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Research Article

Comparative Analysis of E-Cigarette Device Type, E-Liquid Constituents, and Daily Exposure Duration on Periodontal Inflammation and Clinical Attachment Loss

Salman Khan[1], Syeda Kinza Asghar[2], Shah Faisal[3], Qaswa Iftikhar[4], Syeda Areej Fatima[5], Resham Hafeez[6]

[1]BDS, Khyber Medical University, Peshawar, Pakistan
[2]Assistant Professor Periodontology, HBS Medical and Dental College, Islamabad, Pakistan
[3]BDS, DCD (Periodontology), Khyber College of Dentistry, Peshawar, Pakistan
[4]Rashid Latif Dental College, Lahore, Pakistan
[5]BDS, c Endo Esthetic Physician, Watim Medical College, Rawalpindi, Pakistan
[6]Associate Professor Periodontology, Avicenna Dental College, Lahore, Pakistan

Corresponding author: Salman Khan,
BDS, Khyber Medical University, Peshawar, Pakistan, **Email**: salmansheh.ss@gmail.com

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ABSTRACT

This study aimed to conduct a comparative analysis of how various types of e-cigarette devices, e-liquid components, and e-cigarette exposure duration influence periodontal inflammation and clinical attachment loss in adult users. The sample comprised 100 participants in a cross-sectional study, who were recruited using a stratified random sampling method according to the type of device and length of use. Data were collected done using a structured questionnaire, where demographic attributes, e-cigarette device type, e-liquid composition (nicotine concentration and flavouring agents), and the duration of exposure per day were recorded. Clinical periodontal evaluation was conducted using the Plaque Index (Silness and Loe), Gingival Index (Loe and Silness), probing pocket depth, and clinical attachment level measurements at six points per tooth. The relationships between vaping-related variables and periodontal outcomes were statistically analyzed. This research is likely to provide an understanding of the impact of changes in e-cigarette consumption patterns on periodontal health and add to the evidence-based recommendations for dental practitioners on the potential periodontal risks associated with the use of e-cigarettes.

Keywords: Electronic Cigarette, Periodontal Inflammation, Exposure, Attachment

INTRODUCTION

Electronic cigarettes (e-cigarettes), also known as electronic nicotine delivery systems (ENDS), were first introduced at the beginning of the 2000s and have become extremely popular substitutes for traditional tobacco smoking. These devices operate by heating an e-liquid, which containing propylene glycol, vegetable glycerine, nicotine, and other flavouring substances to produce an inhalable aerosol. Even though e-cigarettes seem to be a safer choice when it comes to the delivery of nicotine, evidence is starting to accumulate showing that their consumption is connected with negative effects on both systemic and oral health (Grana et al., 2014; World Health Organization, 2016).

Periodontal disease is an inflammatory disease with a chronic course, which is associated with the loss of supporting tooth structures: gingiva, periodontal ligament, and alveolar bone. Pathogenesis is a complicated interplay between the biofilm of microorganisms and the host immune system. Periodontal disease is already an established risk factor associated with tobacco smoking, which increases the severity of the disease as well as impairs the healing process, accompanied by poor treatment outcomes (Bergstrom, 2004; Johnson and Guthmiller, 2007). Because nicotine is usually delivered by e-cigarettes, there are fears that the device may contribute to the breakdown of periodontal tissues. It has been demonstrated that nicotine has vasoconstrictive properties and decreases gingival blood circulation, neutrophil function, and fibroblast activity, which impairs periodontal defence systems and wound healing (Palmer et al., 2005; Nociti et al., 2015). In addition to nicotine, e-cigarette aerosols contain carbonyl compounds, metals, and flavouring chemicals that can cause oxidative stress and inflammation in the oral tissues (Sundar et al., 2016; Pushalkar et al., 2020). Recent clinical and epidemiological studies have revealed that the use of e-cigarettes was linked to worse periodontal parameters, such as more plaque accumulation, gingivitis, probing pocket depth, and clinical attachment loss, compared to

non-users (Al-Aali et al., 2018; Javed et al., 2019). Although certain studies have indicated that periodontal destruction in e-cigarette smokers might be a weaker phenomenon than that in traditional cigarette smokers, the risk is still higher compared to that in never-smokers (Ganesan et al., 2020).

The nature of the devices and how they are used may also affect periodontal outcomes. Powerful devices and time spent using the device daily are related to aerosol generation and nicotine delivery, potentially worsening inflammatory reactions in periodontal tissue (Farsalinos et al., 2018). The same has been applied to changes in e-liquid components, especially the concentration of nicotine and flavour additives which have been linked to different biological responses in gingival cells and the oral microbiome (Reinikovaite et al., 2018; Pushalkar et al., 2020).

