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Detection of Biofilm Formation by Candida Species in the Oral Cavities of Diabetic Patients Using the Oral Rinse Technique in Erbil City

Dyar Musadaq Sleman[(1)] , Vian Badraddin Nehmatulla[(1)]

ABSTRACT

Background and Objective: Biofilm formation is a type of virulence factor of Candida spp. that promotes growth and protects against antifungal activity, especially in the oral cavity of diabetic patients.

Aim: The objective of this study is to detect biofilm formation by Candida spp. to determine the relationship between colony-forming units (CFU/mL) and blood sugar levels, and to assess the impact of biofilm formation on antifungal activity.

Method: In this current study, which includes two groups: group 1, Diabetic mellitus (55 males and 45 females) (31 Type 1 and 69 Type 2), and group 2, non-diabetic individuals (23 males and 27 females) in Erbil city. Oral rinses were collected for identification using Chromagar Candida and the Vitek 2 ID system. For biofilm formation, Congo Red Agar, tube adherence tests, and the Microtiter plate method were used. Antifungal discs (Voriconazole 1mg), (Fluconazole 25mg), (Miconazole 30mg), (Ketoconazole 10mg), and (Nystatin 100mg). Statistical analysis was performed using GraphPad Prism version 9.0, including independent-samples t-tests and ANOVA, and categorical variables were presented as frequencies and percentages.

Result: Candida spp. were detected in 60% (60/100) of people with diabetes and in 24% (12/50) of non-diabetic individuals. The study identified 15 of 60 isolates (25%) as biofilm producers in diabetic patients. A significant relationship between blood sugar level and oral Candida (CFU/mL) (P =0.0001). Moreover, biofilm formation increases resistance to an antifungal agent (P = 0.0001).

Conclusion: Biofilm formation was associated with increased antifungal resistance. Higher blood glucose levels were associated with increased Candida colony counts.

Keywords: Candida spp., Biofilm, Diabetes mellitus, Oral rinse, Antifungal resistance

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Affiliation Info

[(1)]College of Medicine, Hawler Medical University, Kurdistan Region, Iraq.
Corresponding Author: Dyar Musadaq Sleman
Email: dyar.musadaq@med.hmu.edu.krd
ORCID iD: https://orcid.org/0009-0007-5767-1007

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INTRODUCTION

Biofilm formation enables Candida to survive within the host and evade host defense mechanisms, thereby promoting systemic infection. It is therefore extremely important to identify the Candida spp. causing the infection.[1] Diabetes mellitus (DM) is characterized by underutilization and overproduction of glucose, resulting in hyperglycemia due to impaired insulin action, secretion, or both.[2] The relationship between diabetes and Oral candidiasis has been extensively researched, particularly because diabetes confer heightened vulnerability to fungal infections.[3] Mohammed et al. (2024)from Iraq/ Baghdad province investigated that there is a direct correlation among HbA1c, the level of blood glucose of patients and CFU/mL of Candida spp.[4] Sampath et al.(2019) from Sri Lankan revealed that regardless of the phenotypic or molecular identification methods the yeast population density in people with diabetes (>2000 CFU/mL of the oral rinse) was markedly greater than of the controls, indicating that the oral mucosa in people with diabetes provides a more conducive environment for oral Candida colonization.[5] Net et al. (2007)from America, investigated the potential role of biofilm in antifungal resistance by assessing the impact of isolated matrix material on planktonic cells, the fact that incorporation of the biofilm matrix into non-biofilm and the replication of the biofilm drug-resistant phenotype raises the hope that the matrix may bind or sequester drugs, obstructing their access to intracellular targets.[6] Understanding the relationship between colony-forming units of Candida spp., blood sugar levels, biofilm formation, and antifungal resistance is essential for the treatment of oral candidiasis.

Aim of the study

It is to detect biofilm formation by different Candida spp. and to determine the ratio of Candida spp. in the oral cavities of diabetic patients and non-diabetic individuals. Relationship between the level of blood sugar and colony-forming unit of Candida spp., and to determine the impact of biofilm formation on antifungal agents.

