Original Research

Title: Investigation of the relationship between caries predisposition and salivary characteristics

Running Title: Buffering capacity and caries risk

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Abstract

Purpose: The aim of this study is to investigate the relationship between Decayed, Missing, and Filled Teeth (DMFT) scores, caries activity, and salivary characteristics (flow rate, pH, and buffering capacity) in patients admitted to the Department of Restorative Dentistry at Kocaeli University Faculty of Dentistry.

Materials and Methods: This study included 44 patients aged 18–50 years, classified into high and low caries risk groups, who presented to our clinic. A DMFT score above 8 and the presence of at least two active carious lesions with cavitation (ICDAS II Categories 5 or 6) were considered criteria for the high caries risk group. Conversely, patients with five or fewer carious or restored teeth and no active caries were classified as low caries risk. Saliva samples were collected prior to any restorative procedures. Salivary flow rate, pH, and buffering capacity were measured using the Saliva-Check Buffer Kit (GC Europe, Leuven, Belgium). The correlation between caries activity and salivary buffering capacity was analyzed using ANOVA and Kruskal–Wallis tests. Tukey's and Mann–Whitney U tests were applied for pairwise comparisons.

Results: The highest buffering capacity was observed in the high-risk group aged 25–50 years, while the lowest was found in the high-risk group aged 18–25 years ($p = 0.028$). No statistically significant difference was found between the groups in terms of both unstimulated and stimulated salivary flow rates.

Conclusion: In the absence of pathological conditions, a physiologically low salivary flow rate does not appear to significantly influence caries risk. A meaningful relationship between salivary factors and caries risk becomes evident only when salivary flow is severely reduced.

Keywords: *Saliva, buffering capacity, caries risk, flow rate, pH*

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Introduction

The World Health Organization (WHO) defines risk as the probability of an adverse event occurring or a factor that may increase this probability (1). The most reliable indicator for determining an individual's future caries risk is their previous caries experience (2, 3). It is well established that the primary etiologic factors initiating dental caries are oral streptococci—particularly Streptococcus mutans—as well as other cariogenic bacteria and lactobacilli from existing carious lesions in the oral cavity (4, 5).

Caries is a multifactorial microbial disease of the teeth and one of the most prevalent health problems worldwide. Saliva, which surrounds the hard and soft tissues of the oral cavity, contains various factors essential for host defense; therefore, it serves as an important biomarker for diagnosing dental caries. Clinicians can assess the infectious process of dental caries using saliva kits, which support treatment decisions and offer insight into the progression and prognosis of tooth decay. Saliva can reflect the physiological state of the body and is considered a reliable and reproducible biomarker for caries risk assessment, diagnosis, prognosis, and monitoring (6). However, due to the multifactorial nature of dental caries, identifying a single biochemical marker to predict the disease's severity remains a challenge (7).

Saliva consists primarily of 99.5% water, 0.3% protein, and 0.2% trace elements and inorganic substances (8). Its physiological effects depend on both flow rate and viscosity. Salivary fluid plays a crucial role in forming the oral microbiota and the acquired enamel pellicle (9). Saliva acts as the first line of defense in the oral cavity and is vital for protecting tooth surfaces. It contributes to the reversal of tooth surface demineralization through mechanical washing, antimicrobial activity, buffering capacity, secretion of calcium-phosphate-binding proteins, and antimicrobial peptides (10).

Physiological changes in the human body can be studied by monitoring variations in saliva composition (10–12). Both the secretion and concentration of saliva vary by age and sex (13). The composition of human saliva differs across age groups, as salivary protein concentration tends to increase with age (14). These changes have been associated with a higher caries risk and may serve as indicators of caries incidence (15).

In recent years, regenerative dental therapies have become increasingly prominent in the treatment of dental caries. Assessing caries risk—defined as estimating the likelihood of new caries

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lesions developing within a certain period, as well as predicting changes in the size or activity of existing lesions—can help identify individuals at high risk (16). Early identification of high-risk individuals allows for more effective preventive interventions, improving treatment efficiency. Saliva is easy to collect, inexpensive, and non-invasive, offering practical advantages for both clinicians and patients. Because of these properties, it has become widely used as a biomarker for assessing caries risk.

