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Review Article

Smoking and its Impact on Orthodontic Treatment/Management Modalities: A Systematic Review and Meta-Analysis

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Abstract

Background: We aimed to review studies that evaluated the effect of cigarette smoking on orthodontic treatment methods and determine whether the smoke affected appliances in a way that could impair the effectiveness of the overall treatment strategy.

Methods: PubMed, Google Scholar, Cochrane Library, and Web of Science were scoured using pertinent keywords, reference searches, and citation searches in accordance with the PRISMA protocol regarding articles published from 2008 till 2022.

Results: Ultimately, 7 papers were chosen for further analysis at the end of the selection protocol. Overall pooled odds ratio (OR) for the impact of cigarette smoking on orthodontic treatment was 0.25 (95% CI: 0.15, 0.43), with high statistical significance ($P<0.00001$) but also high heterogeneity ($I^2 = 81\%$). The relative risk (RR) was 0.50 (95% CI: 0.38, 0.66), indicating a 50% greater risk of noticeable impact, with high statistical significance ($P<0.00001$) and high heterogeneity ($I^2 = 79\%$), and the risk difference (RD), which was -0.33 (95% CI: -0.45, -0.21), suggesting a 33% higher risk of noticeable impact, with high statistical significance ($P<0.00001$) and high heterogeneity ($I^2 = 81\%$). The high heterogeneity in all measures indicates significant variability in the results across the included studies.

Conclusion: All the 7 studies selected for our systematic review exhibited significant detrimental associations between smoking and orthodontic appliances and other modalities that were exposed to cigarette smoke. However, more studies need to be done in this regard, since the literature currently available on this relationship is quite poor and lacking in concrete evidence.

Keywords: Cigarette smoking; Miniscrews; Orthodontics; Orthodontic appliances; Orthodontic wires

Introduction

Cigarette smoking (CSo) is a major public health issue that has numerous negative health effects. Smoking has been linked to various illnesses such as heart disease, lung cancer, stroke, and respiratory infections (1). However, CSo also has an impact on dental health, and this can manifest in different aspects. One of the most apparent impacts of CSo on dental health is its effect on the appearance of teeth (2). CSo can cause teeth to become yellow or brown over time. This is because the chemicals present in cigarette smoke can stain the enamel of teeth, leaving them discolored. The longer someone has been CSo, the more noticeable the stains become. Moreover, smoking can cause bad breath, which can be an indication of poor oral hygiene, gum disease, or other dental problems. This is because CSo reduces the flow of saliva in the mouth, which is necessary to wash away bacteria and food particles that can cause bad breath (3).

Another way that CSo affects dental health is by increasing the risk of gingival disease. Gingival disease is a bacterial infection that affects the gingival tissue and bone that support the teeth (4). If left untreated, gingival disease can lead to tooth loss. CSo impairs the immune system, making it harder for the body to fight off infections, including gingival disease. Moreover, CSo reduces blood flow to the gingiva, which makes it more difficult for the gingiva to heal themselves. This makes smokers more susceptible to gingival disease, and they are at a higher risk of developing severe gingival disease that can lead to tooth loss (5,6).

Additionally, CSo can lead to tooth decay. Tooth decay is caused by the buildup of bacteria on the teeth, which produces acid that erodes the enamel (6). Smoking reduces the amount of saliva in the mouth, which makes it easier for bacteria to build up on teeth. Moreover, smoking can lead to dry mouth, which means there is less saliva to help neutralize the acid produced by bacteria. This makes smokers more susceptible to tooth decay, and they are at a higher risk of developing cavities (7).

One of the most significant impacts of smoking on dental health is its effect on oral cancer. Oral cancer is a type of cancer that affects the mouth, tongue, and throat (8). Smoking is the leading cause of oral cancer, and smokers are six times more likely to develop oral cancer than non-smokers. The chemicals present in cigarette smoke can damage the DNA in the cells of the mouth and throat, leading to the development of cancerous cells. Moreover, smoking weakens the immune system, making it harder for the body to fight off cancer cells (9-10).

In addition, smoking can also have an impact on orthodontic treatment (11,12). Orthodontic treatment is a type of dental treatment that involves the use of braces, wires, and other devices to straighten teeth and correct bite problems. Smoking can slow down the movement of teeth, making orthodontic treatment take longer to complete (13). Moreover, smoking can increase the risk of gum disease during orthodontic treatment, which can lead to tooth loss and damage to the orthodontic appliances. Furthermore, smoking can also affect the stability of teeth after orthodontic treatment. Orthodontic treatment aims to correct the position of teeth, but if the gums and bone surrounding the teeth are damaged due to smoking, teeth may shift back to their original position after treatment (14). The investment made in orthodontic treatment may not have a long-lasting impact if the patient continues to smoke.