METHODS

The present study comprised 100 patients with diabetes mellitus, of whom 55 were male and 45 were female. Patients were categorized based on the type of diabetes: 31 had type 1 and 69 had type 2, aged between 19 and 76 years. Those patients visited the Galiawa Diabetic Health Center during the study period from June 2024 to January 2025. The study was a case-control study. Moreover, 50 non-diabetic individuals comprising 23 males and 27 females aged 19 to 53 years from Zhyan Health Center, all non-diabetic individuals, without any immunocompromised diseases. The present study was conducted with the approval of the Ethical Committee of Hawler Medical University, College of Medicine. The oral rinse technique involves giving patients 10 milliliters of sterile buffer phosphate saline (PBS) (pH 7.2) to rinse their mouths for one minute. Oral samples were promptly delivered to the microbiology lab at Hawler Teaching Hospital, and then were centrifuged at 3500 rpm for 10 minutes. After that, take 100 µL of the precipitation and put it on Sabouraud Dextrose agar(SDA) with tetracycline (0.5 mg/mL) added as a supplement.[7]

Inclusion Criteria: All Diabetic patients with Type 1 and 2) non-diabetic individuals (who were in good health and exhibited no symptoms or signs of systemic diseases).

Exclusion Criteria: For Diabetic patients, patients diagnosed with prediabetes supported by Galiawa diabetic health center, and patients infected with HIV, HBV, HBC, cancer, smokers, wearing dentures, drinkers, patients with autoimmune diseases, scleroderma, Sjögren's syndrome, and patients with a kidney transplant)

Non-diabetic individuals (RBS > 105) smoker, wearing a denture, drinker, xerostomia, autoimmune diseases, infected with HIV, HBS, HBC, cancer, patient under chemotherapy, or a kidney transplant).

Identification of Candida spp.

Chrom agar Candida (CAC) and Microscopic Examination

The morphological features of Candida spp. on chromogenic Candida agar (CAC) and SDA, such as colony shape, color, texture, and size, were used to identify Candida spp. then the cells were sub-cultured on CAC for 48 hr. at 37°C. and for Candida spp., a sterile clean coverslip was used to scrape off one of the presumed colonies, which was emulsified in a lacto-phenol cotton blue-stained drop on a microscopic slide.[8]

Vitek 2 ID-YST system (bioMerieux, Marcy-lEtoile, France)

The liquid samples for the Vitek2 YST cards (bioMérieux, France) were obtained from overnight cultures, and the turbidity of Candida spp.

was measured between (1.8 to 2.2) McFarland Standard, a measurement of turbidity. Pure sub-cultures are maintained in a 0.45% (wt/vol) NaCl solution.[8]

Germ Tube formation

The germ-tube test is the gold standard in laboratory testing for Candida albicans and Candida dubliniensis. Add 0.5 mL of human serum to the test tube. The tube was kept at 37°C for 2 to 3 hr. examined under a microscope at magnifications of 10X to 40X.[9]

Biofilm formation methods

Congo red agar method (CRA)

To test biofilm production, a solid medium containing a specific supplement of brain heart infusion broth (BHI) was incubated aerobically for 24 to 48 hr at 37 ˚C. The presence of dark red colonies indicated a positive outcome.[10]

Tube Adherence Test (TAT)

This method, outlined by Millsap et al., was followed to conduct the quantitative biofilm assay. A tiny amount of Candida spp. from overnight culture plates was added to 10 milliliters (ml) of Sabouraud dextrose broth (SDB) containing 8 % glucose. The tubes were rinsed with PBS after 48 hours of incubation at 37°C, and then dyed with 0.1% crystal violet. A film lining the inside of the tube and its base suggested that biofilm formation was progressing well.[11]

Microtiter plate method (MTP)

The strains were inoculated with (SDB) supplemented with 8% glucose and incubated at 37˚C for 24 hr. Biofilm development was detected by adding 100 µL of this standardized cell suspension (1 × 10^6) to microtiter plate wells that previously contained 100 µL of pure fresh (SDB) medium. The microtiter plates were placed in an incubator set at 37°C.

The plates were tapped 3 times with 200 µl of phosphate-buffered saline (pH 7.2), then the contents of each well were emptied. A 1% solution of crystal violet was used to stain adherent biofilms in microplates; adherent Candida cells were evenly stained with 1% crystal violet.[25] Micro-ELISA auto-reader was used to resolve the dye with 100% ethanol, and read at an optical density of 490 nm.[11]

Antifungal sensitivity

Disc diffusion method

A pure fresh culture of the isolate for testing was cultured on (SDA) for 24 hours at 37ºC to confirm viability and purity. An inoculum suspension standardized to a (0.5) McFarland standard by a densitometer. Then, the plates are incubated for 15 minutes following the dispensing of the disc development, and circular inhibitory zones were anticipated after 20-24 hr. at 37°C.[12]

Statistical analysis

The results were analyzed using GraphPad Prism version 9.0 (GraphPad Software, San Diego, CA, USA). After checking the data for normality using the Shapiro-Wilk test, differences between the two groups were analyzed using an independent-samples t-test. In comparison, comparisons among more than two groups were performed using one-way analysis of variance (ANOVA), and the data were given as Mean± Standard Deviation (SD), while category variables were presented as frequency and percentage. A p-value < 0.05 was considered statistically significant.