The aim of this study was to investigate the relationship between the caries risk status of individuals in different risk groups and the physicochemical properties of saliva. Additionally, the study aimed to apply different conservative treatment approaches tailored to each group to lower caries risk and reduce the time patients and clinicians spend in the clinic. Three hypotheses were proposed for this purpose: Caries risk in young and adult individuals would not be affected by buffering capacity, age would not influence the relationship between caries risk and buffering capacity, salivary flow rate changes within physiological limits would have no significant effect on caries risk.

Materials and Methods

Ethical approval

This study was conducted with the approval of the Ethics Committee of Kocaeli University (Decision Number: KU GOKAEK-2024/17.06).

Sample size determination

A power analysis conducted using G*Power 3.1.9.4 software ($\alpha = 0.05$, $1\text{-}\beta = 0.90$, effect size = 0.65) indicated that a minimum total sample size of 40 participants was required, with 10 participants per group. In this study, 44 patients aged 18–50 years—classified as either high or low caries risk—were recruited from the Department of Restorative Dentistry at Kocaeli University Faculty of Dentistry. The participants were initially divided into two age groups: 18–25 years and 25–50 years, with 22 individuals in each group. Each age group was then further subdivided into two caries risk subgroups (high and low), resulting in four subgroups with 11 participants each ($n = 11$).

Study design and patient selection

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Patients with systemic diseases, ongoing medication use, orthodontic treatment, smoking habits, or missing teeth were excluded from the study. Additional exclusion criteria included having fewer than 28 teeth, advanced periodontal disease, temporary fillings or crown bridges, and the use of antibiotics within the past three months. A total of 44 patients were included in the study, comprising 26 females and 18 males. The mean age of the participants was 26.4 years.

The inclusion and exclusion criteria were also shaped by the setting and characteristics of the study population. As the study was conducted in a rural area within a public institution providing government-funded healthcare, the participants' socioeconomic status was relatively homogeneous. Furthermore, to minimize variability, participants with significantly different dietary habits or oral hygiene routines were excluded, ensuring that these factors would not confound the results. These variables were intentionally not included in the analysis, as the primary aim was to compare differences between age groups.

Participant allocation was performed through randomization by two experienced dentists. Clinical examinations were conducted using a dental mirror and probe after drying the teeth with an air syringe. Radiographic assessments included panoramic radiographs and, when necessary, bite-wing radiographs. Patients were classified as high caries risk based on the following criteria: a DMFT score greater than 8 and the presence of at least two active carious lesions with cavitation (ICDAS II Categories 5 or 6) (17). The low-risk group included participants with DMFT scores below 5 (18), good oral hygiene, regular dental visits, and no active caries.

Sampling procedure

Salivary parameters were measured prior to the initiation of restorative procedures using the Saliva-Check Buffer Kit (GC Europe, Leuven, Belgium). The kit includes 20 in vitro pH test strips, 20 saliva collection cups, 20 wax gum pieces for saliva stimulation, 20 saliva dispensing pipettes, 20 buffer test strips, a reference chart for pH and buffering capacity evaluation, and instructions for use (Figure 1). A total of five tests were performed in accordance with the manufacturer’s instructions. The first three tests were related to resting saliva, and the last two assessed stimulated saliva.

