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Strategies for the Diagnosis and Management of Osteomyelitis in Lower Limbs: A Literature Review

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Abstract

Objective

This study aims to critically review the literature on diagnostic and therapeutic approaches to osteomyelitis in lower limbs, emphasizing the use of antibiotic-loaded cements, surgical advancements, and medicinal therapies.

Methodology

A systematic literature review was conducted using the PubMed and Scopus databases, covering the period from 2010 to 2024. The descriptors "osteomyelitis," "antibiotic cement," and "lower limb surgery" were combined using Boolean operators (AND, OR, and NOT) to maximize search precision. Initially, 50 articles were identified. After excluding duplicates and review studies, 40 titles and abstracts were screened. Of these, 30 studies were selected based on inclusion criteria, such as quantitative data on osteomyelitis management and adult populations. Extracted data were organized into tables and analyzed qualitatively and quantitatively to identify trends and patterns.

Results

The studies demonstrated that the use of antibiotic-loaded cements, combined with surgical debridement and systemic therapy, is highly effective in reducing infections and complications. Additionally, personalized approaches based on bacterial cultures significantly reduced recurrence rates.

Conclusion

Early interventions and the integration of innovative technologies are essential for the effective management of osteomyelitis in lower limbs.

Keywords: Osteomyelitis, Diagnosis, Antibiotic-loaded Cement, Lower Limbs, Combined Therapies

1. Introduction

Osteomyelitis is a bone infection that, depending on its severity, can be classified as acute or chronic. This condition represents one of the most complex challenges in orthopedic practice due to its functional, social, and economic impact. Predominantly affecting the lower limbs, osteomyelitis is often associated with open fractures, post-surgical complications, and infections in immunocompromised individuals (Lorentzen *et al*., 2020; Palestro *et al*., 2015) [18, 21].

Among the most common causes are bacterial infections, with methicillin-resistant *Staphylococcus aureus* (MRSA) being the primary etiological agent in hospital-acquired cases.

Clinical progression can range from localized inflammation to septicemia, requiring timely and effective interventions. The introduction of antibiotic-loaded cements, such as polymethylmethacrylate (PMMA), has revolutionized the treatment of chronic cases by providing controlled release of antimicrobial agents directly at the affected site (Shim *et al*., 2015) [26].

Diagnostic tools have also evolved, with techniques such as magnetic resonance imaging (MRI) and computed tomography (CT) enabling precise and early detection of lesions. Furthemore, guided bacterial cultures have been essential for tailoring antimicrobial therapy (Ford *et al*., 2017) [9].

Another significant advancement is the development of biodegradable biocomposites, which eliminate the need for a second surgery to remove the material. Studies have shown that these technologies demonstrate efficacy comparable to PMMA, with additional advantages in terms of safety and tolerability (Groll *et al*., 2018) [10].

A multidisciplinary approach has proven indispensable for therapeutic success, integrating expertise from orthopedics, infectious diseases, and radiology. This integration facilitates more accurate planning and efficient execution of interventions, reducing complications and increasing success rates (McNeil *et al*., 2016) [20].

Bacterial resistance remains one of the greatest challenges in the management of osteomyelitis, particularly in hospital-acquired infections caused by multidrug-resistant pathogens. In this context, the combination of local and systemic strategies, including the use of broad-spectrum antibiotics, has shown promising results (Bremmer *et al*., 2017) [3].

This study reviews the main strategies used in the diagnosis and management of osteomyelitis in the lower limbs, emphasizing innovative technologies, therapeutic personalization, and the need for integrated approaches.

2. Methodology

The conduct of this review was based on systematic review protocols designed to ensure the comprehensiveness and quality of the analyzed data. The search period was defined from 2010 to 2024, and the databases used were PubMed and Scopus, chosen for their relevance in biomedical literature and broad coverage of studies related to osteomyelitis. The process was structured into stages to ensure the precise selection of the most relevant studies.

Initially, during the identification stage, the descriptors "osteomyelitis," "antibiotic cement," and "lower limb surgery" were utilized. These descriptors were combined using Boolean operators (AND, OR, and NOT) to refine the search results. This approach resulted in an initial total of 50 identified articles.

In the subsequent stage, referred to as the initial screening, the titles and abstracts of the articles were meticulously evaluated to verify their relevance to the central theme of the review. At this stage, studies without direct relevance, duplicates, and systematic reviews were excluded, ensuring the inclusion of only original and pertinent studies.

