European Spine Journal (2024) 33:1001–1012
https://doi.org/10.1007/s00586-024-08133-9

REVIEW ARTICLE

Impact of prior spinal fusion surgery on complications and functional outcomes following total hip arthroplasty: an updated systematic review and meta-analysis

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Received: 13 November 2023 / Revised: 14 December 2023 / Accepted: 3 January 2024 / Published online: 24 January 2024

Abstract

Purpose This study aimed to compare the complication rates and functional outcomes between patients with and without a history of spinal fusion undergoing THA.

Methods A systematic search was conducted across PubMed, EMBASE, Scopus, and Cochrane databases. Studies that compared adults with and without a history of spinal fusion after primary THA were included. The methodological quality of the studies was evaluated using MINORS criteria. Meta-analyses were performed utilizing mean differences (MD), standardized mean differences (SMD), and odds ratios (OR), along with 95% confidence intervals (CI).

Results Seventeen studies involving 1,789,356 patients (31,786 in the SF group and 1,757,570 in the Non-SF group) were analyzed. The spinal fusion group exhibited significantly higher rates of dislocation (OR 2.50, 95% CI 1.78–3.52), periprosthetic fracture (OR 1.96, 95% CI 1.39–2.77), overall complications (OR 1.73, 95% CI 1.10–2.71), and revision rates (OR 1.86, 95% CI 1.74–1.99). Furthermore, within the first three months, there was an increased risk of dislocation (OR 4.38, 95% CI 1.36–14.14) and revisions (OR 3.87, 95% CI 1.63–9.18). Longer spinal fusions were significantly associated with a higher risk of dislocations (OR 0.62, 95% CI 0.53–0.71). Additionally, prior spinal fusion was linked to higher levels of pain (SMD 0.11, 95% CI 0.02–0.19) and poorer functional outcomes (MD − 0.09, 95% CI − 0.18 to − 0.00).

Conclusions Patients with a history of spinal fusion undergoing THA exhibit increased complication rates, higher levels of pain, and greater functional limitations than those without prior fusion. These findings have significant clinical implications for optimizing perioperative care in high-risk patient populations.

Keywords Total hip arthroplasty · Spinal fusion · Complications · Functional outcomes

Introduction

Total hip arthroplasty (THA) is one of the most common surgical procedures in older adults, with over 7 million Americans carrying a hip prosthesis and increasing rates [1]. Several studies have demonstrated that hip replacement surgery is highly cost-effective, making it a priority to explore strategies to maximize the cost-benefit ratio [2].

Simultaneously, spinal fusion surgeries represent the most frequent spinal interventions in adults, with increasing costs for healthcare systems [3, 4]. Many patients concurrently present with advanced hip osteoarthritis and degenerative spinal pathology, a condition known as hip-spine syndrome [5]. Chronic pain resulting from these conditions can overlap and complicate etiological diagnosis [6]. Furthermore, a bidirectional association has been established, in which low back pain can predict disability from hip osteoarthritis and vice versa [7, 8].

Approximately 2% of the patients undergoing THA have a history of spinal fusion [9]. While the aim of spinal surgery is to relieve pain and provide stability, the resulting rigid spine may alter relevant spinopelvic parameters for hip biomechanics [10]. Some reports indicate a higher risk of complications, such as dislocation, in THA with a fused spine, although with acceptable functional outcomes [11]. A previous meta-analysis examined this topic, but numerous studies have been published since then [12]. Additionally, this

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review could not analyze patient-reported functional variables, and there are several unanswered questions regarding the impact of the number of fused levels, time between surgeries, different follow-up durations among the analyzed studies, and risk factors for complications [13].

Given the high prevalence of this dual pathology, the associated high costs, and the need to clarify its effect on functional outcomes, an updated meta-analysis is justified to provide the best available evidence on the management of patients with prior spinal fusion undergoing THA. This study aimed to evaluate the impact of prior spinal fusion in terms of complications and functional outcomes after THA.

Materials and methods

Eligibility criteria

This meta-analysis had a protocol registered in PROSPERO () and followed PRISMA guidelines [14]. The search strategy followed the PICOS framework: (P) adult patients undergoing total hip arthroplasty; (I) the intervention group consisted of patients with a history of spinal fusion surgery; (C) the comparative group consisted of patients without a history of spinal fusion surgery; (O) the main outcomes were complications and functional outcomes; (S) comparative studies including cohort studies (prospective or retrospective) and case-control studies were included.

The exclusion criteria included studies that did not share variables, duplicate studies, studies with a high risk of bias, non-adult populations, and studies with incomplete data.

Information sources

A systematic search of the literature was conducted using PubMed, EMBASE, Scopus, and Cochrane Collaboration Library databases. No data limits are specified. Studies of interest found in the references of the included studies from the initial search were also evaluated. The references used in the meta-analysis by Onggo et al. [12] have also been updated.

Search methods for identification of studies

The search equation sought MeSH terms ("total hip arthroplasty" OR THA OR "total hip replacement" OR THR) AND ("spine fusion" OR spine arthrodesis" OR spine arthrodesis OR spine arthrodesis). Two reviewers independently agreed on the selection of eligible studies and reached a consensus on which studies to include. The records of these studies and their supplementary materials were also analyzed.

Data extraction and data items

Two authors independently reviewed the data extracted from the studies. If consensus was not reached, a third author was consulted to complete the data-extraction form. The baseline characteristics of the articles were collected, including study name, period, follow-up, region, study type, number of hips, number of females, and age. The main complications that could be compared were the incidence of revisions, dislocations, aseptic loosening, periprosthetic fractures, prosthetic infections, and overall complications. For functional outcomes, comparisons could be made using physical activity measures such as walking distance, pain assessed using VAS and WOMAC scales, and Harris Hip Score (HHS) and Oxford score. Other secondary variables that could be compared were the risk factors for revision in patients undergoing prosthesis fusion, such as sex and obesity.

