Oral health practices and self-reported adverse effects of E-cigarette use among dental students in 11 countries: an online survey

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Abstract

Objectives: E-cigarette use has become popular, particularly among the youth. Its use is associated with harmful general and oral health consequences. This survey aimed to assess self-reported oral hygiene practices, oral and general health events, and changes in physiological functions (including physical status, smell, taste, breathing, appetite, etc.) due to E-cigarette use among dental students.

Methods: This online, multicounty survey involved undergraduate dental students from 20 dental schools across 11 different countries. The questionnaire included demographic characteristics, E-cigarette practices, self-reported complaints, and associated physiological changes due to E-cigarette smoking. Data were descriptively presented as frequencies and percentages. A Chi-square test was used to assess the potential associations between the study group and sub-groups with the different factors. Statistical analysis was performed using SPSS at P < 0.05.

Results: Most respondents reported regular brushing of their teeth, whereas only 70% used additional oral hygiene aids. Reported frequencies of complaints ranged from as low as 3.3% for tongue inflammation to as high as 53.3% for headache, with significant differences between E-cigarette users and non-users. Compared to non-smokers, E-cigarette users reported significantly higher prevalence of dry mouth (33.1% vs. 23.4%; P < 0.001), black tongue (5.9% vs. 2.8%; P = 0.002), and heart palpitation (26.3% vs. 22.8%; P = 0.001). Although two-thirds of the sample reported no change in their physiological functions, E-cigarette users reported significant improvement in their physiological functions compared to never smokers or tobacco users.

Conclusion: Dental students showed good oral hygiene practices, but E-cigarette users showed a higher prevalence of health complications.

Keywords: E-cigarette, Smoking, Dental students, Oral health, General health, Survey

Introduction

Electronic cigarettes (E-cigarette) or electronic nicotine delivery systems are a relatively new phenomenon amongst tobacco smokers largely because of claims that they may help with smoking cessation [1, 2]. E-cigarette...
use is increasingly popular among the youth and young adults [3]. Indeed, it has been the most popular form of smoking among the youth since 2014 [4, 5]. Typically, E-cigarette users inhale an aerosol containing nicotine, flavorings, and other additives [1]. The Food and Drug Administration (FDA), however, has reported that E-cigarette cartridges and solutions contain contaminants that are potentially harmful to humans: at a minimum, these contaminants cause irritation and inflammation of the airway epithelium [6, 7] and suppressed the immune response of the nasal mucosa [8]. In fact, the proinflammatory signals, and immune-suppressive changes in the respiratory mucosa of E-cigarette uses have been reported to be different from those of non-smokers [8, 9]. Recently, a United States court has recognized the E-cigarette as a smoking tobacco product that should be prohibited or regulated as a dangerous nicotine delivery system that needs to comply with the Federal Food Drug and Cosmetic Act [10].

As with traditional cigarettes, E-cigarettes have oral health consequences [9, 11, 12]. Basically, the oral cavity, being the first part of the body exposed to the constituents of E-cigarettes or any other forms of tobacco, is at increased risk of exposure to the carcinogenic, immunologic, microbial, and clinical effects of these products. The viscosity of e-liquid promotes the colonization of Streptococcus mutans, a major causative factor of dental caries [9]. It has been found that the major ingredients of the e-liquid (nicotine, acetaldehyde, acrolein, formaldehyde and flavoring chemicals like cinnamaldehyde [13, 14]) modify the oral microbiome toward higher abundance of oral pathobionts, alter host response, and enhance periodontal inflammation [11]. Nicotine, a well-known vasoconstrictor, decreases gingival blood flow, and depresses cytokine production (IL-1β, IL-2, TNF-α, and IFN-γ), neutrophil number, and immune cell function, leading ultimately to periodontal disease and tooth loss [15–17]. The propylene glycol content of the E-cigarette breaks down into acetic and lactic acids, and other harmful compounds to the enamel and oral soft tissue [18]. In addition, E-cigarette use can lead to hyposalivation resulting in tissue drying that promotes caries, periodontal disease, and other oral health problems [9, 11, 12, 19]. The vegetable glycerin with other flavoring agents can increase microbial adhesion to enamel and promote biofilm formation, which results in a decreased enamel hardness [18]. Cinnamaldehyde can suppress the phagocytic function of neutrophils and macrophages; and inhibit the natural killer cells’ cell–killing ability of tumor cells, and ciliary beating of airway epithelial cells [20, 21].