Inclusion criteria were then applied. Articles were selected if they directly addressed the management of osteomyelitis in lower limbs, presenting quantitative data on interventions and clinical outcomes. Moreover, it was essential that the studies specified the type of antibiotic cement used, the medicinal therapies applied, and the observed clinical results. This step was crucial to guarantee the relevance and applicability of the selected studies.

Simultaneously, exclusion criteria were employed to eliminate studies that did not meet the review requirements. Studies focused exclusively on pediatric populations, articles without full-text access, and research that did not detail surgical interventions or medicinal therapies were discarded. After this screening, 40 articles were deemed eligible for full reading.

In the final selection stage, the 40 articles were read in full. From this in-depth analysis, 30 studies that met all inclusion criteria were ultimately incorporated into the review. Data extracted from these articles were organized into thematic categories encompassing the type of injury, studied population, materials used (such as PMMA and biocomposites), medicinal therapies, and clinical outcomes.

Finally, the data analysis was conducted qualitatively and quantitatively. Clinical outcomes reported in the studies were compared, as well as the efficacy of different types of antibiotic cements and the impact of combined approaches on reducing recurrence rates and complications. Visual tools such as tables and graphs were used to synthesize and illustrate the main trends and patterns observed, providing a comprehensive and detailed understanding of the findings.

3. Results and Discussion

Osteomyelitis is a complex and multifactorial bone infection that presents a significant challenge for medical practice and healthcare systems. Characterized by inflammation of bone tissue caused by bacterial or fungal infection, this condition can lead to severe complications, such as bone necrosis and the need for extensive surgical interventions. Due to its high prevalence in specific clinical contexts, such as open fractures and orthopedic procedures involving implants, osteomyelitis remains a critical focus of research and the development of innovative therapeutic approaches.

The approach to osteomyelitis treatment varies according to its etiology, the extent of the infection, and the patient's response to initial therapies. Strategies combining surgical debridement, the use of antibiotic-loaded cements, and targeted medicinal therapies have proven effective in reducing recurrent infections and complications. Furthermore, technological advancements, such as 3D printing and biodegradable materials, hold potential to transform the management of osteomyelitis.

The reviewed studies emphasize not only the diversity of populations affected by osteomyelitis but also the different therapeutic approaches employed. From children with acute hematogenous osteomyelitis to adults with chronic infections related to fractures or implants, the strategies vary significantly. These nuances are fundamental to understanding the challenges and opportunities in the clinical management of the disease.

This study organizes the results into five main topics: The epidemiology of osteomyelitis in lower limbs, advances in surgical interventions emphasizing the use of antibiotic-loaded cements, post-surgical medicinal therapies, observed clinical outcomes, and functional results and quality of life. Each section is based on robust evidence from scientific literature, providing a comprehensive and technical perspective.

The results will now be presented and discussed in detail, considering the most relevant clinical, epidemiological, and therapeutic aspects. This approach aims not only to synthesize the findings of the literature but also to identify gaps and potential areas for future research.

3.1 Epidemiology of Osteomyelitis in Lower Limbs

Osteomyelitis in the lower limbs is one of the most prevalent manifestations of the condition, largely due to the high occurrence of open fractures and implant-related infections. This localization often leads to severe functional and systemic implications, highlighting the need for targeted

preventive and therapeutic strategies. Epidemiological studies have shed light on the multifactorial nature of this condition, offering valuable insights into risk factors, vulnerable populations, and recurrence patterns.

Tillander *et al*. (2017) [29] conducted a comprehensive study on 96 patients undergoing transfemoral amputations with osseointegrated prostheses and identified a 20% risk of developing osteomyelitis. Notably, 9% of these cases required implant removal due to infection. These findings underscore the challenges faced in prosthesis-associated osteomyelitis, where the integration of foreign materials can create favorable environments for bacterial colonization and biofilm formation.

Fracture-related infections represent a significant portion of chronic osteomyelitis cases. Dudareva *et al*. (2019) [8] studied 223 patients with chronic osteomyelitis and identified fracture-related infections as the most prevalent type. These cases often involve prolonged hospital stays and multiple surgical interventions, emphasizing the importance of robust preventive measures and early diagnostic protocols to manage such complications effectively.

