

REVIEW ARTICLE

The efficacy of an oscillating-rotating power toothbrush compared to a high-frequency sonic power toothbrush on parameters of dental plaque and gingival inflammation: A systematic review and meta-analysis

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Abstract

Aim: To establish the efficacy of oscillating-rotating power toothbrush (OR-PTB) compared to high-frequency sonic power toothbrush (HFS-PTB) on improving parameters of plaque and gingival inflammation. Safety and participants' preference were secondary interests.

Materials and methods: MEDLINE-PubMed and Cochrane-CENTRAL databases were searched, up to April 2021. Inclusion criteria were (randomized)controlled clinical trials that evaluated healthy humans brushing with an OR-PTB compared to a HFS-PTB. Evaluation for a minimum of 4 weeks, of one or more of the following parameters: plaque index scores (PI), bleeding scores (BS), number of bleeding sites (NoB) and gingival index scores (GI).

Results: Thirty two publications involving 38 comparisons were included after the independent screening. The descriptive analysis showed that in 54% of the comparisons, a significant difference in favour of the OR-PTB was found for PI, BS and GI scores. The Quigley and Hein index showed a significant difference of means (DiffM) between the end scores (DiffM 0.13, 95% CI [0.05;0.21] $p < 0.001$), as well as for the Rustogi-modified Navy index (DiffM 0.01, 95% CI [0.01;0.03] $p = 0.002$). This is in line with the meta-analysis for BS (DiffM 0.09, 95% CI [0.03;0.14] $p = 0.003$), for which the results were in favour of the OR-PTB and considered potentially clinically relevant. NoB showed a significant difference in favour of the OR-PTB for the end scores (DiffM 3.61, 95% CI [2.63;4.58] $p < 0.00001$). No difference in safety was indicated, 78% of participants preferred the OR-PTB.

Conclusion: For patients to maintain good plaque control and improve gingival health, there is a small but significant difference based on longer-term studies between OR-PTB and HFS-PTB. This difference is potentially clinically relevant.

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KEYWORDS

dental plaque, gingival health, oscillating-rotating toothbrush, power toothbrush, sonic toothbrush, systematic review

1 | INTRODUCTION

There is general agreement that the greatest contributor to oral health is regular and thorough dental plaque removal, typically by means of a toothbrush.¹ Toothbrushes are available in many different designs, varying in the shape of the handle, brush head, arrangement of bristles and filament shapes. The brush head in particular is continuously under revision in order to improve effectiveness. Powered toothbrushes (PTBs) have been in use since the 1940s, starting with devices with a circular brush head or a rectangular brush head. Today PTBs are widely used and demonstrate benefits with regard to reducing dental plaque and gingivitis in comparison to manual toothbrushes (MTBs) in both short- and long-term observations.² Because of this cleaning performance and ease of use, PTBs are becoming increasingly accepted.³ Several types of PTBs with different brush head configurations and modes of actions are available on the market. The high-frequency sonic power toothbrush (HFS-PTB) with a side-to-side bristle movement and the oscillating-rotating power toothbrush (OR-PTB) are the most retailed and researched modes of action worldwide.

Almost a decade ago, a solid Cochrane systematic review³ conducted a direct comparison between PTBs with different modes of actions in regards to plaque and gingivitis reduction. At that time, no definitive conclusions could be drawn regarding the superiority of one type of PTB over another. A network meta-analysis was recently published on the effects of OR-PTBs, HFS-PTBs and MTBs. The meta-analysis was limited to randomized control trial (RCT) studies with a duration of up to 3 months in the period 2007–2017 and available in the database of a PTB manufacturer.⁴ The analysis ultimately recommended that patients with various degrees of gingival bleeding use OR-PTBs over HFS-PTBs to improve plaque control and parameters of gingival inflammation.⁴ Another systematic review compared PTBs to MTBs for oral health with no limitation to study duration. This review concluded that a PTB is more effective in reducing dental plaque, gingivitis and bleeding compared with a MTB.⁵ Based on studies solely from the last decade, a recent systematic review further concluded that there is some evidence to suggest that OR-PTBs might remove more plaque and reduce the number of bleeding sites better than other PTBs, including HFS-PTBs.⁶ Based on single brushing exercises, recent evidence also indicates that the use of OR-PTBs results in a larger reduction of plaque scores than the use of HFS-PTBs.⁷ The authors of the study, with moderate certainty, recommended a OR-PTB over a HFS-PTB. However, the authors noted that the clinical relevance of the observed difference deserved further evaluation in longer-term studies.

All other recent systematic reviews^{6,7} on this topic were characterized by various restrictions, such as a specific research design,⁷ year of publication,⁶ or manufacturer database.⁴ Therefore, based on that and the suggestion of a SR for long-term studies there is a

need for a SR that included and updates the findings of the dated Cochrane systematic review Deacon et al. (2010)³ with respect to the comparison of OR and HFS-PTB. Thus, the aim of this systematic review is to evaluate direct comparisons of the oscillating-rotating power toothbrush versus high-frequency sonic power toothbrush mode of action with respect to parameters of plaque and gingival inflammation using data from studies with a minimum duration of 4 weeks. The recommendations that emerge from this review may guide dental care professionals in providing evidence-based advice concerning power toothbrush use to their patients.

