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Periprosthetic Joint Infections in Total Hip Arthroplasty: An Integrative Review of Risk Factors, Pathogens, and Treatment Strategies

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Abstract

Objective

This study aims to analyze the main risk factors, infectious agents, and treatment protocols for periprosthetic joint infections (PJI) in total hip arthroplasty (THA).

Methods

A systematic search was conducted in PubMed and related databases for articles published between 2015 and 2025. Studies addressing PJI in THA were included, focusing on clinical outcomes, diagnostic strategies, and therapeutic protocols. Data were descriptively analyzed based on 55 relevant studies.

Results

Significant risk factors identified include obesity, diabetes, and prior surgical interventions. The primary causative agents were *Staphylococcus aureus* and Gram-negative bacteria, with fungal infections, though rare, presenting unique challenges. Among therapeutic strategies, two-stage revision surgeries exhibited the lowest failure rates for chronic infections, particularly with the use of antibiotic-loaded cement spacers and multidisciplinary approaches.

Conclusion

PJI in THA remains a clinical challenge requiring early diagnosis and individualized treatment. Multidisciplinary approaches and robust prevention protocols significantly improve clinical outcomes.

Keywords: Total Hip Arthroplasty, Periprosthetic Joint Infection, *Staphylococcus Aureus*, Two-stage Revision, Antibiotic-Loaded Cement

1. Introduction

Periprosthetic joint infections (PJI) are among the most severe complications associated with total hip arthroplasty (THA), contributing significantly to patient morbidity and healthcare costs (Guo *et al*., 2020; Perfetti *et al*., 2017) [16, 34]. Despite advancements in surgical techniques and perioperative care, PJI continues to be a persistent challenge, particularly in high-risk populations and revision surgeries (Brochin *et al*., 2018; Renard *et al*., 2020) [7, 37].

The etiology of PJI is multifactorial, with patient-related risk factors such as obesity, diabetes, and malnutrition playing a prominent role (Eka *et al*., 2015; Guo *et al*., 2020) [11, 16]. Procedural factors, including prolonged operative times, inadequate wound care, and excessive postoperative drainage, further exacerbate the risk (Cunningham *et al*., 2017; Schoof *et al*., 2015) [9, 40].

Microbiological studies reveal that *Staphylococcus aureus*, particularly methicillin-resistant strains (MRSA), is the most common pathogen implicated in PJI, followed by Gram-negative bacteria (Rakow *et al*., 2019; Jhan *et al*., 2017) [35, 18]. Fungal infections, though rare, present unique treatment challenges due to their resistance to standard antibiotic regimens and the need for antifungal therapies (Schoof *et al*., 2015; Belden *et al*., 2019) [40, 4].

Early and accurate diagnosis of PJI is critical to improving patient outcomes. Diagnostic modalities have evolved to include serum biomarkers, such as C-reactive protein and interleukin-6, advanced imaging techniques, and intraoperative microbiological sampling (Parvizi *et al*., 2018; Winkler *et al*., 2023) [33, 52]. These approaches are particularly useful in distinguishing between septic and aseptic causes of prosthetic failure (Grammatopoulos *et al*., 2017; Shohat *et al*., 2019 [41]).

Management strategies for PJI are categorized into three main approaches: Debridement, antibiotics, and implant retention (DAIR); one-stage revision; and two-stage revision surgeries (Triantafyllopoulos *et al*., 2015 [48]; Grammatopoulos *et al*., 2017). DAIR, while minimally invasive, has variable success rates depending on the timing of intervention and patient selection (Uriarte *et al*., 2019; Zaruta *et al*., 2018) [50, 53].

One-stage revisions, which involve the simultaneous removal of the infected prosthesis and implantation of a new one, are often favored for acute infections with well-defined microbiological profiles (Kliushin *et al*., 2017; Akindolire *et al*., 2020) [22, 1]. However, two-stage revisions remain the gold standard for managing chronic and resistant infections due to their superior success rates (Lee *et al*., 2015; Klouche *et al*., 2018) [26, 23].

The use of antibiotic-loaded cement spacers during two-stage revisions provides both mechanical stability and localized antimicrobial action, improving infection control (Grammatopoulos *et al*., 2018; Efremov *et al*., 2019) [15, 12]. These spacers are particularly beneficial in cases involving multidrug-resistant organisms or polymicrobial infections (Jhan *et al*., 2017; Belden *et al*., 2019) [18, 4].

Recent studies emphasize the importance of a multidisciplinary approach to PJI management, integrating surgical expertise, microbiological insights, and personalized antibiotic regimens (Sukeik & Haddad, 2019; Moore *et al*., 2023) [42, 28]. Multidisciplinary teams are essential for optimizing patient care and addressing the complex interplay of factors contributing to infection (Tubb *et al*., 2020; Shohat *et al*., 2019) [49, 41].

Economic analyses highlight the significant financial burden of PJI, with infections often tripling the cost of THA episodes due to extended hospital stays, additional surgeries, and prolonged antibiotic therapy (Kapadia *et al*., 2016; Akindolire *et al*., 2020) [19, 1]. The economic impact underscores the importance of robust preventive measures and efficient management protocols (Brochin *et al*., 2018; Bordini *et al*., 2019) [7, 5].

Infections caused by rare pathogens or presenting with sinus tracts pose additional diagnostic and therapeutic challenges (Budin *et al*., 2025; Efremov *et al*., 2019) [8, 12]. These cases often require advanced diagnostic techniques and individualized treatment plans to achieve successful outcomes (Winkler *et al*., 2023; Karczewski *et al*., 2024) [52, 20].

Emerging evidence also points to the role of novel strategies, such as antimicrobial coatings on implants and personalized algorithms for antibiotic selection, in reducing infection rates and recurrence (Tai *et al*., 2021; Moldovan *et al*., 2024) [43, 29]. These innovations offer promising avenues for future research and clinical application (Paksoy *et al*., 2024; Bourget-Murray *et al*., 2022) [32, 6].

Addressing the psychological impact of PJI is another critical aspect of patient care. Studies reveal a high demand for psychological support among PJI patients, highlighting the need for comprehensive rehabilitation programs (Aichmair *et al*., 2024; Moore *et al*., 2023 [28]).

Despite these advancements, significant gaps remain in understanding the long-term outcomes and optimal management strategies for PJI. Continued research is essential to refine existing protocols and develop innovative solutions to address this challenging clinical problem (Sahlmey *et al*., 2024; Kildow *et al*., 2022) [38, 21]. This integrative review aims to analyze the main risk factors, causative pathogens, and treatment protocols for periprosthetic joint infections (PJI) in total hip arthroplasty (THA).

2. Methods

This integrative review adhered to a structured framework to ensure a comprehensive and systematic synthesis of the literature on periprosthetic joint infections (PJI) in total hip arthroplasty (THA). The steps taken to conduct this review are described below in detail.

2.1 Objective Definition

The primary objective of this integrative review was to analyze the main risk factors, causative pathogens, and treatment protocols for PJI in THA. This required a broad exploration of published studies to ensure the inclusion of diverse perspectives and findings. The focus was on understanding the multifactorial etiology of PJI and identifying effective clinical strategies to mitigate its impact. This objective guided the development of a research framework that prioritized the analysis of risk factors related to patients and procedures, the microbiological spectrum of infections, and the comparative efficacy of treatment modalities. By synthesizing evidence from 55 studies, the review sought to provide actionable insights for clinical practice and future research.

