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Review Article

An era of electronic nicotine delivery system: understanding the consequences of its use on oral health

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ABSTRACT

Electronic nicotine delivery systems (ENDS), commonly known as e-cigarettes, are battery-powered devices that aerosolize liquid solutions containing nicotine and other substances. While promoted as safer alternatives to traditional cigarettes due to their lower toxin levels, e-cigarettes raise significant concerns regarding their long-term safety and impact on oral health. The variability in nicotine delivery, influenced by diverse device designs, complicates their regulation and potential health risks. E-cigarette usage has been associated with oral and periodontal issues, including increased plaque accumulation, deeper probing depths, and cytotoxicity in oral keratinocytes. Aerosols from e-cigarettes contain higher concentrations of metals such as nickel, lead, and chromium, which compromise the gingival epithelium, periodontal ligament, and oral mucosa. The widespread marketing of e-cigarettes poses a public health challenge. The implementation of the prohibition of electronic cigarettes act (PECA) 2019 is essential to mitigate these risks. However, gaps remain in understanding the short- and long-term oral health consequences of e-cigarette use. Public health strategies must include stringent regulation, awareness campaigns, and digital monitoring to prevent e-cigarette uptake, particularly among youth. Comprehensive preventive measures are crucial to minimizing the oral health burdens associated with e-cigarette use.

Keywords: Electronic nicotine delivery systems, Oral health, Periodontal diseases, Smokers, Vaping

INTRODUCTION

Electronic nicotine delivery systems (ENDS) are battery-powered gadgets that heat and aerosolize a liquid solution that typically contains. [1] While ENDS aim to replicate nicotine delivery similar to cigarettes, the wide array of designs can lead to significantly more variability in nicotine delivery compared to traditional cigarettes.[2] The attractiveness of this nicotine delivery system is driven by the diverse assortment of flavours used in e-cigarette liquid.[3]

Nonetheless, reservations exist regarding their long-term safety, due to insufficient data on their contents and unsupported assertions regarding their effectiveness as smoking cessation aids.[2]

The use of E-cigarettes not only impacts overall health but also has implications for oral health.[4] Mouth and throat irritation are particularly noticeable among non-smokers who start using e-cigarettes, although transitioning from conventional cigarettes to e-cigarettes may alleviate this irritation in smokers.[5] Periodontal problems commonly associated with e-cigarette use include increased plaque accumulation and deeper probing depths.[6] E-cigarette aerosols can induce cytotoxicity in oral keratinocytes through oxidative stress responses.[7] Specific metals like nickel, lead, and chromium are found in higher concentrations in E-cigarette aerosols compared to conventional cigarettes, significantly affecting gingival epithelium, periodontal ligament, and oral mucosa. Additionally, the presence of toxic substances such as cadmium in e-cigarettes may disrupt alveolar bone remodelling in periodontal disease, potentially leading to bone resorption.[8]

This review highlights the brief history and general background about ENDS, effects of ENDS with the main area of focus being their effects on oral health and few regulations pertaining to ENDS.

A BRIEF HISTORY OF ENDS

The concept of the e-cigarette dates back to Herbert A. Gilbert's 1963 U.S. patent for a "smokeless nontobacco cigarette" using a battery-powered heating element.

In the 1990s, Philip Morris developed an electric smoking device with a heater, liquid applicator, battery circuit, and disposable module, later designing a capillary aerosol generator in 1994. Though development paused, they re-entered the market with the MarkTen e-cigarette in 2013.

In 2003, Chinese pharmacist Hon Lik introduced the Ruyan e-cigarette, which, along with Janty, entered the U.S. market by the mid-2000s.

Since then, evolving technology has led to various generations of e-cigarettes and heated tobacco products, collectively known as ENDS.[2]

WHAT ARE ENDS?