2 | MATERIALS AND METHODS

The systematic review and meta-analyses in this study were prepared and reported in accordance with the *Cochrane Handbook for Systematic Reviews of Interventions*.⁸ In addition, this research adhered to the guidelines of Transparent Reporting of Systematic Reviews and Meta-analyses^{9,10} and Assessing the Methodology Quality of Systematic Reviews.^{11,12}

The protocol for this systematic review was developed a priori and registered with the International Prospective Register of Systematic Reviews¹³ under registration number CRD42020161883.

2.1 | Focused questions

The questions that guided the systematic review, which is focused on healthy participants, were the following.

Primary question:

- What is the efficacy of oscillating-rotating power toothbrush compared to high-frequency sonic power toothbrush in improving parameters of dental plaque and gingival inflammation?

Secondary questions:

- What is the safety of oscillating-rotating power toothbrush compared to high-frequency sonic power toothbrush for oral soft tissues and hard tissues?
- What are participants' preferences between oscillating-rotating power toothbrush and high-frequency sonic power toothbrush?

2.2 | Search strategy

For the comprehensive search strategy that was in place through April 2021, three electronic databases were utilized to search for

appropriate papers that satisfied the study purpose. The National Library of Medicine, Washington, D.C. (MEDLINE-PubMed) and the Cochrane Central Register of Controlled Trials (CENTRAL) were used to identify eligible publications. Table 1 presents the search strategy, including the search terms. All references cited in the papers that were selected for this review were scrutinized to identify additional relevant studies. Further hand searching was not performed other than as part of the Cochrane Worldwide Hand Searching Program and uploaded to CENTRAL.

2.3 | Screening and selection

Two reviewers (NLHH and EvdS) screened the titles and abstracts of publications obtained from the search process using the Rayyan web application.^{14,15} Possible duplicates were flagged and checked by the two reviewers to eliminate identical studies. Disagreements in the screening and selection process were resolved by consensus or, if disagreement persisted, by arbitration through a third reviewer (DES). The reviewers read titles and abstracts in detail to screen for suitability and categorized them as included, excluded or undecided. Once the list of included titles and abstracts was obtained, full-text versions of the papers were retrieved and screened for suitability. After the independent screening process, the search was unblinded and the 'conflicts' that were identified by Rayyan were resolved by the reviewers. The reviewers worked independently and were blinded from each other's results during the screening process.

The eligibility criteria for published studies were the following:

- Publications written in the English language.
- (Randomized) controlled clinical trials (CCT or RCTs).
- Studies conducted on humans who met the following conditions:
 - ≥18 years old
 - In good general health, which means having no systemic disorders
 - Participant brushing
 - Without an orthodontic fixed appliance
- Study duration of a minimum of 4 weeks.
- Intervention: A high-frequency sonic power toothbrush (HFS-PTB) with a side-to-side bristle movement.
- Comparison: An oscillating-rotating power toothbrush (OR-PTB). Only power toothbrushes with a rechargeable battery and a

handle containing a motor that provides mechanical movement to a brush head with filaments.¹⁶

- Primary parameters of interest: Plaque index scores (PI), bleeding scores (BS), number of bleeding sites (NoB), gingival index scores (GI).
- Secondary parameters of interest: Oral soft tissue assessments (OST), gingival abrasion scores (GA), adverse events (AE) and/or panellist questionnaires.

2.4 | Assessment of heterogeneity

The heterogeneity of the primary outcome parameters across publications was detailed according to the following factors:

- Study design and participant characteristics.
- Study procedures and products.
- Plaque and gingivitis indices and their modifications.

To evaluate methodological heterogeneity, the study designs and toothbrushing regimens were evaluated. When clinical or methodological heterogeneity was considered to be high across publications, the sources of heterogeneity were explored by subgroup analyses and sensitivity analysis.

2.5 | Risk of bias assessment and grading

Two reviewers (NLHH and DES) individually scored the methodological qualities and ethical aspects⁷ of the included publications according to the method described in detail by Van der Weijden (2009)¹⁷ and Keukenmeester et al. (2012).¹⁸ When random allocation, defined eligibility criteria, masking of examiners, masking of participants, balanced experimental groups, identical treatment between groups (except for the intervention) and reporting of follow-up were present, the study was classified as having an estimated low risk of bias. When one of these criteria was missing, the study was considered to have an estimated moderate risk of bias. When two or more of these criteria were missing, the study was estimated to have a high risk of bias. Disagreements in the quality assessments were resolved by consensus or, if disagreement persisted, by arbitration through a third reviewer (FvdW).

2.6 | Statistical analyses

2.6.1 | Data extraction

The data from the publications that met the selection criteria were extracted and processed for further analysis. Two reviewers (EvdS and NLHH) evaluated the selected publications for mean baseline, end and incremental difference scores and standard deviations (SDs). To ensure an accurate estimate, any data approximation

TABLE 1 Search terms used for the search strategy

The following strategy was used in the search: {(intervention) AND (specification)}
{(<Intervention:>
Toothbrush* OR 'Toothbrushing'[Mesh])
AND
(<specification:>
power* OR electric*)}

Note: The asterisk (*) was used as a truncation symbol.

in figures was avoided. Some of the studies provided a standard error (SE) of the mean. These values were converted to SDs based on the sample size ($SE = SD/\sqrt{N}$). Numbers with three digits were rounded to two digits. In cases of missing data or undetermined information, attempts were made to contact the first or corresponding author of the included publications for clarification or to retrieve additional data. For studies that had multiple treatment arms and for which data from the control group were compared with more than one other group, the number of participants (N) in the control group was divided by the number of comparisons. Disagreements in the data extraction were resolved by consensus or, if disagreement persisted, by arbitration through a third reviewer (DES).

