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Assessment of Caries Risk in Young Adults Using the Cariogram Model: A Cross-Sectional Study

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ABSTRACT

Background and Objectives: Dental caries is considered one of the most prevalent global health issues, affecting over 3.1 billion people. The Cariogram, a Caries Risk Assessment (CRA) model, helps predict caries risk by evaluating multiple contributing factors. This study aimed to investigate caries risk in young adults in Erbil City, Iraq, using the Cariogram model, incorporating salivary factors and Streptococcus mutans levels.

Methods: This cross-sectional study involved 30 young adults aged 18–25 years (13 males, 17 females). Cariogram software was utilized to determine caries risk based on four main categories: diet, bacteria, susceptibility, and circumstances.

Results: The mean age was 23.38 ± 1.38 years for males and 22.82 ± 1.42 years for females. Caries experience was predominantly classified as better than normal (60%), and the most common fluoride regimen was fluoride toothpaste alone (46.7%). The majority of participants had normal salivary secretion (43.3%) and low buffering capacity (63.3%). Most participants were classified as having a low (33.3%) or medium (30%) risk for caries. Streptococcus mutans levels were highest in Classes 0 and 1 (33.3% each).

Conclusion: Factors such as Streptococcus mutans levels, diet, and individual susceptibility were strongly associated with caries risk.

Keywords: Buffering, Cariogram, Diet, Salivary flow, Streptococcus mutans

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INTRODUCTION

Dental caries is a common health issue worldwide, affecting 3.1 billion people (44%) and causing significant quality-of-life impacts and high economic costs.[1,2] Dental caries results from a combination of physiological, environmental, behavioral, and genetic factors. It is considered an ecological disease driven by imbalances in the oral microbiota, primarily due to frequent sugar consumption, which disrupts the biofilm.[5] Factors such as acid-producing bacteria, salivary flow, fluoride exposure, and tooth structure further influence its development.[3] A decrease in the prevalence of dental caries has been reported over the last three decades,[1] despite it being a largely preventable disease.[4]

Modern dental caries management follows the principle of minimal intervention dentistry (MID), focusing on lifelong tooth health through personalized prevention and noninvasive treatments. The most influential component of MID is caries risk assessment (CRA), which is utilized across the entire lifespan. Through CRA, dentists can significantly reduce the chances of the disease exacerbating or recurring. The main goal of CRA is to predict the development of caries over a predetermined follow-up period.[5] Consequently, CRA is a critical stage associated with minimally invasive therapy, guiding the selection of treatment and preventive measures tailored to the patient's specific risk level.[6]

Different types of CRA models have been developed with varying approaches, and their predictive accuracy depends on study methods and population characteristics.[7,8] The Cariogram model evaluates these various factors and categorizes patients as having low, moderate, or high risk.[11] It presents results in a pie chart that reflects key risk indicators.[6,9] This chart displays five colored sectors representing elements that affect dental caries: circumstances (yellow), bacteria (red), susceptibility (light blue), diet (dark blue), and the likelihood of avoiding cavities (green). The bacteria sector typically refers to Streptococcus mutans (S. mutans).[9] While the Cariogram is widely used, many studies utilizing it have neglected the role of salivary parameters.[10] Furthermore, the comprehensive relationship between caries risk categories and combined factors such as diet, bacteria, and saliva has not been fully explored.

Aim of the study: To determine the caries risk in young adults (18–25 years old) based on comprehensive salivary parameters and bacterial quantity using real-time qPCR according to the Cariogram model.

METHODS

Study Design, Setting, and Population

This study was designed as a cross-sectional study and conducted at the College of Dentistry, Hawler Medical University (HMU) in Erbil City, KRG/ Iraq. The study was carried out from November 2024 to April 2025. This research was approved by the Scientific Research Ethics Committee of Hawler Medical University under Reference Number: HMUD, 2425028. Written informed consent was obtained from each participant at the beginning of the study.

The inclusion criteria of the study

The inclusion criteria for the study were: young adults of both sexes, aged 18–25 years, residing in Erbil City, Iraq, with no serious health problems.

The exclusion criteria of the study

The exclusion criteria were: (1) individuals who had used chlorhexidine gluconate solutions and/or received oral prophylaxis in the past month; (2) those with a drug history that affects saliva secretion; (3) those with a history of chemo-radiation to the head and neck; (4) individuals with chronic or acute upper respiratory diseases, due to their potential to impact oral flora and the antibacterial compounds in saliva; and (5) those wearing orthodontic appliances.

