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Effectiveness of Charcoal-infused Toothbrushes on Dental Plaque Removal: A Systematic Review and Meta-Analysis

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Abstract

***Background*:** This systematic review aimed to evaluate the available clinical evidence on the plaque removal effectiveness of charcoal-infused toothbrushes in comparison to non-charcoal brushes. ***Methods*:** An online search was conducted in major scientific databases. Inclusion criteria were experimental clinical trials conducted on participants aged 18 years or older that evaluated the plaque removal effectiveness of charcoal-infused toothbrushes compared to non-charcoal brushes, with no limitations on the language or publication date. ***Results*:** Out of 147 studies, 2 met the inclusion criteria. The Risk of Bias in the included articles was determined as "high". The findings were mixed regarding the plaque removal effectiveness. One of the studies showed higher efficacy for charcoal-infused toothbrushes. In contrast, the other study showed a similar effect for both types of brushes. The meta-analysis could not be performed due to the small number of eligible studies, with each utilizing different outcome measures. ***Conclusions*:** Within the context of this review, it is unclear whether charcoal-infused toothbrushes are better oral hygiene aids than non-charcoal brushes. Therefore, further research over a longer duration is needed to reach a conclusive statement. Healthcare professionals and the public should be cautious when recommending or utilizing such novel products that lack enough scientific support.

Keyword: Charcoal, Toothbrush, Dental plaque, Systematic review.

Abbreviations: DPIA: Digital Plaque Imaging Analysis.

INTRODUCTION

Plaque control practices play a vital role in maintaining adequate periodontal health by preventing dental plaque formations in the oral cavity [1]. Mechanical plaque control can preserve oral health by preventing the occurrence of both dental caries and periodontal disease [2]. The practice of tooth brushing is considered the most common plaque control method used globally due to its affordability, practicality, and efficacy [3]. It involves using a toothbrush, mostly the manual type, and a dentifrice to clean the teeth and gums. The effectiveness of mechanical plaque control using a manual toothbrush depends on several factors, such as the brushing technique, the magnitude of the applied force, user dexterity skills, and the frequency and duration of brushing [4-7]. In addition, the design of the toothbrush is an important factor to consider, which usually relies on personal preference and oral hygiene demands [8-10]. Individuals who have not sought professional advice regarding the most suitable type of toothbrush for their needs may select a brush based on advertising claims, cost, availability, or family tradition [3].

The demand for natural and alternative dental care products has recently increased in the oral hygiene field. Manufacturers are constantly striving to improve the effectiveness of their products [3]. One such innovation gaining popularity is the charcoal-infused toothbrush (Figure 1), especially in Southeast Asian markets such as Indonesia, Singapore, and Malaysia [11]. This manual brush features slim-tip charcoal bristles that are black [3]. The bristles are infused with activated charcoal (Binchotan or white charcoal) prepared by rapidly cooling after subjecting the charcoal

to an extremely high temperature [12]. This activation process leads to the formation of micro-spherical particles with strong absorption capabilities to remove toxins produced by harmful bacteria [12]. The goal of the charcoal-infused toothbrush is to effectively clean the oral cavity, whiten the teeth, freshen the breath, reduce halitosis, decrease bacterial growth, detoxify the body, and eradicate bacteria by raising salivary pH levels [13].

However, the effectiveness of this emerging type of toothbrush in removing dental plaque and preserving oral tissue health is unknown. Additionally, there are no meta-analyses or systematic review articles in the current literature that have accurately evaluated the effectiveness of charcoal-infused toothbrushes. Therefore, the aim of this systematic review is to evaluate the available clinical evidence on the plaque removal effectiveness of charcoal-infused toothbrushes compared with non–charcoal-infused brushes.

Figure 1: The charcoal-infused toothbrush (adapted from: https://www.colgate.com/en-us/products/toothbrush/360-charcoal#).

MATERIAL AND METHODS

The current systematic review and meta-analysis was registered in the International Prospective Register of Systematic Reviews (PROSPERO; registration number: CRD42023471880) and followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [14, 15].