Assessment of risk of bias in included studies

The methodological quality of the included studies was independently assessed by two reviewers using a standardized evaluation tool for non-randomized research designs (Table 1). The maximum attainable scores were 24 for comparative studies and 16 for noncomparative investigations. Quality ratings were assigned to non-comparative studies as follows: very low (0–4), low (5–7), fair (8–12), or high (13+). Comparative studies were rated as very low (0–6), low (7–10), fair (11–15), or high (16+) based on the reported design elements and risk of bias [15].

Assessment of results

Quantitative data from the included studies were pooled using random-effects meta-analyses and stratified by outcome measures and follow-up time points. Mean differences (MD) and 95% confidence intervals (CI) were estimated for continuous variables measured on the same scale. Standardized mean differences (SMD) were used to account for the different scales reported in disparate units. Odds ratios (OR) were calculated for the dichotomous variables. Heterogeneity was assessed using the I2 statistic, with values below 25%, 25–50%, and above 50% indicating low, moderate, and high heterogeneity, respectively. A fixed-effects model was used when no significant heterogeneity was observed. Incomplete data reporting across studies was addressed following methodological guidance from the Cochrane Handbook [16]. Review Manager 5.4 statistical software was used for all analyses.

Table 1 Assessment of the quality of studies through Methodological Index for Non-Randomized Studies (MINORS)

Study	Clearly stated aim	Con-secutive patients	Prospective collection data	Endpoints	Assess-ment endpoint	Follow-up period	Loss less than 5%	Study size	Adequate control group	Contempo-rary group	Baseline control	Statistical analyses	MINORS
Barry et al. 2016 [17]	2	2	0	2	1	2	0	2	1	2	0	2	16
Bedard et al. 2016 [18]	2	2	2	2	1	2	0	2	0	2	0	2	17
Buckland et al. 2017 [19]	2	2	0	2	1	2	2	2	0	2	0	2	17
Di Martino et al. 2021 [20]	2	2	0	2	2	2	2	2	2	2	1	2	21
Di Martino et al. 2023 [21]	2	2	0	2	2	2	2	2	2	2	1	2	21
Diebo et al. 2018 [22]	2	2	0	2	2	2	2	2	1	2	0	2	19
Eneqvist et al. 2018 [23]	2	0	0	2	2	2	2	2	2	2	2	2	20
Hinman et al. 2019 [11]	2	2	0	2	2	2	0	2	1	2	1	2	18
Klemt et al. 2021 [24]	2	2	0	2	2	2	2	2	2	2	2	2	22
Loh et al. 2017 [25]	2	0	0	2	2	2	2	2	2	2	2	2	20
Malkani et al. 2017 [10]	2	2	0	2	2	2	0	2	0	2	0	2	16
Perfetti et al. 2016 [26]	2	0	0	2	2	2	2	2	2	2	2	2	20
Pheasant et al. 2021 [27]	2	2	0	2	2	2	2	2	0	2	0	2	18
Salib et al. 2019 [28]	2	0	0	2	2	2	2	2	2	2	2	2	20
Sing et al. 2016 [9]	2	2	2	2	2	2	0	2	2	2	2	2	22
Welling et al. 2023 [29]	2	2	0	2	1	2	2	2	1	2	1	2	19
York et al. 2018 [30]	2	2	0	2	2	2	2	1	1	2	0	2	18

Risk of bias across the studies

Funnel plot analysis was conducted using Review Manager 5.4 software to assess potential reporting biases. Funnel plot asymmetry can suggest a publication bias arising from the non-publication of smaller studies with null or inconclusive findings.

Additional analyses

Subgroup analyses were performed based on follow-up time points, specifically at three months, one year, and the final follow-up (≥ 3 years). The influence of shorter or longer fusions was also analyzed, with most studies considering one to two levels as short fusions, except for one study that considered one to three levels as short fusions. In addition, when available, the influence of spinal fusion before or after total hip arthroplasty on the results was assessed.

Sensitivity analysis, which involved sequentially removing the largest contributing trial for each outcome and reanalyzing the data, was conducted using Review Manager 5.4 to assess the robustness of the results and evaluate the impact of excluding individual studies on the overall interpretations.

Results

Study selection

The initial search yielded 360 articles. After removing duplicates, non-adult population studies, studies unrelated to spinal fusion surgery, THA without prior SF, case reports, and reviews based on titles and abstracts, 314 studies were excluded, resulting in 46 articles. After reviewing the full texts of these 46 articles, 33 studies were excluded for not meeting the inclusion criteria, not sharing variables, having a high risk of bias, and incomplete or incomparable data. Ultimately, 13 studies were included in the analysis. Four additional studies were identified based on the references of the included studies. Ultimately, 17 studies were included in the meta-analysis [9–11, 17, 30] (Fig. 1).

Study characteristics

Table 2 presents the main characteristics of the included studies. Seventeen studies involving 1,789,356 patients were included (31,786 in the SF group and 1,757,570 in the Non-SF group). Thirteen of the 17 studies were published in the USA. Five studies were case-control studies, and 12 studies were retrospective in design. The number