The sample size

The sample size of the study was calculated according to a power analysis protocol using G*Power software. Thus, the final sample size consisted of 30 young adult patients (n = 30).

Tools for data collection and study procedure

A. First tool: A structured interview questionnaire

The Cariogram manual's standardized, structured questionnaire was used to interview patients and document all pertinent caries-related parameters. Information was obtained regarding general health, medication use, dietary habits, frequency of meals and snacks, dental hygiene, and fluoride use, as outlined in Table 1.

B. Second tool: Clinical examination (DMFT, PI)

Clinical evaluations of plaque amount were performed in accordance with the Silness and Löe plaque index . Participants were classified into four groups according to the Cariogram Manual .

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The decayed, missing, and filled teeth (DMFT) index was documented using the World Health Organization's (WHO) standards. This index helps estimate the extent of dental caries affecting the dentition, typically excluding the third molars (teeth 1, 16, 17, and 32) from the calculation.

C. Third tool: Saliva and bacteriological test methods

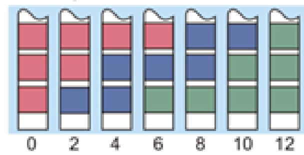
Saliva Secretion Rate: A stimulated salivary collection method was used. Paraffin chewing gum was employed to quantify the rate of stimulated saliva, as described by Dr. Avnish Singh. The patient was instructed not to eat or smoke for at least one hour before sample collection and was seated in a relaxed, upright position. The test began by having the patient chew the paraffin gum for 30 seconds, after which they either spat out or swallowed the accumulated saliva. Following this, the patient continued to chew the gum for a duration of five minutes, during which stimulated saliva was collected into a measuring cup. The volume of saliva was measured, and the secretion rate was calculated (e.g., if 3.5 mL of saliva was collected in 5 minutes, the secretion rate would be 0.7 mL/min). A normal saliva secretion rate is typically greater than 1.0 mL/min.

Buffer Capacity: The buffering capacity of saliva was evaluated using the Saliva-Check BUFFER, as outlined. The test side of a buffer test strip was placed on an absorbent tissue. Saliva was collected in a graduated cup, and one drop was transferred to each test pad using a pipette. After two minutes, the final result was calculated by adding the points corresponding to the final color of each test pad, using a standard conversion table to interpret the results accurately. Mutans Streptococcus Count – DNA Extraction: The collected saliva samples were labeled and stored in disposable, sterile tube containers. Genomic bacterial DNA from saliva samples was extracted using the Bacterial Genomic DNA Extraction Kit (iNtRON Biotechnology), following the manufacturer's protocol. Briefly, an aliquot of saliva (1 mL) was centrifuged at 14,000 rpm for 1 min, and the supernatant was discarded. Both 50 µL of Pre-Buffer and 3 µL of Lysozyme solution were used to resuspend the pellet, which was then incubated at 37°C for 15 min. After adding 250 µL of G-Buffer, the mixture was incubated at 65°C for 15 min. Following the addition of 250 µL of Binding Buffer, the sample was applied to the column and washed with Washing Buffers A and B.

Conversion table

Test pad colour at 2 minutes	
Green	4 points
Green/Blue	3 points*
Blue	2 points
Red/Blue	1 point *
Red	0 points

Examples



*Where a colour combination provides an unclear result, use intermediate scores.

Interpreting the result.

Combined total	Buffering ability of Saliva
0-5	Very low
6-9	Low
10-12	Normal / High

Figure 1. Conversion table

Figure 2. Saliva Check Buffer

Finally, genomic DNA was eluted using 50–200 µL of Elution Buffer and stored at −20°C for further analysis. DNA quality and concentration were measured with a NanoDrop 1000 Spectrophotometer (Lantech, Korea). The final concentration of each DNA sample was adjusted to 10 ng/µL for qPCR.

Real-Time PCR for S. mutans Quantification: Quantitative real-time PCR was used to quantify S. mutans DNA in saliva samples. Species-specific primers targeting the gtfB gene of S. mutans were designed as follows:[17]

Forward Primer: 5′-CTACACTTTCGGGTGGCT TG-3′

Reverse Primer: 5′-GAAGCTTTTCACCATTAG AAGCTG-3′

Each PCR reaction consisted of 10 µL of SYBR

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Green Premix Ex Taq™ (Takara), 0.4 µL of each primer (10 µM), and 1 µL of the extracted DNA template, with the final volume adjusted to 20 µL using distilled water.

