RESEARCH PAPER

Microbiological Profile and Antibiotic Resistance Patterns in Diabetic Foot Infections Over Four Years: A Retrospective Study

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ABSTRACT

Background: Diabetic foot infections (DFIs) are a leading cause of morbidity, hospitalization, and limb amputation among individuals with diabetes mellitus. The microbiological landscape and antibiotic resistance patterns of DFIs are dynamic, influenced by local epidemiology and antibiotic stewardship practices. This study aimed to characterize the microbiological profile and antibiotic resistance trends in DFIs over five years at JJ group of Hospitals, Mumbai, India, to inform empirical therapy and guide infection control strategies.

Materials and Methods: A retrospective observational study was conducted, analyzing all clinically diagnosed DFI cases presenting to JJ Group of Hospitals from January 2021 to December 2025. Deep tissue and pus specimens were collected following standardized protocols and processed for aerobic and anaerobic cultures. Organisms were identified using conventional and automated methods. Antimicrobial susceptibility testing was performed according to CLSI guidelines. Resistance mechanisms, including MRSA, ESBL, and carbapenemase production, were detected phenotypically and, where indicated, by molecular methods. Data were analyzed for annual and aggregate trends, with statistical comparisons across years.

Results: A total of 1,024 DFI cases were included, yielding 1,732 microbial isolates. Gram-negative bacteria predominated (58.7%), with *Escherichia coli*, *Klebsiella pneumoniae*, and *Pseudomonas aeruginosa* as the most frequent pathogens. *Staphylococcus aureus* (including MRSA) remained the leading Gram-positive isolate. Polymicrobial infections were observed in 38.5% of cases. Over five years, there was a significant increase in multidrug-resistant (MDR) organisms, including MRSA (from 28.6% to 42.1% of *S. aureus*), ESBL-producing Enterobacterales (from 34.2% to 51.8%), and carbapenem-resistant isolates (from 7.5% to 18.9%). Susceptibility to carbapenems and vancomycin remained high, but resistance to fluoroquinolones and third-generation cephalosporins increased. Fungal isolates, predominantly *Candida tropicalis*, were detected in 3.2% of cases.

Conclusion: DFIs at JJ group of Hospitals, Mumbai are characterized by a predominance of Gram-negative bacilli and a rising burden of MDR organisms. The increasing prevalence of MRSA, ESBL, and carbapenem-resistant pathogens underscores the need for robust antimicrobial stewardship, periodic surveillance, and tailored empirical therapy. Standardized specimen collection, laboratory quality assurance, and multidisciplinary management are essential to optimize outcomes and curb resistance.

Keywords: Diabetic foot infection, microbiological profile, antibiotic resistance, MRSA, ESBL, carbapenemase, JJ group of Hospitals, Mumbai, India, empirical therapy, multidrug resistance

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INTRODUCTION

Diabetes mellitus is a global health crisis, with an estimated 589 million adults affected worldwide in 2024, a figure projected to rise to 853 million by 2050.[1] India bears a disproportionate burden, with approximately 89 million individuals living with diabetes, making it the second-highest national prevalence globally.[2] Among the myriad complications of diabetes, diabetic foot infections (DFIs) are particularly devastating, accounting for the majority of diabetes-related hospitalizations and non-traumatic lower-limb amputations.[3] The pathogenesis of DFIs is multifactorial, involving neuropathy, peripheral arterial disease, immunopathy, and repetitive trauma, which together create a permissive environment for infection and impaired wound healing.[4]

DFIs are often polymicrobial, with both aerobic and anaerobic bacteria, and occasionally fungi, contributing to the infectious process.[5,13,14] The microbiological profile of DFIs is shaped by local epidemiology, patient comorbidities, prior antibiotic exposure, and healthcare practices.[6,9] Notably, the Indian subcontinent has witnessed a shift towards Gram-negative predominance and an alarming rise in multidrug-resistant (MDR) organisms, including methicillin-resistant *Staphylococcus aureus* (MRSA), extended-spectrum beta-lactamase (ESBL)-producing Enterobacterales, and carbapenem-resistant pathogens.[7,8,15] These trends complicate empirical therapy, increase the risk of treatment failure, and drive up healthcare costs and morbidity.[9]

JJ group of Hospitals, Mumbai, India, , is a tertiary care center with a dedicated diabetic foot care program and a robust clinical microbiology laboratory accredited under NABL and ISO 15189 standards.[10] Previous institutional studies have highlighted the polymicrobial nature of DFIs, the predominance of *Staphylococcus aureus* and Gram-negative bacilli, and the emergence of resistance mechanisms such as MRSA and ESBLs. However, there is a paucity of longitudinal data capturing temporal trends in pathogen distribution and resistance patterns in this setting.