Good oral health behaviors may lessen the negative impact of E-cigarette use on oral health; and, of course, quitting smoking is the most effective way to ensure improved oral health [22–24]. Toothbrushing twice a day with fluoride-containing toothpaste, along with adjunct mouth rinses, should help reduce the risk of caries and periodontal disease [25–27]. Additionally, reducing the daily frequency of refined carbohydrate intake can reduce the risk of caries [28], and regular dental visits will facilitate prompt detection of oral lesions and the institution of caries reversal protocols.

Dental health professionals report their own oral health status more reliably, and are clearly more aware of the positive impact of good oral health behaviors on oral health than the general public [26]. There has always been a strong drive for active engagement of dental practitioners in smoking cessation programs [29–31]. Therefore, dental professionals would be a good study cohort to assess the relationship between oral health practices and cigarette smoking. Unfortunately, only a few studies have assessed dental students’ attitudes and knowledge about the negative effects of E-cigarette use [32, 33]. Hence, there is a paucity of information related to reported health effects, and negative impact of E-cigarette on oral health, particularly among health sciences students. In this study, we aimed to explore the self-reported practices of oral healthcare and hygiene measures, and the possible adverse effects of E-cigarette among dental students in different countries.

**Materials and methods**

This study is a part of a large multinational survey conducted on E-cigarette use amongst dental students. An online cross-sectional survey was conducted among undergraduate dental students from 20 dental schools in 11 countries. Postgraduate students, academic staff, assistants, or technicians were excluded. The study was approved primarily by the Research Ethics Committee at the Faculty of Dentistry, Thamar University (Ref #2019003). In parallel with that, ethical clearance was obtained from all respective participating universities. The study fully complied with the Helsinki declaration. The electronic questionnaire was distributed to the target students via different methods including social media such as WhatsApp and Facebook groups. A hard copy of the questionnaire was also available for coauthors who could meet the dental students face-to-face. The survey had an introductory statement about the study team, study objectives, and confidentiality assurance. Each participant was able to answer the survey once and to edit their answers freely until they chose to submit. By clicking submit it was considered that the student consented to participate in the study.

The questionnaire comprised close-ended questions adopted from some previous studies [34–37] and covered: (1) sociodemographic data (age, sex, current
educational level); (2) tobacco and E-cigarette use (current habits, frequency, etc.); (3) self-perceived oral health, including number of decayed, filled, and missing teeth (DMFT); (4) oral hygiene practices, including frequency of brushing, additional aids, type of toothpaste, dental visits, etc.; (5) self-perceived symptoms due to smoking; and (6) self-perceived changes in physiological functions (including physical status, smell, taste, breathing, appetite, etc.).

**Statistical analysis**
Responses were exported to Excel sheets (MS Excel 2016) where they were checked, coded, and then transferred to a statistical software program (SPSS V25, IBM Corp. USA). Descriptive statistics in terms of frequencies and percentages were obtained for the study variables according to the smoking status (non-smokers, tobacco smokers, E-cigarette users, and dual users). The potential associations between the outcome and explanatory variables were assessed by Chi-square test, with a P-value less than 0.5 considered statistically significant.

**Results**
A total of 5697 dental students from 11 different countries (Croatia, Iraq, Jordan, Kuwait, Lebanon, Malaysia, Nigeria, Saudi Arabia, South Africa, Turkey, and Yemen) took part in the study. Numbers varied greatly across countries, ranging from 110 in Kuwait to 1626 in Yemen.

Of the total participants, 51.1% (n = 2909) were in the clinical years of study. The majority were females (60.5%, n = 3433) and unmarried (94.1%, n = 5361) (Table 1).

As presented in Table 2, 1112 (19.6%) students were current smokers in the following proportions: 596 (10.5%) were tobacco smokers, 255 (4.5%) were E-cigarette users, and 261 (4.6%) were tobacco/E-cigarette dual users. The distribution of respondents by their current smoking status differed significantly by sex and country of origin. With regard to sex, there were significantly more males than females who smoke tobacco, E-cigarettes, or both. With regard to country, Nigeria had the highest proportion of respondents who had never smoked; Saudi Arabia had the least proportion of respondents who had never smoked; no respondent smoked tobacco in Kuwait and no respondent was a dual smoker in Nigeria. No statistically significant associations were observed between smoking status and marital status, age, and education level.