Table 1. Caries Related Factors/ Parameters Used at Baseline for the Cariogram

Factor	Information to be collected	Cariogram score
Caries experience	Mean DMFT values	0: No fillings or caries 1: Above average for the age group 2: Standard for the age range 3. Worse than average for the given age group
Related general diseases	Health background and medications	0: Healthy 1: Existence of a general illness that may have an indirect impact on the development of caries 2: Constantly taking medicine or bedridden
Diet content	Diet history, Content Score	0 = Very low fermentable carbohydrate 1= Low fermentable carbohydrate 'non-cariogenic' diet 2= Moderate fermentable carbohydrate 3=High fermentable carbohydrate
Diet frequency	Questionnaire results: food consumption amount	0: Maximum of 3 meals per day 1: Maximum of 5 meals per day 2: 7 meals maximum per day 3: More than 7 meals every day
Amount of plaque	Silness-Löe plaque index	0 = Extremely good oral hygiene, PI < 0.4 1 = Good oral hygiene, PI = 0.4-1.0 2 = Less than good oral hygiene, PI = 1.1-2.0 3= very poor oral hygiene PI >2.0
Streptococcus mutans	Strip mutans test by qPCR	0= Less than 10,000 CFU/ml 1= Between 10,000 and 100,000 CFU/ml 2= 100,000 and 1,000,000 CFU/ml 3= More than 1,000,000 CFU/ml
Fluoride program	Exposure to fluoride	0: Maximum fluoride exposure 1: Fluoride supplements other than toothpaste, however, they are used seldom 2. Only fluoride toothpaste 3. No fluoride exposure
Saliva secretion rate	Secretion rate of stimulation saliva test (using paraffin wax)	0: Normal saliva secretion 1: Low,0.9–1.1 mL/min 2: Low,0.5–0.9 mL/min 3: Very low, <0.5 mL/min
Saliva buffering capacity	Using Saliva-Check BAFFER	0: Normal / High 1: Low 2: Very Low
Clinical judgement	Dental examiner's opinion: the examiner's own clinical and subjective evaluation of the patient.	0: More favorable 1: Usual situation 2: Worse 3: Very high risk of dental caries

Amplification was performed under the following conditions: initial denaturation at 94°C for 4 minutes, followed by 40 cycles of 94°C for 20 seconds, 55.4°C for 20 seconds, and 72°C for 33 seconds. A dissociation curve was generated post-amplification to confirm primer specificity. The threshold cycle (CT) values were recorded for quantification. To accurately convert the CT values to colony-forming units (CFU/mL), a standard curve was constructed. This linear regression curve was generated by plotting the CT values obtained from serial dilutions of a known pure culture of S. mutans, allowing the CFU values of the unknown samples to be mathematically calculated based on their respective CT values.

D. Fourth tool: Assessment of caries risk using the Cariogram

A risk profile was created using the Cariogram software by collecting caries-related data and scoring it on a predetermined 0–2 or 0–3 scale, with explanations for each score 11, Table 1. Every participant in this study received a clinical judgment score of 1, meaning that risk was assessed using standardized criteria. The Cariogram settings were adjusted to the norm for countries such as Iraq that do not fluoridate their water. A pie chart with five sectors was created by entering the scores into the software: (1) "circumstances" (yellow), (2) "diet" (dark blue), (3) "bacteria" (red), (4) "susceptibility" (light blue), and (5) "chance of avoiding caries" (green). The probability of preventing caries is correlated with the size of the green sector; a larger green sector signifies a reduced risk. Subsequently, risk was divided into five categories. A very low risk was defined as an 81–100% chance of avoiding caries, low risk as 61–80%, medium risk as 41–60%, high risk as 21–40%, and very high risk as a 0–20% chance of avoiding caries.

Statistical Analysis

Data were tabulated and analyzed using statistical software. Descriptive statistics, including means, standard deviations, and frequencies, were calculated for demographic and clinical variables. Independent t-tests were utilized to compare continuous variables between genders, while Chi-square tests were employed to evaluate the distribution of categorical variables (such as S. mutans classes). To assess the relationships between the ordinal Cariogram factors and total caries risk, Spearman's rank correlation coefficients were calculated. A p-value of < 0.05 was considered statistically significant for all tests.

