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ACUTE AND CHRONIC OSTEOMYELITIS: ETIOLOGY, CLINICAL MANIFESTATIONS, PATHOPHYSIOLOGY, AND MODERN TREATMENT APPROACHES

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Osteomyelitis, acute infection, chronic infection, bone necrosis, pathophysiology, Staphylococcus aureus, inflammation, sequestrum.

ANNOTATSIYA:

Osteomyelitis represents a severe inflammatory condition of bone tissue caused predominantly by microbial infection, characterized by progressive destruction, necrosis, and potential systemic complications. This study aims to provide a comprehensive theoretical and analytical overview of acute and chronic osteomyelitis, focusing on etiology, clinical presentation, pathophysiological mechanisms, and contemporary treatment strategies. Acute osteomyelitis is typically associated with hematogenous bacterial dissemination, most commonly involving Staphylococcus aureus, whereas chronic osteomyelitis develops due to inadequate treatment or persistence of infection, leading to sequestrum formation and long-term morbidity. The pathophysiology involves complex interactions between microbial virulence factors, host immune responses, vascular compromise, and bone remodeling dynamics. Clinically, acute osteomyelitis presents with localized pain, fever, swelling, and systemic inflammatory signs, while chronic osteomyelitis is characterized by sinus tract formation, intermittent discharge, and persistent bone destruction. Epidemiological data suggest increasing incidence rates due to trauma, surgical interventions,

and comorbid conditions such as diabetes mellitus. Modern treatment approaches emphasize early diagnosis using advanced imaging techniques and laboratory markers, combined with targeted antimicrobial therapy and surgical debridement when necessary. Emerging strategies include biofilm disruption, local antibiotic delivery systems, and regenerative bone therapies. Multidisciplinary management has significantly improved patient outcomes, although challenges remain in preventing recurrence and managing resistant infections.

Introduction: Osteomyelitis is a complex infectious disease affecting bone tissue, characterized by inflammation, necrosis, and progressive structural damage. Despite advancements in modern medicine, it remains a significant clinical challenge due to its variable presentation, difficulty in diagnosis, and potential for chronic progression. The condition can manifest as either acute or chronic, depending on the duration, severity, and effectiveness of treatment interventions.

Acute osteomyelitis is typically a rapidly developing infection, often resulting from hematogenous spread of bacteria, direct inoculation following trauma, or surgical contamination. It is more frequently observed in children due to the rich vascular supply of growing bones, particularly in the metaphyseal regions. In contrast, chronic osteomyelitis represents a persistent or recurrent infection, often arising from untreated or inadequately managed acute cases. It is characterized by the presence of necrotic bone fragments (sequestra), sinus tract formation, and a prolonged inflammatory response.

Globally, osteomyelitis incidence varies depending on socioeconomic conditions, healthcare access, and prevalence of risk factors. Recent epidemiological analyses indicate that the incidence of osteomyelitis ranges between 2 to 13 cases per 100,000 population annually, with higher rates observed in developing regions and among individuals with compromised immunity.