RESULTS

Table 1: presents the demographic characteristics of this study, which included 100 participants with diabetes (31 Type 1 and 69 Type 2) and 50 non-diabetic individuals. The patient population consisted of 55 males (55%) and 45 females (45%). The non-diabetic individuals consisted of 23 males (46%) and 27 females (54%). Positive growth of Candida spp. about 60 (60%) in diabetic patients, while in non-diabetic individuals, about 12 (24%). Biofilm formation was detected only in DM (15 [25%] of 60 isolates) and was not produced in non-diabetic individuals. CFU/mL (Mean±SD) in DM was 523.7±351.1, while in the non-diabetic individuals it was 77.40±27.22. About the use of oral mouthwash treatment in the DM range, where 11(11%) used and 89(89%) not used, while in the non-diabetic individuals, those who used oral mouthwash were 17 (34%), and those who did not use it were 33(66%). Regarding antifungal medication use in DM, 16 (16%) were used, and 84 (84%) were not, whereas in the non-diabetic individuals, 11 (22%) were used and 39 (78%) were not.

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Table 1. Demographic Characteristic of Study Population

		Non-diabetic individuals(50)	DM-Patients (100)	p. value
Gender	Female	27(54%)	45(45%)	0.298^{NS}
	Male	23(46%)	55(55%)	
Age (Mean±SD)		37.78±10.96	50.35±15.91	0.0001^{++++}
RBS (Mean±SD)		92.82±8.44	180.3±43.10	0.0001^{++++}
Culture growth	No growth of Candida spp.,	38(76%)	40(40%)	0.0001^{++++}
	Growth of Candida spp.	12(24%)	60(60%)	
CFU/mL (Mean±SD)		77.40±27.22	523.7±351.1	0.0001^{++++}
Bio-film formation	Negative	50(100%)	85(75%)	0.004^{++}
	Positive	0	15(25%)	
Using mouth wash	Not used	33(66%)	89(89%)	0.001^{++}
	Used	17(34%)	11(11%)	
Antifungal medication drug	Not used	39(78%)	84(84%)	0.0001^{++++}
	Used	11(22%)	16(16%)	

DM= Diabetes mellitus **CFU/mL** = Colony forming unit

Table 2. Frequency of Oral Candida spp. Isolated From the Oral Rinse of Study Population

Candida spp.	Non-diabetic individuals (50)		Diabetic patients (100)	
	Number	Percentage	Number	percentage
Candida albicans	12	24%	47	78.33%
Candida parapsilosis	0	0%	6	10%
Candida krusei	0	0%	2	3.33%
Candida tropicalis	0	0%	2	3.33%
Candida dubliniensis	0	0%	1	1.67%
Candida sphaerica	0	0%	1	1.67%
Candida glabrata	0	0%	1	1.67%

This table shows the frequency of oral Candida spp. isolated from the oral rinse technique in the study population, 60 (60%) of 100 DM tested positive for Candida spp. compared to only 12 (24%) of 50 normal cases. The prevalence of Candida spp. specifically Candida albicans more common among diabetic patients (78.33% of isolates) in normal cases (24%). Other species, such as Candida parapsilosis (10%), Candida krusei (3.33%), Candida tropicalis (3.33%), Candida glabrata (1.67%), Candida dubliniensis (1.67%), and Candida sphaerica (1.67%), were found only in people with diabetes. Candida parapsilosis was the second- most prevalent species among Candida spp.

