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FUNGAL INFECTIONS IN PATIENTS WITH DIABETES MELLITUS : CORRELATION WITH HbA1C LEVELS AND GLYCEMIC CONTROL

Dermatology

Vishaka Gangakhedkar

Rajesh . G

Zonunmawii

ABSTRACT

Background: Diabetes mellitus (DM) predisposes individuals to fungal infections because of persistent hyperglycemia, impaired immune function, and altered skin barrier integrity. Poor glycemic control has been implicated as an important risk factor for the development and recurrence of fungal infections. Evaluating the spectrum of fungal infections and their association with HbA1c levels may facilitate early diagnosis and improve clinical management.**Objectives:** To evaluate the demographic and clinical profile of diabetic patients with fungal infections, describe the spectrum of fungal infections, and determine their correlation with HbA1c levels and glycemic control.**Methods:** A cross-sectional observational study was conducted among 56 adult patients with diabetes mellitus and confirmed fungal infections. Demographic characteristics, duration of diabetes, treatment history, body mass index, HbA1c, fasting blood glucose, and postprandial blood glucose levels were recorded. Clinical evaluation and appropriate mycological investigations were performed for diagnosis. Fungal infections were categorized according to clinical type and anatomical site, and their association with HbA1c levels was analyzed using appropriate statistical tests.**Results:** Most patients were aged 65–75 years (34.0%), with a slight male predominance (57.1%). Poor glycemic control was common, with 57.1% of patients having HbA1c ≥9.0% and 25.0% having HbA1c between 8.0% and 8.9%. Onychomycosis was the most common fungal infection, followed by tinea cruris and tinea corporis, while the nails and groin were the most frequently affected sites. Candidial infections constituted a substantial proportion of fungal infections, with candidial intertrigo being the most common clinical presentation. Patients with HbA1c ≥8% demonstrated a higher frequency of fungal infections, and poor glycemic control showed a significant association with fungal infections.**Conclusions:** Fungal infections are common among patients with diabetes mellitus and are strongly associated with poor glycemic control. Elevated HbA1c levels increase susceptibility to fungal infections, emphasizing the importance of maintaining optimal glycemic control and incorporating routine screening for fungal infections into comprehensive diabetes management.

KEYWORDS

Diabetes Mellitus; Fungal Infections; Onychomycosis; Dermatophytosis; Candidiasis; Hba1c; Glycemic Control.

INTRODUCTION

Diabetes mellitus (DM) is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from defects in insulin secretion, insulin action, or both. Its global prevalence continues to rise due to urbanization, sedentary lifestyles, population aging, and dietary changes. Chronic hyperglycemia contributes to microvascular and macrovascular complications and impairs innate and adaptive immune responses, increasing susceptibility to infections, particularly fungal infections.[1]

Patients with diabetes are especially prone to fungal infections because persistent hyperglycemia impairs neutrophil function, cell-mediated immunity, and tissue perfusion, while elevated glucose levels provide a favorable environment for fungal growth. Consequently, superficial fungal infections such as candidiasis, dermatophytosis, and onychomycosis occur more frequently in diabetic patients than in the general population. Poor glycemic control may also predispose patients to opportunistic fungal infections, including mucormycosis, which are associated with significant morbidity and mortality.[2–5]

Glycated hemoglobin (HbA1c) is the standard marker of long-term glycemic control, reflecting average blood glucose levels over the preceding two to three months. Several studies have demonstrated that elevated HbA1c levels are associated with an increased prevalence, recurrence, and severity of fungal infections, highlighting the role of poor glycemic control in their development.[6] [7]

Despite their clinical significance, fungal infections in diabetic patients are often underrecognized in routine practice, and the relationship between glycemic control and specific fungal infections remains inadequately characterized. Therefore, the present study was undertaken to evaluate the spectrum of fungal infections in patients with diabetes mellitus and to determine their correlation with HbA1c levels and glycemic control. The findings may help improve early diagnosis, optimize glycemic management, and reduce infection-related morbidity.

