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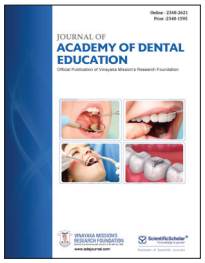

Original Article

The influence of smoking habits on the salivary pH value

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ABSTRACT

Objectives: Saliva plays an important role in oral homeostasis by maintaining the pH value of the oral cavity in the range between 6.1 and 7.8. A lower salivary pH presents a risk factor for various oral diseases. Nicotine from cigarettes reduces the bicarbonate buffer secretion, which leads to a decrease in the salivary pH. The objective of the current research was to estimate the influence of smoking habits on salivary pH value.

Material and Methods: Sixty subjects participated in the study and were divided into two groups: Smokers and non-smokers. Each participant in the study independently filled out the questionnaire concerning their medical condition, medication, and smoking habits. From each participant, unstimulated saliva was collected under resting conditions using the simple drooling method. The paper strip was dipped into the saliva for 5 s, removed, and then, after 15 s, the color change was matched directly with the scale provided with the strip, according to the manufacturer's instructions. Data were analyzed using the Wilcoxon two-sample and Kruskal–Wallis tests, at a significance level of $P \leq 0.05$.

Results: The results showed a significant decrease ($P < 0.001$) in the mean salivary pH in smokers (5.97 ± 0.27) compared to non-smokers (6.92 ± 0.17), with no difference in salivary pH found between subjects smoking standard cigarettes and those smoking electronic cigarettes ($P = 0.6306$). The subjects consuming tobacco for more than 35 years had a significantly lower mean salivary pH ($P = 0.0003$). No significant difference was found in the salivary pH based on the daily number of smoked cigarettes ($P = 0.7338$).

Conclusion: Long-term smoking of cigarettes significantly reduces the salivary pH. The consumption of standard and electronic cigarettes reduces the salivary pH without a significant difference, whereas the daily number of cigarettes had no effect.

Keywords: Electronic cigarettes, Non-smoker, Salivary pH, Smoker, Standard cigarettes

INTRODUCTION

For the oral homeostasis maintenance, saliva has an important role, mainly by retaining the moisture of the oral cavity, enabling self-cleaning, stabilizing the bacterial flora, protecting the integrity of oral tissues, and maintaining acid-base balance.[1,2] Under physiological conditions, the pH value of the oral cavity during the day ranges from 6.2 to 7.6, which depends on the creation, removal, and neutralization rate of acidic products.[3,4] Frequent consumption of carbohydrates and increased numbers of acidogenic bacteria increase the lactic acid formation rate.[5,6] Increased secretion of saliva contributes to faster dilution of acids, and saliva buffer neutralizes them.[7,8]

Saliva has a significant role in oral health maintenance by adaptation of pH levels. The alteration of some saliva characteristics can lead to abnormal changes in the oral environment, causing

plaque and calculus formation as risk factors for gingivitis and periodontitis.[9,10] Factors that reduce the pH value of saliva are an increased number of acidogenic bacteria, the presence of dental plaque, reduced saliva secretion, reduced buffering capacity, as well as the presence of certain substances, such as nicotine from cigarettes, which potentiate the factors mentioned above.[1,4,5,11]

During cigarette consumption, nicotine is absorbed through the mucous membrane of the oral cavity. It reaches the salivary glands through the blood, affecting the decrease in the production of bicarbonate buffer, which leads to (and consequently) a decrease in the salivary pH value.[7]

The aim of this study was to investigate the impact of smoking habits on salivary pH among a selected adult population of the municipality of Pancevo, Serbia, who were indicated dental treatment.

MATERIAL AND METHODS

The research was conducted at the Faculty of Dentistry in Pančevo, in February 2024, on a sample of patients referred for dental examination and treatment. The sample size was calculated after the preliminary salivary pH evaluation before the study, among 10 volunteers (5 non-smokers and 5 smokers). Estimated mean values were 7.01 and 6.71, respectively. With a standard deviation of 0.29, a margin of error set to 0.05, and a power of 0.9, the calculation revealed that 40 respondents were recommended to perform the study.