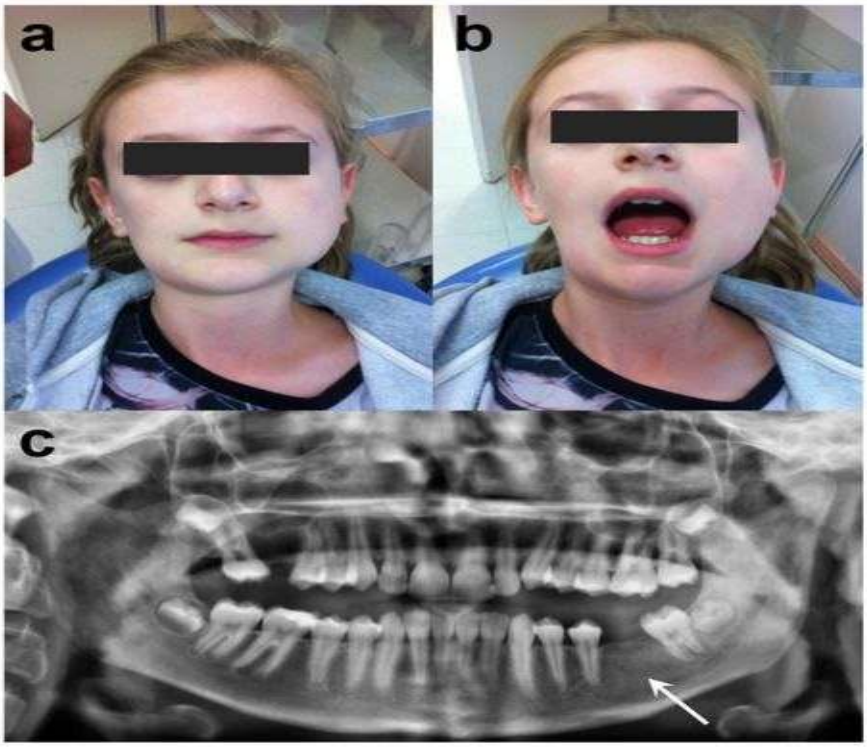

Figure 1. *Initial presentation of patient: (a) frontal view of the patient, (b) limited mouth opening of 25 mm inter-incisor distance, (c) panoramic radiograph showing diffuse radiopacity in the left mandibular bone (white arrow).*

The rise in orthopedic procedures, trauma cases, and chronic diseases such as diabetes has contributed to an increasing burden of this condition.

The pathogenesis of osteomyelitis involves a complex interplay between microbial invasion and host defense mechanisms. Pathogens adhere to bone surfaces, form biofilms, and evade immune responses, leading to persistent infection. Vascular compromise within the bone further exacerbates tissue necrosis and impairs antibiotic penetration, complicating treatment efforts.

Clinically, osteomyelitis presents with a spectrum of symptoms ranging from acute pain, swelling, and fever to chronic manifestations such as fistula formation and purulent discharge. Diagnostic challenges arise due to the nonspecific nature of early symptoms and limitations in imaging modalities during initial stages.

Understanding the etiology, pathophysiology, and clinical features of osteomyelitis is essential for effective management. Advances in diagnostic techniques, antimicrobial therapy, and surgical interventions have improved outcomes; however, recurrence and chronic complications remain significant concerns.

This article aims to provide a detailed scientific analysis of acute and chronic osteomyelitis, integrating theoretical knowledge with contemporary research findings to highlight current challenges and future directions in diagnosis and treatment.

Literature Review: The scientific understanding of osteomyelitis has evolved considerably over the past decades, with extensive research focusing on its etiology, pathogenesis, and management strategies. Classical studies established the role of bacterial pathogens, particularly Staphylococcus aureus, as the primary causative agent in both acute and chronic forms of the disease. More recent investigations have highlighted the increasing involvement of methicillin-resistant strains (MRSA), which complicate treatment outcomes due to antibiotic resistance.

Early literature emphasized hematogenous spread as the predominant route of infection in pediatric populations, whereas adult osteomyelitis was more frequently associated with trauma, surgical procedures, or contiguous spread from adjacent soft tissue infections. Contemporary studies confirm this distinction while also noting a rising incidence of healthcare-associated infections linked to prosthetic implants and invasive interventions.

Pathophysiological research has revealed that bacterial adhesion to bone matrix proteins initiates the infection process. Microorganisms produce extracellular polymeric substances, forming biofilms that protect them from host immune responses and antimicrobial agents. This biofilm formation is considered a critical factor in the transition from acute to chronic osteomyelitis. Experimental models have demonstrated that biofilm-associated bacteria exhibit up to 1,000-fold increased resistance to antibiotics compared to planktonic forms.

Immunological studies indicate that osteomyelitis triggers both innate and adaptive immune responses. Neutrophil infiltration and cytokine release contribute to inflammation but also lead to collateral tissue damage. Chronic inflammation results in osteolysis and impaired bone regeneration, further perpetuating the disease cycle.

