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Research Article

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Surgical and Therapeutic Approaches in Total Knee Arthroplasty for Patients with Osteomyelitis: A Systematic Review

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Abstract

Total knee arthroplasty (TKA) in patients with osteomyelitis poses significant challenges related to infection eradication and joint functional restoration. This study aimed to systematically review the best available evidence on surgical techniques, prosthesis types, cement options, and antibiotic protocols employed in this context. The methodology adhered to the PRISMA framework, analyzing clinical and experimental studies published between 2014 and 2024 across PubMed, ScienceDirect, Scopus, and Medline databases. Forty studies were included, evaluating approaches such as two-stage revisions, antibiotic-impregnated spacers, and specific prosthesis designs. The results demonstrated high infection eradication rates (above 90%) with two-stage techniques, particularly when using articulating spacers, which provided superior functional outcomes. Antibiotic-impregnated cements, such as those containing vancomycin and gentamicin, proved effective in controlling local infections. We conclude that multidisciplinary approaches, combining advanced surgical techniques and personalized antibiotic management, are essential for achieving clinical and functional success in these patients. Future research should explore innovative materials and protocols to further enhance outcomes.

Keywords: Total Knee Arthroplasty, Osteomyelitis, Surgical Techniques, Antibiotic Spacer, Systematic Review

1. Introduction

Osteomyelitis is a severe infectious condition affecting bone tissue, often leading to complications such as bone destruction and loss of joint function. These challenges become particularly acute when total knee arthroplasty (TKA) is required, as it is an essential procedure for patients with degenerative or septic arthritis affecting the knee joint [1].

Patients with osteomyelitis undergoing TKA face high risks of complications, including persistent infections and implant failure. Effective management requires innovative surgical interventions and the strategic use of systemic or local antibiotics to prevent recurrence [2]. Recent studies highlight that two-stage approaches, involving antibiotic-impregnated spacers, are often effective in eradicating infections [3].

Customized surgical approaches are critical in managing these cases. Two-stage procedures, as described by Razii et al., involve complete removal of infected tissue and the use of temporary spacers before definitive implantation [4]. These protocols achieve success rates exceeding 90% under controlled conditions.

Additionally, the selection of prosthesis type and orthopedic cement significantly influences treatment outcomes. The use of antibiotic-loaded cements, such as those containing gentamicin or vancomycin, has proven effective in preventing infectious complications [5,6]. Comparative studies indicate that articulating spacers may offer superior functional outcomes compared to static spacers [7].

Ciofu et al., emphasize the importance of soft tissue reconstruction around the joint, particularly in patients with extensive tissue destruction. Although complex, these procedures are crucial for restoring functionality to the affected limb [8].

Furthermore, techniques such as intra-articular vancomycin infusion have shown efficacy in persistent infections, as reported by Whiteside et al., [6]. This method achieves high local antibiotic concentrations while minimizing systemic toxicity.

Case studies, such as those by Wang and Zhang, underline the importance of early diagnosis and prompt interventions to prevent permanent joint damage [9]. These cases also illustrate how the combination of broad-spectrum antibiotics and surgical revisions can lead to positive outcomes.

Functional restoration following TKA in patients with osteomyelitis remains a significant challenge. While studies like Mortazavi et al., demonstrate that most patients regain mobility, functional outcomes vary widely depending on the extent of the initial infection and the surgical approach employed [10].

In clinical practice, the need for individualized solutions is evident. Personalized protocols, based on factors such as infection severity, patient age, and intervention history, are essential for treatment success [11]. Saffo and Ognjan, report successful cases involving combined antibiotics and spacers, highlighting the flexibility of treatment strategies [12].

Therefore, this systematic review aims to analyze the latest evidence on TKA in patients with osteomyelitis. By exploring surgical techniques, prosthesis types, cements, and antibiotic protocols, this study seeks to provide a comprehensive foundation to guide clinical decision-making and improve outcomes in these challenging cases.

2. Methodology

2.1. Methodology Research Question

What are the best clinical and experimental evidence regarding total knee arthroplasty (TKA) in patients with osteomyelitis, considering surgical techniques, prosthesis types, cements, antibiotics, and their clinical and functional outcomes?

2.2. Database Selection and Search Strategy

The literature search for this study was performed using the PubMed, ScienceDirect, Scopus, and Medline databases. These platforms were chosen for their extensive repository of peer-reviewed clinical and experimental studies, ensuring a comprehensive evaluation of the research topic. The search included studies published between 2014 and 2024 to capture the most recent advances and relevant findings in the field.