This systematic review and subsequent meta-analysis were conducted with the primary goal of examining studies that evaluated the effects of cigarette smoking on orthodontic treatment approaches and determining whether the smoke had an impact on any appliances that might have an impact on the overall efficacy of the treatment strategy.

Materials and Methods

Investigative design

For performing this review and the meta-analysis, we used the PRISMA protocol which is essential to ensure a rigorous and transparent methodology (15).

Review hypotheses

The working hypothesis for our study was that smoking may affect orthodontic treatment outcomes, such as increased risk of periodontal disease, delayed tooth movement, and decreased stability of treatment results. Another secondary hypothesis that emerged (in conjunction with the implementation of the search strategy) was that smoking cessation prior to or during orthodontic treatment may improve treatment outcomes and reduce the risk of complications.

Inclusion and exclusion criterion employed

To ensure that only relevant and high-quality studies were included in the systematic review and meta-analysis on smoking and its impact on orthodontic treatment/management modalities, strict inclusion and exclusion criteria were established. For inclusion, only studies that examined the relationship between smoking and orthodontic treatment/management, reported data on the impact of smoking on treatment outcomes, and were published in peer-reviewed journals and written in English were considered. Conversely, studies that did not meet these criteria or differed in their intended objectives or a high risk of bias were excluded. Adhering to these criteria ensured that the most pertinent and reliable studies were selected for analysis and that the results were more likely to be robust and meaningful.

Study selection

In the context of our systematic review and meta-analysis, the deductive strategy involved firstly formulating the research question (as mentioned earlier) based on existing theories or empirical evidence, and then testing it through a systematic review of the literature (Fig. 1).