In the first test, the level of hydration was visually inspected. The participant’s lower lip was gently held with a gauze swab and separated from the teeth. The inner mucosal surface of the lip was dried and observed under good lighting for 60 seconds. Saliva formation at the minor

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salivary gland orifices was monitored. If saliva appeared within 60 seconds, hydration was considered normal; if it took longer, it was classified as low. The second test evaluated the consistency of resting saliva. This was assessed visually; sticky, frothy, or bubbly saliva was categorized as having increased viscosity, while watery and clear saliva was considered to have normal viscosity. In the third test, the pH of resting saliva was measured. The participant expectorated into a collection cup, and a pH test strip was immersed in the sample for 10 seconds. The resulting color was compared to the pH chart provided with the kit. The measured pH value was used for statistical analysis and classified as follows: 5.0–5.8 (highly acidic), 6.0–6.6 (moderately acidic), and 6.8–7.8 (healthy saliva). The fourth test measured the quantity of stimulated saliva. Participants were asked to chew a wax piece from the kit for 30 seconds and expectorate the initial saliva into a spittoon. They then continued chewing for five minutes, spitting saliva into a collection cup at one-minute intervals. The total volume of collected saliva was recorded using the marked measurements on the cup. Stimulated salivary flow was considered very low if <3.5 mL, low if between 3.5–5.0 mL, and normal if >5.0 mL. In the fifth test, the buffering capacity of saliva was assessed. A buffering test strip was removed from its foil, and one drop of stimulated saliva was applied to each of its three absorbent test pads using a pipette. After waiting for two minutes, the color change was compared to the reference chart. The colors were scored as follows: green (4 points), green/blue (3 points), blue (2 points), blue/red (1 point), and red (0 points). Total scores were interpreted as: 0–5 indicating very low buffering capacity, 6–9 low, 10–12 normal, and >12 high buffering capacity (Figure 2). Following saliva analysis, all patients received routine dental treatment, and individuals identified as high caries risk were provided with tailored oral hygiene education.

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Figure 1: *Saliva Check Buffer Kit*

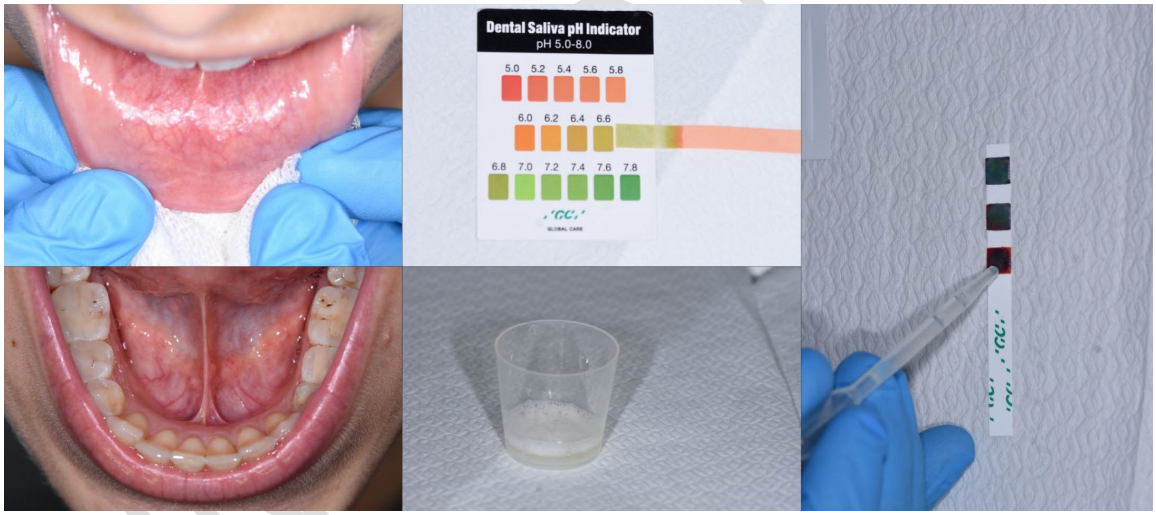


Figure 2: *Saliva Check Buffer tests*

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Statistical analysis

All statistical analyses were performed using the SPSS 29.0 software (IBM Corp., Armonk, NY, USA). The Shapiro-Wilk test was used to evaluate the normality assumption. Continuous variables are presented as mean ± standard deviation. One-way analysis of variance (ANOVA) and Tukey's test for multiple comparisons were performed for stimulated saliva quantity and buffering capacity values that were found to be normally distributed. The Kruskal-Wallis test was used for resting Saliva, viscosity, and pH values that did not show normal distribution, and then the Mann-Whitney U test was used for pairwise comparisons. Correlation analyses were conducted using Pearson's test for normally distributed variables and Spearman's test for non-normally distributed variables.