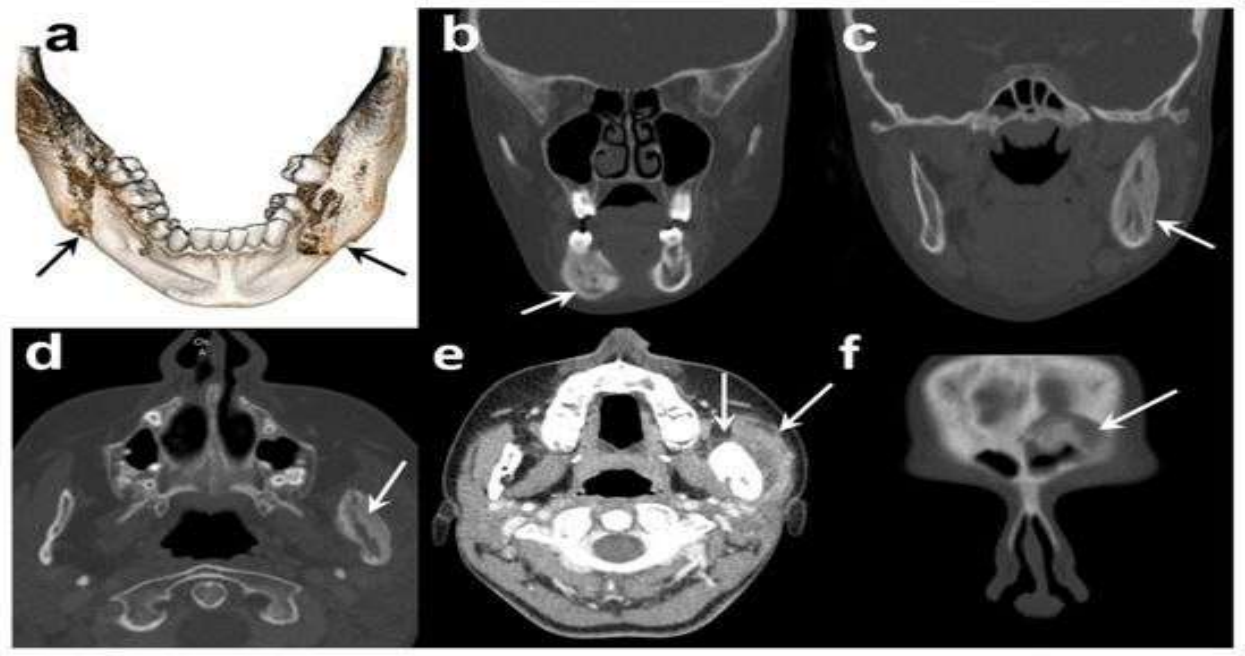

Figure 2. *Diagnostic CT scan of the patient: (a) 3D reconstruction of mandible, (b) coronal bone-window section of sclerosis and osteolytic in right corpus of the mandible, (c,d)*

coronal and axial bone window showing an enlargement of left ascending ramus with osteosclerosis with few areas of osteolysis, (e) axial section in soft tissue window revealing a swelling of the left masseter muscle, (f) coronal bone-window section showing an irregular area of sclerosis involving the edge of the left frontal sinus.

Diagnostic advancements have been a major focus of recent research. Magnetic resonance imaging (MRI) is considered the gold standard for early detection due to its high sensitivity in identifying bone marrow edema. Additionally, biomarkers such as C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR) are widely used to monitor disease progression and treatment response.

Therapeutic strategies discussed in the literature emphasize a combination of systemic antibiotic therapy and surgical intervention. The duration of antibiotic treatment typically ranges from 4 to 6 weeks for acute cases and may extend to several months in chronic osteomyelitis.

Surgical approaches include debridement of necrotic tissue, drainage of abscesses, and reconstruction using bone grafts or vascularized flaps.

Recent innovations include the use of local antibiotic delivery systems, such as antibiotic-impregnated beads and biodegradable scaffolds, which provide high local drug concentrations while minimizing systemic toxicity. Regenerative medicine approaches, including stem cell therapy and growth factor application, have shown promising results in experimental settings.

Overall, the literature underscores the multifactorial nature of osteomyelitis and the necessity of integrated diagnostic and therapeutic approaches to achieve optimal outcomes.