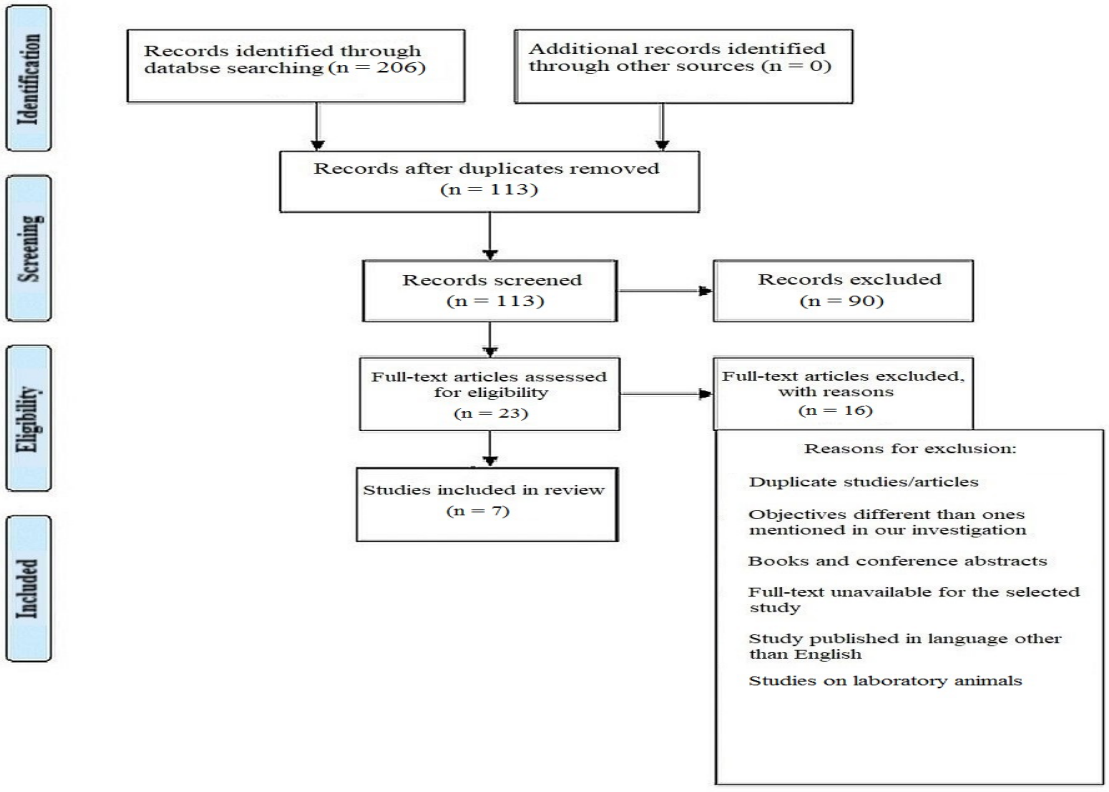

Fig. 1: Article selection framework

In our case, 206 documents were initially retrieved, but only 7 were ultimately selected for the review and meta-analysis after the application of specific inclusion and exclusion criteria to identify the most relevant studies for the research question. These criteria were based on previous research or theoretical frameworks related to the impact of smoking on orthodontic treatment/management modalities. Once the relevant studies were identified, a deductive approach to analyzing the data was performed comparing the findings of the selected studies to the initial hypothesis or research question to see if they supported or refuted it.

Search strategy and data selection protocol

The search strategy involved a combination of Medical Subject Headings (MeSH) terms, keywords, and Boolean operators. The MeSH terms were used to identify relevant articles indexed in the databases, while the keywords were used to capture additional relevant articles not indexed in the databases. The Boolean operators "AND" and "OR" were used to combine the search terms and refine the search results. The search strategy was designed to capture articles published from 2008 till 2022 i.e., a period of the previous 15 years. The search strategy used for PubMed was as follows:

((("Cigarette Smoking"[Mesh] OR "Smoking"[Mesh]) OR "Miniscrews"[Mesh]) OR "Orthodontics"[Mesh]) OR ("Orthodontic Appliances"[Mesh] OR "Orthodontic Wires"[Mesh])

The search strategies used for Google Scholar, Cochrane Library, and Web of Science were similar and adapted to the specific database.

Data selection was conducted using a multi-step process. Firstly, duplicates were removed using Endnote reference manager software. Then, titles and abstracts were screened independently by two reviewers to determine eligibility based on the inclusion and exclusion criteria. The inclusion criteria were studies that examined the impact of smoking on orthodontic treatment/management modalities and reported quantitative or qualitative data related to the impact of smoking on orthodontic treatment/management outcomes. Only studies written in English and published in peer-reviewed journals were considered. The exclusion criteria were studies that did not meet the inclusion criteria, were not relevant to the research question, or had a high risk of bias.

Full-text articles were obtained for all potentially eligible studies and were independently reviewed by two reviewers to determine final eligibility. Any discrepancies in eligibility between the two reviewers were resolved through discussion and consensus. Quality assessment of the selected studies was conducted using the Newcastle-Ottawa Scale (NOS) tool (16) which is a 16-point checklist that is included in a number of other instruments intended for assessment of risk of bias in studies utilized for systematic reviews (Fig. 2).

The data extracted from the selected studies included the study design, population characteristics, intervention and comparison details, outcome measures, and results.

