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A Multi-Center Study of Nosocomial Fungi in Al-Diwaniyah, Iraq

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Abstract

This study investigated the occurrence and antifungal susceptibility profiles of fungal isolates obtained from clinical and environmental sources within a hospital setting. Statistical analysis revealed a significantly higher fungal prevalence in environmental samples (24.79%) compared to clinical ones (4.87%), identifying inanimate surfaces as primary reservoirs for opportunistic pathogens ($P < 0.001$). Antifungal susceptibility testing across various genera, including *Aspergillus, Candida*, and other filamentous fungi, showed diverse resistance patterns. While Miconazole and Ketoconazole exhibited robust efficacy, widespread intrinsic resistance to Fluconazole was observed. Notably, an alarming 100% resistance to Amphotericin B was recorded in *Candida* species and Aspergillus. glaucus, highlighting a critical challenge for conventional systemic treatments. Furthermore, the efficacy of hospital disinfectants was found to be strictly dose-dependent; the Optimal Working Concentration of 0.5% (5 ml/L) was insufficient to inhibit resilient strains like *Candida glabrata*, necessitating a minimum of 1.5% for effective decontamination. These findings underscore a "silent threat" within healthcare facilities, where the persistence of multi-drug resistant fungi on surfaces—compounded by sub-optimal disinfection protocols—poses a severe risk for healthcare-associated infections (HAIs). The study concludes that an urgent revision of hospital hygiene policies and enhanced antifungal stewardship are vital to mitigate the risk of fungal transmission to immunocompromised patients.

Key words - Nosocomial Fungi, Multi-Drug Resistance, Disinfection

Introduction

The global escalation of healthcare-associated infections (HAIs) remains a formidable challenge to modern medicine, with fungal pathogens emerging as a leading cause of morbidity in clinical settings [1]. Unlike bacterial infections, nosocomial fungal infections often present diagnostic difficulties, leading to delayed treatment and high mortality rates, particularly in intensive care units (ICUs) and surgical wards, the increasing prevalence of these infections is closely linked to the growing population of immunocompromised patients, the widespread use of invasive medical interventions, and the selective pressure exerted by the over-prescription of broad-spectrum antibiotics [2,3].

In developing healthcare systems, such as those in Iraq, the burden of nosocomial mycoses is exacerbated by environmental factors and the challenges of maintaining stringent infection control protocols under resource-limited conditions [4]. Specifically, in the Al-Diwaniyah Governorate, the hot and dusty climate facilitates the dispersal of fungal spores like Aspergillus and Mucor, which can easily infiltrate hospital environments through ventilation systems or during construction activities within medical facilities [5]. Recent local data suggested a shifting trend from Candida albicans toward non-albicans Candida species (NACs), which are often more resistant to conventional fluconazole therapy [6]. The rise of antifungal resistance is perhaps the most alarming aspect of contemporary medical mycology. The emergence of multi-drug resistant strains, such as Candida auris, has been documented across the Middle East, posing a significant threat of hospital-wide outbreaks that are extremely difficult to eradicate [7,8]. In Iraq, the lack of routine antifungal susceptibility testing in many provincial hospitals means that many resistant infections go undetected, leading to suboptimal clinical outcomes and increased healthcare costs [9]. Furthermore, the environmental reservoir of fungi within the hospital—including surfaces, medical equipment, and the hands of healthcare workers—serves as a continuous source of transmission [10]. Addressing this issue requires more than just localized reports; it necessitates broad, multi-center surveillance to understand the specific epidemiological map of Al-Diwaniyah [11]. This study aims to fill this critical knowledge gap by identifying the fungal profile across multiple healthcare centers in the province, providing the necessary data to implement effective antifungal stewardship and infection control strategies [12].

Materials and Methods

Study Design and Ethics Declaration

From August 2025 to January 2026, From August 2025 to January 2026, fungal isolates were collected from patients admitted to the Specialized Burns Hospital and Al-Diwaniyah Teaching Hospital. The Human Research Ethics Committee of Al-Diwaniyah Teaching Hospital formally approved this investigation's ethical clearance. (Ref No.: 13). the Centers for Disease Control and Prevention's (CDC) Targeted Environmental Investigation was adopted Checklist [https://www.cdc.gov/fungal] to guarantee a methodical and consistent evaluation of the clinical settings. This methodology was used to carefully identify putative fungal reservoirs and clarify the dynamics of nosocomial pathogen prevalence in these particular healthcare facilities.

