ABSTRACT

Use of e-cigarettes poses unforseen risks

Background and overview – The use of electronic cigarettes (e-cigarettes) is a rapidly growing trend throughout the United States. E-cigarettes have been linked to the risk of causing explosion and fire.

Case description – Data are limited on the associated health hazards of e-cigarette use, particularly long-term effects, and available information often presents conflicting conclusions. In addition, an e-cigarette explosion and fire can pose a unique treatment challenge to the dental care provider because the oral cavity may be affected heavily. In this particular case, the patient's injuries included intraoral burns, luxation injuries, and alveolar fractures.

Conclusions and practical implications – This case report aims to help clinicians gain an increased knowledge about e-cigarette design, use, and risks; discuss the risk of spontaneous failure and explosion of e-cigarettes with patients; and understand the treatment challenges posed by an e-cigarette explosion.

Electronic cigarette explosions involving the oral cavity

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Electronic cigarettes (e-cigarettes) were introduced in 2007, and since that time 2.5 million Americans have begun using battery-powered personal vaporizers (1). The most common device resembles a traditional cigarette, called a *cigalike*, and is considered a first-generation e-cigarette. Later devices, which produce more vapor, include mods, *e-hookahs*, *vapes*, and *vape pens* (2). Regardless of the design, the same core components are present. A lithium-ion battery powers a heating element that atomizes a liquid solution creating a vapor that is inhaled. The heating coils are activated in two different manners: when the user inhales deeply on the mouthpiece or when the user depresses a button (1).

The pharmacologic properties of the addictive and toxic chemicals are difficult to assess given that many different e-cigarette designs (more than 250 brands are on the market) and liquid contents vary (3). The liquid solution consists predominantly of nicotine, flavoring, glycerin, and propylene glycol (1). Nicotine is the primary addictive ingredient in the liquid solution and has concentrations ranging from 0 to 87.2 milligrams per milliliter (3,4). Investigators in a 2014 study reported a discrepancy, by up to 50%, between the concentration indicated on the packaging and the concentration measured in the actual solution (4). Anabasine, nornicotine, and acetaldehyde can be found in e-cigarette liquids, and these chemicals possess additional addictive properties (3).

Carcinogenic and toxic chemicals such as formaldehyde are present in e-cigarette vapor (5). In the absence of quality standards, the consistency and ingredients of e-cigarette products are a noteworthy concern (4).

EMNEORD

Electronic cigarette; tobacco-use cessation; fire; mouth injuries

The US Fire Administration (1) published a document entitled Electronic Cigarette Fires and Explosions in 2014. At the time of publi-

cation, 25 incidents of explosion and fire related to an e-cigarette had been reported since 2009. Ten injuries and no deaths were associated with the documented occurrences. The incidents were categorized based on the amount of injury the person sustained, and the two cases classified as severe involved the oral cavity. The first government-reported case involving the mouth occurred in November 2011 and involved a Colorado man who spent 8 days in the hospital after his mouth, face, and eyes were burned with debris and battery acid. The second case documented by the US Fire Administration occurred in February 2012 and involved a Florida man who lost teeth and part of his tongue after an e-cigarette explosion (1).

Only two events involving the oral cavity have been documented officially by a federal agency; however, an internet search results suggest that e-cigarette explosions involving the oral cavity are occurring more frequently. Five events in the United States have been reported on the internet since the publication of the document by US Fire Administration in October 2014. The five events occurred in Georgia, Colorado, Arkansas, and Florida between September 2015 and November 2015 (6-10). Events outside of the United States have been reported in the United Kingdom and Canada (11,12).

The most commonly documented injuries to the oral cavity after an e-cigarette explosion include intraoral burns, luxation injuries, and chipped and fractured teeth (6-8,10). Of the five cases, three had concerns outside of the dentition (6,7,9). One man sustained a dime-sized hole in his hard palate, causing a communication between the oral and nasal cavities. At the time the report was written, the patient was awaiting a prosthesis to occlude the oronasal communication to prevent nasal regurgitation during eating and to aid in speech (6). Another person, listed as being in critical condition, sustained a spinal fracture, which may prevent him from walking again (7). Internal burns are a serious consequence of an e-cigarette explosion; one man was placed in a medically induced coma because of respiratory tract burns (9).

