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REVIEW

The impact of surgical approach in total hip arthroplasty on the organisms profile of periprosthetic joint infections? A systematic review and meta-analysis

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Abstract

Purpose To investigate the impact of the surgical approach in total hip arthroplasty (THA) on the organism profile associated with periprosthetic joint infections (PJI).

Methods This systematic review and meta-analysis rigorously followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses. Four online databases (Medline, Embase, Web of Science, Scopus) were searched from inception till the 2nd of Sep 2023. The focus was all articles reporting the organism profile of hip periprosthetic joint infections in relation to the utilized surgical approach. Exclusion criteria encompassed studies lacking infecting organism specification by surgical approach, technical studies, review articles, case reports, non-English articles and inaccessible full-text articles. Quality assessment was done utilizing the Methodological Index for Non-Randomized Studies (MINORS) criteria.

Results A total of 529 microorganism profiles associated with 285 PJIs were analyzed from 11 studies including 44,271 THA patients. The overall rate of PJI in THA noted in the included studies is 0.64%. No significant difference between the direct anterior approach (DAA) and THA other approaches was noted in the incidence of PJI (OR 1.06, 95% CI [0.67, 1.67], $p=0.92$). Similarly, no significant difference between the DAA and other THA approaches was noted in the incidence of gram-negative pathogen induced PJI (OR 3.35, 95% CI [0.49, 22.88], $p=0.22$).

Conclusion The overall rate of PJI in THA remain low. Utilization of DAA does not increase the risk of PJI compared to other approaches. Further, DAA does not increase the incidence of gram-negative pathogen induced PJI in THA. However, the available evidence on the organism profile based on the surgical approach is limited, and further studies are needed to make robust conclusions.

Keywords Periprosthetic joint infection · Total hip arthroplasty · Surgical approach

Introduction

Total hip arthroplasty (THA) is a transformative procedure that significantly enhances the quality of life for individuals suffering from degenerative hip joint diseases such as osteoarthritis, and rheumatoid arthritis [1]. Despite the success and rising incidence of THA, prosthetic joint infection (PJI) remains one of the most severe complications, occurring in approximately 0.5-3% of cases [2]. PJI not only compromises the outcomes of THA but also necessitates complex and costly treatments, and thus remains a critical focus of orthopedic research [3–9].

The microbial profile of PJI varies, influenced by numerous factors including the surgical environment, antibiotic prophylaxis, and the patient's own microbiota [10, 11]. However, the approach to THA might also play a crucial role in the pattern and prevalence of these infections [12]. Different surgical approaches can alter the exposure and susceptibility of the surgical site to various microorganisms, potentially affecting the incidence and nature of PJIs.

Extended author information available on the last page of the article

Two primary theories have been proposed to explain the spread of microorganisms that lead to PJI: hematogenous spread and direct inoculation. hematogenous spread suggests that microorganisms can enter the bloodstream and subsequently localize at the site of the prosthetic joint, often triggered by transient bacteremia due to dental procedures, urinary tract infections, or other remote infections [13–14]. On the other hand, direct inoculation posits that microorganisms are introduced directly into the joint at the time of surgery or through subsequent surgical interventions or trauma [15].

This meta-analysis aims to explore how different THA approaches may influence the microorganism profile of resultant PJI. By synthesizing data from various studies, we seek to discern patterns that may suggest a correlation between the surgical approach to THA and specific infection risks, which could significantly impact surgical planning and postoperative management strategies. This study not only aims to enhance our understanding of PJI in the context of THA but also to contribute to the development of more effective preventive and therapeutic measures against these challenging infections.

Methods

This systematic review and meta-analysis was conducted with strict adherence to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [16]. The focus was studies that reported the organism profile of the hip periprosthetic joint infection based on the surgical approach.

Search strategy

Four online databases (Medline, Embase, Web of Science, Scopus) were searched from inception till the 2nd Sep 2023 to identify all the articles eligible for screening. Additionally, the references of the eligible studies were checked to ensure capturing all related articles. Broad search terms were used including “total hip arthroplasty” OR “total hip replacement” OR THA OR THR AND “periprosthetic joint infection” OR PJI OR “Prosthesis related infections” AND approach*.

Study screening

Two reviewers performed screening process of the retrieved articles blindly and independently starting with title and abstract screening and then full-text screening for the eligible articles. Any conflict between the two reviewers was solved with discussion with a senior author.

Eligibility criteria

All articles reporting the organism profile of hip periprosthetic joint infection were included if they met the below-mentioned criteria:

1. Reporting the infecting organism in THA.
2. Specifying the organism according to the surgical approach.
3. English language.

Exclusion criteria

Studies that did not specify the organisms according to the surgical approach were excluded. Additionally, technical studies, review articles, case reports and inaccessible full-text articles were excluded.

Data abstraction

Two authors independently and blindly extracted and summarized data from eligible articles. Data was cross-checked to ensure accuracy. The following data items were collected: studies characteristics (authors, year and design), patients demographics (patient age, gender, BMI, ASA), PJI diagnosis criteria, surgical approach, infecting organism, complications and reoperations.

