



# Effects of Oral pH Changes on Smoking Desire

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**Background:** Nicotine addiction is associated with nicotine absorption from the buccal mucosa, and it is stated that the main factor that determines nicotine absorption is saliva pH. In the literature, the effects of changes in saliva pH values after eating and drinking on smoking desire in smokers were not questioned.

**Aim:** To show the effect of saliva pH changes on smoking desire. The secondary aim was to show the impact of coffee and water drinking on saliva pH and smoking on oral-dental health (oral hygiene and gingival bleeding).

**Study Design:** Case-control study.

**Methods:** A questionnaire was administered that included "Socio-demographic Data Form" and smoking history and Fagerström Test for Nicotine Dependence (FTND). Oral and dental examinations were performed with mirror sonds and using oral hygiene standard Silness and Leøe plaque index and DMFT Index (Index of Decayed Missing or Filled Teeth). Untreated saliva samples were taken, and baseline saliva flow rate and pH values were measured. To assess pH changes, saliva pH was remeasured after sugar-free instant coffee and water consumption. Smoking desire was evaluated with the Visual Analog Scale (VAS).

**Results:** In this study, 24 (55.8%) females and 19 (44.2%) males were among the 43 smoking and 39 nonsmoking cases. Smoking was significantly associated with poor oral hygiene (in smokers 4.71 ( $\pm$ 1.40), in non-smokers 2.30 ( $\pm$ 1.59);  $P < .01$ ). DMFT index was higher in smokers than in non-smokers (in smokers 6.45 ( $\pm$ 3.69), in non-smokers 3.87 ( $\pm$ 2.67);  $P < .01$ ). Gingival bleeding was more prevalent in smokers (0.68 ( $\pm$ 0.76)) than non-smokers (1.20 ( $\pm$ 0.90);  $P = .009$ ). Salivary flow rates were lower in smokers (in smokers 2.56 ( $\pm$ 1.34), in non-smokers 3.00 ( $\pm$ 1.22),  $P = .06$ ). In both groups, pH values increased after coffee consumption and decreased after water; in smokers basal: 6.67 ( $\pm$ 0.41), pH coffee: 6.93 ( $\pm$ 0.36), pH water: 6.85 ( $\pm$ 0.33); in non-smokers pH basal: 6.84 ( $\pm$ 0.37), pH coffee: 7.02 ( $\pm$ 0.37), pH water: 6.97 ( $\pm$ 0.31),  $P < .01$ . The VAS values of smokers at basal 4.73 ( $\pm$ 3.21);  $P < 0.01$ , after coffee consumption 4.91 ( $\pm$ 3.08);  $P < .01$ , and after water 3.15 ( $\pm$ 2.72);  $P < .01$ .

**Conclusion:** The saliva pH increased after coffee consumption and decreased after drinking water. Besides, VAS values decreased significantly after drinking water. The results suggest that a simple behavior such as drinking water may be used in conjunction with behavioral and cognitive therapies to pursue smoking cessation.

## INTRODUCTION

Nicotine addiction is the most common disease of our societies, and it can be treated with medical methods, such as other diseases.<sup>1</sup> Pharmacotherapy with proven scientific efficacy and cognitive and behavioral treatments play an important role in reducing smoking.<sup>2</sup> In this context, it is recommended to question the daily behavior patterns and ensure the person's motivation, identify the factors that trigger the desire to smoke, develop methods to combat them, and organize them in ordinary activities, including eating and drinking.

It can be observed that there is an increase in the desire to smoke during drinking tea and coffee and after meals. Consumption of

acidic foods makes the oral pH acidic, and saliva increases to neutralize it. Caffeine is another psychostimulant found in varying proportions in coffee and tea, and its stimulating effects on the locomotor system are antagonistic at the level of adenosine receptors.<sup>3</sup> It has been reported that smokers consume more caffeine than non-smokers.<sup>4</sup> However, this effect may not be solely due to the pharmacological effects of caffeine but also that the desire to smoke is caused by a change in pH in the mouth. In a study by Parvinen et al., saliva pH was lower in smokers than in non-smokers.<sup>5</sup> It was also reported that saliva secretion capacities were decreased as well.