2.6.2 | Data analysis

Descriptive analysis

A descriptive data analysis was conducted for all included studies to summarize the results. The primary variables of interest were plaque index scores (PI), bleeding scores (BS) and/or gingival index scores (GI). The data were summarized and analysed using vote counting.¹⁹ For the secondary parameters of interest, an overview was presented.

Meta-analysis

When appropriate, a meta-analysis was performed, and the difference of means (DiffM) was calculated using an inverse variance method (review manager 2014) in Review Manager [RevMan Version 5.3.Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014]²⁰ with either the fixed or random-effects model, as appropriate. For the analysis, the assumption was made that summary data were missing at random, and therefore, all available data were included. The data were separated by the following primary indices: Modified Quigley and Hein Plaque index,²¹⁻²³ Rustogi Modified Navy Plaque index,²⁴ papillary bleeding index,²⁵ angular bleeding Index/bleeding on marginal probing,²⁶⁻²⁸ NoB, gingival bleeding index,²⁹ or the (modified) gingival index.³⁰

Heterogeneity was tested using the chi-square test and the I^2 statistic.⁸ A chi-square test resulting in a p -value <0.1 was considered to be an indication of significant statistical heterogeneity. As an approximate guide for assessing the degree of inconsistency across studies, an I^2 statistic of 0%–40% was interpreted as might not be important, a statistic of 40%–60% indicated moderate heterogeneity, 60%–80% indicated substantial heterogeneity, and 80%–100% indicated considerable heterogeneity.³¹

Publication bias

If the meta-analysis comprised sufficient trials to make visual inspection of the plot meaningful (10 trials minimum), funnel plots were used for assessment of publication bias. The presence of asymmetry in the inverted funnel may suggest publication bias.^{8,32}

Additional analysis

The Lan-DeMets version³³ of the O'Brien-Fleming function³⁴ was used for calculating the trial sequential monitoring boundaries (TSMBs). TSA software version 0.9.5.10 Beta (Copenhagen Trial Unit) was used.³⁵⁻³⁸

Furthermore, distribution-based methods were applied in order to determine the clinical relevance of the study results.³⁹⁻⁴⁴ Using the distribution-based method, the clinical relevance was scored as not clinically relevant, potentially clinically relevant or clinically relevant, based on the relationship among the mean difference of the variable, minimal important difference (MID) and effect size.⁴⁴ was interpreted as small, 0.50 (0.40–0.79) as medium and ≥ 0.80 as large. The MID was determined by multiplying the effect size of the difference between groups by the pooled baseline SD of the two groups.³⁹ The MID was calculated by multiplying either 0.2 or 0.5 by the pooled baseline standard deviation.⁴¹

Evaluation of the clinical relevance of the results on the variable plaque indices, BOP, MGI and GBI was performed based on the distribution-based method using the ES,³⁹ MID^{39,45} and clinical judgement.⁴²

2.7 | Grading the body of evidence

The Grading of Recommendations Assessment, Development and Evaluation system, as proposed by the GRADE working group, was used to rank and grade the evidence emerging from this review.^{45,46} Two reviewers (FvdW and DES) rated the certainty of the evidence as well as the strength and direction of recommendations according to the following aspects: risk of bias of the individual studies, consistency and precision among the study outcomes, directness of the study results and detection of publication bias. Any disagreement between the two reviewers was resolved after additional discussion with the third reviewer (EvdS).

3 | RESULTS

3.1 | Search and selection results

Figure 1 presents the search and selection results and the included publications. Among the unique titles and abstracts, there were 14 conflicts ($<2\%$) scored by the reviewers. The comprehensive search of the databases resulted in 32 publications including 38 comparisons that were eligible for inclusion.⁴⁷⁻⁷⁸

3.2 | Study characteristics and heterogeneity assessment

Considerable heterogeneity was observed in the 32 papers with respect to study design; evaluation period; study population and number, gender and age of participants. With the exception of two comparisons^{51,58} that used a cross-over design, all other included studies were

