Journal of ISAKOS 9 (2024) 62–70

Contents lists available at ScienceDirect

Journal of ISAKOS

journal homepage: www.elsevier.com/locate/jisakos

Systematic Review

Debridement, antibiotics, and implant retention (DAIR) for the early prosthetic joint infection of total knee and hip arthroplasties: a systematic review

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ARTICLE INFO

Keywords:
DAIR
Knee
Hip
Arthroplasty
Early
Infection

ABSTRACT

Purpose: Early periprosthetic joint infection (PJI) represents one of the most fearsome complications of joint replacement. No international consensus has been reached regarding the best approach for early prosthetic knee and hip infections.
The aim of this updated systematic review is to assess whether debridement, antibiotics, and implant retention (DAIR) is an effective choice of treatment in early postoperative and acute hematogenous PJI.
Methods: This systematic review was performed using the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines. The diagnostic criteria defining a PJI, the most present pathogen, and the days between the index procedure and the onset of the PJI were extracted from the selected articles. Additionally, the mean follow-up, antibiotic regimen, and success rate of the treatment were also reported.
Results: The articles included provided a cohort of 970 patients. Ten studies specified the joint of their cohort in PJIs regarding either hip prostheses or knee prostheses, resulting in 454 total knees and 460 total hips. The age of the patients ranged from 18 to 92 years old. Success rates for the DAIR treatments in the following cohort ranged from 55.5% up to a maximum of 90% (mean value of 71%).
Conclusion: Even though the DAIR procedure is quite limited, it is still considered an effective option for patients developing an early post-operative or acute hematogenous PJI. However, there is a lack of studies, in particular randomized control trials (RCTs), comparing DAIR with one-stage and two-stage revision protocols in the setting of early PJIs, reflecting the necessity to conduct further high-quality studies to face the burden of early PJI.

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https://doi.org/10.1016/j.jisako.2023.09.003
Received 2 July 2023; Received in revised form 21 August 2023; Accepted 7 September 2023
Available online 13 September 2023

What is already known?

- The incidence of PJI is estimated to be around 1–2% among all joint replacements. With the progressive, increased number of joint replacement procedures performed worldwide, the number of PJIs is expected to increase in the following years.
- Although in recent years steps have been taken to provide pathways and guidance for individuals with a PJI, there remains a lack of evidence, and therefore, a lack of consensus across many facets of patient care. This may partly explain the variability of success rates in revision surgery for PJI across the literature.
- Treatment strategies included surgical irrigation, debridement, antibiotic therapy, and implant retention with or without polyethylene exchange (DAIR). Alternative options are represented by one-stage or two-stage revision surgery.

What are the new findings?

- DAIR is an overall successful treatment for early post-operative and acute hematogenous PJIs in hip and knee prostheses.
- There is still a lack of studies, in particular RCTs, comparing DAIR with one-stage and two-stage revision protocols in the setting of early PJIs.

1. Introduction

Early periprosthetic joint infection (PJI) is a severe complication that can occur after joint replacement surgery [1,2]. It is often associated with the need for multiple revision surgeries, recurring infections, prolonged courses of antibiotics, extended hospital stays, delayed aseptic loosening, and unfavourable functional outcomes [3–6]. The incidence of PJI is estimated to be around 1–2% among all joint replacements [7]. Furthermore, PJI has been found to contribute to 13% of revision hip arthroplasties and 23% of revision knee arthroplasties [8]. In fact, in cases where joint revision is necessary, this complication accounts for 39.6% of all surgical procedures [9–12].

With the progressively increased number of joint replacement procedures performed worldwide, the number of PJIs is expected to increase in the following years [13,14].

Infections associated with prosthetic joints can be categorised into three groups: early infections (occurring within three months after surgery), delayed infections (appearing between three and 24 months after surgery), and late infections (emerging more than 24 months after surgery). Early infections are typically characterised by sudden joint pain, swelling, redness, warmth at the site of the implant, and fever [15]. Another classification system, popularised by Tsukayama in the 1990s, divides periprosthetic joint infections (PJIs) into four categories. This classification takes into account both the time elapsed since the operation and the presumed mode of infection: positive intraoperative cultures, early post-operative infections, hematogenous infections, and late chronic infections [16,17]. Furthermore, McPherson and colleagues proposed a staging system for PJIs that not only considers the type of infection but also factors in the host's condition [18,19].

Different treatment strategies included surgical irrigation, debridement, antibiotic therapy, and implant retention (DAIR) with or without polyethylene exchange. Debridement involves the removal of the hematoma, fibrous membranes, sinus tracts, and devitalized bone and soft tissue [15].