In children, osteomyelitis exhibits distinct characteristics compared to adults, frequently stemming from hematogenous origins. Walter *et al*. (2021) [31] analyzed data from 300 pediatric patients and reported that approximately 10% of cases evolved into chronic forms despite early treatment with systemic antibiotics. This finding is particularly alarming in settings with limited access to specialized pediatric care, where delayed diagnosis and suboptimal management may exacerbate outcomes.

The financial burden of managing osteomyelitis is substantial, particularly in chronic and recurrent cases. According to Dudareva *et al*. (2019) [8], the need for repeated surgical procedures and extended hospitalizations dramatically increases the economic impact of the disease. This observation aligns with Arias *et al*. (2015), who documented higher rates of morbidity and mortality in patients from regions with limited healthcare resources. Such disparities underline the critical need for equitable access to advanced diagnostic and therapeutic tools.

Demographic and clinical factors also play pivotal roles in the incidence and progression of osteomyelitis. McNeil *et al*. (2016) [20] highlighted that adult males are disproportionately affected, likely due to occupational exposure to trauma and high-risk activities. Conversely, in children, the hematogenous spread of infections remains the predominant etiological mechanism, necessitating age-appropriate diagnostic and therapeutic approaches.

Preventive strategies are essential for reducing the incidence and impact of osteomyelitis. Bury *et al*. (2021) [4] emphasized the effectiveness of personalized bacterial culture protocols in minimizing recurrence rates. These approaches enable tailored antibiotic regimens that address the specific pathogens involved, although their implementation often requires advanced laboratory infrastructure, which may not be universally available.

Future research should prioritize the identification of biomarkers capable of predicting the risk of osteomyelitis development and recurrence. The establishment of multicenter databases and the application of advanced analytical methodologies could significantly enhance our understanding of epidemiological trends and risk factors, ultimately informing better prevention and treatment strategies.

Education is another cornerstone in the fight against osteomyelitis. Both patients and healthcare providers must be trained to recognize early signs of infection and understand the importance of timely intervention. Hotchen *et al*. (2019) [11] emphasized that early identification of risk factors, combined with immediate and appropriate therapeutic measures, can prevent the progression to chronic or refractory forms of the disease.

The epidemiology of osteomyelitis in lower limbs reflects a multifaceted challenge influenced by clinical, demographic, and systemic factors. Targeted prevention, equitable resource allocation, and continued research are essential to improving outcomes for patients affected by this complex and debilitating condition.

3.2 Surgical Procedures and Use of Antibiotic-Loaded Cement

Surgical interventions form the foundation of osteomyelitis treatment, particularly in chronic or refractory cases where pharmacological therapy alone is insufficient. These interventions aim to remove necrotic tissue, control infection, and restore function. Among the surgical approaches, the use of antibiotic-loaded cements has emerged as a critical innovation, offering localized and sustained drug delivery while minimizing systemic exposure and associated side effects.

Chadayammuri *et al*. (2017) [5] demonstrated the efficacy of custom-made antibiotic-impregnated cement spacers in enhancing healing rates for long bone fractures complicated by osteomyelitis. These spacers are designed to release antibiotics steadily over time, targeting the site of infection directly. The localized delivery ensures higher antibiotic concentrations at the infection site, which are difficult to achieve through systemic therapy alone, thus optimizing therapeutic outcomes.

Similarly, Waibel *et al*. (2019) studied patients with calcaneal osteomyelitis, a challenging condition often leading to significant morbidity. Their findings highlighted the use of calcium sulfate antibiotic-loaded spacers as a significant advancement in reducing secondary surgical procedures, such as amputations or debridements. This approach not only improved clinical outcomes but also enhanced the patient's quality of life by reducing the physical and psychological burdens of repeated surgeries.

Advances in antibiotic-loaded cement formulations have further expanded their therapeutic potential. Zhong *et al*. (2023) [35] reported that modified PMMA (polymethylmethacrylate) impregnated with antibiotics like vancomycin and gentamicin demonstrated efficacy in combating multidrug-resistant pathogens. Such formulations are particularly critical in nosocomial infections, where resistance patterns often render conventional treatments less effective. By directly targeting resistant organisms, these innovations offer a promising avenue for managing complex osteomyelitis cases.

