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# Microbiological Profile and Antibiotic Resistance Pattern of Osteomyelitis: A Cross-Sectional Study of Patients with Special Reference to Multidrug-Resistant Strains

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## ABSTRACT

**Background:** Osteomyelitis is a complex and challenging bone infection caused by a variety of microorganisms. Its clinical management is complicated by the increasing prevalence of multidrug-resistant (MDR) strains, making it crucial to study the microbiological profile and antibiotic resistance patterns to guide empirical therapy.

**Objective:** The study aims to evaluate the microbiological profile of osteomyelitis and assess the antibiotic resistance patterns of bacterial isolates, with a special focus on MDR strains, in a tertiary care hospital.

**Methods:** A cross-sectional study was conducted from August 2023 to August 2024. A total of 100 clinically suspected osteomyelitis cases were included. Pus, bone sequestrum, and synovial fluid samples were processed for aerobic culture and bacterial identification. Antibiotic susceptibility testing (AST) was performed according to the Clinical and Laboratory Standards Institute (CLSI) 2023 guidelines.

**Results:** Among the 100 cases, 78% were culture-positive. *Staphylococcus aureus* was the most common pathogen (48.7%), followed by *Escherichia coli* (23.1%). Gram-negative bacilli showed 100% sensitivity to Colistin and Polymyxin B. Methicillin-resistant *Staphylococcus aureus* (MRSA) was identified in 42.1% of cases. The prevalence of extended-spectrum beta-lactamases (ESBL) and metallo-beta-lactamases (MBL) producers was found to be 46.8% and 9.3%, respectively.

**Conclusion:** Osteomyelitis remains a significant clinical challenge due to the high prevalence of MDR strains. Effective infection control and antibiotic stewardship are essential to control the spread of these resistant pathogens in hospital settings.

**Keywords:** Osteomyelitis, Multidrug-resistant, MRSA, ESBL, MBL, Antibiotic resistance, Tertiary care hospital

## INTRODUCTION

Osteomyelitis is a progressive inflammatory disease of bone caused by microbial invasion, resulting in bone destruction, necrosis, and potential systemic complications if inadequately treated. Despite significant advances in diagnostic imaging, surgical techniques, and antimicrobial therapy, osteomyelitis continues to pose a substantial clinical challenge worldwide due to its chronic nature, complex pathophysiology, and increasing antimicrobial resistance [1,2]. The disease affects individuals across all age groups, with higher incidence reported in children and elderly populations, particularly in those with underlying comorbidities [3].

Osteomyelitis may be classified as acute, subacute, or chronic based on the duration of infection and pathological features. Acute osteomyelitis typically arises from hematogenous spread, whereas chronic osteomyelitis is often associated with trauma, open fractures, post-surgical infections, or orthopedic implants [4,5]. Ahmed R, Agarwal S, Sharma V, Afaq N, et al. (2024) – ESBL producing organisms
The study detected a high prevalence of ESBL-producing Gram-negative bacteria in clinical isolates. Molecular analysis confirmed the presence of resistance genes such as **CTX-M, TEM, and SHV**, indicating increasing antimicrobial resistance [4].

Chronic osteomyelitis is characterized by the presence of sequestra, sinus tract formation, compromised vascularity, and biofilm production, all of which contribute to therapeutic failure and recurrence [6].

The epidemiology of osteomyelitis varies significantly between developed and developing countries. In low- and middle-income nations, trauma and postoperative infections remain the most common predisposing factors, while hematogenous spread and prosthetic joint infections are more prevalent in high-income countries [7,8]. Diabetes mellitus, peripheral vascular disease, immunosuppression, malnutrition, and prolonged hospitalization further increase the risk of chronic and refractory infections [9].

Microbiologically, *Staphylococcus aureus* remains the most frequently isolated pathogen in osteomyelitis across all age groups [10]. Its ability to adhere to bone matrix proteins, invade osteoblasts, and form biofilms makes it particularly difficult to eradicate [11]. Methicillin-resistant *Staphylococcus aureus* (MRSA) has emerged as a major concern, especially in hospital-

acquired and implant-associated infections [12]. In recent years, Gram-negative bacilli such as *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, and *Acinetobacter baumannii* have been increasingly reported, particularly in chronic, post-traumatic, and healthcare-associated osteomyelitis [13,14].

The emergence of multidrug-resistant (MDR) organisms has significantly altered the clinical management of osteomyelitis. Extended-spectrum beta-lactamase (ESBL) producing Enterobacterales and metallo-beta-lactamase (MBL) producing non-fermenters severely limit therapeutic options and are associated with prolonged hospital stay, increased costs, and poor outcomes [15,16]. Injudicious use of broad-spectrum antibiotics and lack of antimicrobial stewardship have accelerated the spread of resistant strains [17].