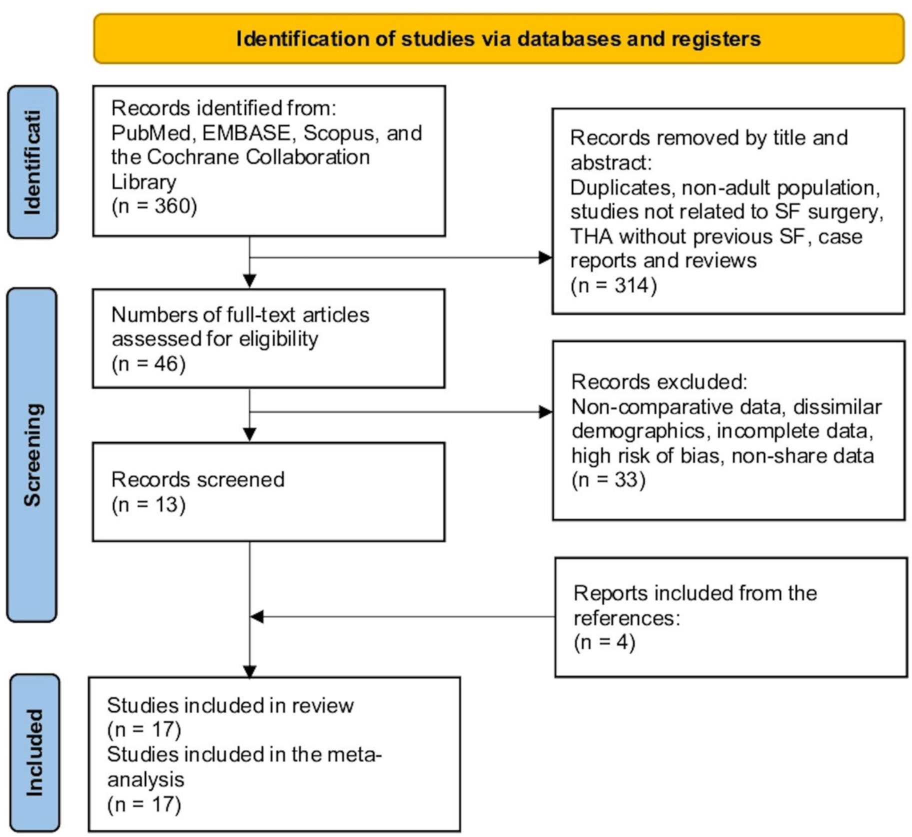

Fig. 1 PRISMA flow diagram depicting the study selection process

Table 2 Baseline characteristics of the included 17 studies

Study	Period	Study design	Region	N hips (SF/non-SF)	n female (SF/Non-SF)	Age (SF/non-SF)
Barry et al. 2016 [17]	2012 to 2015	Case-control	USA	105 (35/70)	(14/31)	68.5/68.4
Bedard et al. 2016 [18]	2004 to 2014	Retrospective cohort	USA	58,702 (48/58654)	NS/NS	NS/NS
Buckland et al. 2017 [19]	2005 to 2012	Retrospective cohort	USA	853,672 (14,668/839004)	(9638/515331)	NS/NS
Di Martino et al. 2021 [20]	2000 to 2017	Retrospective cohort	Italy	68,295 (376/67919)	(233/41363)	67.5/68.8
Di Martino et al. 2023 [21]	2000 to 2019	Retrospective cohort	Italy	78,787 (547/78240)	(206/30748)	68.0/68.8
Diebo et al. 2018 [22]	2009 to 2013	Retrospective cohort	USA	49,920 (711/49209)	(384/28049)	63/65
Eneqvist et al. 2018 [23]	2002 to 2012	Case-control	Sweden	1994 (997/997)	589/595	70.3/70.2
Hinman et al. 2019 [11]	2004 to 2008	Retrospective cohort	USA	11,416 (90/11326)	6656 (66/6590)	70.2/66.4
Klemt et al. 2021 [24]	NS	Retrospective cohort	USA	497 (192/305)	(95/124)	69.6/71.4
Loh et al. 2017 [25]	2006 to 2016	Case-control	Singapore	164 (82/82)	68/68	67.59/67.68
Malkani et al. 2017 [10]	2002 to 2014	Retrospective cohort	USA	62,387 (1809/60578)	NS/NS	NS/NS
Perfetti et al. 2016 [26]	2005 to 2012	Case-control	USA	1868 (934/934)	591/562	64.5/64.5
Pheasant et al. 2021 [27]	2006 to 2018	Retrospective cohort	USA	145 (67/78)	NS/NS	NS/NS
Salib et al. 2019 [28]	1998 to 2015	Case-control	USA	291 (97/194)	54/108	71.0/71.0
Sing et al. 2016 [9]	2005 to 2012	Retrospective cohort	USA	598,995 (9695/589300)	6412/364777	NS/NS
Welling et al. 2023 [29]	2012 to 2019	Retrospective cohort	USA	2090 (1429/661)	868/377	65.9/66.8
York et al. 2018 [30]	2010 to 2014	Retrospective cohort	USA	28 (9/19)	NS/NS	NS/NS

NS: Not specified

of females and their ages are shown in Table 2. Respecto al diagnóstico por el que se realize cirugía de fusion solo fue reportado en cinco estudios: Two studies included degenerative lumbar spinal stenosis with spondylolisthesis (24, 25), one study included central spinal stenosis with and without olisthesis (23), one study included degenerative disc disease (26), and one study included both deformity and disc herniation/myelopathy/stenosis or spondylolisthesis (11). The quality of the studies was high in all cases (Table 1).

Outcomes

Complications

The complications are listed in Table 3. Patients with SF had a significantly higher risk of dislocations (OR 2.50, 95% CI 1.78 to 3.52; participants = 1,776,891; studies = 16; I2 = 90%) (Fig. 2). When divided by follow-up periods, the risk of dislocation was higher at three months (OR 4.38, 95% CI 1.36 to 14.14; participants = 2220; studies = 2;

Table 3 Complications assessment

Effect size	n studies	n participants	Random effect model (OR 95% CI)	I^2 (%)	*P* value
Dislocations	16	1,776,891	OR 2.50, 95% CI 1.78 to 3.52	90%	< 0.00001
3-months dislocations	2	2220	*OR 4.38, 95% CI 1.36 to 14.14	0%	0.01
1-year dislocations	5	1,455,333	OR 2.64, 95% CI 1.48 to 4.71	95%	0.001
Final follow-up dislocations	9	319,338	OR 2.24, 95% CI 1.42 to 3.52	68%	0.0005
Revisions	10	1,590,070	OR 1.86, 95% CI 1.74 to 1.99	96%	< 0.00001
3-months revisions	10	1,590,070	OR 1.86, 95% CI 1.74 to 1.99	96%	0.002
1-year revisions	2	2220	*OR 3.87, 95% CI 1.63 to 9.18	0%	< 0.00001
Final follow-up revisions	3	1,454,787	OR 2.13, 95% CI 1.98 to 2.30	98%	0.02
Total complications	5	746,473	OR 1.73, 95% CI 1.10 to 2.71	79%	0.02
Periprosthetic fracture	5	740,537	OR 1.96, 95% CI 1.39 to 2.77	80%	0.0001
Aseptic loosening	6	808,832	OR 1.66, 95% CI 0.26 to 10.42	90%	0.59
Infection	4	141,443	*OR 1.02, 95% CI 0.84 to 1.25	38%	0.82