There are alternative options available such as one-stage or two-stage revision surgeries [2,20–22]. Two-stage revision surgery has long been considered the 'gold standard'. However, for patients with relatively healthy bone and soft tissue, no prior revision surgeries, or treatment involving effective antibiotics against biofilm-active microorganisms, the treatment of choice would be a one-stage exchange [23].

The options for complex and chronic PJI are resection arthroplasty (RA) (without reimplantation), arthrodesis, and amputation [24–27]. Non-surgical medical treatment such as antibiotic suppression therapy should be reserved for patients with comorbidities or contraindicated for surgery [7,24]. However, the existing recommendations for treatment of the PJI have been refined further by new scientific evidence and clinical experiences [15,28]. It is well known that one-stage revision surgery is usually used to compensate for the shortcomings of two-stage revision surgery in chronic PJI patients. There is no information on definitive indications for which one-stage revision surgery may be used as a primary surgical intervention instead of the DAIR procedure in acute PJI patients [15,28].

The DAIR treatment is less invasive, less technically demanding, has lower morbidity, shorter hospitalisation, better bone stock preservation, and a lower economic burden; however, it is suitable for specific cases [27,29,30]. DAIR treatment indication is still debated among orthopaedic surgeons [29], as the rates of infection control range from 12% to 80% [29]. The decision to retain implants should be based on several factors: nonimmunocompromised patients, low-virulence microorganisms, and biofilm containment within a short period of time [24,26,27,31,32].

Two-stage revision has been the most successful alternative for PJI, with a 91% success rate for eradicating infection [25,27]. However, revision surgeries are very challenging for both patients and surgeons. The patient will undergo multiple operations with extended periods of reduced mobility. In addition, the surgeons will face significant challenges such as difficulties in removing a cemented prosthesis, the risk of bone loss, and injuries to peri-prosthetic soft tissue [24,27,33].

One-stage revision surgery for PJI was introduced as a substitute for two-stage revision surgery on chronic PJI that has been reported to have equivalent infection-free success compared to two-stage revision, with lower mortality and morbidity, fewer hospitalisations, shorter antibiotic treatment duration, and lower overall healthcare costs [25,34,35]. However, if one-stage revision surgery is performed as a suboptimal treatment for patients with conditions that are not suitable for the DAIR procedure, it can be easily predicted that the outcome such as the re-infection rate of one-stage revision surgery will be worse than the DAIR procedure.

Given the aforementioned variables affecting the choice of treatment in the context of early prosthetic infections, the KLIC and the CRIME80 scoring systems have recently been developed with the goal of predicting DAIR failure after AP PJI and AH PJI, respectively [36].

The main goal of this systematic review is to assess the success rate, defined as implant retention with infection clearance, of DAIR in the context of early post-operative and acute hematogenous PJI.

2. Materials and methods

2.1. Study selection

The research question was formulated using a PIOS approach: patient (P); intervention (I); outcome (O), and study design (S).

This systematic review focused on patients with early PJI (P) (total hip or knee arthroplasty), treated by DAIR (I), in order to describe the recurrent infection rate (O). For this purpose, the following study designs were included (S): non-randomised controlled studies (NRCT) as prognostic (PG), prospective (PS), retrospective (RS), case-series (CS), case-control (CC), cohort (C) studies were included.

This systematic review aimed to describe the recurrency infection rate (O) in patients with early PJI (P) (total hip or knee arthroplasty),

treated by DAIR (I) or one-stage revision (C). For this purpose, the following study designs were included (S): randomized control trials (RCT) and NRCT as prognostic (PG), prospective (PS), retrospective (RS), case-series (CS), case-control (CC), cohort (C) studies were included.

2.2. Inclusion and exclusion criteria

As claimed by the Oxford Centre for Evidence-Based Medicine, Level I-IV articles were included in the analysis. Due to the semantic competencies of the authors, publications in English, French, Dutch, Spanish, and Italian were included.

The aim of the current review was to analyse the outcomes of DAIR in the context of either early post-operative or acute hematogenous infections. Several classifications have been proposed [15,17,19]. In order to include all the data coherently with the aim of the current study, only data regarding type I-III PJIs according to Tsukayama et al. [17], grade I-II PJIs according to McPherson et al. [19], or PJIs defined as "early" according to the classification proposed by Zimmerli et al. [15] were included in this systematic review.

Additionally, due to the potential bias arising from the hospital-specific risk of post-operative infections, multicentre studies were not included in the review, nor were studies reporting outcomes following chronic PJIs. Studies where the treatment for early post-operative or acute hematogenous PJI was different than DAIR were not considered eligible for this review, and the diagnostic criteria applied by the single authors to define a PJI needed to be explicit within their methods section.