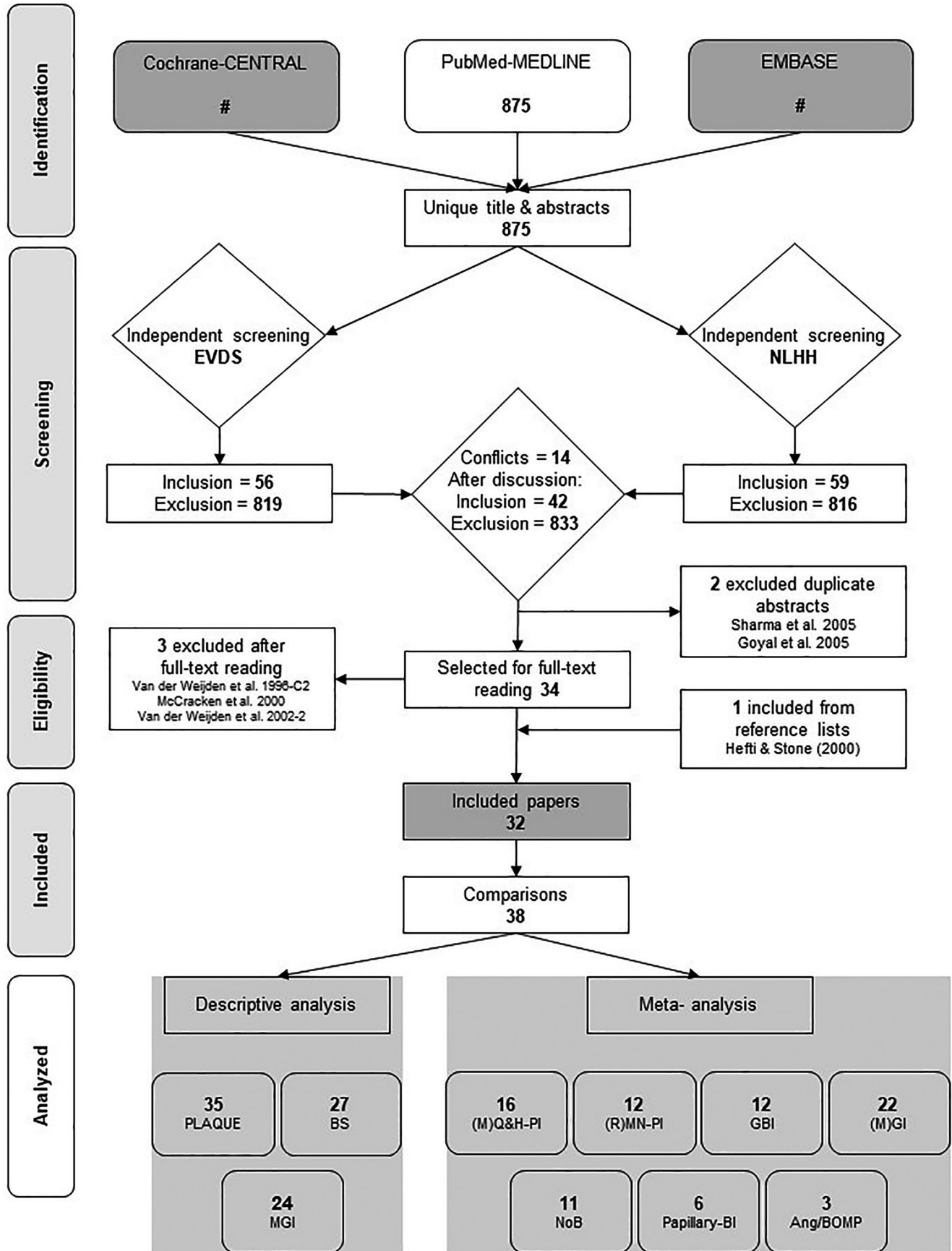


FIGURE 1 Search and selection results. (M)GI, Modified gingival index; (M)Q&H-PI, modified Quigley & Hein plaque index; (R)MN-PI, Rustogi Modification of the Navy plaque index; Ang/BOMP, Angular Bleeding index/ Bleeding on marginal probing; BI, Bleeding index; BS, Bleeding scores; GBI, Gingival bleeding index; MGI, Modified gingival Index; NoB, Number of bleeding sites

TABLE 2 Overview of the descriptive summary of the 32 studies and 38 comparisons with the number and percentages of statistical significance of the OR-PTB compared to the HFS-PTB in numbers and percentages

Outcome	Number of comparisons	Significant difference in favour of the comparison (OR-PTB)	Significant difference in favour of the intervention (HFS-PTB)	No difference	Unknown (?)	Online appendix number
Plaque index scores	35	19 (54%)	3 (9%)	11 (31%)	2 (6%)	S2
Bleeding scores	38 ^a	22 (58%)	8 (21%)	4 (10.5%)	4 (10.5%)	S2
(modified) Gingival index scores	25	12 (48%)	5 (20%)	7 (28%)	1 (4%)	S2
Overall	98	53 (54%)	16 (16%)	22 (22%)	7 (7%)	

Abbreviations: HF-PTB, High-frequency sonic power toothbrush; OR-PTB, Oscillating-rotating power toothbrush.

^aTwelve comparisons evaluated two measures of bleeding scores.

RCTs and had a parallel design. Four comparisons^{48,53,54,57} utilized a split-mouth method in which one comparison⁴⁸ selected two contralateral quadrants and the other three comparisons^{53,54,57} divided the dentitions into the left and the right side. The total study duration varied from 30 days to 6 months. The total number of participants ranged from 30–284. The approximate mean age of the 2805 participants was 40 and varied from 18–83 years old. Information regarding the study characteristics is provided in an overview in online Appendix S1A and in detail in online Appendices S1B,C.

3.3 | Risk of bias assessment

The quality assessments including internal validity, external validity, statistical validity and clinical and ethical considerations are presented in the online Appendices S3A,B. The estimated potential risk of bias is moderate in one publication⁶⁴ and low in the other 31 publications.^{47–63,65–78} Compared to the older studies, the five ethical aspects were more frequently reported in the publications from the last decade.