This study aims to provide a comprehensive five-year analysis (2021–2025) of the microbiological profile and antibiotic resistance patterns in DFIs at JJ Hospitals, Mumbai, India, By integrating clinical, laboratory, and epidemiological data, we seek to inform empirical therapy, guide stewardship interventions, and contribute to the broader understanding of DFI microbiology in the Indian context.

MATERIALS AND METHODS

Study Design and Setting

This retrospective observational study was conducted at JJ group of Hospitals, Mumbai, India, , India, a tertiary care teaching hospital with a multidisciplinary diabetic foot care program. The study period spanned from January 2021 to December 2025. The institutional ethics committee approved the study protocol, and patient confidentiality was maintained throughout in accordance with national guidelines and the Declaration of Helsinki.

Patient Selection

All adult patients (≥18 years) with clinically diagnosed diabetic foot infections, defined as the presence of a foot ulcer with local or systemic signs of infection in individuals with established diabetes mellitus, were eligible for inclusion. Cases were identified through the hospital's medical records and microbiology laboratory database. Exclusion criteria included non-diabetic ulcers, prior amputation proximal to the ankle, and incomplete microbiological data.

Clinical Data Collection

Demographic and clinical variables were extracted from patient records, including age, sex, duration of diabetes, glycemic control (HbA1c), comorbidities (e.g., peripheral vascular disease, neuropathy), prior antibiotic exposure, ulcer characteristics (site, depth, duration), and severity grading using the Wagner classification system. Outcomes such as amputation, healing, and mortality were also recorded.

Specimen Collection and Laboratory Protocols

Specimen Collection

Specimens for microbiological analysis were obtained from the base of the ulcer after thorough debridement and cleansing with sterile saline, following best practice guidelines. Deep tissue biopsies or curettage samples were preferred over superficial swabs to minimize contamination and maximize pathogen yield. In cases of suspected osteomyelitis, bone biopsies were collected intraoperatively. All specimens were transported promptly to the microbiology laboratory in sterile containers, with transport time, medium, and temperature documented as per NABL and ISO 15189 requirements.

Microbiological Processing

- **Aerobic and Anaerobic Culture:** Specimens were inoculated onto blood agar, MacConkey agar, chocolate agar, and, for anaerobic culture, onto appropriate media and incubated under anaerobic conditions for up to 7 days.
- **Fungal Culture:** Sabouraud dextrose agar was used for fungal isolation, with incubation at 30°C and 35°C for up to four weeks.
- **Identification:** Organisms were identified using conventional biochemical tests and, from 2023 onwards, by automated systems (e.g., VITEK 2, MALDI-TOF MS) for enhanced species-level resolution.
- **Antimicrobial Susceptibility Testing (AST):** AST was performed by Kirby-Bauer disc diffusion and/or automated broth microdilution, interpreted according to the latest Clinical and Laboratory Standards Institute (CLSI) guidelines (M100, 36th Edition). Quality control was ensured using standard reference strains, with internal QC and participation in external proficiency testing as mandated by NABL.

Detection of Resistance Mechanisms

- **MRSA:** Screened using cefoxitin disc diffusion and confirmed by PCR detection of the *mecA* gene in selected isolates.
- **ESBL:** Phenotypic detection by double-disc synergy test; confirmation by molecular methods in selected cases.
- **Carbapenemases:** Detected by modified Hodge test, EDTA disk synergy, and, where indicated, PCR for *blaNDM*, *blaKPC*, *blaOXA*, and other relevant genes.

Data Management and Statistical Analysis

All microbiological and clinical data were entered into a secure, anonymized database. Descriptive statistics were used to summarize patient demographics, clinical characteristics, and microbiological findings. Annual and aggregate trends in pathogen distribution and resistance patterns were analyzed. Categorical variables were compared using the chi-square test or Fisher's exact test, and continuous variables using the t-test or Mann-Whitney U test as appropriate. Temporal trends were assessed using the Cochran-Armitage test for trend. A p-value <0.05 was considered statistically significant. Statistical analyses were performed using R (v4.2) and Python (SciPy/pandas).