Changes in the oral microbiome of e-cigarette users have also been documented, and periodontopathogenic bacteria and dysbiosis are more prevalent and can predispose to the development of periodontal diseases (Ganesan et al., 2020). In addition, new evidence indicates that the use of e-cigarettes can adversely affect the treatment response to periodontal therapy, like traditional smoking, thereby complicating treatment (Javed et al., 2021).

Although the literature is growing, the results are conflicting because there are differences in the design of the studies, exposure measures, and outcome measures. The majority of existing research is cross-sectional, which limits causal inference. Thus, more studies are needed to determine the combined influence of the type of e-cigarette device, e-liquid constituents, and the duration of exposure on periodontal inflammation and loss of attachment to provide better evidence for clinicians and policymakers.

METHODOLOGY

This cross-sectional analytical study aimed to determine the relative impact of e-cigarette device type, e-liquid components, and duration of daily exposure on periodontal inflammation and clinical attachment loss in e-cigarette users. The research was conducted within the dental outpatient units and in individual dental clinics over a period of six months. Participants were recruited with written informed consent and personal data were secured during the course of the investigation. A stratified random sampling method was used to select 100 participants as the total sample. Stratification was perfomed in terms of the type of e-cigarette devices to facilitate the proportional representation of pod-based devices, vape pens, and box-mod devices.

The inclusion criteria were adults aged between 18 and 45 years who had taken e-cigarettes daily for at least six months. People who had a history of traditional cigarette smoking in the past year, systemic diseases known to affect periodontal health (such as diabetes mellitus or immunologic disease), were undergoing orthodontic treatment, were pregnant, or had received periodontal therapy (within the last six months) were excluded from the study. Data collection was performed using both a questionnaire-based evaluation and a clinical periodontal examination. Demographic details, the duration of e-cigarette use, the type of e-cigarette device, the length of time exposed to e-cigarettes, and information on the contents of e-liquid, such as nicotine level (nicotine-free, low 0 to 6 mg, and high >6 mg) and the type of flavouring, were collected using a structured, pre-tested questionnaire. The questionnaire was administered in face-to-face interviews to reduce response bias, as well as to clarify the responses. A single calibrated examiner was used to conduct the clinical periodontal assessment to minimise inter-examiner errors. Periodontal parameters were measured at the 6 sites on each tooth with a standard periodontal probe.

Oral hygiene was measured using the Plaque Index (Silness and Loe), and the state of gingival inflammation was measured by the Gingival Index (Loe and Silness). Probing pocket depth, measured in millimeters from the original margin, was used to determine the pocket depth, and clinical attachment loss was used to determine how far the cementoenamel junction is from the base of the periodontal pocket. All measurements were made under standard conditions of lighting and infection control. All the data were entered and analyzed through Statistical Package of the Social Sciences (SPSS) software version 26. Demographic variables and periodontal parameters were calculated using descriptive statistics, such as frequencies, percentages, means, and standard deviations. One-way analysis of variance (ANOVA) was used to compare periodontal outcomes among various types of e-cigarette devices, various concentrations of nicotine, and various times of exposure to the e-cigarette devices. A p-value of 0.05 was considered to be statistically significant.

RESULTS

Table 1: Demographic Characteristics of Participants (N = 100)

This table presents the age distribution, gender, and duration of e-cigarette use among the study participants.

Variable	Category	Frequency (n)	Percentage (%)
Age Group (Years)	18–25	32	32.0
	26–35	41	41.0
	36–45	27	27.0
Gender	Male	68	68.0
	Female	32	32.0
Duration of Use	< 1 year	29	29.0
	1–3 years	46	46.0
	> 3 years	25	25.0