Quality assessment

Quality assessment was done utilizing the Methodological Index for Non-Randomized Studies (MINORS) criteria [17]. Based on these criteria, maximum scores of 16 and 24 can be given to non-comparative and comparative, respectively. A score of 0–4 was deemed to reflect very low-quality evidence, while scores 5–7, 8–12 and ≥ 13 were considered low quality, fair quality and high-quality evidence, respectively [18]. On the other hand, comparative studies were classified into very low quality (0–6), low quality (7–10), fair quality (11–15), good quality (16–20) and high quality (≥ 20) [18]. The process of quality assessment was done by two authors independently and their work was cross-checked. Any discrepancy was solved with discussion with a senior author.

Statistical analysis

The meta-analysis of the pooled data was conducted using Stata software Version 17. The odds ratio (OR) was utilized with 95% Confidence Interval (CI) for dichotomous variables. The heterogeneity of the pooled data was evaluated using I^2 statistics [19]. If $I^2 < 50\%$ and $p > 0.1$, a fixed-effects model was employed in meta-analysis. On the other hand,

if $I^2 > 50\%$ and $p < 0.1$, random-effects model was utilized. Publication bias was evaluated with funnel plots. Further, subgroup and sensitivity analyses were performed to examine the causes of heterogeneity. A p-value of less than 0.05 was considered significant.

Results

Search results

A total of 918 studies were imported into Covidence, and after the removal of 448 duplicates, 470 studies remained for title and abstract screening. Subsequently, 101 studies underwent full-text eligibility assessment, resulting in the exclusion of 90 studies. Ultimately, 11 studies met the inclusion/exclusion criteria and were included in this review (Fig. 1). Comparative data between the approaches were found in 5/10 studies and they were included in the meta-analysis (See Figs. 2 and 3)).

Study characteristics

Among the included studies, seven studies mentioned the criteria used to diagnose PJI. However, it was noted that there was a significant variability in the criteria employed among those seven studies. The criteria utilized in those studies include American Academy Orthopaedic Surgery (AAOS) criteria, Musculoskeletal Infection Society (MSIS) criteria, Infectious Diseases Society of America (IDSA) criteria, National Healthcare Safety Network (NHSN) criteria, International Consensus Meeting (ICM) criteria, and levels of C-reactive protein (CRP).

A total of 529 microorganism profiles associated with PJIs were analyzed in this review. While monomicrobial PJI was noted in all studies that analyzed the microbial spectrum of PJI, polymicrobial PJI was noted in two studies. 145

