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Antibiotic Resistance Patterns in Orthopedic Implant-Associated Infections: A Prospective Observational Study

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Abstract

Background: Orthopedic implants have transformed the management of fractures and degenerative joint disease; however, implant-associated infections remain among the most challenging complications of orthopedic surgery. Biofilm formation on implant surfaces, prolonged antimicrobial exposure, repeated hospitalization, and increasing antimicrobial resistance complicate treatment. Knowledge of institution-specific microbiological and resistance patterns is therefore important for selecting appropriate empirical therapy. Objectives: This study aimed to determine the bacterial profile and antibiotic resistance patterns of orthopedic implant-associated infections and to assess the prevalence of methicillin-resistant Staphylococcus aureus (MRSA), extended-spectrum beta-lactamase (ESBL)-producing Gram-negative bacilli, carbapenem resistance, and multidrug resistance among bacterial isolates. ***Methods***: A prospective observational study was conducted in the Department of Orthopaedics, Lord Buddha Koshi Medical College and Hospital, Saharsa, Bihar, from January 2025 to January 2026. Eighty-four patients with clinically suspected orthopedic implant-associated infection were included. Deep tissue, pus, aspirate, or peri-implant samples were collected using aseptic precautions and subjected to aerobic bacterial culture and antimicrobial susceptibility testing. Susceptibility was interpreted according to contemporaneous Clinical and Laboratory Standards Institute recommendations. Multidrug resistance was defined as acquired non-susceptibility to at least one antimicrobial agent in three or more antimicrobial categories. ***Results***: Of 84 patients, 63 (75.0%) yielded significant bacterial growth, while 21 (25.0%) were culture negative. Seven culture-positive patients had polymicrobial infection, resulting in 70 bacterial isolates. Gram-negative bacteria constituted 36 (51.4%) isolates and Gram-positive organisms 34 (48.6%). Staphylococcus aureus was the commonest pathogen, accounting for 21 (30.0%) isolates, followed by Escherichia coli 10 (14.3%), coagulase-negative staphylococci 9 (12.9%), Klebsiella pneumoniae 9 (12.9%), Pseudomonas aeruginosa 8 (11.4%), Acinetobacter spp. 6 (8.6%), Enterococcus spp. 4 (5.7%), and Proteus spp. 3 (4.3%). MRSA constituted 12/21 (57.1%) of S. aureus isolates, while methicillin resistance occurred in 5/9 (55.6%) coagulase-negative staphylococci. Among Enterobacterales, 11/22 (50.0%) were ESBL producers. Carbapenem resistance was detected in 9/36 (25.0%) Gram-negative isolates. Overall, 30/70 (42.9%) isolates fulfilled criteria for multidrug resistance. All staphylococci remained susceptible to vancomycin and linezolid. ***Conclusion***: Orthopedic implant-associated infections in this study demonstrated a nearly equal distribution of Gram-positive and Gram-negative organisms with a high prevalence of MRSA, ESBL production, carbapenem resistance, and multidrug resistance. Empirical antibiotic therapy should therefore be guided by local antibiograms and followed by early culture-directed de-escalation. Adequate sampling, surgical debridement, appropriate implant management, and antimicrobial stewardship remain essential for successful treatment.

Keywords: orthopedic implant infection; antimicrobial resistance; MRSA; multidrug resistance; biofilm; fracture-related infection; surgical site infection; antibiogram.

INTRODUCTION

Orthopedic implants are routinely used for fracture fixation, joint replacement, spinal stabilization, and reconstructive procedures. Although these devices considerably improve functional outcomes, infection associated with implanted hardware remains a serious complication. Implant-associated infections may result in prolonged hospitalization, repeated surgical debridement, implant removal or revision, impaired bone union, chronic osteomyelitis, loss of function, and substantial financial burden.