*: Fixed effec model

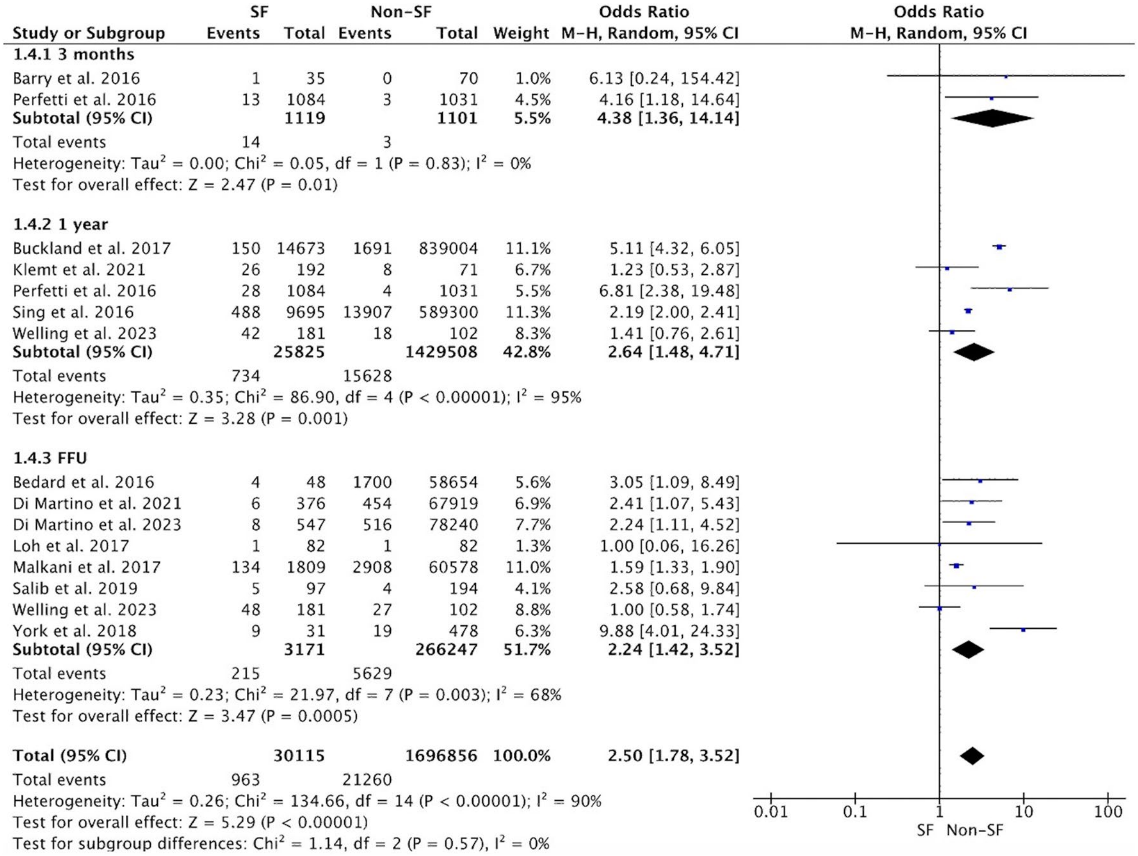

Fig. 2 Forest plot demonstrating a significantly higher risk of dislocation in patients with previous spinal fusion (SF). The risk of dislocation was greatest at 3 months, followed by 1 and 2 years

I2 = 0%), followed by one year (OR 2.64, 95% CI 1.48 to 4.71; participants = 1,455,333; studies = 5; I2 = 95%) and at the end of follow-up (OR 2.24, 95% CI 1.42 to 3.52; participants = 319,338; studies = 9; I2 = 68%). The sensitivity analysis maintained significant differences (OR 2.60, 95% CI 1.62 to 4.16; participants = 1,177,896; studies = 16; I2 = 90%).

Revisions were also significantly more frequent in the SF group (OR 1.86, 95% CI 1.74 to 1.99; participants = 1,590,070; studies = 10; I2 = 96%) (Fig. 3). When divided by follow-up time, there was a higher risk of revisions at three months (OR 3.87, 95% CI 1.63 to 9.18; participants = 2220; studies = 2; I2 = 0%), followed by one year (OR 2.13, 95% CI 1.98 to 2.30; participants = 1,454,787; studies = 3; I2 = 98%), and at the end of follow-up (OR 1.20, 95% CI, 1.03 to 1.40; participants = 133,063; studies = 5; I2 = 82%). Sensitivity analysis was consistent and maintained the same direction of results (OR 1.92, 95% CI 1.72 to 2.16; participants = 991,075; studies = 10; I2 = 96%).

Complications were also significantly more frequent in the SF group (OR 1.73, 95% CI 1.10 to 2.71; participants = 746,473; studies = 5; I2 = 79%). The incidence of periprosthetic fractures was also significantly higher in the SF group (OR 1.96, 95% CI 1.39 to 2.77; participants, 740,537; studies, 5; I2 = 80%). Sensitivity analysis showed a significantly higher risk in patients with SF (OR 1.68, 95% CI 1.25 to 2.26; participants = 678,150; studies = 5; I2 = 19%). There were no differences regarding aseptic loosening (OR 1.66, 95% CI 0.26 to 10.42; participants = 808,832; studies = 6; I2 = 99%), and sensitivity analysis did not show significant differences (OR 1.12, 95% CI 0.85 to 1.46; participants = 209,837; studies = 6; I2 = 21%). There were no significant differences in infection between the two groups (OR 1.02, 95% CI 0.84 to 1.25; participants = 141,443; studies = 4; I2 = 38%), and sensitivity analysis also did not show significant differences (OR 2.37, 95% CI 0.86 to 6.53; participants = 79,056; studies = 4; I2 = 58%).