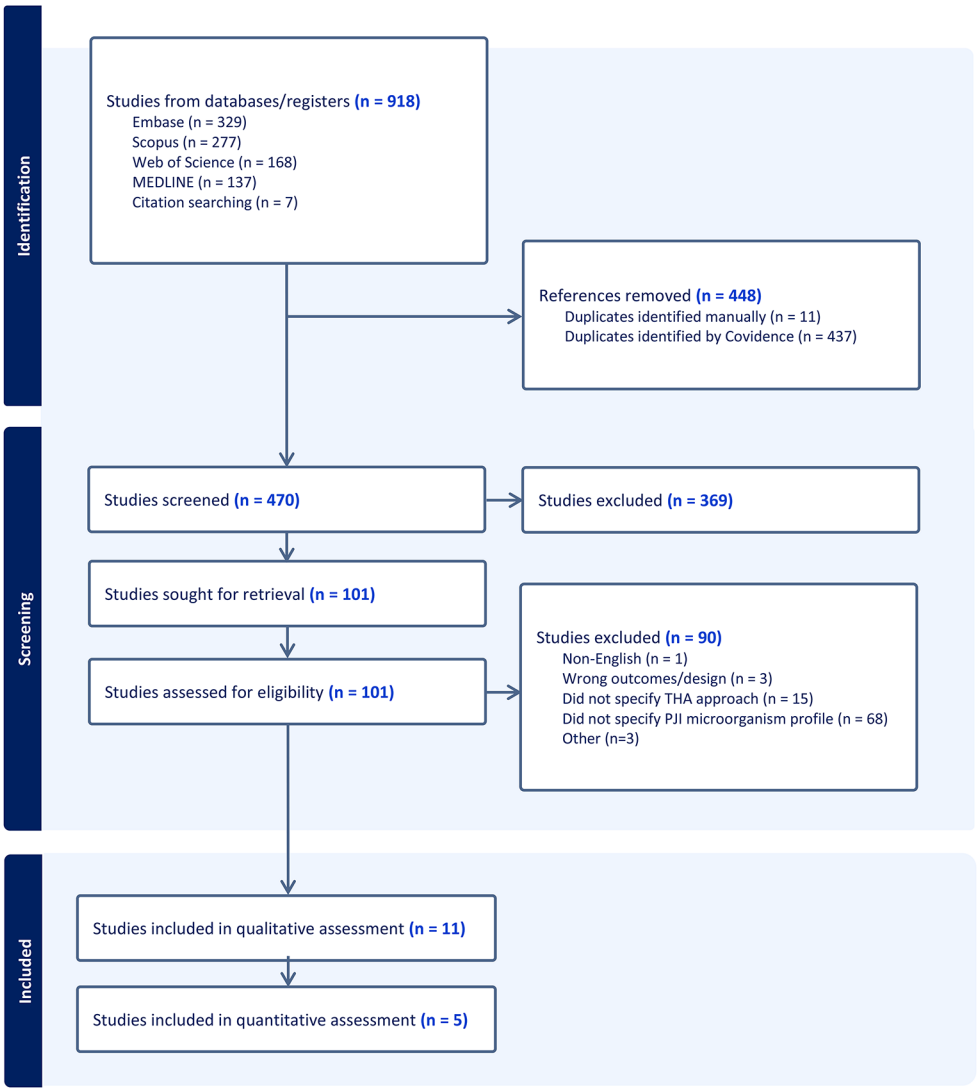

Fig. 1 PRISMA flow diagram of studies included in the analysis

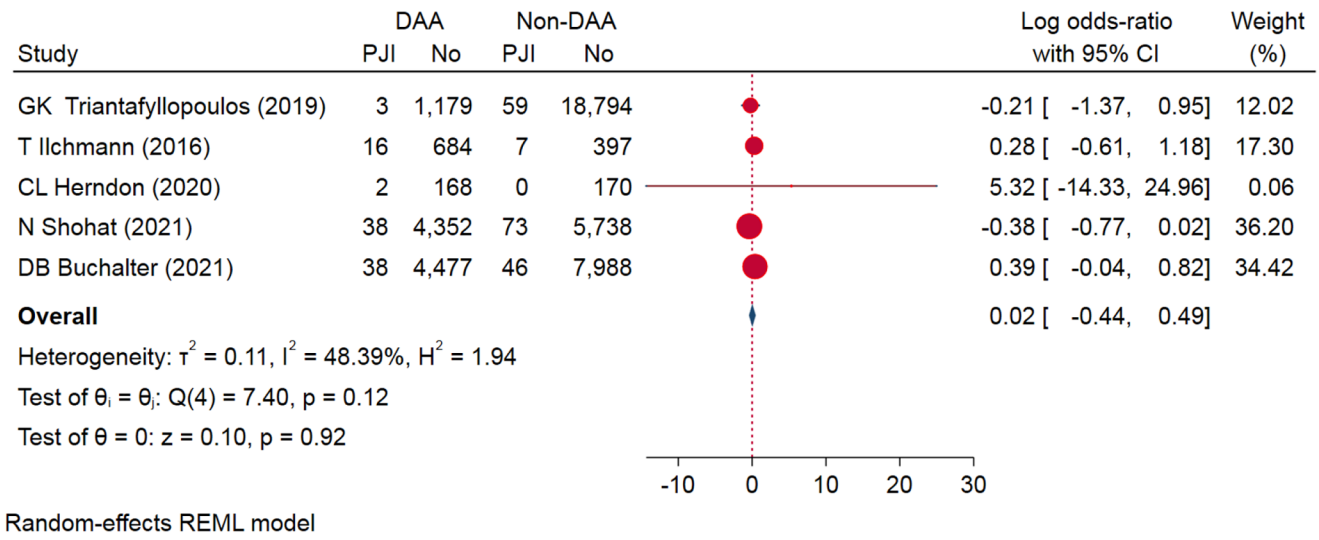

Fig. 2 Forest plot of incidence of PJI compared between DAA and approaches other than DAA in the included studies

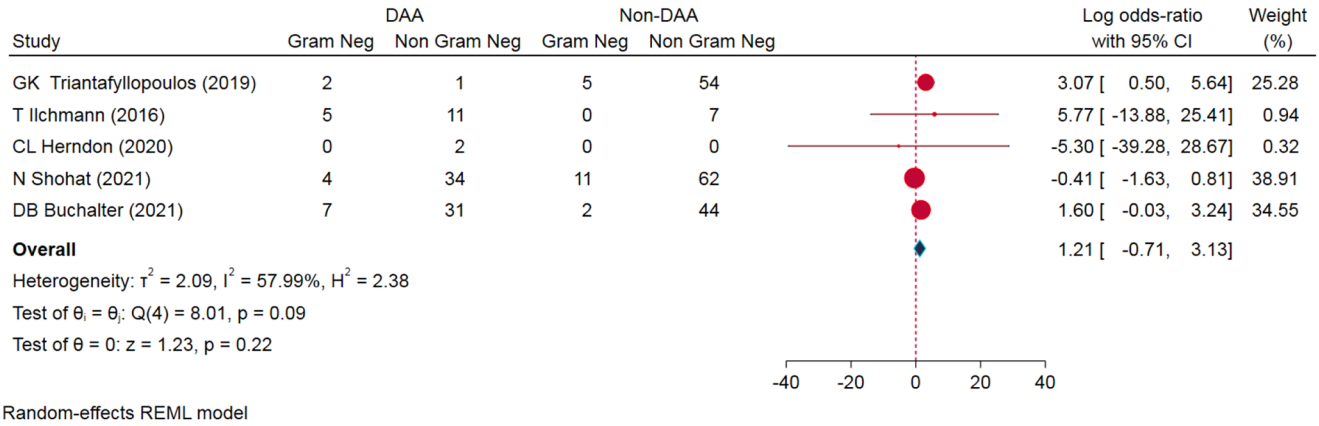

Fig. 3 Forest plot of incidence of gram-negative pathogen-induced PJI compared between DAA and approaches other than DAA in the included studies

microbial profiles were noted in DAA, while 299 from DLA, and 85 from the PA. The characteristics of the included studies are described in Table 1 and the characteristics of the microbial spectrum analyzed are detailed in Table 2.

