E-Cigarette Design Preference and Smoking Cessation:

A U.S. Population Study

Caroline Chen, PhD, **Yue-Lin Zhuang, PhD**, and **Shu-Hong Zhu, PhD**
Moores Cancer Center, University of California, San Diego, California

Abstract

Introduction—Electronic cigarette (e-cigarette) designs may be described as "closed" or "open." Closed systems are disposable or reloadable with prefilled cartridges (cigalikes). Open systems feature a prominent chamber (tank), refillable with e-liquid. This study examined user design preference and its association with smoking cessation.

Methods—A probability sample of current e-cigarette users (*n*=923) among adult ever smokers (*n*=6,560) in the U.S. was surveyed online between February 28 and March 31, 2014 and analyzed in September 2014. Photos of e-cigarette devices were presented alongside survey questions to facilitate respondents' understanding of the questions.

Results—Most e-cigarette users were exclusive users of one design: 51.4% used only closed systems and 41.1% used only open systems, with 7.4% using both. Former smokers were more likely to use open systems than current smokers (53.8% vs 35.2%, p=0.002). Current smokers who attempted to quit in the last 12 months were more likely to use open systems than those who did not (41.4% vs 27.7%, p=0.029). Open system users were more likely than closed system users to use e-cigarettes daily (50.2% vs 22.9%, p<0.0001). Open system users were less likely to report their devices resembled (3.1% vs 73.0%, p<0.0001) or tasted like (29.1% vs 53.3%, p<0.0001) a cigarette, but were more likely to report their devices satisfied cravings than closed system users (82.8% vs 67.2%, p=0.001).

Conclusions—Preference of e-cigarette design is associated with smoking cessation. A device's ability to deliver more nicotine and its flexibility in use might contribute to users' success in quitting smoking.

Introduction

The design of electronic cigarettes (e-cigarettes) is evolving even as their use is increasing.[1–3] The battery-powered devices that vaporize a nicotine-containing solution for inhalation first arrived on the U.S. market in 2007.[4] In 2012, large U.S. tobacco companies began acquiring and designing their own e-cigarette devices.[5] In 2014, the U.S. Food and Drug Administration (FDA) issued the "deeming rule" indicating its plan to regulate e-cigarettes.[6] Currently, e-cigarettes are not yet regulated by the FDA. This study examines users' preferences in e-cigarette designs and their association with smoking cessation in this unregulated environment.

E-cigarettes can generally be grouped into two models: "closed systems" and "open systems." Older generation e-cigarettes were mostly closed systems that mimicked regular cigarettes in size, weight, and appearance, and were either disposable or reloadable with cartridges of prefilled solution.[7] These are also known as "cigalikes."[8] Closed systems do not allow users to fill their devices with third-party "e-liquids" (nicotine-containing solutions). Instead, these devices typically use their own branded, pre-filled cartridges with limited choices of flavors and nicotine concentrations. Closed systems are not customizable. Modification of hardware is considered "tampering," effectively voiding the product warranty.[9]

Open systems, by contrast, invite a do-it-yourself ethos. These devices, also referred to as "tanks," "e-vapors," and "mods," are characterized by hardware that feature a refillable chamber that users can open and fill with their choice of e-liquid. In contrast to closed systems, these devices allow users to select from a greater range of nicotine concentrations among a wider variety of flavors.[10] Users can also purchase basic ingredients and mix their own customized e-liquid.[10]

Open systems also allow users to modify their devices. Specialized mouthpieces and variable voltage options are some examples of possible enhancements.[11] Visually and tactilely, these devices are different from closed systems; they are usually larger and heavier and resemble a fountain pen or small flashlight.

Open systems are generally capable of delivering higher levels of nicotine than closed systems.[12] Increased flexibility such as variable voltage also allows users to adjust the temperature for heating e-liquid, which can increase nicotine yield and puff volume.[11,13] With practice, users can achieve higher nicotine intake from their devices.[14]

The present study examines whether e-cigarette design preference among current users is associated with success in quitting smoking. Open system devices are reportedly more effective in reducing withdrawal symptoms.[12] Online surveys found that an overwhelming proportion of e-cigarette users preferred open systems.[15,16] A survey in the United Kingdom has also found that those who used open systems on a daily basis were more likely to quit.[17] By contrast, a case-control study showed that closed system users were more likely to continue smoking while using e-cigarettes.[18] No study, to the authors' knowledge, has examined the e-cigarette user experience and users' success rate using a representative

sample of the general population. This study is based on a nationally representative sample of U.S. adults.