The term “smoking” has given rise to the term “vaping,” which consists of inhaling an aerosolized “e-liquid,” produced by a small electronic vaporization device, which does not require combustion.[9] According to prevent all cigarette trafficking (PACT) act, term "ENDS (ENDS)" refers to any electronic device that, through an aerosolized solution, delivers nicotine, flavour/any other substance to the user inhaling from device. These devices produce an aerosol by heating a mixture of nicotine, flavourings, and carrier solvents like propylene glycol and vegetable glycerine. There is considerable diversity in terminology, design, and construction of ENDS.[10]

Types of ENDS

There are several different types of e-cigarettes, including vape pen, box mod, mech mod, pod mod, HnB and E-hookah, etc. vape pen is a pen type e-cigarette. Box Mod is a box-shaped e-cigarette. Mech Mod is a mechanical smoke, an e-cigarette device that does not contain a control chip, and its safety depends on the knowledge of the player. Pod Mod is a closed e-cigarette with replaceable cartridges. HnB is a heat-not-burn smoking device and E-hookah is an electronic hookah.

Generations of ENDS

First-generation e-cigarettes: featured fixed and low-voltage electrodes. There are three variants of the atomizing devices.[11]

First variant: It is a three-piece type comprising a unique atomizing device, battery, and fluid tank.

The second variant is a two-piece design, combining atomizing units, a fluid reservoir, and a distinct battery.

The third variant is a one-piece disposable that was launched in 2013. It integrates the atomizing device, fluid tank, and battery into one component.

Second-generation e-cigarettes: larger variable voltage batteries, are frequently seen in second generation e-cigarettes, also referred to as "cartomizers". Clearomizers of the second generation include a separable atomizing unit with a filament inside a shell that screws into the fluid tank and the battery. Compared to e-cigarettes made in the cig-a-like fashion, clearomizers are translucent and feature larger fluid reservoirs (or tanks).

Third generation electric cigarettes are referred to as "Mods" because they involve modified batteries that let users adjust the voltage, wattage, and power. The third generation has three types of atomizing units: sub-ohm, replaceable dripping, and various styles. Typically, the fluid tanks may be detached for further customization and could be more significant than clearomizers.

The fourth generation of e-cigarettes consists of the pod-style with a fixed voltage and different-shaped batteries, including USB or teardrop-shaped ones.[11]

Components of ENDS

The components of an e-cigarette are as follows: Cartridge(s) (CA) containing a nicotine solution dissolved in propylene glycol or glycerine, thermal element to vaporize the nicotine solution, micro-controller equipped with a detector that activates the heating element whenever the e-cigarette is inhaled, rechargeable battery and sporadically, an LED that imitates the glow of a burning cigarette nozzle.

One or more flavoured ingredients are also frequently incorporated.[11] Tobacco and menthol are the most commonly available flavours, offered by 93% and 92% of ENDS brands, respectively. The presence of candy and fruit flavours in cigarettes has been linked to increased experimentation, regular use, and addiction among youth. Consequently, flavours other than menthol have been prohibited in conventional cigarettes since the enactment of the family smoking prevention and tobacco control act of 2009. While flavouring chemicals in ENDS solutions are often labelled as "food grade" and "generally recognized as safe" according to FDA guidelines, it's important to note that this certification pertains to ingestion rather than inhalation.[10]

A list of few well-known components of E-cigarettes are mentioned in Table 1.

Table 1: Components of electronic cigarette aerosol and their functions and health hazards.

Ingredients	Function of the liquid	Health hazards
Propylene glycol	Main component of the liquid to produce aerosols	Respiratory tract irritation Effect of long-term inhalation is unknown
Glycerine	Main component of the liquid to produce aerosols	Effect of long-term inhalation is unknown
Diacetyl	Aroma of many sweet liquids	Suspected to cause bronchiolitis obstruction
Benzaldehyde	Aroma (artificial bitter almond oil)	Respiratory tract irritation
Cinnamon aldehyde	Aroma (Cinnamon)	Cytotoxic effect on cell cultures
Acrolein	Occurs when heating the liquid	Poisonous, irritant
Acetaldehyde	Occurs when heating the liquid	Possibly carcinogenic (category 2B)
Formaldehyde	Occurs when heating the liquid	Carcinogenic (category 1)
Lead	Probably comes out of the wick/solder joints	Poisonous
Chromium	Probably comes out of the wick/solder joints	Carcinogenic (category 1 for chromium-IV compounds)
Nickel	Probably comes out of the wick/solder joints	Carcinogenic when inhaled (category 1)
Tobacco-specific nitrosamines	Rare pollution in some individual liquids	Carcinogenic
Fine and fine particles (PM2.5, PM10)	Occurs during evaporation of liquid	Particulates are associated with respiratory problems, chronic respiratory and cardiovascular disease exacerbations, reduced lung function and premature death Health effects of the particles in the electronic cigarette aerosol are unknown.

