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CLINICAL ARTICLE

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Potential oral health effects of e-cigarettes and vaping: A review and case reports

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Abstract

Objective: In this article, the potential oral health consequences of vaping are described. While most dentists are likely aware of the potential serious health effects involved with vaping, the aim of this article was to raise awareness on identified oral health consequences.

Clinical considerations: Three patients presented to one dental practice with unusual patterns of dental caries, and all three admitted to regular vaping. Vaping components include propylene glycol, glycerin, nicotine, and flavors, which contain sucrose, sucralose, and ethyl maltol. The vapor produced by vaping devices is thick and viscous and much of it is retained on oral tissues. There are over 10 000 different vaping liquids, including some that contain tetrahydrocannabinol (THC) and vitamin E acetate. Vaping clearly has the potential to negatively affect general health, periodontal health, and accelerate the development of caries. There is also evidence that teenagers are being attracted to vaping in astonishing numbers.

Conclusions: The general health consequences of vaping have received considerable attention in the national media. There is much to be learned about the consequences of this behavior. There are also potential serious oral health consequences to vaping. It is likely that the composition of certain vaping solutions may make them more harmful than others

Clinical significance: It is important that dental professionals are made aware of the potential problems related to vaping. Initial reports show that the effect of e-cigarettes on periodontal tissues is similar to that of conventional cigarettes. Some vaping formulations may be highly cariogenic, especially those with sweet flavors, which are used to attract young people. Patients should be routinely questioned about their vaping habits in the medical-dental history.

KEYWORDS

carrier, dental caries, nicotine, THC, vaping, vaping solution, viscous aerosol

1 | INTRODUCTION

In January 2018, the prestigious National Academies of Sciences, Engineering and Medicine published a major report on the public health consequences of e-cigarettes (ECs).[1] They pointed out that there were several potential negative consequences for patients using ECs, but felt that they were generally less dangerous than conventional cigarettes. Regarding pulmonary disease, they concluded that "there is no available evidence whether or not e-cigarettes cause respiratory disease in humans." While that conclusion was likely valid based on available evidence at the time, the recent outbreak of EC, vaping, product use-associated lung injury (EVALI) has captured the

attention of laypersons and health professionals alike. The Centers for Disease Control and Prevention (CDC) reported that as of 10 December 2019, 2409 patients had been hospitalized with a diagnosis of EVALI and 52 deaths had been recorded.[2] An earlier CDC report indicated that most patients reported using vaping liquids containing tetrahydrocannabinol (THC) which is the active ingredient in marijuana.[3] Most THC-containing vaping fluids also contain vitamin E acetate, which acts as a thickener. Vitamin E acetate is the current primary suspect in the development of EVALI, although no single causative agent has been unequivocally identified.

The hospitalized and deceased patients reported using 152 different THC-containing product brands.[2] The diagnosis of EVALI is one of the exclusion and it is important that it be made quickly as the condition progresses rapidly. The tremendous amount of publicity generated by the outbreak seems to have been beneficial, as the number of reported cases has declined rapidly from the high point in September 2019. This significant reduction in reported cases of EVALI is presumably due to reduced consumption of these products. While this publicity has already resulted in new regulations related to vaping and vaping products, it is likely that they will continue to be used, whether legally or not. While little is known about the potential effects of ECs and vaping on oral health, there is limited evidence that there may be significant potential negative effects to both teeth and periodontal tissues. This article was written to review what is known in this area and to report on three patients who vaped using THC and presented with unusual patterns of dental caries.

2 | BACKGROUND INFORMATION

The ECs were patented in China in 2003 and introduced to the European and North American markets in 2006.[4] These devices were marketed aggressively to both young and older generations of the population as a cheaper and safer alternative to traditional cigarette smoking. They were also marketed as a method to assist in smoking cessation for those experiencing difficulty with smoking cessation and for circumvention of smoke-free areas. These marketing efforts have apparently been quite successful, especially among young people.