Collection of Samples and Specimens

Patients (Clinical Specimens)

Using site-specific sterile diagnostic techniques, fungal isolates were recovered from symptomatic patients. Pathological exudates were collected from the wound bed after debridement using sterile swabs that had been pre-moistened with 0.85% physiological saline in order to assess burn wound colonization. Clinical specimens, such as sputum and whole blood, were obtained under strict aseptic conditions in cases exhibiting respiratory or systemic involvement. All samples were sent right away to the lab for quick mycological processing in sterile, leak-proof containers. [13].

Samples from the environment

Specimens were carefully collected from different hospital wards in order to systematically assess the environmental fungal reservoirs within the clinical infrastructure. Based on their source and ecological niche, these samples were then divided into two main experimental cohorts. [14].

Inanimate Hospital Surfaces:

Floor samples were methodically collected from low-clearance zones, such as the corners of the periphery of the ward and the enclosed spaces under patient beds. Sterile cotton swabs that had been pre-saturated with 0.85% physiological saline were used to sample these floor surfaces. Critical high-touch items, like mattresses and bed rails, were also thoroughly swabbed. A uniform surface area was swiped in a cross-hatch pattern to guarantee the complete recovery of both fungal conidia and vegetative mycelial structures, guaranteeing representative microbial yield from these high-contact interfaces.

Critical Medical Equipment

Manual resuscitators (Ambu bags) are used in resuscitation devices, with an emphasis on masks and valves. Artificial Ventilators: Samples were taken of the external surfaces, control panels, and easily accessible connection ports. Dialysis machines: Moist areas near the tubing connectors and external interfaces were swabbed. To maintain fungal viability, sterile swabs were quickly placed in sterile transport tubes with a small amount of saline after being rolled over the targeted surfaces. To prevent cross-contamination, a new pair of sterile gloves was applied to each sampling location.

Identification of fungi

Yeasts and filamentous fungi (molds) are separated using a combination of selective and differential media. Chloramphenicol (0.05 mg/ml) is added to Sabouraud Dextrose Agar (SDA) to prevent the growth of bacteria. Candida species can be directly and presumptively identified using CHROM agar Candida. [15] Yeast was incubated at 37°C for 24–48 hours, while molds were incubated at 25°C for up to two weeks. Filamentous fungi, or molds, are identified by their macroscopic morphology, which includes growth rate, texture (velvety, granular, or cottony), and color (obverse and reverse).and microscopic morphology using the Tease Mount or Slide Culture method and the Lacto phenol Cotton Blue (LPCB) stain. [16,17].

Testing for Antifungal Susceptibility

The Kirby-Bauer disc diffusion method on Mueller-Hinton Agar (MHA) was then used to perform antifungal susceptibility profiling. This procedure ensured consistent interpretation of the inhibition zones by closely adhering to the CLSI M44-A2 standards for yeasts and the M51-A directives for filamentous fungi. [18,19]. After being dipped into the fungal suspension, a sterile cotton swab was uniformly streaked in three directions across the entire surface of the agar plate. Antifungal disks were applied using sterile forceps. The plates were incubated at 35C for 24 to 48 hours after being inverted. Following incubation, the Zone of Inhibition (ZOI) diameters were measured in millimeters (mm) using a digital caliper. The results were categorized as susceptible (S) or resistant (R) using the interpretive breakpoints from the CLSI M44/M51 documents.

Evaluation of Disinfectant Efficacy

Well diffusion method was used in this test .a fungal suspension is prepared in sterile saline and adjusted to a 0.5 McFarland standard (approximately 1 $X10^6$ to 5 $X\ 10^6$ CFU/mL). Inoculation: The surface of Sabouraud Dextrose Agar (SDA)is uniformly inoculated using a sterile swab to create a lawn of fungal growth. Using a sterile cork

borer, circular wells (typically 6 mm to 8 mm in diameter) are punched into the agar medium. The agar plugs are carefully removed using a sterile needle without disturbing the surrounding medium. A fixed volume (usually 50 µL to 100 µL) of the disinfectant (Enzyme plus) at (0.5 , 1 ,1.5)concentration is introduced into each well. One well is typically filled with sterile distilled water as a negative control. The plates are left at room temperature for about 1–2 hours to allow the liquid to diffuse into the agar before being transferred to an incubator at 30C for 24 to 48 hours. The diameter of the resulting Inhibition Zones is measured. The absence of a zone indicates resistance, while the size of the zone is proportional to the efficacy of the disinfectant against the specific fungal isolate. [20].