The reported DMFT and oral hygiene practices are presented in Table 3. Slightly more than one-third of the sample (35.8%, n = 2029) reported having DMFT ≥ 3, 30.9% (n = 1748) reported to having DMFT < 3, and 33% (n = 1889) reported having DMFT = 0, with no statistically significant differences according to the students’ smoking status. A majority of students reported brushing their teeth 2 times or more daily (63.8%) and using fluoride-containing toothpaste (65.6%), with significant differences according to their smoking status (P = 0.003 each). Almost 80% of the participants reported that they eat sweets or drink sugary soft drinks on a daily (36.7%) or weekly basis (45.3%), and up to 72% of the participants reported that they use other oral-care devices, but with no significant differences according to the smoking status (P = 0.104 and P = 0.217, respectively). Most participants (n = 3069, 54.4%) reported regularly visiting the dentist (at least once a year), with a significant difference between E-cigarette users and other groups: 66.1% of E-cigarette smokers compared to 54.3% of non-smokers.

### Table 1 Characteristics of participants by country (N = 5697); % in brackets

| Country          | Total (N) | Gender | Age groups | Educational level | Marital status |
|------------------|-----------|--------|------------|------------------|----------------|
|                  |           | Male   | Female     | ≤ 20 years       | > 20 years     |
|                  |           |        |            | Pre-clinical     | Clinical       |
|                  |           |        |            | Married          | Unmarried      |
| All              | 5697 (100.0) | 2264 (39.7) | 3433 (60.3) | 1844 (32.4) | 3853 (67.6) | 2788 (48.9) | 2909 (51.1) | 336 (5.9) | 5361 (94.1) |
| Croatia          | 233 (4.1)  | 43 (18.5) | 190 (81.5)  | 64 (27.5) | 169 (72.5) | 109 (46.8) | 124 (53.2) | 5 (2.1) | 228 (97.9) |
| Iraq             | 369 (6.5)  | 129 (35.0) | 240 (65.0)  | 146 (39.6) | 223 (60.4) | 227 (61.5) | 142 (38.5) | 11 (3.0) | 358 (97.0) |
| Jordan           | 461 (8.1)  | 123 (26.7) | 338 (73.3)  | 205 (44.5) | 256 (55.5) | 303 (65.7) | 158 (34.3) | 6 (1.3) | 455 (98.7) |
| Kuwait           | 110 (1.9)  | 12 (10.9) | 98 (89.1)   | 25 (22.7) | 85 (77.3) | 39 (35.5) | 71 (64.5) | 4 (3.6) | 106 (96.4) |
| Lebanon          | 257 (4.5)  | 82 (31.9) | 175 (68.1)  | 137 (53.3) | 120 (46.7) | 118 (45.9) | 139 (54.1) | 1 (0.4) | 256 (99.6) |
| Malaysia         | 148 (2.6)  | 35 (23.6) | 113 (76.4)  | 38 (25.7) | 110 (74.3) | 32 (21.6) | 116 (78.4) | 0 (0.0) | 148 (100.0) |
| Nigeria          | 240 (4.2)  | 138 (57.5) | 102 (42.5)  | 49 (20.4) | 191 (79.6) | 64 (26.7) | 176 (73.3) | 10 (4.2) | 230 (95.8) |
| Saudi Arabia     | 596 (10.5) | 292 (49.0) | 304 (51.0)  | 91 (15.3) | 505 (84.7) | 178 (29.9) | 418 (70.1) | 55 (9.2) | 541 (90.8) |
| South Africa     | 204 (3.6)  | 60 (29.4) | 144 (70.6)  | 97 (47.5) | 107 (52.5) | 81 (39.7) | 123 (60.3) | 7 (3.4) | 197 (96.6) |
| Turkey           | 1453 (25.5) | 695 (47.8) | 758 (52.2)  | 640 (44.0) | 813 (56.0) | 710 (48.9) | 743 (51.1) | 33 (2.3) | 1420 (97.7) |
| Yemen            | 1626 (28.5) | 655 (40.3) | 971 (59.7)  | 352 (21.6) | 1274 (78.4) | 927 (57.0) | 699 (43.0) | 204 (12.5) | 1422 (87.5) |
49.3% of tobacco smokers (49.3%), and 55.9% of dual smokers.