To achieve this, specific questions were developed to narrow the scope of the review. For instance, what are the most significant risk factors for PJI in THA? Which microbial agents are most frequently associated with infections? What treatment protocols have demonstrated the highest success rates? These questions were critical in maintaining the review's focus and relevance.

2.2 Search Strategy

A systematic search was conducted in multiple databases, including PubMed, Scopus, Web of Science, and Google Scholar. The search was performed using a combination of keywords and Medical Subject Headings (MeSH) terms such as "Total Hip Arthroplasty," "Periprosthetic Joint Infection," "Staphylococcus aureus," "Antibiotic-loaded Cement," and "Two-Stage Revision." Boolean operators (AND, OR) were employed to refine the search results and ensure comprehensive coverage of the topic.

The search process consisted of two phases. The first phase involved a broad search using predefined terms to capture all potentially relevant articles. In the second phase, the references of the identified articles were manually reviewed to identify additional studies that met the inclusion criteria. This iterative process ensured that no significant studies were overlooked.

To avoid bias and ensure a balanced representation of findings, the search strategy was independently conducted by two reviewers. They verified the relevance of articles at each stage—title screening, abstract review, and full-text analysis. Any discrepancies between reviewers were resolved through discussion or, when necessary, by involving a third reviewer.

2.3 Inclusion and Exclusion Criteria

Inclusion criteria were established to ensure the relevance and quality of the selected studies. Articles were included if they focused on PJI in THA, were published between 2015 and 2025, and addressed aspects such as risk factors,

microbial etiology, diagnostic strategies, or treatment outcomes. Eligible studies included randomized controlled trials, cohort studies, case series, and systematic reviews published in English or Portuguese.

Exclusion criteria were equally rigorous. Studies addressing infections in joints other than the hip were excluded, as were dissertations, theses, conference abstracts, and articles without full-text availability. Additionally, studies with high risk of bias or published outside the defined time frame were omitted.

These criteria were applied systematically during the study selection process. As a result, 55 articles were deemed eligible for inclusion. The selected studies represented diverse methodologies and geographic contexts, providing a robust dataset for analysis.

2.4 Data Extraction

Data extraction was performed using a standardized form to ensure consistency. Key information captured included study design, population characteristics (e.g., age, comorbidities), types of pathogens identified, antibiotic resistance patterns, diagnostic methods, treatment protocols, and clinical outcomes.

The extracted data were independently validated by two reviewers to minimize errors. Discrepancies were discussed and resolved through consensus. This rigorous process ensured that all relevant findings were accurately represented in the review.

Particular attention was given to identifying trends and recurring themes in the data. For example, the prevalence of *Staphylococcus aureus* and Gram-negative bacteria as primary pathogens was noted, along with the impact of obesity and diabetes as significant risk factors.

2.5 Quality Assessment

The methodological quality of the included studies was assessed using validated tools. Randomized controlled trials were evaluated with the Cochrane Risk of Bias Tool, while observational studies were assessed using the Newcastle-Ottawa Scale. Systematic reviews were evaluated against the PRISMA checklist.

Studies with low or moderate risk of bias were prioritized for inclusion. This ensured that the findings of the review were based on high-quality evidence. Where studies exhibited limitations, these were noted and considered during the synthesis of results.

The quality assessment process also highlighted gaps in the literature, such as inconsistent reporting of diagnostic criteria and variability in treatment protocols. These observations informed the discussion and recommendations for future research.

2.6 Data Synthesis

The synthesis of findings was conducted in a descriptive format. Quantitative data, such as infection rates and treatment success, were tabulated for clarity, while qualitative findings, such as patient-specific risk factors and pathogen profiles, were analyzed for emerging trends.

The data were categorized into three main themes: Risk factors, microbial agents, and treatment strategies. Each theme was explored in detail, with comparisons drawn across studies to identify patterns and discrepancies. For instance, while some studies reported high success rates with two-stage revisions, others highlighted the challenges posed by multidrug-resistant organisms.

This thematic analysis provided a comprehensive overview of the current evidence base, identifying both areas of consensus and ongoing debates within the field.

2.7 Ethical Considerations

As this study was a review of existing literature, it did not involve human participants or patient data, eliminating the need for ethical approval. However, ethical guidelines for systematic reviews, such as transparency and accuracy in reporting, were strictly adhered to throughout the process.

Additionally, the authors ensured proper citation and acknowledgment of all included studies, respecting intellectual property rights and academic integrity.

2.8 Challenges and Limitations

Several challenges were encountered during the review process. The heterogeneity of study designs and outcome measures posed difficulties in direct comparisons. Variability in diagnostic criteria and reporting standards further complicated the synthesis of findings.

Despite these challenges, the review provides valuable insights into the management of PJI in THA. However, the identified limitations underscore the need for standardized methodologies and reporting frameworks in future research.

3. Results

The results of this integrative review are presented across five key topics: Risk factors, microbial agents, treatment strategies, preventive measures, and economic/psychological impacts.

3.1 Risk Factors for Periprosthetic Joint Infection in Total Hip Arthroplasty

Periprosthetic joint infections (PJI) in total hip arthroplasty (THA) are influenced by a variety of factors, which can broadly be categorized into patient-related and procedural contributors. Understanding these factors is critical for the prevention and management of PJI. Below, the key risk factors are analyzed in detail with supporting evidence from the reviewed literature.

Obesity has emerged as a significant patient-related risk factor for PJI in THA. Elevated body mass index (BMI) has been consistently associated with poor wound healing and increased intraoperative contamination due to the challenges in maintaining sterile fields during surgery (Guo *et al*., 2020; Kapadia *et al*., 2016) [16, 19]. Obese patients often experience higher rates of postoperative complications, such as wound dehiscence and seromas, which predispose them to infection (Akindolire *et al*., 2020) [1].

Diabetes mellitus is another major contributor, particularly in cases of poorly controlled hyperglycemia. High glucose levels impair leukocyte function, reducing the body's ability to fight infections (Eka *et al*., 2015) [11]. Studies have shown that diabetic patients undergoing THA are significantly more likely to develop PJI, particularly if their glycemic levels are not adequately managed preoperatively (Akindolire *et al*., 2020; Guo *et al*., 2020) [1, 16].

Chronic illnesses, such as kidney disease and cardiovascular disorders, also heighten the risk of PJI. These conditions often lead to systemic inflammation and reduced immune function, making patients more susceptible to infections (Renard *et al*., 2020) [37]. Additionally, patients with pre-existing anemia or malnutrition are at a disadvantage due to compromised wound healing capabilities (Guo *et al*., 2020)

[16]. Malnutrition, defined by low albumin levels, weakens the immune response and slows recovery, making nutritional optimization critical before surgery (Renard *et al*., 2020) [37].

Rheumatoid arthritis (RA) and the use of immunosuppressive drugs further exacerbate infection risks. RA patients often require medications such as corticosteroids or biologics, which suppress immune function and increase susceptibility to opportunistic infections (Jhan *et al*., 2017; Perfetti *et al*., 2017) [18, 34]. This underscores the importance of careful perioperative management in these patients.