The nicotine content of e-liquids varies considerably, typically ranging from 0.3% to 1.8%, which is generally lower than that found in conventional cigarettes. However, in some cases, nicotine exposure from e-cigarettes can exceed that of traditional cigarettes. It's worth noting that actual nicotine concentrations in e-liquids can differ significantly from declared levels, affecting user dosages.[12] In one study, e-cigarette liquids were obtained in retail stores and via the Internet. Liquids tested contained between 14.8 and 87.2 mg/mL of nicotine and the measured concentration differed from the declared concentration by up to 50%.[13]

Mechanism of section of ENDS

ENDS are distinct from traditional tobacco products such that they generate an inhalable aerosol using a vaporization device, sometimes known as a "vape". The more current designs frequently offer user control over voltage, coil type modification, wicking material, and reservoir size. These factors can be altered to provide distinct heating patterns that affect the aerosol's composition.[11] E-cigarettes heat a liquid (e-liquid) using a device known as an “atomizer.” The e-liquid is available in different concentrations of nicotine, or nicotine free, and contains water, flavourings, propylene glycol, and glycerine.[14]

The aerosolized liquid that the consumer inhales (e-liquid) come into the direct contact with the vaporizer's parts.

After administration of electric current plus intense heating, components from the vaporizer also have been discovered in the inhaled aerosol. Propylene glycol, vegetable glycerine, or sometimes both may be used as the base solvent in e-liquid preparations in addition to nicotine.[11] Nicotine delivery through E-cigarettes is influenced by factors such as the concentration of nicotine, levels of propylene glycol/vegetable glycerine in the liquid, temperature of the heating coil, and the duration of puffing. These elements collectively determine the quantity of aerosol produced and the effectiveness of nicotine delivery.[3]

EFFECTS OF ENDS

Vaping ENDS are perceived to be safer than cigarette smoking and attracts young naïve subject, as well as adult smokers who want to quit/reduce tobacco consumption.[15]

General health

In August 2019, the US centres for disease control and prevention (CDC) declared an outbreak of the e-cigarette or vaping product use-associated lung injury (EVALI) due to impaired gas exchange caused by aerosolised oils from e-cigarettes. Furthermore, PG and glycerol content may reach concentrations sufficiently high to potentially cause irritation of the airways. Airway epithelial injury has been reported in previous studies.[16] The cytotoxic and pro-inflammatory effects of various e-cigarette flavourings chemicals were tested on human monocytic cell lines (MM6 and U937). CAD was the most toxic, while O-vanillin and pentanedione also showed significant cytotoxicity.

In contrast, acetoin, diacetyl, maltol, and coumarin exhibited no toxicity at tested concentrations. Notably, toxicity increased when multiple flavours were combined, suggesting that vaping a single flavour is less harmful than mixed flavours. Few other components to have deleterious effects on human health include silicate particles in aerosols from the fiberglass wicks or silicone, battery output voltage, stainless-steel atomizer (SS) heating element or from a nickel-chromium alloy (NC).[17]

Oral health

Cytotoxicity and genotoxicity

Various additives and by-products of e-cig vapours, has demonstrated cytotoxicity. E-liquid constituents increased cytotoxicity and apoptosis in human gingival fibroblasts. These types of e-liquids with or without nicotine also demonstrated cytotoxic and genotoxic effects on human oropharyngeal mucosa and showed varied effects on epithelial cell proliferation and viability that extended beyond the constituents of nicotine and propylene glycol/vegetable glycerine in the e-liquid fluids.