Statically analysis

Fungal prevalence and antifungal susceptibility test data were statistically analyzed using SPSS software (Version 26.0, IBM Corp., USA). The distribution of fungal isolates was shown using a variety of descriptive statistics, including percentages and frequencies. The prevalence of fungi from clinical and environmental sources was compared using the Chi-square test. The antifungal susceptibility data were displayed as Mean ± Standard Deviation (SD).

Results and Discussion

Distribution and prevalence of samples

A total of 203 samples were screened, comprising 121 environmental samples from the hospital settings and 82 clinical specimens from patients. Microbiological analysis revealed a fungal prevalence of 16.7% (34/203). In particular, the clinical isolation rate among patients was 4.87% (4/82), whereas the environmental contamination rate was much higher at 24.79% (30/121) Figure 1. The large number of environmental (n=121) versus clinical (n=82) samples makes it clear that the hospital infrastructure has undergone extensive screening for potential fungal reservoirs. Environmental sampling was meant to fully cover high-risk transmission zones, but clinical sampling was limited by the number of admitted patients who satisfied the inclusion criteria during the study period.

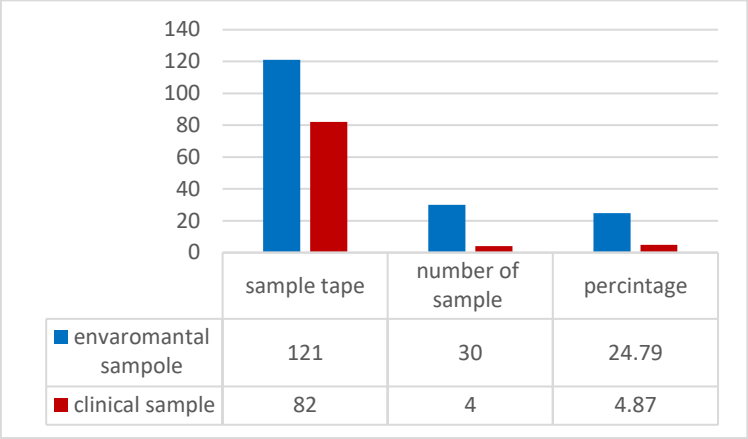


Figure 1 Distribution of isolates among environmental and clinical samples

The statistical analysis revealed a significant disparity in the distribution of fungal isolates between the two studied groups. Out of 121 environmental samples, 30 were positive for fungal growth, representing a prevalence of 24.79%. In contrast, clinical samples showed a much lower prevalence of 4.87% (only 4 positive cases out of 82). The Chi-square test confirmed that this difference is highly significant statistically as illustrated in Figure 2.

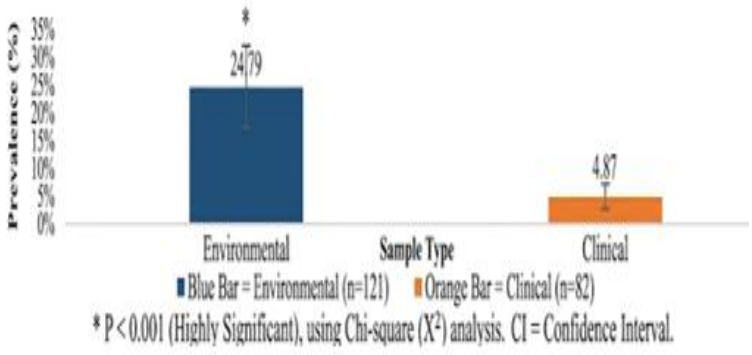


Figure 2. Comparison of fungal prevalence (%) between environment and clinical samples

The high prevalence of fungal isolates in the hospital environment compared to clinical samples suggests that the hospital's inanimate surfaces and air-handling systems may act as a primary reservoir for opportunistic pathogens. The high prevalence of fungal isolates in the hospital environment compared to clinical samples suggests that the hospital's inanimate surfaces and air-handling systems may act as a primary reservoir for opportunistic pathogens. Our findings align with recent studies emphasizing that hospital surfaces (such as bed rails, ventilation grilles, and floors) are frequently contaminated with fungal spores. [21].

Identification of fungi

A total of 34 fungal isolates were found, representing 14 distinct species. Figure (3,4) shows that both clinical and environmental samples had significant species diversity. The genus Candida accounted for the majority of isolates (29.4%), with Candida glabrata being the most prevalent species overall (17.6%/6/34). With five different species—A. niger (8.8%), A. flavus (8.8%), A. glaucus (5.9%), A. versicolor (5.9%), and A. ochraceus (2.9%)—the genus Aspergillus had the greatest species diversity. Rhizopus stolonifera was the third most common isolate overall (11.7%). Other species included Alternaria alternata (5.9%), Rhizoctonia solani (8.8%), and Cladosporium cladosporioides (5.9%). Less frequent isolates included the dermatophytes Penicillium chrysogenum (2.9%) and Trichophyton rubrum (2.9%).