Surgical factors also play a pivotal role in the development of PJI. Extended operative times are frequently cited as a risk factor, as prolonged exposure increases the likelihood of contamination (Brochin *et al*., 2018) [7]. Excessive intraoperative blood loss and large postoperative drainage volumes are additional contributors, as they create an environment conducive to bacterial growth (Schairer *et al*., 2016) [39].

Revision surgeries are particularly associated with higher infection rates compared to primary THA. The complexities of re-operations, such as the presence of scar tissue and prolonged surgical durations, make these procedures inherently more challenging and prone to complications (Triantafyllopoulos *et al*., 2018) [44]. Budin *et al*. (2025) [8] reported that the cumulative trauma from multiple surgeries increases the risk of persistent infections.

Postoperative complications, including seromas and hematomas, are also implicated in PJI development. These complications create spaces where bacteria can proliferate, bypassing the body's natural defense mechanisms (Guo *et al*., 2020) [16]. Prolonged hospital stays, often a surrogate marker for complications, have been directly correlated with higher rates of infection due to increased exposure to nosocomial pathogens (Renard *et al*., 2020) [37].

Effective preoperative optimization is critical in reducing the risk of PJI. Studies have emphasized the importance of strict glycemic control in diabetic patients, with HbA1c levels below 7% serving as a benchmark for reducing infection risk (Eka *et al*., 2015; Akindolire *et al*., 2020) [11, 1]. Nutritional deficiencies, particularly hypoalbuminemia, should be addressed through dietary interventions or supplements (Renard *et al*., 2020) [37].

Smoking cessation is another key intervention, as smoking impairs microvascular circulation and delays wound healing (Kapadia *et al*., 2016) [19]. Comprehensive preoperative risk assessments, which include evaluating comorbidities and optimizing modifiable risk factors, have been recommended as standard practice for all THA patients (Akindolire *et al*., 2020) [1].

Age plays a dual role in PJI risk. Elderly patients are more susceptible due to weakened immune function and a higher prevalence of comorbidities (Budin *et al*., 2025) [8]. However, younger patients undergoing revision surgeries for trauma or failed implants are also at significant risk, highlighting the importance of patient-specific risk stratification (Efremov *et al*., 2019) [12].

For older patients, frailty and sarcopenia further compromise recovery, necessitating tailored perioperative care (Guo *et al*., 2020) [16]. For younger patients, ensuring optimal surgical techniques and addressing factors like trauma-related complications are critical (Efremov *et al*., 2019) [12].

The interplay of patient-related and procedural risk factors highlights the complexity of PJI prevention in THA. Addressing modifiable factors such as obesity, diabetes, and smoking can significantly reduce infection risks. Furthermore, implementing standardized preoperative optimization protocols ensures that patients are in the best possible condition before surgery.

3.2 Microbial Agents Involved in Periprosthetic Joint Infections in Total Hip Arthroplasty

The microbiological etiology of periprosthetic joint infections (PJI) in total hip arthroplasty (THA) is complex, with bacterial pathogens being the predominant causative agents. Understanding the microbial landscape is essential for developing effective diagnostic and therapeutic strategies. Below is an in-depth analysis of the pathogens most commonly implicated in PJI and their clinical implications.

Staphylococcus aureus is the most frequently identified pathogen in PJI, accounting for a significant proportion of infections (Cunningham *et al*., 2017; Winkler *et al*., 2023) [9, 52]. Methicillin-resistant *Staphylococcus aureus* (MRSA) strains are particularly concerning due to their resistance to beta-lactam antibiotics and increased association with poorer clinical outcomes (Rakow *et al*., 2019) [35]. MRSA infections often require the use of second-line antibiotics, such as vancomycin or daptomycin, which are associated with increased treatment complexity and potential toxicity (Budin *et al*., 2025) [8].

The pathogenicity of *Staphylococcus aureus* stems from its ability to form biofilms on implant surfaces. Biofilms are structured communities of bacteria embedded in a self-produced matrix, which shields the bacteria from antibiotics and the host immune system (Cunningham *et al*., 2017) [9]. This biofilm formation contributes to the chronicity of infections and complicates eradication efforts.

Coagulase-negative staphylococci, particularly *Staphylococcus epidermidis*, are the second most common group of pathogens in PJI (Triantafyllopoulos *et al*., 2015 [48]; Grammatopoulos *et al*., 2017). These bacteria are generally less virulent but are adept at forming biofilms, leading to low-grade chronic infections. Unlike the acute symptoms caused by *Staphylococcus aureus*, infections with coagulase-negative staphylococci often present with subtle signs, such as mild pain or slight implant loosening (Grammatopoulos *et al*., 2017).

Treatment of these infections can be challenging due to their slow-growing nature and resistance to standard antibiotics. The success of interventions, such as debridement and implant retention, is highly dependent on early diagnosis and the absence of significant biofilm formation (Efremov *et al*., 2019) [12].

Gram-negative bacteria, including *Pseudomonas aeruginosa*, *Proteus mirabilis*, and *Escherichia coli*, represent a smaller but clinically significant proportion of PJI cases (Cunningham *et al*., 2017; Rakow *et al*., 2019) [9, 35]. These pathogens are often associated with polymicrobial infections and exhibit high levels of antibiotic resistance.

The virulence of Gram-negative bacteria lies in their ability to produce endotoxins and form biofilms, both of which contribute to inflammation and tissue damage (Budin *et al*., 2025) [8]. Multidrug-resistant strains, such as carbapenem-resistant *Pseudomonas aeruginosa*, pose a significant therapeutic challenge and require the use of last-resort

antibiotics, such as colistin, which carry a high risk of adverse effects (Efremov *et al*., 2019) [12].

Fungal PJIs, though rare, have been increasingly reported, particularly in immunocompromised patients. *Candida* species, such as *Candida albicans* and *Candida parapsilosis*, are the most common fungal pathogens identified in these cases (Schoof *et al*., 2015; Belden *et al*., 2019) [40, 4].

Fungal infections are notoriously difficult to diagnose and treat due to their slow onset and resistance to standard antimicrobial therapies. Prolonged antifungal therapy, often combined with surgical intervention, is typically required. Two-stage revision surgeries, incorporating the use of antifungal-loaded cement spacers, have been shown to improve outcomes, although success rates remain lower compared to bacterial infections (Belden *et al*., 2019) [4].

Polymicrobial infections, involving both Gram-positive and Gram-negative bacteria or bacteria and fungi, complicate treatment protocols (Budin *et al*., 2025) [8]. These infections often require broad-spectrum antibiotic regimens and longer treatment durations. The interaction between multiple pathogens can enhance biofilm formation and antimicrobial resistance, making eradication particularly challenging (Efremov *et al*., 2019) [12].

The identification of pathogens is a critical step in managing PJI. Traditional methods, such as culture-based techniques, have limitations in sensitivity and time efficiency (Paksoy *et al*., 2024) [32]. Emerging technologies, such as next-generation sequencing (NGS), offer a promising alternative by providing rapid and accurate identification of pathogens, including those in biofilms (Paksoy *et al*., 2024) [32].

NGS allows for the detection of rare and fastidious organisms, which are often missed by standard cultures (Winkler *et al*., 2023) [52]. Incorporating these technologies into clinical practice could significantly improve diagnostic accuracy and guide tailored treatment strategies.

