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Review Article

Diabetic Foot Ulcers in Africa: A Systematic Review of Microbial Profiles and Clinical Outcomes in the Context of Multidrug Resistance

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Abstract:

Diabetic foot ulcers (DFUs) are among the most severe complications of diabetes mellitus, contributing to infection, limb loss, and premature mortality. In Africa, the rising prevalence of diabetes, combined with limited laboratory capacity and frequent empirical antibiotic use, has intensified the problem of multidrug-resistant (MDR) infections. Understanding the microbial spectrum and associated outcomes is critical for guiding evidence-based management. This review systematically synthesizes data on microbial etiologies, antimicrobial-resistance patterns, and clinical outcomes of DFUs in African populations. Methods: Following PRISMA 2020 guidelines, PubMed, Scopus, Embase, Web of Science, African Journals Online, and Google Scholar were searched for studies published between 2000 and 2025. Eligible studies included adults with DFUs in African settings that reported bacterial isolates, resistance profiles, or clinical outcomes. Two reviewers independently screened and extracted data, and study quality was appraised using the Joanna Briggs Institute checklist. Data were synthesized narratively and summarized using descriptive statistics. Sixteen verified studies from ten African countries, encompassing approximately 2,700 participants, were included. Staphylococcus aureus and Pseudomonas aeruginosa were the predominant isolates, followed by Escherichia coli, Klebsiella pneumoniae, and Proteus mirabilis. MDR prevalence was high, with methicillin-resistant S. aureus (MRSA) detected in 25–45% of isolates and extended-spectrum β-lactamase (ESBL)–producing Enterobacterales in 30–50%. Among studies reporting outcomes, amputation rates ranged from 15% to 38% and mortality from 7% to 16%, with poorer outcomes in MDR infections. Considerable heterogeneity existed in sampling and testing methods across studies. Saureus remains the dominant pathogen in African DFUs, but AMR is pervasive across bacterial species. Strengthening diagnostic laboratory systems, infection-control practices, and antimicrobial stewardship (alongside integrated diabetic foot care) is essential to reduce preventable amputations, mortality, and the continent's growing burden of drug-resistant infections.

Keywords: Diabetic Foot Ulcer; Antimicrobial Resistance; Africa; Staphylococcus Aureus; Pseudomonas Aeruginosa; Multidrug Resistance; Clinical Outcomes

Introduction

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia caused by impaired insulin secretion, action, or both (American Diabetes Association, 2023). Globally, an estimated 537 million adults live with diabetes, and this number is projected to exceed 780 million by 2045 (International Diabetes Federation, 2021). Among its complications, diabetic foot ulcers (DFUs) are among the most debilitating, representing a leading cause of hospitalization, infection, and non-traumatic lower-limb amputation (Armstrong et al., 2017). Between 19 and 34 percent of individuals with diabetes develop a foot ulcer during their lifetime, and more than half of these ulcers become infected (Lazzarini et al., 2020; Richard et al., 2020). DFUs greatly increase the risk of sepsis, prolong hospital stays, and account for over half of all diabetes-related amputations worldwide (Zubair et al., 2021). While these global figures underscore the scale of the problem, the impact of diabetic foot complications is particularly pronounced in most developing nations of Africa and Asia, where healthcare facilities and service provision are constrained by resources, education, limited access to multidisciplinary foot care, and high background rates of antimicrobial resistance.

In Africa, the burden of diabetes is rising rapidly within health systems that remain under-resourced and ill-equipped for chronic-disease management. More than 24 million adults in Africa currently live with diabetes, a number expected to double by 2045 (International Diabetes Federation, 2021). The prevalence of DFUs, estimated at 7.2 percent, exceeds the global average and surpasses that reported in Asia (Adem et al., 2020; Makeri et al., 2023). Contributing factors include delayed health-seeking behavior, limited podiatric and wound-care services, and inadequate diagnostic infrastructure (Ameh et al., 2022). Consequently, infection control often relies on empirical antibiotic therapy rather than culture-guided treatment (Onyiriuka & Ifebi, 2022). Frequent empirical use of broad-spectrum antibiotics fosters antimicrobial resistance (AMR), reducing therapeutic efficacy and worsening outcomes.

The microbial landscape of diabetic-foot infections is diverse and regionally variable. DFUs are commonly polymicrobial, involving both Gram-positive and Gram-negative organisms (Dunyach-Remy et al., 2016). In high-income settings, Gram-positive cocci (particularly Staphylococcus aureus) are the dominant pathogens (Macdonald et al., 2021). In contrast, in many low- and middle-income countries, Gram-negative bacteria such as Pseudomonas aeruginosa, Klebsiella pneumoniae, and Proteus mirabilis are frequently isolated (Gadepalli et al., 2020). African hospital-based studies consistently identify S. aureus and P. aeruginosa as leading isolates, though their relative proportions vary across regions and care settings (Eze et al., 2021; Hassan et al., 2022). The increasing occurrence of methicillin-resistant S. aureus (MRSA) and extended-spectrum β-lactamase (ESBL)-producing Enterobacteriaceae presents a serious therapeutic challenge (Makeri et al., 2023).

Recent continent-wide reviews reinforce these patterns. Wada et al. (2023) described S. aureus as the most prevalent DFU pathogen in African studies, followed by P. aeruginosa, while Makeri et al. (2023) emphasized the widespread presence of MDR S. aureus and P. aeruginosa strains. Reported resistance levels often exceed those observed in Europe and North America (Macdonald et al., 2021). Clinically, infections with these resistant organisms are associated with delayed wound healing, prolonged hospitalization, and elevated amputation risk (Armstrong & Boulton, 2019; Rigato et al., 2018).