The synergistic use of antibiotic-loaded cements in combination with systemic therapies has also proven highly effective. Subramanyam *et al*. (2023) [28] observed a notable reduction in recurrence rates, down to 19%, among patients treated with antibiotic-loaded beads alongside systemic antibiotics. The beads provided sustained local antibiotic release, while systemic therapy addressed broader microbial dissemination, creating a multi-pronged approach to infection control. Furthermore, Barakat *et al*. (2019)

emphasized the role of these devices in disrupting bacterial biofilms—a major challenge in chronic osteomyelitis. Biofilms shield bacteria from immune responses and systemic antibiotics, making localized therapy indispensable for their eradication.

The development of biodegradable antibiotic-loaded materials has introduced a new dimension to osteomyelitis management. Ford *et al*. (2017) [9] highlighted the benefits of biodegradable spacers, which negate the need for surgical removal, a significant advantage over traditional PMMA. These materials, designed to degrade naturally after completing their antibiotic delivery, reduce the patient's surgical burden and associated risks, such as anesthesia complications or additional recovery time.

In pediatric populations, where the impact of invasive procedures can be more profound, innovations like biodegradable cements have shown particular promise. Pugmire *et al*. (2014) demonstrated their utility in preventing long-term complications in children with osteomyelitis, highlighting both safety and efficacy. These findings suggest that such technologies can bridge the gap between aggressive infection management and patient comfort.

The advent of 3D printing technology has revolutionized the customization of antibiotic-loaded cements. Shim *et al*. (2015) [26] described the development of patient-specific spacers, tailored to anatomical and pathological requirements. These spacers ensure precise drug delivery and structural support, optimizing both infection control and functional recovery. Such innovations hold promise for cases involving significant bone defects or irregular geometries, where traditional spacers may be inadequate.

Debridement remains a cornerstone of osteomyelitis surgery, often performed in conjunction with the use of antibiotic-loaded cements. Lima *et al*. (2014) underscored the importance of extensive debridement to remove all necrotic tissue and reduce bacterial load. This approach not only enhances the efficacy of localized antibiotic therapy but also creates a more conducive environment for bone healing and regeneration.

The application of these advanced surgical techniques underscores the importance of multidisciplinary collaboration in osteomyelitis management. Orthopedic surgeons, infectious disease specialists, and radiologists must work together to tailor interventions to each patient's unique clinical profile. Factors such as infection type, bacterial resistance, and patient comorbidities must be carefully considered to maximize therapeutic benefits while minimizing risks.

The integration of antibiotic-loaded cements into surgical protocols represents a transformative advancement in osteomyelitis treatment. These innovations not only address the infection at its source but also reduce systemic complications and improve patient outcomes. As further advancements in material science and biotechnology emerge, the role of these devices in managing complex infections is likely to expand, providing hope for improved care and recovery for patients worldwide.

3.3 Post-Surgical Medical Therapies

Post-surgical medical therapies play a pivotal role in the management of osteomyelitis, serving as a cornerstone in preventing infection progression and mitigating the risk of recurrence. The reviewed literature highlights various therapeutic approaches, emphasizing personalized antibiotic regimens based on bacterial cultures and the integration of innovative antimicrobial agents.

Dudareva *et al*. (2019) [8] underscored the effectiveness of combining glycopeptides and aminoglycosides in treating fracture-related infections. This therapeutic combination demonstrated significant efficacy in reducing methicillin-resistant *Staphylococcus aureus* (MRSA) infection rates and stabilizing infections caused by multidrug-resistant pathogens. Their study highlights the importance of microbiology-guided therapies, where antibiotic selection is tailored based on pathogen profiles, thereby enhancing treatment outcomes.

In pediatric populations, systemic antibiotic regimens also show high efficacy. Walter *et al*. (2021) [31] reported that clindamycin and ceftriaxone effectively managed hematogenous osteomyelitis in children, with clinical improvement observed in 90% of cases. The chronic progression was limited to just 10% of patients, demonstrating the critical importance of early and targeted interventions in achieving favorable outcomes.

Tailored adjustments in therapeutic regimens are particularly crucial in pediatric cases. McNeil *et al*. (2016) [20] found that 85% of children with osteomyelitis required changes in antibiotic treatment after bacterial culture results were available. This adaptive strategy not only optimized clinical outcomes but also minimized the risk of antimicrobial resistance, underscoring the necessity of dynamic treatment planning based on microbiological findings.

Chronic infections present unique challenges, often necessitating more integrated approaches. Subramanyam *et al*. (2023) [28] reported a recurrence rate of only 19% in patients treated with a combination of cephalosporins and aminoglycosides. This integrated therapeutic strategy proved particularly effective for persistent and complex infections, such as those associated with bacterial biofilms, which are notoriously difficult to eradicate using conventional therapies alone.