MATERIALS AND METHODS

This cross-sectional observational study was conducted at Akash Institute of Medical Sciences and Research Centre (AIMS & RC), Bengaluru Rural District, Karnataka, over a period of 18 months from April 2024 to September 2025. The study included adult patients (≥18 years) with a confirmed diagnosis of diabetes mellitus presenting to the outpatient and inpatient departments with clinically suspected fungal infections. Institutional Ethics Committee approval was obtained before the commencement of the study, and written informed consent was obtained from all participants.

Patients aged 18 years and above with diabetes mellitus and clinically suspected fungal infections were included in the study. Patients with congenital or acquired immunodeficiency disorders, those receiving immunosuppressive therapy, patients with gestational diabetes mellitus or impaired glucose tolerance, and those unwilling to participate were excluded.

A detailed clinical history was obtained from each participant, including demographic characteristics, type and duration of diabetes mellitus, treatment history, and history of fungal infections. A comprehensive clinical examination was performed, and the site, morphology, and distribution of fungal lesions were documented. Clinical photographs were obtained after obtaining patient consent whenever appropriate.

Samples from suspected fungal lesions were collected under aseptic precautions and subjected to direct microscopic examination using potassium hydroxide (KOH) mount. Additional microbiological investigations, including Gram staining and skin biopsy, were performed whenever clinically indicated to establish the diagnosis. Venous blood samples were collected in EDTA vacutainers for estimation of glycated hemoglobin (HbA1c). HbA1c levels were measured using the immunoturbidimetric method on a DiaSys analyzer in the Department of Biochemistry. Based on the American Diabetes Association criteria, patients were categorized according to glycemic control using HbA1c values.

The collected data were entered into Microsoft Excel and analyzed using SPSS version 26.0. Categorical variables were expressed as frequencies and percentages, while continuous variables were presented as mean ± standard deviation. The association between

fungal infections and HbA1c categories was assessed using the Chi-square test or Fisher's exact test, as appropriate. Comparisons of continuous variables were performed using Student's *t*-test. A p-value of <0.05 was considered statistically significant.

RESULTS

A total of **56 patients with diabetes mellitus and confirmed fungal infections** were included in the study. The majority of patients were aged 65–75 years (34.0%), followed by those aged 55–64 years (25.0%). Males constituted 57.1% of the study population. Most participants had diabetes for 1–5 years (30.4%), while 63.0% had been receiving treatment for the same duration. Oral hypoglycemic agents were the most commonly prescribed treatment (46.4%), followed by combined oral hypoglycemic agents with insulin (28.6%) and insulin alone (25.0%).

Most patients were either overweight (35.7%) or obese (41.1%). Poor glycemic control was common, with 57.1% of patients having HbA1c ≥9.0% and 25.0% having HbA1c between 8.0% and 8.9%. Fasting and postprandial blood glucose levels were also markedly elevated in the majority of participants.

Onychomycosis was the most common fungal infection, followed by tinea cruris and tinea corporis. These findings indicate that superficial dermatophytoses and nail infections constitute the predominant fungal infections among patients with diabetes mellitus. The nails and groin were the most frequently affected anatomical sites, followed by the trunk and abdomen/buttocks. This distribution reflects the tendency of fungal infections to occur in warm, moist, and occluded body regions among diabetic patients. More than half of the study participants had candidial infections, indicating that Candida species represent a major cause of fungal infections in patients with diabetes mellitus. Candidial intertrigo was the most common clinical presentation, followed by vulvovaginal candidiasis and candidial balanoposthitis. The predominance of intertriginous and genital candidiasis is consistent with the increased susceptibility of diabetic patients to Candida infections.