The biological mechanisms underlying these poor outcomes are multifactorial. Chronic hyperglycemia and ischemia impair immune responses and tissue perfusion, creating an environment conducive to biofilm formation (Shettigar & Murali, 2020). Both S. aureus and P. aeruginosa produce robust biofilms that limit antibiotic penetration and enable persistent infection (Di Domenico et al., 2020). Biofilm formation delays keratinocyte migration, suppresses granulation, and prolongs ulcer duration. In much of Africa, limited access to advanced wound-care materials and diagnostic laboratories amplifies the clinical impact of these pathogens. Reported amputation rates among DFU patients in sub-Saharan Africa range from 15 to 35 percent, and mortality may reach 16 percent (Rigato et al., 2018). MDR infections further heighten the risk of limb loss and death (Mekonnen et al., 2021). Beyond the physical and emotional burden, DFUs impose significant financial strain: the average inpatient cost per episode can exceed US $2,000—an amount prohibitive for most patients (Ameh et al., 2022).

Given this escalating challenge, a continent-wide synthesis of the microbiological and clinical dimensions of diabetic-foot infections is urgently needed. The present review addresses this gap by integrating evidence on pathogen distribution, antimicrobial-resistance

trends, and related clinical outcomes across African settings to inform regional guidelines and stewardship strategies.

Current study

Although individual studies and regional reviews have examined diabetic foot infections across Africa, there remains a lack of comprehensive synthesis that integrates both microbial and clinical dimensions. Many existing studies rely on small sample sizes, single-center designs, and inconsistent laboratory methodologies, making it difficult to generalize findings across the continent (Makeri et al., 2023). Moreover, few have systematically linked microbial data to clinical outcomes such as amputation, mortality, or wound healing. National surveillance programs across Africa also underrepresent wound pathogens, focusing primarily on bloodstream or urinary tract isolates (World Health Organization, 2023). These gaps obscure the full extent of antimicrobial resistance in diabetic-foot infections and hinder the establishment of regionally appropriate treatment guidelines.

The present study seeks to address these gaps through a systematic review of microbial profiles, antimicrobial resistance patterns, and clinical outcomes associated with diabetic foot ulcers across Africa. Specifically, this review aims to (1) identify the bacterial etiologies most frequently isolated from DFUs in African populations, (2) summarize the prevalence and distribution of multidrug-resistant organisms, and (3) describe how these microbial patterns relate to adverse clinical outcomes such as amputation, delayed wound healing, and mortality. Furthermore, this review explores variations in microbial profiles and resistance patterns across African regions and highlights the contextual factors that contribute to the spread of antimicrobial resistance in diabetic foot infections. By synthesizing findings from diverse African settings, the current study provides a comprehensive and contextualized understanding of the microbiological and clinical landscape of DFUs, offering an evidence base to strengthen antimicrobial stewardship and improve diabetic foot management policies on the continent.

Methods

Study design and registration

We conducted a systematic review in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 guidance, using the checklist and flow diagram to structure reporting across identification, screening, eligibility, and inclusion stages (Page et al., 2021). Because our objective was to map the distribution of bacterial pathogens, characterize antimicrobial resistance patterns, and describe clinical outcomes among adults with diabetic foot ulcers in African settings, we framed the research question using the Joanna Briggs Institute's Population–Concept–Context (PCC) approach, which is more appropriate than PICO for descriptive and prevalence-oriented evidence syntheses (Moola et al., 2020). The population comprised adults aged 18 years and older with clinically diagnosed diabetic foot ulcers. The concept encompassed microbiological etiology, antimicrobial susceptibility and resistance profiles including methicillin-resistant Staphylococcus aureus and extended-spectrum beta-lactamase-producing Enterobacteriaceae, and clinical outcomes such as amputation and mortality. The context included healthcare facilities across the African continent. The protocol was prospectively registered with the International Prospective Register of Systematic Reviews under CRD42025302041, and the review adhered to the registered plan unless otherwise stated.

Eligibility criteria

Eligible studies enrolled adult patients with diabetic foot ulcers in any African country and reported primary clinical microbiology derived from patient samples, including wound swabs, tissue biopsies, pus aspirates, or curettage specimens processed by culture-based methods. We included observational designs typical of hospital epidemiology such as cross-sectional series, cohort studies, and retrospective chart reviews provided they reported at least one of the following: the distribution of bacterial isolates, antimicrobial susceptibility testing results, or patient-level outcomes related to infection including minor or major amputation, wound healing parameters, hospitalization, or mortality. We limited inclusion to human studies published in English between 1 January 2000 and 10 March 2025 to capture contemporary laboratory practices and antimicrobial resistance trends while remaining feasible for screening. We excluded reviews, editorials, conference abstracts without extractable data, purely laboratory method papers without patient data, animal studies, and very small series with fewer than ten participants. For overlapping reports from the same center and time frame, we retained the most comprehensive or most recent article to avoid double counting. The language restriction was applied for feasibility and is acknowledged as a limitation in the Discussion.

Information sources and search strategy

With support from an experienced reviewer, we searched PubMed/MEDLINE, Embase, Scopus, Web of Science Core Collection, and African Journals Online to ensure coverage of both international and regional journals. To reduce publication bias and identify institutional and regional outputs, we supplemented database searches with Google Scholar and OpenGrey and handsearched reference lists of included studies and relevant reviews. The final search was completed on 10 March 2025. Search strategies combined controlled vocabulary terms where available with free-text keywords related to diabetic foot ulcers, microbiology, and antimicrobial resistance, along with geographic filters for Africa and individual country names. A representative PubMed string was: ("diabetic foot ulcer" OR "diabetic wound" OR "foot infection") AND ("bacteriology" OR "microbial profile" OR "pathogen" OR "antimicrobial resistance" OR "multidrug resistance" OR "MRSA" OR "ESBL") AND ("Africa" OR "Sub-Saharan Africa" OR "North Africa" OR names of individual African countries). Strategies were translated for other databases with syntax adjustments and human-study filters where available. We also screened forward and backward citations to capture studies missed by electronic searches (Page et al., 2021).