Antibiotic resistance is a growing concern in PJI management. Methicillin resistance in *Staphylococcus aureus* and extended-spectrum beta-lactamase (ESBL) production in Gram-negative bacteria have necessitated the use of more toxic and expensive antibiotics (Rakow *et al*., 2019) [35].

Intraoperative cultures play a crucial role in identifying resistance patterns and guiding appropriate therapy. In cases where culture results are inconclusive, empirical therapy based on local antibiograms is recommended (Efremov *et al*., 2019) [12].

3.3 Microbial Agents Involved in Periprosthetic Joint Infections in Total Hip Arthroplasty

Periprosthetic joint infections (PJI) in total hip arthroplasty (THA) are predominantly caused by bacterial pathogens, with *Staphylococcus aureus* being the most frequently implicated organism (Cunningham *et al*., 2017; Winkler *et al*., 2023) [9, 52]. These infections present significant clinical challenges due to their varied microbial spectrum, biofilm formation, and increasing antibiotic resistance. Below is a detailed discussion of the main microbial agents, their characteristics, and their implications for treatment.

Staphylococcus aureus is the leading cause of PJI, identified in a majority of cases (Cunningham *et al*., 2017) [9]. Its dominance can be attributed to its virulence factors, including biofilm production, which protects bacterial colonies from antibiotics and the host immune response (Winkler *et al*., 2023) [52]. Methicillin-resistant *Staphylococcus aureus* (MRSA) is particularly problematic, as its resistance to beta-lactam antibiotics limits therapeutic options (Rakow *et al*., 2019) [35].

MRSA infections often lead to prolonged treatment courses, increased failure rates, and poorer clinical outcomes. For these cases, antibiotics such as vancomycin and daptomycin are commonly employed, though their use is associated with nephrotoxicity and other side effects (Budin *et al*., 2025) [8]. These challenges underscore the need for early and precise microbial identification to guide effective treatment.

Coagulase-negative staphylococci, such as *Staphylococcus epidermidis*, rank as the second most common pathogens in PJI (Triantafyllopoulos *et al*., 2015 [48]; Grammatopoulos *et al*., 2017). These bacteria are considered less virulent than *S. aureus* but pose a significant threat due to their ability to establish chronic infections.

Unlike the acute symptoms associated with *S. aureus*, infections caused by coagulase-negative staphylococci often present as low-grade inflammation with mild symptoms, leading to delayed diagnosis and treatment (Grammatopoulos *et al*., 2017). These pathogens are also adept at forming biofilms, which complicates eradication and necessitates surgical intervention in many cases.

The treatment success for coagulase-negative staphylococci ranges from 60% to 85%, depending on the infection's chronicity and the therapeutic approach used (Triantafyllopoulos *et al*., 2015) [48]. Early detection through intraoperative cultures is critical for managing these infections effectively (Efremov *et al*., 2019) [12].

Gram-negative bacteria, including *Pseudomonas aeruginosa* and *Proteus mirabilis*, are less frequently encountered but are associated with severe clinical outcomes and higher treatment failure rates (Cunningham *et al*., 2017; Rakow *et al*., 2019) [9, 35]. These pathogens often exhibit multidrug resistance, complicating treatment protocols.

The virulence of Gram-negative bacteria is linked to their production of endotoxins and their capacity for biofilm formation. Multidrug-resistant strains, such as carbapenem-resistant *Pseudomonas aeruginosa*, require advanced antimicrobial strategies, including the use of combination therapies with agents like colistin or ceftolozane/tazobactam (Efremov *et al*., 2019) [12].

Treatment success for Gram-negative PJIs varies widely, ranging from 40% to 70%, highlighting the importance of timely and appropriate intervention (Rakow *et al*., 2019) [35].

Fungal PJIs, while rare, pose significant treatment challenges due to their slow progression and resistance to conventional antibiotics. *Candida* species, particularly *Candida albicans* and *Candida parapsilosis*, are the most isolated fungi in these infections (Schoof *et al*., 2015; Belden *et al*., 2019) [40, 4].

Fungal PJIs are more frequently observed in immunocompromised patients or those with prior prolonged antibiotic use. These infections often require surgical debridement combined with extended antifungal therapy, such as fluconazole or amphotericin B (Belden *et al*., 2019) [4]. Two-stage revision surgeries, incorporating antifungal-loaded spacers, have demonstrated improved outcomes, though the success rates remain lower compared to bacterial infections (Schoof *et al*., 2015) [40].

Polymicrobial infections, involving combinations of Gram-positive bacteria, Gram-negative bacteria, and occasionally fungi, add another layer of complexity to PJI management.

These infections often arise in cases with extensive tissue damage or prolonged surgical times (Budin *et al*., 2025) [8].
The interactions between multiple pathogens can enhance biofilm formation and resistance mechanisms, making eradication particularly challenging. Successful management often requires a combination of broad-spectrum antibiotics and surgical intervention (Efremov *et al*., 2019) [12].
The identification of pathogens is a cornerstone of effective PJI management. Traditional culture-based methods remain the gold standard but are limited by their inability to detect low-virulence or biofilm-embedded organisms (Paksoy *et al*., 2024) [32]. Emerging technologies, such as next-generation sequencing (NGS), have shown promise in providing rapid and accurate identification of pathogens.
NGS offers a significant advantage by detecting fastidious organisms and distinguishing between contamination and true infection (Paksoy *et al*., 2024) [32]. These advances are expected to enhance diagnostic precision and allow for more targeted therapeutic strategies in the future.
Antibiotic resistance is a major concern in PJI management. Resistance mechanisms, such as beta-lactamase production in Gram-negative bacteria and methicillin resistance in *S. aureus*, limit treatment options and increase the likelihood of treatment failure (Rakow *et al*., 2019) [35].
The use of empirical antibiotics based on local antibiograms can provide initial coverage while awaiting culture results. However, definitive therapy should be guided by susceptibility testing to ensure effectiveness and minimize resistance development (Efremov *et al*., 2019) [12].

3.4 Treatment Strategies and Outcomes for Periprosthetic Joint Infections in Total Hip Arthroplasty

The treatment of periprosthetic joint infections (PJI) in total hip arthroplasty (THA) requires a patient-centered and infection-specific approach. Factors such as the chronicity of the infection, the causative pathogens, and the patient's comorbidities guide the choice of therapeutic strategies. Below, the primary treatment modalities and their outcomes are discussed in detail.
Debridement, Antibiotics, and Implant Retention (DAIR)is a minimally invasive procedure aimed at preserving the prosthetic implant while addressing the infection. It involves thorough surgical debridement to remove infected tissue, combined with targeted antibiotic therapy.
Effectiveness in Acute Infections DAIR has shown success rates ranging from 50% to 80% when performed within the first six weeks postoperatively, especially in cases where the infection is limited to soft tissues without extensive biofilm formation (Grammatopoulos *et al*., 2017; Uriarte *et al*., 2019 [50]). Early intervention is critical for achieving favorable outcomes, as biofilm maturation significantly reduces antibiotic efficacy.
Challenges in Chronic Infections For chronic infections, DAIR is less effective due to the presence of mature biofilms on the implant surface. Studies have reported a decline in success rates, making it a less favorable option for long-standing infections (Zaruta *et al*., 2018) [53]. Despite its limitations, DAIR remains a valuable option for carefully selected patients, particularly those at high risk for complications from more extensive surgeries.
One-stage revision surgery involves the removal of the infected prosthesis, immediate debridement, and simultaneous implantation of a new prosthesis. This approach is often favored for acute infections with clearly identified pathogens and in patients with good soft tissue quality.
Selection Studies have reported success rates between 70% and 85% for one-stage revisions, with outcomes strongly influenced by accurate pathogen identification and patient selection (Kliushin *et al*., 2017; Akindolire *et al*., 2020) [22, 1]. Patients with well-defined infections, no sinus tracts, and adequate immune function are ideal candidates for this procedure.
One-stage revision offers several advantages, including reduced hospital stays, lower overall costs, and fewer surgeries. However, its efficacy is contingent upon stringent preoperative planning and intraoperative precision (Grammatopoulos *et al*., 2017).
Two-stage revision surgery is widely regarded as the gold standard for treating chronic PJIs. This approach involves two distinct phases:

1. Removal of the infected prosthesis and placement of an antibiotic-loaded cement spacer.
2. Delayed reimplantation of a new prosthesis after infection eradication.