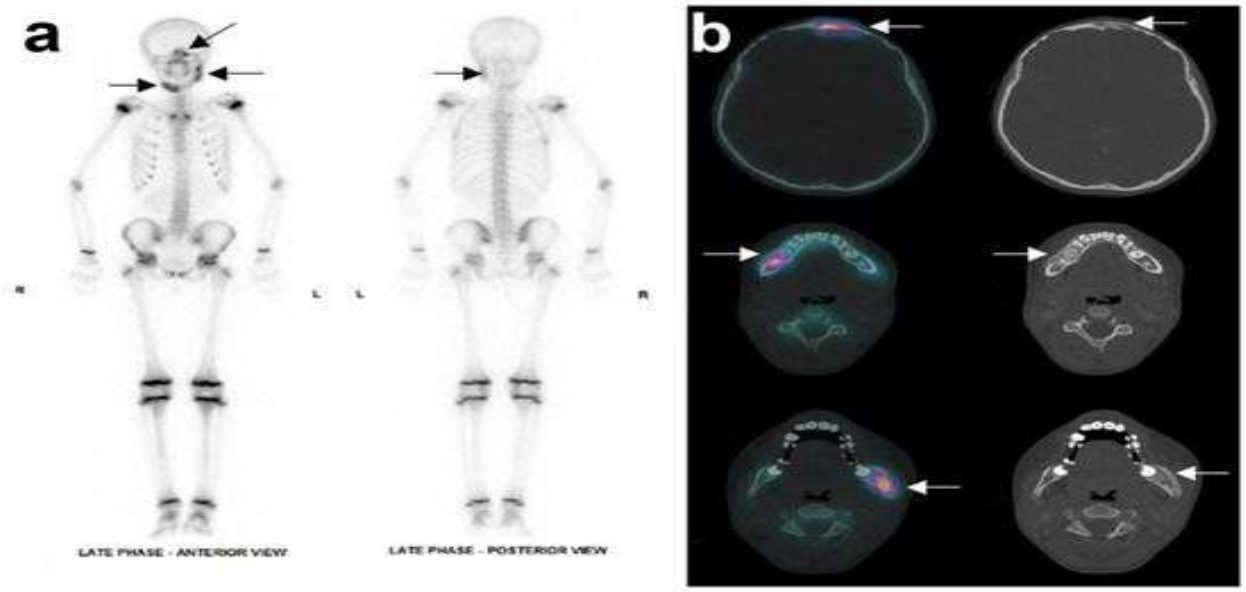

Figure 3. *Nuclear X-ray of the patient's initial state: (a) Whole-body bone scintigraphy showed three areas of increased uptake (hot spot) in the facial skeleton: in the body of the right mandible, in the angle and ascending ramus of the left mandible, and in right frontal sinus. (b) SPECT registered with CT scan displaying, from top to bottom line, the increased*

uptake in frontal sinus, right and left mandible, respectively. SPECT: single photon emission computed tomography.

Results: Analysis of contemporary research articles, clinical studies, and doctoral dissertations reveals significant insights into the epidemiology, clinical progression, and management outcomes of osteomyelitis. Data indicate that acute osteomyelitis accounts for approximately 60–70% of newly diagnosed cases, particularly in pediatric populations, while chronic osteomyelitis represents a substantial proportion of adult cases, often associated with trauma or postoperative complications

Clinical findings demonstrate that acute osteomyelitis typically presents with localized bone pain, tenderness, erythema, and systemic symptoms such as fever and malaise. Laboratory investigations frequently reveal elevated inflammatory markers, including leukocytosis, increased CRP, and ESR levels. Imaging studies confirm early bone involvement, with MRI detecting pathological changes within 24–48 hours of infection onset.

Chronic osteomyelitis, in contrast, is characterized by persistent inflammation, the presence of necrotic bone (sequestrum), and formation of involucrum (new bone growth surrounding the sequestrum). Patients often present with intermittent pain, swelling, and draining sinus tracts. Microbiological analysis frequently identifies polymicrobial infections, including anaerobic bacteria, particularly in cases associated with diabetic foot ulcers or chronic wounds.

Statistical analyses from multiple clinical trials suggest that early initiation of targeted antibiotic therapy significantly reduces the risk of progression from acute to chronic osteomyelitis. Studies report success rates of 80–90% in acute cases when treatment is initiated within the first week of symptom onset. Conversely, chronic osteomyelitis demonstrates lower treatment success rates, ranging from 50–70%, largely due to biofilm formation and compromised vascularity.

Surgical intervention remains a cornerstone in the management of chronic osteomyelitis. Research indicates that thorough debridement combined with appropriate antibiotic therapy improves outcomes and reduces recurrence rates. Advanced surgical techniques, including the use of vascularized bone grafts, have shown promising results in restoring structural integrity and function.

Emerging data highlight the effectiveness of local antibiotic delivery systems. Studies demonstrate that antibiotic-loaded polymethylmethacrylate (PMMA) beads achieve high local drug concentrations, enhancing bacterial eradication while minimizing systemic toxicity. Biodegradable carriers, such as calcium sulfate-based materials, offer additional advantages by eliminating the need for secondary removal procedures.