Literature analysis, case reports, animal studies, cadavers or in vitro examinations, biomechanical information, technical records, reports to redactors, and instructional courses were omitted. Publications with inadequate features of surgical procedure, follow-up, age of patients, clinical inspection, rate of re-infection, and statistical analysis were not considered eligible for this systematic review.

2.3. Search

A systematic review was performed using the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines [37]. An exhaustive study of the Medline, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Cochrane, Embase, Ovid, Web of Science, and Google Scholar databases was performed using the following string: ((((DAIR) OR (debridement)) OR (antibiotic)) OR (implant retention)) AND (infection)) AND (periprosthetic)) AND (hip)) AND (knee).

Additional studies were searched among reference lists of selected papers and systematic reviews. Three independent reviewers (S.D.S., B.B., and A.L.) separately conducted the study, and articles published

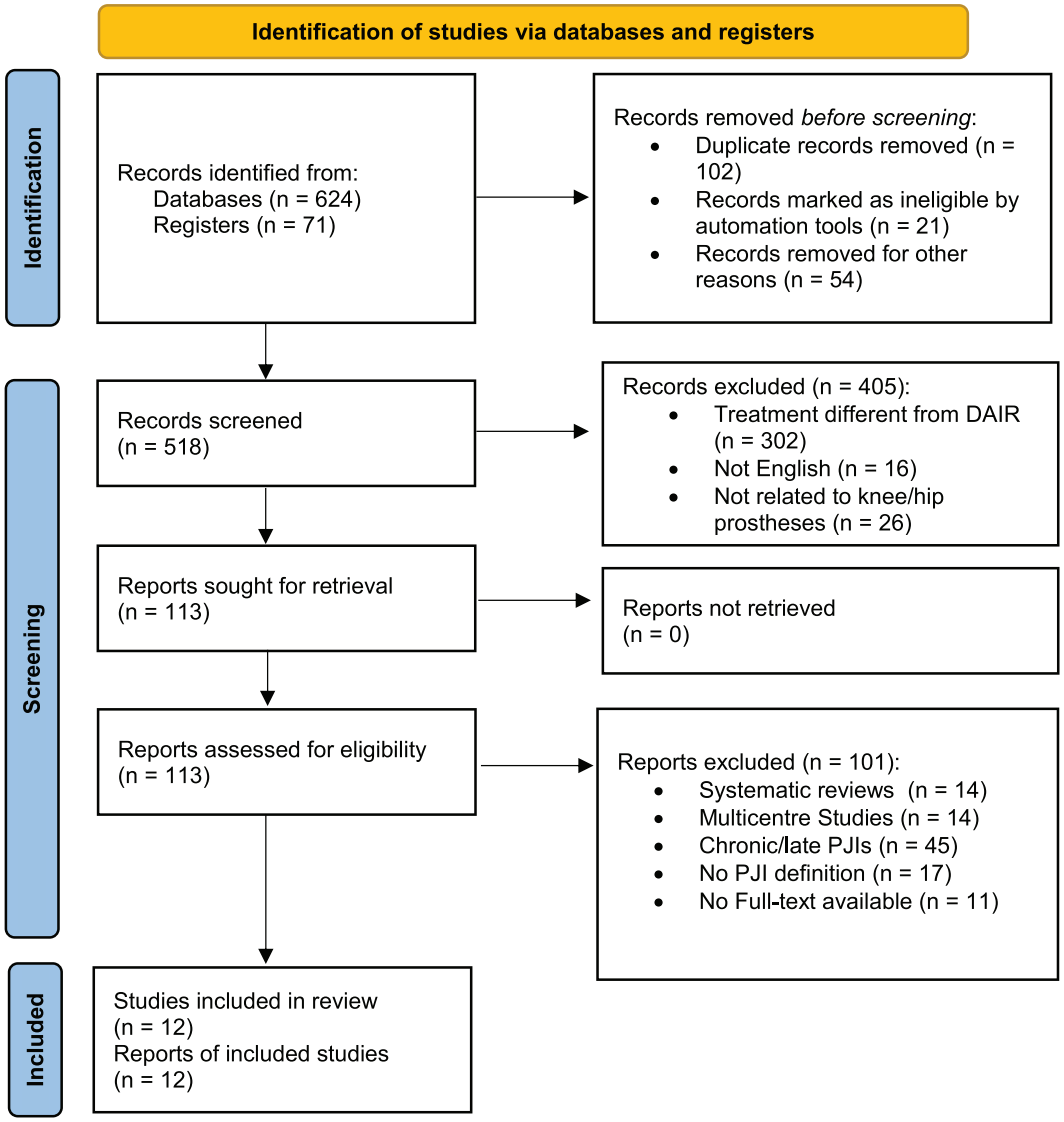

Fig. 1. Study selection process and screening according to the PRISMA flow chart.

from the inception of the databases until September 2022 have been included. The search was performed from August 2022 to September 2022.

