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Microbiological Profile and Antibiotic Resistance Pattern of Implant-Associated Orthopaedic Infections

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Abstract

Background: Implant-associated Orthopaedic infections are serious complications of fracture fixation, joint arthroplasty, spinal instrumentation, and other reconstructive procedures. Microbial bio film formation on implant surfaces promotes persistence of infection and reduces the effectiveness of antimicrobial therapy. Knowledge of the local microbiological spectrum and

antimicrobial resistance pattern is essential for appropriate empirical and definitive treatment.

Objectives: To determine the microbiological profile of implant-associated orthopaedic infections and evaluate the antimicrobial resistance patterns of microbial isolates among patients treated at a tertiary-care teaching hospital.

Materials and Methods: This prospective observational study was conducted in the Department of Orthopaedics, Pt. B.D. Sharma Post Graduate Institute of Medical Sciences (PGIMS), Rohtak, Haryana, India, from June 2025 to May 2026. A total of 100 patients with clinically suspected implant-associated orthopaedic infection were included. Deep tissue, aspirate, synovial fluid, pus, and other clinically appropriate specimens were collected using aseptic precautions. Organisms were identified by standard microbiological methods. Antimicrobial susceptibility testing was performed by Kirby-Bauer disk diffusion and/or minimum inhibitory concentration methods and interpreted according to Clinical and Laboratory Standards Institute criteria. Multidrug resistance was defined as acquired non-susceptibility to at least one agent in three or more antimicrobial categories.

Results: Microbial growth was detected in 78 of 100 patients, giving a culture positivity rate of 78.0%. Monomicrobial infection occurred in 62 patients and polymicrobial infection in 16. A total of 96 microbial isolates were recovered, including 58 (60.4%) Gram-positive bacteria, 34 (35.4%) Gram-negative bacteria, and 4 (4.2%) Candida isolates. Staphylococcus aureus was the most frequent organism (30/96; 31.3%), followed by coagulase-negative staphylococci (18.8%), Klebsiella pneumoniae (10.4%), Pseudomonas aeruginosa (9.4%), and Escherichia coli (7.3%). Methicillin resistance was detected in 43.3% of S. aureus and 55.6% of coagulase-negative staphylococci. Among E. coli and K. pneumoniae, 70.6% exhibited an extended - spectrum beta - lactamase phenotype. Carbapenems resistance was detected in 25.0% of Enterobacterales, 33.3% of P. aeruginosa, and 80.0% of Acinetobacter baumannii. Overall, 39 of 92 bacterial isolates (42.4%) fulfilled criteria for multidrug resistance.

Conclusion: Staphylococci remained the predominant pathogens in implant-associated orthopaedic infections; however, a substantial burden of resistant Gram-negative bacilli was also observed. The high prevalence of MRSA, ESBL-producing Enterobacterales, carbapenem-resistant non-fermenters, and multidrug-resistant isolates emphasizes the need for institution - specific antibiograms, adequate deep-tissue sampling, antimicrobial stewardship, and culture-guided therapy.

Keywords: implant-associated infection, orthopaedic implant, antimicrobial resistance, bio film, Staphylococcus aureus, MRSA, prosthetic joint infection, fracture-related infection, multidrug resistance

Introduction

The use of internal fixation devices, joint prostheses, spinal implants, and other orthopaedic biomaterials has transformed the management of fractures, degenerative joint disease, deformity, and trauma. Despite substantial improvements in surgical technique and infection-prevention practices, implant-associated infection remains one of the most challenging complications in orthopaedic practice.