The amount of nicotine and the absorption rate from the buccal mucosa significantly affect the risk of addiction. In addition to oral

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pH, other factors such as local blood flow, moisture of product and size of the surface area of the tobacco mixture, pH constant holding capacity, and nicotine content of tobacco may affect nicotine absorption. Various absorption-enhancing substances have been investigated to facilitate the absorption of nicotine from the buccal mucosa. It has been shown that increased pH (alkaline) increases the absorption and physiological effects of nicotine by buffering moist snuff products and nicotine gums to alkaline pH. Although other factors may affect the nicotine absorption rate in the mouth, the main factor that determines the absorption rate of nicotine is stated to be pH.<sup>6-8</sup>

There are studies comparing nicotine products containing different amounts of nicotine. However, changes in saliva pH values after eating and drinking on smoking desire in the smokers were not questioned. The relation between pre- and post-coffee/water saliva pH and smoking desire has not been investigated. In this study, the main aim was to examine the effects of changes in the saliva pH values on smoking desire and the impact of water drinking action on the urge to smoke. The secondary aims were to show the effects of coffee and water drinking behavior on saliva pH and smoking on oral-dental health (oral hygiene, gingival bleeding).

## MATERIAL AND METHODS

### Design

This study was a case-control study. After obtaining approval from the Clinical Studies Ethics Committee (2018/09-01), smokers and non-smokers volunteers were invited to the study.

The sample size was calculated as follows. In the preliminary evaluation made before starting the study, saliva samples were taken from 5 non-smoker and 5 smoking volunteers, and pH was measured. Estimated saliva pH for the control group: 7.00, estimated saliva pH for the case group: 6.75, standard deviation 0.29; when 0.05 margin of error and 0.9 power and possible drop-out rate were considered as 10%, it was planned to enroll 35 volunteers for each group.<sup>9</sup>

The inclusion criteria were as follows: not having active disease, being between the ages of 18 and 45 years, not using antibiotics in the past 2 weeks, not using inhaler treatments, not having oral and salivary gland diseases, to be in the week after the menstrual bleeding period in women. In the control group, individuals without smoking history and any secondary smoke exposure were included. Exclusion criteria were the presence of active disease, less than 18 years or greater than 45 years of age, antibiotic use in the past 2 weeks, use of inhaler treatments, oral and salivary gland disease, menstrual irregularities in women, being in the luteal phase, pregnancy, and using hormonal therapy.<sup>10,11</sup>

### Data Collecting

A questionnaire was administered that included "Sociodemographic Data Form" and smoking history and Fagerström Test for Nicotine Dependence (FTND). The scores were classified as low (0-4 points), medium (5-7 points), and high (8-10 points) according

to the Turkish Ministry of Health, Fighting Tobacco Addiction Handbook for physicians.<sup>12-14</sup>

### Oral and Dental Examinations

Oral and dental examinations were performed with the mirror sonds. The oral hygiene standard was estimated using the Silness and Løe plaque index.<sup>15</sup> DMFT Index (Index of Decayed Missing or Filled Teeth), a method for measuring present (decayed teeth) and past (missing and filled teeth) caries experiences in permanent dentition was evaluated and also, debris, calculus, and also gingival bleeding were evaluated.<sup>16</sup>

### Saliva Collection and pH Measurement Procedure

Measurements were made at room temperature (22-25°C), in a standard environment, and in the same place. Oral and dental examinations of all the participants were performed, and saliva samples were taken 3 times; the first sample, the second sample after coffee (pH: 5.5), and the third sample after water (pH: 6.34), in a total of 30 minutes. Saliva flow rates and pH values were measured by taking saliva samples from all cases at least 1 hour after breakfast. Simultaneous Visual Analog Scale (VAS) smokers' actual smoking desire was measured (Figure 1). pH measurements were made with the table device "InoLab pH 720" (WTW, Germany). Device calibrations were made at the beginning of each measurement day and when deemed necessary.

### Visual Analog Scale

VAS is used to assess the current smoking desire. Participants put a vertical mark on a 100 mm line with "no desire to smoking" on the far left and "an excessive desire to smoking" on the far right. Measurements were made with the help of a ruler and evaluated with numbers between 0 and 10. The signs put by the participant at baseline, after coffee, and after drinking water was evaluated as increased or decreased according to whether they were on the right or left and with numerical values.<sup>17,18</sup>

### Statistical Analysis

In this study, assuming a 0.05 margin of error and 0.9 power and a possible drop-out rate of 10%, 35 volunteers were planned for each group. Forty-three volunteers in the case group and 39 volunteers in the control group were included. Continuous variables according to distribution analysis mean  $\pm$  standard deviation (SD) or median-interquartile range (IQR); categorical variables were presented as numbers and percentages. The Student's *t*-test was used to analyze the significance of independent continuous variables within and between groups. In binary analysis, Chi-square and Mann-Whitney *U*-test were used depending on the distribution of data. *P* value <0.05 was considered statistically significant.