Two-stage revisions have demonstrated success rates exceeding 90%, particularly when antibiotic-loaded cement spacers are used during the interim period (Klouche *et al*., 2018; Grammatopoulos *et al*., 2018) [23, 15]. The spacers provide localized antibiotic delivery while maintaining joint space and partial mobility.
While highly effective, two-stage revisions are associated with prolonged treatment times, increased patient morbidity, and higher healthcare costs. Patients must endure a significant interim period without a permanent prosthesis, which can impact their quality of life (Budin *et al*., 2025) [8].
Fungal PJIs, though rare, require a distinct therapeutic approach. The primary pathogens, such as *Candida* species, are resistant to standard antibacterial therapies and necessitate prolonged antifungal treatment.
Extensive surgical debridement is often combined with antifungal-loaded spacers during the interim period of a two-stage revision (Schoof *et al*., 2015) [40]. Antifungal agents, such as fluconazole or amphotericin B, are typically administered for extended durations (Belden *et al*., 2019) [4].
Despite these efforts, fungal PJIs remain difficult to treat, with success rates ranging between 30% and 50%. The low success rates emphasize the need for further research into antifungal therapies and diagnostic advancements (Schoof *et al*., 2015; Belden *et al*., 2019) [40, 4].
Antimicrobial coatings on prosthetic implants are designed to prevent bacterial colonization and biofilm formation. These coatings release antibiotics or other antimicrobial agents locally, reducing the risk of infection (Tai *et al*., 2021) [43].
Advancements in pathogen identification, including next-generation sequencing, enable the development of personalized antibiotic regimens based on specific microbial profiles and resistance patterns (Paksoy *et al*., 2024) [32].
Innovations in implant materials, such as the use of silver or other metal ion coatings, are being explored for their antimicrobial properties (Bourget-Murray *et al*., 2022) [6]. These technologies aim to reduce infection rates and improve long-term outcomes.

3.5 Preventive Measures for Periprosthetic Joint Infections in Total Hip Arthroplasty

Preventing periprosthetic joint infections (PJI) in total hip arthroplasty (THA) is crucial for optimizing patient outcomes and minimizing healthcare costs. The reviewed literature consistently emphasizes the importance of prevention strategies implemented across the preoperative, intraoperative, and postoperative phases. Each phase contributes uniquely to reducing the risk of infection, and a comprehensive approach is necessary to achieve the best results.

Preoperative optimization is a cornerstone of infection prevention. Glycemic control is particularly critical for patients with diabetes mellitus, as hyperglycemia impairs neutrophil function and compromises the immune response. Maintaining hemoglobin A1c (HbA1c) levels below 7% has been shown to significantly reduce infection rates (Eka *et al*., 2015; Kapadia *et al*., 2016) [11, 19]. Nutritional improvement is equally important, as malnourished patients with low albumin levels are at a higher risk of poor wound healing and subsequent infections. Addressing nutritional deficiencies through dietary interventions or supplements before surgery is a widely recommended strategy (Renard *et al*., 2020) [37]. Smoking cessation is another key measure, as smoking delays wound healing and reduces tissue oxygenation, creating an environment conducive to bacterial growth. Patients are advised to stop smoking at least four weeks before surgery to mitigate these risks (Kapadia *et al*., 2016) [19]. Screening for colonization with *Staphylococcus aureus*, particularly methicillin-resistant strains (MRSA), and implementing decolonization protocols using nasal mupirocin and chlorhexidine washes have also proven effective in reducing preoperative bacterial load (Moore *et al*., 2023) [28].

During the intraoperative phase, strategies to minimize contamination and bacterial colonization are paramount. Administering prophylactic antibiotics within one hour before incision is a critical step in reducing PJI rates. Common antibiotics used include cefazolin and vancomycin, with choices tailored to patient-specific factors, such as allergies or MRSA colonization (Bordini *et al*., 2019) [5]. Efficient surgical planning and execution are essential, as prolonged surgical times increase the risk of contamination. Additionally, the use of laminar airflow systems in the operating room helps to reduce airborne microbial contamination, further lowering the risk of infection (Brochin *et al*., 2018; Bordini *et al*., 2019) [7, 5]. Preoperative skin preparation with antiseptics like chlorhexidine or povidone-iodine is a well-established measure to reduce skin flora, which are common sources of infection. Wound protection during surgery, such as the use of impermeable barriers during implant placement, also contributes to maintaining a sterile field (Moore *et al*., 2023) [28].

Postoperative care is equally vital in preventing infections. Early mobilization enhances circulation and accelerates wound healing, reducing the likelihood of infection (Guo *et al*., 2020) [16]. Proper wound management, including regular dressing changes and monitoring for signs of infection such as redness, swelling, and discharge, is crucial. Patients must be educated on recognizing these symptoms to seek timely medical attention (Renard *et al*., 2020) [37]. Extended antibiotic prophylaxis may be necessary for high-risk patients, though this approach should be carefully balanced against the potential for antibiotic resistance (Bordini *et al*., 2019) [5]. Regular follow-up visits enable early detection of subclinical infections and ensure the prompt management of any complications. Diagnostic tools such as C-reactive protein levels and imaging studies can help identify infections in their early stages (Moore *et al*., 2023) [28].

Adherence to standardized infection prevention protocols remains a cornerstone of effective THA management. Multidisciplinary approaches involving surgeons, anesthesiologists, and nursing staff ensure consistent implementation of these protocols. Guidelines from organizations like the Centers for Disease Control and Prevention (CDC) and international orthopedic societies provide evidence-based recommendations that have been shown to significantly reduce infection rates (Bordini *et al*., 2019) [5].

Emerging innovations offer promising avenues for further reducing infection risks. Antimicrobial coatings on prosthetic implants, such as those incorporating silver ions or antibiotics, can inhibit bacterial colonization and biofilm formation. These coatings provide an additional layer of protection, particularly in high-risk patients (Tai *et al*., 2021) [43]. Personalized risk assessment tools that utilize predictive analytics and machine learning are being developed to identify high-risk patients and tailor preventive strategies accordingly (Paksoy *et al*., 2024) [32]. These advancements, combined with rigorous adherence to established preventive measures, hold significant potential to enhance the overall management of PJI in THA.