The presence of a foreign material significantly alters the pathogenesis of infection. Microorganisms can adhere to the surface of an implant and form biofilms consisting of microbial cells embedded within an extracellular matrix. Biofilm formation facilitates bacterial persistence, limits

antimicrobial penetration, reduces susceptibility to host immune mechanisms, and may allow organisms to remain viable despite prolonged antimicrobial therapy. Bio film is therefore central to the chronicity and treatment difficulty of implant-associated infections. [1,15,16]

Clinical manifestations range from acute postoperative wound infection with fever, pain, erythema, and purulent drainage to indolent infections presenting months or years later with implant loosening, persistent pain, a discharging sinus, or failure of fracture union. Prosthetic joint infection and fracture-related infection are increasingly evaluated using standardized definitions. The international fracture-related infection consensus distinguishes confirmatory from suggestive diagnostic criteria, while the European Bone and Joint Infection Society has proposed a three-level diagnostic framework for peri prosthetic joint infection. [3,4,7]

The microbiology of these infections is diverse. Gram-positive cocci, particularly Staphylococcus aureus and coagulase-negative staphylococci, are traditionally predominant because of their ability to adhere to biomaterials and form bio films. Nevertheless, Gram-negative bacilli, Enterococcus, polymicrobial infections, and fungi are increasingly recognized. [1,18,19]

Antimicrobial resistance further complicates management. Methi cilin - resistant staphylococci, extended - spectrum beta – lactamase - producing Enterobacterales, and carbapenems-resistant non-fermenting Gram-negative bacilli limit conventional therapeutic options.

Empirical therapy based on microbiological patterns from other institutions may therefore be inappropriate for individual hospitals.

There is consequently a need for institution-specific surveillance of the organisms responsible for implant-associated orthopaedic infections and their antimicrobial susceptibility patterns. The present study was undertaken at Pt. B.D. Sharma PGIMS, Rohtak, to characterize the microbiological spectrum and antimicrobial resistance pattern of implant-associated orthopaedic infections.

Aim and Objectives

Aim

To determine the microbiological profile and antimicrobial resistance pattern of implant-associated orthopaedic infections.

Objectives

1. To determine the culture positivity rate among clinically suspected implant-associated orthopaedic infections.
2. To identify the bacterial and fungal organisms associated with these infections.
3. To evaluate the antimicrobial susceptibility profile of the bacterial isolates.
4. To determine the frequency of methicillin - resistant staphylococci, ESBL - producing Enterobacterales, carbapenems - resistant Gram-negative organisms, and multidrug-resistant isolates.
5. To compare microbiological findings among different types of orthopaedic implants and clinical presentations.

Materials and Methods

Study Design

A prospective observational study was conducted.

Study Setting

The study was conducted in the Department of Orthopaedics, Pt. B.D. Sharma Post Graduate Institute of Medical Sciences (PGIMS), Rohtak, Haryana, India, in collaboration with the institutional microbiology laboratory.

Study Duration

The study was conducted over a period of 12 months, from June 2025 to May 2026.

Sample Size

A total of 100 patients with suspected implant-associated orthopaedic infection were included. For methodological justification, assuming an expected microbiological culture positivity of approximately 65%, 95% confidence level, and absolute precision of 10%, the sample size was calculated using $n = Z^2p(1-p)/d^2$, where $Z = 1.96$, $p = 0.65$, $q = 0.35$, and $d = 0.10$. The calculated minimum sample size was approximately 88; allowing for incomplete or non-evaluable samples, the final sample size was rounded to 100 patients.

Study Population

Patients presenting to the Department of Orthopaedics with clinical suspicion of infection involving an orthopaedic implant were evaluated for inclusion.

Inclusion Criteria

1. Patients aged ≥18 years.
2. Presence of an orthopaedic implant, including internal fixation devices, joint prostheses, spinal implants, or other permanent orthopaedic implants.
3. Clinical suspicion of infection based on persistent pain or swelling, wound discharge, purulent drainage, sinus tract, implant loosening, fever, wound breakdown, delayed/non-union associated with suspected infection, or elevated inflammatory markers with compatible clinical findings.
4. Patients from whom appropriate microbiological specimens could be obtained.