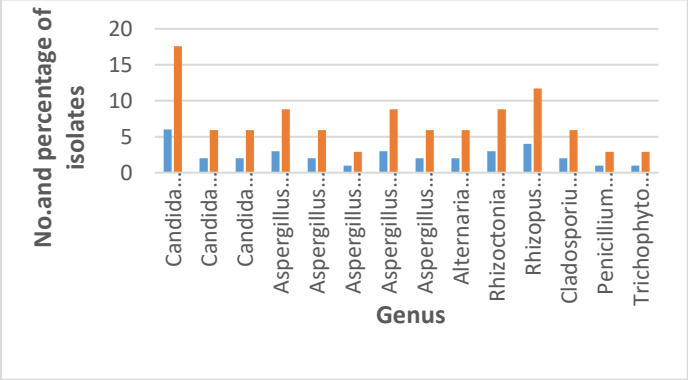
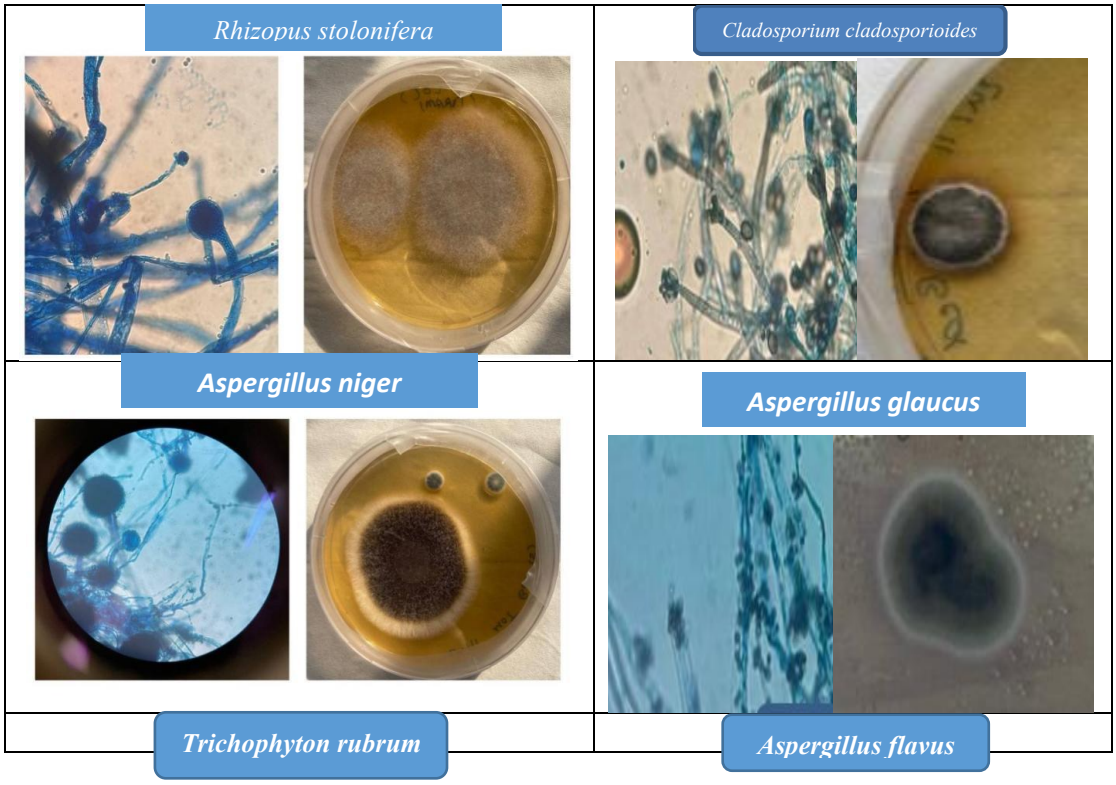