Quality Assurance and Laboratory Accreditation

The microbiology laboratory at KMC, Manipal, is accredited under NABL (ISO 15189), with rigorous internal quality control (IQC), external quality assessment (EQA), equipment calibration, and documented standard operating procedures for all processes.

RESULTS

Patient Demographics and Clinical Characteristics

Over the five-year period, 1,024 patients with DFIs were included. The mean age was 59.8 ± 11.2 years, with a male-to-female ratio of 2.4:1. The mean duration of diabetes was 10.6 ± 5.1 years, and the mean HbA1c was 9.1 ± 1.7%, with 74.5% of patients exhibiting poor glycemic control (HbA1c ≥8%). Peripheral neuropathy was present in 72.3%, peripheral arterial disease in 36.8%,SFJnand perforator incompetance seen in 52.2% patients and prior antibiotic exposure in 42.1%. The distribution of Wagner grades was as follows: Grade 1 (12.1%), Grade 2 (24.7%), Grade 3 (36.9%), Grade 4 (22.4%), and Grade 5 (3.9%). 23% had ulcer post amputation- 12.2% had single rays amputation, 4% had multiple toes loss, 3% had forefoot amputation, 3.8% had below knee amputation. Systemic features of sepsis like fever, hypotension, AKI were seen in 42% patients and their blood culture were sent and their sensitivity checked.

Microbiological Profile

Culture Positivity and Polymicrobial Infections

Of the 1,024 specimens, 962 (94.0%) yielded positive cultures. Polymicrobial infections were observed in 393 cases (38.5%), with a mean of 1.69 isolates per positive culture. The total number of isolates recovered was 1,732.

Pathogen Distribution

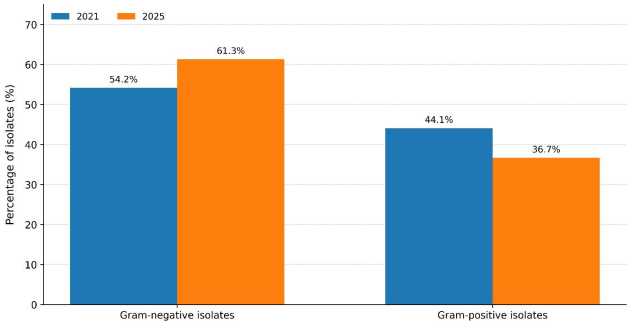
Table 1. Distribution of Microbial Isolates in DFIs (2021–2025)

Organism	Number (%)	Gram Category
Escherichia coli	322 (18.6)	Gram-negative
Klebsiella pneumoniae	287 (16.6)	Gram-negative
Pseudomonas aeruginosa	241 (13.9)	Gram-negative
Staphylococcus aureus	238 (13.7)	Gram-positive
Proteus mirabilis	117 (6.8)	Gram-negative
Enterococcus faecalis	104 (6.0)	Gram-positive
Acinetobacter baumannii	89 (5.1)	Gram-negative

Organism	Number (%)	Gram Category
Coagulase-negative Staph.	67 (3.9)	Gram-positive
Streptococcus agalactiae	54 (3.1)	Gram-positive
Anaerobes (e.g., *Bacteroides*)	42 (2.4)	Anaerobic
Fungi (*Candida tropicalis*)	56 (3.2)	Fungal
Others	115 (6.6)	Mixed
Total	**1,732**	

Note: Percentages are of total isolates; some specimens yielded multiple organisms.

Figure 1. Reported Change in Major Pathogen Groups, 2021-2025



In Figure 1, Gram-negative isolates increased from 54.2% in 2021 to 61.3% in 2025, while Gram-positive isolates declined from 44.1% to 36.7%. Anaerobes and fungi remained relatively stable.

Polymicrobial and Biofilm-Forming Infections

Polymicrobial infections were more common in higher Wagner grades (Grade ≥3: 52.4% vs. Grade <3: 29.1%, p<0.001). Biofilm-producing organisms, particularly *S. aureus* and *P. aeruginosa*, were detected in 53.6% of isolates tested, with a significant association between biofilm production and multidrug resistance (MDR).