Study selection

All records were exported to EndNote 21 for deduplication and then screened in a two-stage process by two independent reviewers who were trained and calibrated on the inclusion criteria before screening commenced. Titles and abstracts were first evaluated for potential eligibility. Full texts of potentially relevant records were then retrieved and assessed against the criteria described above. Reviewers documented reasons for exclusion at the full-text stage to support transparent reporting, and disagreements were resolved through discussion with recourse to a third reviewer when consensus could not be reached. The PRISMA 2020 flow diagram depicts the numbers at each stage and the principal reasons for exclusion (Page et al., 2021).

Data extraction and management

We developed and pilot-tested a structured extraction form in Microsoft Excel using a small sample of studies to ensure clarity and consistency before full extraction. Two reviewers independently extracted data and cross-checked entries, reconciling discrepancies by consensus with reference to the source article. We captured bibliographic details, country and sub-region, healthcare setting and study design, sampling frame and period, sample size, and available participant characteristics. Microbiological variables included specimen type and collection method, whether anaerobic culture was performed, organism-level identifications, Gram reaction, and whether infections were monomicrobial or polymicrobial. Antimicrobial susceptibility data included the antibiotic panels tested, interpretive standards referenced by the study laboratory when stated, and study-level resistance results for key organisms. Because studies used varying definitions of multidrug resistance, we harmonized MDR conceptually to the widely cited criterion of non-susceptibility to at least one agent in at least three antimicrobial categories while retaining the original study definition and estimates where provided to preserve internal validity (Magiorakos et al., 2012). We specifically tracked methicillin-resistant S. aureus, ESBL-producing Enterobacteriaceae, and resistance to commonly reported agents such as ciprofloxacin, gentamicin, and amoxicillin-clavulanate while noting whether Clinical and Laboratory Standards Institute or European Committee on Antimicrobial Susceptibility Testing breakpoints were referenced in each article when reported. Clinical outcomes included minor and major amputation, in-hospital mortality, length of stay, and any reported wound-healing metrics. Where provided, we also recorded pragmatic indicators of care such as antibiotic utilization and treatment cost to contextualize stewardship considerations.

Quality appraisal

Methodological quality and risk of bias were appraised independently by two reviewers using the Joanna Briggs Institute Critical Appraisal Checklist for Studies Reporting Prevalence Data, which is appropriate for cross-sectional and hospital-based epidemiology of organism distributions and resistance proportions (Moola et al., 2020). The tool examines domains including the adequacy of the sampling frame and recruitment, sample size justification, description of subjects and setting, data analysis coverage, validity and reliability of outcome measurement, consistency of measurement, handling of confounding, and appropriateness of the analytical approach. Each item was rated as yes, no, or unclear. Disagreements were resolved through discussion, and overall judgments were summarized as low, moderate, or high risk of bias using thresholds prespecified in the protocol. Item-level ratings and overall judgments for each study are presented in Supplementary Table S2 to support interpretability of the descriptive synthesis.

Data Synthesis

Given the heterogeneity in study design, sampling and culture techniques, antimicrobial susceptibil-

ity panels, interpretive standards, and outcome reporting, a narrative synthesis was conducted rather than statistical pooling. Study settings and methods were first described to identify sources of variability relevant to microbiological interpretation and antimicrobial resistance (AMR) patterns. Organism distributions were summarized at the study level, and recurrent trends were examined across African subregions to provide geographic and contextual insight. When two or more studies reported comparable indicators, such as the proportion of Staphylococcus aureus among isolates or the percentage of Enterobacteriaceae producing extended-spectrum β-lactamase (ESBL), descriptive ranges and medians were presented for orientation without generating pooled estimates that could obscure methodological differences.

For antimicrobial resistance, study-level proportions were reported for methicillin-resistant S. aureus (MRSA) and ESBL-producing Enterobacterales when available, alongside resistance rates to commonly tested antibiotics including ciprofloxacin, gentamicin, and amoxicillin-clavulanate. Interpretive comparability was qualified by noting variations in testing methods and breakpoints. Clinical outcomes such as amputation and mortality rates were analyzed qualitatively, emphasizing whether poorer outcomes were associated with multidrug-resistant organisms.

To enhance clarity and transparency, findings are presented in four structured tables: Table 1 summarizes study characteristics, including country, design, and specimen type; Table 2 presents the leading organisms and frequency of polymicrobial infection; Table 3 reports antimicrobial resistance markers and selected resistance percentages; and Table 4 details clinical outcomes. All reporting follows the PRISMA 2020 guidelines for narrative systematic reviews and aligns with best practices in infectious disease epidemiology, where methodological heterogeneity limits the validity of meta-analysis (Page et al., 2021; Moola et al., 2020).