2.4. Data collection process

Initial screening has been performed on all the articles for relevance by title and abstract and taking the full-text publication if the abstract did not let the examiners appraise the specific inclusion and exclusion parameters. The three investigators (S.D.S., A.L., and B.B.) independently analysed the abstract of each article and then achieved a close understanding of all publications and extracted reports to reduce selection bias and errors. To avoid bias, the chosen publications, the corresponding credentials list, and the publications precluded from the analysis were examined, evaluated, and argued by all the writers. In cases of disagreement, the senior reviewer (U.G.L.) decides. The number of articles included or excluded was registered and reported in the PRISMA flowchart (Fig. 1). Rules by Moher et al. were followed in designing the PRISMA chart [38].

The trial's design, conduct, and reporting of results were performed in conformity with the Good Clinical Practice guidelines reported in the World Medical Association (WMA) Declaration of Helsinki.

2.5. Data items

General study characteristics extracted were: primary author, year of publication, country, type of study, level of evidence, sample size, population demographics, sample size, gender, and mean age (Table 1). The diagnostic criteria defining a PJI, the most present pathogen, and the days between the index procedure and the onset of the PJI are summarised in Table 2. Additionally, the mean follow-up, antibiotic regimen, and success rate of the treatment are reported in Table 3.

2.6. Study risk of bias assessment

The Risk of Bias in non-randomized studies of interventions (ROBINS-I) tool from Cochrane and the Joanna Briggs Institute Critical Appraisal Tool for Case Series were used to assess the quality of each research study [39,40]. Two reviewers (B.B. and A.L.) independently assessed the papers, and if there was a dispute, a third reviewer (S.D.S) was consulted.

2.7. Statistical analysis

Categorical data were summarised as frequencies and percentages. Continuous data were summarised as mean values with standard deviations (SD) or ranges (i.e., minimum and maximum values). A meta-analysis was not performed at the end of the review due to the heterogeneity of the data in the selected articles.

3. Results

3.1. Search results

The literature search identified 695 total studies. No additional studies were found in the grey literature, and no unpublished studies were retrieved. Duplicated article removal resulted in the exclusion of 177 papers. Of the remaining 518 articles, 405 were removed as incompatible with the main aim of this review after the title and abstract evaluation. 113 full-text articles were then screened, leading to the elimination of 101 studies. In the latter exclusion process, the discarded articles were: articles reporting data from chronic or late-hematogenous PJIs (n = 45), multicentre studies (n = 14), and articles not specifying the type of PJI (n = 17). Additionally, systematic reviews (n = 14) and articles with no retrievable full text (n = 11) were discarded.

At the end of the selection process, a total of 12 articles were considered eligible for this study. The PRISMA flowchart of the literature search is reported in Fig. 1.

3.2. Quality of evidence

The ROBINS-I tool for NRCT and the Joanna Briggs Institute Critical Appraisal Tool for case series were used to assess the methodological quality of each article [39,40]. No RCT was included in the review. Retrospective case controls (RCCs) were identified as having a low risk of bias [41,42] or a moderate risk of bias [32]. Retrospective case series (RCSs) were overall of good quality [36,43–50].

The risk of bias assessments for RCTs, NRCTs, and CSs is reported in Figs. 2 and 3.

3.3. Study characteristics

The current review was comprised of 12 studies, of which three were retrospective case controls (RCCs) [32,41,42] and nine were retrospective case series (RCSs) [36,43–50]. The 12 studies included (Table 1) were brought out from 2010 to 2022. Seven of the considered studies were carried out in the USA [32,36,41,44,46,47,49], with the remaining being located in Brazil [48], China [43], Germany [45], the Netherlands [50], and Portugal [42]. Multicentre studies were considered ineligible due to the lack of homogeneity.

The articles included provided a cohort of 970 patients. Ten studies specified the joint of their cohort in PJIs regarding either hip prostheses or knee prostheses [36,41,43–50], resulting in 454 total knees and 460 total hips. The age of the patients ranged from 18 to 92 years.