Figure 3 Number and percentages of fungal species isolated in the current study



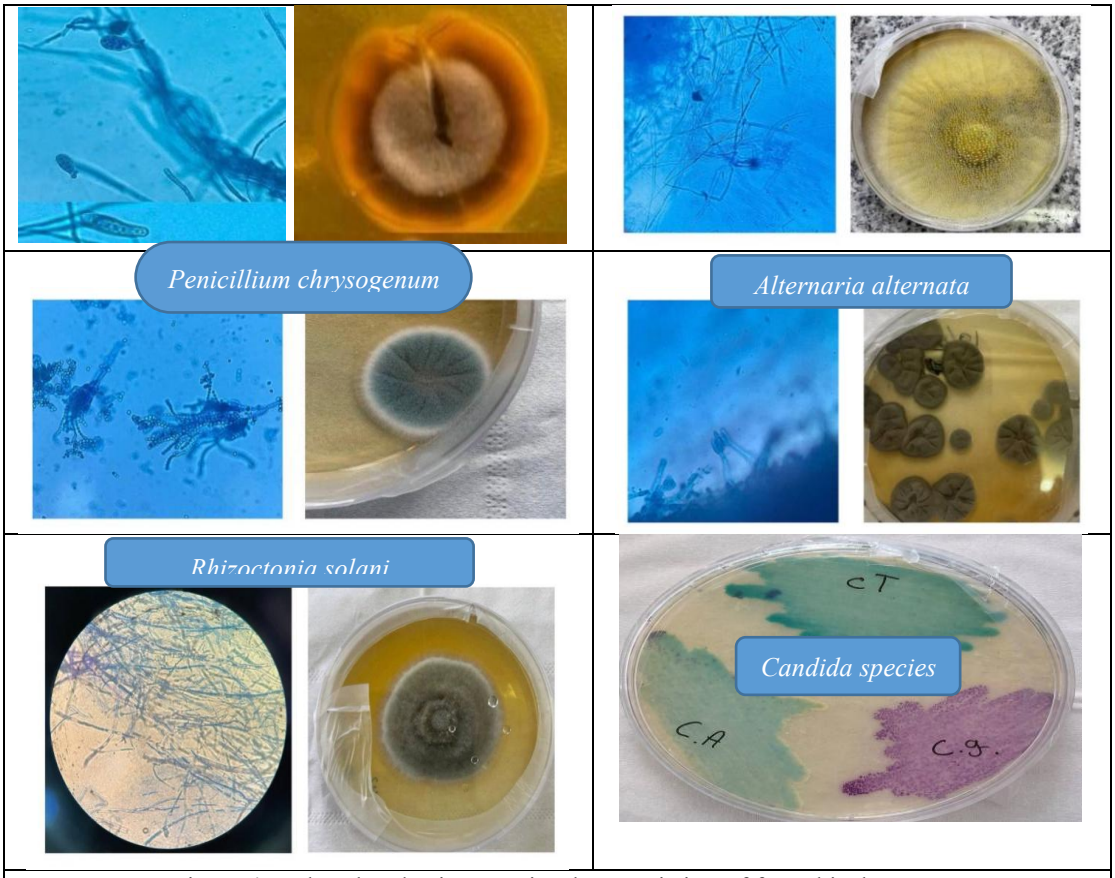
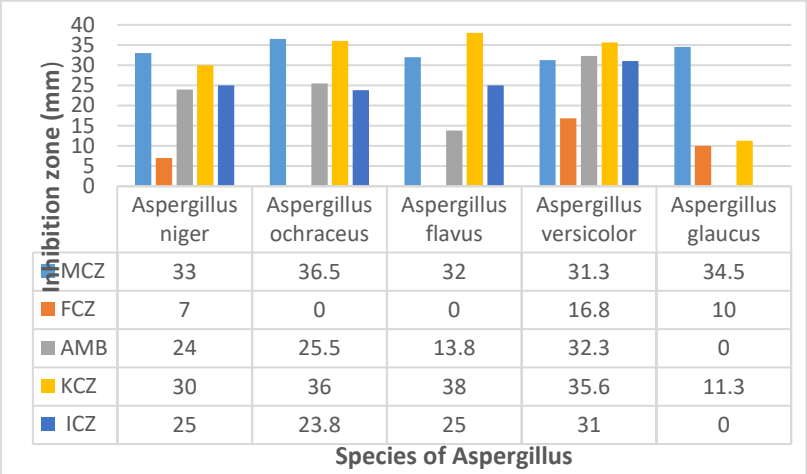