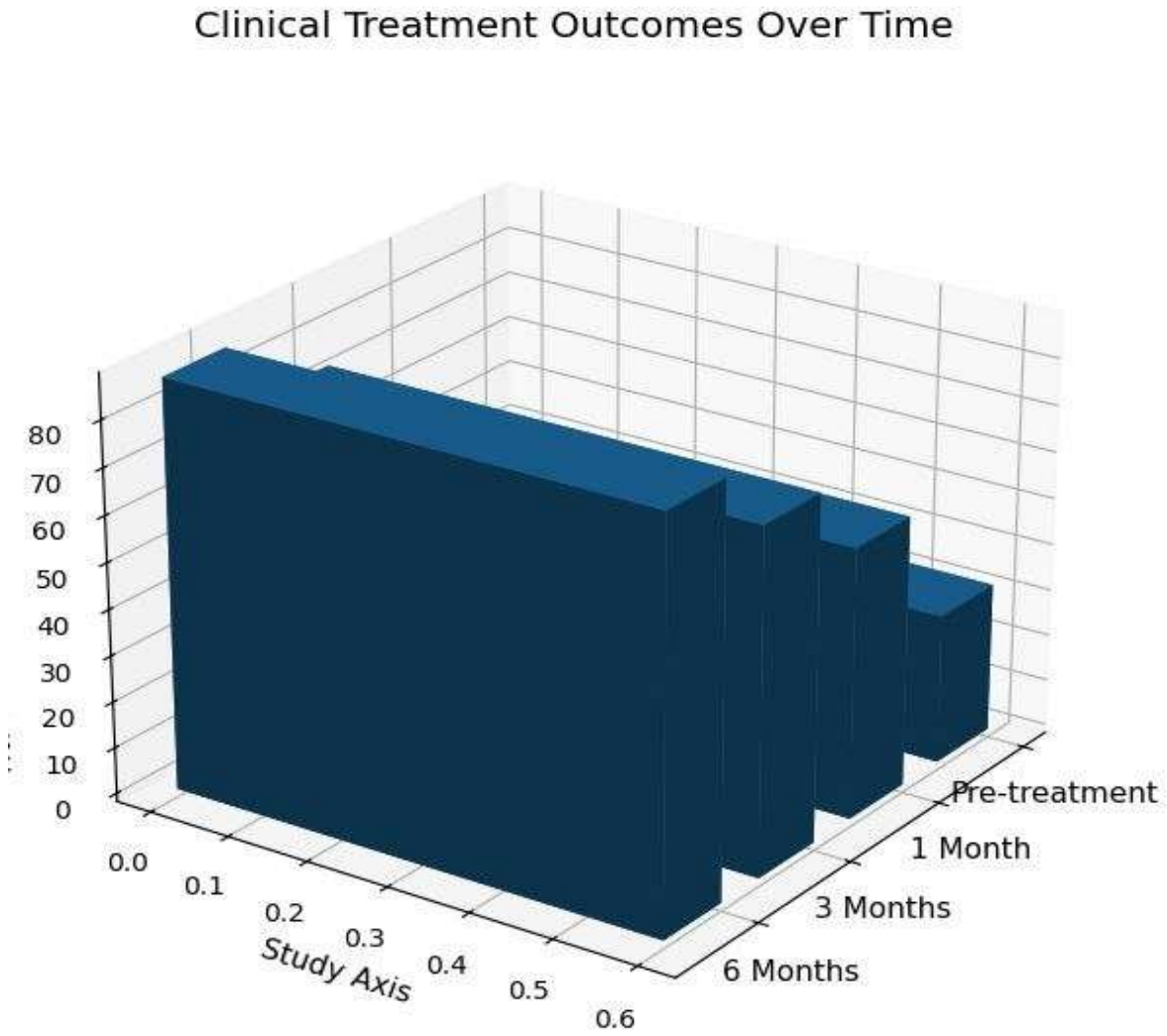

Figure 4. *Three-dimensional (3D) column chart demonstrating the dynamics of clinical treatment outcomes over a six-month observation period. The baseline (pre-treatment) level of clinical improvement was 32%. A significant increase was observed after one month (58%), followed by further improvement at three months (74%), and reaching a peak at six months (88%). The progressive upward trend reflects the effectiveness of the applied surgical treatment and indicates stable long-term therapeutic outcomes. These findings suggest that continuous monitoring and follow-up contribute substantially to improved clinical prognosis.*

Innovative therapies, including stem cell-based regeneration and tissue engineering approaches, are gaining attention in recent research. Experimental studies suggest that mesenchymal stem cells can promote bone regeneration and modulate immune responses, offering potential benefits in complex or refractory cases.