The Food and Drug Administration (FDA) estimated that more than 3.5 million middle and high school students used EC in 2018, even though sales to minors are prohibited in most jurisdictions. EC use from 2017 to 2018 increased 78% among high school students and 48% among middle school students.[5]

Vaping involves use of an electronic device with a specifically formulated liquid which usually, but not always contains nicotine. The liquid is heated in the device and forms a viscous aerosol, which is then inhaled by the smoker. Some of the aerosol is absorbed into the bloodstream, some remains adherent to structures in the oral cavity and the rest is expelled into the atmosphere. The device consists of four components: a mouthpiece; a tank or reservoir to hold the liquid; a heating element; and a lithium battery. (Figure 1)

Vaping devices can be open (refillable) or closed (not refillable) and come in many different shapes, sizes, and colors. The actual dose

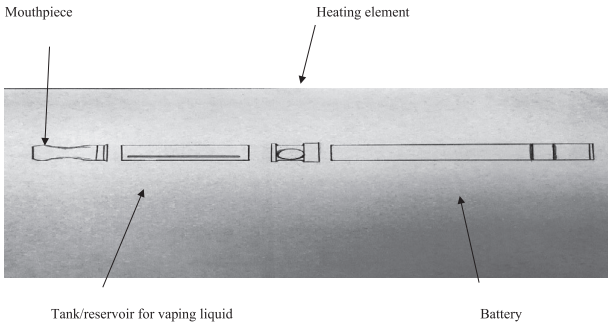

FIGURE 1 Diagram illustrating the parts of a vaping device

of nicotine and other chemicals delivered by vaping devices varies considerably depending on the actual composition of the liquid, the behavior patterns of the user, and factors related to the device itself. Some of these factors include the type of vaping device, the device battery power, device settings, and combination of internal components.[6]

There are currently over 10 000 commercially available e-liquid formulations[7] (Table 1). These formulations basically have three components: a base, nicotine, and flavors. All three of these components have the potential to negatively affect oral health. The base consists of combinations of propylene glycol and glycerin in purified water. A typical volume fraction ratio would be 20% propylene glycol to 80% glycerin, although this can vary considerably. Propylene glycol is a colorless liquid that possesses a faintly sweet taste. When heated into an aerosol, its breakdown products include acetic acid, lactic acid, and propionaldehyde, all of which can demineralize enamel. These products are also hygroscopic, and can bind water in saliva, which can result in xerostomia.

Glycerin is a colorless, odorless, and sweet-tasting liquid. It is 60% as sweet as sucrose but is not metabolized by cariogenic bacteria. However, in combination with some flavorings it results in a 4-fold increase in microbial adhesion and two times increase in biofilm formation. The viscous aerosols produced by heated e-liquids allow *Streptococcus mutans* to stick to enamel, resulting in demineralization and can lead to rampant caries.[8]

The nicotine content of e-liquids varies considerably. Typical concentrations range from 0.3% to 1.8%, and are generally lower than those of conventional cigarettes. However, in some instances nicotine exposures can actually exceed those of conventional cigarettes. A typical vaping session would result in approximately 10 puffs, with a typical user creating an average of 150 puffs per day. One electronic cartridge can produce 200 to 400 puffs, which could produce a nicotine dose equivalent to the smoking of two to three packs of regular cigarettes.[9] It also should be mentioned that the actual concentration of nicotine in e-liquids has been found to differ by as much as 50% from the declared concentration.[10] Obviously, actual doses are related to the concentration of nicotine in the e-liquid and the vaping habits of the user.

TABLE 1 A table illustrating various vaping flavors and their components

E-liquid brand	Flavors	Base	Nicotine content (mg)
Mother's milk	Cream, strawberry, milk	30% propylene glycol & 70% vegetable glycerin	0-18
Boosted e-juice	Strawberry milkshake	40% Propylene glycol & 60% vegetable glycerine	0-12
The milk	30 %Propylene glycol and 70% vegetable glycerin	Milk, fruit cereal, brown sugar	0-12
Mr. Cookie	30% Propylene glycol and 70% vegetable glycerin	Cookie, butter caramel	0-18
Big willies custard	30% Propylene glycol and 70% vegetable glycerin	Custard, vanilla, butterscotch	0-18
Jimmy the juice man	30% Propylene glycol and 70% vegetable glycerin	Raspberry, lime, orange	0-18
Peachy strawberry	30% Propylene glycol and 70% vegetable glycerin	strawberry, peach	0-18
Space jam	30% Propylene glycol and 70% vegetable glycerin	Pomegranate, blueberry	0-12
Oh face	30% Propylene glycol and 70% vegetable glycerin	Strawberry, cream	0-12
Wastegate	40% Propylene glycol and 60% vegetable glycerin	Raspberry, cheesecake, vanilla icecream	0-12

E-liquids are available in a wide variety of various flavors. These flavors provide tastes or fragrances similar to candy, fruits, bakery products, beverages, menthol, and tobacco. Chemically the components of these flavors include saccharides, esters, acids, and aldehydes. The sweet taste of e-liquids is provided by the inclusion of sucrose or sucralose and the sweet fragrance is created by ethyl maltol. in vitro studies have shown that some of these flavors significantly promote increased biofilm formation and enamel demineralization compared to a base/nicotine control, when used in vaping devices.[7] It is believed that the sweet flavors have been added to e-liquids to make them especially attractive to young people.