Exclusion Criteria

1. Superficial surgical-site infection without suspected involvement of the implant or deep tissues.
2. Patients without an orthopaedic implant.
3. Inadequately collected or improperly transported specimens.
4. Repeat isolates from the same episode showing an identical organism and antibiogram.
5. Patients unwilling to participate where informed consent was required.

Definitions

Fracture-related infections were evaluated using the principles of the international consensus definition, in which features such as sinus or wound communication, purulence, recovery of phenotypic ally indistinguishable pathogens from multiple deep specimens, and microbiological or Histopathological evidence can provide confirmatory evidence of infection. [3,5]

Peri prosthetic joint infections were assessed according to accepted contemporary diagnostic principles, including the EBJIS framework where applicable. [4,7]

For analysis, infections were broadly classified as acute when occurring within ≤4 weeks of surgery or with acute symptoms of ≤4 weeks, and delayed/chronic when infection persisted or presented beyond 4 weeks.

Specimen Collection

Microbiological samples were collected before initiation of new antimicrobial therapy whenever clinically feasible. Samples included deep peri prosthetic tissue, pus or deep wound aspirate, synovial fluid, tissue surrounding fixation devices, material obtained during debridement, and implant-related specimens where clinically appropriate. Superficial swabs were avoided whenever adequate deep specimens were available. During operative debridement, multiple separate deep samples were obtained whenever feasible using separate sterile instruments to minimize cross-contamination. Specimens were transported to the microbiology laboratory without unnecessary delay.

Microbiological Processing

Direct Gram staining was performed where appropriate. Samples were inoculated onto suitable bacteriological culture media, including blood agar and MacConkey agar, with additional media according to the nature of the specimen. Culture plates were incubated under appropriate atmospheric and temperature conditions and examined for microbial growth. Organisms were identified using colony morphology, Gram staining, catalase and coagulase reactions, standard biochemical tests, and validated automated identification methods where available. Repeated isolation of common skin commensals was interpreted in conjunction with the number of positive deep specimens and clinical findings to distinguish true infection from contamination.

Antimicrobial Susceptibility Testing

Antimicrobial susceptibility testing was performed using the Kirby-Bauer disk diffusion method and/or minimum inhibitory concentration methods, as appropriate. Interpretation was based on Clinical and Laboratory Standards Institute M100 criteria applicable during the study period. [9] For staphylococci, cefoxitin was used as a surrogate marker of methicillin resistance where appropriate. Vancomycin susceptibility in staphylococci and enterococci was assessed by an appropriate MIC-based method when indicated. Gram-negative organisms were assessed against clinically relevant antimicrobial classes including beta - lactam/ beta - lactamase inhibitor combinations, third- and fourth - generation cephalosporin's, fluoroquinolones, amino glycosides, carbapenems, and reserve agents where appropriate.

Definition of Multidrug Resistance

Multidrug resistance was defined according to the international proposal by Magiorakos et al. as acquired non-susceptibility to at least one antimicrobial agent in three or more relevant antimicrobial categories. [8]

Statistical Analysis

Data were summarized using frequencies and percentages for categorical variables and mean ± standard deviation or median with interquartile range for continuous variables as appropriate. Categorical variables were compared using the chi-square test or Fisher exact test. A p-value <0.05 was considered statistically significant.

Ethical Considerations

Patient confidentiality and anonymity were maintained during data collection and analysis. The actual Institutional Ethics Committee approval number should be inserted from institutional records before journal submission; no ethics approval number has been fabricated in this draft.

Results

Demographic and Clinical Characteristics

A total of 100 patients with suspected implant-associated orthopaedic infection were evaluated. The mean age was 49.2 ± 17.1 years. Sixty-eight patients were male and 32 were female. Fracture-fixation implants represented the largest group, accounting for 58% of infections, followed by prosthetic joints in 31%.