PROMs

Functional outcomes

Functional outcomes are shown in Table 4. Regarding functional outcomes, patients with previous SF showed significantly more pain (SMD 0.11, 95% CI 0.02 to 0.19;

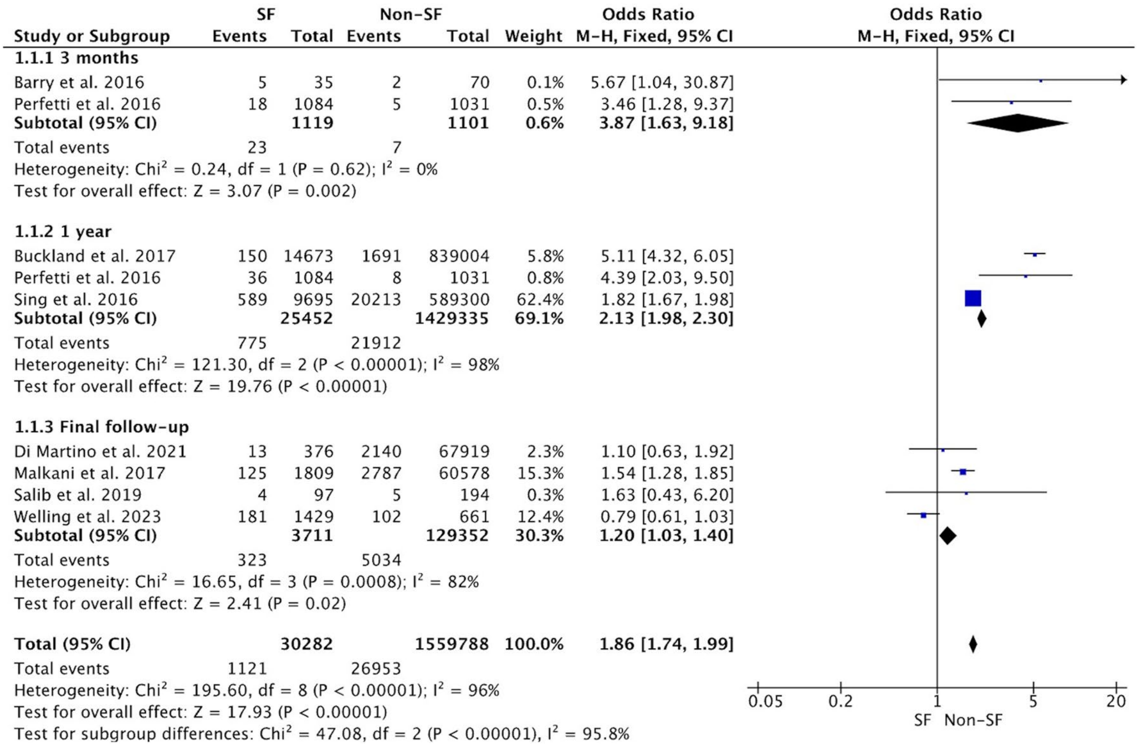

Fig. 3 A forest plot showing that patients with previous SF had a higher risk of revision. The risk of revision was greatest at 3 months, followed by 1 and 2 years

Table 4 Functional outcomes

Effect size	n studies	n participants	Fixed effect model (MD/SMD 95% CI)	I^2 (%)	*P* value
Pain	3	2262	SMD 0.11, 95% CI 0.02 to 0.19	0%	0.01
Functionality	3	2449	MD − 0.09, 95% CI − 0.18 to − 0.00	0%	0.04
Physical activity (walking distance)	2	11,521	SMD − 0.02, 95% CI − 0.21 to 0.16	0%	0.82

participants = 2262; studies = 3; I2 = 0%) (Fig. 4a) and worse functionality (MD − 0.09, 95% CI − 0.18 to − 0.00; participants = 2449; studies = 3; I2 = 0%) (Fig. 4b). Although sensitivity analysis did not show significant differences, only three studies were evaluated (SMD 0.22, 95% CI − 0.03 to 0.46; participants = 268; studies = 3; I2 = 0%) and (MD − 6.74, 95% CI − 20.67 to 7.18; participants = 455; studies = 3; I2 = 0%) respectively. Finally, there were no differences with respect to physical activity by walking distance (SMD − 0.02, 95% CI -0.21 to 0.16; participants = 11,521; studies = 2; I2 = 0%) (Fig. 4c).

Additional analyses

Regarding dislocations, the analysis demonstrated the influence of short or long fusions, with long fusions showing a significantly higher risk of dislocations (OR 0.62, 95% CI 0.53 to 0.71; participants = 25,107; studies = 4; I2 = 41%) (Fig. 5a). In the revisions, the influence of SF before or after THA was compared, and no significant differences were observed between the groups (OR 0.82, 95% CI 0.64 to 1.06; participants = 2769; studies = 3; I2 = 0%) (Fig. 5b).

Publication bias was assessed using funnel plots, which revealed heterogeneity and publication bias in all complication outcomes including dislocation, revisions, total complications, periprosthetic fracture, and aseptic loosening, except for infection (Fig. 6).