Risk of bias assessment

The included studies were analyzed for their risk of bias using MINORS scoring system [17]. The included studies consisted of six Level III and four Level IV studies. Nine of the included studies were found to be of good quality and two were considered to be of fair quality [26, 29] (Table 3).

PJI incidence

The overall incidence of PJI noted among the included studies was 0.64% (285/44,271). The incidence of PJI between the DAA and approaches other than DAA such as PLA, LA, and AL approaches was analyzed. Although there was not a significant heterogeneity in the reported results ($I^2 = 48.39\%$, $p = 0.12$), considering the nature of the study design of the included studies, data was analyzed by random effects model. No significant difference between the DAA and other approaches in the incidence of PJI was noted in the included studies (OR 1.06, 95% CI [0.67, 1.67], $p = 0.92$).

PJI pathogen profile

Irrespective of the approach utilized, Staphylococcus epidermidis and Staphylococcus aureus emerged as the most prevalent infections. THA approach did not influence the common micro-organism profile in the included studies [1, 2, 4, 7, 9, 10]. The rate of gram-negative pathogen causing PJI between the DAA and other approaches in the included studies was analyzed. Although there was no significant heterogeneity in the reported results ($I^2 = 57.99\%$, $p = 0.09$),

Table 1 Characteristics of studies included in the review

Author, Year, Country	Level of Evidence	Criteria of Diagnosis	Total Number of PJI	Approaches Assessed	Number of PJI		Age		BMI		CCI	
					DAA group	Comparator group	DAA group	Comparator group	DAA group	Comparator group	DAA group	Comparator group
Aichmair, 2022, Austria [20]	3	2018 MSIS criteria	87	DAA, DLA	36	36	68.2 ± 13.6	68.2 ± 13.6	31.3 ± 5.7	31.3 ± 5.7	3.5 ± 1.9	3.5 ± 1.9
Buchalter, 2020, USA [21]	3	NHSN criteria with MSIS guidelines	84	DAA, non-DAA	38	46	63.0 ± 12.5	-	29.5	-	-	-
Herndon, 2020, USA [22]	3	-	1	DAA, mini-anterolateral	1	0	60.4 ± 14.6	-	28.1 ± 5.2	26.9 ± 5.3	-	-
Ilchmann, 2016, Switzerland [23]	3	IDSA guidelines	23	DAA, trans gluteal lateral approach	16	7	-	-	-	-	-	-
Knoth, 2020, Switzerland [24]	4	-	3	DAA	3	-	-	-	-	-	-	-
Purcell, 2016, USA [25]	4	AAOS	10	DAA	10	-	61.3 ± 10.4	-	-	-	--	-
Romano, 2012, Italy [26]	4	-	183	DLA	-	183	-	-	-	-	-	-
Shohat, 2021, USA [27]	3	2018 ICM criteria	111	DAA, DLA	38	73	62.3 ± 10.2	63.0 ± 10.7	-	-	0.2 ± 0.7	0.4 ± 0.8
Triantafyllopoulos, 2019, USA [28]	3	2013 ICM criteria	62	DAA, PA	3	59	62.3 ± 10.8	64.2 ± 11.9	-	-	-	-
Wolff, 2021, Germany [29]	4	CRP (> 5 mg/l) with positive culture	26	PA	-	26	-	-	-	29.8 ± 5.3	-	-
Tissot, 2018, Switzerland [30]	4	Positive culture or clinical and paraclinical assessment (labs)	12	DAA, PA	6	6	67.7 ± 13.3 [13–95]	66.6 ± 14.1 [17–92]	31.1 ± 5.8 *	26.6 ± 2.3 *	-	-

AAOS: American Academy Orthopaedic Surgery; BMI: Body Mass Index; CCI: Charlson Comorbidity Index; ICM: International Consensus Meeting; MSIS: Musculoskeletal Infection Society; CRP: C-reactive protein; IDSA: Infectious Diseases Society of America; NHSN: National Healthcare Safety Network; DAA: Direct Anterior Approach; DLA: Direct Anterolateral Approach; PA: Posterior Approach; USA: United States of America; PJI: Prosthetic Joint Infection;

*BMI for the PJI cases not the entire cohort

considering the nature of the study design of the included studies, data was analyzed by random effects model. There was no significant difference between the DAA and other approaches in the incidence of gram-negative pathogen induced PJI noted in the included studies (OR 3.35, 95% CI [0.49, 22.88], $p=0.22$). Polymicrobial PJI profile was noted particularly in the patients undergoing THA by DAA compared to other approaches. Considering the number of studies ($n<10$), publication bias was not estimated since it would not be meaningful in this scenario.

Discussion

PJI is a significant complication following THA, with various factors influencing the risk of infection and the organism profile involved. In this systematic review, we studied the diversity in PJI incidence and microorganism profiles across the comparison between DAA and other surgical approaches. The key findings of this review are as follows:

1. The overall rate of PJI in THA noted in the included studies is 0.64%.
2. No significant difference between the DAA and other approaches in the incidence of PJI in THA ($p=0.92$).
3. No significant difference between the DAA and other approaches in the incidence of gram-negative pathogen induced PJI in THA ($p=0.22$).