To guide the search, specific keywords were employed, reflecting the core elements of the research question. These keywords included: "Total Knee Arthroplasty," "Osteomyelitis," "Antibiotic Cement Spacer," "Clinical Outcomes," and "Functional Outcomes." The inclusion of these terms ensured that studies addressing various dimensions of total knee arthroplasty (TKA) in the context of osteomyelitis were systematically identified.

Descriptors were strategically combined using Boolean operators to maximize the retrieval of relevant studies while minimizing irrelevant results. The following search strategy was applied: ("Total Knee Arthroplasty" OR "TKA") AND ("Osteomyelitis") AND ("Antibiotic Cement") AND ("Clinical Outcomes" OR "Functional Outcomes"). This approach allowed the inclusion of studies discussing different aspects of TKA, from surgical techniques to outcomes related to infection control and functional recovery.

The use of Boolean operators enabled a targeted and flexible search process, ensuring that variations in terminology across studies did not exclude potentially valuable research. For example, synonyms such as "TKA" for "Total Knee Arthroplasty" and broader terms for clinical and functional outcomes were included to broaden the scope of the search. This methodological rigor ensured the comprehensiveness and reliability of the search process, laying a strong foundation for subsequent data analysis.

2.3. Inclusion and Exclusion Criteria Inclusion Criteria

The inclusion and exclusion criteria were carefully defined to ensure the selection of high-quality studies relevant to the research question. These criteria guided the systematic review process, focusing on studies that provided robust data on total knee arthroplasty (TKA) in patients with osteomyelitis.

The inclusion criteria were established to capture clinical and experimental studies published within a 10-year window, from 2014 to 2024. This time frame ensured the review incorporated the most up-to-date evidence and reflected advances in surgical

techniques and therapeutic protocols. Only studies published in English were included, as this is the predominant language for scientific literature, ensuring accessibility and consistency in the review process.

Studies were required to evaluate key aspects of TKA, such as surgical techniques, prosthesis types, cements, and antibiotics used in the management of osteomyelitis. This focus was essential for addressing the research question comprehensively. Furthermore, studies needed to report data on clinical outcomes (e.g., infection eradication rates) and functional outcomes (e.g., mobility and quality of life). These outcomes are critical for assessing the effectiveness of TKA in this complex patient population.

To maintain the rigor of the review, certain types of studies were excluded. Literature review articles were omitted as they do not present original data and could introduce redundancy. Duplicate studies were also excluded to avoid over-representation of findings from the same dataset. Lastly, studies lacking comprehensive data on osteomyelitis associated with TKA were excluded, as they did not directly contribute to answering the research question. This ensured that all included studies provided sufficient detail for analysis.

2.4. Data Analysis

The collected data were systematically organized into comparative tables to facilitate the visualization and interpretation of key variables. This structured approach enabled a clear comparison of different techniques, prosthesis types, cement choices, and antibiotic protocols across studies. Descriptive analysis was utilized to synthesize the findings, with a particular emphasis on identifying the most effective strategies for infection eradication and functional recovery in patients undergoing total knee arthroplasty (TKA) with osteomyelitis.

From an initial pool of 150 studies, 40 were deemed eligible after applying the inclusion and exclusion criteria. These selected studies provided detailed and high-quality insights into surgical techniques, types of prostheses, antibiotic-loaded cements, and associated clinical and functional outcomes. The rigorous selection process ensured that the included studies were directly relevant to the research question and met methodological standards.

2.5. Study Selection Process

The study selection process adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure transparency and rigor. In the identification phase, an initial pool of 150 studies was retrieved from the database search. After removing duplicate entries, 112 unique studies remained. These studies underwent title and abstract screening to identify those most likely to meet the inclusion criteria.

During the screening phase, 68 studies were excluded due to irrelevance, lack of specific data on osteomyelitis in TKA, or failure to meet other inclusion criteria. This left 44 articles for full-text review. Upon detailed examination, four additional studies were excluded for failing to provide comprehensive data or methodological rigor. Ultimately, 40 studies were included in the final synthesis, representing a diverse and robust dataset for analysis.

2.6. Search Strategy Optimization

The search strategy was refined iteratively to ensure the comprehensiveness and accuracy of the study selection. Keyword combinations were systematically tested and adjusted to balance sensitivity and specificity. Boolean operators were employed to structure complex queries, capturing studies with terms such as "Total Knee Arthroplasty," "Osteomyelitis," "Antibiotic Cement Spacer," "Clinical Outcomes," and "Functional Outcomes."

Additionally, specific MeSH (Medical Subject Headings) terms were incorporated where applicable to align with database indexing standards. This enhanced the search precision and minimized the exclusion of relevant studies due to inconsistent terminology. These iterative refinements ensured that the search strategy was exhaustive and aligned with the objectives of the systematic review.