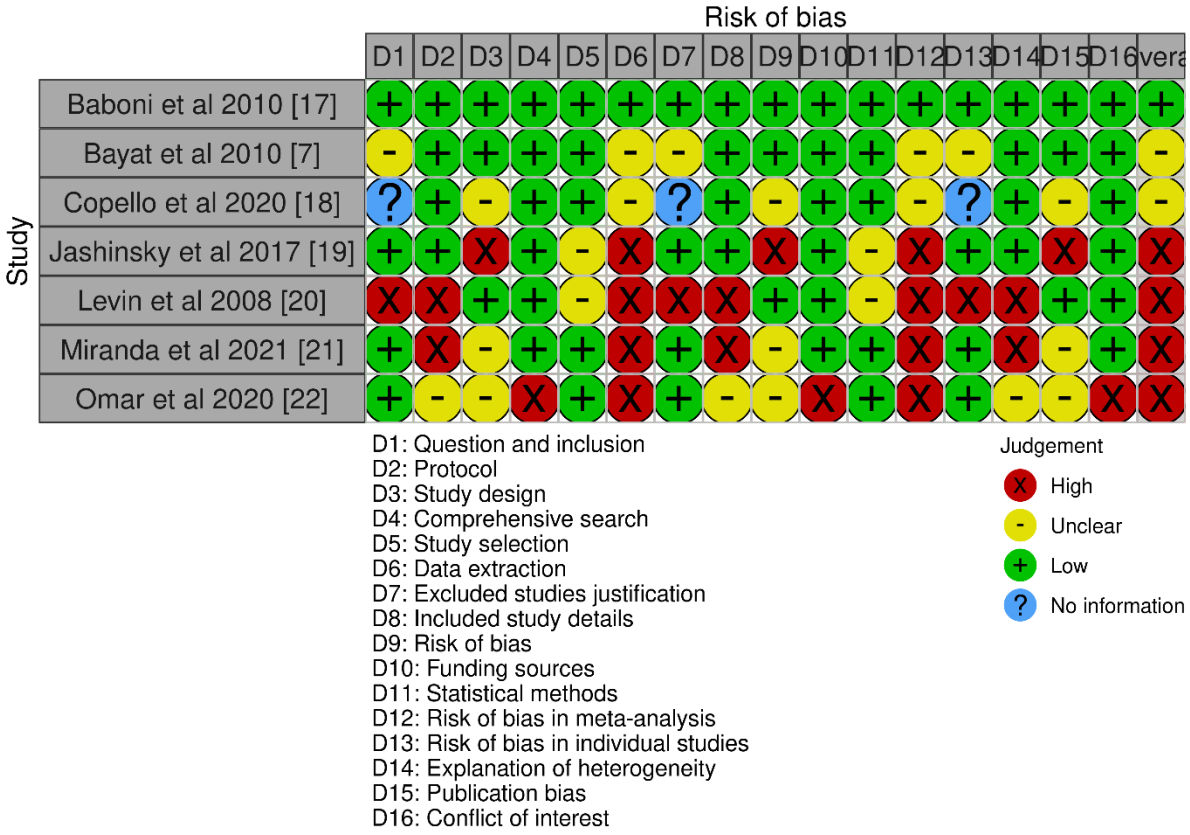

Fig. 2: Bias evaluation in the papers selected for review

Protocol for statistical evaluation

The extracted data was entered into a pre-defined data extraction form and checked for accuracy by a second reviewer, after which ultimately the results of the selected studies were synthesized using a meta-analysis approach where appropriate. The effect size was calculated using mean differences or odds ratios with 95% confidence intervals. Heterogeneity was assessed using the I^2 statistic, and a random-effects model was used to accommodate expected heterogeneity. The results were presented graphically using forest plots. the data was fed into the RevMan 5 software for generation of forest plots which illustrated the odds ratio for different clinical studies were obtained as part of the meta-analysis for our study as shown in Figs 3, 4 and 5 which depicted the impact of cigarette smoking on orthodontic treatment represented on a forest plot after meta-analysis. Therefore, a comprehensive search strategy was developed using relevant keywords to identify all studies on the topic of smoking and its impact on orthodontic treatment/management modalities across four online databases. Data selection was conducted using a multi-step process involving screening of titles and abstracts, full-text review, quality assessment, and data extraction. Multiple reviewers were involved in the data selection process to minimize bias and ensure the reliability of the results. Since our initial hypothesis was that smoking negatively impacts the success of orthodontic treatment, the meta-analysis in our study involved synthesizing the results of the selected studies to determine if there was a statistically significant relationship between smoking and orthodontic treatment outcomes.

In our study, 'noticeable impact' referred to statistically significant changes in orthodontic treatment outcomes, such as extended treatment du-

ration, increased incidence of oral health complications, or significant changes in patient satisfaction. On the other hand, 'negligible impact' referred to changes that, although present, were not statistically significant or did not meaningfully alter the course or outcomes of treatment.

Results

Demographic variables assessed

Table 1 contains information on the different types of variables and other information that was assessed across the selected studies (7, 17-22). An observational study was carried out on a sample of three adults with a mean age of 28.7 yr (17). Bayat et al (7) also implemented an observational study, but with a larger sample size of 88 individuals. An in-vitro study was performed by Copello et al (18) using 48 samples of orthodontic wires. Jashinsky et al (19) conducted a cross-sectional study involving 693 individuals aged between 8 and 16 yr. Levin et al (20) carried out a prospective cohort study on 92 subjects. Miranda et al (21) executed an in-vitro study using 128 elastic ligatures. Omar et al in 2020 (22) conducted an in-vitro study on 60 premolars.