Eighty percent of the explosions the US Fire Administration reported occurred during charging; however, the events involving the mouth occurred while the e-cigarette was in use (1). Also, at the time of the US Fire Administration document, no explosions with associated fires related to mods had been reported. The document stated, "Most of the PVs [personal vaporizers] and mods use larger batteries that are removed from the vaporizer and placed in an external charging unit. This helps to ensure that a proper power supply is used to charge the batteries" (1). Although it has been conjectured that the external charging unit has a better battery design (1), it is evident that mods may not be safer devices; in the case we report below, the patient was using this type of e-cigarette. The November 2015 fire and explosion case involving the Colorado man also was caused by a mod (7).

Many consumer products are required to be tested by a nationally recognized organization, such as UL (formerly known as Underwriters Laboratories) (1). However, e-cigarettes are not required by law to undergo product safety testing. Although no specific regulations are in place, an e-cigarette user could opt to use a battery that has been tested and certified by UL, because UL developed lithium-ion battery standards. Consumers also can decrease the chance of a lithium-ion battery explosion or fire by following the manufacturer's instructions for charging the battery and only charging it with the unit that was sold with the e-cigarette. E-cigarette users also should be aware that the battery should not be charged with a standard USB port because the voltage and current provided can vary greatly. Instead, they should use the USB port and connection device provided by the manufacturer of the e-cigarette. The use of nonapproved power adapters appears to be responsible for most incidents, because the battery is subjected to a higher current than is safe and ultimately can result in an explosion or fire (1).

Case report

A 28-year-old man, with no relevant medical history aside from smoking, was transported via ambulance to the emergency department of a level I trauma center in South Carolina after an e-cigarette explosion and fire. The patient reported uneventfully using the e-cigarette for 11 days from December 25, 2015, to January 4, 2016. On January 4, the e-cigarette unexpectedly exploded and burst into flames. The patient was using the e-cigarette as a smoking cessation aid at the time, as he switched from traditional cigarettes to e-cigarettes in an attempt to titrate his nicotine consumption down. On the day of the event, the patient charged the lithium-ion battery in a standard 120-volt outlet in an external charging device that was purchased separately. After a standard charge cycle, the patient inserted the batteries into the device, placed the mod between his lips, and depressed the button. The patient described feeling a warm sensation in his right hand and seeing a bright light, followed by severe pain in his mouth. The patient then realized that his e-cigarette had exploded, and he had to act to control the fire that ignited his clothes hamper and bedding. After he extinguished the fire, the patient was driven by a private vehicle to a regional hospital.

After seeking care at an outlying hospital, the patient was transported via ambulance to a facility equipped with a trauma team. On admission to the emergency department, the trauma team evaluated and stabilized him. The preliminary concern was airway security. However, the patient's respiratory tract was unaffected by the explosion, and the patient was maintaining 100% oxygen saturation with room air. The trauma team ordered computed tomographic (CT) scans and radiographs to assess the trauma to the anterior maxilla and

Kort efter eksplosionen

Fig. 1. Initial appearance in the emergency department, with the patient displaying burns to the dorsal surface of the tongue, maxillary gingiva, and mucosa.

***Fig. 1**. Patienten netop ankommet til traumecenter med forbrændinger på tungeryggen, gingiva og mundslimhinde.*

CT-scanning

Fig. 2. Sagittal CT scan showing multiple alveolar fractures.

***Fig. 2**. Sagittal CT-scanning viser multiple alveolære frakturer.*

CT-scanning

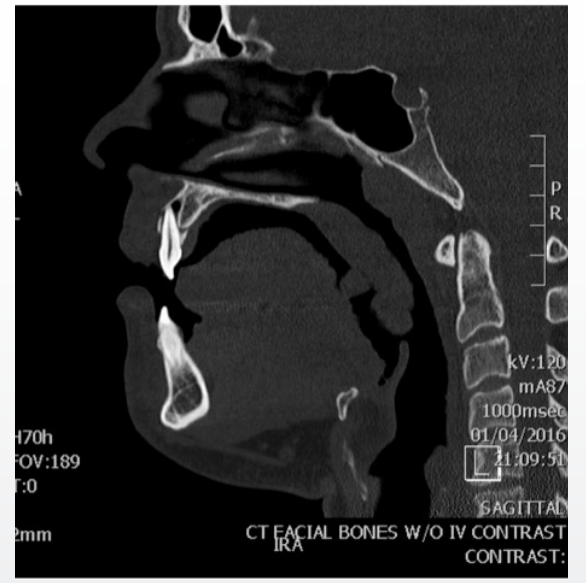

Fig. 3. Sagittal CT scan shows tooth no. 9 displaced from the socket.

