The impact of vaping on tooth enamel and mucous membranes

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Abstract. This article is devoted to determining the impact of vaping on tooth enamel and mucous membranes. In recent years, vaping has become widespread as an alternative form of nicotine consumption. The question of its safety for human health still needs to be resolved. Given the direct contact of electronic cigarette aerosols with the tissues of the oral cavity, it is important to establish their impact on tooth enamel and mucous membranes. The study analyzed current scientific data on the effects of vaping on hard and soft tissues of the oral cavity and identified clinical manifestations, mechanisms, and diagnostic markers of damage.

It was shown that scientists are studying changes in tooth enamel, mucous membrane, and oral microbiome in people who use electronic cigarettes. It has been established that regular vaping contributes to changes in the physicochemical properties of enamel, a decrease in its hardness, and an increase in the roughness of its surface, which creates conditions for dental plaque adhesion and an increased risk of caries. The oral mucosa undergoes chronic irritation, inflammatory changes, and a decrease in regenerative potential. This is associated with the cytotoxic effect of vape aerosol components, the activation of oxidative stress, and the disruption of the epithelial barrier. In addition, changes in the normal composition of the oral microbiome and a shift in its functional activity in a pro-inflammatory direction play a major role in the pathogenesis of enamel disorders.

The data obtained indicate that vaping is dangerous for the condition of the enamel and oral mucosa. This should be taken into account by dentists when assessing the condition of the oral cavity and developing preventive measures.

Keywords: mucous membrane, tooth enamel, microbiome, oral cavity, vaping.

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Introduction

Nowadays, the use of electronic cigarettes or vaping is becoming widespread among different age groups. The highest level is among young people, due to their positioning as a less harmful alternative to traditional smoking. However, accumulated scientific data show that vaping is not neutral and safe for the human body. It can have a negative impact on various human organs and systems. Among them, a significant impact is determined on the tissues of the oral cavity, which are the first to come into contact with the aerosol of electronic cigarettes [1, 2]. That is why the oral cavity is considered one of the main areas of toxic effects of vaping components.

The aerosol from electronic cigarettes contains nicotine, propylene glycol, glycerin, flavorings, volatile organic compounds, and other chemicals that can interact with the hard and soft tissues of the oral cavity [1, 3, 4]. Review studies and clinical observations indicate an association between vaping and the development of inflammatory changes in the mucous membrane, impaired cell proliferation, and a decrease in the regenerative potential of the oral epithelium [1, 5, 6, 7]. These processes can create conditions for increased tissue vulnerability to mechanical, chemical, and microbial factors.

Of particular interest is the effect of vaping on tooth enamel, as regular contact with e-cigarette aerosols can alter the physicochemical properties of its surface. Although data on direct enamel demineralization remain limited, studies indicate possible changes in enamel microstructure, increased surface roughness, and the creation of conditions conducive to dental plaque adhesion [1, 8]. Such changes may be clinically significant in the long term, especially when vaping is combined with other risk factors for caries development.

Along with damage to hard tooth tissue, modern literature pays considerable attention to the impact of vaping on the periodontium and oral mucosa. Systematic reviews and meta-analyses show that the use of electronic cigarettes is associated with a deterioration in periodontal health, including an increase in periodontal pocket depth, inflammatory changes in the gums, and an increased risk of developing periodontitis [3, 4]. Although some authors note that these changes may be less pronounced compared to traditional smoking, the available data do not allow vaping to be considered safe for periodontal tissues.

At the cellular level, it has been established that the components of e-cigarette liquids can induce cytotoxic effects, apoptosis, and impaired functional activity of oral epithelial cells and gingival fibroblasts [9, 10, 11]. Special attention should be paid to the role of flavorings, which can exacerbate the negative effects of aerosols and contribute to the development of an inflammatory response. The activation of oxidative stress and disruption of the integrity of the epithelial barrier are considered key mechanisms in the pathogenesis of mucosal changes associated with vaping [11, 12]. In addition, electronic cigarettes affect the normal composition of the oral microflora. As a result of vaping, the level of opportunistic microorganisms increases and the risk of infectious complications rises [6, 13].

Despite the growing number of publications, the available data on the effects of vaping on tooth enamel and oral mucosa remain fragmented and sometimes contradictory. Some studies have limitations related to design, duration of observation, and the variety of vaping products used [7, 8, 14, 15]. This necessitates the systematization and analysis of current scientific data in order to form a comprehensive picture of the potential risks of vaping for hard and soft tissues of the oral cavity. This is important for the prevention of dental diseases and the development of effective clinical recommendations.

The aim of the study is to determine the main features of the impact of vaping on tooth enamel and mucous membranes.