Figure 4. Cultural and Microscopic Characteristics Of fungal isolates

Antifungal Susceptibility

The susceptibility of *Aspergillus* isolates to five antifungal agents was evaluated (Figure 5). The results demonstrated a diverse range of inhibition zones, reflecting varying degrees of efficacy across the species. Ketoconazole (KCZ) and Miconazole (MCZ) emerged as the most potent agents. Specifically, *A. ochraceus* and *A. flavus* exhibited high sensitivity to KCZ, with inhibition zones reaching 36 mm and 38 mm, respectively. Amphotericin B (AMB) showed robust activity against *A. versicolor* (32.3 mm) but was notably ineffective against *A. glaucus*, which recorded a 0 mm zone. Fluconazole (FCZ) showed the weakest performance overall. Total resistance (0 mm) was observed in *A. ochraceus* and *A. flavus*, while the maximum zone recorded for other species did not exceed 16.8 mm. The findings of this study highlight significant challenges in the chemical control of *Aspergillus* species within hospital environments. The observed resistance to Fluconazole across almost all *Aspergillus* isolates (zones of 0–10 mm) is consistent with the established pharmacological profile of this genus. Unlike *Candida* species, *Aspergillus* possesses intrinsic resistance to Fluconazole due to structural differences in the cyp51A gene, which encodes the target enzyme for azoles [22]. This confirms that Fluconazole is an inappropriate choice for managing

Aspergillus-related contamination or infections. The high sensitivity to Ketoconazole and Miconazole suggests that these older-generation imidazoles maintain strong binding affinity to the fungal Lanosterol 14-alpha-demethylase enzyme in these specific isolates [23]. The large inhibition zones (up to 38 mm) indicate that these environmental strains have likely not developed the efflux pump mechanisms often seen in clinical settings where patients undergo long-term azole therapy. Amphotericin B and the Threat of *A. glaucus*. The total resistance of *A. glaucus* to Amphotericin B is a finding of high clinical concern. AMB is often considered a "gold standard" for systemic fungal infections. Resistance in environmental isolates may stem from alterations in the ergosterol content of the fungal cell membrane, which prevents the drug from forming lethal trans-membrane pores [24].



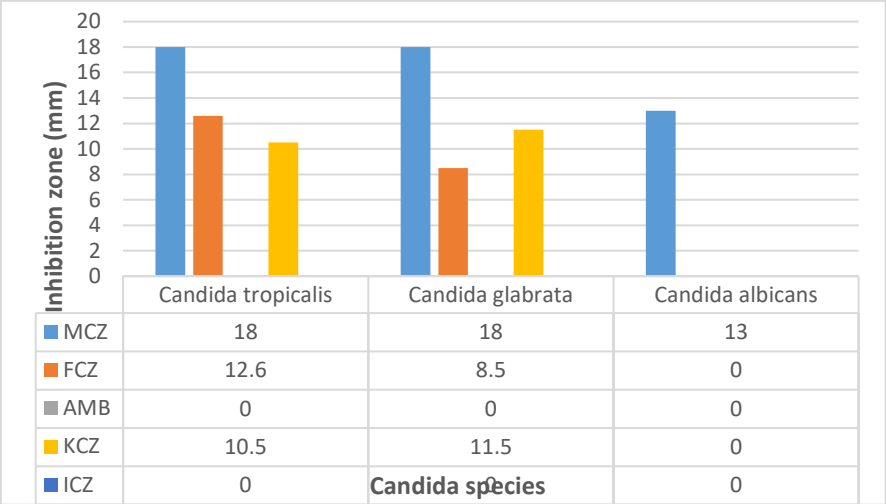
	Aspergillus niger	Aspergillus ochraceus	Aspergillus flavus	Aspergillus versicolor	Aspergillus glaucus
MCZ	33	36.5	32	31.3	34.5
FCZ	7	0	0	16.8	10
AMB	24	25.5	13.8	32.3	0
KCZ	30	36	38	35.6	11.3
ICZ	25	23.8	25	31	0

MCZ: Miconazole; FCZ: Fluconazole; AMB: Amphotericin B: KCZ: Ketoconazole; ICZ: Itraconazole

Figure 5. Antifungal susceptibility for *Aspergillus* spp.