***Fig. 3**. Sagittal CT-scanning viser +1 displaceret fra alveolen.*

to evaluate the oral cavity and gastrointestinal tract for potential foreign bodies. Specifically, the trauma team ordered abdomen and chest radiographs, CT scans of the facial bones without contrast material, CT scans of the cervical spine without contrast material, and CT scans of the head without contrast material. The CT scans and radiographs indicated that no foreign bodies were present and helped confirm the need for a dental consultation.

The dental resident and attending on-call performed an intraoral clinical examination that revealed that teeth nos. 8 and 10 were either avulsed or fractured along the root surface, tooth no. 9 was luxated palatally, and tooth no. 7 was subluxated (Fig. 1). The CT scans verified the avulsion of tooth no. 10 and the trauma to teeth nos. 7, 8, and 9 and the maxillary alveolar bone (Figs. 2 and 3). The trauma team consulted the oral and maxillofacial surgery department, and they confirmed the diagnoses reached by the dental resident and attending on-call. Lastly, the trauma team consulted the speech pathology department to conduct a swallow study, but the patient refused the test because he was swallowing secretions with no difficulty. At the time of discharge, the patient's only concerns were related to the oral cavity. The trauma team devised a plan to provide follow-up dental care in an outpatient setting.

Tre dage efter eksplosionen

Fig. 4. Appearance at follow-up in the dental center 3 days after the explosion. Tooth no. 9 is displaced 6 millimeters to the palate and extruded 4 mm.

***Fig. 4**. Billedet ved opfølgende undersøgelse tre dage efter eksplosionen. + 1 er displaceret 6 mm palatinalt og ekstruderet 4 mm.*

CLINICAL RELEVANCE

E-cigarettes are a new nicotine-based product with a novel delivery system and have the potential to affect public health significantly. E-cigarette explosions and fires pose unforeseen risks and may cause damage to the dentition and soft tissues of the mouth.

Røntgen

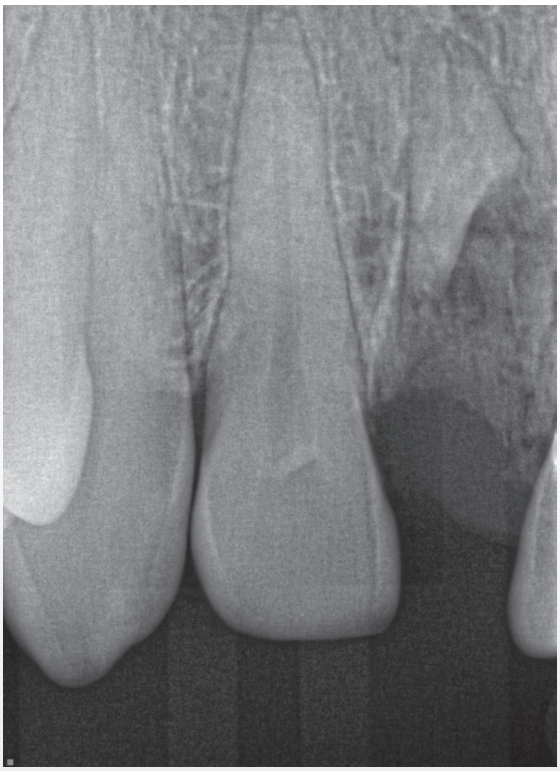

Fig. 5. Periapical radiograph showing that tooth no. 7 is present and completely seated in the socket, and approximately 5 millimeters of apex no. 8 remains.

***Fig. 5**. Periapikalt røntgenbillede viser, at 2+ er placeret i alveolen, og at kun ca. 5 mm af apex af 1+ er til stede.*

Findings

As a result of the explosion, the patient received the following injuries:

-tooth no. 7: subluxated;
-tooth no. 8: 5 millimeters of root apex present in the socket after a root fracture;
-tooth no. 9: lateral luxation 6 mm to the palate and extruded 4 mm;
-tooth no. 10: avulsed;
-multiple fractures of the maxillary anterior alveolus;
-burns on the dorsal surface of the tongue: coagulation necrosis of the superficial tissue;
-burns of the maxillary anterior gingiva and mucosa: diffuse sloughing with frank ulceration;
-sensitivity associated with teeth nos. 6, 7, and 11 from concussive injury.