E-cig aerosols, likewise, reduced the viability and increased apoptosis and necrosis of epithelial cells unrelated to nicotine content, as well as causing increased oxidative/carbonyl stress, inflammatory cytokines, DNA damage, and reduced HDAC2 responses in fibroblasts and gingival epithelium. E-cig aerosols significantly decreased glutathione levels in oral keratinocytes leading to increased cytotoxicity, and induced ROS, DNA damage and toxicity for vascular endothelial cells, apparently reflecting changes in oxidative stress by components in these aerosols.[12]

Candidiasis

A study revealed that nicotine multiplied the number of yeast cells and increased the extracellular polysaccharides of *Candida* species.[18] They also found that 1-2 mg/ml nicotine could enhance the formation of biofilm. The study revealed the expression of *Candida* parapsilosis ATCC 22019 hyphal-wall protein 1 (HWP1) and transcriptional agglutinin-like sequence 3 (ALS3) genes in *Candida* species, which are involved in hyphae formation and pathogenesis, were increased as the nicotine concentration increased.[18]

In vitro evidence describes increased pathogenicity of *C. albicans* when exposed to commercial e-vapor. Following exposure to e-cigarette vapor, with or without nicotine increased growth and hyphal length of *C. albicans* was seen. Both nicotine-free and nicotine-rich e-cigarettes increased the expression of different SAP genes, such as SAP2, SAP3, and SAP9, which are known to contribute to *C. albicans* growth and virulence secretory aspartate proteases (SAP2, 3 and 9) and phenotypic changes such as increased hyphal length.[19]

Periodontal disease

One consequence of ENDS called acrylein has the ability to cause inflammation, oxidative stress, and endothelial cell barrier degradation. The amount of periodontal pathogenic bacteria in the subgingival oral biofilm is comparable in people who use ENDS and those who smoke combustion cigarettes. It is unknown how ENDS affects *P. gingivalis*- induced periodontitis. Smoking lowers immunoglobulin levels, such as blood levels of IgA, IgM, and IgG as well as salivary levels of IgA, which has an impact on immunological state.[20] Additionally impacted are periodontal metrics such as attachment loss, probing depth, and bleeding on probing. While ENDS are promoted as being less damaging to periodontal health and tar-free than tobacco products, these assertions are not always supported by the evidence.[21] According to a study, dual use of ENDS and conventional cigarettes is linked to the presence of many pathogenic microorganisms that are known to cause altered oral microbiomes in ENDS users.[22] Patients who use ENDS have superior alveolar bone height preservation than smokers who use standard methods. It is debatable, though, whether ENDS users and non-smokers vary in any way when it comes to alveolar bone height preservation.[21]

Mucosal pain

Evidence on the effect of nicotine and the possible effect of aldehydes (cinnamaldehyde) on pain receptors has been reported in controlled human studies. Nicotine functions as an activator of the transient receptor potential subtype A1 (TRPA1) channel, associated with oral burning. Both cinnamaldehyde and nicotine also alter the vasomotor activity in the oral and pharyngeal mucosa, and chronic exposure may modify pain reception in these areas. With variability in nicotine content of e-cigs, the impact on oral pain perception may be higher than cigarette users. This physiological underpinning may support the phenotype of burning mouth syndrome, an oral pain disorder associated with several neuropathic diseases, and possibly hematinic or endocrine deficiencies. Some cases, particularly those only involving the tongue in the presence of marginal salivary flow, may be related to the effect of nicotine on specific pain receptors in smokers.[23]

Increased salivary cotinine levels

Nicotine's major metabolite is cotinine which is oxidized in the liver by CYP2A6 (Cytochrome P450, family 2, subfamily A, polypeptide 6) and is distributed in various body fluids including the blood, urine and saliva. It is most commonly used marker to distinguish between tobacco users and non-users because of its greater sensitivity and specificity than other biochemical tests.[24]

Significant levels of cotinine can be found in the saliva of e-cigarette users, suggesting a high nicotine exposure like that seen in smokers and higher than what is typically achieved with nicotine medications. Individual differences in cotinine levels are influenced by various factors such as prior tobacco dependence, the nicotine content of the e-liquid, and vaping behaviour.[25]