Results

No significant differences were observed between the groups in terms of resting salivary flow rate ($p = 0.120$) or stimulated salivary flow rate ($p = 0.117$). The relevant data are presented in Table 1. In the high caries risk group, 72.7% of patients aged 18–25 years and 90.9% of those aged 25–50 years exhibited increased salivary viscosity. In contrast, the corresponding rates were 27.3% in the low-risk group aged 18–25 years and 9.1% in the low-risk group aged 25–50 years.

The highest mean buffering capacity was observed in the high-risk group aged 25–50 years (8.45), which was significantly higher than that in the high-risk group aged 18–25 years ($p = 0.028$). The mean buffering capacity values for the remaining groups were 6.18 in the high-risk group aged 18–25 years, 7.27 in the low-risk group aged 18–25 years, and 8.0 in the low-risk group aged 25–50 years.

With regard to salivary pH, the lowest intermediate value was recorded in the high-risk group aged 18–25 years. These pH values were significantly lower than those of the low-risk patients in both age groups (18–25 years: $p = 0.016$; 25–50 years: $p = 0.015$). However, the difference compared to the high-risk group aged 25–50 years was not statistically significant ($p = 0.530$). The significance levels for all measured parameters across the groups are illustrated in Figure 3.

Pearson's correlation analysis, conducted between stimulated salivary flow rate and buffering capacity—both normally distributed variables—revealed a statistically significant positive correlation at the 0.05 level (Pearson's $r = 0.336$, $p = 0.026$). For variables not meeting

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normality assumptions, Spearman's correlation analysis was performed. The results showed a significant negative correlation between viscosity and both salivary pH (rho = –0.534, $p < 0.001$) and unstimulated salivary flow rate (rho = –0.527, $p < 0.001$) at the 0.01 significance level. Although a positive correlation was observed between unstimulated salivary flow rate and pH, this relationship was not statistically significant (rho = 0.222, $p = 0.148$).

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Tablo 1. *Statistical values and standard deviations of the data obtained from the tests.*

		Age between 18-25	95% CI LB	95% CI UB	Age between 25-50	95% CI LB	95% CI UB	p Value
HIGH RISK	RESTING SALIVA (%)	54.5 ±0.52 FN / 45.5±0.52 FL	1.194	1.896	45.5±0.52 FN / 54.5±0.52 FL	1.103	1.805	p=0.657
	SALIVA CONSISTENCY (VISCOSITY, %)	72.7 ±0.46 IV / 27.3±0.46 NV	1.413	2.041	90.9 ±0.30 IV / 9.1±0.30 NV	1.706	2.111	p=0.399
	pH	6.2±0.39	6.045	6.574	6.4±0.17	6.319	6.554	p=0.530
	STIMULATED SALIVA QUANTITY (mL)	6.68±3.45	4.363	9.0	8.22±4.87	4.952	11.503	p=0.788
	BUFFERING CAPACITY*	6.18±1.83	4.95	7.41	8.45±2.01	7.1	9.81	p=0.028
LOW RISK	RESTING SALIVA (%)	72.7±0.46 FN / 27.3±0.46 FL	1.413	2.041	90.9±0.30 FN / 9.1±0.30 FL	1.706	2.111	p=0.374
	SALIVA CONSISTENCY (VISCOSITY, %)	27.3±0.46 IV / 72.7 ±0.46 NV	0.958	1.586	9.1±0.30 IV / 90.9±0.30 NV	0.888	1.293	p=0.399
	pH	6.8±0.42	6.477	7.051	6.6±0.50	6.481	7.155	p=0.973
	STIMULATED SALIVA QUANTITY (mL)	9.63±3.05	7.587	11.686	9.40±3.92	6.769	12.049	p=0.999
	BUFFERING CAPACITY*	7.27±1.90	5.99	8.55	8±1.48	7.0	9.0	p=0.785