Accurate microbiological diagnosis plays a pivotal role in the management of osteomyelitis. Isolation of the causative organism from deep tissue or bone samples remains the gold standard, as superficial swab cultures often fail to reflect the true pathogen [18]. Antimicrobial susceptibility testing (AST) is essential for guiding targeted therapy and preventing treatment failure [19].

Given the rising burden of MDR organisms and the variability in local microbiological patterns, continuous surveillance studies are essential. The present study was undertaken to evaluate the microbiological profile and antibiotic resistance patterns of osteomyelitis in a tertiary care hospital, with special emphasis on MRSA, ESBL, and MBL producing organisms, to aid clinicians in selecting appropriate empirical and definitive antimicrobial therapy [20–22].

## MATERIALS AND METHODS

### Study Design and Setting

A hospital-based cross-sectional study was conducted in the Department of Microbiology in collaboration with the Department of Orthopedics at a tertiary care centre over a period of one year (August 2024 to August 2025).

### Study Population

A total of 100 patients clinically suspected of osteomyelitis were included.

**Inclusion Criteria**

1. Patients of all age groups and both sexes
2. Clinically and radiologically suspected cases of osteomyelitis
3. Patients undergoing surgical debridement or drainage
4. Patients who provided informed consent

**Exclusion Criteria**

1. Patients already on prolonged antibiotic therapy (>72 hours)
2. Patients with superficial wound infections without bone involvement
3. Culture-negative cases due to improper or inadequate sample collection
4. Patients unwilling to participate

**Sample Collection and Processing**

Specimens including pus, bone sequestrum, and synovial fluid were collected aseptically and transported immediately to the microbiology laboratory. Samples were processed for aerobic culture using standard bacteriological techniques.

**Identification and Antibiotic Susceptibility Testing**

Isolates were identified by colony morphology, Gram staining, and biochemical tests. Antimicrobial susceptibility testing was performed using the Kirby-Bauer disc diffusion method and interpreted according to CLSI 2023 guidelines.

**Detection of Resistance Mechanisms**

- MRSA: Cefoxitin disc diffusion method
- ESBL: Combination disc method
- MBL: Imipenem-EDTA combined disc test

## RESULTS

Out of the 100 clinically suspected cases of osteomyelitis, 78% yielded positive bacterial growth, indicating a high diagnostic yield of properly collected deep samples. The tibia emerged as the most frequently involved bone, followed by the femur, reflecting the vulnerability of long bones to trauma and hematogenous spread.

Trauma was the most common predisposing factor, accounting for 41% of cases, followed by postoperative infections and orthopedic implants. Diabetes mellitus acted as a significant comorbidity, particularly in chronic and implant-associated infections.

Among culture-positive cases, Gram-positive cocci predominated. *Staphylococcus aureus* was the most common isolate, accounting for nearly half of all infections. Gram-negative bacilli constituted a substantial proportion, with *E. coli* being the leading pathogen. A high rate of ESBL production (46.8%) was observed among Gram-negative isolates, while MBL production was detected in 9.3% of cases.

MRSA accounted for 42.1% of *S. aureus* isolates. Glycopeptides and linezolid retained excellent activity against Gram-positive cocci, while colistin and polymyxin-B remained the most effective agents against Gram-negative bacilli. Fluoroquinolone resistance was notably high across both groups.

**Table 1: Distribution of Culture Results (n = 100)**

| Culture result | Number of cases | Percentage (%) |
|---|---|---|
| Culture positive | 78 | 78% |
| Culture negative | 22 | 22% |
| **Total** | **100** | **100%** |

Out of the 100 clinically suspected osteomyelitis cases included in the study, **78 (78%) showed significant bacterial growth**, while **22 (22%) samples were culture negative**. This high culture positivity indicates an appropriate selection of clinically suspected cases and adequate sample collection techniques.

**Table 2: Distribution of Bones Involved in Osteomyelitis (n = 100)**

| Bone involved | Number of cases | Percentage (%) |
|---|---|---|
| Tibia | 49 | 49% |
| Femur | 33 | 33% |
| Fibula | 5 | 5% |
| Ulna | 3 | 3% |
| Radius | 2 | 2% |
| Metacarpal | 2 | 2% |
| Metatarsal | 2 | 2% |
| Calcaneus | 2 | 2% |
| Humerus | 2 | 2% |
| **Total** | **100** | **100%** |