Discussion

This meta-analysis demonstrated that patients undergoing total hip arthroplasty (THA) with a history of lumbar spinal fusion (SF) had a significantly increased rate of reoperations

a) VAS / WOMAC pain

Study or Subgroup	SF Mean	SF SD	SF Total	Non-SF Mean	Non-SF SD	Non-SF Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Barry et al. 2016	3.05	2.45	34	2.7	1.9	70	4.1%	0.17 [−0.24, 0.58]
Eneqvist et al. 2018	20.4	46.7	997	16.1	46.7	997	88.7%	0.09 [0.00, 0.18]
Loh et al. 2017	84.52	39	82	74.94	39	82	7.2%	0.24 [−0.06, 0.55]
Total (95% CI)			**1113**			**1149**	**100.0%**	**0.11 [0.02, 0.19]**

Heterogeneity: $Chi^2 = 0.96$, df = 2 (P = 0.62); $I^2 = 0\%$
Test for overall effect: Z = 2.51 (P = 0.01)

b) HHS / Oxford Score

Study or Subgroup	SF Mean	SF SD	SF Total	Non-SF Mean	Non-SF SD	Non-SF Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Eneqvist et al. 2018	0.66	1	997	0.75	1	997	82.5%	−0.09 [−0.18, −0.00]
Loh et al. 2017	76.74	46.5	82	83.65	46.5	82	6.8%	−0.15 [−0.45, 0.16]
Salib et al. 2019	81	262.9691	97	84	303.6612	194	10.7%	−0.01 [−0.25, 0.23]
Total (95% CI)			**1176**			**1273**	**100.0%**	**−0.09 [−0.17, −0.01]**

Heterogeneity: $Chi^2 = 0.53$, df = 2 (P = 0.77); $I^2 = 0\%$
Test for overall effect: Z = 2.10 (P = 0.04)

c) Physical activity / Walking distance

Study or Subgroup	SF Mean	SF SD	SF Total	Non-SF Mean	Non-SF SD	Non-SF Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Barry et al. 2016	114	116.6	35	133.7	175	70	20.7%	−0.12 [−0.53, 0.28]
Hinman et al. 2019	45	405.8326	90	28	3,800.5094	11326	79.3%	0.00 [−0.20, 0.21]
Total (95% CI)			**125**			**11396**	**100.0%**	**−0.02 [−0.21, 0.16]**

Heterogeneity: $Chi^2 = 0.30$, df = 1 (P = 0.58); $I^2 = 0\%$
Test for overall effect: Z = 0.23 (P = 0.82)

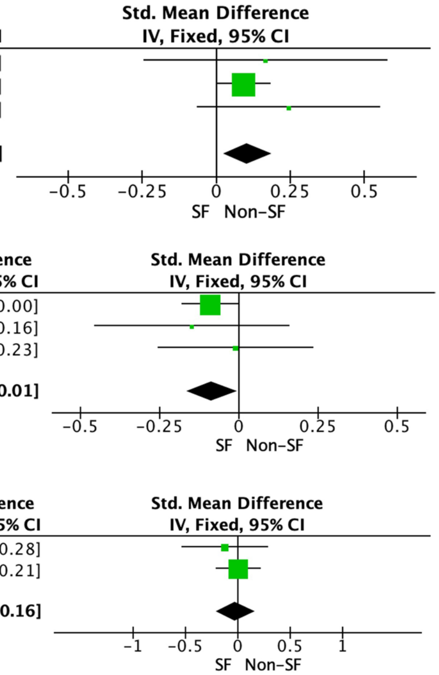

Fig. 4 **a** Forest plot demonstrating significantly greater pain in patients with previous SF, as measured by VAS and WOMAC pain scales; **b** forest plot showing significantly poorer function in patients with previous SF, as measured by HHS and Oxford scores; **c** forest plot showing no significant differences in physical activity and walking distance variables

a) Fusion levels

Study or Subgroup	Short fusion Events	Short fusion Total	Long fusion Events	Long fusion Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Buckland et al. 2017	357	12079	107	2594	40.1%	0.71 [0.57, 0.88]
Diebo et al. 2018	0	478	0	233		Not estimable
Sing et al. 2016	315	7392	173	2303	59.3%	0.55 [0.45, 0.66]
York et al. 2018	3	9	6	19	0.6%	1.08 [0.20, 5.87]
Total (95% CI)		**19958**		**5149**	**100.0%**	**0.62 [0.53, 0.71]**
Total events	675		286			

Heterogeneity: $Chi^2 = 3.39$, df = 2 (P = 0.18); $I^2 = 41\%$
Test for overall effect: Z = 6.63 (P < 0.00001)

b) SF 1st vs THA 1st

Study or Subgroup	SF-THA Events	SF-THA Total	THA-SF Events	THA-SF Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Di Martino et al. 2021	13	376	9	303	7.3%	1.17 [0.49, 2.77]
Welling et al. 2023	181	1429	102	661	92.7%	0.79 [0.61, 1.03]
Total (95% CI)		**1805**		**964**	**100.0%**	**0.82 [0.64, 1.06]**
Total events	194		111			

Heterogeneity: $Chi^2 = 0.70$, df = 1 (P = 0.40); $I^2 = 0\%$
Test for overall effect: Z = 1.53 (P = 0.13)

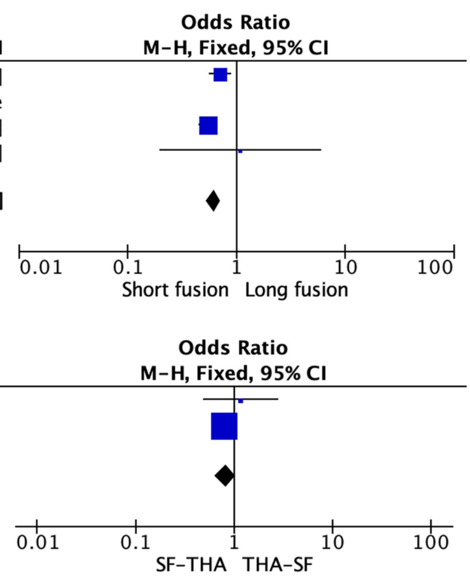

Fig. 5 **a** Forest plot indicating longer fusions presented a significantly higher risk of dislocation than shorter fusions; **b** forest plot showing no differences in the timing of SF versus THA

and dislocations compared with patients without previous SF. Specifically, the risk of these complications was particularly high during the first 3 months after surgery. In addition, the SF group exhibited a statistically significant increase in the incidence of periprosthetic fractures and overall complications. Beyond mechanical complications, these patients reported significantly worse scores on validated scales for chronic pain and functional disability at the end of follow-up than patients without a history of SF undergoing primary THA.