*FN: Resting Flow Normal, FL: Resting Flow Low, IV: Increased Viscosity, NV: Normal Viscosity, CI: Confidence Interval, LB: Lower Bound, UB: Upper Bound. * Buffering capacity values represent a score determined by the measurement system, ranging from 0 to 12, with higher scores indicating greater buffering capacity.*

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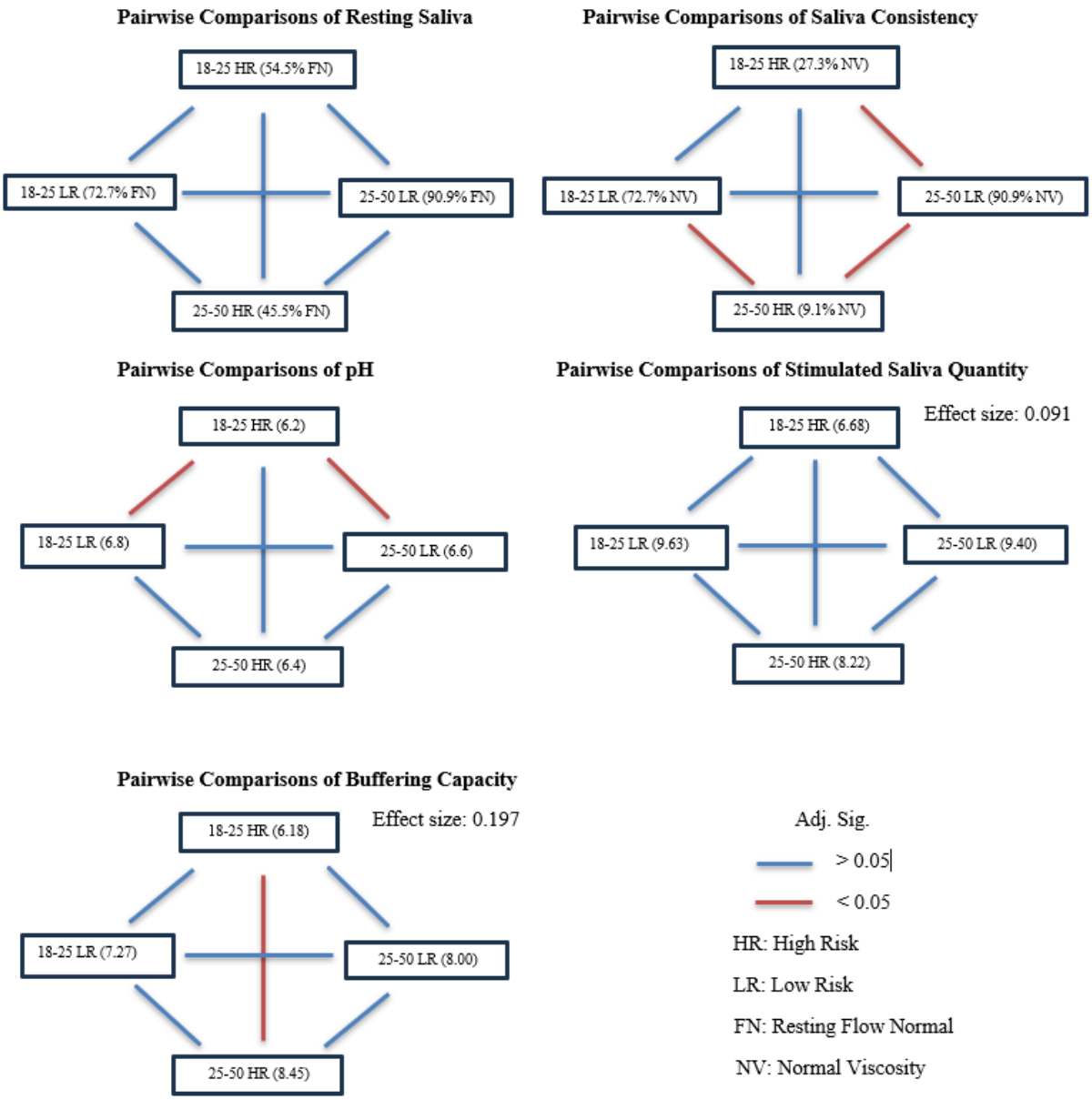