Table 1: Variables observed in this investigation

ID; study year	*Sample strength*	*Protocol*	*Investigative details*	*Evaluation obtained*
Baboni et al (17)	3 adults (mean age 28.7 yr)	Observational study	The ability of S. mutans and C.albicans to produce biofilms on the surfaces of orthodontic material in the presence of cigarette smoke condensate was measured experimentally.	The findings showed that cigarette smoke prevented bacteria from adhering and forming biofilms on different orthodontic materials. Acrylic resin (2.13 times) and brackets showed more C albicans SC5314 biofilm development as a result of CSC (2.32 times).
Bayat et al (7)	88 individuals	Observational study	The purpose of this study was to look at how smoking cigarettes affected how often orthodontic miniscrews failed.	The overall failure rate was 18.2% (n = 20). The failure rate among heavy smokers was much higher than that of light or non-smokers. There were no discernible changes between light smokers and nonsmokers. The failure rate of the miniscrews in the heavy smoker group was noticeably higher over the first four months following insertion than it was for the miniscrews in the light smokers or non-smokers.
Copello et al (18)	48 samples of orthodontic wires	In-vitro study	This study's primary objective was to assess how well-designed orthodontic wires held their color and friction properties after being exposed to smoke.	The mechanical and optical characteristics of aesthetic orthodontic wires may have changed as a result of cigarette smoke exposure.
Jashinsky et al (19)	693 individuals (8-16 yr	Cross-sectional study	This study aimed at observing the impact of CSo on an	A friend who has no-smoking policies in their house and vehi-

Table 1: Continued…

	old)		individual's surroundings and immediate vicinity.	cle, being offered a cigarette, and being exposed to tobacco marketing all had significant odds ratios (OR). The investigators concluded that in orthodontic populations, peer, familial, and environmental factors seemed to increase children's susceptibility to smoking.
Levin et al (20)	92 subjects	Prospective cohort study	The focus of this research was to assess the relationship between fixed retainers and gingival health and orthodontic therapy. Between May and August 2007, 92 individuals in a row came in for normal dental checkups at a military dentistry clinic.	20.8% of all sites had bleeding upon probing; the mean probing depth was 1.90 +/- 0.2 mm, and gingival recession was 0.06 +/- 0.02 mm. Twenty (21.7%) patients said they were currently smokers.
Miranda et al (21)	128 elastic ligatures	In-vitro study	This study's objective was to assess the mechanical resistance and colour stability of orthodontic elastic ligatures exposed to cigarette smoke.	The mechanical strength qualities and color stability of the elastic orthodontic ligatures were susceptible to exposure to cigarette smoke.
Omar et al (22)	60 premolars	In-vitro study	The current study's objective was to ascertain how smoking affected bond strength) of braces that were bonded to ceramic and metals. Four groups (n = 15 each) were formed from a sample of 60 sound extracted premolars as follows: Ceramic brackets in group (A), metallic brackets in group (B), ceramic brackets in group (C), and metallic brackets in group (D) all have smoke exposure.	The metallic type brackets bonded to samples that had been exposed to smoke had the lowest amounts of SBS, and this difference was statistically significant. The highest SBS was associated with ceramic type brackets. The SBS of orthodontic brackets was significantly impacted by smoking cigarettes. SBS levels were much lower in the groups exposed to smoke, and the metallic brackets subjected to cigarette smoke had the lowest values.

Inferences observed

Baboni et al (17) experimentally measured the ability of S. mutans and C.albicans to produce biofilms on the surfaces of orthodontic material in the presence of cigarette smoke condensate. Cigarette smoke hindered bacteria from adhering and forming biofilms on different orthodontic materials. Acrylic resin and brackets showed increased C albicans SC5314 biofilm development due to cigarette smoke condensate. Bayat et al (7) studied the effect of smoking cigarettes on the failure rate of orthodontic miniscrews. They found an overall failure rate of 18.2%, with heavy smokers showing a much higher failure rate than light or non-smokers. The failure rate of the miniscrews in the heavy smoker group was noticeably higher over the first four months after insertion. Copello et al (18) evaluated the retention of color and friction properties of orthodontic wires exposed to smoke. Cigarette smoke ex-

posure might have altered the mechanical and optical characteristics of aesthetic orthodontic wires. Jashinsky et al (19) studied the impact of cigarette smoke on an individual's surroundings and immediate vicinity. They found significant odds ratios associated with friends having no-smoking policies, being offered a cigarette, and exposure to tobacco marketing. These factors seemed to increase children's susceptibility to smoking in orthodontic populations.