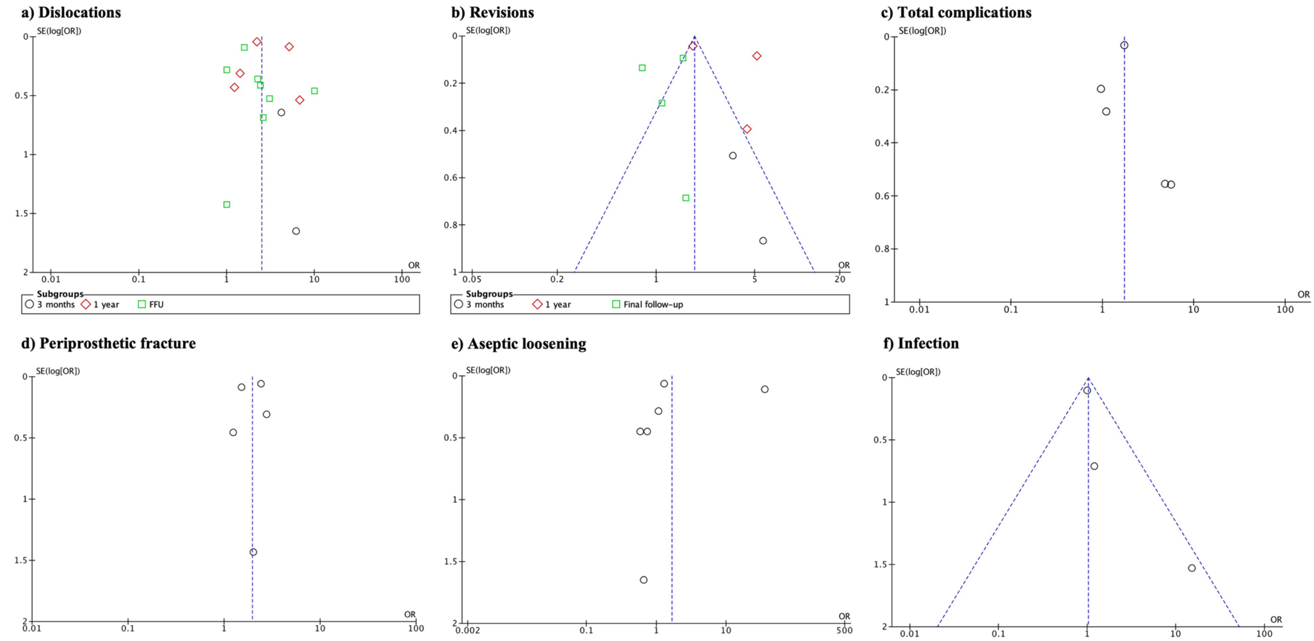

Fig. 6 Funnel plots demonstrating evidence of publication bias for the effect sizes of dislocations, revisions, total complications, periprosthetic fracture, and aseptic loosening. No bias was observed during infection

Several hypotheses could explain the increased rates of instability and early mechanical failure after hip arthroplasty in patients with previous SF. One possibility is that spinal column stiffness and alignment abnormalities make it difficult to achieve optimal orientation of the acetabular and femoral components during surgery, leading to suboptimal or inadequate positioning [31]. The ankylosed lumbar spine due to multiple fusions could limit the surgeon's ability to place the prosthesis at the ideal angles described in the literature (e.g., acetabular abduction and anteversion), necessitating specific strategies and approaches for these complex cases.

Another theory is based on the transfer of increased biomechanical stress to adjacent non-fused lumbar segments through rigid instrumentation of multiple lumbar segments, particularly at the lumbosacral junction. This phenomenon has been described in the literature as “adjacent segment disease” [31]. Similarly, SF alters the load distribution and mobility of the spine, thereby increasing the demand for the remaining spinal structures. When a hip prosthesis is implanted, restoring mobility of the hip joint, the rigid lumbar spine is subjected to new forces and ranges that can destabilize the arthroplasty, favoring aseptic loosening or prosthetic dislocation.

The higher rate of mechanical complications in patients with previous SF is consistent with that reported for other conditions associated with spinal stiffness, such as ankylosing spondylitis [32]. Under these conditions, an increased risk of dislocation, aseptic loosening, intraoperative fractures, and the need for spinal re-fusion after total hip arthroplasty has also been observed [32]. Therefore, in patients with previous SF undergoing THA, prophylactic measures should be maximized during the procedure and postoperative period to minimize the risk of implant failure.

To reduce complications in this complex group, one possible strategy would be to optimize preoperative planning and utilize available imaging techniques to accurately guide the placement of prosthetic components and ensure appropriate ranges of motion. Although studies are heterogeneous, three-dimensional preoperative planning has demonstrated greater accuracy in implant placement than standard methods in several studies [33]. While the impact on functional outcomes is controversial, improving positioning precision could at least decrease legal liability in the event of complications.

Robotic surgery is another promising technology for maximizing correct implant orientation [34]. Although its adoption is still limited and there are debates about its real cost-effectiveness, recent meta-analyses have described a lower rate of early complications and better component positioning within safe ranges in robotic surgeries than in conventional procedures [34]. Even in specific subgroups, such as patients with ankylosing spondylitis, severe acetabular dysplasia, or fracture arthroplasty, robotic platforms proved useful for guiding implants in these challenging situations [35]. One potential avenue suggested by these results is the development of new implants tailored specifically for allergic patients. Another explanation could be that this patient population has different normal ranges of motion compared to the thresholds proposed by Lewinnek et al. [36]. Additionally, Malkani et al. [10] emphasize considering not just the fusion level but the underlying spinal pathology or deformity [10]. The type of surgery performed is also relevant, as Sing et al. [9] established greater risk of dislocation with fusions of more than three levels, consistent with our meta-analysis finding lower dislocation rates in shorter fusions [9].