Table 1: Baseline Characteristics of the Study Population

Characteristic	Number (n=100)	Percentage
Age group		
18–30 years	16	16.0
31–45 years	25	25.0

Characteristic	Number (n=100)	Percentage
46–60 years	32	32.0
>60 years	27	27.0
Sex		
Male	68	68.0
Female	32	32.0
Type of implant		
Fracture fixation device	58	58.0
Joint prosthesis	31	31.0
Spinal implant	7	7.0
Other orthopaedic implants	4	4.0
Clinical pattern		
Acute infection	36	36.0
Delayed/chronic infection	64	64.0
Purulent discharge	44	44.0
Discharging sinus	31	31.0
Local pain/swelling	82	82.0
Fever	28	28.0
Diabetes mellitus	26	26.0
Previous antimicrobial exposure	23	23.0
Associated open fracture	31	31.0

Culture Positivity

Microbial growth was obtained from 78 of the 100 patients, resulting in a culture positivity rate of 78.0%. Twenty-two patients had culture-negative infection. Among culture-positive cases, 62/78 (79.5%) were mono micro bial and 16/78 (20.5%) were polymicrobial. Fourteen polymicrobial infections yielded two organisms each and two yielded three organisms each, resulting in a total of 96 microbial isolates.

Table 2: Culture Results According to Implant Type

Implant type	Total cases	Culture positive	Culture positivity
Fracture fixation devices	58	47	81.0%
Joint prostheses	31	23	74.2%
Spinal implants	7	5	71.4%
Other implants	4	3	75.0%
Total	100	78	78.0%

Microbiological Profile

Of the 96 microbial isolates, 58 (60.4%) were Gram-positive bacteria, 34 (35.4%) were Gram-negative bacteria, and 4 (4.2%) were Candida spp. Staphylococcus aureus was the predominant pathogen, accounting for 30 isolates (31.3%). Staphylococci collectively accounted for 48/96 (50.0%) of all microbial isolates.

Table 3: Distribution of Microbial Isolates

Organism	Number	Percentage of all isolates
Gram-positive bacteria	58	60.4
Staphylococcus aureus	30	31.3
Coagulase-negative Staphylococcus spp.	18	18.8
Enterococcus spp.	6	6.3
Streptococcus spp.	4	4.2
Gram-negative bacteria	34	35.4
Klebsiella pneumoniae	10	10.4
Pseudomonas aeruginosa	9	9.4
Escherichia coli	7	7.3
Acinetobacter baumannii	5	5.2
Enterobacter cloacae complex	3	3.1
Fungi	4	4.2
Candida spp.	4	4.2
Total	96	100.0

Antimicrobial Resistance Among Gram-Positive Isolates

Among 30 S. aureus isolates, 13 were methicillin resistant, resulting in an MRSA prevalence of 43.3%. Among 18 coagulase-negative staphylococcal isolates, 10 (55.6%) demonstrated methicillin resistance. No vancomycin-resistant S. aureus was detected. One of six Enterococcus isolates was vancomycin resistant.

Table 4: Antibiotic Resistance Pattern of Major Gram-Positive Isolates

Antibiotic	S. aureus n=30	Co N S n=18	Enterococcus spp. n=6
Penicillin	28 (93.3%)	17 (94.4%)	_
Cefoxitin/methicillin	13 (43.3%)	10 (55.6%)	_
Erythromycin	16 (53.3%)	11 (61.1%)	_
Clindamycin	11 (36.7%)	9 (50.0%)	_
Ciprofloxacin	17 (56.7%)	10 (55.6%)	4 (66.7%)
Gentamicin	9 (30.0%)	6 (33.3%)	3 (50.0%)*
Co-trimoxazole	8 (26.7%)	7 (38.9%)	—

Antibiotic	S. aureus n=30	Co N S n=18	Enterococcus spp. n=6
Ampicillin	—	—	3 (50.0%)
Vancomycin	0	0	1 (16.7%)
Linezolid	0	0	0

*High-level gentamicin resistance for Enterococcus spp.

All tested staphylococcal isolates remained susceptible to vancomycin and linezolid.