There have been some reports of problems with the EC devices themselves. Explosion of vaping pens has been reported as a result of overheating of the lithium battery. It has been estimated that over 2000 explosions and burn injuries, including two deaths, occurred in the United States between 2015 and 2017.[11]

One of the major marketing points related to ECs is to assist smokers in quitting the habit. Although ECs are ostensibly used to assist with smoking cessation, the evidence does not support this as an effective strategy. One study showed that the odds of successful smoking cessation were 28% lower in those who used ECs compared with those who did not.[12] It has been reported that 80% of those who use ECs to quit smoking fail.[13] Rather than being effective smoking cessation devices for adults, ECs may act as smoking initiation devices for youth.

3 | POTENTIAL ORAL HEALTH EFFECTS OF ECS AND VAPING

The relationship between cigarette smoking and periodontal disease has long been established.[14-16] ECs generally contain various concentrations of nicotine, and have the potential to have similar effects. A recent cross-sectional assessment evaluated several types of tobacco use patterns including vaping and concluded that all of them were associated with worse periodontal health compared with tobacco never users.[17] Another study of 13 650 adolescents found that dual use of conventional and ECs was associated with self-reported poor oral health outcomes.[18] A short-term study that investigated the gingival response that occurred when smokers switched from smoking to vaping found a significant increase in gingival inflammation at 2 weeks.[19] Another study evaluated peri-implant parameters in vaping individuals, and concluded that clinical and radiographic peri-implant parameters were compromised in these patients as a result of an increased inflammatory response.[20] Thus, although the topic has not been studied extensively, it seems reasonable to conclude that vaping may be expected to have a negative influence on gingival, periodontal, and implant health. The individual effect would be determined by the concentration of nicotine in the vaping product, the heat output of the vaping device, the frequency of consumption, and the host response of the patient.

Scant research has been conducted into the actual cariogenic potential of vaping. A few anecdotal cases of vaping-related rampant caries have been reported and limited in vitro studies have been conducted.[7,11]The in vitro study referenced demonstrated that effects of vaping vary with different e-liquids. The aerosols created during vaping are thick and viscous, and also may contain significant amounts of sucrose. With certain flavors, investigators were able to show a four times increase in microbial adhesion to enamel, a two times increase in biofilm formation, and a 27% decrease in enamel hardness. Byproducts of heating propylene glycol are acetic and lactic acid, which could contribute to enamel demineralization. The sensation of "dry mouth" created by some vaping liquids could also lead to excessive consumption of soft drinks and sports drinks. More research is essential to determine which types of flavors have the highest cariogenic potential.

There are also some documented effects on general health related to vaping. The nicotine content is critical in this regard. There is evidence that vaping may damage endothelial cells that line blood vessels.[16] Not all flavors seem to have the same effect, and menthol and cinnamon flavors seem to be the worst. There is also evidence that the e-liquid aerosol contains significant amounts of potentially toxic trace metals.[21] The source for this is the core assembly and solder joints. The authors of the study commented that because ECs are

a source of hazardous trace metals, it is debatable that they should be marketed as a "safe" alternative to smoking conventional cigarettes.

4 | CASE REPORTS

In the past several months, three patients presented to the private practice of one of the authors B. S. V. All had unusual patterns of dental caries. The common factor between these patients is that they all reported regular use of ECs with THC-containing vaping solutions.

Patient number 1 was a 52-year-old female. The health history was not significant. The patient was undergoing orthodontic therapy to optimally align the teeth prior to full mouth rehabilitation. Class VI carious lesions were found on teeth 6 to 11. (Figure 2) All 28 teeth had circumferential Class V carious lesions that extended into the gingival sulcus. The patient reported using THC-containing ECs approximately 12 times per day. After an initial phase of caries control, several teeth received core buildups. Definitive rehabilitation will be accomplished with 28 lithium disilicate and monolithic zirconia crowns. NaF toothpaste (Clinpro 5000, 3M-ESPE, St. Paul, Minnesota) was prescribed and the patient underwent a smoking cessation program to assist her to discontinue vaping. When treatment is complete, she will be placed on 3-month recall.