3.3.1 | Ethical aspects

IRB approval was reported for all studies since 2002, with the exception of one study.⁶⁴ From the same year onward, all participants provided written informed consent. The presence of a conflict of interest (COI) was reported in 16 out of 32 publications.^{60,62–65,67,69–78} Of the 16 publications, 10 publications disclosed a combination of non-industry authors and industry-related authors.^{60,62,65,67,69,72,74,76–78} Only the non-industry authors declared not having a COI. The source of funding was reported in 22 publications^{49,53,54,56,57,59–78} and of those, two publications^{70,73} stated that products were supplied by one or more manufacturers.

3.4 | Results of study outcomes

The online Appendices S4, S5 and S6 detail the results from the data extraction for the primary parameters of interest: PI, BS, PBI, GBI and the Modified Gingival Index scores (MGI).

3.4.1 | Descriptive analysis

Tables 2 and 3 present an overview of the descriptive analysis of the 32 publications and 38 comparisons. Table 2 indicates statistical significance results of OR-PTBs compared to HFS-PTBs. The overall difference was significant in favour of the OR-PTB in 54% of the comparisons that evaluated PI, 58% with respect to BS and 48% with respect to MGI scores. In total, 22 out of the 98 primary outcome parameters of interest indicated no difference between both toothbrushes (Details are shown in online Appendix S2). Table 3 presents an overview of the secondary parameters of interest. In the included studies, there was no difference between the toothbrushes with respect to safety (Online Appendices S7 and S8), and participants in seven out of the nine publications preferred the OR-PTB (Online Appendix S9).

3.4.2 | Meta-analysis

Primary outcomes

Tables 4–10 present an overview of the outcomes of the meta-analysis, and the forest plots are displayed in online Appendices S10 to S16. The meta-analysis was based on 16 comparisons using the modified Quigley and Hein Plaque index (MQHPI). The results revealed that the Difference of Means (DiffM) was significant ($p < 0.001$) in favour of the OR-PTB for end scores (DiffM = 0.13, 95% CI [0.05; 0.21]) (Table 4). In addition, the (Rustogi) modified Navy Plaque index (RMNPI) demonstrated a statistically significant DiffM ($p = 0.002$) for the end scores (DiffM = 0.01 (95% CI [0.00; 0.03]) in favour of the OR-PTB (Table 5).

The Angular Bleeding index Bleeding On Marginal Probing indices showed a significant difference in the end scores (DiffM = 0.09; 95% CI [0.03; 0.14] $p = 0.003$) in favour of the OR-PTB (Table 7). Regarding gingival bleeding tendency, meta-analysis for Number of Bleeding (NoB) was significant in favour of the OR-PTB for the end scores (DiffM = 3.61 (95% CI [2.63; 4.58] $p < 0.0001$)) and the incremental difference scores (DiffM = 3.61 (95% CI [2.64; 4.59] $p < 0.0001$; Table 8). For the PBI, GBI and MGI, the baseline, end and mean differences were not significantly different (Tables 6, 9, 10).

Publication bias

It was possible to draw funnel plots for 14 trials, which can be found in the online Appendices S10B,D, S11B,D,G, S14B,D,G, S15B,D,G and S16B,D,G. Most outcomes are located at the top of the funnel plots, with the exception of one funnel plot of the end scores of the MQ&HPI (S16G). The presence of this asymmetry in the inverted tunnels is suggestive of a form of publication bias.^{8,32}

3.5 | Additional analysis

The TSA graphs for each index are presented in the online Appendices S10E, S11E, S12C, S13C, S14E, S15C,E and S16E. The TSA suggests that for the indices of plaque scores, NoB scores and MGI, the required information size (RIS) was reached. The RIS was not fulfilled for the PBI, angular bleeding index/ bleeding on marginal probing indices or GBI.

Evaluation of the clinical relevance of the results on parameters of gingival inflammation was performed according to the distribution-based method using the ES,³⁹ MID^{41,45} and clinical judgement.⁴² The results of the clinical relevance assessments indicate that the difference between the OR-PTB and the HFS-PTB was potentially clinically relevant (see online Appendices S17A,B). Of the clinical relevance assessments for the PI scores, 34% and 31% of the included experiments were potentially clinically relevant and clinically relevant, respectively. For the bleeding/gingivitis assessment, the percentages were 28% and 30%.

3.6 | Evidence profile

Table 11 presents a summary of the various factors used to rate the quality of evidence and appraise the strength and direction of recommendations according to GRADE,^{45,46} including the level of certainty.⁷⁹ All 32 studies in this review were RCTs with a crossover or parallel design. The directness of the studies is generalizable, as all

studies had a minimum duration of 4 weeks. The risk of bias varied from low to moderate, and as many studies were industry financed, reporting bias cannot be ruled out. According to the descriptive analyses and meta-analyses, the outcomes are relatively consistent and precise. There is a small difference in the clinical parameters of gingival inflammation in favour of the OR-PTB. The strength of the recommendation was estimated to be moderate. Therefore, the direction of the recommendation is that there is a moderate certainty that there is a small but clinically relevant advantage of OR-PTB over HFS-PTB.