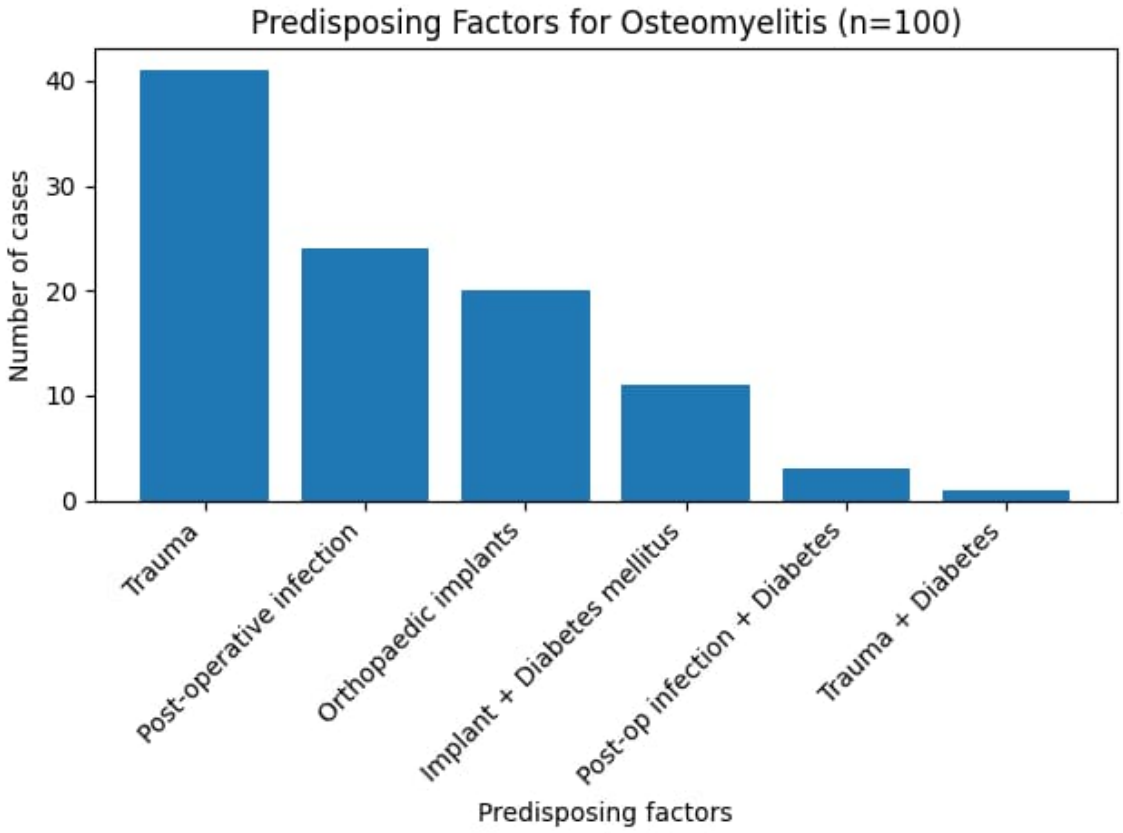
The **tibia was the most commonly affected bone (49%)**, followed by the **femur (33%)**. Other bones such as fibula, ulna, radius, and small bones of the hand and foot were less frequently involved. The predominance of tibial involvement may be attributed to its subcutaneous location and vulnerability to trauma.

**Table 3: Predisposing Factors for Osteomyelitis (n = 100)**

| Predisposing factor | Number of cases | Percentage (%) |
|---|---|---|
| Trauma | 41 | 41% |
| Post-operative infection | 24 | 24% |
| Orthopaedic implants | 20 | 20% |
| Implant + Diabetes mellitus | 11 | 11% |
| Post-operative infection + Diabetes mellitus | 3 | 3% |
| Trauma + Diabetes mellitus | 1 | 1% |

| Predisposing factor | Number of cases | Percentage (%) |
|---|---|---|
| **Total** | **100** | **100%** |

**Trauma was the most common predisposing factor (41%)**, followed by **post-operative infections (24%)** and **orthopaedic implant-related infections (20%)**. Diabetes mellitus was frequently associated as a co-morbid condition, either alone or in combination with trauma or surgical intervention, highlighting its role in chronic and complicated infections.




**Graph 1: Predisposing Factors for Osteomyelitis**

**Table 4: Bacterial Isolates from Culture Positive Cases (n = 78)**

| Organism | Number of isolates | Percentage (%) |
|---|---|---|
| *Staphylococcus aureus* | 38 | 48.7% |
| *Escherichia coli* | 18 | 23.1% |

| Organism | Number of isolates | Percentage (%) |
|---|---|---|
| *Klebsiella pneumoniae* | 5 | 6.4% |
| *Pseudomonas aeruginosa* | 4 | 5.1% |
| Coagulase-negative Staphylococci | 4 | 5.1% |
| *Staphylococcus lugdunensis* | 4 | 5.1% |
| *Proteus mirabilis* | 3 | 3.8% |
| *Acinetobacter baumannii* | 2 | 2.6% |
| **Total** | **78** | **100%** |

Among the culture-positive cases, **Gram-positive cocci predominated**, with *Staphylococcus aureus* being the most common isolate (48.7%). Among Gram-negative bacilli, *E. coli* was the leading pathogen. This distribution reflects the typical microbiological pattern seen in chronic osteomyelitis.