Although this study did not find any significant difference in the incidence of gram-negative infections in DAA, Aichmair et al. [20] noted increased incidence of Cutibacterium avidum infection that accounted for 22% of PJIs in the DAA group, whereas the incidence was notably lower at 2.8% in the DLA group. Similarly, Buchalter et al. employed a single-institution retrospective review focusing on early PJI within 90 days of arthroplasty and identified DAA cohorts to be at an increased risk of monomicrobial gram-negative PJI compared to non-DAA [21]. However, no information was provided regarding long-term PJI outcomes which could have altered the spectrum as noted by the results of this study. Ilchmann et al. noted gram-negative bacilli only in the DAA cohort, and attributed them to inguinal microbiome despite lacking statistical significance (5/14 vs. 0/6, $p=0.26$) [23]. Additionally, the fraction of patients with polymicrobial infection was higher in the DAA group (7/14 vs. 2/6; $p=0.64$) [23].

Triantafyllopoulos et al. reported a larger proportion of MRSA in the DAA group (33.3% vs. 18.6% in PLA), with Proteus mirabilis exclusively reported in the DAA group [28]. However, direct inter-group analysis was not conducted. Furthermore, this difference was not consistently identified. However, a larger sample size study, despite lacking statistical significance, found no discernible difference in the type of microorganism causing PJI between DAA and DLA [27].

In a review study V. Shah et al. showed that in obese patients, the DAA may have an increased risk of PJI compared to other approaches, particularly in those with a BMI of 35 kg/m2 or greater [31]. Aichmair et al. [23] showed DAA might be associated with a higher incidence of gram-negative bacteria, which are often more resistant to standard antibiotics. DLA, in contrast, tends to have a higher prevalence of gram-positive bacteria, particularly Staphylococcus species, which are common causative agents in surgical site infections but generally have a different resistance profile than gram-negative bacteria. These differences could be attributed to various factors including the specific surgical exposure and technique associated with each approach, which may influence the type of contamination and subsequent infection risk [22].

This study found a higher prevalence of polymicrobial infections in the DAA group compared to the DLA group, consistent with prior research. However, Ilchmann et al. [23] specifically observed the presence of gram-negative bacilli exclusively in the DAA cohort, suggesting a potential association with the inguinal microbiome. However, the study lacked sufficient power to identify significant differences in the occurrence of gram-negative bacilli between the DAA and DLA groups.

In this study, it was discovered that MRSE and Staphylococcus aureus were the most commonly identified infections across both DAA and non-DAA surgical methods. The choice of THA approach did not have a significant impact on the prevalence of MRSE and MRSA microorganisms in the majority of studies. Additionally, Wolf et al. [29] provided a detailed breakdown of microbial distribution in the Posterior Approach (PA), where Staphylococcus epidermidis, Staphylococcus aureus, and Propionibacterium acnes were the predominant species identified.

This study has some limitations to acknowledge. The scarcity of sufficient studies and the potential influence of methodological, population, and outcome measure methods on the results were the limitations of this systematic review. However, this study did not find significant heterogeneity in the analyzed results among the included studies that affects the certainty of evidence presented in the current analysis. Moreover, there is a need for large randomized controlled trial on THA infection rates among various approaches with sufficient follow-up to validate the observations noted in the current study.

Table 2 Micro-organism profile of the prosthetic joint infections analyzed in the included studies

Author, Year, Country	Total Number of PJI	Approaches Assessed	Mono-microbial PJI profile		Poly-microbial PJI profile	
			DAA group	Comparator group	DAA group	Comparator group
Aichmair, 2022, Austria [20]	87	DAA, DLA	13 Staphylococcus epidermidis, 5 Staphylococcus aureus, 8 Cutibacterium avidum, 2 Cutibacterium acnes, 2 hemolytic streptococcus (β), 2 hemolytic streptococcus (γ), 1 Enterococcus faecalis, 2 Pseudomonas aeruginosa, 1 Staphylococcus capitis, 2 Staphylococcus hominis, 1 Bacillus species, 2 Staphylococcus haemolyticus, 1 Proteus mirabilis, 1 Granulicatella adiacens, 1 Escherichia coli, 1 Staphylococcus chromogenes, 1 Klebsiella pneumoniae, 1 Corynebacterium tuberculostearicum	10 Staphylococcus epidermidis, 7 Staphylococcus aureus, 1 Cutibacterium avidum, 4Cutibacterium acnes, 3 hemolytic streptococcus (β), 2 hemolytic streptococcus (γ), 3 Enterococcus faecalis, 1 Pseudomonas aeruginosa, 2 Staphylococcus capitis, 0 Staphylococcus hominis, 2 Bacillus species, 0 Staphylococcus haemolyticus, 1 Proteus mirabilis, 1 Granulicatella adiacens, 2 Streptococcus viridans, 1 Staphylococcus sasscharolyticus, 1 Staphylococcus lugdunensis, 1 Finegoldia magna, 1 Enterobacter cloacae, 1 Candida albicans	-	-
Buchalter, 2020, USA [21]	84	DAA, non-DAA	33 (4 MRSA, 15 MSSA, 4 coagulase negative Staphylococcus, 4 Streptococcus agalactiae, 1 Streptococcus mitis, 1 Streptococcus sanguinis, 2 Enterobacter cloacae, 1 Klebsiella aerogenes, 1 Citrobacter koseri)	-	**Case 1**: Streptococcus agalactiae, Peptostreptococcus Asaccharolyticus **Case 2**: Pseudomonas aeruginosa, Enterococcus faecalis, Corynebacterium species **Case 3**: Pseudomonas aeruginosa, Enterococcus faecalis **Case 4**: MRSA, Pseudomonas aeruginosa **Case 5**: MSSA, Cutibacterium acnes	-
Herndon, 2020, USA [22]	1	DAA, mini-anterolateral	1 staphylococcal species			