RESULTS

The present study included 13 males (43.3%) and 17 females (56.7%). The mean age was 23.38 ± 1.38 years for males and 22.82 ± 1.42 years for females. There were no significant differences between genders in terms of age ($p = 0.287$, independent t-test).

The distribution of caries-related factors is detailed in Table 2. Most participants (60%) were reported as having "better than normal" caries experience. Regarding diet, 53.3% followed a low fermentable carbohydrate (non-cariogenic) diet, and 53.3% consumed a maximum of five meals per day. Plaque index results indicated that 66.7% maintained good oral hygiene. The distribution of S. mutans was balanced, with 33.3% in Class 0 and 33.3% in Class 1. Fluoride use was most common through fluoride toothpaste alone (46.7%). In terms of salivary parameters, 43.3% of participants had normal secretion rates, while 63.3% had low saliva buffering capacity.

Caries risk categories

The majority of participants were categorized as having either a low risk (33.3%, n = 10) or a medium risk (30%, n = 9) of developing caries. A smaller proportion was identified as having a very low risk (13.3%, n = 4) or very high risk (20%, n = 6), and only 3.3% (n = 1) were classified as high risk. The distribution of caries risk categories varied between genders (Table 3), though not significantly ($p = 0.086$). For males, the majority were classified as having medium (38.5%) or very high (30.8%) risk. Conversely, the majority of females fell into the low-risk category (47.1%) .

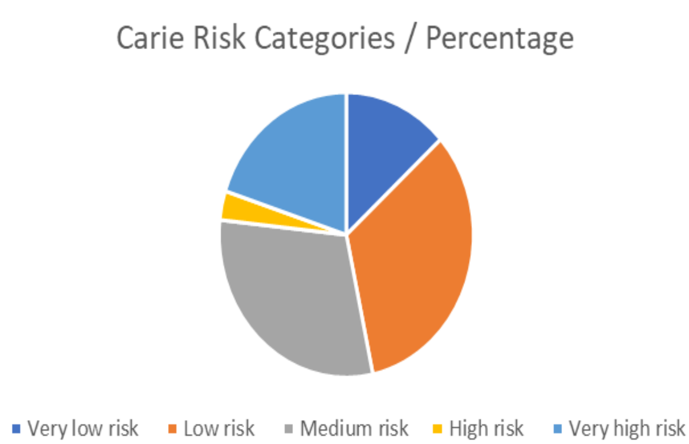

Figure 3. Distribution of caries risk percentages across different categories

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Table 2. Distribution of Caries Related Factors Among the Study Population

Variable	Category	Frequency	Percent (%)
Caries Experience	Caries free and no fillings	1	3.3
	Better than normal	18	60.0
	Normal for the age group	8	26.7
	Worse than normal	3	10.0
Diet Content	Low fermentable carbohydrate, 'non-cariogenic' diet	16	53.3
	Moderate fermentable carbohydrate content	12	40.0
	High fermentable carbohydrate intake, inappropriate diet	2	6.7
Diet, Frequency	Maximum three meals per day (including snacks)	9	30.0
	Maximum five meals per day	16	53.3
	Maximum seven meals per day	4	13.3
	More than seven meals per day	1	3.3
Plaque Amount	Extremely good oral hygiene, PI <0.4	1	3.3
	Good oral hygiene, PI = 0.4-1.0	20	66.7
	Less than good oral hygiene, PI = 1.1-2.0	9	30.0
Streptococcus mutans	class 0	10	33.4
	class 1	10	33.4
	class 2	5	16.6
	class 3	5	16.6
Fluoride Program	Additional F measures, infrequently	13	43.3
	Fluoride toothpaste only	14	46.7
	Avoiding fluorides, no fluoride	3	10.0
Saliva Secretion Scores	Normal saliva secretion	13	43.3
	Low, 0.9 - 1.1 ml stimulated saliva/min	4	13.3
	Low, 0.5 - 0.9 ml saliva/min	10	33.3
	Very low, Xerostomia, <0.5 ml saliva/min	3	10.0
Saliva Buffer Capacity	Normal / High (10-12)	5	16.7
	Low (6-9)	19	63.3
	Very Low (0-5)	6	20.0

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Table 3. Distribution of Caries Risk Categories by Gender