**Table 5: Antibiotic Sensitivity Pattern of Gram-Negative Bacilli (n = 32)**

| Antibiotic | Sensitive isolates n (%) |
|---|---|
| Colistin | 32 (100%) |
| Polymyxin-B | 32 (100%) |
| Imipenem | 29 (90.6%) |
| Meropenem | 29 (90.6%) |
| Piperacillin/Tazobactam | 26 (81.2%) |
| Amikacin | 24 (75%) |
| Gentamicin | 21 (65.6%) |
| Ciprofloxacin | 9 (28.1%) |

**Explanation**

All Gram-negative isolates showed **100% sensitivity to Colistin and Polymyxin-B**. High sensitivity was also observed with carbapenems. Fluoroquinolone resistance was notably high, indicating limited utility in empirical therapy.

**Table 6: ESBL Producers among Gram-Negative Bacilli (n = 32)**

| **Organism** | **Total isolates** | **ESBL producers n (%)** |
|---|---|---|
| *E. coli* | 18 | 8 (44.4%) |
| *Klebsiella spp.* | 5 | 3 (60%) |
| *Pseudomonas spp.* | 4 | 1 (25%) |
| *Proteus spp.* | 3 | 1 (33.3%) |
| *Acinetobacter spp.* | 2 | 2 (100%) |
| **Total** | **32** | **15 (46.8%)** |

Nearly **half of the Gram-negative isolates were ESBL producers**, with the highest proportion observed among *Acinetobacter* and *Klebsiella* species, reflecting a significant resistance burden.

**Table 7: MBL Producers among Gram-Negative Bacilli (n = 32)**

| **Organism** | **MBL producers n (%)** |
|---|---|
| *Pseudomonas spp.* | 2 (50%) |
| *Proteus spp.* | 1 (33.3%) |
| Others | 0 |
| **Total** | **3 (9.3%)** |

MBL production was detected in **9.3% of Gram-negative isolates**, predominantly among *Pseudomonas* species, indicating emerging carbapenem resistance.

**Table 8: Antibiotic Sensitivity Pattern of Gram-Positive Cocci (n = 46)**

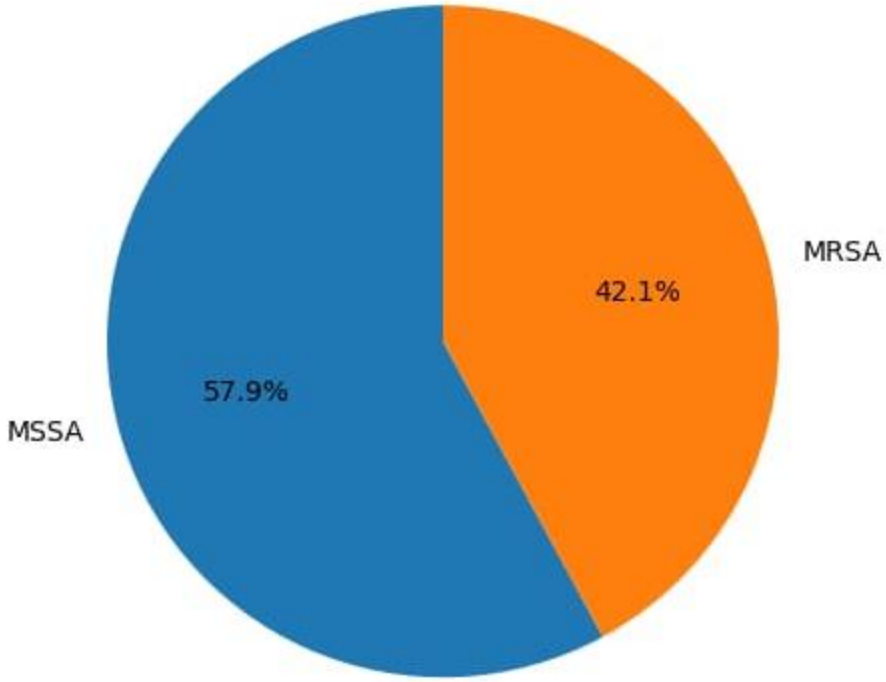
| Antibiotic | Sensitive isolates n (%) |
|---|---|
| Vancomycin | 46 (100%) |
| Teicoplanin | 46 (100%) |
| Linezolid | 45 (97.8%) |
| Gentamicin | 42 (91.3%) |
| Amikacin | 41 (89.1%) |
| Ciprofloxacin | 12 (26.1%) |

All Gram-positive isolates were **uniformly sensitive to Vancomycin and Teicoplanin**, while resistance to fluoroquinolones was high, limiting their empirical use.