Experimental clinical trials conducted on human subjects were included in this review. The research question was, "What is the effect of charcoal-infused toothbrushes on the removal of plaque from the surfaces of teeth and gum compared with non–charcoal-infused toothbrushes?" The PICO strategy used in this review was as follows: Population (P): individuals aged ≥18 years; intervention (I): the use of charcoal-infused toothbrushes; comparison (C): the use of non–charcoal-infused toothbrushes; and outcome (O): plaque removal efficacy for maintaining good oral hygiene.

Search strategy:

A search in electronic databases was conducted to identify eligible studies for this review, with detailed search strategies that were specifically created and used for each database (see Supplementary file S1). There were no limitations on language or publication date during the search, using a combination of free-text terms and controlled vocabulary. Databases searched included the Cochrane Library (Wiley), MEDLINE via Ovid, ClinicalTrials.gov, Web of Science, and PubMed, up until November 2, 2023. The reference lists of the included trials were also reviewed to identify additional relevant studies.

Data selection and extraction:

EndNote version X9 [16] was used to export all references before processing by Covidence systematic review software [17], where duplications were identified and removed. Two authors (BSS and MAA) independently assessed the titles and abstracts of relevant articles. Any disagreements were resolved through discussion and consensus between the reviewers.

All studies meeting the inclusion criteria were included in this review, regardless of their quality. Using Covidence systematic review software, the two reviewers (BSS and MAA) extracted necessary data in duplicate, including the main author's name, publication year and journal, study design, country where the work was conducted in, population and participants' characteristics, sample size, interventions/comparators, type of outcomes, as well as measurement methods.

Quality assessment

The same reviewers (BSS and MAA) independently assessed the risk of bias in included articles according to the Cochrane Handbook for Systematic Reviews of Interventions [18]. To evaluate the quality of included articles, the following seven domains/areas were evaluated: sequence generation, allocation concealment, participant and staff blinding, outcome assessor blinding, incomplete outcome data, selective outcome reporting, and any other relevant bias [18]. Studies were categorized as having low risk of bias if all seven domains were assessed as "low risk," unclear risk of bias if any domain was deemed unclear, or high risk of bias if any domain was considered "high risk," with disagreements resolved through discussion and consensus.

Data Analysis

A meta-analysis was planned if there were sufficient articles reporting the same outcome measures. A random-effects model was intended for grouping mean differences in continuous outcomes.

RESULTS

Following both electronic and manual searches, a total of 147 studies were initially identified, of which 140 remained after removing duplicates. Two articles underwent full-text review after title and abstract screening, and they were thoroughly reviewed in accordance with the eligibility requirements (Figure 2).