Another controversial aspect in patients with previous spinal fusion is determining the optimal timing for total hip arthroplasty in relation to the time elapsed since lumbar instrumentation. Unfortunately, in this meta-analysis, it was not possible to consistently analyze the influence of the interval between surgeries because the vast majority of studies did not provide data divided into subgroups according to that interval. An exception was the study by Klemt et al. [24], who categorized patients based on the time between spinal fusion and total hip arthroplasty, finding that a longer interval between procedures was associated with a lower rate of observed complications [24]. They also described fewer complications when total hip arthroplasty was performed prior to lumbar instrumentation compared to the reverse order [24]. However, in the subgroup analysis of this meta-analysis, no significant differences were found between performing one surgery and the other. Therefore, there is no consensus regarding the optimal timing of surgical intervention in these patients. The general trend indicates that allowing a longer interval between spinal fusion and total hip arthroplasty is associated with fewer complications; however, the ideal time cutoff is not well defined [37]. There is also no agreement on which procedure should be performed first when both surgeries are necessary. Welling et al. [29] analyzed a large American database and found that the sequential order of surgeries did not influence the dislocation rate, even in revision procedures [29]. Further prospective studies stratified by the time between surgeries are required to clarify these aspects.

This is the first meta-analysis to statistically compare functional outcomes between patients with and without previous spinal fusion. Previous studies have shown that, on average, patients undergoing total hip or knee arthroplasty report slightly lower functionality than healthy control subjects [38]. In this meta-analysis, pooled analyses showed that those with previous lumbar instrumentation had significantly higher residual pain and worse functional scores post-surgery than those without previous spinal fusion. Another potential explanation for the increased pain in those with prior fusion is that this group may have been taking more opioids, which has been associated with poorer surgical outcomes, as reported by Jain et al. [39]. Reduced range of motion in this population, linked to decreased quality of life according to Sadler et al. [40], could also account for compromised function or pain levels postoperatively [40].

These findings have implications for preoperative counseling and establishment of realistic expectations in these patients. Traditionally, total hip has been considered a highly effective procedure for relieving pain and improving functionality in patients with advanced osteoarthritis. However, in the presence of complicating factors, such as previous spinal fusion, it is reasonable to expect a more modest recovery and functional improvement compared to uncomplicated primary cases. Open communication about the probabilities of complications and functional outcomes will optimize patient satisfaction [41].

Another relevant factor in these cases is the discrepancy in leg length [42]. Although analyses could not be performed because only one study reported this, this study reported a higher incidence of leg length inequality in patients with previous lumbar instrumentation [27]. This asymmetry, even mild, is often more symptomatic in the presence of rigid spines owing to limited pelvic compensation ability [27]. Physiological rotation of the pelvis to the level leg discrepancy is restricted after spinal fusion [43]. Therefore, optimizing leg equalization through meticulous preoperative planning is particularly important for these patients.

The limitations of this study are as follows. Most studies were retrospective in nature, which can introduce bias and limitations in data collection. Although the number of included studies was adequate, some variables had a small number of available studies, which may affect the generalizability of the results. Additionally, estimations were required to complete the missing baseline and functional outcome scale improvement data using the Cochrane calculator. Weilling et al. compared dislocations and revisions between the SF-THA and THA-SF groups, which could have introduced selection bias. Pheasant et al. included patients with limb length discrepancy (LLD), which may act as a confounding factor, although it was considered to affect both the groups similarly. Despite these isolated limitations in some studies, sensitivity analysis accounting for them revealed no significant differences when these studies were excluded from each analysis. In addition, there was a lack of specificity regarding the exact spinal levels that were fused. While the studies adequately described whether the fusion constructs were long or short (and thus included in the analysis), the precise region was not reported. Therefore, it cannot be determined whether some fusions include the lumbosacral junction. Only one study by Barry et al. specified this detail, finding that 70.6% of spinal fusions involved the S1 vertebra or the pelvis [17]. There has also been no consistent report on the etiology of the need for previous spinal fusion surgery. Only 5 of the 23 included studies specifically described the underlying pathology or reason for spinal fusion was originally performed. Additionally, the total complications reported in studies may not be fully representative and could include select complications, which may impact the interpretation of the results. Future studies should seek to standardize functional scales to facilitate comparison and analysis of outcomes. This work highlights the importance of recognizing, following the concepts developed by Jean Dubouset on the ' C cone of economy, in which the pelvis acts as a key link between the lower joints and the spine (Dubouset, 1980) [44]. When planning a spinal fusion it is necessary to carefully consider the balance throughout this chain of joints, from the feet to the head, in order to minimise subsequent mechanical compensations.

Conclusions

In conclusion, this systematic review and meta-analysis indicated that patients with prior spinal fusion undergoing THA showed greater risks of dislocation, periprosthetic fracture, reoperation, and overall complications than those without a history of spinal fusion. The risk of dislocation was the highest at three months post-operatively and for longer versus shorter fusions. Although no differences emerged for aseptic loosening or infection, patients with prior spinal fusion demonstrated significantly worse pain and functional outcomes. The clinical implications of increased risk of adverse events and inferior functional outcomes in patients with prior spinal fusion undergoing THA suggest that such patients may benefit from elevated risk stratification and optimized preoperative evaluation using advanced techniques and postoperative rehabilitation. Functional variations warrant a more comprehensive investigation given the reporting limitations. Future studies should employ a standardized, prospective collection of patient characteristics, surgical details, and outcome measures to clarify relationships more rigorously.

Funding No funding was received.

Declarations

Conflict of interest The authors have no relevant financial or nonfinancial interests to disclose.

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