Patients with poor glycemic control (HbA1c ≥8%) had a significantly higher prevalence of onychomycosis and candidial infections compared with those having HbA1c <8% ($P = 0.041$ and $P = 0.018$, respectively). Although tinea cruris and tinea corporis were more frequently observed among patients with elevated HbA1c levels, these associations did not reach statistical significance

Table 1. Baseline Demographic and Clinical Characteristics of the Study Population (n = 56)

Variable		n (%)
Age (years)	35–44	11 (19.6)
	45–54	12 (21.4)
	55–64	14 (25.0)
	65–75	19 (34.0)
Gender	Male	32 (57.1)
	Female	24 (42.9)
Duration of diabetes (years)	1–5	17 (30.4)
	6–10	11 (19.6)
	11–15	12 (21.4)
	16–20	16 (28.6)
Duration of treatment (years)	1–5	35 (62.5)
	6–10	13 (23.2)
	11–15	5 (8.9)
	16–19	3 (5.4)
Treatment modality	Oral hypoglycemic agents	26 (46.4)
	Insulin	14 (25.0)
	Oral hypoglycemic agents + Insulin	16 (28.6)
Body mass index (kg/m²)	Normal	8 (14.3)
	Overweight	20 (35.7)
	Obese Class I	23 (41.1)
	Obese Class II/III	5 (8.9)
HbA1c category	Good control (<7%)	2 (3.6)
	Fair control (7.0–7.9%)	8 (14.3)
	Poor control (8.0–8.9%)	14 (25.0)
	Very poor control (≥9.0%)	32 (57.1)
Fasting blood sugar (mg/dL)	<126	3 (5.4)
	126–139	4 (7.1)
	140–159	6 (10.7)
	160–179	10 (17.9)
	≥180	33 (58.9)
Postprandial blood sugar (mg/dL)	<180	2 (3.6)
	180–199	1 (1.8)
	200–239	11 (19.6)
	240–279	15 (26.8)
	≥280	27 (48.2)

Table 2. Distribution of Candidal Infections (n = 56)

Candidal Infection	Frequency	Percentage (%)
Yes	31	55.4
No	25	44.6
Total	56	100.0

Table 3. Types of Candidial Infection (n = 31)

Type of Candidial Infection	Frequency	Percentage (%)
Candidial intertrigo	10	32.3
Vulvovaginal candidiasis	9	29.0
Candidial balanoposthitis	8	25.8
Oral candidiasis	4	12.9
Total	31	100.0

Table 4. Association of Fungal Infections with HbA1c Levels (n = 56)

Variable	HbA1c <8%	HbA1c ≥8%	P value
Fungal infection	7 (19.4%)	47 (41.2%)	0.018

Table 5. Association of Types of Fungal Infections with HbA1c Levels (n = 56)

Variable	HbA1c <8%	HbA1c ≥8%	P value
Onychomycosis	5 (27.8)	17 (44.7)	0.041*
Tinea cruris	7 (38.9)	13 (34.2)	0.712
Tinea corporis	6 (33.3)	8 (21.1)	0.298
Candidial infection	6 (33.3)	25 (65.8)	0.018*

*Chi-square test; $P < 0.05$ considered statistically significant.

Figure 1. Distribution of Types of Fungal Infections (n = 56)

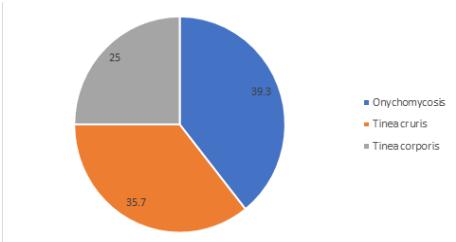
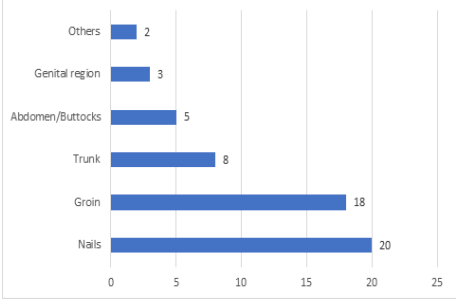