Table 4 shows the subjective complaints reported by respondents. The frequencies of perceived health problems associated with smoking ranged from as few as 3.3% who reported tongue inflammation to as many as 53.3% who reported headache. Compared to non-smokers, tobacco users, E-cigarette users, and dual users reported significantly higher prevalence of dry mouth (29.3%, 33.1% and 28.1%, respectively, vs. 23.4%; \( P < 0.001 \)), black tongue (3.9%, 5.6% and 6.1%, respectively, vs. 2.8%; \( P = 0.002 \)), and heart palpitation (29.6%, 26.3% and 28.4%, respectively, vs. 22.8%; \( P = 0.001 \)).

Table 5 highlights the self-reported changes in physiological functions within the past month as reported by respondents. Overall, a majority reported “no change” in their physiological functions compared to non-smokers, tobacco users and dual users (\( P < 0.05 \)).

**Discussion**

E-cigarette use is associated with numerous oral health consequences, including, but not limited to, xerostomia, oral candidiasis, oral mucosal lesions, halitosis, dental caries, and periodontal disease [9, 12, 19, 38]. Although the negative impact of tobacco use on oral health can, to a degree, be mitigated by good oral health behaviors, quitting smoking, and not resorting to E-cigarette use, is the most effective way to ensure good and sustained oral health [22–24]. In this context, dental students and professionals are considered role models for the community and should be at the forefront of fighting dental diseases and the associated deleterious habits. The present survey aimed to assess self-reported oral hygiene practices and the perceived effects of E-cigarettes among dental students across 11 different countries. Collectively, the results revealed good oral hygiene practices including tooth brushing and using additional oral hygiene means,
### Table 3  DMFT and oral hygiene practices among dental students based on the current status of smoking

| Number of decayed, filled, and missing teeth do you have? | Total | Never smoke | Tobacco only | E-cigarette only | Dual user | P |
|----------------------------------------------------------|-------|-------------|--------------|------------------|-----------|---|
| None                                                     | 1889  | 1525 (33.5) | 198 (33.3)   | 77 (30.2)        | 89 (34.1) | 0.517 |
| < 3 teeth                                                | 1748  | 1403 (30.8) | 171 (28.7)   | 92 (36.1)        | 82 (31.4) |   |
| ≥ 3 teeth                                                | 2029  | 1627 (35.7) | 226 (38.0)   | 86 (33.7)        | 90 (34.5) |   |
| How many times do you brush your teeth per day?          |       |             |              |                  |           | 0.003 |
| None                                                     | 255   | 185 (4.1)   | 44 (7.4)     | 16 (6.3)         | 10 (3.8)  |   |
| Once a day                                               | 1799  | 1449 (31.8) | 195 (32.8)   | 83 (32.5)        | 72 (27.6) |   |
| ≥ 2 times a day                                          | 3614  | 2924 (64.2) | 355 (59.8)   | 156 (61.2)       | 179 (68.6) |   |
| Do you use fluoride containing toothpaste?               |       |             |              |                  |           | 0.003 |
| Yes                                                      | 3709  | 3013 (66.3) | 356 (59.9)   | 181 (71.3)       | 159 (61.2) |   |
| No                                                       | 608   | 476 (10.5)  | 85 (14.3)    | 21 (8.3)         | 26 (10.0) |   |
| I don’t know                                             | 1334  | 1054 (23.2) | 153 (25.8)   | 52 (20.5)        | 75 (28.8) |   |
| How often do you eat sweets or drink sugary soft drinks? |       |             |              |                  |           | 0.104 |
| On a daily basis                                         | 2081  | 1698 (37.3) | 217 (36.5)   | 92 (36.1)        | 74 (28.4) |   |
| On a weekly basis                                        | 2569  | 2041 (44.8) | 279 (46.9)   | 120 (47.1)       | 129 (49.4) |   |
| Rarely                                                   | 1016  | 816 (17.9)  | 99 (16.6)    | 43 (16.9)        | 58 (22.2) |   |
| Do you use other oral-care devices besides toothbrush and toothpaste? |       |             |              |                  |           | 0.217 |
| No                                                       | 1594  | 1291 (28.4) | 176 (29.7)   | 59 (23.2)        | 68 (26.1) |   |
| Yes                                                      | 4056  | 3251 (71.6) | 417 (70.3)   | 195 (76.8)       | 193 (73.9) |   |
| How often do you visit your dentist?                     |       |             |              |                  |           | 0.002 |
| > 2 times a year                                         | 737   | 585 (12.9)  | 71 (12.0)    | 39 (15.4)        | 42 (16.1) |   |
| 1–2 times a year                                         | 2332  | 1880 (41.4) | 221 (37.3)   | 127 (50.0)       | 104 (39.8) |   |
| Rarely                                                   | 2577  | 2073 (45.7) | 301 (50.8)   | 88 (34.6)        | 115 (44.1) |   |