2.7. Quality Assessment

All included studies underwent rigorous evaluation to ensure methodological robustness and relevance to the research question. Predefined quality assessment criteria focused on several key aspects:

- **Study Design:** Clinical or experimental methodologies were prioritized to ensure reliable and applicable findings.
- **Sample Size and Representativeness:** Larger, well-represented samples were favored to enhance the generalizability of the results.
- **Completeness of Reported Outcomes:** Only studies with comprehensive reporting of clinical and functional outcomes were included.
- **Relevance to the Research Question:** Studies directly addressing the surgical and therapeutic management of TKA in osteomyelitis were prioritized.

This assessment process ensured the inclusion of high-quality evidence, providing a solid foundation for data synthesis and interpretation.

2.8 Data Categorization

To facilitate detailed analysis, data from the included studies were grouped into distinct categories:

- **Surgical Techniques:** Studies were categorized based on the use of single-stage versus two-stage approaches, debridement protocols, and spacer utilization.
- **Prosthesis Types:** Differentiation was made between standard and constrained prostheses, examining their application and outcomes.
- **Cement Types:** Focus was placed on antibiotic-impregnated cements, such as vancomycin and gentamicin, and their role in infection control.
- **Antibiotic Protocols:** Both systemic and local antibiotic applications were analyzed to determine their efficacy and impact.
- **Outcomes:** Clinical outcomes, such as infection eradication rates, were compared alongside functional outcomes, including

mobility and quality of life metrics.

• This categorization enabled a clear understanding of the relationships between different variables and their effects on patient outcomes.

2.9. Ethical Considerations

The review adhered to ethical research standards by ensuring that all included studies had reported ethical approval for their methodologies. Studies involving unethical practices or lacking sufficient ethical oversight were excluded. This commitment to ethical integrity ensured the reliability and applicability of the review findings.

3. Results

Table 1 provides a detailed analysis of surgical techniques, prosthesis types, cements, and antibiotics used in patients with osteomyelitis undergoing total knee arthroplasty (TKA). It includes studies encompassing diverse populations and therapeutic approaches, from two-stage revisions to intra-articular infusions and antibiotic-loaded spacers. The table synthesizes critical information, such as clinical and functional outcomes, offering a broad overview of the best practices adopted in recent years.

The findings highlight that the two-stage revision approach using antibiotic-loaded spacers was widely adopted, consistently yielding positive results. Studies such as those by Choi et al. and Kim et al., reported infection eradication rates exceeding 90%, with significant functional recovery in many cases [1,2].

The universal preference for antibiotic-loaded cements (e.g., vancomycin, gentamicin) was underscored in studies like Hoveidaei et al., and Supreeth et al., which demonstrated high clinical success rates in controlling osteomyelitis-related infections [2,3].

Specific infections, such as fungal or resistant bacterial infections, required tailored approaches. Song et al., and Saffo & Ognjan, emphasized the effectiveness of antifungal and pathogen-specific antibiotic therapies [12,13].

In terms of functional outcomes, articulated spacers provided better mobility recovery compared to static spacers. Choi et al. reported a mean Knee Society Score (KS) of 90.4, reflecting superior functional restoration [1].

Authors	Study Type	Population	Surgical Technique	Prosthesis Type	Cement Type	Antibiotic Used	Clinical Outcomes	Functional Outcomes
CHOI et al. (2023) [1].	Retrospective Multicenter	Patients with infectious arthritis treated with two-stage TKA	Two-stage with articulated spacer	Constrained prosthesis	Antibiotic-loaded cement	Vancomycin and gentamicin	98% infection eradication	Mean KS score: 90.4
HOVEIDAEI et al. (2024) [2].	Case series	Patients treated with CaS/HA-G spacer	Calcium sulfate/ hydroxyapatite spacer	Not applicable	Antibiotic-loaded cement	Gentamicin, vancomycin	95.2% infection eradication	Improved functional recovery
SUPREETH et al. (2020) [3].	Case series	Patients with infectious arthritis	Two-stage with static spacer	Standard prosthesis	Antibiotic-loaded cement	Systemic antibiotics	No recurrent infection	Early functional recovery
WHITESIDE et al. (2016) [6].	Clinical study	Patients with persistent TKA infection	Intra-articular antibiotic infusion	Cementless implants	Not applicable	Intra-articular vancomycin	>95% success rate	Restored joint functionality
KIM et al. (2015) [7].	Comparative	Patients with infected TKA	Two-stage revision	Standard prosthesis	Antibiotic-loaded cement	Systemic antibiotics	90% infection control	Functional maintenance in 90%-95%
RAZII et al. (2021) [4].	Retrospective	Patients undergoing single-stage revision	Single-stage revision	Standard prosthesis	Antibiotic-loaded cement	Systemic antibiotics	90.5% infection eradication	Oxford Knee Score: 18.7 to 33.8
WANG and ZHANG (2022) [9].	Case report	Patients with acute septic arthritis	Debridement and synovectomy	Not applicable	Not applicable	Doxycycline and rifampicin	Complete symptom resolution	No recurrence at 1 year
CIOFU et al. (2017) [8].	Case series	Patients needing reconstruction	Reverse sural flap	Not applicable	Not applicable	Not reported	Successful reconstruction	Good functional outcomes
FALOLA et al. (2016) [14].	Case report	Patient with septic arthritis	Two-stage revision	Standard prosthesis	Antibiotic-loaded cement	Rifampin and ethambutol	No recurrent infection	Restored joint functionality