The Musculoskeletal Infection Society (MSIS), the International Classification of Diseases, Ninth Revision Codes (ICD-9-CM), and International Consensus Meeting Diagnostic Criteria (ICMDC) were applied for the definition of PJIs in four [41,45,46,48], one [47], and three [36,

Table 1
Population and demographics.

Author, Year	Country	Type of study	LOE	Sample size			Gender		Age
				TOT	KNEE	HIP	M	F	
Barros et al., 2021	Portugal	RCC	III	38	NR	NR	NR		NR
Chalmers et al., 2021	USA	RCS	IV	122	70	52	67	55	65 ± 11.6
Chang et al., 2017	China	RCS	IV	5	3	2	NR		NR
Estes et al., 2010	USA	RCS	IV	20	16	4	NR		67 (28–91)
Fink et al., 2017	Germany	RCS	IV	67	44	23	37	30	67.8 (30.0–80.0)
Klement et al., 2019	USA	RCS	IV	189	80	109	NR		64.3 ± 12
Manrique et al., 2019	USA	RCS	IV	176	58	118	91	85	62.2 (18–92)
Riesgo et al., 2017	USA	RCC	III	74	36	38	47	26	61 (31–92)
Rudelli et al., 2021	Brasil	RCS	IV	56	25	31	22	44	67
Tirumala et al., 2021	USA	RCS	IV	149	90	59	76	73	66.4 ± 10.3
Van Kleunen et al., 2010	USA	RCC	III	18	NR	NR	7	11	55.3 (40–90)
Veerman et al., 2022	Netherlands	RCS	IV	56	32	24	NR		NR

LOE, Level Of Evidence; M, Male; F, Female; RCC, Retrospective Case Control; RCS, Retrospective Case Series; NR, Non-Reported.

Table 2
Infection characteristics.

Author, Year	Diagnostic criteria	Most Present organism		Index-PJI days
		Type	Tot. Patients (%)	
Barros et al., 2021	At least one positive deep (subfascial) sample was collected intra-operatively, either synovial fluid or periprosthetic tissue	CoNS, S. Aureus E. Coli	21 (32.) 18 (28.1) 7 (10.9)	22.6 (6–30)
Chalmers et al., 2021	ICMDC	MSSA CNSA MRSA	34 (28) 25 (21) 15 (12)	21
Chang et al., 2017	At least two positive samples of the same microorganism identified or matched to blood, joint synovial fluid, or tissue culture	MRSA CoNS	4 1	NR
Estes et al., 2010	At least 2 or more positive cultures for the same organism with the same antibiotic sensitivity profile, or any patient meeting 2 or more of the diagnostic criteria explicitly stated in the study	MSSA	4 (20)	7.4
Fink et al., 2017	MSIS	*S. aureus* MSSE *P. acnes*	24 17 4	5.0 (1–21)
Klement et al., 2019	MSIS	*S. aureus* MRSA CoNSA	110 56 54	NR
Manrique et al., 2019	ICD-9-CM	NR		14.4 (1–28)
Riesgo et al., 2017	MSIS	MSSE MSSA	7 6	<28
Rudelli et al., 2021	MSIS	MRSA	11	24
Tirumala et al., 2021	ICMDC	S. aureus, Streptococcus sp.	NR	NR
Van Kleunen et al., 2010	Purulent wound drainage, pain, fever, wound erythema, and elevated markers for infection	MSSA CNSA MRSA	9 (50) 3 (16) 3 (16)	19.4
Veerman et al., 2022	ICMDC	*S. aureus*	9	30

MSSA, methicillin sensitive *Staphylococcus aureus*; MSSE, methicillin sensitive *Staphylococcus epidermidis*; MRSE, methicillin resistant *Staphylococcus epidermidis; P. acnes*, *Propionibacterium acnes*; ICMDC, International Consensus Meeting Diagnostic Criteria; ICD-9-CM, International Classification of Diseases, Ninth Revision codes; *S. aureus, Staphylococcus aureus*; sp species; CNSA, coagulase-negative *Staphylococcus aureus.*

Table 3
Outcomes.