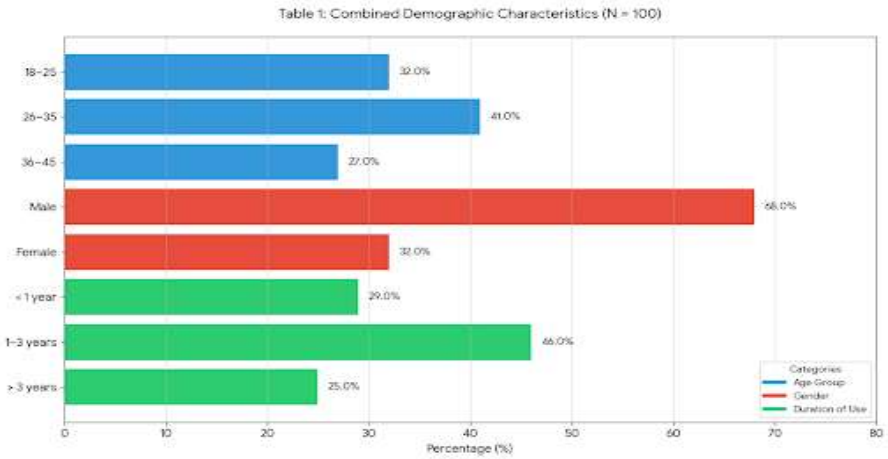


Table 2: Distribution of E-Cigarette Device Types

This table shows the frequency and percentage distribution of different e-cigarette device types used by participants.

Device Type	Frequency (n)	Percentage (%)
Pod-based devices	38	38.0
Vape pens	34	34.0
Box-mod devices	28	28.0

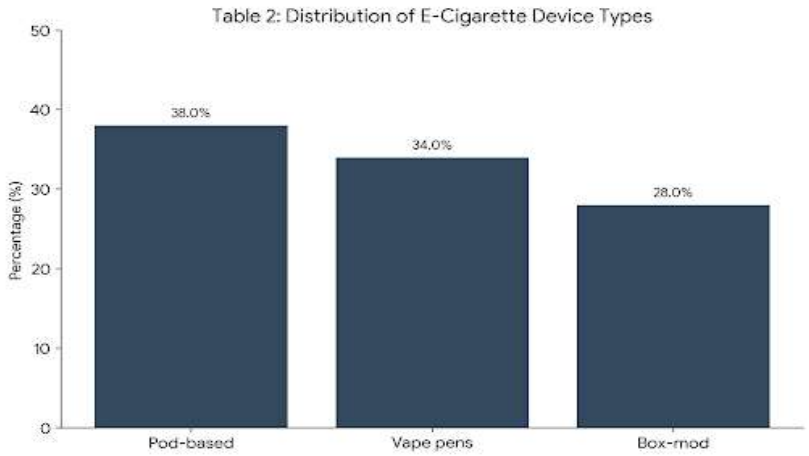


Table 3: E-Liquid Constituents Used by Participants

This table outlines nicotine concentration levels and flavor types of e-liquids reported by the participants.

Variable	Category	Frequency (n)	Percentage (%)
Nicotine Concentration	Nicotine-free	18	18.0
	Low (≤6 mg)	42	42.0
	High (>6 mg)	40	40.0
Flavor Type	Fruit-based	39	39.0
	Mint/Menthol	33	33.0
	Tobacco-flavored	28	28.0

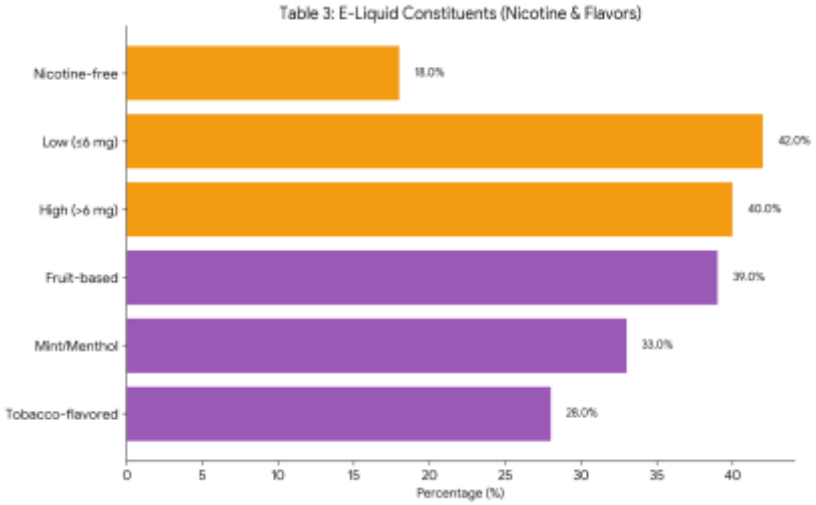


Table 4: Daily Exposure Duration of E-Cigarette Use

This table depicts the distribution of participants according to their daily duration of e-cigarette exposure.