Healthy individuals aged over 18 who reported smoking standard or electronic cigarettes for at least a year and those who had never smoked, were included in the study. Exclusion criteria were the self-reported presence of active disease, oral and salivary gland disease, pregnancy, usage of inhaler treatments, antibiotics, probiotics, steroids, and non-steroidal anti-inflammatory drugs within the past month, and chronic consumption of alcoholic drinks. Former smokers and dual smokers (those who smoke both tobacco and electronic cigarettes) were also excluded. The final study sample included 60 adult respondents (26 males, 34 females), divided into two groups: Smokers and non-smokers.

The purpose and protocol were explained in detail to the respondents, and they confirmed with written consent to participate in the research as volunteers. The study procedures were conducted in complete accordance with the World Medical Association`s Declaration of Helsinki and after approval by the "Ethics Committee for Research, Faculty of Dentistry in Pancevo" (32/2–2024).

Each participant in the study independently filled out the questionnaire. The data obtained based on the survey questionnaire were gender, age, medical condition (metabolic, degenerative, congenital, infectious disease, oral and salivary gland disease), medication (inhaler treatments, antibiotics, probiotics, steroids, and non-steroidal anti-inflammatory drugs), potential pregnancy, whether they smoke, what type of cigarettes (standard or electronic), for how long, how often, and how many cigarettes per day they smoke. For the purpose of saliva collection and salivary pH measurement, subjects were asked not to consume anything (food, drink, water, cigarettes, or chewing gum) for 30 min before the examination. The examination was performed from 9 am to 12 pm to avoid daily variations in saliva secretion. Approximately 1.0–1.5 mL of unstimulated saliva was collected under resting conditions using the simple drooling method. Participants were instructed to sit on a dental chair in the coachman position, to allow the accumulation of saliva in the floor of the mouth and let the saliva drop into a plastic tube. The same examiner performed the pH value determination using a paper strip (pH Test Strips; Lohand Biological; China). The test strip was dipped into the saliva for 5 s, removed, and then after 15 s the color change was matched directly with the scale, which was provided with the strip, according to the manufacturer's instructions.

Statistical analyses were done using the Statistical Analysis System (SAS) statistical package (SAS Institute, 2010). The mean, minimum, and maximum values and the percentage share of each category were calculated from the descriptive indicators. Furthermore, the standard deviation was presented to estimate the variation. To test the statistical significance of the differences between two or three different groups, a two-sample Wilcoxon test and a Kruskal–Wallis test with a significance level of $P \leq 0.05$ were used.

RESULTS

A total of 60 respondents participated in the research, 26 (43.33%) male and 34 (56.67%) female. The youngest respondent was 20 years old, and the oldest was 67 years old. The average age of the respondents was 33.15 years [Table 1].

Of the total number of respondents, 56.67% were smokers, of whom about 3/4 smoke standard cigarettes, and only 1/4 smoke electronic cigarettes [Table 2].

The mean salivary pH in the non-smokers' group was 6.92 and in the smokers' group 5.97 [Figure 1].

According to the Wilcoxon two-sample test, smokers have a statistically significantly lower mean salivary pH (5.97 ± 0.27) than non-smokers (6.92 ± 0.17), $P < 0.0001$. Furthermore, both standard cigarettes (5.96 ± 1.20) and electronic cigarettes (6.00 ± 0.00) smokers have a statistically significantly lower salivary pH compared to non-smokers (6.92 ± 0.17), $P < 0.0001$, while no difference in salivary pH was found between standard cigarettes and electronic

Table 1: Structure of respondents by gender and age.

Respondents	*n*	Percentage	Age		
			Mean±standard deviation	Minimum	Maximum
Males	26	43.33	34.62±16.63	20	67
Females	34	56.67	32.03±13.15	22	56
Total	60	100	33.15±14.68	20	67

Table 2: Distribution of respondents by group.