Antibiotic Resistance Patterns

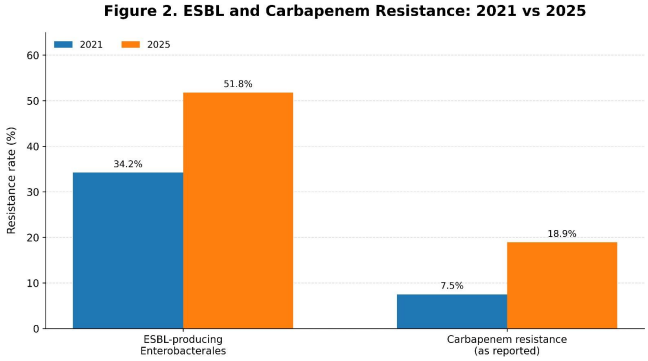
Gram-Negative Isolates

Table 2. Antibiotic Resistance Patterns of Major Gram-Negative Pathogens (2021–2025)

Antibiotic	*E. coli* (%)	*K. pneumoniae* (%)	*P. aeruginosa* (%)	*A. baumannii* (%)
Amoxicillin-clavulanate	78.2	74.5	NT	NT
Ceftriaxone	69.4	71.2	22.1	81.3
Piperacillin-tazobactam	28.7	31.6	19.4	44.7
Ciprofloxacin	66.1	68.9	34.2	72.5
Gentamicin	41.5	39.2	48.6	59.3
Amikacin	12.3	15.7	13.2	22.8
Imipenem	9.8	11.2	16.7	18.9
Colistin	2.1	3.5	4.7	9.8

NT: Not tested.

Figure 2. ESBL and Carbapenem Resistance: 2021 vs 2025



ESBL rates in Enterobacterales increased from 34.2% in 2021 to 51.8% in 2025 (p<0.01). Carbapenem resistance rose from 7.5% to 18.9% over the same period (p=0.02).

Gram-Positive Isolates

Table 3. Antibiotic Resistance Patterns of Major Gram-Positive Pathogens (2021–2025)

Antibiotic	*S. aureus* (%)	*E. faecalis* (%)
Penicillin	100	72.1
Cefoxitin (MRSA)	35.7	NT
Erythromycin	61.2	44.8
Clindamycin	38.9	29.4
Ciprofloxacin	54.3	41.7
Gentamicin	32.1	36.2
Linezolid	0	0
Vancomycin	0	0
Teicoplanin	0	0

MRSA prevalence among S. aureus increased from 28.6% in 2021 to 42.1% in 2025 (p=0.03). All Gram-positive isolates remained susceptible to vancomycin, teicoplanin, and linezolid.

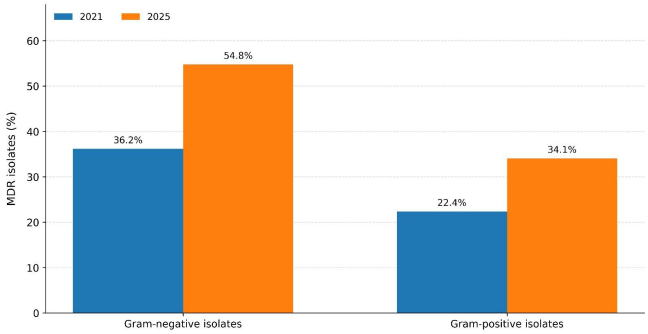
Anaerobic and Fungal Isolates

Anaerobic bacteria, including *Bacteroides* spp., were isolated in 2.4% of cases, predominantly in polymicrobial infections and higher Wagner grades. All anaerobes were sensitive to metronidazole and clindamycin. Fungal isolates, mainly *Candida tropicalis*, were detected in 3.2% of cases, with no significant resistance to fluconazole observed.

Multidrug Resistance and Predictors

Overall, 41.6% of isolates were classified as MDR (non-susceptible to ≥1 agent in ≥3 antimicrobial categories). MDR carriage was significantly associated with higher Wagner grade (≥3), prior antibiotic exposure, and polymicrobial infection (p<0.01 for all). MRSA, ESBL, and carbapenemase production were confirmed by molecular methods in representative isolates.

Figure 3. Multidrug Resistance by Pathogen Group, 2021-2025



The proportion of MDR Gram-negative isolates increased from 36.2% in 2021 to 54.8% in 2025. MDR among Gram-positive isolates rose from 22.4% to 34.1%.