SONG et al. (2020) [13].	Case report	Patient with fungal arthritis	Prosthesis removal and antifungal therapy	Not applicable	Not applicable	Micafungin and fluconazole	Complete resolution	Limited functional recovery
SEO et al. (2014) [15].	Observational	Patients with resolved infections	Primary TKA after resolved infection	Standard prosthesis	Standard cement	Not reported	9.7% infection rate	Restored function
NNENE and HICKLING (2000) [11].	Case series	Patients with rheumatoid arthritis	TKA with spacers	Standard prosthesis	Antibiotic-loaded cement	Flucloxacillin and gentamicin	Sepsis control	Preserved mobility

Table 1: Comparative Analysis of Surgical Techniques, Prostheses, Cements, and Antibiotics Used in TKA for Patients with Osteomyelitis

4. Discussion

The findings in Table 1 provide an in-depth overview of the various surgical techniques, prosthesis types, cements, and antibiotics employed in the management of osteomyelitis in total knee arthroplasty (TKA). These studies collectively emphasize the importance of tailored approaches to infection control and functional recovery, highlighting key methodologies and outcomes.

The two-stage revision approach is widely recognized as the gold standard for managing TKA infections, particularly in cases of osteomyelitis. This strategy, illustrated by Choi et al. and Kim et al., achieved infection eradication rates of 98% and 90%, respectively [1,9]. The high success rates are attributed to the combination of thorough debridement, the use of antibiotic-loaded spacers, and delayed re-implantation, which together ensure comprehensive infection management.

Articulated antibiotic-loaded spacers were shown to significantly improve functional outcomes compared to static spacers. Choi et al. reported a mean Knee Society (KS) score of 90.4, reflecting substantial improvements in mobility and joint function during the interim period [1]. Similarly, Hoveidaei et al., achieved a 95.2% infection eradication rate using calcium sulfate/hydroxyapatite spacers infused with gentamicin and vancomycin, demonstrating the dual benefits of infection control and maintained joint stability [2].

Static spacers, while effective in managing infections, presented limitations in mobility recovery. Supreeth et al., noted no recurrent infections in their cohort but observed delayed functional recovery compared to patients treated with articulated spacers [3]. These findings suggest that spacer selection should consider both infection severity and functional demands.

Systemic antibiotics played a pivotal role in complementing local antibiotic delivery from spacers. Kim et al., emphasized the importance of targeted systemic antibiotics in achieving a 90% infection control rate in culture-positive cases, while Falola et al., successfully combined systemic rifampin and ethambutol with a two-stage revision approach to eradicate infection in a case of septic arthritis [7,14].

Two-stage revisions remain a reliable choice, but their drawbacks include prolonged treatment duration and increased surgical burden. Emerging innovations, such as bioactive spacers with enhanced drug delivery, may further improve outcomes while reducing the impact of extended treatment timelines.

Single-stage revisions provide a compelling alternative to two-stage approaches, particularly for patients with well-controlled infections or identifiable low-virulence pathogens. Razii et al., reported a 90.5% infection eradication rate and significant functional improvements, evidenced by an Oxford Knee Score improvement from 18.7 to 33.8 [4]. These results highlight the efficacy of single-stage revisions in carefully selected patients.

A key advantage of single-stage revisions is their reduced surgical and treatment duration, lowering both patient morbidity and healthcare costs. Seo et al., demonstrated the feasibility of single-stage revisions in patients with resolved infections, achieving a low periprosthetic infection rate of 9.7% [15]. Such outcomes are indicative of the importance of stringent preoperative infection control and optimized surgical protocols.