Author, Year	Antibiotic Regimen (IV)		Mean follow-up (mo)	Success rate (%)
	Type	Duration (weeks)		
Barros et al., 2021	Vancomycin, Piperacillin, Tazobactam	NR	42.1 (24–66)	89.5
Chalmers et al., 2021	NR	6	24	58.4
Chang et al., 2017	Daptomycin	4	27	80
Estes et al., 2010	Rifampicin combination therapy	6	3.5 (1.2–7.5)	90
Fink et al., 2017	Vancomycin, Rifampicin	2	41.8 (24–132)	71.6
Klement et al., 2019	NR	NR	12	55.5
Manrique et al., 2019	NR	NR	70.3 (12.72–207)	77.8
Riesgo et al., 2017	Vancomycin Povidone-iodine	6	34.9 ± 7.8 (12.9–66.4)	72
Rudelli et al., 2021	Teicoplatin, Amikacin	6	5	82
Tirumala et al., 2021	Amoxicillin + Clavulanate, Amoxicillin + Clindamycin, Levofloxacin, Doxycyline, Vancomycin + Cefepine	6	72 (45–125)	82.5
Van Kleunen et al., 2010	Cefazolin, Vancomycin	6	31 (13–57)	72
Veerman et al., 2022	Cefazolin	NR	24	63

49,50] articles, respectively. The remaining studies defined PJIs with specific criteria reported in Table 2.

The most common pathogen species involved was Staphylococcus spp. In particular, Staphylococcus aureus was the most prevalent pathogen, present in nine out of 12 included studies [32,36,43–46,48–50].

After the prophylactic administration, the antibiotic regimen was mainly culture-specific, leading to high heterogeneity among the cohort. The intravenous regimen had a minimum duration of two weeks.

Ten studies reported the mean follow-up regarding their cohorts [32, 36,41–45,47–49], resulting in a mean follow-up for the current review of 35.1 months. The remaining two articles had a minimum follow-up of 12 [46] and 24 [50] months each.

3.4. Success rate

The average rate of success for the DAIR treatments in the following cohort was 71%. Treatment success was defined according to Masri et al. [51], Martinez-Pastor et al. [52], and Zimmerli et al. [15], who stated that a patient could be judged infection-free at follow-up if he or she was free of clinical signs for infection (fever, local pain, redness, warmth, sinus tract infection) and had a c-reactive protein (CRP) level less than 10 mg/l.

Additionally, treatment failure was defined according to Byren et al. and Masri et al. if surgery was required as a result of exacerbation or if a new infection appeared after a symptom-free phase within the follow-up period [45,53].

Success rates below 60% were reported by Chalmers et al. [36] and by Klement et al. [46], with 58.4% and 55.5%, respectively. The highest rates were found by Estes et al. [44] and by Barros et al. [42], reaching 90% and 89.5%, respectively.

4. Discussion

Although in recent years steps have been taken to provide pathways and guidance for individuals with a PJI, there remains a lack of evidence and, therefore, a lack of consensus across many facets of patient care. This may partly explain the variability of success rates in revision surgery for PJI across the literature [13,54,55].

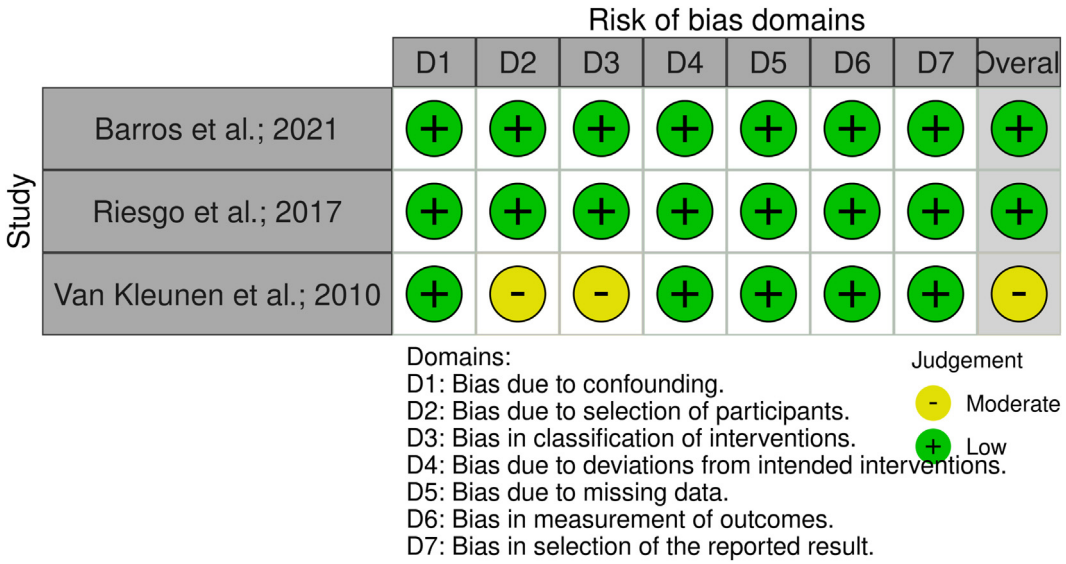

Fig. 2. The risk of bias assessments for NRCTs studies.