Methods

Study Sample

The University of California, San Diego designed an online survey and commissioned GfK (Menlo Park, CA) to administer the survey to a probability sample of the U.S. population (KnowledgePanel®). The KnowledgePanel® is an ongoing probability panel that relies on address-based sampling from a sample frame of residential addresses that covers about 97% of U.S. households, including those with unlisted phone numbers, and those without landlines and Internet access.[19] Households without Internet were provided a computer with WiFi to complete the survey. The authors chose this survey because of its representativeness to other population surveys that examine current social attitudes across the U.S.[20,21]

The survey aimed to gather information on use and perceptions of e-cigarette models, current cigarette usage, and smoking history among the U.S. population. To increase efficiency in sampling, the study oversampled ever smokers (because e-cigarettes are known to be used mostly by ever smokers). A total of 9,334 adults were invited; 8,619 completed the survey, a response rate of 92.3%.[19,20,22] Among them, 6,560 were ever smokers and 925 current e-cigarette users. Two e-cigarette users did not answer the questions on the type of devices they used and were excluded, making the effective sample size 923. Never smokers were excluded in this analysis. The survey was conducted between February 28, 2014 and March 31, 2014. Data were analyzed in September 2014. The study was approved by the University of California, San Diego's IRB (#111664). Participants provided informed consent.

Measures

An ever smoker was defined as having smoked at least 100 cigarettes in their lifetime. A current smoker was an ever smoker who smoked every day or some days at the time of the survey, and a former smoker was an ever smoker who did not smoke at the time of the survey. A heavy smoker was defined as a smoker who smoked >15 cigarettes per day. A quit attempt was defined as having quit smoking for at least 24 hours. All ever smokers were asked whether they were smoking 12 months before the current survey.

An e-cigarette user was defined by answering *yes* to *every day* or *some days* to the question: *Do you currently use e-cigarettes every day, some days, or not at all?* The choice of device was assessed by multiple questions. Before the questions on e-cigarette devices, survey respondents were first shown photos of different systems (Appendix Figure 1). Use of closed system devices was determined by two questions:

1. *Do you currently use disposable e-cigarettes?* along with photos and a caption, *Looks like a cigarette; one piece.*

2. *Do you currently use a 2-piece (or 3-piece) e-cigarette similar to the ones shown below (not [personal vaporizer] PV or [advanced personal*

vaporizer] APV)? followed by photos and a caption, *2 or 3 piece; consists of battery and cartomizer (or cartridge and atomizer).*

A positive response for either question resulted in coding the respondent as a closed system user.

Use of open system devices was assessed by two questions:

1. *Do you currently use a PV or APV e-cigarette (e.g., eGo) similar to the ones shown below?* followed by photos of three models and a caption, *Personal vaporizer. Customizable. May be used with tanks, cartomizers, clearomizers, or drip tips.*

2. *Do you currently use a mod or handmade e-cigarette?* followed by photos and the caption, *Personal vaporizer. Endlessly customizable. May be used with tank devices, cartomizers, clearomizers, or drip tips.*

An eGo, PV, and APVrefer to various open system designs. A positive response for either of these questions resulted in coding the respondent as an open system user.

Current e-cigarette users were also presented with statements about their experience using e-cigarettes: *My e-cigarette looks like a regular cigarette; When I hold my e-cigarette it feels like I'm holding a regular cigarette; My e-cigarette tastes like a regular cigarette; The throat hit I get from my e-cigarette is like the one from a regular cigarette; Puffing on e-cigarette vapor feels like puffing on cigarette smoke*; and *E-cigarettes satisfy my cravings like regular cigarettes*. Four response categories were provided (from *strongly agree* to *strongly disagree*). Respondents who chose *strongly agree* or *somewhat agree* were coded as agreeing with the statement.