## RESULTS

Forty-three smokers were included in the case group, and 39 non-smokers were included in the control group (Table 1). The most common reason for starting smoking was stress (22%). The second most common causes were curiosity (13.4%), followed by wannabe (12.2%). When the factors triggering smoking requests were questioned, the most frequently stated factor was after meals

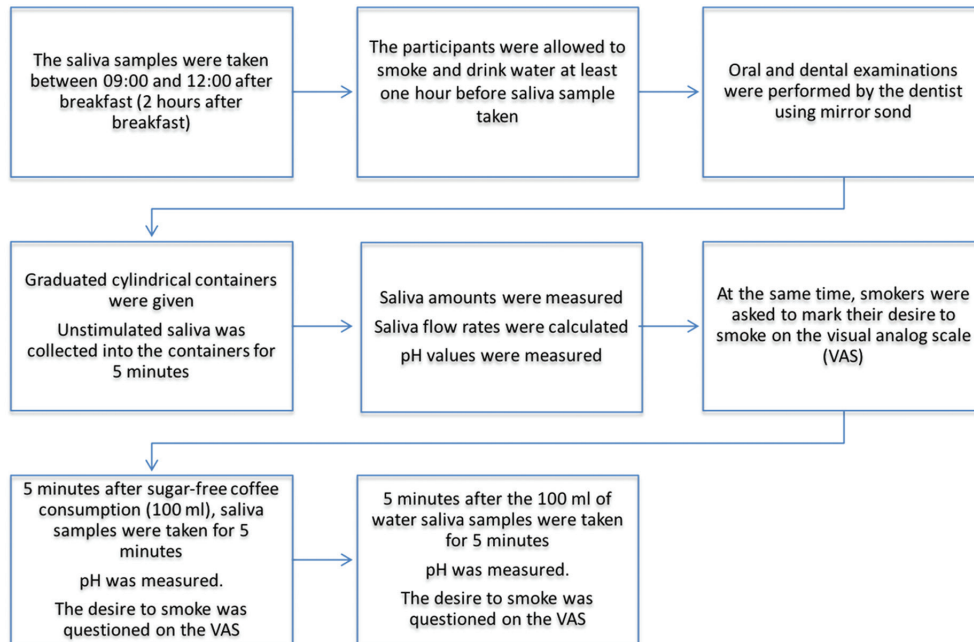


FIG. 1. Saliva collection and pH measurement procedure.

(37.8%). In addition, stress (29.3%), ambience (27.9%), alcohol (22%), coffee (19.5%), and tea (18.3%) were other trigger factors.

The oral hygiene scores, DMFT values, debris and calculus scores, and gingival bleeding values of the case and control groups are summarized in Table 2. Smoking was significantly associated with

poor oral hygiene ( $P < .01$ ). DMFT values were higher in smokers than in non-smokers ( $P < .01$ ). “M” datas indicating missing teeth were analyzed, and it was observed that there was more tooth loss in the smoker group compared to the non-smoker group (in smokers 2.62 ( $\pm 3.08$ ), in non-smokers 0.58 ( $\pm 1.18$ ),  $P < .01$ ). Also, debris and calculus values were higher in smokers than in non-smokers, and gingival bleeding was more prevalent in non-smokers than in smokers ( $P = .009$ ).