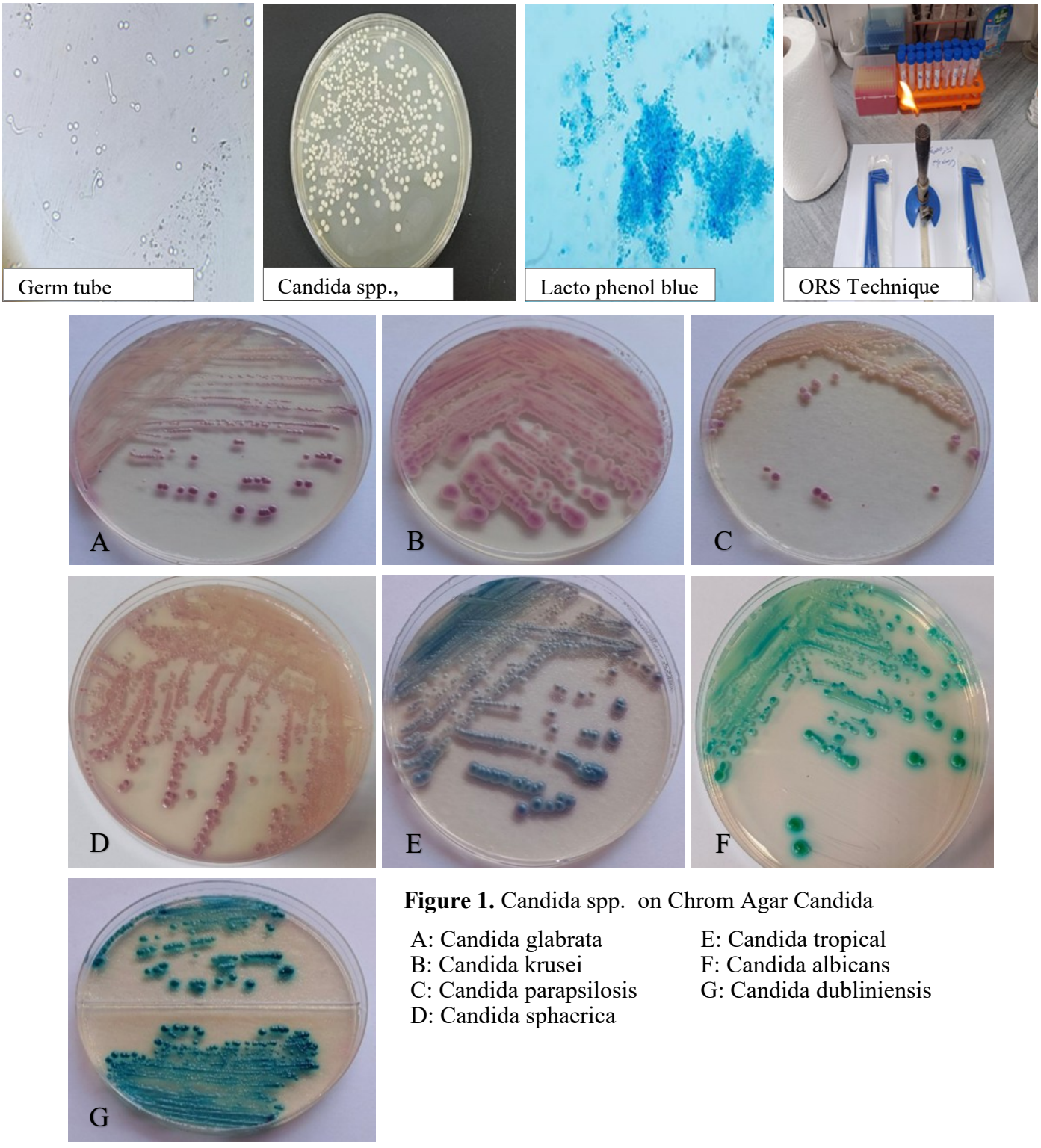

Figure 1. Candida spp. on Chrom Agar Candida

A: Candida glabrata
B: Candida krusei
C: Candida parapsilosis
D: Candida sphaerica
E: Candida tropical
F: Candida albicans
G: Candida dubliniensis

The color of Candida spp. depends on Chromagar company, Candida albians green color, Candida tropicalis with metallic blue color, Candida krusei is pink color with fuzzy, Candida parapsilosis pink to white color, Candida glabrata pink to mauve brown, Candida dubliniensis dark-green to bluish-green, and Candida sphaerica pink to white.

Table 3 shows that, among 60 (60%) positive cultures, only 15 (25%) formed biofilms. At the same time, 45(75%) were negative for biofilm formation. It also shows a significant relationship between biofilm formation and CFU/mL of Candida spp. (p-value < 0.05). That means biofilm formation increased the CFU/mL of oral Candida spp.