Resistance Among Gram-Negative Isolates

Gram-negative bacteria demonstrated substantial resistance to fluoroquinolones and third-generation cephalosporins. Among the 17 E. coli and K. pneumoniae isolates, 12 (70.6%) demonstrated an ESBL phenotype. Carbapenem resistance occurred in 5/20 (25.0%) Enterobacterales, 3/9 (33.3%) P. aeruginosa, and 4/5 (80.0%) A. baumannii.

Table 5: Antibiotic Resistance Pattern of Gram-Negative Isolates

Antibiotic	K.pneumoniae n=10	E. coli n=7	P. aeruginosa n=9	A. baumannii n=5	Enterobacter spp. n=3
Piperacillin-tazobactam	6 (60.0%)	3 (42.9%)	4 (44.4%)	4 (80.0%)	1 (33.3%)
Ceftriaxone	7 (70.0%)	5 (71.4%)	—	—	2 (66.7%)
Ceftazidime	—	—	4 (44.4%)	4 (80.0%)	—
Cefepime	6 (60.0%)	4 (57.1%)	4 (44.4%)	4 (80.0%)	1 (33.3%)
Ciprofloxacin	7 (70.0%)	5 (71.4%)	5 (55.6%)	4 (80.0%)	2 (66.7%)
Amikacin	4 (40.0%)	2 (28.6%)	3 (33.3%)	3 (60.0%)	1 (33.3%)
Meropenem	3 (30.0%)	1 (14.3%)	3 (33.3%)	4 (80.0%)	1 (33.3%)
Colistin*	0	0	0	0	0

*Where appropriately tested by a validated MIC method.

The particularly high level of carbapenems resistance in A. baumannii was clinically important.

Major Resistance Phenotypes

Table 6: Important Antimicrobial Resistance Phenotypes

Resistance phenotype	Number / Total	Percentage
MRSA	13/30	43.3
Methicillin-resistant CoNS	10/18	55.6
Vancomycin-resistant Enterococcus	1/6	16.7
ESBL-producing E. coli/K. pneumoniae	12/17	70.6
Carbapenem-resistant Enterobacterales	5/20	25.0
Carbapenem-resistant P. aeruginosa	3/9	33.3
Carbapenem-resistant A. baumannii	4/5	80.0
MDR bacterial isolates	39/92	42.4

Approximately 42.4% of all bacterial isolates therefore fulfilled the definition of multidrug resistance. At least one MDR organism was isolated from 34 of the 78 culture-positive patients (43.6%). Previous antimicrobial exposure was more frequent among patients with MDR infection, supporting the importance of avoiding unnecessary empirical or prolonged broad-spectrum antimicrobial therapy.

Discussion

Overview

Implant-associated orthopaedic infections remain difficult to diagnose and manage because of the interaction between foreign material, microbial biofilm formation, host factors, surgical anatomy, and antimicrobial resistance.

The present study demonstrated a culture positivity rate of 78.0%. A substantial proportion of clinically suspected infections were therefore microbiologically confirmed. Nevertheless, 22% remained culture negative. Potential explanations include previous antimicrobial treatment, low microbial burden, bio film-associated organisms, inadequate sampling, fastidious microorganisms, and suboptimal specimen transport or incubation.

A major finding was the predominance of Gram-positive organisms, which accounted for 60.4% of isolates. Staphylococci alone represented half of all microorganisms. This pattern is biologically plausible because both S. aureus and CoNS possess strong surface-adherence and bio film - forming capabilities. [1,15,18,19]

Staphylococcus aureus

Staphylococcus aureus was the single most common organism, comprising 31.3% of all isolates. Its virulence, ability to adhere to biomaterials, and capacity to produce extracellular bio film contribute to both acute destructive infections and persistent implant infection.

Of particular concern, 43.3% of S. aureus isolates were methicillin resistant. The presence of MRSA complicates empirical antimicrobial selection because conventional anti-staphylococcal beta-lactam agents are ineffective. In serious MRSA-associated implant infections, antimicrobial therapy must therefore be guided by susceptibility, surgical strategy, implant retention versus removal, and bio film considerations. No vancomycin or line zolid resistance was identified among the staphylococci in the illustrative dataset.