	Clear inclusion criteria	Standard condition	Valid methods of identification	Consecutive inclusion	Complete inclusion	Clear demographics	Clear clinical information	Clear outcomes	Site(s)/clinic(s) demographic information	Appropriate statistical analysis
Chalmers et al.; 2021	Y	U	Y	Y	Y	N	Y	Y	Y	Y
Chang et al.; 2017	Y	Y	Y	Y	Y	U	U	Y	Y	Y
Estes et al.; 2010	Y	Y	Y	Y	Y	U	U	Y	Y	Y
Fink et al.; 2017	Y	Y	Y	Y	Y	Y	Y	Y	Y	U
Klement et al.; 2019	Y	Y	Y	U	Y	Y	N	Y	Y	Y
Manrique et al.; 2019	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Rudelli et al.; 2021	Y	U	N	Y	Y	Y	U	Y	Y	Y
Tirumala et al.; 2021	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Veerman et al.; 2022	Y	Y	Y	Y	Y	Y	N	Y	Y	Y

Y	Yes
N	No
U	Unclear

Fig. 3. The risk of bias assessments for Case Series studies.

The main finding of this study is that DAIR is an overall successful treatment for early post-operative and acute hematogenous PJIs in hip and knee prostheses, confirming the current trends in the literature.

In the current review, treatment success rates ranged from 55.5% to 90%, with an average rate of 71%. These results are in line with the current literature [56,57]. However, some of the available reviews did not include protocols using rifampin-based combination therapy, which offers benefits in PJIs caused by Staphylococcus species [58,59], so they may not have ideally evaluated the outcome of DAIR [18].

One of the strengths of this systematic review relies on the fact that it considers only early post-operative and acute hematogenous PJIs, restricting the timing from the index procedure to the postinfection treatment, as well as conferring homogeneity to the study cohort. To the authors' knowledge, no other reviews have analysed the role of DAIR, excluding late and chronic PJIs.

In terms of prognostic factors, the timing of intervention is important. A short duration of symptoms and a small index procedure-to-DAIR timeframe are commonly considered the best prognostic factors in terms of eradication of infection, implant preservation, and good functional outcomes [18,60].

Also, to optimise the DAIR procedure, an accurate patient history and preoperative workup including the evaluation of patient comorbidities, must be performed. For example, obesity was considered a significant risk factor for PJI after the first hip and knee arthroplasty in different analyses [61,62], but a clear correlation with failures after the DAIR procedure was not found [45,63,64].

The duration of antibiotic therapy and the specific pathogen responsible for the PJI are crucial considerations in the context of the DAIR procedure. Typically, intravenous antibiotics for a period of 2–6 weeks following a DAIR procedure are administered [29,58,65–68]. However, according to recent guidelines by the Infectious Diseases Society of America (IDSA), a duration of 4–6 weeks of intravenous therapy is also recommended for PJIs caused by organisms other than Staphylococci or in cases where Rifampin combination therapy cannot be utilised [69]. Furthermore, several studies have provided support for the implementation of long-term antibiotic suppression therapy for a

minimum of 6 months after the DAIR procedure to enhance treatment outcomes [64,70,71].

The most common bacteria responsible for most PJIs are *Staphylococcus aureus*, *Propionibacterium acnes*, *Staphylococcus epidermidis,* and coagulase-negative Staphylococcus [72], as confirmed by this review and by the study of Motififard and colleagues [73]. In this context, given the frequency with which Staphylococci cause early-onset and late hematogenous PJIs, there has been significant work to try to define the optimal management of Staphylococcal PJI treated with a DAIR procedure [18]. The combination of Rifampicin plus Levofloxacin highlights good results for acute Staphylococcal infections [71,74]. However, the necessary duration of therapy for some patients with PJI may need to be very long to continue the benefit [22].

When considering alternatives to DAIR, a 2-stage exchange technique is typically regarded as the "gold standard" for the management of late and chronic PJI. The success rate of hip arthroplasty surgery is almost 90%, according to long-term statistics [75]. For knee arthroplasty infections treated with a two-stage arthroplasty exchange, the reported success rate ranges from 72% to 95% [33,76–81]. However, it's important to note that this approach is typically reserved for patients with prolonged symptom duration and the presence of mature biofilms. [23], thus being more applicable to chronic PJIs.