### Table 4  Perceived related effects/events among dental students based on the current status of smoking

| Have you experienced the following problems in the last month? | Total | Never smoke | Tobacco only | E-cigarette only | Dual user | P |
|---------------------------------------------------------------|-------|-------------|--------------|------------------|-----------|---|
| Sore mouth and/or throat                                     | 1600  | 1314 (28.9) | 162 (27.4)   | 54 (21.4)        | 70 (26.8) | 0.062 |
| Dry mouth and/or throat                                      | 1367  | 1042 (23.4) | 172 (29.3)   | 81 (33.3)        | 72 (28.1) | < 0.001 |
| Mouth and/or tongue inflammation                             | 517   | 425 (9.4)   | 52 (8.8)     | 25 (9.9)         | 15 (5.7)  | 0.245 |
| Black tongue                                                | 182   | 129 (2.8)   | 23 (3.9)     | 14 (5.6)         | 16 (6.1)  | 0.002 |
| Gingivitis                                                   | 1077  | 883 (19.4)  | 111 (18.7)   | 42 (16.7)        | 41 (15.8) | 0.354 |
| Nose bleeding                                                | 485   | 390 (8.6)   | 46 (7.7)     | 21 (8.4)         | 28 (10.7) | 0.557 |
| Headache                                                    | 3015  | 2476 (54.5) | 311 (52.4)   | 112 (44.3)       | 116 (44.6) | < 0.001 |
| Cough                                                       | 1635  | 1293 (28.5) | 198 (33.4)   | 62 (24.6)        | 82 (31.4) | 0.026 |
| Chest pain                                                  | 1000  | 756 (16.7)  | 141 (23.7)   | 44 (17.5)        | 59 (22.7) | < 0.001 |
| Dizziness                                                   | 1715  | 1390 (30.9) | 179 (30.4)   | 68 (27.4)        | 78 (30.1) | 0.698 |
| Heart palpitation                                           | 1351  | 1035 (22.8) | 176 (29.6)   | 66 (26.3)        | 74 (28.4) | 0.001 |
| Allergy                                                     | 997   | 823 (18.1)  | 93 (15.7)    | 35 (13.9)        | 46 (17.6) | 0.195 |

Yes response is reported
but it also revealed that more E-cigarette users reported dry mouth and heart palpitation compared to non-smokers. Unexpectedly, however, E-cigarette users reported some improvements in some of their physiological functions compared to tobacco smokers or non-smokers.

Owing to a lack of studies on the oral health effects amongst dental students who are E-cigarette users, we weighed the results of our study against what has been reported in the general population. Many recent population-based studies in USA found an association between E-cigarette use and/or dual use, and untreated dental caries [39], self-reported bad oral health [40], chronic obstructive pulmonary disease [41] and other respiratory [42] and health symptoms [43]. Although a recent systematic review stated that E-cigarette use was less harmful than smoking conventional cigarettes, it pointed to a greater susceptibility of E-cigarette users to the development of alterations in oral soft tissues than