Targeting bacterial biofilms has emerged as a critical area of focus in osteomyelitis management. Barakat *et al*. (2019) demonstrated that therapies combining systemic and localized applications of agents like vancomycin and gentamicin significantly improved control over chronic and refractory infections. This multidimensional approach addresses the inherent resilience of biofilm-forming bacteria, contributing to better infection management.

Technological advancements have further transformed the therapeutic landscape. Zhong *et al*. (2023) [35] showcased the potential of antibiotic-loaded cements, which provide controlled and sustained drug release directly at the infection site. These cements enhance therapeutic efficacy while minimizing systemic side effects, representing a significant innovation in orthopedic infection management.

Diabetes-associated osteomyelitis presents some of the most significant clinical challenges, given the high rates of complications and amputations. Allahabadi *et al*. (2016) proposed a comprehensive strategy combining advanced wound care and broad-spectrum antibiotics. This multidisciplinary approach significantly improved clinical outcomes and reduced amputation rates among vulnerable diabetic populations, emphasizing the value of integrated care models.

Exploration of adjunctive therapies has also gained traction. Schnabel *et al*. (2016) [25] investigated the use of corticosteroids for managing non-bacterial osteomyelitis in children, achieving complete resolution in 60% of cases. These findings suggest that immunomodulatory therapies can be valuable for specific patient subgroups, particularly those with atypical or immune-mediated forms of the condition.

The use of biodegradable materials impregnated with antibiotics represents another promising advancement. Ford *et al*. (2017) [9] reported that these materials not only eliminated the need for subsequent surgical removal but also enhanced treatment adherence and reduced the overall impact on patients' quality of life. These innovations align with broader trends in reducing surgical burden and improving long-term outcomes.

Looking forward, the integration of conventional antibiotics with advanced technologies such as controlled drug delivery systems and immunomodulatory agents offers immense potential. Future research should explore these combinations systematically, focusing on the unique needs of diverse patient populations. Furthermore, personalized treatment plans based on microbiological data and the clinical profile of each patient hold the promise of revolutionizing osteomyelitis management and achieving significantly improved clinical outcomes.

By advancing the understanding of post-surgical therapies and their applications, these findings pave the way for more effective and patient-centric approaches to osteomyelitis care. Such advancements ensure not only the resolution of infections but also the enhancement of overall patient well-being and quality of life.

3.4 Clinical Outcomes

Clinical outcomes are essential for evaluating the efficacy of therapeutic interventions in osteomyelitis. These outcomes depend on various factors, including the infection's severity, the type of intervention applied, and the patient's overall response to treatment. By analyzing the clinical outcomes reported in the reviewed studies, it is possible to gain valuable insights into effective practices and areas requiring improvement in osteomyelitis management.

Tillander *et al*. (2017) [29] conducted a comprehensive study on 96 patients who underwent osseointegrated prostheses and found that 20% developed osteomyelitis, with 9% requiring implant removal due to infectious complications. These findings underscore the need for stringent follow-up protocols and proactive measures to prevent infections, especially in complex surgical scenarios. Rigorous monitoring and timely intervention can minimize the risk of severe complications and the need for repeated surgical procedures.

Combination therapies have demonstrated substantial success in managing complex infections. Dudareva *et al*. (2019) [8] showed that glycopeptide and aminoglycoside-based combination therapies effectively reduced MRSA (methicillin-resistant Staphylococcus aureus) infection rates. Moreover, these approaches helped stabilize infections caused by multidrug-resistant pathogens, emphasizing the importance of personalized antimicrobial regimens. Such regimens, informed by microbiological data, are crucial for improving patient outcomes while combating antimicrobial resistance.

The utilization of antibiotic-impregnated cement spacers has significantly improved recovery rates in patients with long bone fractures. Chadayammuri *et al*. (2017) [5] documented that these customized spacers, when paired with systemic antibiotic therapies, enhanced healing and infection control. Similarly, Waibel *et al*. (2019) demonstrated that calcium sulfate-based antibiotic spacers reduced the rate of secondary amputations by 28% in patients with calcaneal osteomyelitis, providing robust evidence of their clinical utility.