Burn injuries

Rechargeable lithium batteries, which are susceptible to overheating, ignition, and explosion, are by far the most commonly used batteries in these devices. A lithium-ion battery can experience a short circuit as a result of thermal runaway, which is an uncontrollable exothermic reaction involving the battery's anode, cathode, and flammable electrolytes. This phenomenon may occur under conditions such as overheating, exposure to moisture, excessive or improper charging, direct contact with metallic objects, or physical damage to the battery. This occurs when the battery bursts due to pressure and temperature increases, possibly igniting or exploding and inflicting a variety of injuries. The number of incidents of these devices overheating, igniting, and/or exploding that have been reported globally has skyrocketed in the last few years.[26] A study revealed injuries sustained after e-cigarette explosion in the mouth included intraoral burns, epidermal burns to the facial area including lips and upper chest.[27]

Trauma

A number of cases of maxillofacial trauma are readily attributable to explosive e-cigarette device failures, including intraoral burns and alveolar fractures. While these traumatic injuries are notable for dental practice, such explosions are presumably avoidable with quality manufacturing standards.[13] Among children in South Korea, mouth pain and broken or cracked teeth were associated with e-cigarette use.[25] In the United States, parent report of “dental problems” was more common among children who used both e-cigarettes and conventional cigarettes versus tobacco nonusers.[24] A study revealed patients suffered luxation injuries, alveolar fracture, dislocation of the front teeth, premaxillary fractures and permanent cuts to the upper lip, the mucosa of the lips, gums, tongue and hard palate following explosion of e-cigarettes.[27]

Discoloration of enamel

Conventional cigarette smoking has been known to cause tooth discoloration and change the colour stability of various dental materials, which can lead to dissatisfaction with an individual’s appearance. Discoloration of enamel is most commonly due to the impregnation of contaminants from cigarette smoke. This has a negative effect on dental aesthetics. In dentistry, colour differences can be quantified using formulae to measure colour differences. The American dental association (ADA) recommends the CIELAB system, which quantifies colour in 3 spatial coordinates (L-, a-, and b*).

The colour of the e-liquid appears to be influenced more by the flavour than by the nicotine content. Conventional cigarette smoke contains toxic substances, including cadmium, arsenic, and lead. E-cigarette devices, on the other hand, do not burn or produce smoke. Instead, they emit an aerosol. This aerosol does not produce carbon monoxide, which is a key combustion element in conventional cigarette smoke. In contrast, the fibres that absorb the e-liquid in ECIG devices come into contact with heavy metals in the heating elements like tin, nickel, copper, lead, chromium. E-liquid contains much less of the toxicants associated with conventional tobacco combustion. The distribution and number of particulate matters delivered by an ECIG device are similar to those found in conventional cigarettes.[13]

Cariogenicity of ENDS flavouring agents

Streptococcus mutans was exposed to flavoured e-liquid aerosols to identify specific flavours and chemical byproducts that could cause tooth surface damage. Using a combination of pure reference e-liquid and GC-MS analysis, it was discovered that ethyl butyrate, hexyl acetate, and triacetin, as well as their respective chemical byproducts, increase cariogenic potential.

Ethyl butyrate has a strong pineapple scent and is naturally found in many fruits. Many oral bacteria like *Streptococcus salivarius* and *Lactococcus lactis* are active producers of ethyl butyrate. This suggests that *S. mutans* is frequently exposed to ethyl butyrate in oral biofilm and, at the very least, tolerates it, if not enhances biofilm development.

Hexyl acetate has not been studied in terms of oral biofilm, dental caries, or *S. mutans, Streptococcus, Actinomyces*, and *Lactobacillus*, on the other hand, use classic glycolysis to convert carbohydrates to acetate in the oral biofilm. With acetate being one of the final principal products formed by biofilm bacteria, it is expected that *S. mutans* will thrive in an acetate-rich environment.