Empirical Therapy and Clinical Outcomes

Empirical therapy most commonly included amoxicillin-clavulanate, piperacillin-tazobactam, or cefuroxime-sulbactam, with vancomycin or linezolid added for suspected MRSA. De-escalation based on culture results was achieved in 61.2% of cases. Clinical outcomes were poorer in patients with MDR infections, with higher rates of amputation (28.7% vs. 14.3%, p=0.01) and prolonged hospitalization.

Representative clinical presentations of diabetic foot infections are shown in **Figures 4-8**. The images illustrate the spectrum of disease severity encountered during the study period, ranging from deep ulceration and soft tissue necrosis to extensive gangrene requiring surgical debridement or amputation. These findings correlate with the high proportion of advanced Wagner grade lesions observed in the study population.

Figure 4: Advanced Diabetic Heel Ulcer with Tissue Necrosis



Figure 4. Clinical photograph demonstrating a deep diabetic heel ulcer with extensive tissue loss, slough formation, and areas of necrosis. The lesion represents an advanced diabetic foot infection requiring aggressive debridement and microbiological evaluation

Figure 5: Diabetic Foot Gangrene Involving the Forefoot



Figure 5. Clinical image showing ischemic and infective changes involving the forefoot and toes with gangrenous discoloration. Such presentations are commonly associated with peripheral vascular disease and severe diabetic foot infection.

Figure 6: Extensive Soft Tissue Involvement in Severe Diabetic Foot Infection



Figure 6. Operative specimen demonstrating extensive soft tissue destruction and purulent involvement associated with advanced diabetic foot infection. The image highlights the severity of tissue damage encountered in complex cases.

Figure 7: Surgically Excised Infected Tissue from Diabetic Foot



Figure 7. Gross surgical specimen obtained following debridement/amputation for advanced diabetic foot infection showing extensive inflammatory and necrotic tissue changes.

Figure 8: Severe Diabetic Foot Infection with Extensive Gangrenous Changes



Figure 8. Clinical photograph showing advanced diabetic foot disease with extensive gangrene and tissue destruction involving the distal foot. Such cases often require multidisciplinary management and may necessitate amputation.

DISCUSSION

Microbiological Landscape of DFIs

This five-year surveillance study at JJ Group of Hospitals provides a comprehensive overview of the evolving microbiological profile and antibiotic resistance patterns in diabetic foot infections. The predominance of Gram-negative bacilli, particularly *E. coli*, *K. pneumoniae*, and *P. aeruginosa*, aligns with recent Indian and international reports, reflecting a shift from the historical Gram-positive paradigm.[6,8,11] *Staphylococcus aureus* remains a major pathogen, with MRSA rates rising steadily, underscoring its continued clinical significance.[6,15]

Polymicrobial infections were frequent, especially in advanced Wagner grades, and were associated with increased MDR carriage and poorer outcomes.[7,8] The detection of biofilm-producing organisms in over half of the isolates highlights the role of biofilms in chronicity, treatment failure, and resistance development.[12] Anaerobic and fungal pathogens, though less common, contributed to the complexity of severe and recalcitrant infections.[13,14]

Antibiotic Resistance Trends

The study documents a worrisome escalation in antibiotic resistance over five years. ESBL-producing Enterobacterales and carbapenem-resistant isolates increased significantly, mirroring national and global trends driven by antibiotic overuse and inadequate stewardship.[15,16] MRSA prevalence among *S. aureus* isolates rose from 28.6% to 42.1%, with all MRSA confirmed to harbor the *mecA* gene. Notably, vancomycin, teicoplanin, and linezolid retained universal activity against Gram-positive isolates, while colistin and amikacin remained effective against most Gram-negative MDR pathogens, albeit with emerging resistance.

The high rates of resistance to fluoroquinolones, third-generation cephalosporins, and even piperacillin-tazobactam in both Gram-negative and Gram-positive organisms challenge the efficacy of commonly used empirical regimens.[8,9,15] The detection of carbapenemase genes (*blaNDM*, *blaKPC*, *blaOXA*) in Enterobacterales and non-fermenters is particularly concerning, as these organisms are associated with limited therapeutic options and increased mortality.[8,16]

Clinical and Stewardship Implications

The findings have direct implications for empirical therapy and infection control. The predominance of MDR Gram-negative bacilli and MRSA necessitates empirical regimens that combine a beta-lactam/beta-lactamase inhibitor or carbapenem with anti-MRSA coverage in severe or high-risk ulcers, as recommended by national and international guidelines.[9,17] De-escalation based on culture and susceptibility results is essential to minimize unnecessary broad-spectrum antibiotic use and curb resistance.[17]