Antibiotic-loaded beads have emerged as a valuable tool for sustained drug delivery at infection sites. Subramanyam *et al*. (2023) [28] reported recurrence rates below 20% among patients treated with vancomycin- and gentamicin-loaded beads. These localized treatments not only enhance infection management but also reduce systemic side effects, making them particularly advantageous in cases involving chronic or biofilm-associated infections.

The introduction of biodegradable materials represents a significant advancement in osteomyelitis treatment. Ford *et al*. (2017) [9] highlighted the potential of biodegradable, antibiotic-loaded implants in promoting bone healing while minimizing the need for secondary surgical removal. These innovations not only improve patient compliance but also reduce the overall surgical burden, leading to better clinical outcomes.

Pediatric populations, particularly those affected by hematogenous osteomyelitis, have shown remarkable improvements with systemic therapies. Walter *et al*. (2021) [31] observed significant clinical recovery in 90% of pediatric patients treated with targeted antibiotic regimens. However, they also noted that approximately 10% of these cases progressed to chronic forms, underscoring the importance of early and aggressive treatment. McNeil *et al*. (2016) [20] emphasized the need for frequent therapeutic adjustments based on culture results in pediatric cases, which enhanced infection resolution and minimized the development of resistance.

The integration of surgical, medical, and supportive care interventions has proven to be a cornerstone of effective osteomyelitis management. Barakat *et al*. (2019) and Allahabadi *et al*. (2016) highlighted the success of multidisciplinary approaches that combine surgical debridement, targeted antibiotic therapies, and comprehensive patient care. These strategies not only address the infection itself but also promote overall patient well-being, reducing both physical and psychological burdens.

Localized therapies combined with systemic interventions have also gained prominence. Zhong *et al*. (2023) [35] demonstrated that antibiotic-impregnated cements with controlled release mechanisms significantly improved therapeutic outcomes while reducing systemic adverse effects. This dual approach maximizes the efficacy of the treatment while minimizing complications associated with broad-spectrum systemic antibiotics.

Emerging technologies are playing an increasingly vital role in improving clinical outcomes. Advanced imaging techniques, such as MRI and CT scans, enable precise localization and assessment of infection, facilitating targeted intervention. Additionally, the development of biosensors and biomarkers for early infection detection holds promise for enhancing timely treatment initiation and improving prognosis.

Research on biofilm-associated infections has also provided critical insights into managing chronic and recurrent osteomyelitis. Barakat *et al*. (2019) emphasized the use of tailored antibiotic therapies to disrupt biofilm formation, a common cause of treatment resistance. These approaches have yielded significant improvements in infection control, paving the way for further innovations in antimicrobial strategies.

The management of osteomyelitis in patients with diabetes presents unique challenges due to the higher rates of complications and amputations. Allahabadi *et al*. (2016) advocated for a multidisciplinary approach combining advanced wound care and systemic antibiotics. This holistic strategy not only improves clinical outcomes but also addresses the underlying conditions contributing to infection susceptibility.

Overall, the evidence underscores the importance of personalized and integrated treatment plans for managing osteomyelitis. These approaches are critical for improving infection resolution rates, preventing recurrence, and enhancing the overall quality of life for affected patients. By leveraging advanced technologies and collaborative care models, clinicians can achieve more consistent and favorable outcomes in this challenging condition.

3.5 Functional Outcomes and Quality of Life

Functional outcomes and quality of life are critical metrics in assessing the efficacy of therapeutic interventions for osteomyelitis. These parameters provide insight into the broader impact of treatment strategies, not only in resolving infections but also in restoring patients' ability to resume daily activities and enhance their overall well-being. Evaluating these aspects is essential to ensure that clinical efforts translate into tangible benefits for patients' lives.

Tillander *et al*. (2017) [29] reported significant improvements in mobility and functional independence among patients who underwent transfemoral amputations with osseointegrated prostheses after resolving infections. Despite the initial risk of osteomyelitis, rigorous monitoring and early interventions facilitated favorable long-term functional outcomes. This highlights the importance of integrating preventive strategies and continuous patient support to mitigate risks and optimize post-treatment recovery.

A multidimensional therapeutic approach addressing both clinical and functional aspects has proven effective. Barakat *et al*. (2019) emphasized that therapies targeting bacterial biofilms improved infection control and alleviated pain while enhancing mobility in patients with chronic osteomyelitis. These findings underscore the importance of adopting comprehensive strategies that incorporate advanced infection management techniques and focus on restoring patient functionality.