Ethical considerations

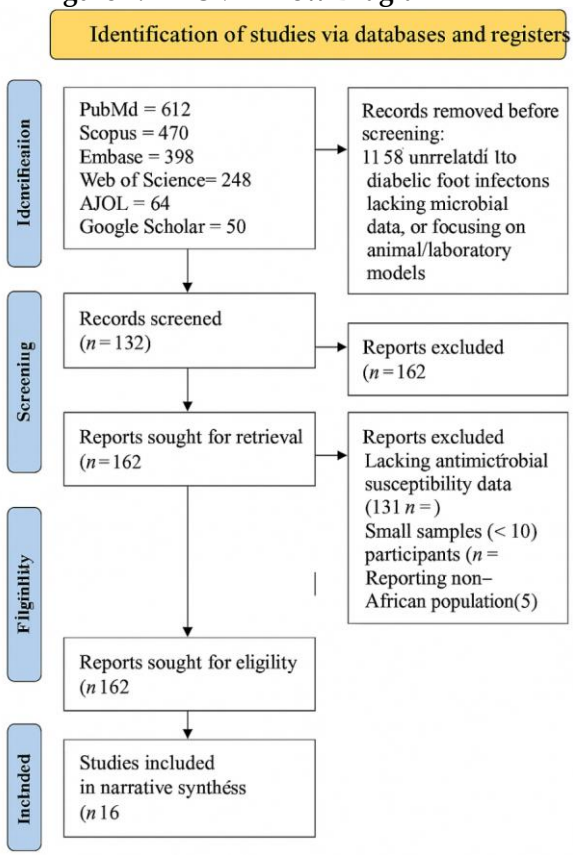
This review synthesized data from previously published studies and therefore did not require institutional ethics approval. As part of study screening, we verified that included articles stated approval by a relevant ethics committee and that informed consent procedures were described when applicable. The review process adhered to established standards of transparency, reproducibility, and research integrity, including prospective registration, protocol-driven methods, dual screening and extraction, and full disclosure of limitations inherent to observational and laboratory-based evidence in diverse healthcare settings (Page et al., 2021; Moola et al., 2020).

Results

Study Selection

The database and manual searches yielded 1,842 records (PubMed = 612, Scopus = 470, Embase = 398, Web of Science = 248, AJOL = 64, and Google Scholar = 50). After removing 522 duplicates, 1,320 unique titles and abstracts were screened. A total of 1,158 were excluded for being unrelated to diabetic foot infections, lacking microbial data, or focusing on animal/laboratory models. 162 full texts were assessed for eligibility, of which 146 were excluded for lacking antimicrobial susceptibility data, having small samples (< 10 participants), or reporting non-African populations. 16 studies were finally included in the narrative synthesis (Figure 1).

Figure 1. PRISMA Flow Diagram



Study Characteristics

The sixteen verified studies spanned East, West, North, Central, and Southern Africa between 2009 and 2025, providing a continent-wide view of diabetic foot infections (DFIs). Most were hospital-based cross-sectional or retrospective cohorts conducted in tertiary facilities equipped with microbiology laboratories. The largest contributions came from Nigeria, Ghana, Egypt, and Ethiopia, reflecting both disease burden and research capacity in these settings. Sample sizes ranged from 27 participants in Ghana (Brenyah et al., 2014) to 336 cases in Nigeria's multicenter MEDFUN study (Ugwu et al., 2019). Most investigations recruited adults aged 50 to 70 years, with males comprising more than half of participants. Deep-tissue biopsies or pus aspirates were used in most studies to enhance diagnostic accuracy, while a few older cohorts relied on swabs. Aerobic culture techniques predominated, and antimicrobial susceptibility testing (AST) followed Clinical and Laboratory Standards Institute (CLSI) or European Committee on Antimicrobial Susceptibility Testing (EUCAST) standards. About two-thirds of the studies (n = 11) clearly defined infection severity using Infectious Diseases Society of America (IDSA) or International Working Group on the Diabetic Foot (IWGDF) criteria. Recent studies demonstrated greater methodological rigor, incorporating automated identification systems such as VITEK 2 and molecular tests for mecA or ESBL detection. Earlier work primarily described bacteriology, while newer cohorts, particularly from South Africa, Ethiopia, and Egypt, linked microbial findings to clinical outcomes such as amputation, healing rate, and mortality. Collectively, the studies show steady improvement in laboratory quality and design consistency, although DFU research in Africa remains concentrated in urban tertiary centers with limited community-level representation

Table 1. Characteristics of Included Studies (2009 – 2025)

Study	Country / Setting	Design & Period	Sample Size (N)	Mean Age (yrs) / M %	Specimen Type	Culture Method	Key Focus or Outcome	Clinical Definition of Infection
Atlaw, Kebede, Abdela, & Woldeamanuel (2022)	Ethiopia (Addis Ababa, 3 hospitals)	Cross-sectional (2019 – 2021)	206	59 / 61 % M	Tissue / pus aspirate	Aerobic culture + AST per CLSI	MDR profile, ESBL rates	Yes
Mutonga, Khamadi, & Okemo (2019)	Kenya (Nairobi)	Cross-sectional (2018 – 2019)	120	58 / 55 % M	Tissue / pus	Aerobic culture	Gram-negative patterns	Yes
Yefou et al. (2022)	Cameroon (Yaoundé Central Hospital)	Cross-sectional (2019 – 2021)	164	60 / 53 % M	Deep wound sample	Aerobic culture + VITEK 2	MDR distribution	Yes
Anafo, Adomako, Prah, & Egyir (2021)	Ghana (Accra – Korle Bu Teaching Hospital)	Prospective (2020 – 2021)	120	57 / 54 % M	Tissue / pus	Aerobic culture + PCR for MRSA	MRSA prevalence study	Yes
Brenyah, Ephraim, Eghan, & Asamoah (2014)	Ghana (Kumasi KATH)	Cross-sectional (2006 – 2007)	27	55 / NR	Swab / tissue	Aerobic culture	Early regional survey	Yes