Group	*n*			Percentage		
	Σ	Male	Female	Σ	Male	Female
Non-smokers	26	13	13	43.33	21.67	21.67
Smokers	34	13	21	56.67	21.67	35.00
Standard cigarettes	26	13	13	43.33	21.67	21.67
Electronic cigarettes	8	0	8	13.33	0	13.33

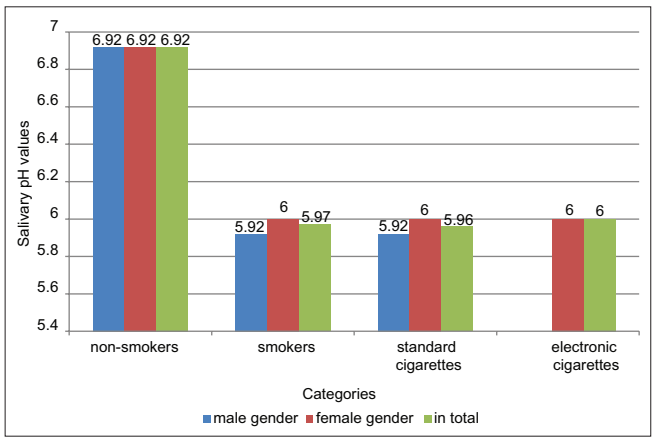

Figure 1: Mean values of salivary pH by groups.

cigarettes smokers (P = 0.6306). There was no statistically significant difference in salivary pH between smokers and non-smokers based on gender or age (both P = 0.2347) [Table 3].

Among smokers, no significant difference in salivary pH values in relation to the number of cigarettes consumed per day (P = 0.7338) was found. Regarding the length of smoking experience, the Kruskal–Wallis test showed that respondents who have smoked cigarettes for more than 35 years have a statistically significantly lower mean value of salivary pH (5.50 ± 0.71), P < 0.0001 [Table 4].

DISCUSSION

It is well known that oral environment homeostasis is largely dependent on saliva. Saliva consists of 99% water; however, its physicochemical properties are determined by the presence of inorganic and organic substances, which could be affected by many factors, such as genetic disorders, diabetes, and smoking. Previous studies have documented that various chemical compounds found in tobacco smoke or e-cigarette vapor are dissolved in saliva and affect its biochemical composition and function.[12]

The result of the present study coincides with the results of Singh's *et al.* and Rehan's *et al.* research, where it was obtained that there is a significant salivary pH decrease in smokers compared to non-smokers using pH paper indicators.[5,13] Furthermore, the results agree with studies that used other methods.[1,7] Such findings were expected, bearing in mind that nicotine is absorbed through the mucosa of the oral cavity and reaches the salivary glands through the blood, affecting the reduction of bicarbonate buffer and the consequent decrease in the pH salivary value.[7] Furthermore, it should be considered that during the consumption of hot smoke, there is a drying of the oral cavity and the creation of a suitable environment for acidogenic bacteria, whose activity will also lead to the creation of an acidic environment.[14] Another explanation could be that smoking leads to a decrease in the enzymatic activity of salivary proteins, such as lactate dehydrogenase, salivary amylase, and acid phosphatase.[15]

However, it should be mentioned that in some previous studies, besides the low average pH value of salivary pH value of smokers, no statistically significant difference was observed.[6] The authors questioned the correctness of the indicator for salivary pH as well as the time of its testing. There are also studies in which a higher average pH salivary value was recorded among smokers. In the research done by Al-Weheb *et al.*, it was found that the pH in smokers was higher (7.32) than in non-smokers (7.27).[16] Here, it should be considered that the research was conducted on young people, aged 24–29 years. Furthermore, the time of sample collection should be questioned, as well as the fact that the subjects consumed chewing gum 30 min before the test, to collect stimulated saliva, which are all factors that could affect saliva pH values.

The results of the present study revealed that smoking electronic cigarettes significantly lowers the pH value of saliva. This result can be explained by the presence of chemicals in the steam of electronic cigarettes, such as aldehydes, which alter the saliva's physical and chemical properties.[15] On the other hand, no significant difference in salivary pH was determined

Table 3: Differences in salivary pH by groups.