The dental treatment of this e-cigarette explosion required immediate, interim, and long-term treatment plans. The initial treatment was delayed 3 days to allow the lips and gingiva to heal because the oral mucosal lesions were too painful to begin addressing dental concerns immediately (Fig. 4). The patient rinsed with saline and 0.12% chlorhexidine until any treatment commenced. Because of the pain associated with the intraoral burns, we administered systemic analgesics and educated the patient about preventive measures. The patient was to avoid hot, spicy, and acidic foods and beverages. We recommended a soft diet and the avoidance of carbonated and alcoholic beverages. We obtained periapical radiographs (Fig. 5). We removed tooth no. 9 and the remaining portion of tooth no. 8 by using elevators and forceps with local anesthetic. We noted multiple fractured segments of alveolar bone within the traumatized maxillary segment. We irrigated the extraction sites with copious amounts of saline and sutured with 4-0 chromic gut sutures. Tooth no. 7 had decreased mobility compared with that

16 dage efter eksplosionen

Fig. 6. Appearance 16 days after the explosion reveals healing of the extraction sites and burns of the facial gingiva.

***Fig. 6**. 16 dage efter eksplosionen ses heling af ekstraktionssårene og forbrændingerne af den faciale gingiva.*

16 dage efter eksplosionen

Fig. 7. Appearance 16 days after the explosion reveals remarkable healing of the burns on the dorsal surface of the tongue.

***Fig. 7**. 16 dage efter eksplosionen ses bemærkelsesværdig heling af forbrændingerne på tungeryggen.*

the day of the event, but the tooth was in hyperocclusion. We adjusted the occlusion as indicated to reduce excessive forces on tooth no. 7. We discussed the need to perform ongoing pulp testing and possible endodontic therapy for teeth nos. 6, 7, and 11. We reviewed oral hygiene procedures at this appointment, with the instructions to brush the unaffected teeth carefully while avoiding the ulcerated and necrotic areas, and the patient continued the 0.12% chlorhexidine rinse for 2 weeks.

The patient returned 16 days later (Fig. 6) for alginate impressions for interim maxillary partial fabrication. The dorsal surface of the tongue was healed almost completely (Fig. 7). He then returned for the delivery of the wire and acrylic partial (Fig. 8). The patient is expected to be in this interim prosthesis for approximately 4 to 6 months when we will evaluate him for implant prosthetics.

Discussion

E-cigarettes are not under the authority of the US Food and Drug Administration (FDA) but are considered to be a tobacco product under US law. This essentially means e-cigarettes have been marketed, sold, and consumed in an unregulated environment with little evidence of short- and long-term effects (2). An example of an e-cigarette liquid component lacking definitive safety data is propylene glycol, the chemical found in theater fog machines. This organic chemical is responsible for generating the e-cigarette vapor and accounts for 66% of the fluid content. The FDA deemed propylene glycol to be generally recognized as safe more than 60 years ago (13). However, documented adverse effects of propylene glycol include mouth and throat irritation, dry cough, central nervous system effects, behavior changes, and spleen damage (3,5). The adverse effects could be more severe than documented because propylene glycol has never been studied under the conditions of use in e-cigarettes. There are no studies that specifically simulate the duration, inhalation, and frequency of use (5). However, investigators in other studies have documented the following health consequences associated with e-cigarette use: elevated heart rate and blood pressure, airway inflammation, impaired immunologic response, impaired bac-

25 dage efter eksplosionen

Fig. 8. Appearance of the maxillary partial in place 25 days after the explosion.

***Fig. 8**. Midlertidig partiel protese i overkæben 25 dage efter eksplosionen.*

terial phagocytosis, ulcerative colitis, lipoid pneumonia, and subacute bronchial toxicity (2).

Another adverse effect that remains unstudied is secondhand and thirdhand exposure. The high concentration of the nicotine found in some e-cigarette liquids can increase exposure risks to nonusers, particularly children. The residual nicotine found on indoor surfaces can lead to thirdhand exposure because it can remain on surfaces for weeks to months. Another risk that e-cigarette liquids pose to children is accidental ingestion. Poison control has reported an increase in unintentional nicotine ingestion, particularly by children (4).