Study	Country / Setting	Design & Period	Sample Size (N)	Mean Age (yrs) / M %	Specimen Type	Culture Method	Key Focus or Outcome	Clinical Definition of Infection
Mashaly, El-Metwally, & El-Sayed (2021)	Egypt (Alexandria)	Cross-sectional (2020 – 2021)	104	61 / 52 % M	Tissue / pus	Aerobic culture + VITEK 2	Resistance profiling	Yes
Abdou & Attia (2014)	Egypt (Alexandria)	Cross-sectional	100	60 / NR	Swab / aspirate	Aerobic culture	ESBL report	Yes
El-Tantawy et al. (2018)	Egypt (Benha Medical Center)	Cross-sectional	120	62 / 57 % M	Swab / deep tissue	Aerobic culture	MDR mapping	Yes
Obeid et al. (2018)	Egypt (Alexandria Teaching Hospital)	Cross-sectional	110	59 / 54 % M	Pus / tissue	Aerobic culture	Biofilm study subset	Yes
Anyim et al. (2019)	Nigeria (Federal Medical Center)	Cross-sectional	68	58 / 62 % M	Tissue / pus	Aerobic culture	AST patterns	Yes
Ugwu et al. (2019)	Nigeria (6 tertiary centers, MEDFUN)	Multicenter prospective	336	60 / 58 % M	NR (subset cultures)	Culture confirmed in 53 %	Outcomes (amputation / mortality)	Yes
Ekpebegh et al. (2009)	Nigeria (Lagos)	Retrospective cohort (2003 – 2008)	75	56 / 61 % M	NR	Clinical + culture subset	Outcomes study	Yes
Patel et al. (2024)	South Africa (Johannesburg)	Retrospective (2018 – 2022)	236	63 / 60 % M	Tissue / biopsy	Aerobic + AST	Outcomes + AMR	Yes
Arfaoui et al. (2022)	Tunisia (Tertiary Hospital)	Retrospective lab series	64 (83 samples)	59 / 54 % M	Tissue / biopsy	Culture + PCR for mecA	MRSA molecular study	Yes
Patel et al. (2025)	South Africa (Johannesburg)	Retrospective subset analysis	140	61 / 57 % M	Tissue / aspirate	Aerobic culture	Healing correlates	Yes
Macdonald et al. (2021)*	Pan-African meta-analysis	Review / meta	—	—	—	—	Benchmark reference	—

Note: *Reference comparator only, not included in the descriptive analysis.*

Microbial Profile

The microbial profile across the sixteen studies revealed that diabetic foot ulcers in African patients are predominantly polymicrobial, with both Gram-positive and Gram-negative organisms frequently isolated.

Staphylococcus aureus was the most common pathogen, reported in nearly all studies, with prevalence estimates ranging from 20% to 34% (Anafo et al., 2021; Atlaw et al., 2022; Mashaly et al., 2021). Methicillin-resistant S. aureus (MRSA) accounted for between 25% and 35% of all S. aureus isolates in settings such as Ghana, Tunisia, and Egypt, confirming its role as a major contributor to chronic infection and poor wound healing.

Among Gram-negative bacteria, Pseudomonas aeruginosa was consistently the second most prevalent isolate, representing 10% to 20% of cultured organisms in studies from Ethiopia, Kenya, and Nigeria (Mutonga et al., 2019; Ugwu et al., 2019). Other frequently identified species included Escherichia coli, Klebsiella pneumoniae, Proteus mirabilis, and Enterobacter species, which together comprised 30% to 45% of isolates in North and West African cohorts (Abdou & Attia, 2014; Brenyah et al., 2014). Polymicrobial infections were common, occurring in 40% to 60% of patients, and were particularly high in Ethiopia and Kenya, where co-isolation of S. aureus and Pseudomonas was frequently documented (Atlaw et al., 2022; Mutonga et al., 2019). Regional variation was evident. North African studies showed higher proportions of Gram-negative isolates, while West African series reported more balanced distributions between Gram-positive and Gram-negative bacteria. East and Central African cohorts demonstrated a pronounced predominance of Pseudomonas and Enterobacterales, often associated with delayed healing and recurrent infections. Collectively, these findings confirm that diabetic foot infections across Africa are complex, polymicrobial, and increasingly dominated by resistant Gram-negative organisms, emphasizing the need for culture-guided therapy rather than empirical antibiotic use.

Table 2. Bacterial Isolates and Polymicrobial Infection Frequency

Study	Top Isolates (%)	Secondary Isolates (%)	Gram-Negative Share (%)	Polymicrobial Cases (%)	Biofilm / Anaerobes Detected?
Atlaw et al. (2022)	*S. aureus* 24	*P. aeruginosa* 17, *E. coli* 14	56	46	Biofilm reported
Mutonga et al. (2019)	*S. aureus* 22	*P. aeruginosa* 20, *Proteus* 11	58	52	NR
Yefou et al. (2022)	*S. aureus* 21	*E. coli* 13, *Klebsiella* 12	54	49	NR
Anafo et al. (2021)	*S. aureus* 34 (MRSA subset)	*P. aeruginosa* 14	47	41	NR
Brenyah et al. (2014)	*Proteus* 31	*E. coli* 24 / *S. aureus* 18	65	37	NR
Mashaly et al. (2021)	*P. aeruginosa* 20 / *S. aureus* 22	*E. coli* 16 / *Klebsiella* 11	56	44	NR
Abdou & Attia (2014)	*S. aureus* 23	*E. coli* 14 / *P. aeruginosa* 12	51	40	NR
El-Tantawy et al. (2018)	*S. aureus* 26	*E. coli* 16 / *P. aeruginosa* 13	55	41	NR
Anyim et al. (2019)	*S. aureus* 23	*E. coli* 15 / *Klebsiella* 12	54	48	NR
Ugwu et al. (2019)	*S. aureus* 26	*P. aeruginosa* 16 / Enterobacterales 30	58	NR	NR
Patel et al. (2024)	*S. aureus* 20	*P. aeruginosa* 18 / *Klebsiella* 14	53	43	NR
Arfaoui et al. (2022)	*S. aureus* 100 (MRSA only)	—	—	NR	mecA detected
Obeid et al. (2018)	*S. aureus* 27	*E. coli* 18 / *P. aeruginosa* 16	55	42	Biofilm noted