Figure 3. *Significance of the values obtained between groups.*

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Discussion

The aim of this study was to determine the effect of the physicochemical properties of saliva on caries risk across different age groups. The hypotheses formulated for this purpose were addressed using the following data. No significant difference in buffering capacity was observed between the young and adult age groups; therefore, the first hypothesis was accepted. However, the buffering capacity of patients aged 25–50 years in the high-risk group was significantly higher than that of patients aged 18–25 years in the same group. In contrast, no significant difference was found between the age groups within the low-risk group. Thus, the second hypothesis was partially accepted. Since no significant difference was found in salivary flow rate between the groups, the third hypothesis was also accepted.

In this study, the decision to divide participants into two age groups (18–25 and 25–50 years) was based on the understanding that significant physiological and behavioral changes occur between these life stages. The 18–25 age group typically represents a period of optimal oral health, whereas individuals aged 25–50 may begin to show early signs of age-related changes in oral health. These age groups were selected to better capture potential differences between individuals at distinct developmental stages. The age distribution within these groups contributed to an overall mean age of 26.4 years. The mean age for the 18–25 group was 21.2 years, and 31.6 years for the 25–50 group. Although both groups contained an equal number of participants (22 each), the narrower age range in the younger group contributed to the lower overall mean age.

Clinically, saliva refers to “whole saliva,” which includes secretions from salivary glands, gingival exudates, microorganisms and their by-products, epithelial cells, food debris, and traces of nasal exudate (19). Saliva plays a vital role in maintaining long-term dental health. The salivary bicarbonate buffer system is responsible for rapid acid neutralization (10). Salivary flow rate and buffering capacity are crucial for regulating the oral microbiota by preventing microbial colonization and buffering or eliminating acids produced in the mouth (20).

In this study, parameters such as salivary flow rate, pH, viscosity, and buffering capacity—each potentially influencing caries risk—were evaluated. Previous studies on the relationship between salivary properties and caries prevalence in adults have reported conflicting results (21–24). This study aimed to examine the impact of salivary characteristics on caries risk in young and adult populations.

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Zero *et al.* (2) emphasized that age should be considered when evaluating caries risk factors. While some studies reported a significant association between salivary flow rate and caries risk (23, 25), a study conducted in 2020 on patients aged 19–65 years found no such relationship (26). Similarly, in the present study, no significant relationship was found between salivary flow rate and caries risk. The discrepancy may stem from the fact that previous studies showing significant associations often included patients with systemic conditions such as Sjögren's syndrome or asthma, while our study population consisted of healthy individuals. This suggests that while pathologically low salivary flow rates may increase caries risk, physiological variations do not appear to have the same effect.

Salivary ions, along with salivary proteins, contribute to the viscoelastic structure of saliva. This structure aids digestion, enhances antimicrobial defense, and facilitates taste perception (27). Previous research has identified a significant relationship between salivary viscosity and the number of decayed, missing, and filled teeth (28). Increased cariogenic activity in viscous saliva may be attributed to decreased flow rate, reduced clearance ability, and lower buffering capacity (29, 30).