Comparison groups	Number of respondents	Salivary pH-value Mean±standard deviation	Wilcoxon two-sample test (Z)	*P*-value
Non-smokers	26	6.92±0.17	7,0950	<0.0001
Smokers	34	5.97±0.27		
Non-smokers	26	6.92±0.17	5.71912	<0.0001
Standard cigarettes	26	5.96±1.20		
Non-smokers	26	6.92±0.17	3.87729	<0.0001
Electronic cigarettes	8	6.00±0.00		
Standard cigarettes	26	5.96±1.20	0.4854	0.6306
Electronic cigarettes	8	6.00±0.00		
Male non-smokers	13	6.92±0.28	0.0000	1.0000
Female non-smokers	13	6.92±0.28		
Male smokers	13	5.92±0.28	−1.2105	0.2347
Female smokers	21	6.00±0.00		
Non-smokers <29	16	6.93±0.25	−0.2853	0.7778
Non-smokers >30	10	6.90±0.32		
Smokers <29	21	6.00±0.00	−1.2105	0.2347
Smokers >30	13	5.92±0.28		

Wilcoxon two-sample test, values of $P \leq 0.05$ are statistically significant

Table 4: Differences in salivary pH values among smokers.

Comparison groups	Number of respondents	Salivary pH-value Mean±standard deviation	Kruskal-Wallis	DF	*P*-value
Cigarettes per day					
<10	2	6.00±0.00	0.2963	2	0.7456
Around 15	11	6.00±0.00			
>20	21	5.95±0.22			
Smoking experience					
5–20 years	22	6.00±0.00	14.5882	2	<0.0001
21–35 years	10	6.00±0.00			
36–50 years	2	5.50±0.71			

Kruskal-Wallis test, values of $P \leq 0.05$ are statistically significant

between standard cigarettes and electronic cigarettes smokers, although electronic cigarettes are presented to the market as an alternative and healthier option for nicotine consumption.[17-19] Those results coincide with the recent study conducted by Hasan *et al.*[15] However, it should be considered that for the reasons mentioned above, people who consume this type of cigarette are usually former smokers of standard cigarettes, so it was difficult to determine the direct influence of electronic cigarettes on pH salivary values.

Statistical analysis showed no significant difference in the pH salivary value depending on the number of daily consumed cigarettes. A possible explanation could be found in the fact that the majority of respondents in the present study smoke more than 10 cigarettes/day. On the other hand, Pancu *et al.* revealed a noticeable drop in pH value among smokers who consume more than 10 cigarettes/day.[20]

In the present study, subjects who smoked for more than 35 years had a significantly lower salivary pH value than other smokers. Their average salivary pH value was 5.5, which represents a critical value not only for the beginning of the decomposition of hydroxyapatite crystals but also increases the risk of other oral diseases. Singh *et al.* offered the explanation that the decrease in salivary flow rate among long-term smokers has an impact on lower salivary pH values due to a decrease in bicarbonate secretion.[5] Furthermore, it should be considered that the consumption of nicotine over a long period leads to

the activation of cholinergic receptors in the brain and other organs, which causes a change in the secretion of saliva itself.[21] In addition to affecting cholinergic receptors, chronic exposure to tobacco smoke alters and suppresses taste receptor function, leading to a reduction in salivary flow rate[22]

Potential shortcomings of this study could be considered. The comparison was based solely on data related to smoking habits, and subjects were not clinically examined for the presence of periodontitis and dental caries, which could also have an impact on the salivary pH values.[23,24] Out of all the properties of saliva, only the pH value was examined. To obtain even more reliable data on the impact of cigarette consumption, other physicochemical properties such as flow rate, buffering capacity, and enzymatic activity should also be assessed in future studies. The next research should include factors such as the amount of nicotine marked on the pack of cigarettes and a larger sample of nicotine-free electronic cigarette smokers. In addition, using digital pH meters or other precise analytical methods could improve accuracy. Furthermore, in the future, a longitudinal investigation would be recommended.

CONCLUSION

The study showed that long-term cigarette smoking was associated with significantly lower salivary pH values. The consumption of standard and electronic cigarettes reduced the salivary pH without a significant difference. The number of daily consumed cigarettes, gender, and age did not affect the salivary pH value.

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Ethical approval: The research/study was approved by the Institutional Review Board at the Ethics Committee for Research, Faculty of Dentistry in Pancevo, number 32/2-2024, dated 26th January 2024.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent.

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