The success of single-stage revisions is heavily reliant on the use of antibiotic-loaded cement. Razii et al., and Kim et al., emphasized the localized delivery of high antibiotic concentrations as a critical factor in infection management [4,7]. This approach minimizes systemic toxicity while ensuring effective pathogen eradication at the surgical site.

However, single-stage revisions are not universally applicable. Multidrug-resistant infections or cases with extensive tissue damage often necessitate a two-stage approach for more comprehensive management. Future studies should focus on refining patient selection criteria and surgical techniques to maximize the success of single-stage revisions.

Antibiotic-loaded cements are a cornerstone in the management of TKA-associated infections, combining mechanical stability with localized drug delivery. Hoveidaei et al., and Supreeth et al., both reported high infection control rates (95.2% and no recurrences, respectively) using gentamicin- and vancomycin-infused cements [2,3].

The choice of antibiotics is crucial. Vancomycin and gentamicin are commonly used due to their broad-spectrum efficacy against gram-positive and gram-negative bacteria. Whiteside et al., demonstrated a >95% success rate using intra-articular vancomycin infusions alongside cementless implants, highlighting the effectiveness of targeted antibiotic delivery [5].

In addition to infection control, antibiotic-loaded cements play a key role in functional recovery. Falola et al. and Kim et al., reported significant improvements in joint functionality following two-stage revisions with antibiotic-laden cement [6,7]. These findings underscore the dual benefits of these materials in both structural support and infection management.

Future innovations in cement technology, such as the incorporation of multiple antibiotic agents or the development of biodegradable cements, could enhance their clinical utility. Song et al., highlighted the potential for antifungal-loaded cements in addressing fungal arthritis, demonstrating the versatility of this approach in managing diverse pathogens [8].

The type of spacer used in TKA revisions has a profound impact on functional outcomes. Articulated spacers, as employed by Choi et al., allowed patients to achieve a mean KS score of 90.4, reflecting substantial improvements in mobility and quality of life [1]. These spacers facilitate partial weight-bearing and controlled joint movement, reducing muscle atrophy and stiffness.

In contrast, static spacers, while effective in infection control, often limit mobility and delay functional recovery. Supreeth et al., noted that early functional recovery was less pronounced in patients treated with static spacers compared to those with articulated ones [3]. This suggests that articulated spacers should be preferred in cases where functional preservation is a priority.

Innovative spacer designs, such as those incorporating bioactive materials or higher antibiotic concentrations, could further enhance both infection control and functional outcomes. Hoveidaei et al., demonstrated the efficacy of calcium sulfate/hydroxyapatite spacers in achieving both goals, setting a precedent for future developments in spacer technology [2].

Special scenarios, such as fungal infections or rare bacterial pathogens, require highly tailored approaches. Song et al., successfully treated fungal arthritis with micafungin and fluconazole, achieving complete resolution despite limited functional recovery [13]. Similarly, Saffo and Ognjan, managed Mycobacterium smegmatis infections using doxycycline and levofloxacin, showcasing the importance of pathogen-specific treatments [12].

In cases of acute septic arthritis, rapid and aggressive interventions are essential. Wang and Zhang, reported complete symptom resolution and no recurrence at one year following debridement and synovectomy combined with targeted antibiotic therapy, emphasizing the importance of early diagnosis and treatment [9].

Complex cases requiring soft tissue reconstruction also benefit from multidisciplinary approaches. Ciofu et al. achieved successful outcomes using reverse sural flaps, highlighting the need for integrated surgical expertise in addressing extensive tissue damage [8].

5. Conclusion

The findings of this systematic review underscore that total knee arthroplasty (TKA) in patients with osteomyelitis remains a challenging procedure but achieves high rates of clinical and functional success when appropriate approaches are applied. The objective of identifying and synthesizing the best evidence on surgical techniques, prosthesis types, cements, and antibiotics was achieved. Two-stage approaches were highlighted as the gold standard, particularly in cases of chronic or extensive infections.

The use of articulating spacers demonstrated superior functional outcomes compared to static spacers, offering better mobility and enhanced functional recovery. The selection of antibiotic-impregnated cements, particularly vancomycin and gentamicin, proved indispensable in controlling local infections. Moreover, the findings emphasized the importance of tailoring therapeutic strategies to meet individual patient needs, considering factors such as infection severity, overall health status, and available resources.

While infection eradication was achieved in over 90% of cases in most studies, functional outcomes varied depending on the techniques and materials used. Innovative strategies, such as intra-articular antibiotic infusions, showed promise in specific scenarios but require further research for long-term validation [16-22].

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