The clinical management of these infections is complicated by the ability of microorganisms to adhere to implant surfaces and form biofilms. Bacteria embedded within biofilms exhibit altered metabolic activity and reduced susceptibility to both host immune mechanisms and antimicrobial agents. Consequently, organisms that appear susceptible during routine laboratory testing may persist clinically when established within an implant-associated biofilm. This biological characteristic also explains why antibiotic treatment alone is often inadequate without appropriate surgical management.
The microbiological spectrum of orthopedic implant-associated infection is geographically variable. Traditionally, Staphylococcus aureus and coagulase-negative staphylococci have been considered dominant pathogens because of their ability to adhere to foreign material. However, recent Indian studies have documented a substantial contribution from multidrug-resistant Gram-negative organisms, including Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, and Acinetobacter species.

The increasing prevalence of antimicrobial resistance makes empirical treatment increasingly difficult. Local surveillance is therefore essential because antibiograms from other hospitals or geographical regions may not accurately represent the resistance pattern encountered in individual institutions. The present study was undertaken to characterize bacterial pathogens and their antibiotic resistance patterns among patients presenting with orthopedic implant-associated infections at a tertiary care hospital in Saharsa, Bihar.

Aim and Objectives

The primary aim was to determine the microbiological profile and antibiotic resistance patterns of bacterial isolates obtained from orthopedic implant-associated infections. Specific objectives were to identify the predominant bacterial pathogens, determine antimicrobial susceptibility among Gram-positive and Gram-negative isolates, estimate the prevalence of MRSA, methicillin-resistant coagulase-negative staphylococci, ESBL-producing Enterobacterales, carbapenem-resistant Gram-negative bacilli and multidrug-resistant organisms, and evaluate selected clinical factors associated with multidrug-resistant infection.

MATERIALS AND METHODS

Study Design and Setting

This prospective observational study was conducted in the Department of Orthopaedics, Lord Buddha Koshi Medical College and Hospital, Saharsa, Bihar, India, over a period of 13 months from January 2025 to January 2026. Microbiological processing and antimicrobial susceptibility testing were performed in coordination with the institutional microbiology laboratory.

Study Population and Sample Size

A total of 84 consecutive patients with clinically suspected orthopedic implant-associated infection were included. This sample size was considered appropriate for a single-centre observational study conducted over approximately one year and allowed estimation of common bacterial and resistance patterns while remaining feasible within the expected clinical workload.

Eligibility Criteria

Patients of either sex with an orthopedic implant in situ and clinical or intraoperative suspicion of implant-associated infection were eligible. Suspected infection was based on persistent wound discharge, purulent drainage, wound dehiscence, implant exposure, local pain or tenderness, erythema, swelling, fever, radiological evidence of loosening or osteolysis, sinus formation, or intraoperative evidence of infection. Patients with inadequate specimens, superficial skin contamination without evidence of deep infection, isolated cellulitis unrelated to the implant, or incomplete microbiological information were excluded. Repeat isolates with identical susceptibility profiles from the same infectious episode were counted only once.

Specimen Collection and Microbiological Processing

Where possible, specimens were collected before initiation or modification of antimicrobial therapy. Deep tissue specimens, peri-implant tissue, pus aspirates, joint aspirates, or samples collected during debridement or revision surgery were preferred over superficial wound swabs. Multiple samples were obtained in operative cases whenever clinically feasible to improve diagnostic yield and distinguish true infection from contamination. Specimens were transported promptly to the microbiology laboratory. Direct microscopy and Gram staining were performed where indicated, followed by inoculation on appropriate aerobic culture media. Isolates were identified using colony morphology, Gram staining, catalase, coagulase, oxidase, biochemical testing, and other standard microbiological methods available in the laboratory.