Statistical Analysis

All percentages were weighted by population parameters based on the most recent U.S. Current Population Survey.[23] A survey-specific, post-stratification adjustment was used to account for any survey non-responses, as well as any non-coverage, and oversampling resulting from the survey-specific sampling design. The smoking prevalence for the U.S., based on the weighted analysis of this survey, was 17.2%, which is quite close to the most recently published national estimate of 16.8% from the 2014 National Health Interview Survey.[24]

Ninety-five percent CIs were computed based on the sampling distribution of the corresponding summary statistic. A Wald chi-square test was used to determine if a term had a significant effect.[25] All calculations were generated using SAS, version 9.3.

Results

Most e-cigarette users used only one type of device. As shown in Table 1, 41.1% used open systems exclusively and 51.4% used closed systems exclusively. Among all current and former smokers who currently use e-cigarettes, 7.4% used both closed and open system devices.

Table 1 also shows the demographics of users. Among exclusive users, there was no significant gender difference between closed or open system users. Open system users were more likely to be younger (aged <45 years). There were no other significant differences either by education or by ethnicity, except that those who identified their ethnicity as "other" were more likely to use open systems over closed systems than users who chose a listed ethnicity.

Table 2A shows that former smokers were significantly more likely than current smokers to use open systems (53.8% vs 35.2%, p=0.002) and less likely to use closed systems (41.4% vs 56.1%, p=0.012). Furthermore, current smokers who had tried to quit were more likely to use open systems than those who had not tried to quit (41.4% vs 27.7%, p=0.029). Conversely, current smokers who had made no attempts to quit were more likely to use closed system devices than those who had tried to quit (65.0% vs 48.9%, p=0.011).

Because former smokers included long-term former smokers who had quit more than a year ago, a separate analysis was conducted for those who reported smoking in the 12 months preceding the survey. The results are presented in Table 2B. Recent former smokers were those who were smoking 12 months ago but who had quit by the time of the survey. The sample size for data presented in Table 2B was smaller than that in Table 2A, but the results showed the same pattern. Those who had successfully quit smoking within the last 12 months were more likely to use open systems than those who continued to smoke (55.1% vs 34.8%, p=0.006), and were less likely to use closed systems (39.6% vs 57.3%, p=0.015). Among those who continued to smoke, those who had made a quit attempt were more likely to use open systems (40.1% vs 28.2%, although p=0.061), and less likely to use closed systems (49.9% vs 66.4%, p=0.010).

Figure 1 shows the proportion of daily users among "exclusive" open and closed system users, and "both" system users. Those who exclusively used open systems were more than twice as likely to be daily users than those who exclusively used closed systems (50.2% vs 22.9%, p<0.0001). The likelihood of "both" users being daily e-cigarette users was 35.8%, falling somewhere in the middle. In addition, those daily users who used open systems were less likely to be heavy smokers than those daily users who used closed systems (10.5% vs 18.2%, data not shown in Figure 1). However, the difference was not statistically significant (p=0.378).

Table 3 presents users' experience of open and closed systems. Only data for exclusive users were presented here because it was not clear which device "both users" were referring to when they answered questions on their perceptions of using an e-cigarette. Few open system users (3.1%) agreed that *My e-cigarette looks like a regular cigarette*, in contrast to almost three quarters of closed system users (73.0%, p<0.0001). Also, only a small proportion (10.5%) of open system users agreed that their e-cigarette *felt like a regular cigarette*, in contrast to more than half the closed system users (55.4%, p<0.0001). Additionally, open system users were less likely than closed system users to agree that *My cigarette tastes like a regular cigarette* (29.1% vs 53.3%, p<0.0001).

There was no significant difference between open and closed system users' responses to the statements: *The throat hit I get from my e-cigarette is like the one from a regular cigarette* and *Puffing on e-cigarette vapor feels like puffing on cigarette smoke.* Regardless of device, about half of the e-cigarette users thought the "throat hit" from an e-cigarette was like that from a cigarette whereas the other half did not. Nearly two thirds of e-cigarette users agreed that puffing on e-cigarette vapor resembled puffing on cigarette smoke.

When asked whether *e-cigarettes satisfy my cravings like regular cigarettes*, open system users were significantly more likely to agree that e-cigarettes satisfied their cravings (about 82.8% vs 67.2%, *p*=0.001).

Discussion

This study found that, in 2014, more e-cigarette users were using closed than open systems in a representative sample of smokers in the U.S. However, those who succeeded in quitting smoking were more likely to use open systems. Further, among those who still smoked cigarettes, those who tried to quit in the last 12 months were also more likely to use open systems than those who had not tried to quit.