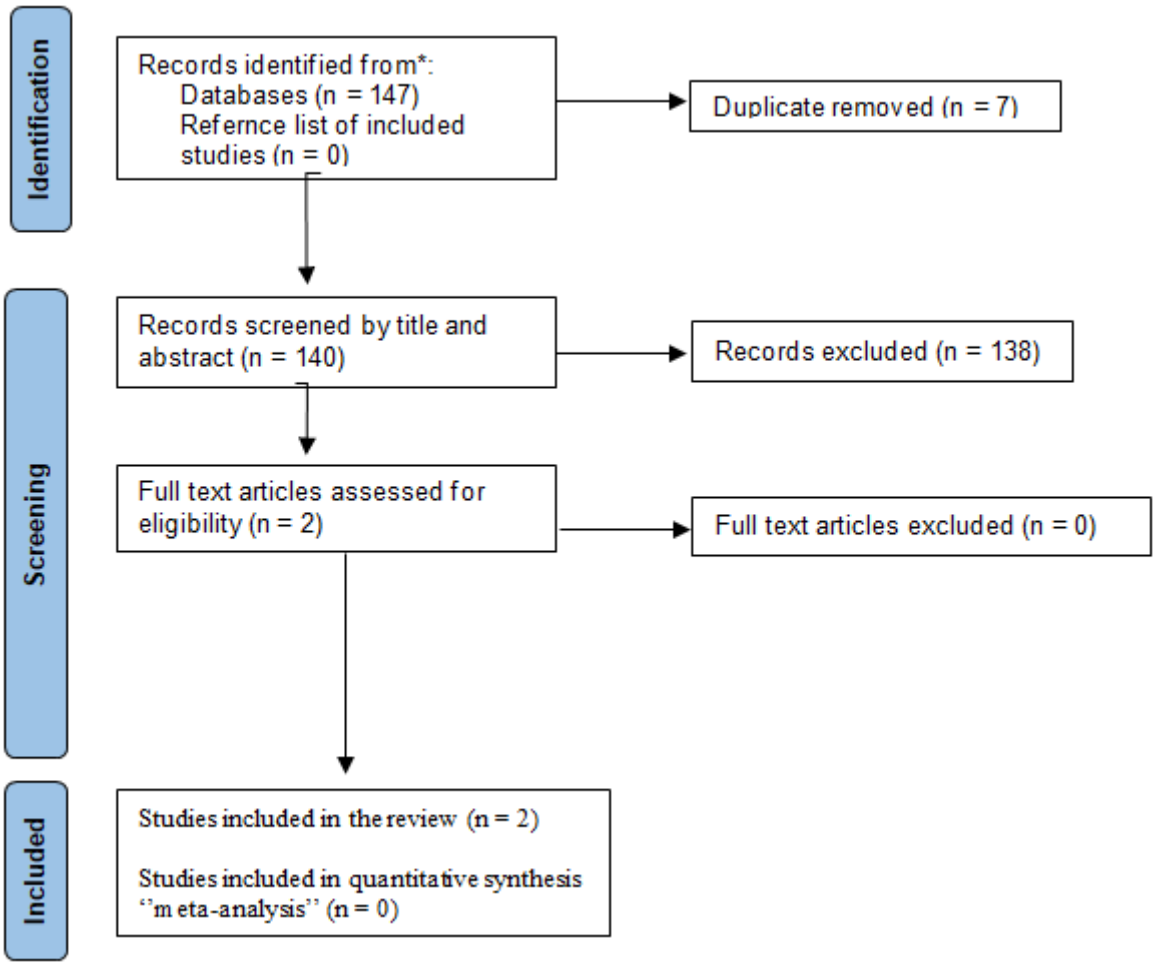

Figure 2: PRISMA flowchart of the study selection process

A summary for the characteristics of the included articles is presented in Table 1. One study utilized a parallel group randomized controlled trial design [19], whereas the other employed a crossover group randomized controlled trial design [20]. Both studies included a total of 85 participants aged ≥18 years, with sample sizes ranging from 25 to 60 participants. These studies were conducted in a university setting in India. All studies reported information on the primary outcome: plaque removal efficacy for maintaining good oral hygiene. One study [20] measured the outcome using a full mouth Plaque Index (PI) score [21] and found that charcoal-infused toothbrushes were more effective in removing dental plaque than non–charcoal-infused brushes. However, the other study [19] used the Turesky–Gilmore–Glickman modification of the Quigley–Hein PI [22] and concluded that both types of brushes had similar effects on plaque removal. Due to the

limited number of eligible studies using different outcome measures, a meta-analysis could not be conducted for this review.