| Table 5 Perceived physiological functions among dental students based on the current status of smoking |
|---------------------------------|-----------|-----------|----------|-----------|-----------|
| Have you experienced changes in the following physiological functions in the past month? |
| Physical status                  | Total     | Smoking status | Never smoke | Tobacco only | E-cigarette only | Dual user |
| Worsened                         | 564 (10.3)| 436 (10.0)    | 89 (15.1)   | 13 (5.2)    | 26 (10.2)         |
| No change                        | 4362 (79.8)| 3520 (80.6) | 454 (76.8)  | 193 (76.6)  | 195 (76.2)        |
| Improved                         | 542 (9.9) | 413 (9.5)     | 48 (8.1)    | 46 (18.3)   | 35 (13.7)         |
| Smell                             |           |              |            |            |                   |
| Worsened                         | 259 (4.7) | 175 (4.0)     | 64 (10.8)   | 9 (3.6)     | 11 (4.3)          |
| No change                        | 4873 (89.1)| 3958 (90.6) | 497 (84.2)  | 202 (80.2)  | 216 (84.4)        |
| Improved                         | 335 (6.1) | 236 (5.4)     | 29 (4.9)    | 41 (16.3)   | 29 (11.3)         |
| Taste                             |           |              |            |            |                   |
| Worsened                         | 224 (4.1) | 148 (3.4)     | 53 (9.0)    | 11 (4.4)    | 12 (4.7)          |
| No change                        | 4918 (90.0)| 3998 (91.5) | 499 (84.4)  | 204 (81.0)  | 217 (84.8)        |
| Improved                         | 325 (5.9) | 222 (5.1)     | 39 (6.6)    | 37 (14.7)   | 27 (10.5)         |
| Breathing                         |           |              |            |            |                   |
| Worsened                         | 546 (10.0)| 376 (8.6)     | 106 (17.9)  | 25 (10.0)   | 39 (15.2)         |
| No change                        | 4564 (83.5)| 3742 (85.7) | 442 (74.8)  | 185 (74.0)  | 195 (76.2)        |
| Improved                         | 354 (6.5) | 249 (5.7)     | 43 (7.3)    | 40 (16.0)   | 22 (8.6)          |
| Appetite                          |           |              |            |            |                   |
| Worsened                         | 869 (16.0)| 688 (15.8)    | 115 (19.5)  | 30 (12.0)   | 36 (14.1)         |
| No change                        | 3879 (71.2)| 3114 (71.6) | 407 (69.0)  | 175 (70.3)  | 183 (71.8)        |
| Improved                         | 697 (12.8)| 549 (12.6)    | 68 (11.5)   | 44 (17.7)   | 36 (14.1)         |
| Mood                              |           |              |            |            |                   |
| Worsened                         | 1437 (26.3)| 1179 (27.0) | 172 (29.1)  | 30 (11.9)   | 56 (21.9)         |
| No change                        | 3355 (61.3)| 2682 (61.4) | 349 (59.0)  | 167 (66.3)  | 157 (61.3)        |
| Improved                         | 678 (12.4)| 509 (11.6)    | 71 (12.0)   | 55 (21.8)   | 43 (16.8)         |
| Memory                            |           |              |            |            |                   |
| Worsened                         | 907 (16.6)| 743 (17.0)    | 110 (18.6)  | 18 (7.2)    | 36 (14.1)         |
| No change                        | 4087 (74.8)| 3263 (74.8) | 430 (72.8)  | 198 (78.9)  | 196 (76.6)        |
| Improved                         | 469 (8.6) | 359 (8.2)     | 51 (8.6)    | 35 (13.9)   | 24 (9.4)          |
| Quality of sleep                 |           |              |            |            |                   |
| Worsened                         | 1257 (23.0)| 1015 (23.2) | 157 (26.6)  | 35 (13.9)   | 50 (19.5)         |
| No change                        | 3441 (62.9)| 2750 (62.9) | 355 (60.1)  | 175 (69.4)  | 161 (62.9)        |
| Improved                         | 774 (14.1)| 608 (13.9)    | 79 (13.4)   | 42 (16.7)   | 45 (17.6)         |
| Stamina                           |           |              |            |            |                   |
| Worsened                         | 1035 (18.9)| 803 (18.4) | 155 (26.4)  | 29 (11.5)   | 48 (18.8)         |
| No change                        | 3761 (68.8)| 3025 (69.3) | 373 (63.4)  | 189 (75.0)  | 174 (68.0)        |
| Improved                         | 667 (12.2)| 539 (12.3)    | 60 (10.2)   | 34 (13.5)   | 34 (13.3)         |
ex-smokers and non-smokers, and concluded that neither
the safety nor efficacy of E-cigarette use in the long-term,
either as a smoking cessation aid or as an alternative to
tobacco smoking that is less harmful to health, has been
established [44].