Daily Exposure Duration	Frequency (n)	Percentage (%)
< 30 minutes/day	27	27.0
30–60 minutes/day	44	44.0
> 60 minutes/day	29	29.0

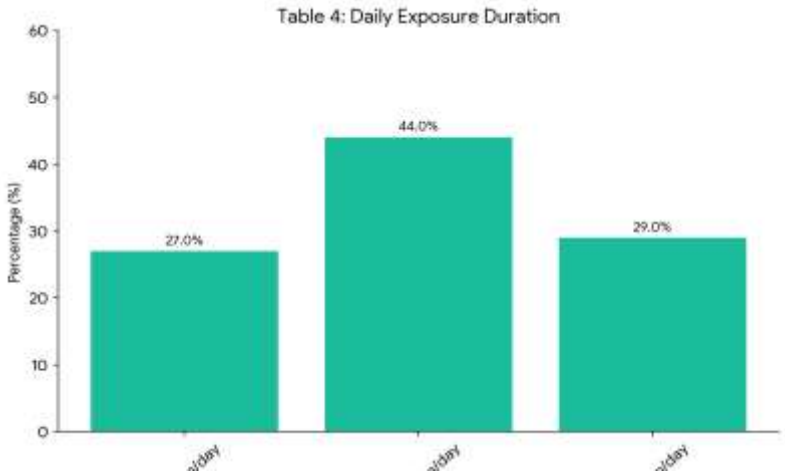


Table 5: Comparison of Periodontal Parameters by Device Type

This table compares mean periodontal parameters across different e-cigarette device types.

Parameter (Mean ± SD)	Pod-based	Vape Pen	Box-mod	p-value
Plaque Index	1.42 ± 0.31	1.58 ± 0.34	1.76 ± 0.36	0.021
Gingival Index	1.36 ± 0.29	1.54 ± 0.33	1.69 ± 0.35	0.018
Pocket Depth (mm)	3.1 ± 0.6	3.4 ± 0.7	3.8 ± 0.8	0.009
Clinical Attachment Loss (mm)	2.4 ± 0.5	2.7 ± 0.6	3.1 ± 0.7	0.006

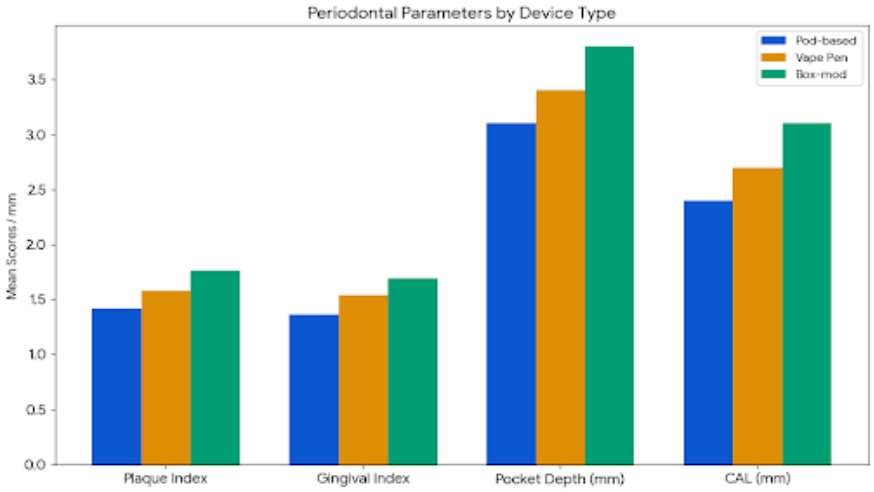
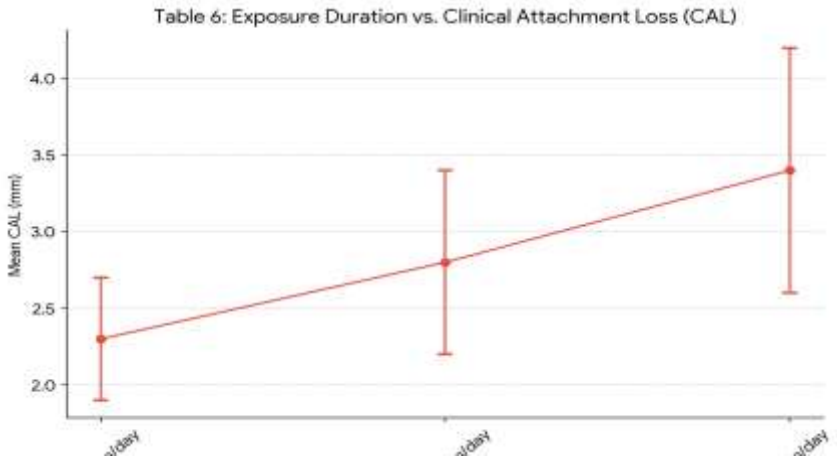


Table 6: Association Between Daily Exposure Duration and Clinical Attachment Loss

This table illustrates the association between daily e-cigarette exposure duration and mean clinical attachment loss.