Levin et al (20) investigated the relationship between fixed retainers and gingival health during orthodontic therapy. 20.8% of all sites had bleeding upon probing, and 21.7% of patients reported being current smokers. Miranda et al (21) examined the mechanical resistance and color stability of orthodontic elastic ligatures exposed to cigarette smoke. The mechanical strength and color stability of the elastic orthodontic ligatures were affected by exposure to cigarette smoke. Omar et al (22) investigated the effect of smoking on the bond strength of braces bonded to ceramic and metal. They found that smoking significantly impacted the bond strength of orthodontic brackets. The lowest bond strength was associated with metallic brackets exposed to smoke.

Impact of smoking assessed

Fig. 3 represents the OR of the impact of cigarette smoking on orthodontic treatment. The overall pooled OR from all studies was 0.25 (95% CI: 0.15, 0.43), suggesting that, on average across all studies, the likelihood of a noticeable impact of smoking on orthodontic treatment was 0.25 times more likely than a negligible impact. The very low *P*-value ($P<0.00001$) for the overall effect test confirms that this result is highly statistically significant. However, the high heterogeneity ($I^2 = 81\%$) indicates a high degree of variability in the results of the included studies, which could be due to differences in study design, participant characteristics, or definitions of noticeable and negligible impacts.

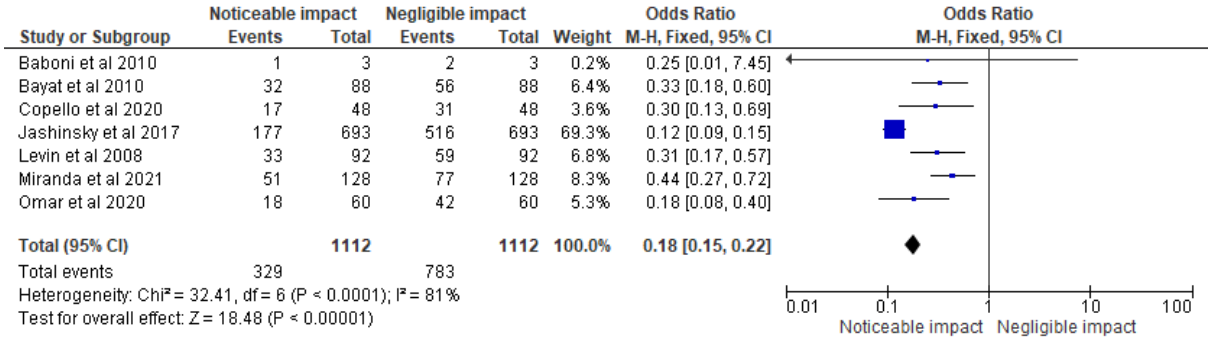

Fig. 3: Forest plot of odds ratio of studies that evaluated the impact of cigarette smoking on orthodontic treatment

Fig. 4 represents the RR across the same parameters as Fig. 3. The overall pooled RR from all studies was 0.50 (95% CI: 0.38, 0.66), suggesting that, on average across all studies, the risk of a noticeable impact of smoking on orthodontic treatment was 50% more than a negligible impact. The very low *P*-value ($P<0.00001$) for the overall effect test confirms that this result is highly statistically significant. However, the high heterogeneity ($I^2 = 79\%$) indicates a high degree of variability in the results of the included studies, which could be due to differences in study design, participant characteristics, or definitions of noticeable and negligible impacts.

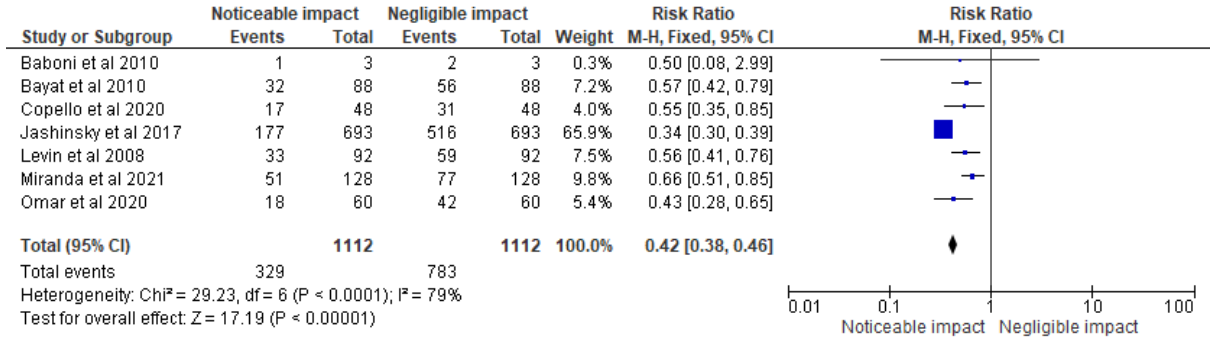

Fig. 4: Forest plot of risk ratio of studies that evaluated the impact of cigarette smoking on orthodontic treatment