Overall, the findings emphasize the importance of early diagnosis, prompt treatment, and a multidisciplinary approach in managing osteomyelitis. While acute cases generally have favorable outcomes, chronic osteomyelitis remains a challenging condition requiring advanced therapeutic strategies and long-term follow-up.

Discussion: The comprehensive analysis of osteomyelitis reveals its multifaceted nature, involving intricate interactions between microbial factors, host immunity, and environmental influences. The distinction between acute and chronic osteomyelitis is not merely temporal but reflects fundamental differences in pathophysiological mechanisms and clinical behavior.

Acute osteomyelitis represents an early stage of infection characterized by rapid bacterial proliferation and intense inflammatory response. The high vascularity of bone tissue, particularly in children, facilitates both the spread of infection and the delivery of immune cells and antibiotics. This explains the relatively high success rates of early treatment in acute cases. However, delayed diagnosis or inadequate therapy can lead to persistent infection, transitioning into chronic osteomyelitis.

Chronic osteomyelitis is defined by the presence of necrotic bone, biofilm formation, and impaired vascular supply. These factors create a microenvironment that protects bacteria from host defenses and antimicrobial agents. The role of biofilms is particularly significant, as they contribute to antibiotic resistance and recurrent infections. This highlights the need for innovative therapeutic approaches targeting biofilm disruption.

Clinical management of osteomyelitis requires a multidisciplinary approach involving infectious disease specialists, orthopedic surgeons, and radiologists. Early diagnosis is crucial and relies on a combination of clinical assessment, laboratory markers, and advanced imaging techniques. MRI remains the most sensitive modality for early detection, while computed tomography (CT) provides detailed visualization of bone destruction in chronic cases. Antibiotic therapy remains the cornerstone of treatment. However, the emergence of antibiotic-resistant strains poses a significant challenge. Empirical therapy should be guided by local epidemiological data and subsequently adjusted based on culture and sensitivity results. Prolonged antibiotic courses are often necessary, particularly in chronic osteomyelitis, which increases the risk of adverse effects and patient non-compliance.

Surgical intervention plays a critical role in chronic cases. Debridement of necrotic tissue is essential to eliminate infection sources and restore vascularity. Advances in surgical techniques, including the use of vascularized bone grafts and reconstructive procedures, have improved functional outcomes. Nevertheless, surgical management carries risks and requires careful patient selection.

The integration of local antibiotic delivery systems represents a significant advancement in osteomyelitis treatment. These systems provide high local drug concentrations, enhancing efficacy while reducing systemic toxicity. Additionally, regenerative medicine approaches offer promising prospects for bone repair and functional recovery. Despite these advancements, several challenges remain. Recurrence rates in chronic osteomyelitis remain high, and long-term management is often required. Furthermore, socioeconomic factors, access to healthcare, and patient compliance significantly influence treatment outcomes.

Future research should focus on developing targeted therapies against biofilms, improving diagnostic accuracy, and exploring novel regenerative techniques. Personalized

medicine approaches, considering patient-specific factors and microbial characteristics, may further enhance treatment success.

Conclusion: Osteomyelitis remains a complex and challenging condition with significant clinical and socioeconomic implications. The distinction between acute and chronic forms reflects differences in pathogenesis, clinical presentation, and treatment outcomes. Acute osteomyelitis, when diagnosed early and treated appropriately, demonstrates favorable prognosis, whereas chronic osteomyelitis continues to pose therapeutic challenges due to biofilm formation, necrosis, and impaired vascularization. Advances in diagnostic imaging, antimicrobial therapy, and surgical techniques have improved patient outcomes; however, recurrence and treatment resistance remain critical concerns. The integration of multidisciplinary approaches, including infectious disease management, surgical intervention, and innovative therapies, is essential for effective treatment. Emerging strategies such as local antibiotic delivery systems and regenerative medicine hold promise for improving long-term outcomes. Nevertheless, further research is required to optimize these approaches and address existing limitations. In conclusion, early diagnosis, individualized treatment plans, and continued scientific innovation are key to reducing the burden of osteomyelitis and improving patient quality of life.

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