Results

It has now been established that electronic cigarette contain harmful elements that can have negative effects on various organs and systems in the human body. Electronic cigarettes are battery-powered and work by heating a solution. When heated, the liquid, which contains nicotine, various carrier substances, and fruit flavorings, produces vapor. It is this vapor that users inhale and exhale, just as they would when smoking traditional tobacco [16, 17, 18]. In their work, Sleiman et al. [19] showed that during heating (vapor formation), by-products of thermal decomposition are formed. The main components of the refill liquids were identified as propylene glycol, glycerin, nicotine, ethanol, acetone, and propylene oxide. The latter, with a mass concentration of 0.4-0.6%, is a possible carcinogen and respiratory tract irritant. Aerosols formed by vaporizers contained up to 31 compounds, including nicotine, nicotyrine, formaldehyde, acetaldehyde, glycidol, acrolein, acetone, and diacetyl. Glycidol is a probable carcinogen, and acrolein is a potent irritant. In addition, aldehyde emissions increased by 60% after several reuses of the device. This may be due to the accumulation of common polymerization products that decomposed when heated [18, 19, 20].

Scientists note the negative impact of vaping on the condition of hard tooth tissue and the oral mucosa. In addition, vaping can activate cellular and molecular mechanisms that damage tooth enamel. It also creates favorable conditions for the development of subclinical disorders and chronic pathological processes in the oral cavity [1, 2, 7, 21]. Studies have shown that people who smoke electronic cigarettes tend to have higher levels of periodontal inflammation than non-smokers, as evidenced by clinical parameters such as dental plaque index, bleeding on probing, probing pocket depth, clinical attachment loss, and significant marginal bone loss [22, 23]. Figueredo et al. [3] and Thiem et al. [4] noted that people who use electronic cigarettes are more likely to show signs of gingivitis, increased gum bleeding, and increased periodontal pocket depth (Table 1).

Table 1. Changes in tooth enamel associated with vaping

Indicator	Nature of changes	Clinical significance
Enamel microhardness	Decrease	Increased sensitivity, wear
Surface roughness	Increase	Dental plaque adhesion
Acid resistance	Decrease	Risk of demineralization

Source: compiled by the author based on [1, 8]

Data from observational and experimental studies show that tooth enamel undergoes changes in its physical and chemical properties when regularly exposed to aerosols from electronic cigarettes. In particular, there is a disruption of the microstructural integrity of the surface layer of the enamel, manifested by an increase in its roughness and a decrease in microhardness [8, 13, 15, 17]. Such changes are considered functionally significant, since even a slight disturbance of the enamel surface can contribute to more intense adhesion of microorganisms and the formation of persistent dental plaque.

The clinical significance of these changes is exacerbated by the fact that e-cigarette aerosols contain components that can alter the acid-base balance in the oral cavity. This creates conditions for enamel demineralization, especially with prolonged exposure and poor oral hygiene. Although direct evidence of massive loss of enamel mineral components in vape users remains limited, the combination of structural and functional changes is considered a potential factor in increasing caries risk [1, 8].

In parallel with the damage to hard tooth tissues, the most convincing results have been obtained regarding changes in the oral mucosa. Clinical observations and systematic reviews

indicate that vaping is associated with the development of local irritation, erythematous changes, dryness of the mucous membrane, and subjective sensations of burning or discomfort [2, 5, 7]. These symptoms are often chronic and may persist even in the absence of obvious morphological damage.

At the histological and cellular level, it has been found that the components of electronic cigarette aerosols have a direct cytotoxic effect on oral epithelial cells and gingival fibroblasts. Experimental studies have shown the induction of apoptosis, cell cycle disruption, and reduced cell viability after contact with vaping liquids, especially flavored ones [9, 10, 11]. These changes are accompanied by a decrease in the regenerative potential of the mucous membrane, which is important for maintaining its barrier function. It should be noted that flavorings exacerbate the negative effects of vaping. Studies show that flavored liquids are capable of causing an inflammatory response and contributing to the disruption of cellular homeostasis [10, 11]. This indicates that flavorings are biologically active agents that affect the condition of the mucous membrane.

The key pathogenetic mechanism of mucosal damage during vaping is considered to be the activation of oxidative stress. An increase in the level of reactive oxygen species leads to damage to cell membranes, proteins, and DNA, which, in turn, triggers a cascade of inflammatory reactions [11]. The activation of pro-inflammatory signaling pathways correlates with clinical manifestations of irritation and chronic inflammation of the mucous membrane. In a study by Sundar et al. [23], it was found that oxidative stress through protein carbonylation is an important factor in the development of inflammation and DNA damage. This leads to premature stress-induced aging (a state of irreversible growth arrest that exacerbates chronic inflammation) in the gingival epithelium, which may contribute to the pathogenesis of oral diseases. Flavored e-cigarettes cause increased oxidative/carbonyl stress and the release of inflammatory cytokines in human periodontal tissue fibroblasts.

Data on changes in the oral microbiome during vaping are of considerable interest. Studies have shown that the aerosol from electronic cigarettes can modify the species composition of the microflora, promoting the growth of opportunistic bacteria and reducing the diversity of commensal microorganisms [6, 13, 16]. Such changes are considered a factor that increases the risk of developing inflammatory and infectious lesions of the mucous membrane and periodontium.