Periodic local antibiograms and resistance surveillance are indispensable for guiding therapy and stewardship interventions.[15,16,18] The association of MDR carriage with higher Wagner grade, prior antibiotic exposure, and polymicrobial infection underscores the need for early, aggressive management and multidisciplinary care, including surgical debridement, vascular assessment, and optimized glycemic control.[7,17]

Laboratory Quality Assurance and Methodological Rigor

The study's strength lies in its adherence to standardized specimen collection, processing, and AST protocols, underpinned by NABL accreditation and ISO 15189 compliance.[10,19,20] The use of deep tissue and bone biopsies, prompt transport, and both aerobic and anaerobic culture maximized pathogen yield and minimized contamination.[5,17] Automated identification and susceptibility platforms, coupled with molecular confirmation of resistance mechanisms, enhanced diagnostic accuracy and epidemiological insight.[10,20]

Limitations

As a retrospective, single-center study, the findings may not be fully generalizable to other settings with different patient populations or healthcare practices. Potential biases include incomplete clinical data, selection bias in specimen collection, and under-detection of fastidious or anaerobic organisms. The lack of routine molecular epidemiology and sequencing for all MDR isolates limits the granularity of resistance surveillance. Nonetheless, the large sample size, five-year duration, and rigorous laboratory protocols lend robustness to the conclusions.

CONCLUSION

Diabetic foot infections at JJ Group of Hospitals, Mumbai are characterized by a predominance of Gram-negative bacilli, frequent polymicrobial and biofilm-associated infections, and a rising burden of multidrug-resistant organisms, including MRSA, ESBL, and carbapenemase producers. These trends complicate empirical therapy, increase the risk of adverse outcomes, and demand vigilant antimicrobial stewardship.

Empirical regimens for moderate-to-severe DFIs should reliably cover Enterobacterales and methicillin-resistant Gram-positives, with carbapenems and glycopeptides reserved for refractory or life-threatening infections. Periodic local antibiograms, standardized laboratory protocols, and multidisciplinary management are essential to optimize patient outcomes and contain resistance. Further research should focus on molecular epidemiology, novel diagnostics, and targeted interventions to reduce the MDR DFI burden.

