less blood loss. HA may be sufficient for elderly patients with comorbidities. Future studies should assess the outcomes in different age groups.

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Disclosure of conflict of interest

None.

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