4 | DISCUSSION

The purpose of this systematic review was to comprehensively summarize the available scientific literature with respect to the efficacy of oscillating rotating (OR) and high-frequency sonic (HFS) PTBs in reducing dental plaque and gingival inflammation. More than a decade ago this was also evaluated and at that time, the authors concluded that there is some evidence that OR-PTBs reduce plaque and gingivitis more than side-to-side brushes in the short term, although the difference was small and the clinical importance was unclear.³ In order to come to a better current understanding of the different potential benefits between PTB modes of action, there was a need for an up to date comprehensive review that systematically appraises and synthesizes the published evidence from longer-term evaluations without restrictions. The current review has demonstrated that both types of PTB are effective in dental plaque removal and in improving the parameters of gingival inflammation. With a moderate degree of certainty, this review, therefore, concludes that there is a small but clinically relevant significant difference in favour of OR-PTB over HFS-PTB.

4.1 | Toothbrushes and mode of action

Powered toothbrushes have electrically driven brush heads developed to improve plaque removal efficacy. The role of the user

TABLE 3 Overview of the descriptive summary of safety assessments and panel list questionnaire comparing OR-PTB with HFS-PTB

Outcome	Number of publications	Number of publications and the result	Online appendix number
Intra-oral safety assessments	23	15 No difference 8 Unknown	S7
Gingiva abrasion score	1	No difference between the products	NA
Adverse events	22	18 Reported no AE 10 Reported AE assessed as possibly related to the study product 1 Reported AE unrelated to the products	S8
Panellist questionnaire	9	5 Significant in favour of OR-PTB 3 Numerically in favour for OR-PTB 1 Unknown	S9

Abbreviations: AE, Adverse Event; HFS-PTB, High-frequency sonic power toothbrush; NA, not applicable; OR-PTB, Oscillating-rotating power toothbrush.

is mainly to guide the brush filaments across the dentition. Several PTBs are currently in the market, with variations in brush head design, filament pattern and speed of motion.⁴ The studies included in this review frequently do not provide specific details on the toothbrush (head) design and variables related to the mode of action. The studies often note little beyond the brand and type. Thus, while marketing claims suggest that brush head design is important with respect to efficacy, this has been less researched than effects of the modes of action of specific brush technologies. The factors that distinguish different brush heads are filament arrangement, orientation, size, shape and flexibility, brush head size and shape. The development of different brush heads is driven by consumer preference and thus expected to help lead to more compliant behaviour. Also, a pressure sensor or a timer can contribute to the improvement of brushing behaviours, which could lead to improved efficacy.

However, with limited reporting on most of these details, it was impossible to isolate and analyse outcomes related to these factors.⁸⁰

4.2 | Longer-term effect designs

It has been suggested that studies up to 4 weeks in duration can be used for evaluating the effect on plaque scores and that longer-term studies are necessary for measurements regarding parameters of gingival inflammation, such as BS and GI.^{81,82} The inclusion criterion for the present study was, therefore, a study duration of a minimum of 4 weeks. This choice is in line with the American Dental Association guidelines for Seals concerning toothbrushes,⁸³ which require studies to be of at least a 30-day duration to assess efficacy. With respect to short term and long term, there are variations in interpretations. Previous systematic reviews comparing PTBs to MTBs have used a minimum duration of 1 month,^{84,85} and the criterion for long term was a follow-up beyond 3 months.^{3,83} In the current review, 12 studies had an evaluation period of 3 months or longer.

4.3 | Bias and ethical considerations

The results of a systematic review are strongly dependent on the quality of the methodology, validity and estimated risk of bias of the included studies. In a recent systematic review,⁷ five ethical aspects were introduced as part of the risk of bias assessment, including reported funding or a declared (or absent) COI. Details on the ethical aspects of the present review are presented in online Appendices S3A,B. In general, approval by a medical committee, informed consent, declaration of a COI and disclosed funding are well reported in studies from 2000 onwards. Trial registration is less reported and has only reported in studies since 2016.

Although reporting ethical aspects may not be fundamental to a trial, the Consolidated Standards of Reporting Trials (CONSORT) Statement⁸⁶ first published in 1996 recommends that factors such as the study registration, protocol and funding and approval by an

institutional ethical review board are reported. In addition, funding bodies and medical journals strictly enforce ethical review.⁸⁶ The International Committee on Medical Journal Editors, therefore, has prepared a form to disclose financial and non-financial relationships and activities and COIs.⁸⁷ This disclosure is currently standard when a manuscript is submitted to a scientific journal. As such, taking ethical aspects as part of the quality assessment in a systematic review is a judicious choice.

4.4 | Conflicts of interest and sources of funding

A potential for a COI exists when professional judgement concerning a primary interest, such as patients' welfare or the validity of research, may be influenced by a secondary interest, such as financial gain.⁸⁷ Financial relationships are often judged to undermine the credibility of a journal, the authors, or the science itself.⁸⁷ Other interests, such as personal relationships or rivalries, academic competition and intellectual beliefs,⁸⁷ may also present conflicts. Authors, reviewers, editors and editorial board members of journals in the peer-review and publication process must, therefore, consider and disclose their relationships and activities when fulfilling their different roles. Transparent and complete disclosures are required to help maintain public trust in the scientific process. In the current systematic review, 14 (45%) publications reported a variety of COIs. Nine papers^{66,67,69,72,74,76-78} were written in conjunction with authors related to industry. The rate of COIs in the present study is much lower than the 76% that was found in a systematic review of RCTs from six dental journals published between January 2011 and March 2012.⁸⁸ This difference may be explained by the fact that the included studies in the present review were published over a decade ago when COI reporting was not common.