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Table 3. Comparison of Biofilm Formation by the Oral Candida spp. to the CFU/mL

	Biofilm formation		P-value
	Negative	Positive	
Number of isolates from 60	45(75%)	15(25%)	0.0001
Mean±SD	654.9±233.0	1527±460.0	

*Data was analyzed by independent samples t-test. P-value < 0.05

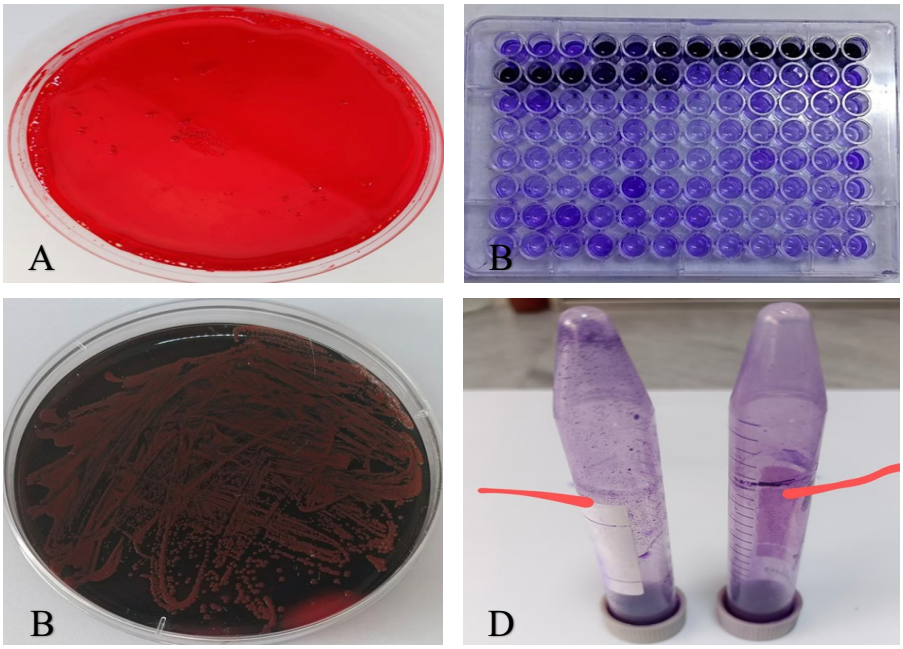

Figure 2. Biofilm Formation Methods

A: Negative biofilm formation on CRA B: Positive biofilm formation on CRA
C: Microtiter Plate Method D: Tube Adherence Method CRA = Congo Red Agar

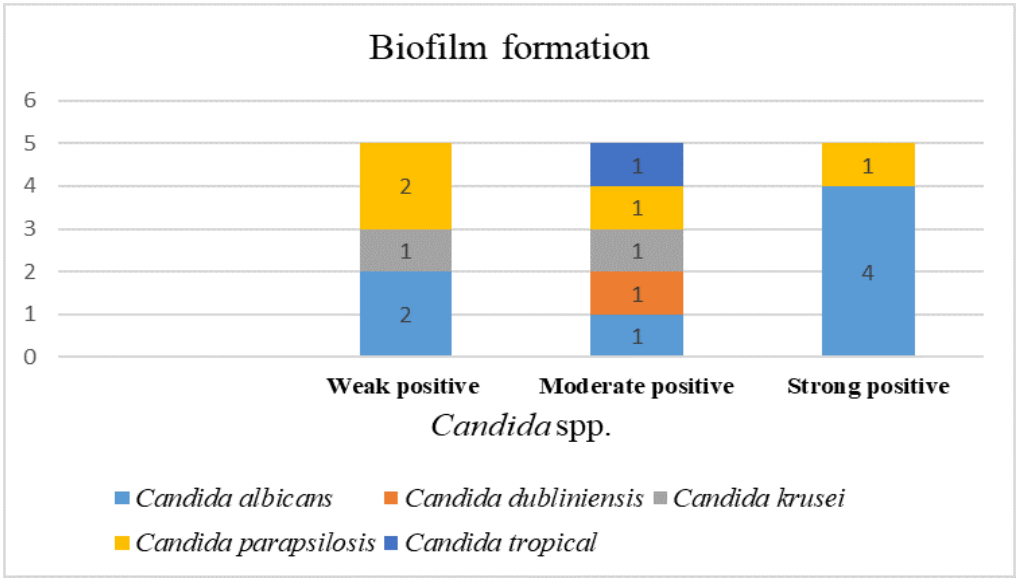

Figure 3. Biofilm formation by Oral Candida spp. in diabetic patients, p-value=0.483

The results show that of 15 Candida spp. (25%), 60 were positive for DM. Candida albicans is the most prevalent for biofilm formation about 7 (11.67%) and followed by Candida parapsilosis about 4(6.67), Candida krusei about 2(3.33%) Candida dubliniesis 1(1.67%) and Candida tropical 1(1.67%).