TABLE 1. General Demographic Features of Patient Population

|                      | Smokers, n (%) | Non-smokers, n (%) | P    |
|----------------------|----------------|--------------------|------|
| Age, year, mean (SD) | 32.76 (9.38)   | 28.74 (9.55)       | .056 |
| Gender, n (%)        |                |                    |      |
| Female               | 24 ( 55.8)     | 29 (74.4)          | .079 |
| Male                 | 19 (44.2)      | 10 (25.6)          |      |
| Married, n (%)       | 20 (46.5)      | 15 (38.5)          | .462 |
| Education, n (%)     |                |                    |      |
| Primary education    | 10 (23.3)      | 5 (12.8)           | .326 |
| High school          | 15 (34.9)      | 18 (46.2)          |      |
| University           | 11 (25.6)      | 7 (17.9)           |      |
| Master degree        | 7 (16.3)       | 7 (17.9)           |      |
| PhD                  | -              | 2 (5.1)            |      |
| Occupation, n (%)    |                |                    |      |
| Cleaning staff       | 7 (16.3)       | 3 (7.7)            | .307 |
| Patient care staff   | 7 (16.3)       | 2 (5.1)            |      |
| Management staff     | 3 (7)          | 4 (10.3)           |      |
| Nurse                | 6 (14)         | 3 (7.7)            |      |
| Physician            | 6 (14)         | 8 (20.5)           |      |
| Student              | 10 (23.3)      | 16 (41)            |      |
| Other                | 4 (9.3)        | 3 (7.7)            |      |

The saliva flow rates, saliva pH values and changes in the case and control groups, and VAS values in smokers are summarized in Tables 3 and 4. Although it was not statistically significant, salivary flow rates were lower in smokers ( $P = .06$ ). The smokers’ basal saliva pH values were lower than the non-smokers, but it was not statistically significant ( $P = .104$ ). In both groups, pH values increased after coffee consumption and decreased after water, and this is shown in Figure 2. The changes between  $pH_{\text{basal}}$  (pH1) and  $pH_{\text{coffee}}$  (pH2) ( $P < .01$ ),  $pH_{\text{coffee}}$  (pH2), and  $pH_{\text{water}}$  (pH3) ( $P = .019$ ) were significant as summarized in Table 4. The VAS values of smokers at basal 4.73 ( $\pm 3.21$ ) (VAS1), after coffee consumption 4.91 ( $\pm 3.08$ ) (VAS2), and after water 3.15 ( $\pm 2.7$ ) (VAS3) (Figure 3). The change between basal—VAS1 and after coffee—VAS2 was not statistically significant, but the difference between after coffee—VAS2 and after water—VAS3 was statistically significant ( $P < .01$ ) (Table 4).

### DISCUSSION

In this study, it was observed that the basal saliva pH values of the smokers were lower than non-smokers, and the pH of saliva increased after drinking an acidic beverage (pH 5.5) such as coffee. The pH of saliva decreased after drinking water in both groups.

**TABLE 2.** Oral Hygiene, DMFT, Debris, Calculus, and Gingival Bleeding in Smokers and Non-smokers

|                        | Oral Hygiene | DMFT         | Debris       | Calculus     | Gingival Bleeding |
|------------------------|--------------|--------------|--------------|--------------|-------------------|
| Smokers, mean (SD)     | 4.71 (±1.40) | 6.45 (±3.69) | 2.86 (±0.93) | 1.79 (±0.77) | 0.68 (±0.76)      |
| Non-smokers, mean (SD) | 2.30 (±1.59) | 3.87 (±2.67) | 1.52 (±1.13) | 1.06 (±0.98) | 1.20 (±0.90)      |
| <i>P</i>               | <.01         | <.01         | <.01         | <.01         | .009              |

**TABLE 3.** Saliva Flow Rate and pH Values of Smokers and Non-smokers

|                        | Saliva Flow Rate | pH Basal Saliva | pH After Coffee | pH After Water | <i>P</i> |
|------------------------|------------------|-----------------|-----------------|----------------|----------|
| Smokers, mean (SD)     | 2.56 (±1.34)     | 6.67 (±0.41)    | 6.93 (±0.36)    | 6.85 (±0.33)   | <.01     |
| Non-smokers, mean (SD) | 3.00 (±1.22)     | 6.84 (±0.37)    | 7.02 (±0.37)    | 6.97 (±0.31)   | <.01     |
| <i>P</i>               | .06              | .104            | <.01            | <.01           |          |