Antimicrobial Susceptibility Testing

Antimicrobial susceptibility testing was performed by the Kirby-Bauer disk diffusion method and/or minimum inhibitory concentration-based methods where available. Interpretation followed contemporaneous CLSI recommendations. Gram-

positive organisms were tested, as appropriate, against cefoxitin, erythromycin, clindamycin, ciprofloxacin, gentamicin, cotrimoxazole, doxycycline, linezolid, vancomycin, and teicoplanin. Gram-negative bacilli were evaluated against amoxicillin-clavulanate, ceftriaxone, ceftazidime, cefepime, ciprofloxacin, gentamicin, amikacin, piperacillin-tazobactam, meropenem, and other clinically indicated agents. Methicillin resistance was determined using cefoxitin susceptibility. ESBL production was identified according to standard phenotypic methods where indicated. Carbapenem resistance was based on non-susceptibility to tested carbapenems. Multidrug resistance was defined as acquired non-susceptibility to at least one antimicrobial agent in three or more antimicrobial categories.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using standard statistical methods. Continuous variables were summarized as mean ± standard deviation or median with interquartile range according to distribution, while categorical variables were expressed as frequencies and percentages. Associations between categorical variables were assessed using the chi-square test or Fisher exact test. A two-sided p-value <0.05 was considered statistically significant.

RESULTS

A total of 84 patients with suspected implant-associated infection were included. The mean age was 42.6 ± 15.8 years, with an age range of 18-76 years. Males constituted 61 (72.6%) cases and females 23 (27.4%), producing a male-to-female ratio of approximately 2.7:1. Fracture fixation devices represented the majority of infected implants. Plates and screws were involved in 36 (42.9%) cases, intramedullary nails in 23 (27.4%), prosthetic joints in 11 (13.1%), external fixation devices in 8 (9.5%), and miscellaneous implants in 6 (7.1%).

Characteristic	n (%)
Total patients	84
Mean age	42.6 ± 15.8 years
Male	61 (72.6)
Female	23 (27.4)
Plate and screw fixation	36 (42.9)
Intramedullary nail	23 (27.4)
Prosthetic joint	11 (13.1)
External fixator	8 (9.5)
Other orthopedic implants	6 (7.1)
Discharging sinus	29 (34.5)
Diabetes mellitus	17 (20.2)
Previous antibiotic exposure	49 (58.3)
Previous surgery at same site	26 (31.0)

Of 84 patients, 63 (75.0%) demonstrated significant bacterial growth, whereas 21 (25.0%) were culture negative. Fifty-six culture-positive patients had monomicrobial infection and seven had polymicrobial infection. Accordingly, 70 bacterial isolates were recovered from the 63 culture-positive patients. Gram-negative organisms marginally predominated, accounting for 36/70 (51.4%) isolates, while Gram-positive bacteria accounted for 34/70 (48.6%).

Organism	Number	Percentage
Staphylococcus aureus	21	30.0
Coagulase-negative staphylococci	9	12.9
Enterococcus spp.	4	5.7
Escherichia coli	10	14.3
Klebsiella pneumoniae	9	12.9
Pseudomonas aeruginosa	8	11.4
Acinetobacter spp.	6	8.6
Proteus spp.	3	4.3
Total	70	100

Resistance Pattern Among Gram-Positive Organisms

Among the 21 S. aureus isolates, 12 (57.1%) were MRSA while 9 (42.9%) were methicillin susceptible. Five of nine coagulase-negative staphylococcal isolates (55.6%) were methicillin resistant. Resistance to erythromycin, ciprofloxacin and clindamycin was frequent among staphylococci, whereas doxycycline and gentamicin retained better activity. No resistance to linezolid or vancomycin was observed among S. aureus isolates.

Antibiotic	Susceptible n (%)	Resistant n (%)
Cefoxitin	9 (42.9)	12 (57.1)
Erythromycin	8 (38.1)	13 (61.9)
Clindamycin	11 (52.4)	10 (47.6)
Ciprofloxacin	8 (38.1)	13 (61.9)
Gentamicin	13 (61.9)	8 (38.1)
Cotrimoxazole	12 (57.1)	9 (42.9)
Doxycycline	16 (76.2)	5 (23.8)
Linezolid	21 (100)	0
Vancomycin	21 (100)	0
Teicoplanin	20 (95.2)	1 (4.8)

Resistance Pattern Among Gram-Negative Organisms

Gram-negative bacilli showed substantial resistance to third-generation cephalosporins and fluoroquinolones. Of 22 Enterobacterales isolates, 11 (50.0%) were ESBL producers. Among all 36 Gram-negative organisms, 9 (25.0%) were carbapenem resistant. Carbapenem resistance was most frequent among Acinetobacter spp., followed by Klebsiella pneumoniae and Pseudomonas aeruginosa. Amikacin and meropenem retained greater overall activity than cephalosporins and fluoroquinolones.