Table 4 shows the effect of blood sugar level on CFU/mL of oral Candida spp. he p-value is < 0.05, indicating a significant correlation.

Table 4. Correlation Between the Level of RBS and CFU/mL of Oral Candida spp

	CFU vs. RBS
Pearson correlation ®	0.7540
95% confidence interval	0.6545 to 0.8278
R squared	0.5685
P value	<0.0001
P value summary	****

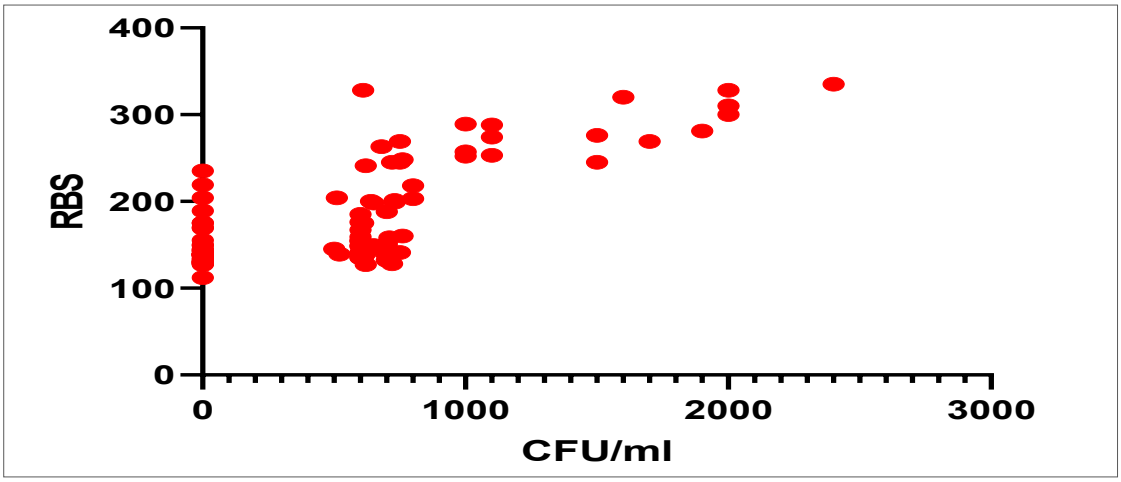

Figure 4. Impact of level blood sugar on CFU/mL

*Data was analyzed by Pearson correlation used for analysis
RBS = Random blood sugar

This result shows that the CFU/mL range is associated with blood sugar level.

Table 5 shows the effect of positive and negative biofilm formation on antifungal disc activity. Candida spp. with biofilm formation showed higher resistance to antifungal discs than those without biofilm formation. Biofilm formation increases the resistance of Candida spp. (p-value < 0.05). The result showed that biofilm has the highest resistance against (Nystatin 100 mg), followed by (Miconazole 30 mg), (Fluconazole 25mg), (Ketoconazole 10 mg), and (Voriconazole 1 mg)

Table 5. Effect of Biofilm Formation on Antifungal Agents

	Type of antifungal agents									
	VOR 1mg		FLU 25mg		KTC10mg		MIC 30mg		NYS100mg	
	R	S	R	S	R	S	R	S	R.	S.
Number of values	8	52	9	51	8	52	10	50	38	22
Mean±SD	1888±285.0	687.9±175.1	1757±474.5	702.2±210.3	1888±285.0	716.7±182.9	1770±365.3	693.4±137.0	998.7±518.9	655.5±91.12
p. value	0.0001		0.0001		0.0001		0.0001		0.003	

R = Resistance, S= sensitive

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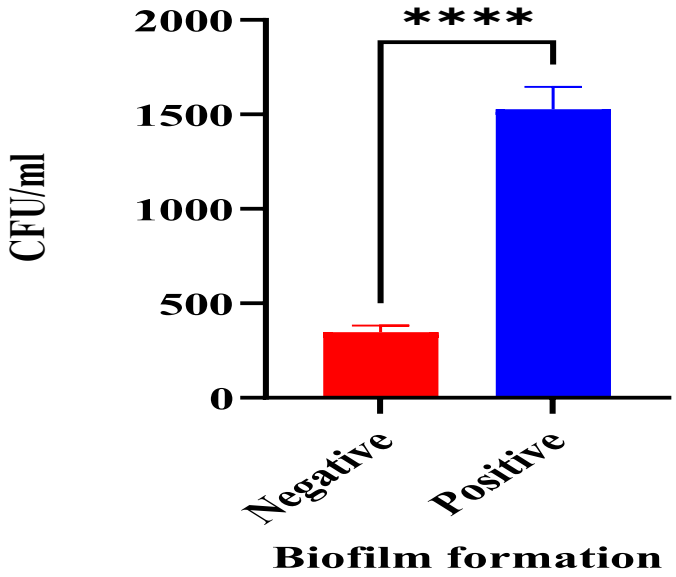