Figure 6, appear the total resistance observed in *Candida* isolates against Amphotericin B and Itraconazole in this study is a critical indicator of environmental adaptation. Recent data suggest that hospital surfaces act as selective pressure environments where fungi develop robust biofilms. According to Nami *et al*. [22], *Candida* species isolated from hospital settings increasingly show reduced susceptibility to polyenes due to alterations in the ERG3 and ERG11 genes, which could explain the 0 mm inhibition zones recorded in our results [25]. While *C. albicans* was historically sensitive to most azoles, our findings show a significant shift toward resistance. This aligns with the global trend reported by [26], who noted that the widespread use of agricultural and prophylactic antifungals has led to the emergence of "non-wild type" *Candida* strains with elevated minimum inhibitory concentrations (MICs).The lack of any inhibition zone for Fluconazole in case of *C. albicans* isolates

underscores the urgent need for local antifungal stewardship. The relative success of Miconazole (up to 18 mm) compared to other azoles in this study can be explained by its ability to bypass certain efflux pump mechanisms. Unlike Fluconazole, Miconazole exerts an additional fungicidal effect by inducing an oxidative stress burst (peroxidase accumulation) within the fungal vacuole. This multi-target action, as described by [27], makes it more resilient against the common resistance pathways developed by *Candida tropicalis and C. glabrata*

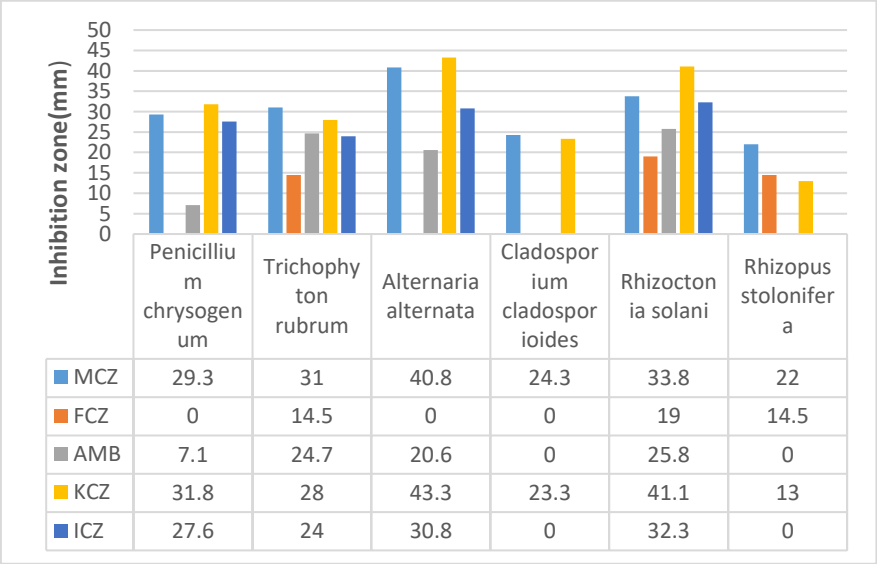


MCZ: Miconazole; FCZ: Fluconazole; AMB: Amphotericin B: KCZ: Ketoconazole; ICZ: Itraconazole

Figure 6. Antifungal susceptibility for *Candida* spp.

The antimicrobial screening for the remaining filamentous fungi (Figure 7) revealed distinct susceptibility trends, particularly among the environmental saprophytes and dermatophytes, *Alternaria alternata and Rhizoctonia solani* showed the highest susceptibility across the panel, with Ketoconazole (KCZ) zones exceeding 40 mm. Consistent with the previous groups, Fluconazole (FCZ) failed completely (0 mm) against *Penicillium chrysogenum, Alternaria alternata, and Cladosporium*, confirming a broad-spectrum resistance to this agent among non-Candida molds. *Rhizopus stolonifera and Cladosporium* demonstrated total resistance (0 mm) to Amphotericin B (AMB), which is medically significant given the aggressive nature of mucormycosis-related fungi like *Rhizopus.* The lack of an inhibition zone for Amphotericin B in Rhizopus stolonifera is a standout finding. Members of the Mucorales order are notorious for their rapid growth and variable susceptibility to polyenes. According to [28]., environmental strains of Rhizopus often exhibit high MICs to standard antifungals, making environmental decontamination of hospital surfaces a critical priority to prevent hospital-acquired mucormycosis. The high sensitivity of Alternaria

and Rhizoctonia to Ketoconazole and Miconazole (zones >30 mm) suggests that these isolates lack the specific efflux pumps (such as the ABC transporters) that typically neutralize azole drugs. Cowen et al. [29] noted that while clinical strains often evolve resistance through repeated exposure, environmental saprophytes usually remain highly susceptible to imidazoles unless they have been cross-exposed to agricultural fungicides .The total resistance of Penicillium chrysogenum to Fluconazole (0 mm) while remaining sensitive to Itraconazole (27.6 mm) illustrates the difference in binding affinity between triazoles. As highlighted by Berman and Krysan [30]., larger azole molecules like Itraconazole often maintain better "fit" within the pocket of the 14-alpha-demethylase enzyme in molds compared to the smaller Fluconazole molecule, which is primarily optimized for yeast