In this study, current DMFT scores were used to determine patients' caries risk status. In addition to the effects of salivary parameters on caries development, one study suggested a feedback loop in which existing carious lesions reduce salivary quality, while treating caries improves it (31). This finding highlights the importance of completing restorative treatments and improving oral hygiene to enhance salivary quality, particularly in high-risk individuals. In our study, salivary viscosity was found to be higher in the high-risk group compared to the low-risk group in both age categories. While no significant difference in caries risk was found in young patients (18–25 years), a significant difference was observed in adults (25–50 years). These findings support the presence of a relationship between salivary viscosity and caries risk.

Salivary buffer systems are responsible for maintaining acid–base balance in the oral environment (32). Generally, buffering capacity is inversely related to microbial attack and, by extension, caries risk (30). Several studies have shown that incorporating tests for salivary buffering capacity into dental assessments can help predict caries risk and guide treatment in high-risk individuals (33–35). However, buffering capacity may lose its predictive value when the unstimulated salivary flow rate is low (32).

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As expected, buffering capacity values in the high-risk group were lower than those in the low-risk group, though the difference was not statistically significant. The lowest buffering capacity was recorded in patients aged 18–25 in the high-risk group. Interestingly, the highest buffering capacity was observed in patients aged 25–50 within the same risk group. This unexpected result may be due to the accumulation of DMFT scores with age, including patients with good oral hygiene in the high-risk group. These findings are consistent with previous research indicating that salivary quality improves after restorative treatment (31). However, the fact that the group with the lowest unstimulated salivary flow rate was also the 25–50-year-old high-risk group supports the argument that buffering capacity may be ineffective when salivary flow is low (32).

The findings of this study have practical implications for dental practice. Understanding the physicochemical properties of saliva—particularly buffering capacity and viscosity—can offer valuable insights into individual caries risk and support more personalized prevention and treatment strategies (10). Routine evaluation of salivary buffering capacity during dental examinations may help identify high-risk patients who could benefit from additional preventive measures, such as fluoride therapy or dietary counseling to reduce acid exposure (36). This approach may be especially important for younger individuals, as the lowest buffering capacities in our study were found in high-risk patients aged 18–25 years.

Incorporating the monitoring of salivary viscosity into caries risk assessment protocols could further improve clinical decision-making (37). Elevated viscosity, associated with reduced clearance and buffering ability, was significantly related to caries risk in our study. Clinicians might consider recommending strategies such as increased hydration, the use of saliva-stimulating agents (e.g., sugar-free gum), or dietary modifications to help manage viscosity in high-risk individuals (38).

Furthermore, the study underscores the bidirectional relationship between caries and salivary quality. This highlights the importance of promptly addressing active carious lesions to improve the protective properties of saliva. For high-risk patients, a comprehensive management approach—including restorative treatment, improved oral hygiene practices, and the use of remineralizing agents—may lead to better salivary health and reduced caries risk over time (39).

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By integrating salivary diagnostics into routine dental care, clinicians can implement more targeted caries prevention and management strategies. Such approaches have the potential to improve oral health outcomes and reduce the long-term need for restorative treatments (40).

The assessment of salivary physicochemical properties—especially viscosity and buffering capacity—provides valuable information about caries risk. Integrating these parameters into clinical protocols could enhance prevention strategies and improve patient outcomes (37). Although this study offers important insights into the relationship between saliva and caries risk within a defined population in Turkey, its generalizability is limited due to the homogeneity of the sample and its rural setting. Participants primarily relied on public health services and had relatively uniform socioeconomic and lifestyle characteristics, which limits the applicability of the results to more diverse populations. Future research should include multi-center studies with larger and more heterogeneous samples from various regions and socioeconomic backgrounds to better understand these associations and confirm the broader relevance of the findings.

Conclusion

No significant difference was observed between the groups in terms of salivary flow rate. However, viscosity values were higher in patients in the high-risk group compared to those in the low-risk group. Additionally, salivary pH was lower in high-risk patients across both age groups. As expected, buffering capacity was generally lower in the high-risk group, with the exception of one subgroup. The findings of this study suggest that both oral hygiene habits and individual salivary characteristics play a significant role in determining caries risk and the development of new carious lesions. Overall, the results support the conclusion that dental caries is a multifactorial disease influenced by physiological factors such as saliva composition, in addition to behavioral factors like oral hygiene practices.