Figure 5. Association between biofilm and CFU/mL

The result shows a positive increase in CFU/mL of Oral Candida spp. in DM, indicating that biofilm formation protects Candida spp. from antifungal activity and extends their growth range.
Figure 6 shows the level of biofilm formation, from weak to strong. The result showed that strong biofilm increases the CFU/mL of Oral Candida spp. in DM > 1500. p-value < 0.05, while negative biofilm formation showed the lowest range of CFU/mL < 500.

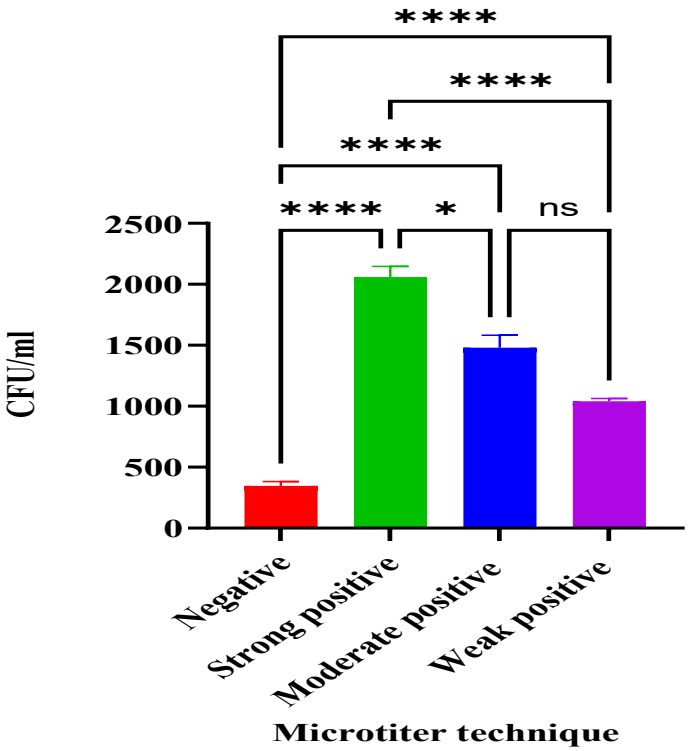

Figure 6. Microtiter technique for evaluation of biofilm range

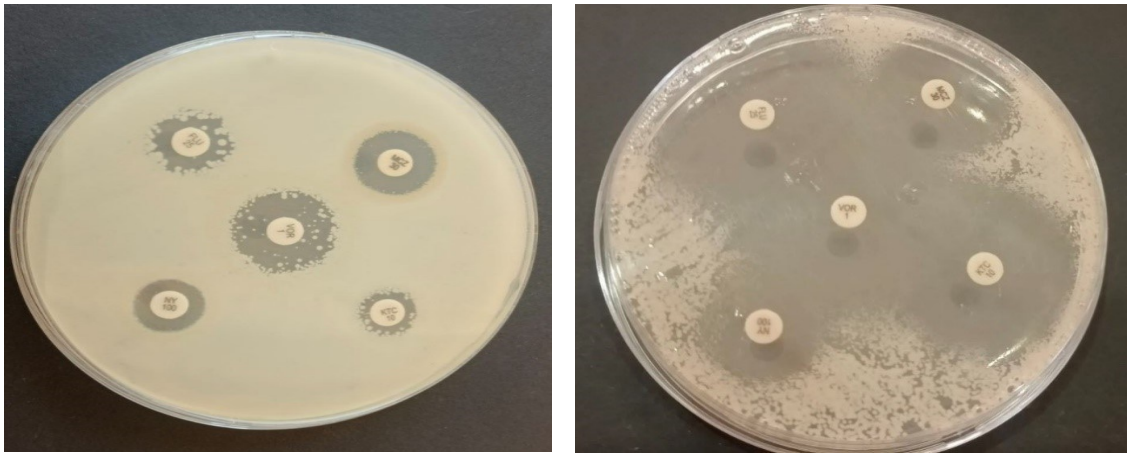

Figure 7. Antifungal Sensitivity

A: Candida albicans biofilm Formation positive show resistance
B: Candida albicans Biofilm Negative (VOR 1 = Voriconazole 1mg), (NYS100mg = Nystatin 100mg), (MIC30mg= Miconazole 30mg), (KTC 10mg = Ketoconazole), (FLU25mg = Fluconazole 25mg).