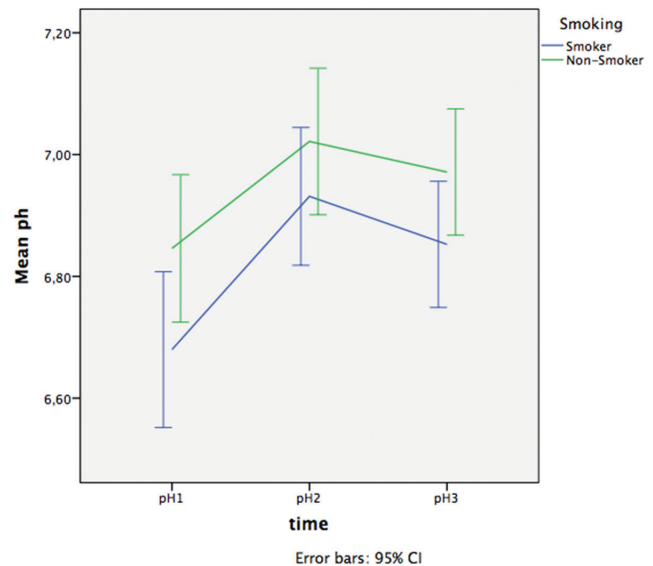
The changes between pH1 and pH2 and the changes between pH2 and pH3 were significant. Differences were observed in the VAS values that we used to evaluate the smoking desire. Changes were observed in the VAS values we used to assess the smoking desire. The difference between VAS1 and VAS2 was not observed significantly, but the difference between VAS2 and VAS3 was statistically significant. Also, it was observed that salivary flow rates were lower in smokers. As a result of evaluations for oral health, it was observed that smoking was significantly associated with poor oral hygiene. DMFT values were higher in smokers than in non-smokers. Debris and calculus values were higher in smokers than in non-smokers, and gingival bleeding was more prevalent in non-smokers than in smokers.

Nicotine absorption was studied in various commercial products with different nicotine concentrations and different pH values. It was found that higher pH products gave more nicotine than low pH products. It has been shown that nicotine is in the non-ionized form at alkaline pH and is more easily absorbed in the buccal mucosa. It is not sufficiently absorbed in the ionic form at acidic pH values.<sup>9,19,20</sup> In saliva, pH has been reported to show a rapid and temporary increase after smoking. Other studies report that the pH value is relatively lower in smokers compared to non-smokers.<sup>21</sup> However, the correlation between smoking desire and saliva pH has not been extensively studied. Our study observed that saliva pH increased after drinking coffee, but there was no significant change in smoking desire.

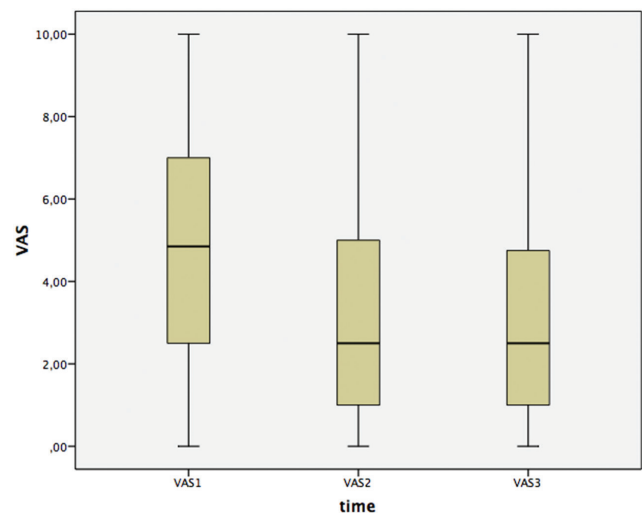
There was no statistically significant change between VAS1—basal and VAS2—after coffee, but a statistically significant decrease in VAS3 values after drinking water suggested that smoking desire was decreased. The smoking desire was assessed with VAS, which was previously described in the literature. VAS is a

**TABLE 4.** pH and VAS Changes in Smokers

|                                  | Mean (SD)                 | <i>P</i> |
|----------------------------------|---------------------------|----------|
| pH basal–pH after coffee         | 6.67 (±0.41)–6.93 (±0.36) | <.01     |
| pH after coffee–pH after water   | 6.93 (±0.36)–6.85 (±0.33) | .019     |
| VAS basal–VAS after coffee       | 4.73 (±3.21)–4.91 (±3.08) | >.05     |
| VAS after coffee–VAS after water | 4.91 (±3.08)–3.15 (±2.72) | <.01     |