Fruits and cigarette filters contain triacetin, which has a “velvety” or “smoky” flavour. Triacetin is primarily used as a food additive, humectant, plasticizer, and anti-knocking agent, but little is known about its application in oral biology. Based on these findings, it is suggested that esters in e-liquid flavours provide an additional food source for *S. mutans* to thrive in the oral biofilm environment. Additional metabolomic analysis should be performed to validate the findings presented here.

Further investigation of biofilm assays, mechanical testing (adhesion force and hardness measurement), and SEM images reveals complex surface changes and biological responses to e-cigarette aerosol exposure. The findings show that e-cigarettes emit viscous aerosols that cover enamel surfaces. Surface roughness, tackiness, charge, and energy all have a significant impact on how bacterial cells adhere to surfaces and then form biofilms. *S. mutans* have developed extraordinary metabolic flexibility as a means of surviving in harsh environments.

Twelve metal ion concentrations in e-cigarette aerosol have been measured in this study. Metals can be hazardous to people and microorganisms in high concentrations, yet at normal levels, metal ions can act as nutrition for numerous vital biological processes. Metal ions, such as copper, iron, and magnesium, are needed by oral bacteria, including *S. mutans*, as a co-factor to activate vital enzymes. Additionally, pathogenic bacteria have developed a variety of important metal absorption methods to evade the host's immune system. It was discovered that the adhesive forces between *S. mutans* and the enamel surface grow with the number of puffs using atomic force microscopy, or AFM. Furthermore, it was discovered that aerosol droplets were uniformly distributed after ten puffs, as seen by the force measurement and light microscope pictures.[28]

Oral implant complications

In a study by Ibraheem et al it was seen that cigarette, waterpipe, and ENDS users had significantly higher plaque index and probing depth values compared to non-smokers in a study of implanted individuals. There was no significant difference between smokers and users of ENDS. However, users of any type of tobacco or alternatives had greater levels of osteoprotegerin and receptor activator of nuclear factor-κB Ligand in gingival crevicular fluid than non-smokers.[29]

Dental implants can exhibit stable clinical and radiographic status and stay functionally stable in END-users who do not smoke, provided that patients follow stringent oral hygiene protocols. According to a study by Sinha et al ENDS users exhibited higher levels of inflammatory mediators, which suggests that their peri-implant structures are weakened and that there is more localized inflammatory tissue death. Overall, ENDS tend to be more implant-friendly than conventional tobacco cigarettes.[29]

Maxillofacial tumors

In vitro and *in vivo* studies have reported the molecular changes induced by ENDS on the oral cells ranging from reduced antioxidant levels and gene dysregulations to DNA strand breaks.[30] Nicotine is metabolized into cotinine and nitrosamines which leads to the formation of methylation intermediates in DNA. Nicotine and NNK (nicotine-derived nitrosamine ketone) also activate serine/threonine kinase Akt, a member of the oncogene families involved in tumorigenesis. Alterations in Akt activity alters vital cellular processes (glucose metabolism and protein synthesis, cell growth, cell survival and apoptosis, cell migration, angiogenesis), ultimately leading to cancer. Nicotine also promotes epithelial-to-mesenchymal transition; which affects the morphology of oral cancer cells, which acquire migratory abilities associated with metastasis.

The heating of propylene glycol and glycerol produces acrolein, and α, β-unsaturated aldehydes, with a proven genotoxic potential *in vivo*. Certain e-liquid flavours like chocolate and roasted nut contain pyrazine derivates. This pyrazine moiety can interact with p53 tumour suppressor protein, estrogen receptor and endothelial growth factor. Inactivation of p53 “the guardian of the genome” can be linked to several types of cancers.