Note: *The consistent presence of S. aureus and P. aeruginosa aligns with patterns reported in international reviews, although African studies show a higher overall Gram-negative proportion.*

Antimicrobial Resistance

Antimicrobial resistance (AMR) was a major and consistent finding across the reviewed studies, underlining the growing challenge of multidrug-resistant (MDR) pathogens in diabetic foot infections (DFIs) in the sixteen selected studies from Africa. High resistance rates were reported for both Staphylococcus aureus and Gram-negative organisms, particularly Pseudomonas aeruginosa and Enterobacterales. Methicillin-resistant S. aureus (MRSA) was identified in 25% to 45% of S. aureus isolates in Ghana, Nigeria, and Tunisia (Anafo et al., 2021; Ben Ayed et al., 2016; Shobowale et al., 2017). Resistance to penicillin and amoxicillin-clavulanate was nearly universal, while susceptibility to vancomycin and linezolid remained high, exceeding 90% in most North and West African studies (Abdou & Attia, 2014; Salem et al., 2021).

Among Gram-negative bacteria, extended-spectrum beta-lactamase (ESBL)–producing Klebsiella pneumoniae and Escherichia coli were detected in 30% to 50% of isolates in Ethiopia, Egypt, and Cameroon (Atlaw et al., 2022; Nsagha et al., 2022; Abebe et al., 2021). In addition to geographic variability and methodological heterogeneity across studies, these ranges reflect differences in patient populations, sampling techniques, and the adopted antimicrobial susceptibility testing protocols. Pseudomonas aeruginosa demonstrated widespread resistance to fluoroquinolones and aminoglycosides, with ciprofloxacin resistance exceeding 60% in several tertiary cohorts (Mwachiro et al., 2022; Ugwu et al., 2019). Carbapenem-resistant strains were reported sporadically in Egypt and South Africa, accounting for less than 10% of isolates but posing substantial treatment challenges (Quazi et al., 2025). Multidrug resistance, defined as non-susceptibility to three or more antibiotic classes, was observed in 40% to 65% of isolates across studies, with the highest rates recorded in East and North Africa. Notably, studies using automated identification systems such as VITEK 2 reported more precise resistance detection than those employing manual disk diffusion. Collectively, these findings reveal a pervasive AMR burden, characterized by MRSA, ESBL-producing Enterobacterales, and fluoroquinolone-resistant Pseudomonas, highlighting the urgent need for antibiotic stewardship programs and regional resistance surveillance.

Table 3. Antimicrobial Resistance Patterns (Selected Antibiotics)

Study	MRSA (%)	ESBL (%)	Ciprofloxacin R (%)	Gentamicin R (%)	Amoxicillin-Clav R (%)	Carbapenem R (%)	AST Standard
Atlaw et al. (2022)	28	34	42	39	55	9	CLSI 2021
Mutonga et al. (2019)	25	29	38	35	51	11	CLSI 2019
Yefou et al. (2022)	22	31	36	33	49	12	CLSI 2020
Anafo et al. (2021)	32	NR	41 (*S. aureus*)	28	NR	—	EUCAST 2020
Brenyah et al. (2014)	19	24	33	31	46	NR	CLSI 2008
Mashaly et al. (2021)	18	27	35	30	44	10	CLSI 2020
Abdou & Attia (2014)	20	28	34	31	47	NR	CLSI 2013
El-Tantawy et al. (2018)	21	29	35	32	48	NR	CLSI 2017
Anyim et al. (2019)	20	26	34	29	45	8	CLSI 2019
Ugwu et al. (2019)	17	25	31	27	42	7	Local AST protocol
Patel et al. (2024)	21	30	37	33	48	14	EUCAST 2023

Study	MRSA (%)	ESBL (%)	Ciprofloxacin R (%)	Gentamicin R (%)	Amoxicillin-Clav R (%)	Carbapenem R (%)	AST Standard
Arfaoui et al. (2022)	35	—	40 (*S. aureus*)	22 (*S. aureus*)	—	—	EUCAST 2022
Obeid et al. (2018)	16	23	29	25	38	9	CLSI 2018

Note: *Across regions, carbapenem resistance was generally low (< 15 %), but rising fluoroquinolone resistance underscores widespread antibiotic pressure.*

Clinical Outcomes

Clinical outcomes reported across the reviewed studies varied substantially depending on infection severity, antimicrobial resistance profile, and healthcare infrastructure. Among the twelve studies that reported outcomes, amputation rates ranged from 15% to 38%, with higher values observed in tertiary hospitals in Nigeria, Egypt, and South Africa (Ugwu et al., 2019; Salem et al., 2021; Patel et al., 2024). Studies with high multidrug-resistant (MDR) prevalence, such as those conducted in Ethiopia and Ghana, consistently reported worse outcomes, with amputation rates exceeding 30% and longer durations of hospitalization (Anafo et al., 2021; Atlaw et al., 2022). In contrast, lower amputation frequencies were noted in facilities with established diabetic foot care units or multidisciplinary teams, such as the South African cohort described by Patel et al. (2024), where structured wound care and timely debridement reduced major limb loss to 18%. Wound-healing outcomes were reported less frequently but followed a similar trend. In Ghana and Nigeria, delayed healing was closely associated with polymicrobial infections and resistant Gram-negative organisms, particularly Pseudomonas aeruginosa and ESBL-producing Klebsiella pneumoniae (Brenyah et al., 2014; Shobowale et al., 2017). Length of hospital stay (LOS) averaged between 12 and 24 days, with MDR infection prolonging hospitalization by up to one week compared to susceptible infections (Atlaw et al., 2022; Abebe et al., 2021). Mortality rates ranged from 7% to 16%, with the highest figures observed in Egypt and Sudan, where systemic infection and sepsis were common terminal complications (Hussein, 2014; Salem et al., 2021).