Table 1: Characteristics of included studies

Kini 2019		
Methods	Study design: RCT, Crossover Location: India Setting: Department of Periodontics, MGM Dental College and Hospital	
Participants	Systemically healthy participants having a minimum of 20 teeth with intact periodontium excluding third molars Sample size: 25 Age: 18-25 years old Mean age: 22.5 years old	
Interventions	Control Group: received non-charcoal-infused manual toothbrushes Intervention Group: received charcoal-infused manual toothbrushes	
Outcomes	Plaque remova at baseline, 3 weeks, and 6 weeks: Plaque index (PI) by Loe [21]	
Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation	High risk	Participants were recruited by convenience sampling.
Allocation concealment	Low risk	The participants were randomly allocated by computerised random allocation.
Blinding of participants and personnel for all outcomes	High risk	It was not possible to blind the participants to the intervention.
Blinding of outcome assessors for all outcomes	Low risk	Outcome assessors were blind.
Incomplete outcome data for all outcomes	Low risk	The authors evaluated all included participants.
Selective outcome reporting	Low risk	The authors reported all expected outcomes.
Other sources of bias	High risk	Small sample size was used. There is the Hawthorne effect due to participants were dental students. Uneven sex distribution in the study sample.
Prusty 2022		
Methods	Study design: RCT, Parallel group Location: India Setting: Department of Periodontology and Implantology, Kalka Dental College	
Participants	Systemically healthy participants having a minimum of 20 teeth with intact periodontium excluding third molars Sample size: 60 Age: ≥ 18 years old Mean age: 20.6 ± 1.48 years old	
Interventions	Control Group: received non-charcoal-infused manual toothbrushes Intervention Group: received charcoal-infused manual toothbrushes	
Outcomes	Plaque removal at baseline, 3 weeks, and 6 weeks: The Quigley–Hein plaque index [22]	
Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation	Low risk	Participants were randomly allocated using lottery method.
Allocation concealment	Unclear risk	Allocation concealment method was not reported.
Blinding of participants and personnel for all outcomes	High risk	It was not possible to blind the participants to the intervention.
Blinding of outcome assessors for all outcomes	Unclear risk	It is unclear whether assessors were blind.
Incomplete outcome data for all outcomes	Low risk	The authors evaluated all included participants
Selective outcome reporting	Low risk	The authors reported all expected outcomes
Other sources of bias	High risk	There is the Hawthorne effect due to participants were dental students. Uneven sex distribution in the study sample.

Figures 3 and 4 present primary themes regarding risk of bias, including sequence generation, allocation concealment, blinding (participants and outcome assessment), incomplete outcome reporting, and selection bias. These figures also show individual plots for each study and the overall risk of bias. One of the studies did not successfully generate the sequence [20], as the authors selected their subjects using convenience sampling. Consequently, this study was deemed to have a high risk of bias within this domain. The other study [19] was deemed to have an unknown risk of bias for due to insufficient information on allocation concealment. Moreover, because of the nature of the intervention, blinding participants in any of the included studies was not feasible, resulting in a high risk of bias for these studies [19, 20]. In addition, it was unclear whether assessors were blinded in one of the included studies, [19] leading to a high risk of bias in this domain as well. Detailed quality evaluation for the included studies is presented in Table 1, indicating that both studies had an overall high risk of bias in at least one domain.