Figure 2. Anatomical Distribution of Fungal Lesions (n = 56)



DISCUSSION

Diabetes mellitus is associated with an increased susceptibility to fungal infections owing to persistent hyperglycemia, impaired innate and adaptive immune responses, microvascular dysfunction, and altered skin barrier integrity. Elevated blood glucose levels promote fungal colonization and impair neutrophil chemotaxis, phagocytosis, and intracellular killing, thereby increasing the risk of superficial as well as opportunistic fungal infections. The present study evaluated the spectrum of fungal infections in diabetic patients and examined their correlation with HbA1c levels and glycemic control.

Demographic and Clinical Characteristics

The present study included **56 diabetic patients with confirmed fungal infections**. The majority of patients belonged to the **65–75-year age group (34.0%)**, followed by those aged **55–64 years (25.0%)**, indicating that fungal infections were more common among older adults. A slight male predominance was observed, with **57.1% males** and **42.9% females**. Similar demographic findings have been reported by Chidambara Murthy et al., who observed a male predominance (62.2%) with most patients in the 51–60-year age group.[11] Bhardwaj et al. also reported a predominance of males (59.1%), while Kumar et al. documented that nearly 81% of diabetic patients with cutaneous manifestations were between 46 and 75 years of age.[12] [13] These observations suggest that advancing age and male sex may contribute to an increased burden of fungal infections, possibly because of prolonged disease duration, cumulative metabolic derangements, and declining immune function.

Most patients in the present study had diabetes for **1–5 years (30.4%)**, while **62.5%** had received treatment for the same duration. Oral hypoglycemic agents were the most frequently used therapy (**46.4%**), followed by combination therapy (**28.6%**) and insulin alone (**25.0%**). Similar treatment patterns have been described by Gupta et al. and Kandaswamy et al., who reported oral hypoglycemic agents as the principal mode of treatment among patients with type 2 diabetes mellitus.[14] [15] Although fungal infections are commonly associated with long-standing diabetes, our findings indicate that they may occur even during the early years of the disease, particularly in the presence of inadequate glycemic control.

The majority of patients were either **overweight (35.7%)** or **obese (41.1%)**, reflecting the close association between obesity and type 2 diabetes mellitus. Furthermore, glycemic control was poor in most participants, with **57.1%** having HbA1c levels ≥9% and an additional **25.0%** having HbA1c values between 8.0% and 8.9%. Elevated fasting blood glucose (≥180 mg/dL) was present in **58.9%** of patients, while **48.2%** had postprandial blood glucose levels ≥280 mg/dL. These findings indicate poor metabolic control among the study population, consistent with previous reports demonstrating that uncontrolled diabetes predisposes patients to infectious complications.[11] [14]

Spectrum of Fungal Infections

Onychomycosis was the most common fungal infection in the present study, accounting for **39.3%** of cases, followed by **tinea cruris (35.7%)** and **tinea corporis (25.0%)**. The nails (**35.7%**) and groin (**32.1%**) were the most commonly affected anatomical sites, followed by the trunk and abdomen/buttocks. These findings are consistent with those of Chidambara Murthy et al., who reported fungal infections as the most frequent infectious dermatosis in diabetic patients, with candidiasis and dermatophytosis being the predominant clinical presentations.[11] Mahajan et al. similarly documented dermatophytosis as one of the leading fungal infections, particularly tinea unguium and tinea corporis/cruris, while Kumar et al. reported superficial dermatophytosis as the commonest fungal disorder among diabetic patients.[16] [13]

Other investigators have also demonstrated a high prevalence of fungal infections in diabetes mellitus. Bhardwaj et al. observed fungal infections in 28.1% of diabetic patients, predominantly dermatophytosis, whereas Mandal et al. found fungal infections in 41.7% of cases, with tinea infections constituting the majority.[12] [17] Rasid et al. reported onychomycosis as the most frequent fungal manifestation, while Vâ ă et al. described tinea pedis and cutaneous mycoses as common presentations among diabetic individuals.[18] [19] Although the prevalence of individual fungal infections varies across studies, onychomycosis, dermatophytosis, and candidiasis consistently represent the most common fungal disorders in patients with diabetes mellitus.