Functional changes in the subgingival microbiome include a shift in the metabolic activity of bacteria towards pro-inflammatory profiles, which can maintain chronic inflammation even in the absence of pronounced clinical symptoms [13, 17]. This highlights the importance of microbiological markers as tools for the early diagnosis of disorders associated with vaping (Table 2).

Table 2. Markers of oral mucosal disorders associated with vaping

Group of markers	Indicators	Diagnostic significance
Clinical	Dryness, erythema, burning sensation	Early signs of damage
Cellular	Apoptosis, decreased proliferation	Impaired regeneration
Inflammatory	Activation of pro-inflammatory pathways	Chronic inflammation
Microbiological	Dysbiosis, changes in microbiome function	Infectious risk

Source: compiled by the author based on [2, 5, 6, 9, 10, 11, 13]

Further analysis of the literature allows us to expand our understanding of the nature of oral cavity damage caused by vaping by assessing the dose-response relationship and duration of exposure to electronic cigarettes. A number of studies indicate that the intensity of clinical and subclinical changes in the mucous membrane and periodontal tissues correlates with the frequency of use of vaping devices and the duration of aerosol exposure [3, 4, 14]. With regular vaping, there is a cumulative effect of damage, manifested by a gradual increase in the inflammatory response and a decrease in the adaptive capacity of the mucous membrane. Users of electronic cigarettes have impaired cellular homeostasis and functional characteristics of the mucous membrane [4, 7]. In addition, vaping affects the healing and regeneration processes of oral tissues. Scientific research by Sancilio et al. [9] and Auschwitz et al. [11] shows that the migration and proliferation of epithelial cells slows down under the influence of aerosol components. This can negatively affect the healing process of microtraumas and postoperative wounds in the oral cavity.

Special attention in the studies was paid to changes in the local immune microenvironment of the oral mucosa. It has been established that vaping can disrupt the balance between pro-inflammatory and anti-inflammatory factors, contributing to the formation of a state of chronic low-level inflammation [11]. Such immune imbalance can increase the sensitivity of the mucous membrane to bacterial and fungal infections, as well as complicate the course of existing dental diseases.

Further generalization of the data indicates that vaping may indirectly affect the clinical course of periodontal diseases through modification of the subgingival microbiome. Changes in the metabolic activity of microorganisms and an increase in the proportion of conditionally pathogenic species create conditions for maintaining the inflammatory process in periodontal tissues even with relatively moderate clinical manifestations [6, 13].

Thus, the results obtained indicate the effect of vaping on oral tissues and confirm that electronic cigarettes are not biologically neutral with respect to tooth enamel and mucous membranes. Analysis of the literature data shows that even in the absence of combustion products, electronic cigarette aerosols can initiate a series of pathological changes that are both local and systemic in nature [1, 2, 7]. Changes in the physicochemical properties of tooth enamel have been identified, including a decrease in microhardness and an increase in surface roughness. It has been shown that contact between enamel and vape aerosol components can create conditions for increased adhesion of microorganisms and the formation of dental plaque [1, 8]. Although the issue of direct enamel demineralization remains controversial, the results obtained confirm the assumption of a potential long-term negative effect of vaping on the caries resistance of hard tooth tissues.

Established cellular mechanisms of damage, including induction of apoptosis and impaired proliferation of oral keratinocytes, confirm the role of direct cytotoxic effects of vaping liquids, especially flavorings [9, 10, 11]. This indicates a more pronounced biological activity of flavored aerosols compared to unflavored ones. Of particular importance in the pathogenesis of mucosal changes is the activation of oxidative stress and pro-inflammatory signaling pathways. Increased levels of reactive oxygen species and disruption of the redox balance of cells are considered key links connecting exposure to vape aerosol with the development of chronic low-level inflammation [11]. This mechanism can explain the presence of subclinical changes in the mucous membrane even in the absence of pronounced morphological damage.

The effect of vaping on the oral cavity depends on the intensity and duration of electronic cigarette use. The data obtained indicate the need to assess the condition of the mucous membrane, tooth enamel, and oral microbiome prior to standard dental examination of patients who use electronic cigarettes. This approach will help identify disorders and prevent their progression.

Conclusions

The results show that vaping is associated with complex changes in oral tissues, including tooth enamel, mucous membranes, and the microbiome. Regular exposure to e-cigarette aerosols contributes to the disruption of the physicochemical properties of enamel, a reduction in its protective characteristics, and the creation of conditions for increased dental plaque adhesion. The oral mucosa reacts to vaping with the development of subclinical and clinically pronounced inflammation, a decrease in regenerative potential, and a violation of the barrier function. The main role in the development of changes is played by the activation of oxidative stress, the induction of cellular apoptosis, and the modification of the microbiome. All this indicates that electronic cigarettes cannot be considered safe for the condition of tooth enamel and the oral cavity.

Prospects for further research. Further research may focus on studying the condition of tooth enamel and oral mucosa in e-cigarette users depending on the amount and duration of vaping.

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