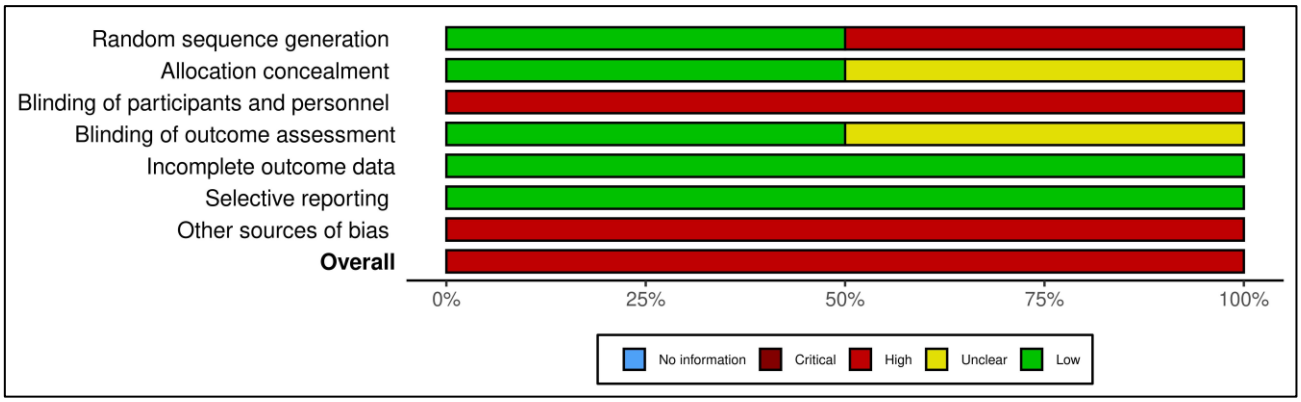

Figure 3: Overall risk of bias

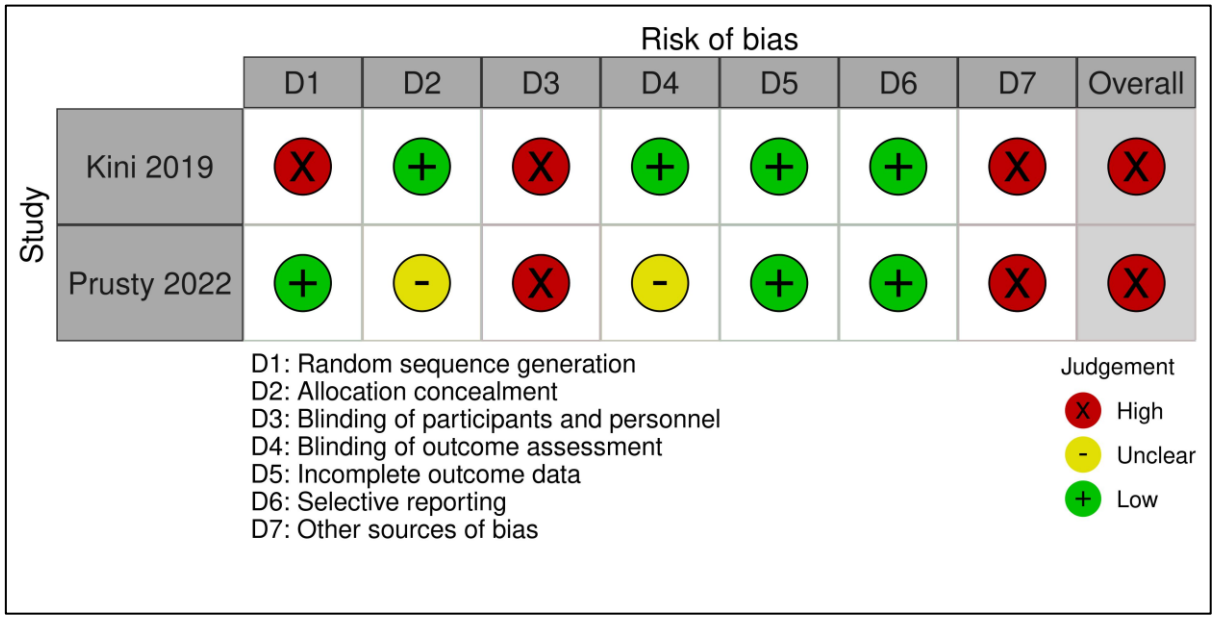

Figure 4: Risk of bias for individual studies

DISCUSSION

To date, no review exists in the current literature that evaluates the effectiveness of charcoal-infused toothbrushes. This systematic review is the first to compare traditional non–charcoal-infused brushes with charcoal-infused toothbrushes by examining the available clinical data on their plaque removal efficacy. The findings of this review were mixed, as only two studies were eligible for inclusion, with one showing higher efficacy for charcoal-infused toothbrushes in removing dental plaque, while the other showed a similar effect for both types of brushes. Additionally, due to the small number of eligible studies and utilization of different outcome measures (different plaque indices) in those studies, a meta-analysis could not be conducted in this review. Therefore, a definitive conclusion regarding the efficacy of these newly emerged toothbrushes could not be reached.

Dental plaque is a causative factor for the onset and progression of both dental caries and periodontal disease [23]. Manufacturers of charcoal toothbrushes

claim that their products can effectively remove plaque, control bacterial growth, and reduce oral halitosis [11]. The reduction in dental plaque when using charcoal toothbrushes can be attributed to both mechanical and chemical mechanisms [19]. The mechanical effect is similar to that obtained with conventional non–charcoal-infused brushes. Charcoal brushes have the advantage of natural or chemical cleaning due to their absorbent properties, aiding in plaque biofilm removal and neutralizing bacterial toxins, which may reduce the incidence of dental caries and periodontal disease [19, 24, 25]. A study conducted in South India demonstrated the caries reduction effect of charcoal, which was attributed to the reduction in dental plaque in [26]. After comparing the caries reduction efficacy between normal toothpaste, charcoal, and stick of neem tree, the findings revealed a low incidence of carries with charcoal (4%), followed by neem (10%), and almost no effect for normal toothpaste (100%) [25]. A similar caries reduction effect was observed in another study conducted on 7,233 school children in Guwahati, India [27]. The results revealed a low caries incidence in chewing sticks (8.5%), followed by using charcoal (38.7%) and toothbrush (41.8%), whereas a high incidence was observed with the use of finger rubbing (73.5%) [27]. On the other hand, in a study conducted in rural Bangladesh on children with cerebral palsy, around 6.4 times (odds ratio = 6.4, p-value = 0.015) higher caries incidence was reported among those who utilized oral hygiene products such as powder or charcoal than among those who used fluoridated toothpaste [28]. However, no published data were found regarding charcoal's ability to reduce the incidence of periodontal disease. Since the current literature regarding charcoal's caries reduction ability is conflicting, with no available evidence suggesting that charcoal can reduce periodontal disease, future research should focus on investigating charcoal's clinical influence on the initiation and progression of both dental caries and periodontal disease.