REFERENCES

1. International Diabetes Federation. (2025). *IDF diabetes atlas* (11th ed.). https://idf.org/news-and-resources/resources/idf-diabetes-atlas-11th-edition-2025/
2. International Diabetes Federation. (n.d.). *India diabetes country report 2000–2050*. IDF Diabetes Atlas. Retrieved October 16, 2026, from https://diabetesatlas.org/data-by-location/country/india/
3. Armstrong, D. G., Boulton, A. J. M., & Bus, S. A. (2017). Diabetic foot ulcers and their recurrence. *The New England Journal of Medicine, 376*(24), 2367–2375. doi:10.1056/NEJMra1615439
4. Raja, J. M., Maturana, M. A., Kayali, S., Khouzam, A., & Efeovbokhan, N. (2023). Diabetic foot ulcer: A comprehensive review of pathophysiology and management modalities. *World Journal of Clinical Cases, 11*(8), 1684–1693. doi:10.12998/wjcc.v11.i8.1684
5. Citron, D. M., Goldstein, E. J. C., Merriam, C. V., Lipsky, B. A., & Abramson, M. A. (2007). Bacteriology of moderate-to-severe diabetic foot infections and in vitro activity of antimicrobial agents. *Journal of Clinical Microbiology, 45*(9), 2819–2828. doi:10.1128/JCM.00551-07
6. Macdonald, K. E., Boeckh, S., Stacey, H. J., & Jones, J. D. (2021). The microbiology of diabetic foot infections: A meta-analysis. *BMC Infectious Diseases, 21*, Article 770. doi:10.1186/s12879-021-06516-7
7. Gadepalli, R., Dhawan, B., Sreenivas, V., Kapil, A., Ammini, A. C., & Chaudhry, R. (2006). A clinico-microbiological study of diabetic foot ulcers in an Indian tertiary care hospital. *Diabetes Care, 29*(8), 1727–1732. doi:10.2337/dc06-0116
8. Saseedharan, S., Sahu, M., Chaddha, R., Pathrose, E., Bal, A., Bhalekar, P., Sekar, P., & Krishnan, P. (2018). Epidemiology of diabetic foot infections in a reference tertiary hospital in India. *Brazilian Journal of Microbiology, 49*(2), 401–406. doi:10.1016/j.bjm.2017.09.003
9. Kwon, K. T., & Armstrong, D. G. (2018). Microbiology and antimicrobial therapy for diabetic foot infections. *Infection & Chemotherapy, 50*(1), 11–20. doi:10.3947/ic.2018.50.1.11
10. Manipal Academy of Higher Education. (n.d.). *Department of microbiology*. Retrieved October 16, 2026, from https://www.manipal.edu/academics/departments/microbiology-kmc-manipal
11. Govindaswamy, S., Subbarayan, E., Jaishwanth, V. M., Anantha Kumar, S. S., Santhosh, S., & Renji, S. A. (2025). Bacteriological profile and antimicrobial susceptibility patterns in patients with diabetic foot infections in a tertiary care hospital in South India. *Journal of Pure and Applied Microbiology, 19*(3), 1948–1954. doi:10.22207/JPAM.19.3.21
12. Theodorakopoulos, G., & Armstrong, D. G. (2025). Biofilm in diabetic foot ulcers: A systematic narrative review. *International Wound Journal, 22*(12), Article e70795. doi:10.1111/iwj.70795
13. Villa, F., Marchandin, H., Lavigne, J.-P., Schuldiner, S., Cellier, N., Sotto, A., & Loubet, P. (2024). Anaerobes in diabetic foot infections: Pathophysiology, epidemiology, virulence, and management. *Clinical Microbiology Reviews, 37*(3), Article e00143-23. doi:10.1128/cmr.00143-23
14. Chellan, G., Shivaprakash, S., Karimassery Ramaiyar, S., Varma, A. K., Varma, N., Thekkeparambil Sukumaran, M., Rohinivilasam Vasukutty, J., Bal, A., & Kumar, H. (2010). Spectrum and prevalence of fungi infecting deep tissues of lower-limb wounds in patients with type 2 diabetes. *Journal of Clinical Microbiology, 48*(6), 2097–2102. doi:10.1128/JCM.02035-09
15. Indian Council of Medical Research. (2025). *Antimicrobial resistance research and surveillance network: Annual report, January 2024–December 2024* (8th ed.). https://www.icmr.gov.in/icmrobject/uploads/Report/1763981012_icmramrsnannualreport2024.pdf
16. World Health Organization. (2022). *Global antimicrobial resistance and use surveillance system (GLASS) report: 2022*. https://www.who.int/pubLications/i/item/9789240062702
17. Senneville, É., Albalawi, Z., van Asten, S. A., Abbas, Z. G., Allison, G., Aragón-Sánchez, J., Embil, J. M., Lavery, L. A., Alhasan, M., Oz, O., Uçkay, I., Urbančič-Rovan, V., Xu, Z.-R., & Peters, E. J. G. (2024). IWGDF/IDSA guidelines on the diagnosis and treatment of diabetes-related foot infections (IWGDF/IDSA 2023). *Diabetes/Metabolism Research and Reviews, 40*(3), Article e3687. doi:10.1002/dmrr.3687
18. Magiorakos, A.-P., Srinivasan, A., Carey, R. B., Carmeli, Y., Falagas, M. E., Giske, C. G., Harbarth, S., Hindler, J. F., Kahlmeter, G., Olsson-Liljequist, B., Paterson, D. L., Rice, L. B., Stelling, J., Struelens, M. J., Vatopoulos, A., Weber, J. T., & Monnet, D. L. (2012). Multidrug-resistant, extensively drug-resistant and pandrug-resistant bacteria: An international expert proposal for interim standard definitions for acquired resistance. *Clinical Microbiology and Infection, 18*(3), 268–281. doi:10.1111/j.1469-0691.2011.03570.x
19. International Organization for Standardization. (2022). *Medical laboratories—Requirements for quality and competence* (ISO Standard No. 15189:2022). https://www.iso.org/standard/76677.html
20. Clinical and Laboratory Standards Institute. (2026). *Performance standards for antimicrobial*

susceptibility testing (36th ed., CLSI supplement M100). https://clsi.org/shop/standards/m100/