**Table 9: Distribution of MRSA and MSSA (n = 38)**

| Type | Number | Percentage (%) |
|---|---|---|
| MSSA | 22 | 57.9% |
| MRSA | 16 | 42.1% |
| **Total** | **38** | **100%** |

Among *Staphylococcus aureus* isolates, **42.1% were MRSA**, indicating a substantial burden of methicillin resistance in osteomyelitis cases.

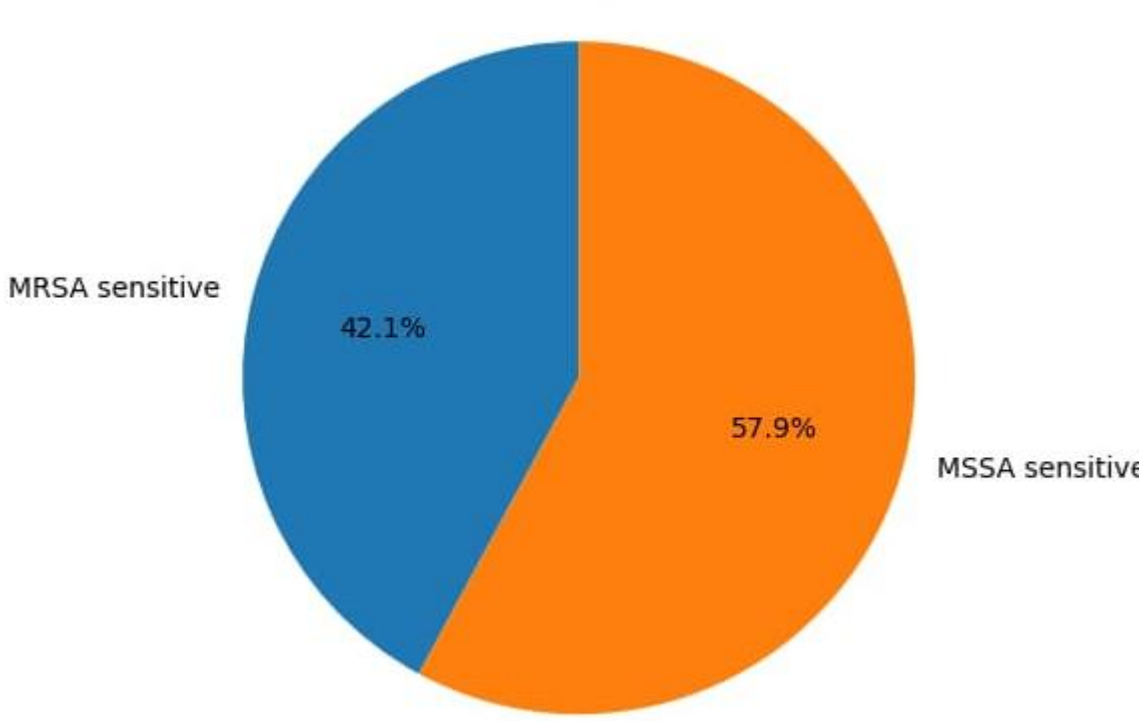



**Graph 2: Distribution of MRSA and MSSA**

**Table 10: Antibiotic Sensitivity Pattern of MRSA vs MSSA**

| Antibiotic | MRSA n (%) | MSSA n (%) |
|---|---|---|
| Vancomycin | 16 (100%) | 22 (100%) |
| Linezolid | 15 (93.7%) | 22 (100%) |
| Gentamicin | 14 (87.5%) | 21 (95.4%) |
| Ciprofloxacin | 4 (25%) | 6 (27.2%) |

Both MRSA and MSSA isolates retained excellent susceptibility to glycopeptides and linezolid, while resistance to fluoroquinolones was common, especially among MRSA strains.




**Graph 3: Antibiotic Sensitivity Pattern of MRSA vs MSSA**

## DISCUSSION

Osteomyelitis remains a formidable clinical challenge due to its chronic course, complex host–pathogen interaction, and the rising prevalence of multidrug-resistant (MDR) organisms. In the present study, a culture positivity rate of 78% was observed among clinically suspected cases. This finding is comparable with reports by Vijayakumar et al. and Vemu et al., who documented culture positivity rates ranging from 65% to 82% in tertiary care settings, emphasizing the importance of appropriate deep tissue sampling in suspected osteomyelitis cases [14,15].