Closed system devices were introduced to the U.S. market at an earlier point in time than open system devices.[11,26] If most regular e-cigarette users stayed with the design they used first, then it may be expected that a greater proportion of e-cigarette users in 2014 were using closed system devices. What is interesting, however, is that the choice of device is not equally distributed across users by smoking status: Those who tried to quit smoking and those who successfully quit tended to use open systems. This agrees with an earlier online study from the United Kingdom,[17] although the present study (based on a representative sample of the U.S. population) found a much larger proportion of open system use among current e-cigarette users.

One possible reason why smokers who tried to quit cigarettes prefer open systems is their capacity to deliver high concentrations of nicotine. Because open systems are refillable with a wide variety of e-liquids, users can choose higher nicotine strengths to increase their nicotine intake.[27,28] Open systems also offer greater customizability, allowing users to add accessories that adjust nicotine concentrations.[27] For example, increasing the voltage to heat e-liquids to higher temperatures[11,13] and adding modifications such as "drip tips" can result in the delivery of more nicotine.[29] Furthermore, the plethora of e-liquid flavors for open systems can be attractive.[10,16,18,30] By contrast, closed system users have a more limited range of nicotine concentrations, as they are constrained to reloading their device with pre-filled cartridges offered by the device manufacturer.[9]

Open systems may also support an enhanced sense of perceived control over the cessation process. Perceived control over a difficult behavior change process can have a significant and positive impact.[31] Users of open systems may choose among a greater range of e-liquid flavors and hardware enhancements than users of closed systems. The daily ritual of adjusting and filling open systems may also play a role in enhancing a sense of control. In

other words, open system users may feel they are effectively customizing their own quitting process, increasing their confidence in quitting.

The present study also found that open system users were significantly more likely to be daily users. Daily use of e-cigarettes may be an indication of consistent nicotine intake, and has been found to be associated with successful smoking cessation.[17,32] Given the devices available at the time of the study, using open system devices and using them daily might have been the most efficient nicotine-replacement strategy.[16–18,33]

User experience of each design also offered interesting contrasts. Closed system users were more likely than open system users to report that their devices looked, felt, and tasted more like regular cigarettes. However, open system users reported that their devices satisfied their nicotine cravings better. As closed system devices more closely resembled regular cigarettes and were initially less expensive than open systems,[34,35] it is possible that smokers wishing to try e-cigarettes may have first used a model that is familiar to them: a design that looked like a regular cigarette. Over time, smokers who became increasingly serious about quitting may have diversified, tried different e-cigarette designs, and discovered that open systems work better than closed systems for satisfying their nicotine cravings.[30] How such a transition takes place, if at all, will be best addressed in a longitudinal study.

It is noteworthy that open system users were less likely than closed system users to report that their devices tasted like regular cigarettes, a popular topic among e-cigarette users.[36] Open system devices have a greater variety of flavors than closed system devices. The observation that those who tried to quit smoking or succeeded in quitting smoking preferred devices that offer a large variety of flavors beyond common cigarette flavors is worth further investigation.

Although use of open systems is associated with a greater chance of quitting smoking, tobacco companies have favored closed systems. A survey in 2013–2014 found that tobacco companies were more likely to manufacture closed systems.[10] Products such as VUSE, blu, MarkTen, Green Smoke, and Nicocigs, all owned by large tobacco companies, are all closed system devices.[9,37–40] One tobacco company has urged the FDA to ban open systems entirely, citing concerns about nicotine abuse and malfunctioning hardware.[41–43] As smaller e-cigarette companies are more likely to own open systems, an FDA regulatory decision on the design of e-cigarettes can result in unintended consequences, increasing the market share of large tobacco companies and altering the relative proportions of smokers using closed and open systems.