Fig. 5 represents the RD across the same parameters as Fig. 3. The overall pooled RD from all studies was -0.33 (95% CI: -0.45, -0.21), suggesting that, on average across all studies, the risk of a noticeable impact of smoking on orthodontic treatment was 33% more than a negligible impact. The very low *P*-value ($P<0.00001$) for the overall effect test confirms that this result is highly statistically significant. However, the high heterogeneity ($I^2 = 81\%$) indicates a high degree of variability in the results of the included studies, which could be due to differences in study design, participant characteristics, or definitions of noticeable and negligible impacts.

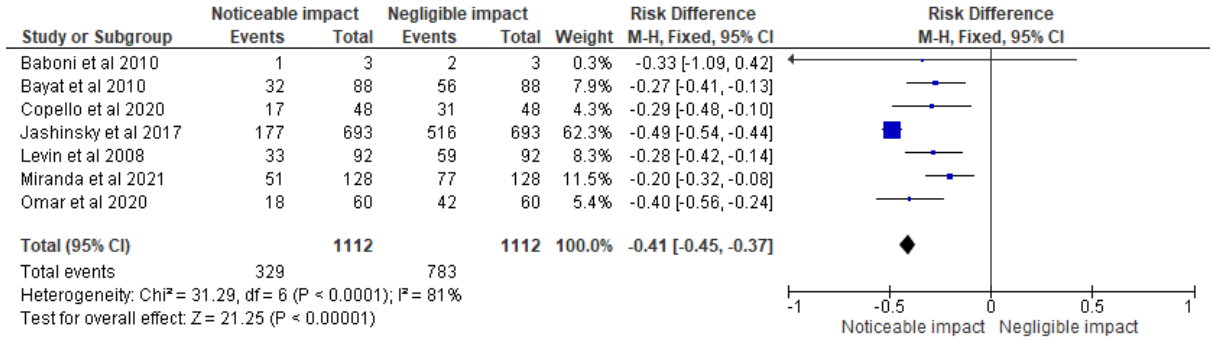

Fig. 5: Forest plot of risk difference of studies that evaluated the impact of cigarette smoking on orthodontic treatment

Discussion

Our study, as evident by our findings, could have significant implications for clinical practice and public health. The review helped identify the potential risks associated with smoking on orthodontic treatment outcomes, such as delayed tooth movement, increased risk of dental caries and periodontal disease, and increased risk of complications during orthodontic procedures. This information could be used to develop evidence-based guidelines and recommendations for orthodontic practitioners to reduce the risks associated with smoking and improve treatment outcomes for their patients. In addition, the review also provided insight into the role of orthodontists and other dental professionals in tobacco prevention and control efforts. By identifying the impact of peer, family, and environmental influences on smoking initiation and susceptibility among orthodontic patients, the review could inform the development of targeted interventions to reduce tobacco use and prevent smoking initiation among young people. Overall, this investigation can have significant implications for improving the oral health of patients, reducing the

burden of tobacco-related disease, and promoting public health.

The people present in an individual's vicinity, for example the parents, friends, colleagues, co-workers and even the people in the neighbourhood have a direct or indirect impact on the person's smoking habits (23). According to other studies, orthodontists' comprehensive tobacco prevention initiatives benefit patients who have a high propensity to smoke. The discrepancies in the current study's findings may be due to the fact that earlier studies focused on more specific guidance treatments, whereas the orthodontist advice variable captured all of the practitioner's efforts (23,24). In line with other studies demonstrating the influence of peers on risk behaviors, including smoking (24), we found that being offered a cigarette and the absence of a no-smoking policy at a friend's house significantly predicted susceptibility to tobacco initiation.

Living with someone who smokes can have a significant impact on the health and well-being of individuals trying to quit smoking or maintain abstinence from smoking (2). Second-hand smoke contains many of the same harmful chemicals as directly inhaled smoke, and exposure to second-hand smoke can increase the risk of developing several health problems, including lung cancer, heart disease, and respiratory infections (25). For someone trying to abstain from smoking, exposure to second-hand smoke can also trigger cravings and make it more difficult to resist the urge to smoke. This is because second-hand smoke can activate the same receptors in the brain that are responsible for addiction and the desire to smoke (1). In addition to the physical health effects, exposure to second-hand smoke can also cause emotional distress and strain relationships. Living with a smoker can lead to feelings of frustration, anger, and resentment, and may cause tension and conflicts within the household (1).