As presented in the online Appendices S3A,B, 22 of 32 of the included publications reported a source of funding. COIs and funding sources are often reported under the same heading, although these are separate items. Funding does not always indicate a problematic influence, but authors should carefully consider agreements with study sponsors, both for-profit and non-profit, and discuss terms such as authors' access to all of the study's data, their ability to analyse and interpret the data and to prepare and publish manuscripts independently, taking into account the principle of academic freedom. From toothpaste trials, it is evident that COIs are not associated with positive conclusions.⁸⁹ As toothpaste and toothbrushes are the most recommended products in oral care, the results on COIs and positive conclusions regarding toothpaste can be considered to apply to toothbrush studies as well.⁸⁹

4.5 | Clinical relevance and clinical judgement

The evaluation of clinical relevance in research is key to simplify the transfer of knowledge from research into daily practice.⁹⁰ It is possible

TABLE 4 Meta-analysis for the modified Quigley and Hein Plaque index using a random model

Modified Quigley and Hein Plaque index	Number of comparisons	Effect size				Heterogeneity			Online Appendix number			TSA	
		Comparison	DiffM	95% CI	p-Value	I ²	p-Value	Forrest plot	Funnel plot	Number	TSA does research the RIS or not (yes/no)		
Grossman et al. (1995) ⁴⁷	16	Baseline	-0.03	(-0.08; 0.02)	0.19	0%	0.95	S10A	S10B	NA	NA		
Robinson et al. (1997) ⁴⁹		End	0.13	(0.05; 0.21)	<0.001	54%	0.008	S10C	S10D	S10E	Yes		
Yankell & Emling (1997) ⁵⁰		Difference	?	?	?	?	?	NA	NA	NA	NA		
Putt et al. (2001) ⁵³													
Van der Weijden et al. (2002-1) ⁵⁴													
Goyal et al. (2005) ⁵⁵	2x												
Patters et al. (2005) ⁵⁶													
Rosema et al. (2005) ⁵⁷													
Williams et al. (2009) ⁶⁰													
Büchel et al. (2014) ⁶⁵													
Schmickler et al. (2016) ⁷⁰													
Schmalz et al. (2017-AJD) ⁷¹													
Schmalz et al. (2018-COI) ⁷³													

Note: p-Values are presented in bold if $p \leq 0.05$. Abbreviations: ?, Unclear; NA, Not applicable; RIS, Required Information Size; TSA, Trial sequential analysis.

TABLE 5 Meta-analysis for the Rustogi modified Navy Plaque index using a random model

Rustogi modified Navy Plaque index	Number of comparisons	Comparison	DiffM	Effect size			Heterogeneity			Online Appendix number			TSA												
				95% CI	p-Value	I ²	p-Value	I ²	Forrest plot	Funnel plot	Number	TSA does research the RIS or not (yes/no)													
Goyal et al. (2009) ⁵⁵	12	Baseline	-0.00	(-0.01; 0.00)	0.08	0%	0.81	S11A	S11B	NA	NA	NA	NA												
Ayad et al. (2012) ^{61,2x}																									
Klukowska et al. (2012) ⁶²																									
Klukowska et al. (2013) ⁶³																									
Klukowska et al. (2014-12w) ⁶⁶																									
Klukowska et al. (2014-6wCOL) ⁶⁷																									
Klukowska et al. (2014-6wPH) ⁶⁸																									
Ccahuana-Vasquez et al. (2015) ⁶⁹																									
Ccahuana-Vasquez et al. (2018) ⁷⁴																									
Adam et al. (2020) ⁷⁷																									
Goyal et al. (2021) ⁷⁸																									
Goyal et al. (2009) ⁵⁵														14	Difference	0.01	(0.00; 0.02)	0.01	81%	<0.00001	S11F	S11G	NA	NA	NA
Ayad et al. (2012) ^{61,2x}																									
Klukowska et al. (2012) ⁶²																									
Klukowska et al. (2013) ⁶³																									
Klukowska et al. (2014-12w) ⁶⁶																									
Klukowska et al. (2014-6wCOL) ⁶⁷																									
Klukowska et al. (2014-6wPH) ⁶⁸																									
Ccahuana-Vasquez et al. (2015) ⁶⁹																									
Ccahuana-Vasquez et al. (2018) ⁷⁴																									
Lv et al. (2018) ^{75,2x}																									
Adam et al. (2020) ⁷⁷																									
Goyal et al. (2021) ⁷⁸																									

Note: p-Values are presented in bold if $p \leq 0.05$.

Abbreviations: ?, Unclear; NA, Not applicable; RIS, Required Information Size; TSA, Trial sequential analysis.

TABLE 6 Meta-analysis for the Papillary Bleeding index using a random model

Papillary Bleeding index	Number of comparisons	Comparison	Effect size			Heterogeneity			Online appendix number			TSA	
			DiffM	95% CI	p-Value	I ²	p-Value	Forrest plot	Funnel plot	Number	TSA does research the RIS or not (yes/no)		
Robinson et al. (1997) ⁴⁹	6	Baseline	0.05	(-0.04; 0.15)	0.28	29%	0.22	S12A	NA	NA	NA	NA	
Schmickler et al. (2016) ⁷⁰ 2x		End	-0.08	(-0.18; 0.02)	0.13	55%	0.05	S12B	NA	S12C	No	No	
Schmalz et al. (2017-AJD) ⁷¹		Difference	?	?	?	?	?	NA	NA	NA	NA	NA	
Schmalz et al. (2018-COII) ⁷³ 2x													

Note: p-Values are presented in bold if $p \leq 0.05$.
Abbreviations: ?, Unclear; NA, Not applicable; RIS, Required Information Size; TSA, Trial sequential analysis.