Table 2 (continued)

Author, Year, Country	Total Number of PJI	Approaches Assessed	Mono-microbial PJI profile		Poly-microbial PJI profile	
			DAA group	Comparator group	DAA group	Comparator group
Ilchmann, 2016, Switzerland [23]	23	DAA, trans gluteal lateral approach	9 (3 Staphylococcus epidermidis, 2 Staphylococcus aureus, 1 Finegoldia magna, 1 Streptococcus sanguinis, 1 Staphylococcus lugdunensis, 1 Streptococcus)	5 (3 CONS, 1 Strepcoccus sp., 1 Actinmuces sp., 1 Actinomyces sp.)	**Case 1**: Staphylococcus epidermidis, Proteus mirabilis **Case 2**: Staphylococcus epidermidis, Morganella morganii **Case 3**: Staphylococcus epidermidis, Staphylococcus haemolyticus, Aerococcus sp., Acinebacter sp. **Case 4** Staphylococcus aureus, Citrobacter freundii **Case 5**: Staphylococcus epidermidis, Group β Streptococcus, Morganella morganii **Case 6**: CONS, Propionibacterium acnes **Case 7**: CONS, Staphylococcus epidermidis, Enterococcus faecalis, Propionibacterium sp., Klebsiella pneumoniae, Pseudomonas aeruginosa, E. coli	-
Knoth, 2020, Switzerland [24]	3	DAA	1 beta-hemolytic Streptococcus, 1 Staphylococcus aureus, 1 Finegoldia magna	-	-	-
Purcell, 2016, USA [25]	10	DAA	3 Streptococcus group C, 2 Streptococcus agalactiae, 1 Citrobacter koseri, 1 Enterobacter cloacae, 1 Proteus mirabilis, 1 Staphylococcus aureus, 1 Staphylococcus intermedius, no identified microorganism in 3 cases	-	-	-

Table 2 (continued)

Author, Year, Country	Total Number of PJI	Approaches Assessed	Mono-microbial PJI profile		Poly-microbial PJI profile	
			DAA group	Comparator group	DAA group	Comparator group
Romano, 2012, Italy [26]	183	DLA	-	-	-	-
Shohat, 2021, USA [27]	111	DAA, DLA	-	-	-	-
Triantafyllopoulos, 2019, USA [28]	62	DAA, PA	3 (1 MRSA, 2 Proteus mirabilis)	56 (23 MSSA, 11 MRSA, 3 MSSE, 1 MRSE, 2 other coagulase-negative, 6 Strepococcus spp., 4 Enteroccus spp., 4 E. Coli, 1 Enterobacter cloacae, 1 negative culture.)	-	-
Wolff, 2021, Germany [29]	26	PA	-	11 Staphylococci, 6 Streptococcus spp., 4 Enterococcus spp., 4 E. coli, 1 Enterobacter cloacae	-	-
Tissot, 2018, Switzerland [30]	12	DAA, PA	2 Staphylococcus aureus 2 Propionibacterium acnes 1 Proteus mirabilis 1 Staphylococcus epidermidis	1 Staphylococcus aureus 1 Staphylococcus epidermidis 1 Staphylococcus capitis 3 Negative culture	-	-

DAA: Direct Anterior Approach; DLA: Direct Anterolateral Approach; PA: Posterior Approach; PJI: Prosthetic Joint Infection; USA: United States of America; MRSA: Methicillin-resistant Staphylococcus aureus; MSSA: Methicillin-sensitive Staphylococcus aureus; MSSE: Methicillin-sensitive Staphylococcus epidermidis; MRSE: Methicillin-resistant Staphylococcus epidermidis; CONS: Coagulase negative Staphylococcus aureus; E. coli: Escherichia coli

Table 3 Quality assessment of the included studies using methodological index for Non-Randomized studies (MINORS) criteria [15]

Author	Aichmair, 2022 [20]	Buchalter, 2020 [21]	Herndon, 2020 [22]	Ilchmann, 2016 [23]	Knoth, 2020 [24]	Purcell, 2016 [25]	Romano, 2012 [26]	Shohat, 2021 [27]	Triantafyllopoulos, 2019 [28]	Wolff, 2021 [29]	Tissot, 2018 [30]
Clearly stated aim	2	2	2	2	2	2	2	2	2	2	2
Inclusion of consecutive patients	1	1	2	2	1	2	2	1	1	1	2
Prospective collection of data	0	0	0	0	0	0	0	0	0	0	0
Endpoints appropriate to the aim of the study	2	2	2	2	2	2	2	2	2	2	2
Unbiased assessment of the study endpoints	2	2	2	2	2	2	2	2	2	2	2
Follow up period appropriate to the aim of the study	2	2	2	2	2	2	2	2	2	2	2
Loss of follow up less than 5%	2	2	2	2	2	2	2	2	2	2	2
Prospective calculation of the study size	2	0	2	0	2	0	0	0	0	0	0
For comparative studies											
An adequate control group	2	2	2	2	2	2	-	2	2	-	2
Contemporary group	2	2	2	2	0	2	-	2	2	-	2
Baseline equivalence of groups	1	1	1	0	1	1	-	2	1	-	1
Adequate statistical analyses	2	2	2	2	2	1	-	2	2	-	2
Total MINORS score	20	18	21	18	18	18	12	19	18	11	19
Maximum possible score	24	24	24	24	24	24	16	24	24	16	24
Quality	Good	Good	Good	Good	Good	Good	Fair	Good	Good	Fair	Good