Risk Category	Male (N=13) Percent (Male)	Female (N=17) Percent (Female)	P value
Very low risk (chance of avoiding caries 81-100%)	1 (7.7%)	3 (17.6%)	0.086
Low risk (chance of avoiding caries 61-80%)	2 (15.4%)	8 (47.1%)	
Medium risk (chance of avoiding caries 41-60%)	5 (38.5%)	4 (23.5%)	
High risk (chance of avoiding caries 21-40%)	1 (7.7%)	0 (0%)	
Very high risk (chance of avoiding caries 0-20%)	4 (30.8%)	2 (11.8%)	

Correlations with Caries Risk
As shown in Table 4, the highest positive correlation with overall caries risk was observed for host susceptibility (Spearman's correlation = 0.734, $p < 0.001$). Bacterial presence also showed a strong positive correlation (0.538, $p < 0.001$). Diet followed with a moderate correlation (0.502, $p = 0.001$). Circumstances had the weakest, yet still significant, correlation (0.498, $p = 0.001$).

Table 4. Correlation Between Caries Risk (1-5) and Factors of Cariogram

Factor	Correlation Coefficient	Significance (2-tailed)
Circumstances	0.498	0.001
Bacteria	0.538	0.000
Susceptibility	0.734	0.000
Diet	0.502	0.001

Distribution of Streptococcus mutans
Class 0 (S. mutans levels < 10,000 CFU/mL) and Class 1 (10,000 to 100,000 CFU/mL) each accounted for 33.3% of the total participants. Class 2 and Class 3 each accounted for 16.7%. A Chi-square test revealed no significant difference in the distribution of S. mutans classes between males and females ($p = 0.602$).

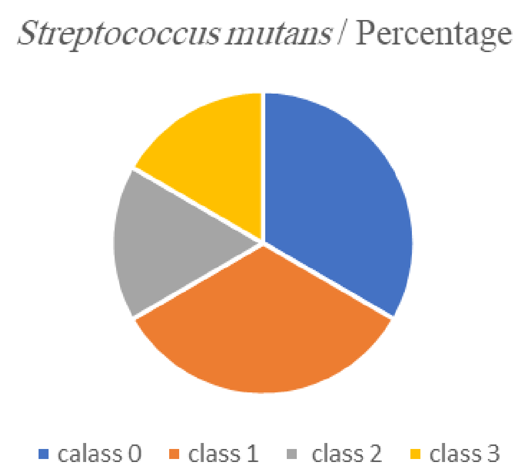

Figure 4. Distribution of Streptococcus mutans percentages across different classes

DISCUSSION
Dental caries remains a significant global health issue, resulting from a complex interplay of factors such as diet, host susceptibility, oral hygiene, saliva composition, genetics, and the presence of microorganisms over time.[12] Dental caries arises from multiple causes, including overall health, plaque, saliva secretion, the quantity and type of microorganisms, fluoride exposure, and social and behavioral factors.[13] To address this, the Cariogram software assesses caries risk using these different factors to identify high-risk patients and guide prevention and treatment.[14] While it effectively highlights key risk factors for individuals, its graphical benefits are limited at the community level, making population-wide interventions less

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effective both clinically and cost-wise.[13] Furthermore, although the Cariogram algorithm incorporates various parameters, many studies have excluded or modified these factors, potentially affecting its effectiveness in certain contexts.[15] The present study, however, included all factors according to the Cariogram model for a more comprehensive assessment, recognizing that the exclusion of parameters—such as saliva characteristics can significantly impact the accuracy of caries risk evaluation.

Caries experience should be scored based on the different grades outlined in the Cariogram manual.[16,17] In this study, caries experience was categorized into the following groups: caries-free with no fillings, better than normal, normal for the age group, and worse than normal. The majority of participants (60%) were classified as better than normal, with the lowest category being caries-free (3.3%). Previous studies have found that caries experience scores tend to increase with age, exhibiting the highest scores in the 31–44 and 45–60 year age groups and the lowest in the 3–6 year group.[16] Due to the present study's methodology, which evaluated only a single age group (18–25 years), the broader impact of age on caries experience could not be evaluated.