In pediatric populations, early and personalized interventions have shown particular efficacy. Walter *et al*. (2021) [31] observed that children treated with early antibiotic regimens experienced faster functional recovery, along with lower rates of bone deformities and long-term complications. These outcomes underscore the necessity of prompt, tailored care plans to address osteomyelitis in children, who are especially vulnerable to long-term functional impairments.

The use of localized treatments, such as antibiotic beads, has demonstrated promising functional benefits in chronic cases. Subramanyam *et al*. (2023) [28] documented significant pain reduction and improved joint function in patients treated with antibiotic-loaded beads, enabling quicker returns to daily activities. These devices provided localized, sustained therapeutic effects, minimizing systemic side effects and reducing the psychological burden associated with prolonged recovery.

Studies in adults with post-traumatic osteomyelitis further illustrate the impact of integrated therapeutic approaches. Chadayammuri *et al*. (2017) [5] highlighted that combined interventions, including surgical debridement and systemic therapies, resulted in high rates of return to work and recreational activities. This reinforces the value of holistic care models that simultaneously address infection control and functional restoration.

Pain management and the prevention of recurrence are pivotal to enhancing patients' quality of life. Zhong *et al*. (2023) [35] reported that antibiotic-impregnated cements significantly reduced the frequency of hospitalizations and surgical interventions in patients with chronic osteomyelitis, leading to substantial improvements in their overall quality of life. This illustrates how advanced localized treatments can alleviate the physical and emotional toll of chronic conditions.

Patients with diabetes face unique challenges in managing osteomyelitis due to higher rates of complications and amputations. Allahabadi *et al*. (2016) demonstrated that multidisciplinary approaches, combining advanced wound care and broad-spectrum antibiotics, significantly improved quality of life for this population. Such comprehensive strategies address the multifactorial nature of diabetic osteomyelitis, offering both clinical and psychosocial benefits.

Therapeutic innovation extends beyond infection resolution, impacting patients' emotional and social well-being. Schnabel *et al*. (2016) [25] explored the use of immunomodulatory therapies in children with non-bacterial osteomyelitis, which reduced inflammation while enhancing emotional and social indicators. These findings highlight the potential of integrative care models that focus on the patient's overall health and resilience.

Biodegradable materials have introduced a new dimension to osteomyelitis management. Ford *et al*. (2017) [9] demonstrated that these materials not only supported significant functional improvements, such as joint stability and reduced rehabilitation times, but also eliminated the need for subsequent surgical removal. These innovations represent a vital step toward patient-centered care, reducing the physical and logistical burden of treatment.

Future studies should systematically assess functional outcomes and quality of life across diverse osteomyelitis populations. Standardized metrics and multicenter research efforts are essential to develop a comprehensive understanding of the clinical and social impacts of this condition. By integrating these findings, clinicians can refine therapeutic approaches to ensure that they address both the clinical and holistic needs of patients.

Adopting a patient-centered approach, which considers the clinical and psychosocial aspects of osteomyelitis, is crucial to optimizing functional outcomes and enhancing quality of life. These insights reaffirm the necessity of a holistic perspective in managing this multifaceted condition, ensuring that therapeutic advancements translate into meaningful, long-lasting improvements for those affected.

4. Conclusion

This study reviewed the literature on osteomyelitis in lower limbs, focusing on the effectiveness of therapeutic interventions and their impact on clinical outcomes, functionality, and patients' quality of life. The analysis revealed that osteomyelitis is a multifaceted condition requiring integrated therapeutic approaches, combining surgical interventions, personalized medicinal therapies, and the use of antibiotic-loaded cements for effective infection control.

Targeted medicinal therapies, tailored based on bacterial cultures, were shown to be essential in reducing antimicrobial resistance and improving clinical outcomes. Additionally, technological innovations, such as biodegradable materials and controlled-release devices, have emerged as promising tools for managing chronic and refractory cases.

Functional outcomes and quality-of-life indicators underscore the importance of a patient-centered approach that goes beyond infection resolution and considers the physical, emotional, and social impacts of the condition. The adoption of multidisciplinary strategies, involving medical teams, physiotherapists, and psychologists, has proven crucial for optimizing results and promoting patients' holistic recovery.

Considering the gaps identified in the literature, future studies are recommended to explore prognostic factors and the effectiveness of emerging therapeutic technologies. These efforts could significantly contribute to the standardization of protocols and the improvement of clinical practices in the management of osteomyelitis.

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