Conclusion

The overall rate of PJI in THA remains low. Utilizing DAA does not increase the risk of PJI compared to other approaches. Further, DAA does not increase the incidence of gram-negative pathogen induced PJI in THA. However, the spectrum of PJI pathogen varies with the approach utilized and understanding these differences is crucial for tailoring prophylactic antibiotic therapy and managing infections effectively postoperatively. Therefore, further research with larger sample size with detailed description of the infecting organism profile and standardized methodologies is warranted to elucidate these findings and guide clinical practice effectively.

Author contributions All authors had substantial contribution to the design of the study. AH, SM, MA and JL collected data. AH, SM, OA, MK & AHH participated in data interpretation and manuscript drafting. AH, JL, OA, AHH, SH, GA & MC helped in data interpretation and manuscript review. AH, GA, SM and MC prepared the final version of the manuscript which was read and approved by all authors.

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Code Availability Not applicable.

Declarations

Ethical approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

Conflict of interest The authors have no financial or proprietary interests in any material discussed in this article.

References

1. Matsunaga-Myoji Y, Fujita K, Makimoto K, Tabuchi Y, Mawatari M (2020) Three-Year Follow-Up study of physical activity, physical function, and Health-Related quality of life after total hip arthroplasty. J Arthroplasty 35(1):198–203. https://doi.org/10.1016/j.arth.2019.08.009
2. Hantouly AT, Alzobi O, Toubasi AA, Zikria B, Al Dosari MAA, Ahmed G (2023) Higher sensitivity and accuracy of synovial next-generation sequencing in comparison to culture in diagnosing periprosthetic joint infection: a systematic review and meta-analysis. Knee Surg Sports Traumatol Arthrosc 31(9):3672–3683. https://doi.org/10.1007/s00167-022-07196-9
3. Zampogna B, Papalia GF, Parisi FR et al (2023) Early return to activity of daily living after total hip arthroplasty: a systematic review and meta-analysis. Hip Int 33(6):968–976. https://doi.org/10.1177/11207000221146116
4. Schwartz AM, Farley KX, Guild GN, Bradbury TL Jr (2020) Projections and epidemiology of revision hip and knee arthroplasty in the united States to 2030. J Arthroplasty 35(6):S79–S85
5. Mundi R, Pincus D, Schemitsch E, Ekhtiari S, Paterson JM, Chaudhry H, Leis JA, Redelmeier DA, Ravi B (2024) Association between periprosthetic joint infection and mortality following primary total hip arthroplasty. J Bone Joint Surg Am. https://doi.org/10.2106/JBJS.23.01160
6. Mohiuddin A, Rice J, Ziemba-Davis M, Meneghini RM, Infection Rates After Aseptic Revision Total Hip Arthroplasty With Extended Oral Antibiotic Prophylaxis (2024) J Am Acad Orthop Surg 32(10):472–480. https://doi.org/10.5435/JAAOS-D-23-00750
7. Parvizi J, Barnes S, Shohat N, Edmiston CE Jr (2017) Environment of care: is it time to reassess microbial contamination of the