Regarding plaque amount, good oral hygiene (PI = 0.4–1.0) showed the highest frequency (66.7%). In terms of diet, 53.3% followed a low fermentable carbohydrate, non-cariogenic diet, while 40% consumed a moderate amount of carbohydrates. Regarding meal frequency, 53.3% had a maximum of five meals per day, and 30% consumed up to three meals. Fluoride use was most common through fluoride toothpaste alone (46.7%), and 43.3% utilized additional fluoride measures infrequently. A previous study reported similar trends, finding that 50% of participants consumed 4–5 meals per day, and 41.1% had a diet correlated with 10^4–10^5 CFU/mL based on Lactobacillus count and sugar content.[17] Regionally, a study in Benghazi, Libya, found that higher sugar consumption and fewer daily tooth brushings were significantly linked to increased dental caries in children, resulting in an average of three carious lesions.[18] In comparison, a study from Ankara, Turkey, which evaluated caries risk in a young adult population (90 individuals aged 19–25 years), found that 77.8% used only fluoride toothpaste.[17]

The results of the present study show that the most common salivary secretion rate was normal (43.3%), while xerostomia (< 0.5 mL/min) had the lowest frequency (10%). Numerous studies have highlighted low salivary flow rate as a key factor in caries progression, with individuals exhibiting a flow rate below 0.7 mL/min being at a significantly higher risk for developing caries.[13] These observed differences across the literature may be due to variations in study populations and geographic locations. The highest buffering capacity in this study was observed in the low range (63.3%), while the lowest frequency was found in the normal/high range (16.7%). This finding contrasts with a previous study conducted in Turkey, which assessed caries risk and salivary buffering capacity among 120 young individuals (18–25 years old) and reported a higher percentage (50.8%) of participants in the normal range.[15]

Most participants in the current study were classified as having a low (33.3%) or medium (30%) risk for caries, with fewer individuals falling into the very low (13.3%) or very high (20%) risk categories. Only 3.3% were classified as high risk. Gender comparisons showed no significant difference (p = 0.086). Similarly, a study by Lakhotia et al.[19] found no significant difference in caries risk between males and females among 90 schoolchildren aged 7–10, despite similar oral hygiene, diet, and socioeconomic factors. Few studies in the literature have specifically aimed to determine gender differences in Cariogram caries risk categories. Research by Widyagdo et al.[20] found that 81.3% of males aged 15–24 had a moderate caries risk, with bacteria (22.9%), susceptibility (19.4%), and diet (12.1%) being the most significant risk factors. This aligns closely with the results of the present study, where host susceptibility, bacteria, and diet were also identified as key factors associated with caries risk. However, it is important to note that Widyagdo et al. focused exclusively on male smokers. Similarly, a cross-sectional Cariogram-based comparison study by Iype et al.[21] found that bacteria, susceptibility, and diet were the main factors associated with caries risk in children with intellectual disabilities. These findings highlight the consistency of these factors across different demographic groups while emphasizing the importance of considering population-specific variables.

The S. mutans distribution showed that 33.3% of participants were in Class 0 (less than 10,000 CFU/mL) and 33.3% were in Class 1 (10,000 to 100,000 CFU/mL). Statistical analysis (p = 0.602) indicated no significant differences between genders regarding the distribution of S. mutans. In contrast, a previous study conducted in Erbil, Iraq, found a weak but significant correlation between caries risk categories and the presence of S. mutans and Lactobacillus in the saliva of 200 women.[22] In that study, pregnant women had a lower chance of preventing caries (50.57%) compared to non-pregnant women (60.26%). However, both groups identified the susceptibility sector as the dominant risk factor, followed by bacteria, diet, and circumstances, which is largely consistent with the present findings.

Limitations

This study has several important limitations. First, the sample size was very small (n = 30) due to the restricted timeframe of the investigations. This severely limits the generalizability of the findings to the broader young adult population. Second, because this research utilized a cross-sectional design, the results can only establish statistical associations and cannot definitively prove causal relationships between the variables and caries development. Third, evaluating a single patient across a relatively large number of parameters (including advanced qPCR analysis and comprehensive Cariogram data entry) made the statistical processes complex and introduced high financial costs, which limited the feasibility of utilizing a larger cohort.

CONCLUSION

Based on the findings of this study, the most significant factors associated with higher caries risk categories were the presence of bacteria (especially Streptococcus mutans), diet, and host susceptibility. These factors demonstrated statistically significant associations with caries risk. Further investigations are needed to explore additional underlying factors, such as behavioral patterns and genetic mutations.

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Conflict of interest

The authors declare no conflicts of interest.

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