TABLE 7 Meta-analysis for the Angular Bleeding index/ Bleeding On Marginal Probing using a fixed model

Angular Bleeding index/ Bleeding On Marginal Probing	Number of comparisons	Effect size			Heterogeneity			Online Appendix number			TSA	
		Comparison	DiffM	95% CI	p-Value	I ²	p-Value	Forrest plot	Funnel plot	Number	TSA does research the RIS or not (yes/no)	
Putt et al. (2001) ⁵³	3	Baseline	0.00	(-0.06; 0.07)	0.93	0%	0.77	S13A	NA	NA	NA	NA
Van der Weijden et al. (2002-1) ⁵⁴		End	0.09	(0.03; 0.14)	0.003	40%	0.19	S13B	NA	S13C	no	no
Rosema et al. (2005) ⁵⁷		Difference	?	?	?	?	?	NA	NA	NA	NA	NA

Note: p-Values are presented in bold if $p \leq 0.05$.
Abbreviations: ?, Unclear; NA, Not applicable; RIS, Required Information Size; TSA, Trial sequential analysis.

TABLE 8 Meta-analysis for the number of bleeding sites using a random model

Number of bleeding sites	Number of comparisons	Effect size			Heterogeneity			Online Appendix number			TSA	
		Comparison	DiffM	95% CI	p-Value	I ²	p-Value	Forrest plot	Funnel plot	Number	TSA does research the RIS or not (yes/no)	
Goyal et al. (2009) ⁵⁵	11	Baseline	0.94	(-0.30; 2.18)	0.14	0%	0.72	S14A	S14B	NA	NA	
Williams et al. (2009) ⁶⁰												
Klukowska et al. (2012) ⁶²		End	3.61	(2.63; 4.58)	<0.00001	1%	<0.00001	S14C	S14D	S14E	Yes	
Klukowska et al. (2013) ⁶³												
Klukowska et al. (2014-12w) ⁶⁶		Difference	3.61	(2.64; 4.59)	<0.00001	81%	<0.00001	S14F	S14G	NA	NA	
Klukowska et al. (2014-6wCOL) ⁶⁷												
Klukowska et al. (2014-6wPH) ⁶⁸												
Ccahuana-Vasquez et al. (2015) ⁶⁹												
Ccahuana-Vasquez et al. (2018) ⁷⁴												
Adam et al. (2020) ⁷⁷												
Goyal et al. (2021) ⁷⁸												

Note: p-Values are presented in bold if $p \leq 0.05$.

Abbreviations: ?, Unclear; NA, Not applicable; RIS, Required Information Size; TSA, Trial sequential analysis.

TABLE 9 Meta-analysis for the Gingival Bleeding index using a random model

Gingival Bleeding Index	Number of comparisons	Effect size			Heterogeneity			Online Appendix number			TSA	
		Comparison	DiffM	95% CI	p-Value	I ²	p-Value	Forrest plot	Funnel plot	Number	TSA does research the RIS or not (yes/no)	
Goyal et al. (2009) ⁵⁵	12	Baseline	-0.01	(-0.03; 0.01)	0.48	82%	<0.00001	S15A	S15B	NA	NA	
Klukowska et al. (2012) ⁶²												
Klukowska et al. (2013) ⁶³		End	0.01	(-0.01; 0.02)	0.29	93%	<0.00001	S15C	S15D	S15E	No	
Klukowska et al. (2014-12w) ⁶⁶												
Klukowska et al. (2014-6wCOL) ⁶⁷		Difference	0.01	(-0.00; 0.02)	0.08	90%	<0.00001	S15F	S15G	NA	NA	
Klukowska et al. (2014-6wPH) ⁶⁸												
Ccahuana-Vasquez et al. (2015) ⁶⁹												
Starke et al. (2017) ⁷²												
Ccahuana-Vasquez et al. (2018) ⁷⁴												
Mirza et al. (2019) ⁷⁶												
Adam et al. (2020) ⁷⁷												
Goyal et al. (2021) ⁷⁸												

Note: p-values are presented in bold if $p \leq 0.05$.

Abbreviations: ?, Unclear; NA, Not applicable; RIS, Required Information Size; TSA, Trial sequential analysis.

TABLE 10 Meta-analysis for the (modified) Gingival index using a random model

(Modified) Gingival index	Number of comparisons	Effect size			Heterogeneity			Online Appendix number														
		Comparison	DiffM	95% CI	p-Value	<i>i</i> ²	p-Value	Forrest plot	Funnel plot	TSA												
										Number	TSA does research the RIS or not (yes/no)											
Grossman et al. (1995) ⁴⁷	22	Baseline	0.00	(-0.00; 0.01)	0.27	0%	0.71	S16A	S16B	NA	NA											
Yankell & Emiling (1997) ⁵⁰																						
Putt et al. (2001) ⁵³																						
Goyal et al. (2009) ