# Electronic Cigarettes and Peri-Implantitis: An Umbrella Review

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Electronic cigarettes (e-cigarettes) are offered to consumers as a healthier option than traditional tobacco. However, the long-term effect of non-heat-burning tobacco and e-cigarettes on periodontal and peri-implantitis is unknown. The present review evaluates the impact of electronic cigarettes on peri-implantitis and compares the results with traditional cigarettes and nonsmokers. Systematic/meta-analysis studies were searched in PubMed, MEDLINE, EMBASE, Cochrane Library, and Google Scholar until December 30, 2022. Five systematic/meta-analysis studies were identified based on the search strategy in the selected databases. The overall quality assessment of the studies showed acceptable evidence with high quality. All systematic review studies showed that compared with traditional tobacco smoke, electronic cigarettes might reduce or not change the clinical inflammatory symptoms of periodontitis and peri-implantitis, such as bleeding on probing, probing depth, peri-implant bone loss, and response to treatments. Electronic cigarettes contain nicotine, which can harm periodontal and implant health. On the other hand, a wide range of oral health consequences may be associated with using e-cigarettes. E-cigarette is a potential risk factor for the healing process and the results of implant treatment.

***Key Words: electronic cigarettes, dental implants, peri-implantitis, review***

## INTRODUCTION

Peri-implantitis is a bacterial infection in the soft tissues surrounding the implant, that causes inflammation and progressive bone loss. If not treated properly, it can lead to implant failure.[1,2] Several known systematic factors and inflammatory disorders reinforce the intensity and progression rate of inflammation in peri-implantitis,[3–8] damaging habits,[9] especially smoking.[10,11]

E-cigarettes entered the market in 2006 and became the most ubiquitous tobacco product as a hobby among people.[12] E-cigarettes were introduced as a healthy alternative to traditional cigarettes and smoking cessation in 2014 and transformed into current global trends.[13] E-cigarettes are small handheld devices that contain a battery that heats a solution and produces an aerosol. Usually, the liquid comprises a mixture of nicotine, humectants, and chemical flavoring agents.[14,15] However, due to the discovery of heavy metals and other hazardous elements, they are not considered a secure substitute for traditional tobacco cigarettes.[16] Additionally, e-cigarette users still have a higher risk of oral mucosal lesions, tooth damage, and periodontal disease than nonsmokers.[17–20]

A study showed that consumption of unburned tobacco products has less destructive effects on periodontal treatment than traditional smokers.[21] However, it has been established that all forms of tobacco may potentially increase the proliferation of oral epithelial cells.[22]

Several studies investigated the effect of smoking on implant failure and peri-implantitis,[23–30] in contrast, some studies suggest that e-cigarettes are a healthy option in comparison to traditional smoking,[28,29] and other studies raised concerns about the effect of e-cigarettes on the oral mucosa.[23,27]

Therefore, the current umbrella study reviews the findings of 5 systematic reviews/meta-analyses to answer the following question: What are the effects of electronic cigarettes on peri-implant conditions?

## MATERIALS AND METHODS

This review was based on the Statement of Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA).[31]

### *Study design*

This umbrella review included 5 systematic/meta-analysis reviews and resources that examined electronic cigarettes and peri-implantitis.[9,17,26,30,32]

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https://doi.org/10.1563/aaid-joi-D-24-00157



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### *Eligibility criteria*

This study is based on previous systematic studies/meta-analyses. The inclusion and exclusion criteria were as follows: systematic reviews and meta-analyses published in English that examined peri-implantitis and periodontal effects of e-cigarettes. Evidence from laboratory, animal, and human studies was included. There were no restrictions on the types of e-cigarette devices and e-liquids considered. However, because the focus was on the side effects of e-cigarettes on periodontal and peri-implant health, self-reported side effects and studies on the health effects of passive vaping were excluded.

### *Search strategy*

Electronic databases of PubMed, MEDLINE, EMBASE, Cochrane Library, and Google Scholar were searched until December 2022 by considering language restrictions and according to PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-analyses). The search was performed based on medical subject headings (MeSH) and non-MeSH terms in simple or multiple conjunctions, which included (peri-implantitis), (dental implants), (electronic cigarettes), and (systematic review or meta-analysis). The search was performed on PubMed and EMBASE, MEDLINE, Cochrane Library, and Google Scholar databases to find all publications.

### *Study selection*

Two independent reviewers (M.R. and Q.P.) evaluated studies for the analysis. Accordingly, on researcher (M.R.) extracted qualitative or quantitative data from the studies, and the other (Q.P.) confirmed qualified data.

The collected information included the authors' names, the year and type of the study, the number of patients and implants, the outcome assessment results, the comparison results, and the conclusions.

### *Risk of bias assessments*

Two independent authors (A.F. and K.B.) assessed the selected systematic reviews. Systematic reviews were appraised based on the risk of bias in systematic reviews (ROBIS) criteria.[33] This tool has two main phases and one optional stage. In the first stage, the relevance of a study is evaluated (optional phase one), then the reviewing process and risk of bias are considered in phases 2 and 3. Four main domains that can cause bias in a review article (study eligibility, selection process of studies, data collection and assessment, and synthesis) are covered by the ROBIS tool.

Studies were then classified into three categories: high (3–4 negative), moderate (2 negatives), and low (less than 2), based on the risk of bias.

### *Outcomes assessed*

In the study of Akram et al,[23] databases were searched up to May 2018. Outcomes assessed included peri-implant bone loss, probing depth, plaque index, and bleeding during probing.[23] Alfadda's[25] study conducted an electronic search in 5 electronic databases, including controlled trials and prospective studies up to January 2017. Farronato et al[24] searched electronic databases up to August 2021. Outcomes assessed included plaque index, probing depth, bleeding on probing, radiographic crestal bone loss, and peri-implant blood fluid analysis.[24] In a review of D'Ambrosio et al,[28] a literature search was conducted in 2 electronic databases until April 2022. In the study of Wasfi et al,[30] 3 databases were searched to identify studies comparing chronic e-cigarette use on health between August 31, 2017, and January 29, 2021. The risk of bias and certainty of evidence were assessed.[30] A literature search was conducted in 3 databases in a systematic review by Caggiano et al.[27] In Travis et al,[29] 4 electronic databases were searched up to January 25, 2022. Methodological quality was assessed using the AMSTAR-2 quality assessment tool.[29] In the study of Ralho et al,[17] 3 electronic databases were searched to identify articles published until November 2018. The methodological quality of the selected studies was evaluated with using the ROBINS-I guidelines.[17] In the study by Yang et al,[32] 3 electronic databases were searched. The quality assessment tool of the public health performance project was used to evaluate the evidence.[32]

## Results

### *Study selection*

A search of PubMed, MEDLINE, EMBASE, Cochrane Library, and Google Scholar yielded 49 systematic/meta-analysis review articles. After removing duplicate sources, 25 studies remained to investigate the titles and abstracts. After carefully evaluating these publications, 15 studies met the eligibility criteria, full papers were read, and 5 systematic/meta-analysis articles for data extraction were selected. Details of the research strategy and a summary of the most important features of these articles are in Figure 1 and the Table.

### *Quality assessment*

All the papers correctly answered the target review question which was the e-cigarette effect on peri-implantitis (phase #1). Most of the studies showed a low risk of bias. Only 1 study showed a moderate risk of bias regarding the synthesis and findings (Figure 2).

### *Study characteristics*

The Table presents general data on included studies: authors and year of publication, number, type of studies, interventions, outcomes, and main results.

This umbrella review aims to update the evidence identified in previous systematic reviews/meta-analyses[9,17,26,30,32] on the effects of e-cigarettes on peri-implant inflammation. Previous studies have shown sufficient evidence of periodontal outcomes, particularly changes in bone loss, implant failure and plaque index, clinical adhesion loss, probing depth, peri-implant bone loss, and proinflammatory cytokine levels.

In a systematic review of D'Ambrosio et al,[28] 18 articles met the inclusion criteria to enter the study. They found that e-cigarettes may reduce clinical inflammatory symptoms of periodontitis and, hypothetically, peri-implantitis compared with traditional smoke.[28]

In the Wasfi et al[30] study, 180 articles were eligible for inclusion. Outcomes, including inflammation, immune response, periodontal and peri-implant clinical parameters, lung function, respiratory symptoms, and cardiovascular disease, showed nonsignificant



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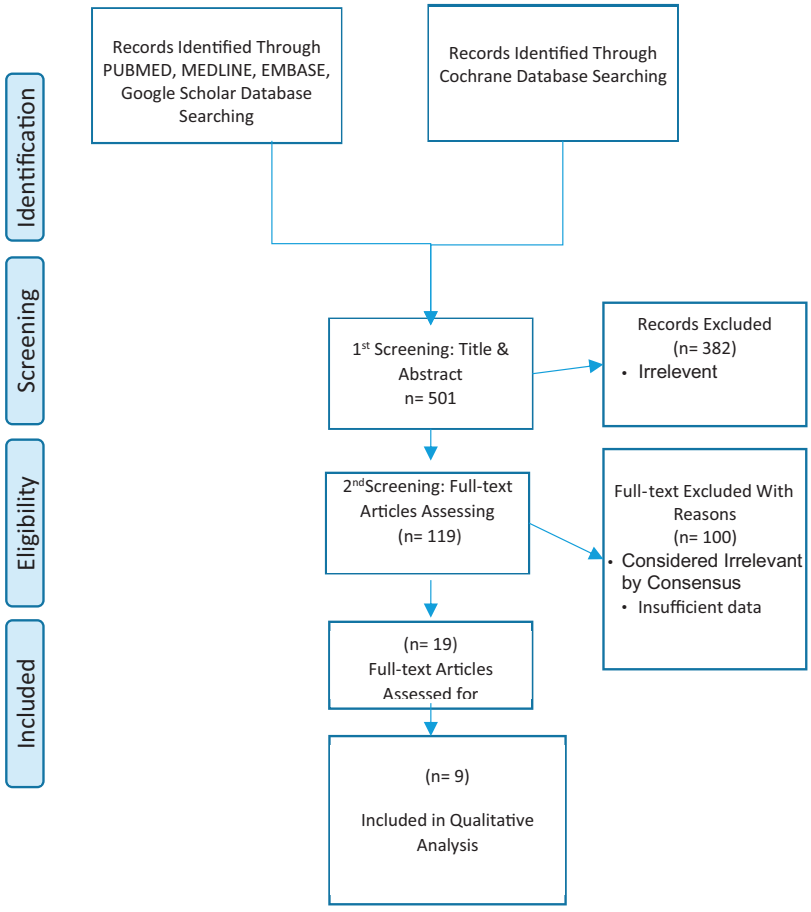


**Figure 1.** Flow charts for the studies were identified, displayed, and included in the study.

results when comparing daily e-cigarettes to nonsmokers. The only notable exception was related to oral health, where most studies reported inflammation among daily e-cigarette users compared with nonsmokers.[30]

Eight articles were selected for analysis in the study by Ralho et al.[17] Periodontal and peri-implant clinical and radiographic parameters, including plaque index, clinical adhesion loss, probing depth, peri-implant bone loss, and proinflammatory cytokine levels, were worse among e-cigarette and regular smokers than nonsmokers. Also, the amount of bleeding during probing was higher in nonsmokers compared with e-cigarettes and traditional smokers. In addition, various oral mucosa lesions were more common in the e-cigarettes.[17]

In a study by Pesce et al,[26] 5 articles were selected for evaluation. A significant difference was observed in comparing traditional and electronic cigarettes regarding plaque index and probe depth. Analysis of probe bleed values shows a significant difference between traditional and nonsmokers. Based on the SUCRA ranking, nonsmokers showed the most favorable results for probing depth and plaque index, followed by electronic smokers. Smokers were clearly in last place. Dealing with bleeding in the study, electronic cigarettes led to the best results, followed by traditional ones. Nonsmokers were ranked last.[26]

In a study by Yang et al,[32] 99 articles were included. The investigated outcomes were as follows: oral, throat, dental, and periodontal effects, cytotoxic/genotoxic/oncological effects; oral microbiome; and traumatic/accidental injury. The majority of mouth and throat symptoms experienced by e-cigarette users were relatively minor and temporary, with some evidence that conventional smokers who switched to e-cigarettes experienced mitigation of these symptoms. E-cigarette exposure increases the risk of deteriorating periodontal, dental, and gingival health as well as changes to the oral microbiome. Extensive dental damage as a result of e-cigarette explosions was described in case reports. Components of e-cigarette vapor have known cytotoxic, genotoxic, and carcinogenic properties.[32]

## Discussion

Our review pooled evidence from systematic reviews/meta-analyses examining the periodontal effects of e-cigarettes compared with traditional cigarettes from studies conducted. The evidence reviewed from human studies shows the potential for reduced or unchanged clinical inflammatory symptoms of periodontitis and peri-implantitis when using e-cigarettes compared with traditional cigarettes. Furthermore, there was insufficient evidence linking the long-term use of e-cigarettes with chronic changes in peri-implantitis and an increased risk of dental problems compared with smokers or nonsmokers.

In the D'Ambrosio et al[28] study, the same as several other studies, it has been shown that e-cigarettes can have adverse effects on periodontal and peri-implant health.[17,30]

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TABLE

Baseline characteristics of systematic reviews on the peri-implantitis health-risk of electronic cigarette

| Study | No. of studies | Design | Date | Assessment method | Outcome | Conclusion |
|---|---|---|---|---|---|---|
| Yang et al,[32] Systematic review | 98 | 7 randomized control<br>11 experimental<br>15 case reports<br>46 descriptive<br>19 in vitro | From 2010 to 2019 | Effective Public Health Practice Project (EPHPP) | Oral, throat, dental, and periodontal effects, cytotoxic/genotoxic/oncological effects, oral microbiome, and traumatic/accidental injury | Using e-cigarettes can endanger periodontal, dental, and oral health |
| D'Ambrosio et al,[28] Systematic review | 18 | 7 randomized control<br>9 experimental<br>2 case reports | From 2003 to April 2022 | ROBINS-I | They found that e-cigarettes may reduce clinical inflammatory symptoms of periodontitis and, hypothetically, peri-implantitis compared with traditional smoke.[28] | E-cigarettes as an alternative product contain nicotine and can have adverse effects on periodontal and peri-implant health.[28] |
| Wasfi et al,[30] Systematic review | 93 | 71 cross-sectional<br>9 cohort<br>8 RCTs<br>2 quasi-experimental<br>2 case-control | From August 31, 2017 to 29 January 29, 2021 | CASP RoB | Outcomes, including inflammation, immune response, periodontal and peri-implant clinical parameters, lung function, respiratory symptoms, and cardiovascular disease, showed nonsignificant results when comparing daily e-cigarettes to nonsmokers. The only notable exception was related to oral health, where most studies reported inflammation among daily e-cigarette users compared with nonsmokers.[30] | E-cigarette users had no statistically significant differences in inflammation or clinical periodontal parameters compared with smokers. However, they had different findings for peri-implant clinical parameters.[30] |
| Ralho et al,[17] Systematic review | 8 | 6 case-control<br>2 cross-sectional | From January 1, 2003 to November 15, 2018 | ROBINS-I | Periodontal and peri-implant clinical and radiographic parameters, including plaque index, clinical adhesion loss, probing depth, peri-implant bone loss, and proinflammatory cytokine levels, were worse among e-cigarette and regular smokers than nonsmokers. Also, the amount of bleeding during probing was higher in nonsmokers compared with e-cigarettes and traditional smokers. In addition, various oral mucosa lesions were more common in e-cigarettes.[17] | E-cigarettes are less harmful than traditional cigarettes. However, e-cigarette users are more prone to changes in oral biological tissues than smokers or nonsmokers, so there is still a clear need to develop new studies.[17] |
| Pesce et al,[26] Systematic review | 5 | 3 comparative study<br>2 prospective study | Until December 2021 | NIH quality assessment tool for observational cohort and cross-sectional studies | A significant difference was observed in comparing traditional and electronic cigarettes regarding plaque index and probe depth. Analysis of probe bleed values shows a significant difference between traditional and nonsmokers. Based on the SUCRA ranking, nonsmokers showed the most favorable results for probing depth and plaque index, followed by electronic smokers. Smokers were clearly in last place. Dealing with bleeding in the study, electronic cigarettes led to the best results, followed by traditional ones. Nonsmokers were ranked last.[26] | Periodontal parameters were similar between e-cigarettes and nonsmokers, while traditional smokers presented the worst index. Bleeding on probing was reduced in both traditional and e-cigarette smokers. The clinical relevance of the present study showed a reduction in the effect on the periodontal tissue of electronic cigarettes compared with traditional cigarettes, despite recent studies demonstrating that e-cigarettes increase oxidative stress and inflammatory responses[26] |

In a study by Pesce et al,[26] periodontal parameters were similar between e-cigarettes and nonsmokers, while traditional smokers presented the worst index. Bleeding on probing was reduced in both conventional and e-cigarette smokers. The clinical relevance of the present study showed a reduction in the effects on the periodontal tissue from electronic cigarettes compared with traditional cigarettes, despite recent studies demonstrating that e-cigarettes increase oxidative stress and inflammatory responses.[26] The study by Yang et al[32] stated that using e-cigarettes can endanger periodontal, dental, and oral health. A previous



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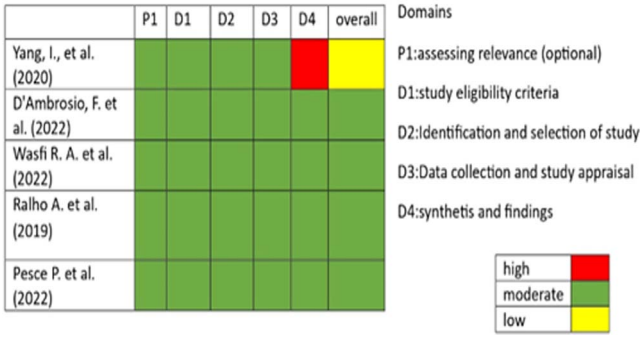


**Figure 2.** Risk of bias assessment.

study[19] also explained that although there is considerable evidence that e-cigarette compounds can induce oxidative stress, evidence for long-term human exposure due to e-cigarette use is limited. Furthermore, neither inflammatory biomarkers nor immune responses were observed between e-cigarettes and nonsmokers.

The scientific evidence of previous studies showed that smoking could play a significant role in the treatment outcomes of peri-implantitis.[24] For example, hookah and smoking hurt peri-implant health, including implant failure rate and marginal bone loss.[23,25] The systematic review of Caggiano et al[27] discussed the role of smoking cessation on the health status around the implant and response to treatment, and due to the lack of sufficient evidence, they suggested conducting focused research to evaluate smoking cessation on the health status peri-implant and response to treatment. Finally, Travis et al[29] emphasized the design of new systematic reviews with better reporting systems.

Few studies with limited duration found no significant difference in the odds of not developing peri-implantitis among e-cigarette users compared with smokers, despite substantial adverse effects on oral health. Furthermore, the overall certainty of the evidence in many of the studies identified by the present review suggests that there is no significant difference between e-cigarettes and smokers regarding peri-implantitis. However, among the few samples where differences were observed, e-cigarette users had poorer outcomes than nonsmokers but better outcomes than smokers.

Despite studies examining oral health, findings are mixed, with 3 of 5 studies reporting significantly higher inflammation among e-cigarette users than nonsmokers. However, for many other oral health outcomes, more recent evidence than previously limited evidence does not support worsening periodontal health in e-cigarette users compared with nonsmokers or the hypothesis that switching from smoking to e-cigarettes caused decreasing the risk of periodontal diseases.[19]

## Conclusion

Compared with traditional tobacco smoke, electronic cigarettes may reduce or not change the clinical inflammatory symptoms of periodontitis and peri-implantitis, such as bleeding on probing. However, electronic cigarettes contain nicotine, adversely affecting periodontal and implant health. On the other hand, a wide range of oral health consequences such as increased risk of dental caries, gingivitis, and oral cancers may be associated with using e-cigarettes.

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