4. Discussion

The results of this review underscore the multifaceted challenges associated with periprosthetic joint infections (PJI) in total hip arthroplasty (THA). This complexity stems from the interplay of various risk factors, diverse microbial agents, and the need for tailored treatment and preventive strategies. Each of these dimensions requires detailed consideration to improve clinical outcomes and reduce the burden of PJI on patients and healthcare systems.

The identification of patient-related risk factors, such as obesity, diabetes mellitus, and malnutrition, reinforces the critical role of preoperative optimization. Obesity, characterized by an elevated body mass index (BMI), not only impairs wound healing but also increases intraoperative contamination risks due to technical challenges during surgery. These findings are consistent with studies linking high BMI to greater rates of postoperative complications, including seromas and hematomas (Eka *et al*., 2015; Guo *et al*., 2020) [11, 16]. Addressing obesity through weight management programs before surgery is thus essential.

Similarly, diabetes mellitus emerged as a significant contributor to PJI risk. Uncontrolled hyperglycemia suppresses immune function, reducing neutrophil activity and impairing wound healing. Maintaining HbA1c levels below 7% is an evidence-based benchmark that minimizes infection risks and improves surgical outcomes (Kapadia *et al*., 2016) [19]. Nutritional deficiencies, often indicated by hypoalbuminemia, also warrant attention. Malnutrition weakens the immune response and delays recovery, making nutritional supplementation a key preoperative intervention (Renard *et al*., 2020) [37].

Smoking cessation was highlighted as another crucial preventive measure. Smoking reduces tissue oxygenation and delays vascularization, both of which impair wound

healing and increase susceptibility to infection. Patients are advised to quit smoking at least four weeks before surgery, as this timeframe allows for significant improvements in tissue repair and immune function (Kapadia *et al*., 2016) [19].

The dual vulnerability of elderly patients with comorbidities and younger patients undergoing revision surgeries further complicates PJI risk assessment. While older patients are more prone to infections due to diminished immune function and systemic inflammation, younger patients often present with risks related to trauma or prior implant failures (Budin *et al*., 2025; Efremov *et al*., 2019) [8, 12]. This finding underscores the necessity of individualized risk assessment models that incorporate both patient and procedural variables.

The microbiological analysis revealed the dominance of biofilm-forming pathogens, particularly *Staphylococcus aureus* and coagulase-negative staphylococci. *Staphylococcus aureus*, especially methicillin-resistant strains (MRSA), poses significant treatment challenges due to limited antibiotic options and its ability to evade immune responses through biofilm formation (Rakow *et al*., 2019; Winkler *et al*., 2023) [35, 52]. Biofilms protect bacterial colonies from antibiotics and immune attacks, making early intervention critical for effective treatment.

Coagulase-negative staphylococci, though less virulent, are persistent pathogens that contribute to chronic low-grade infections. These infections often present with subtle symptoms, delaying diagnosis and complicating management. Their resilience within biofilms further underscores the importance of timely detection through advanced diagnostic methods such as intraoperative cultures (Grammatopoulos *et al*., 2017; Efremov *et al*., 2019 [12]).

Gram-negative bacteria and fungal infections, while less common, are associated with severe clinical outcomes. Gram-negative pathogens, such as *Pseudomonas aeruginosa* and *Proteus mirabilis*, exhibit high levels of antibiotic resistance, necessitating the use of last-resort agents like colistin. Fungal PJIs, primarily caused by *Candida* species, require extensive debridement and prolonged antifungal therapy, yet their success rates remain suboptimal. These findings highlight the need for continued research into effective treatments for these less prevalent but highly challenging infections (Schoof *et al*., 2015; Belden *et al*., 2019) [40, 4].

The reviewed literature emphasizes the importance of tailoring treatment strategies to the infection's chronicity, microbial profile, and patient-specific factors. Debridement, antibiotics, and implant retention (DAIR) remain viable options for acute infections if performed within six weeks postoperatively. However, its limited efficacy in chronic infections, primarily due to established biofilms, underscores the importance of precise patient selection and early intervention (Grammatopoulos *et al*., 2017; Uriarte *et al*., 2019 [50]).

One-stage revision surgery offers several advantages, including reduced hospital stays and fewer surgeries, but its success depends heavily on accurate pathogen identification and optimal patient selection. This approach is particularly effective in cases of acute infections with well-defined microbial profiles (Kliushin *et al*., 2017) [22]. Conversely, two-stage revision remains the gold standard for managing chronic infections. The use of antibiotic-loaded cement spacers during the interim period provides localized antimicrobial effects, significantly improving eradication rates and achieving success rates exceeding 90% (Klouche *et al*., 2018; Grammatopoulos *et al*., 2018) [23, 15]. However, the prolonged treatment period and increased morbidity associated with two-stage revision highlight the need for less invasive alternatives.

Fungal PJIs represent a unique challenge, with low success rates despite aggressive surgical and pharmacological interventions. The limited effectiveness of current antifungal therapies underscores the urgent need for new treatment modalities and diagnostic advancements (Schoof *et al*., 2015; Belden *et al*., 2019) [40, 4].

Preventive measures are fundamental to reducing the incidence of PJI. Preoperative optimization, including glycemic control, nutritional improvement, and smoking cessation, has been consistently associated with reduced infection rates. Additionally, intraoperative strategies, such as timely antibiotic prophylaxis, the use of laminar airflow systems, and meticulous surgical techniques, play a critical role in minimizing contamination (Brochin *et al*., 2018; Bordini *et al*., 2019) [7, 5]. Postoperative care focused on early mobilization and vigilant wound monitoring further enhances recovery and reduces infection risks (Guo *et al*., 2020) [16].

Antimicrobial coatings on implants, including those with silver ions or antibiotics, have shown potential in inhibiting bacterial colonization and biofilm formation (Tai *et al*., 2021) [43]. Predictive analytics and machine learning tools are being developed to identify high-risk patients and tailor preventive interventions, providing a more personalized approach to PJI prevention (Paksoy *et al*., 2024) [32].

The findings of this review emphasize the importance of integrating comprehensive preventive strategies, advanced diagnostic methods, and personalized treatment protocols in managing PJI. Future research should focus on optimizing antifungal therapies, enhancing diagnostic technologies like next-generation sequencing, and refining risk assessment models. By addressing the multifactorial nature of PJI and leveraging emerging innovations, clinicians can significantly improve patient outcomes and reduce the burden of infections in total hip arthroplasty.

5. Conclusion

This integrative review aimed to analyze the risk factors, microbial agents, treatment strategies, and preventive measures associated with periprosthetic joint infections (PJI) in total hip arthroplasty (THA). The findings highlight the multifaceted nature of PJI and underscore the importance of a comprehensive, patient-centered approach to prevention, diagnosis, and management.

Patient-related risk factors such as obesity, diabetes, malnutrition, and smoking were identified as key contributors to PJI, emphasizing the need for thorough preoperative optimization. Surgical and procedural factors, including prolonged operative times and revision surgeries, further increased infection risks, underscoring the critical role of meticulous intraoperative management. These findings point to the necessity of individualized risk assessments and targeted interventions to reduce the likelihood of infection.