FIGURE 2 Case 1

Patient number 2 was a 21.5-year-old female. The health history was not significant. Carious lesions were found on 16 teeth. (Figure 3) The Class V lesions on teeth 3, 15, 19, and 30 were considered to be extensive. The patient reported using THC-containing ECs approximately eight times per day. Tooth #15 received endodontic therapy, a dowel and core, and a lithium disilicate crown. The remaining teeth were restored with resin composite. NaF toothpaste was prescribed and the patient received smoking cessation therapy to assist her to discontinue vaping. She was placed on 3-month recall.

Patient number 3 was a 24.5-year-old male. He has asthma and uses an albuterol-sulfate inhaler as needed. Albuterol sulfate is acidic and reduces salivary flow rates. He had erosive lesions in the form of cupping on multiple posterior teeth. In addition, he had nine teeth that were carious. Most of the lesions were relatively incipient and not obvious radiographically. Several of the teeth had multiple lesions (Figure 4A,B). The patient reported using THC-containing ECs approximately 10 times per day. The lesions were restored with a combination of direct resin composite, core buildups where indicated, and lithium disilicate onlays and crowns. NaF toothpaste was prescribed and the patient was encouraged to discontinue vaping, and placed on 6-month recall.

While there is no proof that the carious lesions found in these three patients were related to vaping, use of ECs with THC-containing solutions

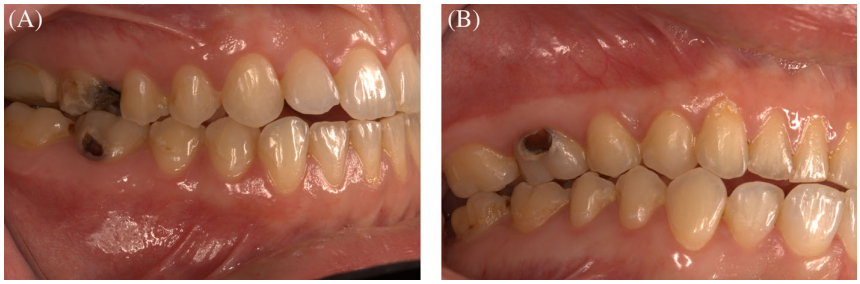

FIGURE 3 A, Case 2 and B, Case 2

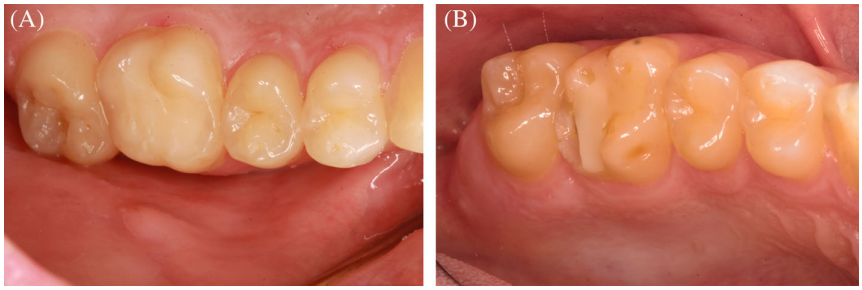

FIGURE 4 A, Case number 3 and B, Case number

was a habit that all three patients had in common. Contributing factors could possibly be xerostomia induced by the vaping chemicals and binge eating that is commonly associated with use of marijuana.

5 | DISCUSSION

ECs have been marketed very successfully as safe alternatives to smoking cigarettes, and as a strategy to help people successfully quit smoking. The success of the marketing program is evident by the tremendous increase in the number of youth attracted to vaping. Dental professionals must be aware of the potential problems related to vaping.

This article describes three different patients who all presented with unusual patterns of dental caries including the incisal surfaces of the maxillary incisors and multiple Class V lesions, which were quite extensive in nature. All these patients reported that they were frequent users of ECs with THC-containing solutions. Though this does not show causality, there may be an association between vaping and dental caries.

Patients should therefore be routinely questioned about their vaping habits in the medical-dental history.

6 | CONCLUSION

Although the evidence must be regarded as preliminary, a number of red flags have been raised relative to vaping and ECs. The outbreak of EVALI is extremely serious and has the attention of the FDA, CDC, the media, and health professionals. It appears that vaping may be just as harmful or perhaps may be even more harmful to oral health than conventional smoking. Given that the marketing related to vaping presented it as less harmful and more healthy than smoking, perhaps it could be said that vaping is a wolf in sheep's clothing. Obviously, more research is needed.

CONFLICT OF INTEREST

The authors do not have any financial interest in the companies whose materials are included in this article.

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