These figures show differences between Candida spp., with biofilm formation affecting antifungal disc resistance, while without biofilm formation, Candida spp. show sensitivity.

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DISCUSSION

Biofilms are a critical virulence factor produced by Candida spp. in the oral cavity, particularly in diabetic individuals who exhibit increased susceptibility to persistent Candida colonization and infection. A significant will increase in colony-forming units per milliliter is induced by the conducive environment for Candida spp. established by hyperglycemia associated with diabetes mellitus, elevated blood glucose levels facilitate increased Candida adhesion and growth on oral surfaces by providing a nutritional supply.[6] This investigation revealed that the prevalence of Candida spp. was higher in DM than healthy individuals. This observation aligns with the findings from Iraq, by Al-Harba et al.[13] Glucose in saliva acts as a nutrient for Candida spp. and inhibits the phagocytic function of neutrophils, thereby facilitating Candida colonization.[14] The findings of our study revealed that Candida albicans was the predominant isolated species, consistent with the study in Iraq/Duhok province by Sultan and Saadullah.[15] The findings of our investigation revealed a statistically significant association between the prevalence rate of CFU/mL and blood sugar levels this outcome aligns with the findings of Shenoy et al.[16] Sashikumar et al. expressed satisfaction with the substantial positive association between salivary glucose and CFU/mL of Candida spp. across the entire study population, corroborating findings by other researchers that elevated Candida levels correspond to increased salivary glucose concentrations.[17] Thomson et al. discovered a link between the manifestation of Candida infection signs and symptoms and yeast counts above 400 CFU/mL in saliva.[18] The current findings indicate greater colonization with Candida spp. in diabetic patients than in healthy individuals, corroborating prior investigations. Research conducted by Lotfi-Kamran et al.[19] Studies by Sampath et al. revealed that a substantial proportion of people with diabetes exceeded the threshold for oral yeasts compared with the control group.[5] The findings of our investigation indicated biofilm formation by Candida spp. exclusively in patients with diabetes and absent in non-diabetic individuals. This finding is corroborated in Iraq/Sulaimani province by Mohammed et al.[20] The initial phase of Candida colonization and infection involves yeast adherence to epithelial cell surfaces.[16] Rajendran et al. discovered a substantial correlation between HbA1c levels and biofilm production.[21] The findings of our investigation indicated that Candida spp. exhibiting biofilm development and influencing antifungal efficacy, corroborating the results of Kumar et al.[22] The findings of our investigation indicate that Candida albicans exhibited strong biofilm development. This outcome aligns with the findings from Iraq/Baghdad province by Rubaie and Qaysi.[23,24] The present study showed Candida spp. with biofilm formation is more resistant against antifungal agents than without biofilm formation. This result is consistent with the findings from Brazil by Yamauchi.[25] The current study demonstrates that biofilm formation exhibited greater resistance to nystatin 100mg. This outcome is consistent with Chandra et al.[26]

Limitation

The main limitation of the present study was a sample size of non-diabetic individuals, because of exclusion criteria applied during non- diabetic individual's selection like (RBS > 105), smoker, wearing a denture, drinker, xerostomia, and non-diabetic individuals with certain condition like autoimmune diseases, infected with HIV, HBS, HBC, cancer, patient under chemotherapy, or a kidney transplant, reduced the number of non-diabetic individuals.

CONCLUSION

This study demonstrated that biofilm formation was associated with increased antifungal resistance. And the colony-forming unit of Candida spp. increases with blood sugar levels. Biofilms contribute to the persistence of Candida infections, resulting in substantial clinical and economic challenges. Also, the isolation of Candida spp. occurs more frequently in diabetic patients than in non-diabetic individuals. Candida spp. are more prevalent in patients with DM than in non-diabetic individuals. Consequently, characterization of biofilms is crucial for identifying therapeutic strategies to prevent and treat chronic infections. We recommend studying other virulence factors that enhance the growth and pathogenicity of Candida spp. in the oral cavities of diabetic patients, thereby contributing to the development of antifungal resistance.

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Conflict of Interest

The authors declare no conflicts of interest.

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