Antibiotic	Susceptible n (%)	Resistant n (%)
Amoxicillin-clavulanate*	11 (39.3)	17 (60.7)
Ceftriaxone*	12 (42.9)	16 (57.1)
Ceftazidime	15 (41.7)	21 (58.3)
Cefepime	16 (44.4)	20 (55.6)
Ciprofloxacin	13 (36.1)	23 (63.9)
Gentamicin	20 (55.6)	16 (44.4)
Amikacin	25 (69.4)	11 (30.6)
Piperacillin-tazobactam	22 (61.1)	14 (38.9)
Meropenem	27 (75.0)	9 (25.0)

*Interpretation applies to organisms for which the antimicrobial is clinically appropriate.

Multidrug Resistance

Overall, 30 of 70 isolates (42.9%) met the definition of multidrug resistance. MDR was detected in 13/34 (38.2%) Gram-positive organisms and 17/36 (47.2%) Gram-negative organisms.

Resistance phenotype	Number/total	Percentage
MRSA	12/21	57.1
Methicillin-resistant CoNS	5/9	55.6
ESBL-producing Enterobacterales	11/22	50.0
Carbapenem-resistant Gram-negative bacilli	9/36	25.0
MDR among Gram-positive isolates	13/34	38.2
MDR among Gram-negative isolates	17/36	47.2
Overall MDR	30/70	42.9

Factors Associated with MDR Infection

MDR organisms were more frequently recovered from patients with prior antibiotic exposure, previous surgery at the same anatomical site, prolonged wound discharge, and hospitalization during the preceding three months. Prior antibiotic exposure, previous surgery at the same site, and chronic sinus formation showed statistically significant associations with MDR infection.

Factor	MDR infection n/N (%)	Non-MDR n/N (%)	p-value
Prior antibiotic exposure	24/43 (55.8)	19/43 (44.2)	0.018
No prior antibiotic exposure	6/27 (22.2)	21/27 (77.8)	
Previous surgery at same site	14/23 (60.9)	9/23 (39.1)	0.031
No previous surgery	16/47 (34.0)	31/47 (66.0)	
Diabetes mellitus	8/14 (57.1)	6/14 (42.9)	0.205
No diabetes	22/56 (39.3)	34/56 (60.7)	
Chronic sinus >4 weeks	15/26 (57.7)	11/26 (42.3)	0.047
No prolonged sinus	15/44 (34.1)	29/44 (65.9)	

DISCUSSION

The present study demonstrates a substantial antimicrobial-resistance burden among orthopedic implant-associated infections at a tertiary care hospital in Bihar. Gram-negative bacteria collectively slightly outnumbered Gram-positive bacteria, although Staphylococcus aureus remained the single most common organism. Resistant phenotypes including MRSA, ESBL production, carbapenem resistance, and multidrug resistance were frequent.

The predominance of S. aureus is consistent with the established importance of staphylococci in foreign-body infections. Their surface adhesins and capacity for biofilm formation allow persistent colonization of orthopedic hardware and contribute to treatment failure. In the present study, S. aureus constituted 30% of all isolates, while another 12.9% were coagulase-negative staphylococci.

The MRSA rate of 57.1% represents an important therapeutic concern. Methicillin resistance limits the utility of conventional beta-lactam therapy and often necessitates glycopeptide or oxazolidinone use. The preservation of linezolid and vancomycin activity among staphylococci is reassuring, but these agents should remain reserved for appropriate indications because indiscriminate use can promote future resistance.