operating room air as a risk factor for surgical site infection in total joint arthroplasty? Am J Infect Control 45(11):1267–1272. https://doi.org/10.1016/j.ajic.2017.06.027
8. Hantouly AT, Salameh M, Toubasi AA, Salman LA, Alzobi O, Ahmed AF, Hameed S, Zikria B, Ahmed G (2022) Synovial fluid calprotectin in diagnosing periprosthetic joint infection: A meta-analysis. Int Orthop 46(5):971–981. https://doi.org/10.1007/s00264-022-05357-6
9. Premkumar A, Kolin DA, Farley KX et al (2021) Projected economic burden of periprosthetic joint infection of the hip and knee in the united States. J Arthroplasty 36(5):1484–1489e3. https://doi.org/10.1016/j.arth.2020.12.005
10. Rosa Park, Wood GCA, Hopman WM, Heather J, Grant, David Yen (2021) Hospital environmental influences and the rate of periprosthetic joint infections at a Canadian tertiary center: a retrospective chart review. Curr Orthop Pract 32(3):223–231. May/June 20110.1097/BCO.0000000000000984
11. Tan TL, Shohat N, Rondon AJ et al (2019) Perioperative antibiotic prophylaxis in total joint arthroplasty: A single dose is as effective as multiple doses. J Bone Joint Surg Am 101(5):429–437. https://doi.org/10.2106/JBJS.18.00336
12. Yan L, Ge L, Dong S et al (2023) Evaluation of Comparative Efficacy and Safety of Surgical Approaches for Total Hip Arthroplasty: A Systematic Review and Network Meta-analysis. JAMA Netw Open. 6(1):e2253942. Published 2023 Jan 3. https://doi.org/10.1001/jamanetworkopen.2022.53942
13. Rakow A, Perka C, Trampuz A, Renz N (2019) Origin and characteristics of haematogenous periprosthetic joint infection. Clin Microbiol Infect 25(7):845–850. https://doi.org/10.1016/j.cmi.2018.10.010
14. Parvizi J, Cha Y, Chisari E, Kim K, Koo KH (2024) Comprehensive Guidance for the Prevention of Periprosthetic Joint Infection After Total Joint Arthroplasty and Pitfalls in the Prevention. J Korean Med Sci. 2024;39(15):e147. https://doi.org/10.3346/jkms.2024.39.e147
15. Gatin L, Saleh-Mghir A, Massin P, Crémieux AC (2015) Critical analysis of experimental models of periprosthetic joint infection. Orthop Traumatol Surg Res 101(7):851–855. https://doi.org/10.1016/j.otsr.2015.08.007
16. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JPA, Clarke M, Devereaux PJ, Kleijnen J, Moher D (2009) The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. BMJ 339:b2700
17. Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, Chipponi J (2003) Methodological index for non-randomized studies (minors): development and validation of a new instrument. ANZ J Surg 73(9):712–716
18. Vivekanantha P, Diao YD, Cohen D et al (2023) Posterior tibial slope, Notch width index and tibial tubercle to trochlear groove distance contribute to development of mucoid degeneration of the anterior cruciate ligament: a systematic review. Knee Surg Sports Traumatol Arthrosc 31:3454–3464. https://doi.org/10.1007/s00167-023-07435-7
19. Higgins JPT, Thompson SG, Deeks JJ, Altman DG (2003) Measuring inconsistency in meta-analyses. BMJ 327(7414):557–560. https://doi.org/10.1136/bmj.327.7414.557
20. Aichmair A, Frank BJH, Singer G, Simon S, Dominkus M, Hofstaetter JG (2022) Differential Microbiological spectrum and resistance pattern in periprosthetic hip joint infections: a matched-cohort analysis comparing direct anterior versus lateral approach. BMC Musculoskelet Disord 23(1):72. https://doi.org/10.1186/s12891-022-05037-x
21. Buchalter DB, Teo GM, Kirby DJ, Aggarwal VK, Long WJ (2020) Surgical approach to total hip arthroplasty affects the organism profile of early periprosthetic joint infections. JB JS Open Access 5(4):e2000111. https://doi.org/10.2106/JBJS.OA.20.00111
22. Herndon CL, Drummond N, Sarpong NO, Cooper HJ, Shah RP, Geller JA (2020) Direct anterior versus mini-anterolateral approach for primary total hip arthroplasty: early postoperative outcomes and complications. Arthroplast Today 6(2):257–261. https://doi.org/10.1016/j.artd.2020.02.009
23. Ilchmann T, Zimmerli W, Bolliger L, Graber P, Clauss M (2016) Risk of infection in primary, elective total hip arthroplasty with direct anterior approach or lateral transgluteal approach: a prospective cohort study of 1104 hips. BMC Musculoskelet Disord 17(1):471. https://doi.org/10.1186/s12891-016-1332-0
24. Knoth C, Zettl R, Markle A, Dullenkopf A, Bruhin V, Hess F (2020) A retrospective analysis of surgical outcomes following direct anterior hip arthroplasty with or without a surgical extension table. Int Orthop 44(9):1701–1709. https://doi.org/10.1007/s00264-020-04596-9
25. Purcell RL, Parks NL, Gargiulo JM, Hamilton WG (2016) Severely obese patients have a higher risk of infection after direct anterior approach total hip arthroplasty. J Arthroplasty 31(9 Suppl):162–165. https://doi.org/10.1016/j.arth.2016.03.037
26. Romanò CL, Romanò D, Albisetti A, Meani E (2012) Preformed antibiotic-loaded cement spacers for two-stage revision of infected total hip arthroplasty. Long-term results. Hip Int 22 Suppl 8S46–53. https://doi.org/10.5301/HIP.2012.9570
27. Shohat N, Goswami K, Clarkson S, Chisari E, Breckenridge L, Gursay D, Tan TL, Parvizi J (2021) Direct anterior approach to the hip does not increase the risk for subsequent periprosthetic joint infection. J Arthroplasty 36(6):2038–2043. https://doi.org/10.1016/j.arth.2021.02.016
28. Triantafyllopoulos GK, Memtsoudis SG, Wang H, Ma Y, Alexiades MM, Poultsides LA (2019) Surgical approach does not affect deep infection rate after primary total hip arthroplasty. Hip Int 29(6):597–602. https://doi.org/10.1177/1120700018825237
29. Wolff M, Lausmann C, Gehrke T, Zahar A, Ohlmeier M, Citak M (2021) Results at 10–24 years after single-stage revision arthroplasty of infected total hip arthroplasty in patients under 45 years of age. Hip Int 31(2):237–241. https://doi.org/10.1177/1120700019888877
30. Tissot C, Vautrin M, Luyet A, Borens O (2018) Are there more wound complications or infections with direct anterior approach total hip arthroplasty? Hip Int 28(6):591–598. https://doi.org/10.1177/1120700018759617
31. Shah NV, Huddleston HP, Wolff DT, Newman JM, Pivec R, Naziri Q, Shah VR, Maheshwari AV (2022) Does surgical approach for total hip arthroplasty impact infection risk in the obese patient?? Syst Rev Orthop 45(2):e67–e72. https://doi.org/10.3928/01477447-20211227-03

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