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Türkçe öz: *Çürük yatkınlığı ile tükürük özellikleri arasındaki ilişkinin araştırılması. Amaç: Diş Hekimliği Fakültesi Restoratif Diş Tedavisi Bölümü' ne başvuran hastalarda Çürük-Kayıp-Restorasyonlu Diş (DMFT) skorları ile çürük aktivitesi ve tükürük özellikleri (akış hızı, pH ve tamponlama kapasitesi) arasındaki ilişkiyi araştırmak. Gereç ve Yöntem: Çalışmaya kliniğimize başvuran 18-50 yaş arası yüksek ve düşük çürük riski taşıyan toplam 44 hasta dahil edilmiştir. DMFT skorunun 8'in üzerinde olması ve ağızda iki aktif çürük ile kaviteleşmiş lezyon (ICDAS II Kategori 5 veya 6) bulunması yüksek çürük riski olarak kabul edilmiştir. Bunun yanı sıra ağızda beş veya daha az sayıda çürük ya da restore edilmiş diş bulunması ve aktif çürük bulunmaması düşük çürük riski grubuna dahil edilme kriteri olarak belirlenmiştir. Tükürük toplama işlemleri, tedavi öncesinde gerçekleştirilmiştir. Tükürük örneklerinin akış hızı, pH ve tamponlama kapasitesi Saliva-Check Buffer Kit (GC Europe, Leuven, Belçika) kullanılarak ölçülmüştür. Ölçülen çürük aktivitesi sonuçları ile tükürük tamponlama kapasitesi arasındaki korelasyon, ANOVA ve Kruskal-Wallis testleri kullanılarak analiz edilmiştir. Ayrıca, çiftler arası karşılaştırmalar için Tukey ve Mann-Whitney U testleri kullanılmıştır ($p < 0.05$). Bulgular: En yüksek tamponlama kapasitesi değerleri 25-50 yaş arası yüksek risk grubunda, en düşük tamponlama kapasitesi değerleri ise 18-25 yaş arası yüksek risk grubunda saptanmıştır ($p=0.028$). Hem uyarılmış hem de uyarılmamış tükürük akış hızları açısından gruplar arasında anlamlı bir fark bulunmamıştır ($p=0.657$). Sonuç: Patolojik durumlar dışında, fizyolojik olarak düşük tükürük akış hızının çürük riski üzerinde anlamlı bir etkisi olmadığı gözlemlenmiştir. Bununla birlikte, tükürük faktörleri ile çürük riski arasındaki ilişki, tükürük akış hızının çok düşük olduğu durumlarda daha belirgin hale gelmiştir.*
Anahtar Kelimeler: tükürük, tamponlama kapasitesi, çürük riski, akış hızı, pH

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Ethics Committee Approval: This study was conducted with the approval of the Kocaeli University Non-Interventional Clinical Research Ethics Committee (Project No: GOKAEK-2024/17.06).

Informed consent: Detailed written informed consent was obtained from the participants or their legal guardians prior to the study.

Peer-review: Externally peer-reviewed.

Author contributions: MOT, VT participated in designing the study. MOT, ES, GY, VT participated in generating the data for the study. MOT, GNC, VT participated in gathering the data for the study. MOT, ES, VT, NT participated in the analysis of the data. MOT, ES wrote the majority of the original draft of the paper. MOT, ES, GY, GNC, VT, NT, ST, MD participated in writing the paper. MOT, ES, GY, GNC, VT, NT, ST, MD has had access to all of the raw data of the study. MOT, ES, VT, NT has reviewed the pertinent raw data on which the results and conclusions of this study are based. MOT, ES, GY, GNC, VT, NT, ST, MD have approved the final version of this paper. MOT, ES, GY, GNC, VT, NT, ST, MD guarantees that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

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