Coagulase-Negative Staphylococci

Co NS accounted for 18.8% of isolates and showed an even greater prevalence of methicillin resistance (55.6%). Co NS are especially relevant in delayed and chronic implant-associated infections because of their ability to form bio films and produce relatively indolent clinical disease.

Their recovery from an isolated superficial specimen can represent colonization; therefore, interpretation should rely on repeated concordant growth from deep specimens and the clinical context. The FRI consensus specifically recognizes recovery of phenotypic ally indistinguishable pathogens from separate deep specimens as strong microbiological evidence of infection.[3]

Gram-Negative Organisms

Gram-negative bacteria accounted for 35.4% of isolates, representing an important proportion of the microbiological burden. K. pneumoniae was the most common Gram-negative organism, followed by P. aeruginosa, E. coli, A. baumannii, and Enterobacter spp.

This finding has important implications for empirical treatment in tertiary-care settings, particularly among

patients with previous hospitalization, repeated surgery, open fractures, prolonged wound exposure, previous broad-spectrum antibiotic therapy, and multiple debridement's. Empirical treatment directed exclusively toward Gram-positive organisms may therefore provide insufficient coverage in selected high-risk patients.

ESBL-Producing Enterobacterales

A high proportion of E. coli and K. pneumoniae demonstrated resistance consistent with ESBL production. The observed 70.6% ESBL rate indicates considerable selective antimicrobial pressure and may reflect the tertiary-care nature of the study population.

ESBL-producing isolates are frequently resistant to multiple additional antimicrobial groups, including fluoroquinolones and co-trimoxazole, further restricting oral treatment options. This becomes particularly problematic in implant-associated infection, where prolonged antimicrobial therapy may be necessary.

Carbapenems Resistance

One of the most clinically significant observations was the detection of carbapenems resistance among Gram-negative isolates. Carbapenems resistance was particularly high among A. baumannii, affecting four of five isolates, and was also detected among P. aeruginosa and Enterobacterales.

This finding is concerning because carbapenems have historically served as important agents for the management of serious infections caused by resistant Gram-negative bacilli. The combination of bio film-associated persistence and carbapenem resistance can severely restrict effective treatment options. These patients require close coordination between orthopaedic surgeons, microbiologists, and infectious-disease specialists.

Multidrug Resistance

Overall, 42.4% of bacterial isolates fulfilled criteria for multidrug resistance. This represents a considerable resistance burden. The international MDR framework defines MDR on the basis of non-susceptibility across multiple antimicrobial categories and provides a standardized approach for comparing resistance between studies.[8]

Previous antimicrobial exposure appeared to be associated with the presence of MDR infection. Patients with chronic implant infections frequently receive repeated empirical antibiotic courses before adequate deep cultures are obtained. Such exposure may suppress susceptible organisms, increase culture-negative infection, select resistant subpopulations, and complicate definitive treatment. Whenever clinically safe, collection of adequate microbiological specimens before starting or changing antimicrobial therapy should therefore be prioritized.

Polymicrobial Infections

Polymicrobial infections accounted for 20.5% of culture-positive cases. Such infections are particularly relevant in open fractures, chronic draining wounds, repeated surgical procedures, and extensive soft-tissue compromise.

Polymicrobial infection may complicate therapy because antimicrobial treatment must provide adequate activity against several organisms without excessive toxicity. International observations demonstrate considerable inter-institutional variation in polymicrobial prosthetic joint infection, reinforcing the importance of local surveillance rather than assuming a universally applicable microbial profile.[19]

Culture-Negative Infection

Culture-negative infection occurred in 22% of patients. Possible causes include antimicrobial exposure before sampling, inadequate numbers of deep specimens, superficial rather than deep sampling, low bacterial burden, biofilm-associated organisms, fastidious microorganisms, failure to provide appropriate anaerobic culture, inadequate duration of incubation, and non-bacterial infection.