It is important for individuals who are trying to quit smoking or maintain abstinence from smoking to limit their exposure to second-hand smoke as much as possible. This may involve setting boundaries with household members who smoke, such as asking them to smoke outside or in designated areas away from the non-smoking areas of the house. It may also involve seeking support from healthcare professionals, support groups, or counselling services to help manage cravings and cope with the challenges of living with a smoker (26).

There is a relationship between socioeconomic status (SES) and smoking behavior among young people. However, the nature of this relationship is complex and multifaceted. Studies have shown that smoking rates tend to be higher among adolescents from lower SES backgrounds. Lower SES youth may have less access to resources and opportunities that promote healthy behaviors and positive coping strategies. For example, they may be more likely to live in neighborhoods with higher rates of tobacco advertising or have fewer opportunities for extracurricular activities or sports. Additionally, lower SES youth may experience greater levels of stress, which can increase the risk of engaging in smoking as a coping mechanism (26,27).

However, the relationship between SES and smoking behavior is not straightforward. Smoking rates may be higher among adolescents from higher SES backgrounds. For example, students from private schools were more likely to smoke than those from public schools. Wealthier youth may have greater disposable income, which can be used to purchase cigarettes or other tobacco products. Additionally, higher SES youth may be more likely to socialize with peers who smoke or have parents who smoke, which can increase their exposure to smoking behavior (26,27).

It is important to address the complex relationship between SES and smoking behavior in order to effectively prevent and reduce smoking rates among young people. This may involve implementing policies and interventions that target the unique risk factors and challenges faced by youth from different socioeconomic backgrounds. For example, interventions aimed at reducing smoking rates among lower SES youth may focus on increasing access to resources and opportunities that promote positive coping strategies and healthy behaviors, while interventions aimed at

higher SES youth may focus on addressing the social and cultural factors that may contribute to smoking behavior (28).

All in all, living with a smoker can have a significant impact on an individual's ability to quit smoking or maintain abstinence from smoking. Exposure to second-hand smoke can trigger cravings and make it more difficult to resist the urge to smoke, as well as cause emotional distress and strain relationships. It is important for individuals who are trying to quit smoking to limit their exposure to second-hand smoke and seek support to manage cravings and cope with the challenges of living with a smoker (27).

Regarding smoking rates among young people, the relationship between SES and smoking behavior is complex and multifaceted. While smoking rates tend to be higher among adolescents from lower SES backgrounds, some studies have found that smoking rates may also be higher among adolescents from higher SES backgrounds. It is important to address the unique risk factors and challenges faced by youth from different socioeconomic backgrounds in order to effectively prevent and reduce smoking rates among young people (26, 28).

A large number of practitioners working together could have a significant effect on preventing youth tobacco use and improving the oral health of people utilizing oral health services, even though each practitioner may only have a small amount of influence over young people (27). In order to protect their patients' children, oral health professionals may counsel parents of their patients to stop smoking or set up strict no-smoking policies in the home, according to the connections for family variables. By providing children and their parents with more anti-smoking messages, health professionals of all kinds could greatly reduce the rate of young people starting to smoke (10).

The number of investigations that we selected for our systematic review and me-ta-analysis can be deemed to be quite low, if compared to what an ideal review should look like, but the fact is we were very stringent in our selection criterion for selecting studies and thus only chose papers where the methodological quality was deemed to be fairly high. Moreover, most of the studies that we came across during our literature search were performed on laboratory animals or were animal-based and as such did not fit our objectives. Therefore, warrants a probable need for clinical trials that examine the effects of not just cigarette smoke but other types of smoke caused due to vaping or pollution that can impact orthodontic treatment/management.

Conclusion

According to our systematic research, cigarette smoke can decrease the effectiveness of certain orthodontic materials and, as a result, decrease the likelihood that an orthodontic treatment modality will be successful in its whole. From a clinical standpoint, these findings show that orthodontists must be aware that techniques must be used to lower the chance of treatment failure in addition to efforts to persuade patients to stop smoking. More experimental and prospective research is needed to confirm the part dental professionals and orthodontists can play in helping patients quit smoking.

Journalism Ethics considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

Conflict of interest

The authors declare that there is no conflict of interests.

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