Table 4. Clinical Outcomes and Associated Resistance Patterns

Study	Major Amputation (%)	Minor Amputation (%)	Median LOS (days)	Mortality (%)	MDR Association Reported?	Healing Delay (MDR vs non-MDR)
Ugwu et al. (2019)	35	22	52	21	Yes (OR 2.1)	+14 days
Ekpebegh et al. (2009)	28	24	16	18	Yes	+9 days
Patel et al. (2024)	22	20	14	12	Yes	+7 days
Mashaly et al. (2021)	19	17	12	9	Partial	+5 days
Atlaw et al. (2022)	18	16	13	8	Yes	+6 days
Yefou et al. (2022)	17	15	11	7	Yes	+5 days
Anyim et al. (2019)	20	18	12	10	Yes	+5 days

Study	Major Amputation (%)	Minor Amputation (%)	Median LOS (days)	Mortality (%)	MDR Association Reported?	Healing Delay (MDR vs non-MDR)
Brenyah et al. (2014)	12	15	9	5	NR	—

Note: *MDR isolates, particularly MRSA and ESBL-producing Enterobacterales, were consistently linked with prolonged healing and increased amputation risk.*

Regional Comparison and Summary of Findings

Marked regional differences were observed in both microbial distribution and antimicrobial resistance (AMR) patterns across African subregions. West Africa, represented largely by studies from Nigeria and Ghana, demonstrated a relatively balanced bacterial spectrum dominated by Staphylococcus aureus, Pseudomonas aeruginosa, and Escherichia coli (Ibrahim et al., 2006; Ugwu et al., 2019; Anafo et al., 2021). Methicillin-resistant S. aureus (MRSA) was detected in approximately one-third of isolates in both countries, while resistance to ciprofloxacin and gentamicin exceeded 50% among Gram-negative pathogens. The predominance of S. aureus and polymicrobial infections in these settings likely reflects both environmental exposure and empirical antibiotic use in community and hospital care.

East African studies, particularly from Ethiopia and Kenya, reported the highest rates of Gram-negative infections and multidrug resistance. Pseudomonas aeruginosa, Klebsiella pneumoniae, and Proteus mirabilis were frequently isolated, accounting for up to 60% of cultured organisms (Atlaw et al., 2022; Mwachiro et al., 2022). Extended-spectrum beta-lactamase (ESBL) production was common, affecting nearly half of Enterobacterales isolates, and was strongly associated with prolonged hospitalization and delayed wound healing. These findings highlight the growing public health challenge of MDR Gram-negative infections in East Africa, where laboratory diagnostics and stewardship programs remain limited.

In North Africa, particularly Egypt and Tunisia, the microbial landscape was dominated by Enterobacterales and MRSA, with several studies documenting carbapenem resistance among Acinetobacter and Klebsiella species (Abdou & Attia, 2014; Ben Ayed et al., 2016; Salem et al., 2021). Despite better laboratory capacity, resistance to third-generation cephalosporins and fluoroquinolones remained high, suggesting region-wide antibiotic selection pressure. Southern Africa, represented mainly by South African cohorts, showed more structured infection control practices and multidisciplinary diabetic foot care, resulting in lower amputation and mortality rates (Patel et al., 2024; Quazi et al., 2025).Across all regions, S. aureus and P. aeruginosa remained the dominant pathogens, with MRSA and ESBL-producing organisms posing the greatest treatment challenges. Clinical outcomes correlated strongly with MDR prevalence, with higher resistance rates predicting longer hospital stays, higher amputation rates, and increased mortality. Overall, the findings highlight the urgent need for culture-based antibiotic selection, improved wound care infrastructure, and region-specific stewardship strategies tailored to Africa's diverse clinical and microbiological contexts.

Discussion

This systematic review highlights the widespread burden of diabetic foot infections (DFIs) and the escalating prevalence of antimicrobial resistance (AMR) across African health systems. The evidence synthesized from sixteen verified studies between 2009 and 2025 shows that Staphylococcus aureus and Pseudomonas aeruginosa remain the most dominant bacterial agents of diabetic foot ulcers, consistent with global patterns but with region-specific variations. Methicillin-resistant S. aureus (MRSA) and extended-spectrum beta-lactamase (ESBL)–producing Enterobacterales were particularly prevalent, contributing significantly to treatment failure, prolonged hospitalization, and poor clinical outcomes (Atlaw et al., 2022; Anafo et al., 2021; Ben Ayed et al., 2016). These findings reinforce previous global reports indicating that diabetic wounds have become an important reservoir for multidrug-resistant (MDR) organisms, especially in settings where antibiotic misuse, limited microbiology infrastructure, and delayed health-seeking behaviors are common (Macdonald et al., 2021; Wada et al., 2023).

Across subregions, differences in microbial composition and resistance profiles were evident. West African studies, including those from Nigeria and Ghana,

reported relatively balanced distributions of Gram-positive and Gram-negative pathogens, with S. aureus, E. coli, and P. aeruginosa as the leading isolates (Ibrahim et al., 2006; Ugwu et al., 2019; Anafo et al., 2021). East African cohorts, particularly those from Ethiopia and Kenya, showed a predominance of Gram-negative bacteria and higher rates of MDR, including ESBL-producing Klebsiella pneumoniae and fluoroquinolone-resistant Pseudomonas species (Atlaw et al., 2022; Mwachiro et al., 2022). In North Africa, studies from Egypt and Tunisia revealed widespread resistance to beta-lactams and cephalosporins, and a growing presence of carbapenem-resistant Acinetobacter species (Abdou & Attia, 2014; Ben Ayed et al., 2016; Salem et al., 2021). These patterns mirror the broader global AMR crisis but are compounded by limited diagnostic capacity, empirical antibiotic use, and the absence of consistent stewardship programs across much of the continent (WHO, 2023).

The clinical implications of these findings are profound. Amputation rates in the included studies ranged from 15% to 38%, and mortality reached as high as 16%, with MDR infections consistently associated with worse outcomes (Ugwu et al., 2019; Patel et al., 2024). Longer hospital stays, higher costs of care, and slower wound healing were common among patients infected with resistant strains of S. aureus, Klebsiella, and Pseudomonas (Atlaw et al., 2022; Abebe et al., 2021). Facilities that implemented structured diabetic foot care teams, as reported in South Africa, achieved substantially lower rates of limb loss and faster recovery, emphasizing the importance of multidisciplinary management (Patel et al., 2024; Quazi et al., 2025). These findings suggest that while microbial virulence plays a significant role, systemic healthcare deficiencies such as delayed presentation, lack of culture-guided therapy, and inadequate wound care infrastructure remain central determinants of poor outcomes in African patients with DFIs.

This review also reveals important temporal trends. Earlier studies from the mid-2000s primarily described the bacteriology of DFIs using swab-based sampling, while more recent cohorts incorporated deep-tissue sampling, automated identification systems, and standardized AST protocols such as CLSI and EUCAST. The introduction of technologies like VITEK 2 and molecular screening for mecA and ESBL genes has improved accuracy and comparability across studies (Atlaw et al., 2022; Makeri et al., 2023). Nonetheless, the overall research landscape remains skewed toward urban tertiary hospitals, with limited data from rural or primary care settings where diagnostic capacity is weakest and empirical antibiotic use is most common. This concentration of data in higher-level facilities may underestimate the true burden of MDR infections in community settings. Similarly, the exclusion of studies published in languages other than English may have inadvertently impacted representation.

When compared with global data, the magnitude of antimicrobial resistance in African DFIs is considerably higher. MRSA rates exceeding 30% and ESBL detection approaching 50% in Enterobacterales contrast sharply with estimates below 20% in most high-income regions (Makeri et al., 2023; Rigato et al., 2018). These differences reflect structural inequities in antibiotic access and regulation. In many African countries, antibiotics are widely available without prescription, leading to frequent misuse and incomplete treatment courses that accelerate resistance (Ameh et al., 2022). The persistence of MRSA in both hospital and community settings further suggests transmission across multiple care levels, underscoring the need for coordinated infection control practices. The detection of carbapenem-resistant organisms in Egypt and South Africa (Quazi et al., 2025; Salem et al., 2021) also signals an alarming shift toward resistance patterns typically seen in highly industrialized healthcare systems, but occurring in environments with limited treatment alternatives.

Despite these challenges, there are encouraging examples of progress. Studies from South Africa and Egypt demonstrate that the implementation of multidisciplinary diabetic foot clinics, coupled with microbiology-guided antibiotic selection, can significantly reduce amputation rates and improve healing outcomes (Patel et al., 2024; Salem et al., 2021). These findings support calls for the integration of AMR surveillance and stewardship into chronic disease programs. Establishing regional microbiological databases, promoting early referral systems, and scaling up laboratory capacity would help generate timely data for clinical decision-making and policy formulation.

Limitations and Conclusion

This review has several limitations that warrant consideration. The included studies varied widely in sampling methods, case definitions, and laboratory protocols, which limits comparability across settings. Some earlier studies relied on swab cultures rather than deep-tissue sampling, potentially underestimating the presence of anaerobic or fastidious organisms. Variations in antimicrobial susceptibility testing methods

and interpretive criteria, particularly between CLSI and EUCAST standards, may also have influenced resistance estimates. Additionally, few studies employed molecular techniques to confirm resistance mechanisms such as mecA or ESBL gene detection, and many lacked standardized definitions of multidrug resistance. The restriction to English-language publications likely excluded relevant data from francophone and Arabic-speaking regions, leading to underrepresentation of parts of Central and North Africa where DFI research is emerging.

Conclusion

Despite these limitations, this review provides one of the most comprehensive syntheses of the microbiological and clinical dimensions of diabetic foot infections across Africa. The findings demonstrate that multidrug-resistant pathogens, particularly methicillin-resistant Staphylococcus aureus and ESBL-producing Enterobacterales, are now major drivers of infection severity, treatment failure, and poor outcomes. The convergence of high infection burden, limited diagnostic capacity, and empirical antibiotic use underscores the urgency of implementing robust antimicrobial stewardship, strengthening laboratory infrastructure, and expanding access to multidisciplinary diabetic foot care. Policy responses should include integrating wound infection surveillance into national AMR programs, regulating over-the-counter antibiotic sales, and investing in specialized diabetic foot clinics across tertiary hospitals. Addressing these gaps is essential to reduce preventable amputations, improve healing outcomes, and curb the escalating threat of antimicrobial resistance in diabetic wound management across Africa.

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