The tibia was the most frequently involved bone in our study, followed by the femur. Similar observations have been reported by Panteli and Giannoudis and Khonglah et al., who attributed the predominance of tibial involvement to its subcutaneous location, poor soft-tissue coverage, and increased vulnerability to trauma and hematogenous spread [6,22]. Long bones are

particularly prone to infection in developing countries due to delayed presentation and inadequate initial wound management.

Trauma emerged as the most common predisposing factor (41%) in our study, followed by postoperative infections and orthopedic implant-associated infections. This pattern is consistent with findings from studies conducted in low- and middle-income countries, where trauma and surgical interventions are major contributors to chronic osteomyelitis [16,17]. The frequent association of diabetes mellitus observed in our study further supports its role in impaired immunity, delayed wound healing, and persistence of infection, as highlighted by Sia and Berbari [9].

Microbiologically, Gram-positive cocci predominated, with *Staphylococcus aureus* accounting for 48.7% of isolates. This observation aligns with extensive global literature identifying *S. aureus* as the principal etiological agent of osteomyelitis [1,3,10]. The organism's ability to adhere to bone matrix proteins, invade osteoblasts, and form biofilms contributes significantly to chronicity and treatment failure [29].

The proportion of methicillin-resistant *Staphylococcus aureus* (MRSA) in our study was 42.1%, which is comparable to Indian studies by Habeeb Khadri and Alzohairy and Mita et al., who reported MRSA prevalence ranging from 35% to 55% [12,23]. The high burden of MRSA underscores the growing challenge of managing osteomyelitis in hospital settings. The universal susceptibility of MRSA isolates to vancomycin and teicoplanin in our study mirrors findings from several Indian and international studies, reaffirming glycopeptides as the drugs of choice for serious MRSA infections [11,13].

Gram-negative bacilli constituted a significant proportion of isolates, with *Escherichia coli* being the most common Gram-negative pathogen. Similar microbiological trends have been reported in chronic and post-traumatic osteomyelitis by Abid et al. and Fantoni et al., particularly in patients with prolonged hospital stays and implant-associated infections [20,13]. The increasing isolation of Gram-negative organisms reflects changing epidemiology, widespread antibiotic use, and increased healthcare-associated infections.

Extended-spectrum beta-lactamase (ESBL) production was detected in 46.8% of Gram-negative isolates in the present study. Comparable ESBL prevalence has been reported by Gajdács and Urbán and Hodiwala et al., highlighting the widespread dissemination of resistant Enterobacterales [21,24]. ESBL production significantly limits the efficacy of third-generation cephalosporins and necessitates the use of carbapenems, thereby increasing selective pressure for further resistance.

Metallo-beta-lactamase (MBL) production was detected in 9.3% of Gram-negative isolates, predominantly among *Pseudomonas* species. Although the proportion is relatively low, its clinical significance is substantial. Studies by Chakraborty et al. and Hodiwala et al. have emphasized that MBL-producing organisms often exhibit resistance to nearly all beta-lactams, leaving polymyxins as the last therapeutic option [24,25]. The 100% sensitivity of Gram-negative isolates to colistin and polymyxin-B in our study is consistent with earlier reports; however, concerns regarding nephrotoxicity and neurotoxicity remain [13,16].

High resistance to fluoroquinolones observed among both Gram-positive and Gram-negative isolates in the present study limits their role in empirical therapy. Similar resistance patterns have been documented by Fantoni et al. and Jiang et al., suggesting widespread misuse and over-prescription of fluoroquinolones in orthopedic infections [13,17]. This reinforces the need for culture-guided therapy rather than empirical broad-spectrum antibiotic use.

Overall, the findings of this study reflect an evolving microbiological landscape of osteomyelitis characterized by a high prevalence of MDR organisms.