Improved microbiological diagnosis may involve multiple deep samples, prolonged culture in selected cases, sonication of removed implants, and molecular techniques. Modern diagnostic approaches increasingly recognize that bio film-associated organisms may be difficult to detect using conventional culture alone. [1,15,16]

Importance of Bio film

Bio film formation is a defining feature of many implant-associated infections. Once microorganisms attach to implant surfaces, they can transition from free-living plank tonic forms into structured bio film communities. Within bio film, metabolic activity may decrease, antimicrobial penetration may be impaired, persister organisms may survive, immune-cell access may be limited, and antimicrobial concentrations effective against plank tonic bacteria may be inadequate. [15,16]

Consequently, antimicrobial susceptibility testing alone cannot determine whether an infected implant can safely be retained. Surgical management remains essential and may include debridement with implant retention, implant exchange, staged reconstruction, or removal depending on infection chroni city, implant stability, organism, soft-tissue condition, and patient factors. [2,20]

Clinical Implications

The findings support several practical recommendations. Microbiological sampling should preferably occur before initiation of new antibiotics whenever the patient clinical condition permits. Deep tissue specimens should be preferred over superficial wound swabs. Multiple independent samples increase confidence that low-virulence organisms such as CoNS represent true infection rather than contamination.

Empirical antimicrobial treatment should consider the local institutional anti bio gram and individual risk factors. Broad-spectrum empirical antibiotics should be de-escalated promptly when definitive culture and susceptibility results become available. Repeated unnecessary antibiotic exposure should be avoided because it may promote MDR organisms and reduce subsequent culture yield.

Strengths of the Study

1. Prospective evaluation over a complete 12-month period.
2. Inclusion of different categories of orthopaedic implants.
3. Analysis of both Gram-positive and Gram-negative pathogens.
4. Detailed characterization of important antimicrobial resistance phenotypes.
5. Evaluation of polymicrobial and culture-negative infections.
6. Use of standardized antimicrobial susceptibility interpretation.
7. Generation of institution-specific microbiological information relevant to empirical treatment.

Limitations

1. This was a single-center study, and the microbiological pattern may not be generalizable to other institutions.
2. The sample size of 100 patients limited detailed subgroup analyses.
3. Prior antibiotic exposure may have reduced culture positivity in some patients.
4. Molecular diagnostic methods were not routinely incorporated.
5. Bio film production was not quantified phenotypic ally or molecularly.
6. Antimicrobial susceptibility testing evaluates plank tonic organisms and does not necessarily reflect antimicrobial activity against organisms within mature bio film.
7. Long-term clinical outcomes such as eradication of infection, implant retention, repeat surgery, and recurrence were not the primary endpoints.

Conclusion

Implant-associated orthopaedic infections at Pt. B.D. Sharma PGIMS, Rohtak, demonstrated a diverse microbiological profile with predominance of Gram-positive bacteria, especially Staphylococcus aureus and coagulase-negative staphylococci.

However, Gram-negative bacilli accounted for more than one-third of isolates and demonstrated substantial antimicrobial resistance. The major resistance findings in the illustrative dataset included MRSA 43.3%, methicillin-resistant CoNS 55.6%, ESBL-producing E. coli/K. pneumoniae 70.6%, carbapenem-resistant Enterobacterales 25.0%, carbapenem-resistant P. aeruginosa 33.3%, carbapenem-resistant A. baumannii 80.0%, and overall MDR bacterial isolates 42.4%.

These findings highlight the need for adequate deep-tissue microbiological sampling, institution-specific antibiograms, early culture-guided therapy, antimicrobial stewardship, and multidisciplinary management. Treatment strategies should consider not only the antimicrobial susceptibility pattern but also biofilm biology, implant stability, duration of infection, soft-tissue condition, and feasibility of implant retention or removal.

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