Yet, a blurring of lines between design concept and reality is taking place. Tobacco companies are beginning to call their closed devices "vapors" and "tanks," possibly recognizing the increasing popularity of open systems.[44] In appropriating the street names of open systems, manufacturers are associating their closed designs with open systems, even though their products preclude user modification.[9,37]

Limitations

This study has several limitations. The survey was conducted in 2014 in the U.S. Also, the cross-sectional design limited the authors' ability to determine whether smokers switched from closed to open systems, and vice versa. Smokers attempting to quit may prefer open systems for reasons other than their ability to deliver more nicotine. Newer closed system devices may deliver nicotine levels comparable to that of open systems.[45] Future studies are needed to examine whether smokers making quit attempts chose open systems because of their ability to deliver more nicotine or because of an enhanced perception of control over the quitting process.

Conclusions

This study used a cross-sectional representative sample of the U.S. population to show that smokers who were attempting to or who successfully quit smoking were more likely to use open than closed system e-cigarette designs. Before the FDA implements regulatory policies,[6] e-cigarette designs will continue to evolve in their absence. At this critical time as policies to regulate e-cigarettes are being formulated, regulators need to take into account the design of devices that can facilitate quitting smoking.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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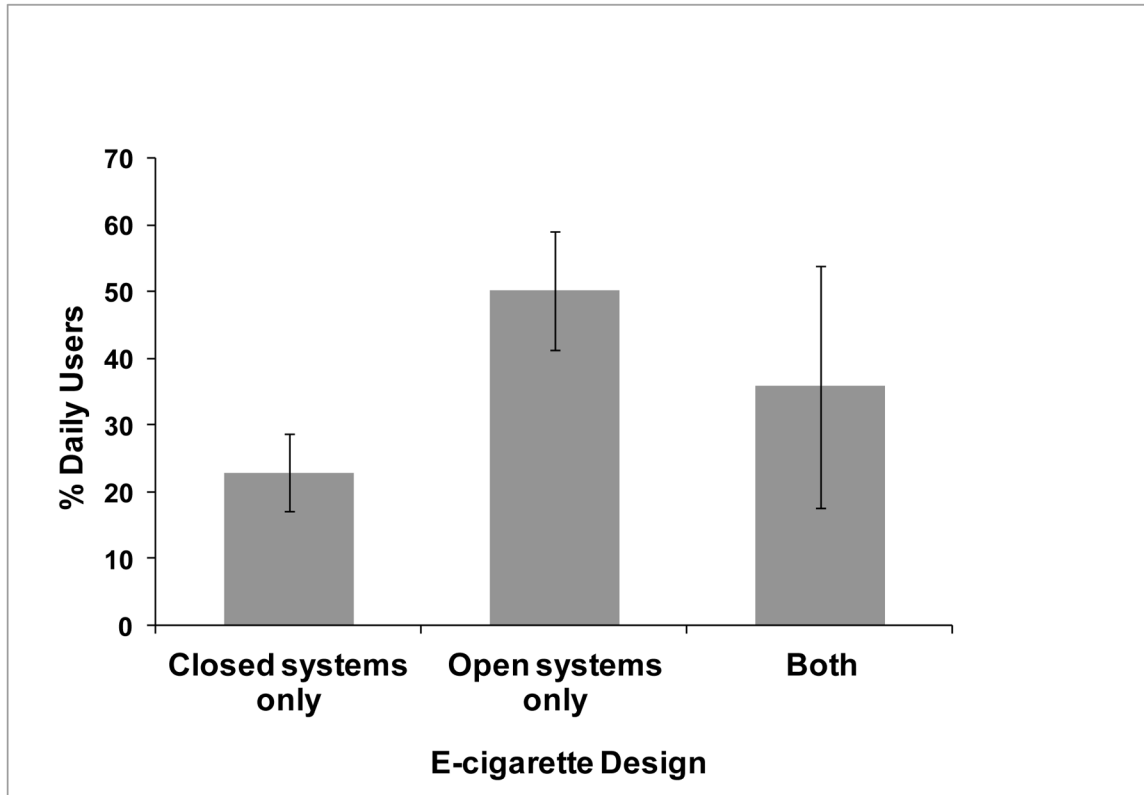
Figure 1.
Proportion of daily e-cigarette users among all users (*n*=923).