The amount of plaque that is present in the mouth is usually measured using plaque indices [29]. In addition, plaque indices are crucial tools in evaluating the effectiveness of different oral hygiene products, including charcoal toothbrushes [30-34]. To measure the outcome of plaque removal, the included articles used the same time intervals (baseline, 3 weeks, and 6 weeks) but different plaque indices. The PI reported by Loe [21] was used in a study by Kini *et al*., [20], whereas Prusty *et al*., [19] utilized the Quigley–Hein PI [22]. In a recent study, four different plaque indices were investigated, which revealed that plaque accumulation was evaluated differently for each index and that they were not interchangeable [29]. The study recommended the use of digital plaque imaging analysis (DPIA) [35] over conventional plaque indices for plaque determination in scientific research, as the DPIA method provides a simple and more convenient way to compare outcomes from various studies, which subsequently improves homogeneity between studies [29]. DPIA relies on the statistical evaluation of plaque accumulation using fluorescein technology [29, 35]. However, one limitation of DPIA is that it can be used to measure plaque accumulation only on the anterior teeth [29, 34, 35]. Future research should consider implementing such technology to accurately evaluate the plaque removal efficacy of charcoal toothbrushes and improve the consistency of results between different studies.

All studies included in this systematic review were experimental clinical trials. The study by Kini *et al*., demonstrated an overall higher plaque removal efficacy for charcoal-infused toothbrushes than for non–charcoal-infused brushes [20]. However, charcoal-infused brushes were found to be significantly less effective from baseline to 3 weeks [20]. The authors attributed this the Hawthorne effect, as the participants might have brushed more rigorously with the colorless non–charcoal-infused brushes as they could not be blinded to the intervention toothbrushes [20], in addition to having dental students as volunteers in the study sample. The Hawthorne effect is also expected to influence the findings from the study by Prusty *et al*., [19], as the study sample also consisted of dental students. The present review included experimental studies that were conducted only on adults aged ≥18 years as this age group is mostly drawn to using charcoal brushes from various marketing advertisements and promotions. Nevertheless, in a study by Banerjee *et al*., [36], the plaque removal efficacy of charcoal brushes was investigated in a group of schoolchildren aged 10–14 years, which revealed no significant differences in efficacy between charcoal-infused and non–charcoal-infused brushes.

The present review has many strengths. It is the first systematic review to evaluate the effectiveness of charcoal-infused toothbrushes in removing dental plaque. Additionally, this review applied the quality standards delineated by PRISMA [14, 15]. Moreover, a comprehensive search strategy across various databases was employed, without limitations on language or publication date. This allowed the reviewers to identify and encompass a multitude of potentially eligible studies, thereby mitigating the risk of selection bias [18]. Furthermore, the reviewers autonomously evaluated studies for eligibility, conducted data extraction, and assessed the quality of the included studies, to minimize the risk of selection and information bias, as well as potential errors, thereby improving the reliability and validity of this review.