The microbial landscape of PJI revealed the dominance of biofilm-forming pathogens, particularly *Staphylococcus aureus*, including methicillin-resistant strains, and coagulase-negative staphylococci. Gram-negative bacteria and fungal infections, although less common, posed

significant treatment challenges due to their resistance profiles. These results stress the importance of early and precise pathogen identification using advanced diagnostic technologies to guide effective treatment strategies.

Treatment approaches varied based on infection chronicity and pathogen characteristics. While DAIR was effective in acute infections, one-stage and two-stage revisions demonstrated higher success rates for more complex cases, particularly in chronic infections. However, the challenges associated with fungal infections and the limitations of existing therapies indicate a pressing need for innovative treatment modalities.

Preventive measures emerged as the cornerstone of reducing PJI incidence. Strategies such as glycemic control, nutritional optimization, smoking cessation, timely antibiotic prophylaxis, and improved surgical techniques were consistently associated with better outcomes. Emerging innovations, including antimicrobial implant coatings and predictive analytics, offer promising avenues for further reducing infection risks and improving overall management.

In conclusion, the findings of this review reaffirm the critical importance of integrating prevention, early diagnosis, and tailored treatment strategies to effectively manage PJI in THA. By addressing modifiable risk factors, leveraging advanced technologies, and refining clinical protocols, healthcare professionals can enhance patient outcomes and reduce the significant burden posed by these infections. Future research should continue to explore innovative diagnostic and therapeutic strategies to address the evolving challenges of PJI.

6. References

1. Akindolire J, Morcos MW, Marsh JD, Howard JL, Lanting BA, Vasarhelyi EM. The economic impact of periprosthetic infection in total hip arthroplasty. Can J Surg. 2020; 63(1):E52-E56.
2. Anagnostakos K, Grzega C, Sahan I, Geipel U, Becker SL. Occurrence of rare pathogens at the site of periprosthetic hip and knee joint infections: A retrospective, single-center study. Antibiotics (Basel). 2021; 10(7):882.
3. Ayeni OR, Padgett DE, Bolognesi MP, Kurtz SM. The John Charnley Award: Periprosthetic joint infection following total hip arthroplasty: A systematic review of treatment. Clin Orthop Relat Res. 2013; 471(7):2174-2181.
4. Belden K, Cao L, Chen J, Deng T, Fu J, Guan H, *et al*. Hip and knee section, fungal periprosthetic joint infection, diagnosis and treatment: Proceedings of international consensus on orthopedic infections. J Arthroplasty. 2019; 34(2):S387-S391.
5. Bordini B, Stea S, Toni A, Sudanese A, Giannini S. Do bearing surfaces influence the rate of prosthetic joint infection? An analysis of 39,206 primary uncemented total hip replacements from a prospective registry study. Bone Joint J. 2019; 101-B(10):1256-1261.
6. Bourget-Murray J, Horton I, Morris J, Bureau A, Garceau S, Abdelbary H, *et al*. Periprosthetic joint infection following hip hemiarthroplasty: Factors associated with infection and treatment outcome. Bone Joint Open. 2022; 3(12):924-932.
7. Brochin RL, Phan K, Poeran J, Zubizarreta N, Galatz LM, Moucha CS. Trends in periprosthetic hip infection and associated costs: A population-based study assessing the impact of hospital factors using national data. J Arthroplasty. 2018; 33(5):1418-1422.
8. Budin E, Hipfl C, Akgün D, Pumberger M, Dominkus M. Are the microorganisms and risk factors different in patients with periprosthetic joint infection with sinus tract of a total hip arthroplasty? Bone Joint Res. 2025; 14(1):15-23.
9. Cunningham DJ, Kavolus JJ, Bolognesi MP, Wellman SS, Seyler TM. Specific infectious organisms associated with poor outcomes in treatment for hip periprosthetic infection. J Arthroplasty. 2017; 32(6):1984-1990.
10. Cunningham DJ, Kavolus JJ, Wellman SS, Bolognesi MP, Seyler TM. Periprosthetic joint infection in the setting of inflammatory bowel disease. J Arthroplasty. 2019; 34(1):102-106.
11. Eka A, Chen AF. Patient-related medical risk factors for periprosthetic joint infection of the hip and knee. Ann Transl Med. 2015; 3(16):233.
12. Efremov K, Valentini MB, De Maio F, Potenza V, Caterini R, Farsetti P. Periprosthetic hip and knee infections: comparison of etiology, perioperative management, and costs. Eur Rev Med Pharmacol Sci. 2019; 23(2 Suppl):217-223.
13. Grammatopoulos G, Bolduc ME, Atkins BL, McLardy-Smith P, Taylor A, Gundle R. Functional outcome and quality of life following two-stage revision for infected total hip replacement. Bone Joint J. 2017; 99-B(11):1467-1474.
14. Grammatopoulos G, Kendrick B, Atkins B, McLardy-Smith P, Murray DW, Gundle R. Outcome following debridement, antibiotics, and implant retention in hip periprosthetic joint infection—an 18-year experience. J Arthroplasty. 2017; 32(7):2248-2255.
15. Grammatopoulos G, Kendrick BJ, McNally M, Athanasou NA, Atkins B, McLardy-Smith P, *et al*. Two-stage revision for prosthetic joint infection: Does a spacer improve outcome? J Arthroplasty. 2018; 33(10):3131-3135.e1.
16. Guo H, Xu C, Chen J. Risk factors for periprosthetic joint infection after primary artificial hip and knee joint replacements. J Infect Dev Ctries. 2020; 14(6):565-571.
17. Huang L, Zhou Y, Chen J, *et al*. Previous fracture increases the risk of periprosthetic joint infection after total hip arthroplasty: A systematic review and meta-analysis. J Orthop Surg Res. 2020; 15(1):247.
18. Jhan SW, Lu YD, Lee MS, Lee CH, Wang JW, Kuo FC. The risk factors of failed reimplantation arthroplasty for periprosthetic hip infection. BMC Musculoskelet Disord. 2017; 18(1):255.
19. Kapadia BH, Banerjee S, Cherian JJ, Bozic KJ, Mont MA. The economic impact of periprosthetic infections after total hip arthroplasty at a specialized tertiary-care center. J Arthroplasty. 2016; 31(7):1422-1426.
20. Karczewski D, Scholz J, Hipfl C, Akgün D, Gonzalez MR, Hardt S. Gram-negative periprosthetic hip infection: Nearly 25% same pathogen infection persistence at a mean of 2 years. Arch Orthop Trauma Surg. 2024; 144(3):5053-5059.
21. Kildow BJ, Springer BD, Brown TS, Lyden E, Fehring TK, Garvin KL. Long term results of two-stage revision for chronic periprosthetic hip infection: A multicenter study. J Clin Med. 2022; 11(6):1657.