The predominance of superficial fungal infections observed in the present study may be explained by impaired cell-mediated immunity, peripheral vascular insufficiency, neuropathy, increased skin surface glucose concentrations, and prolonged exposure of moist body areas to fungal organisms. These factors collectively create a favorable environment for fungal colonization and chronic infection.

Candidial Infections

Candidial infections were identified in **55.4%** of patients with fungal infections, indicating that Candida species constituted a substantial proportion of fungal infections in the present study. Among these, **candidial intertrigo (32.3%)** was the most common presentation, followed by **vulvovaginal candidiasis (29.0%)**, **candidial balanoposthitis (25.8%)**, and **oral candidiasis (12.9%)**.

These findings are comparable with those reported by Chidambara Murthy et al., who observed candidial balanoposthitis as the most common candidial infection among diabetic patients.[11] Mandal et al. also reported candidial balanoposthitis and vulvovaginal candidiasis as common manifestations, particularly among patients with elevated HbA1c levels.[17] Gupta et al. demonstrated that candidiasis occurred more frequently among patients with uncontrolled diabetes, while Roslind et al. identified candidiasis as the leading fungal infection in their diabetic cohort.[14] [20] The predominance of candidial infections in intertriginous and genital regions is attributable to the warm, moist environment, increased tissue glucose concentrations, and impaired host immunity associated with diabetes mellitus.

Association Between HbA1c Levels and Fungal Infections

A major objective of the present study was to evaluate the relationship between glycemic control and fungal infections. The results demonstrated that patients with **HbA1c ≥8%** had a higher frequency of fungal infections than those with **HbA1c <8%**. Onychomycosis and candidial infections were more frequently observed among patients with poor glycemic control, and this association was statistically significant, whereas tinea cruris and tinea corporis did not demonstrate a significant association with HbA1c levels.

Our findings are in agreement with those of Mandal et al., who reported a significant association between elevated HbA1c levels and fungal infections ($p = 0.032$).[17] Gupta et al. likewise demonstrated that dermatophytosis and candidiasis occurred more frequently among patients with uncontrolled diabetes, supporting the role of chronic hyperglycemia in increasing susceptibility to fungal infections.[14] Roslind et al. also observed a significantly higher prevalence of fungal infections among patients with poor glycemic control, whereas Chatterjee et al. reported that patients with infective dermatoses had significantly higher mean HbA1c values than those with non-infective skin disorders.[20] [21]

The biological mechanisms underlying this association are well established. Chronic hyperglycemia impairs neutrophil chemotaxis, phagocytosis, and intracellular killing, while reducing antioxidant defenses and cell-mediated immunity. Increased glucose concentrations in sweat and tissues further promote fungal adherence, colonization, and proliferation. Additionally, diabetic neuropathy and microangiopathy compromise local tissue perfusion and skin integrity, facilitating persistent and recurrent fungal infections. Therefore, HbA1c serves not only as a marker of long-term glycemic control but also as an important predictor of susceptibility to fungal infections.

CONCLUSION

The findings of the present study highlight the importance of routine screening for fungal infections in patients with diabetes mellitus, particularly among those with poor glycemic control. Early diagnosis and prompt treatment of fungal infections, together with optimization of blood glucose levels, may reduce morbidity, prevent recurrent infections, and improve patient quality of life. Regular dermatological examination should therefore form an integral component of comprehensive diabetes care. Future multicenter studies with larger sample sizes and mycological confirmation of fungal species are warranted to further clarify the relationship between glycemic control and fungal infections in diabetic populations.

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