Table 1

Current Device Use among Smokers Who Use E-Cigarettes

	N	Open systems (*n*=550) % (95% CI)	Closed systems (*n*=301) % (95% CI)	Both systems (*n*=72) % (95% CI)
Total	923	41.1 (35.8 – 46.4)	51.4 (46.2 – 56.7)	7.4 (4.8 – 10.0)
Gender				
Male	321	43.7 (35.4 – 52.0)	48.5 (40.3 – 56.7)	7.8 (3.6 – 12.1)
Female	602	38.8 (32.0 – 45.5)	54.2 (47.6 – 60.9)	7.0 (3.9 – 10.1)
Age (years)				
18–24	37	48.5 (25.2 – 71.7)	50.0 (26.7 – 73.2)	1.6 (0.0 – 4.1)
25–44	272	50.6 (41.9 – 59.3)	41.7 (33.3 – 50.1)	7.7 (2.9 – 12.5)
45–64	486	31.4 (24.8 – 37.9)	59.8 (53.0 – 66.6)	8.8 (5.1 – 12.5)
65+	128	27.4 (16.1 – 38.7)	66.6 (54.7 – 78.4)	6.1 (0.8 – 11.3)
Education				
High school	257	37.9 (29.8 – 45.9)	54.0 (45.9 – 62.2)	8.1 (3.7 – 12.4)
>High school	666	44.9 (38.3 – 51.4)	48.5 (42.2 – 54.8)	6.7 (4.0 – 9.3)
Ethnicity				
Non-Hispanic white	756	36.8 (31.1 – 42.6)	56.1 (50.3 – 61.9)	7.1 (4.3 – 9.9)
Non-Hispanic black	42	42.0 (17.7 – 66.2)	55.2 (31.2 – 79.3)	2.8 (0.0 – 6.4)
Hispanic	56	51.4 (34.1 – 68.7)	37.2 (21.2 – 53.2)	11.4 (0.3 – 22.5)
Other	69	63.0 (45.1 – 80.8)	29.2 (13.3 – 45.1)	7.8 (0.0 – 18.1)

Table 2A

Preference of E-cigarette Device among All E-cigarette Users

	Former smokers (*n*=212)	Current smokers (*n*=711)	Chi-square test	Current smokers (quit attempt) (*n*=360)[a]	Current smokers (no quit attempt) (*n*=349)[a]	Chi-square test
	%	%	*p*-value	%	%	*p*-value
Open system exclusive users	53.8	35.2	**0.002**	41.4	27.7	**0.029**
Closed system exclusive users	41.4	56.1	**0.012**	48.9	65.0	**0.011**
Both systems users	4.8	8.6	0.131	9.7	7.3	0.500

Note: Boldface indicates statistical significance (*p*<0.05).

[a]Two respondents who did not answer quit attempt questions were excluded.

Table 2B

Preference of E-cigarette Device among Those Who Were Smoking 12 Months before the Survey

	Former smokers (n=129)	Current smokers (n=686)	Chi-square test	Current smokers (quit attempt) (n=344)[a]	Current smokers (no quit attempt) (n=340)[a]	Chi-square test
	%	%	*p*-value	%	%	*p*-value
Open system exclusive users	55.1	34.8	**0.006**	40.1	28.2	0.061
Closed system exclusive users	39.6	57.3	**0.015**	49.9	66.4	**0.010**
Both systems users	5.3	8.0	0.381	10.0	5.4	0.127

Note: Boldface indicates statistical significance (p<0.05).

[a]Two respondents who did not answer quit attempt questions were excluded.

Table 3

User Experience of Different E-cigarette Devices

User experience	Open-system exclusive users (*n*=301) % (95% CI)	Closed-system exclusive users (*n*=549) % (95% CI)
My e-cigarette looks like a regular cigarette.	3.1 (0.8 – 5.5)	73.0 (66.8 – 79.2)
When I hold my e-cigarette it feels like I'm holding a regular cigarette.	10.5 (4.6 – 16.5)	55.4 (48.7 – 62.1)
My e-cigarette tastes like a regular cigarette.	29.1 (21.0 – 37.2)	53.3 (46.5 – 60.1)
The throat hit I get from my e-cigarette is like the one from a regular cigarette.	50.4 (41.4 – 59.4)	43.2 (36.5 – 50.0)
Puffing on e-cigarette vapor feels like puffing on cigarette smoke.	69.2 (60.7 – 77.6)	63.6 (57.1 – 70.1)
E-cigarettes satisfy my cravings like regular cigarettes.	82.8 (76.2 – 89.5)	67.2 (60.9 – 73.5)