Daily Exposure Duration	Mean CAL (mm) ± SD	p-value
< 30 minutes/day	2.3 ± 0.4	
30–60 minutes/day	2.8 ± 0.6	
> 60 minutes/day	3.4 ± 0.8	< 0.001



DISCUSSION

The current paper evaluated the correlation between e-cigarette device type, e-liquid components, and daily exposure duration, as well as periodontal inflammation and clinical attachment loss. The results found that greater intensity of e-cigarette smoking, especially with more developed forms of devices, higher nicotine concentration, and more time of daily use, corresponded to a much poorer periodontal parameter. These findings support the fact that the use of e-cigarette can have a negative impact on the periodontal tissues instead of being a safe alternative to traditional smoking.

The results of improved aerosol generation and greater penetration of nicotine and other toxicants into periodontal tissues may explain the increased gingivitis and accumulation of plaque in the mouths of people using high-powered e-cigarette devices. It has been experimentally shown that exposure to aerosols of the e-cigarette causes the release of pro-inflammatory cytokines, including interleukin-6 and tumor necrosis factor-alpha, in gingival fibroblasts, which in turn contribute to the development of periodontal inflammation (Sancilio et al., 2016; Willershausen et al., 2014). These are inflammatory processes that have been proven to contribute to periodontal attachment loss.

The correlation between the increased nicotine levels and the increased clinical attachment loss in this research study is in agreement with reports that indicate that nicotine interferes with the functionality of periodontal cells through inhibition of the growth and development of fibroblasts, collagen formation, and angiogenesis. In vitro researchers demonstrate that nicotine exposure causes periodontal ligament cell metabolism changes and apoptotic pathways that result in defective tissue repair and regeneration (Cattaneo et al., 2000; Giannopoulou et al., 2001). These biological effects could be one of the reasons why periodontal parameters decrease with dose attributable to the use of high-nicotine level e-liquids.

The duration of daily exposure proved to be an important predictor of periodontal destruction, as people who reported higher vaping durations had a higher periodontal loss in the form of attachment loss. This result is in line with the principle of cumulative exposure, which presupposes that cumulative exposure to aerosolized chemicals leads to the augmentation of oxidative stress and inflammatory load in the periodontal tissues (Lee et al., 2019). The dose-response relationships are similar to research on the effects of nicotine delivery systems on oral health outcomes (Tomar and Asma, 2000; Leite et al., 2018).

Newer data indicate that the use of e-cigarettes could affect periodontal health by altering the host immune response and not by microbial means only. There is evidence of inhibited antibody response and neutrophil chemotaxis in nicotine-exposed individuals that may decrease periodontal pathogen resistance (Sopori, 2002; Arnson et al., 2010). Such changes in immunology could potentially predispose the e-cigarette users to faster progression of periodontal diseases despite the comparatively young age and comparatively shorter exposure periods.

Even though the e-cigarette does not have the toxins in its combustion as in the traditional cigarette, its aerosol consists of ultrafine particles, metals, and aldehydes that can trigger the toxicity of the cells. Recent clinical studies have indicated that periodontal conditions of exclusive e-cigarette users are similar to those of early-stage periodontitis, and vaping cannot be regarded as a biologically neutral stimulus of periodontal tissues (Tattan et al., 2022; Kim et al., 2023).

This study is a cross-sectional design, which has limitations for causal inference, and self-reported vaping behaviours can be prone to reporting bias. Nonetheless, the standardized periodontal indices and stratified sampling increase the quality of the results. It is suggested that longitudinal research should be conducted to assess the development of the disease and determine whether periodontal damage caused by the use of e-cigarettes could be reversed after quitting.

The results of the study indicate that dental practitioners should regularly check the trends of e-cigarette use and conduct specific counselling on the risks of periodontitis. Periodontal risk assessment should consider vaping history to enhance early detection and prevention of periodontal disease in this increasing number of individuals who use vaping products.

CONCLUSION

This paper concludes that the kind of e-cigarette device, e-liquid constituents, and the length of time spent using it have a great impact on periodontal health. Higher levels of periodontal inflammation and clinical attachment loss were noted in users of higher-powered devices, higher concentrations of nicotine, and higher durations of exposure per day. The results of this study denote that e-cigarette smoking is not an alternative to regular smoking, which is not dangerous and may lead to the advancement of periodontal disease. The nature of dental users of e-cigarettes should be taken into account when performing periodontal assessment and patient education, but additional longitudinal research is advised to allow forming causal relationships and long-term periodontal outcomes.

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