The substantial contribution of Gram-negative organisms is particularly relevant to empirical antibiotic selection. Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, and Acinetobacter collectively formed a considerable proportion of infections. Half of the Enterobacterales in this study were ESBL producers, while one-quarter of Gram-negative isolates demonstrated carbapenem resistance. These findings indicate that routine empirical use of third-generation cephalosporins may provide inadequate coverage in patients with established implant-associated infection.
Amikacin and meropenem retained comparatively greater activity against Gram-negative isolates, although neither should be regarded as universally active. Routine empirical escalation to carbapenems should be avoided unless justified by patient severity, previous microbiological history, or institutional resistance data, because unnecessary use may accelerate selection of carbapenem-resistant organisms.

Overall MDR prevalence was 42.9%, with a slightly greater burden among Gram-negative organisms. Prior antibiotic exposure showed a significant association with MDR infection, emphasizing the consequences of repeated empirical antimicrobial treatment before definitive microbiological diagnosis. Previous surgery and chronic sinus formation were also associated with MDR isolation, possibly reflecting repeated healthcare exposure, prolonged infection, biofilm maturation, and cumulative antibiotic selection pressure.

The culture-negative rate of 25% also deserves attention. Culture-negative implant infection may arise from previous antibiotic treatment, inadequate sampling, superficial rather than deep sampling, fastidious organisms, biofilm-associated low bacterial burden, or limitations of conventional culture. Multiple deep tissue samples, prolonged incubation, sonication of removed implants, and selected molecular methods may improve diagnostic yield.

These findings support a combined surgical and microbiological approach to implant-associated infection. Appropriate debridement, assessment of implant stability, consideration of retention versus removal, adequate numbers of deep specimens, and culture-directed antimicrobial treatment are all necessary. Empirical antimicrobial therapy should reflect patient severity and local epidemiology and should be narrowed as soon as susceptibility data become available.

Clinical Implications

The high prevalence of resistant organisms suggests that a single empirical regimen is unlikely to be appropriate for every orthopedic implant infection. Stable patients should ideally undergo deep sampling before broad-spectrum antimicrobial therapy is started. In severe infection, empirical treatment should provide appropriate Gram-positive coverage, including MRSA where clinically indicated, together with Gram-negative coverage selected according to the institutional antibiogram. The regimen should subsequently be de-escalated when microbiology results are available. Hospital antibiotic policies should also clearly differentiate prophylactic therapy from treatment of established implant infection and should discourage prolonged or repeated prophylactic antibiotic courses.

Strengths and Limitations

This study provides local microbiological and resistance information from a region for which published orthopedic implant-infection data are relatively limited. It evaluates both Gram-positive and Gram-negative resistance phenotypes and includes clinically relevant markers such as MRSA, ESBL production, carbapenem resistance, and MDR. The study was, however, conducted at a single centre and included a moderate number of patients. Anaerobic organisms, fungi, and molecular identification were not systematically assessed. Biofilm formation was not directly quantified, implant sonication was not routinely available, and prior antibiotic treatment may have contributed to culture-negative infections. Long-term outcomes following debridement, implant retention, implant removal, or revision were outside the principal scope of the study.

CONCLUSION

Orthopedic implant-associated infections at Lord Buddha Koshi Medical College and Hospital demonstrated a substantial burden of antimicrobial resistance. Staphylococcus aureus was the most common individual pathogen, but Gram-negative bacteria collectively represented slightly more than half of the isolates. MRSA was detected in 57.1% of S. aureus isolates, half of Enterobacterales were ESBL producers, 25% of Gram-negative isolates were carbapenem resistant, and 42.9% of all isolates were multidrug resistant. These findings emphasize the importance of obtaining appropriate deep specimens before antimicrobial therapy whenever clinically feasible, developing and periodically updating a local antibiogram, avoiding unnecessary broad-spectrum antibiotics, and implementing culture-directed de-escalation. Successful management of implant-associated infections requires integration of microbiological diagnosis, antimicrobial stewardship, surgical source control, and appropriate management of the infected implant.

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