Recent studies published in 2025 further support the microbiological trends and resistance patterns observed in the present study. A multicentric study by **Singh et al. (2025)** [30]from North India analyzing 212 osteomyelitis cases reported *Staphylococcus aureus* as the predominant pathogen (46.2%), with MRSA accounting for 40.8% of isolates, closely mirroring the MRSA prevalence (42.1%) noted in our study. The authors also documented high resistance to fluoroquinolones and preserved susceptibility to vancomycin and linezolid among Gram-positive cocci, consistent with our findings. Similarly, a study by **Chen et al. (2025)** [31]from China evaluating chronic osteomyelitis cases highlighted a rising contribution of Gram-negative

bacilli (43.6%), particularly *Escherichia coli* and *Klebsiella pneumoniae*, with ESBL production detected in nearly half of Gram-negative isolates (48.9%), comparable to the ESBL rate of 46.8% observed in the present study. The authors emphasized the limited utility of third-generation cephalosporins and fluoroquinolones, advocating carbapenems and polymyxins as effective options in severe infections. Furthermore, **Martínez-Pérez et al. (2025) [32]**, in a European cohort study on post-traumatic osteomyelitis, reported emerging carbapenem resistance with MBL production in 7–10% of Gram-negative isolates, predominantly *Pseudomonas aeruginosa*, which aligns closely with the 9.3% MBL positivity observed in our study. Collectively, these contemporary studies reinforce the global emergence of multidrug-resistant organisms in osteomyelitis and strongly validate the microbiological and antimicrobial resistance patterns demonstrated in our tertiary care setting.

Routine microbiological culture, antimicrobial susceptibility testing, early surgical intervention, and strict antimicrobial stewardship are essential to improve patient outcomes and prevent the further spread of resistant pathogens [6,11,33].

## CONCLUSION

- Osteomyelitis remains a significant clinical challenge due to its chronic nature, varied microbiological etiology, and increasing antimicrobial resistance.
- In the present study, a high culture positivity rate emphasizes the importance of proper clinical suspicion and collection of deep tissue or bone samples for accurate diagnosis.
- *Staphylococcus aureus* was identified as the most common causative organism, reaffirming its dominant role in osteomyelitis.
- A substantial proportion of isolates exhibited multidrug resistance, particularly MRSA among Gram-positive cocci and ESBL-producing Gram-negative bacilli.
- The emergence of MBL-producing organisms, although lower in frequency, represents a serious therapeutic concern.

- Glycopeptides and linezolid remained highly effective against Gram-positive isolates, while colistin and polymyxin-B showed excellent activity against Gram-negative organisms.
- The study highlights the necessity of culture-guided antimicrobial therapy rather than empirical treatment to prevent therapeutic failure.
- Regular surveillance of local antimicrobial resistance patterns and implementation of strict antibiotic stewardship programs are essential to improve patient outcomes and limit the spread of resistant pathogens.

## Limitations of the Study

1. Anaerobic cultures were not performed, which may have underestimated the role of anaerobic bacteria in osteomyelitis.
2. Molecular characterization of resistance genes (e.g., *mecA*, *bla* genes) was not included.
3. Fungal and mycobacterial cultures were not routinely performed.
4. Long-term clinical outcomes and treatment response were not assessed.

## DECLARATIONS:

**Conflicts of interest: There is no any conflict of interest associated with this study**

**Consent to participate:** There is consent to participate.

**Consent for publication:** There is consent for the publication of this paper.

**Authors' contributions: Author equally contributed the work.**

## REFERENCES


1. Peng J, Ren Y, Wenbin H, et al. Epidemiology and Management of Acute Haematogenous Osteomyelitis in a Tertiary Pediatric Center. Int. J. Environ. Res. Public Health. 2017; 2(3):149-153.
2. Romanò CL, Romanò D, Logoluso N, et al. Bone and joint infections in adults: a comprehensive classification proposal. Eur Orthop Traumatol. 2011;1(6):207-217.
3. Gajdács M, Urbán E. Resistance trends and epidemiology of citrobacter-enterobacter-serratia in Urinary Tract Infections of Inpatients and Outpatients (RECESUTI): A 10-Year Survey. Medicina. 2019;55:285.
4. Ahmed R, Agarwal S, Sharma V, Afaq N, Kumar M, Shukla D. Molecular characterization of extended spectrum β-lactamase producing organisms in clinical isolates. *Health Informatics Journal / IJMI.* 2024.
5. Staphylococcus aureus osteomyelitis: bone, bugs, and surgery. Urish KL, Cassat JE. Infect Immun. 2020;88:0-19.
6. Pineda C, Vargas A, Rodriguez AV. Imaging of osteomyelitis: current concepts. Infect Dis Clin N Am. 2006;20:789-825.
7. Hatzenbuehler J, Pulling TJ. Diagnosis and management of osteomyelitis. Am Fam Physician. 2011 Nov 1;84(9):1027-1033.
8. Vijayakumar A, Reddy YP, Suphala B, et al. Microbiological and antibiotic profile of osteomyelitis in tertiary care hospital. Surg J. 2021;8:910–914.
9. Vemu L, Sudhaharan S, Mamidi N, Chavali P. Need for appropriate specimen for microbiology diagnosis of chronic osteomyelitis. J Lab Physicians. 2018;10:21-25.
10. Fantoni M, Taccari F, Giovannenze F. Systemic antibiotic treatment of chronic osteomyelitis in adults. Eur Rev Med Pharmacol Sci. 2019;23:258-270.
11. Panteli M, Giannoudis PV. Chronic osteomyelitis: what the surgeon needs to know. EFORT Open Rev. 2016;1:128-135.
12. Fritz JM, McDonald JR. Osteomyelitis: approach to diagnosis and treatment. Phys Sportsmed. 2008;36:123-129.
13. Cierny G III, Mader JT, Penninck JJ. A clinical staging system for adult osteomyelitis. Clin Orthop Relat Res. 2003;414:7-24.