The largest growing population of e-cigarette users is adolescents. Many investigators have identified factors such as aggressive marketing, social media, tempting flavor choices, and the ability to obscure use (2). A history of tobacco use is the strongest risk factor for e-cigarette use among adolescents; however, some nicotine-naive adolescents initiate e-cigarette use. It is this population of approximately 160,000 that represents a growing public health concern (2). It is for this reason that e-cigarettes are speculated to serve as a gateway drug (5). Adolescents experimenting with e-cigarettes may develop nicotine dependence inadvertently and then transition to using traditional combustible tobacco products (2).

Young adults have become the second largest population of e-cigarette users. In contrast to the adolescent population, young adults are turning to e-cigarettes as a smoking cessation aid. E-cigarette manufacturers make no therapeutic claims about serving as a nicotine replacement therapy; therefore, the FDA does not regulate them as a replacement therapy (5). Despite this fact, many people still may view e-cigarettes as a reasonable alternative to smoking traditional tobacco cigarettes. The findings reported in the literature are conflicting about the effectiveness of smoking cessation because variable factors such as type of system, liquid concentration, battery voltage, puff length, intervals between puffs, and user characteristics in the articles differ. E-cigarettes have potential advantages over traditional cigarettes, but the data are deficient (4).

Investigators in one uncontrolled cohort study found that at a 6-to 24-month follow-up, 10% to 50% of people who used nicotine-containing e-cigarettes had stopped smoking (2). This result is positive, but the amount of nicotine delivered may have been equal to or greater than the amount of nicotine delivered by a traditional cigarette due to variability in the amount of nicotine delivered by various devices and the lack of experimental controls. Compared with a conflicting study with negative results, virtually no nicotine may have been delivered. This comparison underscores the difficulty in designing relevant experiments that create applicable data in regard to e-cigarette safety. More research needs to be conducted under tight constraints with stricter parameters that simulate the behavior of e-cigarette use (2).

Although some may assume that e-cigarettes are a safer alternative to traditional tobacco cigarettes, this viewpoint may be unsubstantiated because the short- and long-term health effects are essentially unknown. The negative health consequences of nicotine use are well known and include carcinogenesis, cardiovascular disease, teratogenicity, and toxicity (5). The use of e-cigarettes compounds the negative effects of nicotine with the unknown factor of the likely harmful constituents such as aldehydes, metals, volatile organic compounds, and reactive oxygen species that are not found in tobacco smoke (2). Only limited data are available about the effects of long-standing exposures to aerosolized nicotine, propylene glycol, and flavorings (5). Essentially, evidence of the decreased harm of e-cigarettes compared with that of traditional cigarettes with long-term use is not available. There are considerable discrepancies in the health-effects research and data for e-cigarette use (4).

Conclusions

E-cigarettes are a new nicotine-based product with a novel delivery system and have the potential to affect public health significantly (4,5). E-cigarette explosions and fires pose unforeseen risks and may cause damage to the dentition and soft tissues of the mouth.

Abbreviation key. CT: Computed tomographic. e-cigarettes: Electronic cigarettes. FDA: Food and Drug Administration.

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ABSTRACT (DANSK)

Eksplosion af elektroniske cigaretter involverer mundhulen

Baggrund *– Brug af elektroniske cigaretter (e-cigaretter) er hastigt voksende i hele USA. E-cigaretter er forbundet med risiko for eksplosion og brand.*

Patienttilfælde *– Der er begrænset viden om sundhedsfaren ved brug af e-cigaret, navnlig langsigtede virkninger. De foreliggende informationer giver ofte modsatrettede konklusioner. Eksplosion og brand af en e-cigaret kan udgøre en vanskelig behandlingsudfordring, da mundhulen kan blive kraftigt skadet. I dette patienttilfælde indgik intraorale forbrændinger, luksation af tænder og alveolære frakturer.*

Konklusioner og praktiske implikationer *– Denne kasuistik giver klinikere større viden om e-cigaretters opbygning, brug og risici; risikoen for spontane fejl og eksplosion af e-cigaretter bør diskuteres med patienter, også for at forstå behandlingsudfordringer ved en e-cigareteksplosion.*

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