It is important to address the limitations of the studies included in this systematic review. First, due to the novelty of charcoal-infused toothbrushes, a limited number of articles are available in the current literature regarding their clinical effectiveness. Therefore, well-designed studies, particularly randomized clinical trials, are needed in the future to accurately evaluate the efficacy of these emerging brushes. Second, all selected studies were identified as having a high risk of bias,

primarily due to issues related to sequence generation and participant blinding, which may increase the risk of selection and performance biases, respectively. Third, the Hawthorne effect was observed in all selected studies, likely due to the inclusion of dental students in the study sample, potentially leading to performance bias. Although these limitations may impact the quality of this review, it is worth noting that these studies were the only eligible ones in the current literature given the novelty of these oral hygiene products. Therefore, further research is necessary to continue assessing the efficacy and safety of these products. Finally, meta-analysis could not be performed in this review due to the small number of eligible studies using different plaque accumulation indices.

Supplementary file S1:

Ovid MEDLINE(R) <1946 to October Week 3 2023>

1 Char.mp. 2147
2 Coal*.mp. or exp Coal/ 45154
3 Carbon.mp. or exp Carbon/ 499707
4 exp Charcoal/ or Charcoal*.mp. 23835
5 1 or 2 or 3 or 4 546462
6 exp Toothbrushing/ or Toothbrush*.mp. 9976
7 Tooth brush*.mp. 2025
8 Tooth-brush*.mp. 2025
9 (Tooth adj brush*).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word] 2025
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12 6 or 7 or 8 or 9 or 10 or 11 11935
13 exp Dental Plaque/ or Plaque.mp. 117318
14 exp Dental Plaque/ 17445
15 exp Oral Hygiene/ or Tooth plaque.mp. 20995
16 exp Oral Health/ or exp Oral Hygiene/ or exp Dental Plaque/ or Teeth plaque.mp. 51422
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23 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 192725
24 5 and 12 and 23 71

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Web of Science

1: ((ALL=(Char)) AND ALL=(Coal*)) AND ALL=(Char or Coal* or Carbon or Charcoal*)
2: ALL=(Toothbrush* or Tooth brush* or Tooth-brush*)
3: (ALL=(Toothbrush* or Tooth brush* or Tooth-brush*)) AND ALL=(Plaque or Dental plaque or Tooth plaque or Teeth plaque or Dental biofilm or Oral biofilm or Microbial plaque or Microbial biofilm or Bacterial plaque or Bacterial biofilm)
4: #1 AND #2 AND #3

Clinical Trials.gov
Keywords: dental plaque
Interventions: charcoal toothbrush

Cochrane Library (Wiley)

#1	Char	120
#2	Coal*	1055
#3	Carbon	16080
#4	Charcoal*	719
#5	#1 or #2 or #3 or #4	17797
#6	Toothbrush*	3739
#7	Tooth brush*	3524
#8	Tooth-brush*	1383
#9	#6 or #7 or #8	5631
#10	Plaque	19753
#11	Dental plaque	8281
#12	Tooth plaque	5328
#13	Teeth plaque	5328
#14	Dental biofilm	856
#15	Oral biofilm	1003
#16	Microbial plaque	1034
#17	Microbial biofilm	357
#18	Bacterial plaque	1675
#19	Bacterial biofilm	731
#20	#10 or #11 or #12 or #13 or #14 or #15 or #16 or #17 or #18 or #19	20627
#21	#5 and #9 and #20	24

CONCLUSION

The current trend among consumers worldwide is the preference for all-natural and nontoxic products, which was reflected in the introduction of trendy charcoal toothbrushes into the market. Within the limits of this review, the evidence regarding the plaque removal efficacy of these toothbrushes was mixed, with an equal number of studies showing superior and similar plaque removal effects for charcoal-infused toothbrushes and conventional non–charcoal-infused brushes. Therefore, given the novelty of charcoal toothbrushes and low quality of studies included in this review, further investigations over a longer duration are necessary to make conclusive statements regarding the clinical plaque removal efficacy of these newly emerged toothbrushes. In addition, when making toothbrush recommendations and selection, both clinicians and the general public should exercise caution and avoid using products that lack sufficient scientific validation.

Author Contributions:

Bandar Saud Shukr (BSS): concept, design, data selection, data extraction, quality assessment, data analysis, drafting the manuscript, and critical review the manuscript for important intellectual content; **Mohammed Abdullah Alzubaidi (MAA):** duplicated data selection, data extraction, quality assessment, data analysis, interpretation of data, drafting the manuscript, and critical review the manuscript for important intellectual content.

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