The present findings concur with previous stud-
ies among dental students elsewhere [26, 45]. However,
dental students still seem to need some motivation in
the use additional oral hygiene devices such as flossing,
mouth rinses, and/or interdental brush use and even flu-
oride-containing paste. Dental students, the future den-
tal professional, through good oral hygiene attitude and
practices, can act as role models and play a positive role
in improving the oral health status of their patients and
the community at large [26, 46].

Another important finding of the present study was the
significantly higher proportion of E-cigarette users who
had dry mouth and black tongue when compared to non-
smokers. This finding is not surprising, as E-cigarette
use has been reported to cause numerous oral mucosal
conditions such as xerostomia and hairy tongue [9, 12,
19]. These findings agree with those of previous studies
that reported a significant association between E-ciga-
rette and oral mucosal diseases [11, 22, 38]. The harm-
ful consequences of nicotine on oral tissues have been
well established [11, 38]. Thus it is important to include
information about the harmful effects of E-cigarettes in
the oral health/dental education curriculum, and to train
personnel on how to support quitting the habit [32].
Additionally, the dental curriculum and that of other
health disciplines should include information on the oral/
general health impact of E-cigarettes [32, 47].

More E-cigarette users reported better physiological
functions, especially breathing, mood, taste, physical sta-
tus, and memory, compared to non-smokers and tobacco
users. Although these findings are consistent with many
previous studies that reported improvement of general
health outcomes, they must be interpreted with caution
since such improvement were in context of switching
from traditional smoking to E-cigarette use [2, 19, 34,
48]. In other words, after long-term exposure to the very
deterious effects of conventional smoking, the switch-
ers perceive the less deleterious effects of E-cigarettes as
an improvement.

The main strength of the present study is the large sam-
ple size and involvement of students from various coun-
tries with different economic and cultural backgrounds.
Nevertheless, the study has some limitations that should
be considered when interpreting the results. The main
limitation is the self-reported nature of responses, which
might have introduced bias. But this might not be of such
great concern given that the respondents are dental stu-
dents: that is to say they can easily determine whether
there are alterations in their mouths, and whether these
alterations, if present, may be E-cigarette-induced. This is
also applied to the self-reported DMFT. Another limita-
tion is the non-response bias, and thus the results cannot
be extrapolated to non-participants. Also, despite the
multicultural, multi-county sample, the percentage of
E-cigarette users in the total sample was relatively small,
and subsequently we were not able to run multivariate
analysis so as to identify predictors of the outcomes. It
follows that the results of the study should be interpreted
with caution. Finally, we did not investigate the time of
smoke smoking before switching to E-cigarette use
among E-cigarette users with previous experience of cig-
arette smoking. We focused only on the current status of
smoking whether cigarette smoking, E-cigarette use, dual
smoking or never.

Overall, the perceived improvement in health outcomes
and the wrong perception about the safety of E-cigarettes
may explain the growing popularity of E-cigarettes [5].
Unfortunately, E-cigarette users do not view E-cigarette
use (vaping) as a harmful habit, and studies have shown
that vaping is considered favorably by users concern-
ning overall health perception [49–51]. This emphasizes
the urgent need for educating dental students about the
long-term health effects of E-cigarettes and implement-
ing tobacco cessation programs.

Conclusion
Irrespective of the noted good oral hygiene practices
among dental students, those who were E-cigarette users
reported more oral health-related conditions, particu-
larly xerostomia and black tongue, and heart palpati-
one, even though they unexpectedly reported significant
improvement in their physiological functions compared
to non-smokers.

Abbreviations
E-cigarette: Electronic cigarettes; FDA: Food and drug administration; IL: Inter-
leukin; TNF: Tumor necrosis factor; IFN: Interferon; DMFT: Decayed, missing,
filled teeth; SPSS: Statistical package for the social sciences; US: United States.

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Availability of data and materials
The datasets supporting the findings of this article are available from the corresponding author.

Declarations

Ethics approval and consent to participate
This study was approved primarily by the Research Ethics Committee at the Faculty of Dentistry, Thamar University, Dhamar, Yemen (Ref#: 2019003). The study was conducted in accordance with the Declaration of Helsinki Ethical Principles. All participants were informed about the study objectives. Participation was voluntary and the participant can withdraw from the study at any time without penalty. Informed consent was obtained from all participants. By clicking on 'submit' the student consented to participate in the study. Names, email, or any other personal identifiers were not included in the data collected.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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