	Penicillium chrysogenum	Trichophyton rubrum	Alternaria alternata	Cladosporium cladosporioides	Rhizoctonia solani	Rhizopus stolonifera
MCZ	29.3	31	40.8	24.3	33.8	22
FCZ	0	14.5	0	0	19	14.5
AMB	7.1	24.7	20.6	0	25.8	0
KCZ	31.8	28	43.3	23.3	41.1	13
ICZ	27.6	24	30.8	0	32.3	0

MCZ: Miconazole; FCZ: Fluconazole; AMB: Amphotericin B: KCZ: Ketoconazole; ICZ: Itraconazole

Figure 7. Antimicrobial susceptibility for other species

Evaluation of Disinfectant Efficacy

The susceptibility of fungal isolates to the tested disinfectant demonstrated a clear dose-dependent response (Figure 8). As the concentration increased from 0.5% to 1.5%, there was a significant expansion in the inhibition zones across all species. *Alternaria alternata and Trichophyton rubrum* exhibited the greatest sensitivity, with inhibition zones reaching 42 mm and 39.5 mm respectively at the 1.5% concentration. *Candida albicans* showed a strong response to higher concentrations (35.5 mm at 1.5%), although it was significantly less sensitive at the lowest dose (0. 5%).*Aspergillus flavus* emerged as the most resilient species in this panel. Even at the highest concentration (1.5%), its inhibition zone remained relatively small (14.5 mm), indicating a high

tolerance to chemical disinfection. Notably, *Candida glabrata* showed zero inhibition at the 0.5% concentration, highlighting its survival potential at low-level disinfection.

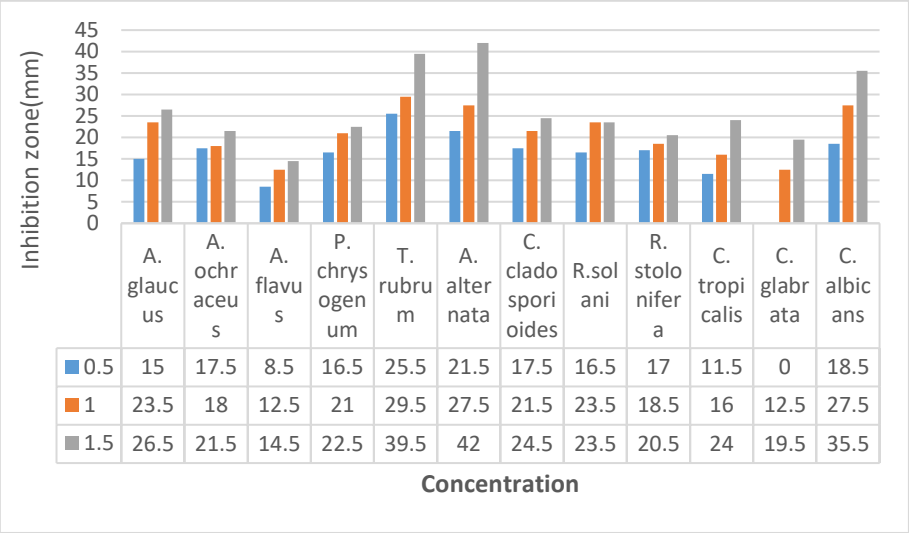


Figure 8. Disinfectant susceptibility for Fungi species

The concentrations selected for this study (0.5%, 1%, and 1.5%) were specifically designed to evaluate the efficacy of the hospital's standard disinfection protocol. Since the hospital utilizes a 0.5% concentration (5 ml/L), our findings indicate that this standard dose may be sub-optimal for certain resilient species, such as Candida glabrata, which showed no inhibition at this level. This suggests a critical need for reviewing current disinfection guidelines to prevent the survival of resistant fungal reservoirs.

Conclusion

In conclusion, this study highlights a significant disparity between the fungal load found on environmental surfaces and clinical samples, with environmental reservoirs serving as a major source of potential outbreaks. The high prevalence of fungi on inanimate surfaces, coupled with the alarming 100% resistance of Candida and Aspergillus glaucus to Amphotericin B, indicates that conventional antifungal treatments are facing a serious challenge within hospital settings. Furthermore, the discovery that standard disinfection protocols are insufficient against resilient strains like C. glabrata—requiring a concentration three times higher than the currently used 0.5%—proves that "one-size-fits-all" hygiene policies are inadequate.

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