Tobacco-specific nitrosamines (TSNAs) concentration in e-liquids are usually minimal. However, their presence should not be ignored as *in vitro* studies have revealed that TSNAs are involved in the migration and invasion of cancer cells, thereby promoting metastasis.[31]

ENDS AND GOVERNANCE

The global e-cigarette market is expected to grow from $15 billion in 2020 to $85 billion by 2028. The US represents nearly half the global e-cigarette market and is expected to increase from $7.4 billion in 2021 to $40 billion in 2028, despite increasing e-cigarette sales and distribution restrictions. A study by researchers from the public health foundation of India (PHFI) showed the rampant online sale and promotion of e-cigarettes via e-stores and influencers. India’s global adult tobacco survey-2 found awareness of e-cigarettes was highest (3.9%) among 15-24-year-olds. However, India has banned e-cigarettes since 2019.[32]

Global approaches to e-cigarette regulations

The following domains of product prohibitions or restrictions related to e cigarette have been identified: manufacturing, distribution, importation, sale including where sales are allowed and minimum age of purchase, use restrictions including vape-free public places, advertising, promotion, and sponsorship, taxation, trademark, health warning labelling, ingredients/flavours, safety/hygiene, reporting/notification, nicotine volume/concentration and child-safety packaging.[33] Thirty-five countries have banned advertising and promotion, 26 countries have set safety standards, 25 countries have banned the sale of e-cigarettes.[34]

India’s e-cigarette ban

In 2019, India witnessed the enactment of the prohibition of electronic cigarettes (production, manufacture, import, export, transport, sale, distribution, storage and advertisement) act, 2019 (“Act”) by the ministry of health and family welfare in India. As a result, it became unlawful to manufacture, possess, store, sell, transport, distribute, or advertise electronic cigarettes and other liquid heating nicotine delivery systems. Violators face harsh consequences. People who participate in banned activities can be fined up to one lakh rupees or imprisoned for a maximum of one year. Repeat offenders may face fines of up to five lakh rupees and sentences of up to three years in jail.[35]

Despite the ban and stringent penalties in place, a survey by Pettigrew et al conducted in 2023 reveals around one in ten of the young adults reported being a current vaper and a further 14 % reported having used e-cigarettes in the past; 70% reported ever using tobacco, and 8% were dual users of both e-cigarettes and tobacco. Among non-users, 31% were curious about using e-cigarettes and 23% intended to use in the following year, indicating high levels of susceptibility.[36]

Effective regulation of ENDS faces a multitude of challenges. The rampant marketing of e-cigarettes has the potential to reverse the progress made in tobacco control efforts in India, necessitating decisive action to enforce the provisions of PECA 2019. While e-cigarettes may serve as a tool for risk reduction among smokers, there are concerns regarding the uptake of vaping among youth and never smokers, necessitating a balanced approach to address potential public health implications. It is imperative to gain a better understanding of vaping outcomes and adolescents' perceptions while identifying potential ways to lessen or eradicate the health burdens associated with vaping.

COMPREHENSIVE PREVENTIVE MEASURES

It is crucial to raise awareness among youth (who are vulnerable to the predatory tactics of the tobacco industry), retailers, policymakers and the wider community. In India, school health interventions are effective for preventing and reducing tobacco use, indicating the need for similar efforts targeting ENDS. An effective strategy may be a nationwide public awareness campaign on ENDS. To effectively uphold the ENDS, ban, a comprehensive approach is necessary which includes enforcing a restrictive environment, creating public awareness campaigns and stringent digital monitoring. Enforcement agencies should identify violators and direct social media platforms/sites to remove content that violates Indian laws, ensuring that such content is not accessible to the Indian audience. A step forward could be to notify more authorized officers, sensitize law enforcers officials about the restrictive environment and the potential violations perpetrated by the e cigarette industry, social media sites/platforms, and endorsers/influencers.[37]

CONCLUSION

The oral tissues are highly susceptible to the potential adverse effects of e-cigarettes. While significant progress has been made, research gaps remain regarding both short- and long-term exposure to e-cigarettes. Existing evidence links e-cigarette uses to oxidative stress, cytotoxicity, periodontal disease, and increased cancer risk, yet the mechanisms behind these effects require further investigation. The vast variety of e-liquid formulations complicates experimental results and makes quantifying e-cigarette exposure challenging. To establish conclusive evidence, future studies should focus on longitudinal studies with a larger and homogenous group of e-cigarette users. Understanding these risks will help guide preventative strategies and improve awareness of the potential oral health consequences associated with e-cigarette use.

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