In contrast to the two-stage revision protocol, an alternative approach known as one-stage revision has been suggested, offering several advantages. These benefits include shorter hospital stays, avoidance of a second procedure along with its associated complications, enhanced postoperative mobility and pain management, as well as cost reduction [82]. However, it is important to note that the one-stage revision protocol is typically recommended for patients who have relatively intact or minimally compromised bone and soft tissue. Additionally, it is generally suitable for individuals who have not undergone previous revision surgeries or have not received treatment with biofilm-active antibiotics. In such cases, the one-stage exchange method is considered the preferred treatment option [23].

In a meta-analysis encompassing 375 patients who underwent one-stage arthroplasty exchanges, the findings revealed a reinfection rate of 13%, indicating an 87% freedom from reinfection [83].

However, it is crucial to remember the primary objective behind arthroplasty, which is to alleviate pain and restore full functionality. The implant's fixation is designed to be dependable and long-lasting, minimising the risks of fractures and damage to the surrounding soft tissues. Considering the dual objective of treating the infection while preserving optimal function, it is important to contemplate the option of retaining the implant. By doing so, the aim remains to achieve the best possible outcome in terms of both infection management and functional recovery [84].

Additionally, in contrast to DAIR, one-stage and two-stage protocols appear to bear the disadvantages of increased costs, higher skill requirements, and worse post-operative joint functions [14,85–88] and they are more indicated in contexts of late and chronic infections, potentially after failed DAIR [89].

4.1. Strengths

The strengths of this study lie in the consistency of the cohort. Only early post-operative and acute hematogenous infections were included, given the fact that late and chronic PJI are associated with different outcomes and treatment strategies.

In addition, to improve the quality of the current review, all the included articles were subjectively evaluated by the Cochrane risk of bias tools [40] and by the critical appraisal tool by the Joanna Briggs Institute [39] in order to determine their potential risk of bias; no articles were judged as having a critical risk of bias.

Furthermore, multicentre studies were excluded from this systematic review in order to avoid potential bias due to treatments carried out in different settings and protocols.

4.2. Limitations

This study has some limitations. In some studies, data on the rate of re-infection, revision rate, microorganisms involved in infection, and the protocol of antibiotic therapy are not reported or adequately explained. In addition, the surgical procedure, duration, and type of antibiotic therapy are not consistent throughout the cohort, both due to the lack of a standardized protocol and to the different underlying pathogens causing the PJI, yielding severe bias in the reported outcomes.

At the same time, the higher rates of success reported in the current study may have occurred due to the small sample size of some included studies [43] and, additionally, the present results are not stratified between hips and knee infections.

The diagnostic criteria to define a PJI and the antibiotic regimen applied in each study are also not constant throughout the whole cohort, and the inclusion of revision arthroplasties as index procedures may induce bias towards more unfavorable results. Also, another limitation of this study lies in the choice to exclude multi-centre studies, which, on the one hand, aimed at avoiding diagnostic and treatment factors biassed solely on location, while on the other, majorly decreased the cohort of this study.

Additionally, the heterogeneous length of follow-up may generate some inconsistency within the outcomes, given the fact that one study presents a mean follow-up of less than 12 months [48]. Furthermore, studies involving procedures from the late 1990s to the early 2000s may involve a greater risk of treatment failure due to the lack of updates in the treatment that was performed at the time.

Finally, as observational studies constituted the main source for the analysis, selection bias and confounding factors due to diverse expectations in reverse total shoulder arthroplasty (RTSA) patients should be taken into consideration.

5. Conclusions

In conclusion, even though the debridement, antibiotics, and implant retention (DAIR) procedure is quite limited, it is still considered an effective option for patients developing an early postoperative or acute hematogenous periprosthetic joint infection (PJI). However, there is a lack of studies, in particular randomized control trials (RCTs), comparing DAIR with one-stage and two-stage revision protocols in the setting of early PJIs, reflecting the necessity to conduct further high-quality studies to face the burden of early PJI.

Funding

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Umile Giuseppe Longo reports a relationship with Journal of ISAKOS that includes: board membership.

Authors contributions

Conceptualization, U.G.L. and S.D.S.; methodology, B.B., A.L.; software, I.P.; validation, U.G.L., N.C.B.; formal analysis, B.B., A.L.; investigation, B.B., B.B, A.L.; data curation, B.B., A.L.; writing—original draft preparation, B.B., B.B., A.L.; writing—review and editing, S.D.S.; visualization, N.C.B.; supervision, U.G.L. and S.L.; project administration, S.L. All authors have read and agreed to the published version of the manuscript.

Ethical approval

Not applicable.

Consent to participate

Not applicable.

Consent to publish

Not applicable.

Availability of data and materials

Not applicable.

Code availability

Not applicable.

Acknowledgement

Not applicable.

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