**FIG. 2.** The changes of pH values, basal—pH1, after coffee—pH2, and after water—pH3, in smokers and non-smokers.



**FIG. 3.** The changes of VAS values, basal—VAS1, after coffee consumption—VAS2, and after water—VAS3, in smokers.



method that has been used in previous studies to evaluate smoking desire and is considered valid.<sup>17,18</sup> As indicated in Table 4, although VAS scores did not change with coffee consumption, a significant change was observed after water consumption decreased in VAS score, which suggests a decrease in smoking desire. These findings indicate that water consumption may reduce smoking desire in smokers; however, this finding merits more research in this area. Our study showed an increase in saliva pH values after caffeine, and at the same time, an increase in VAS values was found, but it was not found statistically significant. Participants associated this situation with their traditional preference for tea. The factors that trigger nicotine use include stress, daily routine, eating and drinking habits, and caffeine. Caffeine and nicotine interactions can be explained by neurochemical mechanisms. Caffeine is a non-selective antagonist at the level of A1 and A2A receptors. Chronic caffeine exposure has been shown to produce a change in the number and function of central adenosine receptors. Acting as an agonist at A1 and A2 receptors, adenosine inhibits the mediated effects of D1 and D2 dopamine receptors.<sup>4,22</sup> Use of nicotine with caffeine provides the potential for stimulation via the dopaminergic pathway.<sup>23</sup> studies are reporting that there is no interaction between caffeine and nicotine, and studies reporting that caffeine consumption increases the number of cigarettes smoked. However, epidemiological studies relate co-consumption of caffeine and nicotine after meals and between meals rather than pharmacological effects. It has been reported that smokers consume more caffeine than non-smokers.<sup>24,25</sup> In a study by Emurian et al., it was shown that there was more smoking in the 20 min after coffee consumption compared to the 20 min before. In other studies, it was reported that there is no interaction between caffeine and nicotine and between co-consumption of caffeine and nicotine after meals and between meals rather than pharmacological effects. And also, it was tested that increased dosage of caffeine may alter nicotine intake in smokers. As a result, it has shown an upward trend in cigarette consumption during caffeine consumption and a trend toward higher plasma nicotine levels in the low-dose caffeine group compared to the decaffeinated group.<sup>26,27</sup>

Although our results were not statistically significant, smokers were found to have lower saliva flow rates than non-smokers, similar to the literature.<sup>28,29</sup> Also, it was shown that smokers' had poor oral hygiene than non-smokers, and tooth loss was higher in smokers than non-smokers. Also, that gingival bleeding was lower in smokers than in non-smokers. Furthermore, previous studies have shown that smokers show more symptoms of periodontal disease than non-smokers.<sup>30,31</sup> Similar to our results, it was reported that bleeding was reduced in young adult smokers, regardless of plaque and calculus distribution.<sup>32</sup>

Although saliva pH increased after drinking coffee, its effect on smoking desire could not be shown statistically. However, it can be seen that drinking water lowers saliva pH values, and the desire to smoke after drinking water decreases. Drinking the appropriate amount of water during the day is a recommended healthy behavior, and regulations in our daily eating and drinking habits are thought to be an important support for smoking cessation treatments. Based

on our results, it can be said that quitting smoking is necessary for better oral and dental health. The fact that the results of this cross-sectional study we obtained in our single-center cannot be generalized for all smokers is the limitation of this study.

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**Ethics Committee Approval:** Ethics committee approval was received for this study from the Clinical Studies Ethics Committee of Dokuz Eylül University (2018/09-01), and registered at ClinicalTrials.gov (Identifier: NCT04032236).

**Patient Consent for Publication:** N/A.

**Data-sharing Statement:** The data that support the findings of this study are available from the corresponding author upon reasonable request.

**Author Contributions:** Concept - G.Ö.Ş., G.K., B.E., O.K.; Design - G.Ö.Ş., G.K., B.E., O.K.; Supervision - O.K.; Resources - G.Ö.Ş., G.K.; Materials - G.Ö.Ş., G.K.; Data Collection and/or Processing - G.Ö.Ş., G.K.; Analysis and/or Interpretation - G.Ö.Ş., B.E.; Literature Review - G.Ö.Ş., G.K.; Writing - G.Ö.Ş., G.K.; Critical Review - G.Ö.Ş., G.K., B.E., O.K.

**Conflict of Interest:** The authors have no conflicts of interest to declare.

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