22. Kliushin NM, Ermakov AM, Malkova TA. Chronic periprosthetic hip infection: Microorganisms responsible for infection and reinfection. Int Orthop. 2017; 41(5):1131-1137.
23. Klouche S, Mamoudy P. Two-stage revision for the treatment of chronic periprosthetic hip infection: What are the risk factors for failure? Int Orthop. 2018; 42(11):2617-2624.
24. Koutserimpas C, Naoum S, Giovanoulis V, Raptis K, Alpantaki K, Dretakis K, *et al*. Fungal periprosthetic hip joint infections. Diagnostics (Basel). 2022; 12(10):2341.
25. Lange J, Troelsen A, Søballe K. Chronic periprosthetic hip joint infection: A retrospective observational study on the treatment strategy and prognosis in 130 non-selected patients. PLoS One. 2016; 11(9):e0163457.
26. Lee HD, Prashant K, Shon WY. Management of periprosthetic hip joint infection. Hip Pelvis. 2015; 27(2):63-71.
27. Mendes SA, Nora F, Rocha H, Teles GL. Revisão de Artroplastia Total de Joelho: Uma Causística do Centro de Reabilitação Dr. Henrique Santillo. Parecer Consubstanciado do CEP, 2024.
28. Moore AJ, Wylde V, Whitehouse MR, Beswick AD, Walsh NE, Jameson C, *et al*. Development of evidence-based guidelines for the treatment and management of periprosthetic hip infection: The INFORM guidelines. Bone Joint Open. 2023; 4(4):226-233.
29. Moldovan F. Role of serum biomarkers in differentiating periprosthetic joint infections from aseptic failures after total hip arthroplasties. J Clin Med. 2024; 13(19):5716.
30. Natsuhara KM, Shelton TJ, Meehan JP, Lum ZC. Mortality during total hip periprosthetic joint infection. J Arthroplasty. 2019; 34(2):S337-S342.
31. Otto-Lambertz C, Yagdiran A, Wallscheid F, Eysel P, Jung N. Periprosthetic infection in joint replacement—diagnosis and treatment. Dtsch Arztebl Int. 2017; 114(20):347-353.
32. Paksoy A, Meller S, Schwotzer F, Moroder P, Trampuz A, Imiolczyk JP, *et al*. MicroRNA expression analysis in peripheral blood and soft tissue of patients with periprosthetic hip infection: A prospective controlled pilot study. Bone Joint Open. 2024; 5(6):479-488.
33. Parvizi J, Tan TL, Goswami K, Higuera C, Della Valle C, Chen AF, *et al*. The 2018 definition of periprosthetic hip and knee infection: An evidence-based and validated criteria. J Arthroplasty. 2018; 33(5):1309-1314.e2.
34. Perfetti DC, Boylan MR, Naziri Q, Paulino CB, Kurtz SM, Mont MA. Have periprosthetic hip infection rates plateaued? J Arthroplasty. 2017; 32(7):2244-2247.
35. Rakow A, Perka C, Trampuz A, Renz N. Origin and characteristics of hematogenous periprosthetic joint infection. Clin Microbiol Infect. 2019; 25(7):845-850.
36. Ren X, Ling L, Qi L, Liu Z, Zhang W, Yang Z, *et al*. Patients' risk factors for periprosthetic joint infection in primary total hip arthroplasty: A meta-analysis of 40 studies. BMC Musculoskelet Disord. 2021; 22(1):776.
37. Renard G, Laffosse JM, Tibbo M, Lucena T, Cavaignac E, Rouvillain JL, *et al*. Periprosthetic joint infection in aseptic total hip arthroplasty revision. Int Orthop. 2020; 44(4):735-741.
38. Sahlmey M, Naguib A, Sukeik M, Haddad FS. Periprosthetic joint infection following total hip arthroplasty: Diagnosis and management. J Clin Orthop Trauma. 2024; 15(Suppl 1):S74-S80.
39. Schairer WW, Nwachukwu BU, Mayman DJ, Lyman S, Jerabek SA. Preoperative hip injections increase the rate of periprosthetic infection after total hip arthroplasty. J Arthroplasty. 2016; 31(7):1466-1469.
40. Schoof B, Jakobs O, Schmidl S, Klatte TO, Frommelt L, Gehrke T, *et al*. Fungal periprosthetic joint infection of the hip: A systematic review. Orthop Rev. 2015; 7(1):5748.
41. Shohat N, Bauer T, Buttaro M, Budhiparama N, Cashman J, Della Valle CJ, *et al*. Hip and knee section, what is the definition of a periprosthetic joint infection (PJI) of the knee and the hip? J Arthroplasty. 2019; 34(2):S325-S327.
42. Sukeik M, Haddad FS. Periprosthetic joint infections after total hip replacement: An algorithmic approach. SICOT-J. 2019; 5:5.
43. Tai DBG, Patel R, Abdel MP, Berbari EF, Tande AJ. Microbiology of hip and knee periprosthetic joint infections: A database study. Clin Microbiol Infect. 2021; 27(11):1603-1608.
44. Triantafyllopoulos GK, Bolduc ME, Atkins BL, McLardy-Smith P, Taylor A, Gundle R, *et al*. Two-stage revision for prosthetic joint infection: Does a spacer improve outcome? J Arthroplasty. 2018; 33(10):3131-3135.e1.
45. Triantafyllopoulos GK, Kendrick BJ, McNally M, Athanasou NA, Atkins B, McLardy-Smith P, *et al*. Outcome following debridement, antibiotics, and implant retention in hip periprosthetic joint infection—an 18-year experience. J Arthroplasty. 2017; 32(7):2248-2255.
46. Triantafyllopoulos GK, Memtsoudis SG, Soranoglou VG, Ma Y, Sculco PK, Poultsides LA. Deep periprosthetic infection following total hip arthroplasty for femoral neck fracture: Risk factors and treatment outcomes. Int Orthop. 2019; 43(11):2609-2614.
47. Triantafyllopoulos GK, Poultsides LA, Memtsoudis SG, Zhang W, Sculco PK, Ma Y, *et al*. Irrigation and debridement with implant retention for the treatment of periprosthetic joint infection. SICOT J. 2019; 5:41.
48. Triantafyllopoulos GK, Poultsides LA, Sakellariou VI, Zhang W, Sculco PK, Ma Y, *et al*. Irrigation and debridement for periprosthetic infections of the hip and factors determining outcome. Int Orthop. 2015; 39(5):1203-1209.
49. Tubb CC, Polkowski GG. Diagnosis and prevention of periprosthetic joint infections. J Am Acad Orthop Surg. 2020; 28(7):e340-e348.
50. Uriarte I, Moreta J, Mosquera J, Legarreta MJ, Aguirre U, Martínez de los Mozos JL. Debridement, antibiotics, and implant retention for early periprosthetic infections of the hip: Outcomes and influencing factors. Hip Pelvis. 2019; 31(3):158-165.
51. Winkler TW, Goetze C, Perka C. Re: One-stage exchange arthroplasty for chronic periprosthetic hip infection: Results of a large prospective cohort study. Bone Joint J. 2018; 100-B(2):262.
52. Winkler TW, Karczewski D, Andronic O, *et al*. Implant retention treatment of periprosthetic hip infection with

and without exchange of modular components. Bone Joint J. 2023; 105-B(6 Suppl A):101-107.
53. Zaruta DA, Qiu B, Liu AY, Ricciardi BF. Indications and guidelines for debridement and implant retention for periprosthetic hip and knee infection. Curr Rev Musculoskelet Med. 2018; 11(3):347-356.
54. Zubizarreta N, Poeran J, Galatz LM, Moucha CS. Trends in hip arthroplasty revisions and associated complications. J Arthroplasty. 2018; 33(5):1215-1222.
55. Zubizarreta N, Whitehouse MR, Beswick AD. Management strategies for infection-related complications in arthroplasty: A systematic review. Bone Joint Open. 2023; 4(5):333-345.