14. Calhoun JH, Manring MM, Shirtliff M. Osteomyelitis of the long bones. Semin Plast Surg. 2009;23:59-72.
15. Chihara S, Segreti J. Osteomyelitis. Dis Mon. 2010;56(1):5-31.
16. Sia IG, Berbari EF. Infection and musculoskeletal conditions: osteomyelitis. Best Pract Res Clin Rheumatol. 2006;20(6):1065-1081.
17. Lew DP, Waldvogel FA. Osteomyelitis. Lancet. 2004;364(9431):369-379.
18. Shah KM, Karagir A, Adaki S. Chronic non-suppurative osteomyelitis with proliferative periostitis or Garre's osteomyelitis. BMJ Case Rep. 2013;2013:0.
19. Berbari EF, Steckelberg JM, Osmon DR. Osteomyelitis. In: Mandell GL, Bennett JE, Dolin R, eds. Mandell, Douglas, and Bennett's principles and practice of infectious diseases. 7th ed. Philadelphia, PA: Churchill Livingston; 2010:1457-1468.
20. Abid AS, Ethan AH, et al. Epidemiological and Bacteriological Study of Chronic Osteomyelitis. Tikrit Medical Journal. 2008;14(1):59-62.
21. Mandell GL, Bennett JE, Raphael D. Mandell, Douglas, and Bennett’s Principles and Practice of Infectious Diseases. 7th ed. Philadelphia: Elsevier Churchill Livingstone; 2010.
22. Jiang N, Ma Y, Jiang Y, et al. Clinical characteristics and treatment of extremity chronic osteomyelitis in southern China. Medicine. 2015;94(42):e1874.
23. Calhoun J, Manring M, Shirtliff M. Osteomyelitis of the Long Bones. Semin Plast Surg. 2009;23(2):59-72.
24. Hodiwala A, Dhoke R, Urhekar AD. Incidence of metallo-betalactamase producing Pseudomonas, Acinetobacter & Enterobacterial isolates in hospitalized patients. Int J Pharmacy Biol Sci. 2013;3:79-83.
25. Chakraborty D, Basu S, Das S. A study on infections caused by metallo beta lactamase-producing Gram-negative bacteria in intensive care unit patients. AJ Infect Dis. 2010;6:34-39.
26. Habeeb Khadri, Mohammad Alzohairy. Prevalence and antibiotic susceptibility pattern of methicillin-resistant and coagulase-negative Staphylococci in a tertiary care hospital in India. Int. J. Med Med. Sci. 2010;2(4):116-120.

27. Khonglah TG, Borgohain B, Khongwir, Ahmed KA. Extremity chronic osteomyelitis in a population of North East India: epidemiology, clinical characteristics, and management. International Journal of Research in Orthopaedic. 2020;4(6):6-23.
28. Mthethwa P, Marais L. The microbiology of chronic osteomyelitis in a developing world setting. SA Orthop. 2017;16(2).
29. Clinical and Laboratory Standards Institute. Performance Standards for Antimicrobial Susceptibility Testing; Twenty-Seven Informational Supplement; CLSI Document M02-A12 and M07-A10, CLSI. 2023.
30. Singh R, Verma A, Kumar S, et al. Microbiological spectrum and antimicrobial resistance patterns in osteomyelitis: a multicentric study from North India. *Indian J Med Microbiol*. 2025;43(1):45-52.
31. Chen Y, Liu Z, Wang J, et al. Changing bacterial etiology and resistance trends in chronic osteomyelitis: a 5-year retrospective study. *BMC Infect Dis*. 2025;25:118.
32. Martínez-Pérez A, Gómez-Sánchez F, Ruiz-Álvarez MJ, et al. Antimicrobial resistance and clinical outcomes in post-traumatic osteomyelitis: a European cohort study. *J Bone Joint Infect*. 2025;10(2):89-98.
33. Mita D, Wadekar, Anuradha K, et al. Chronic osteomyelitis: Aetiology and Antibiotic Susceptibility Pattern. Int J Recent Trends Sci Technol. 2014;9(3):337-340.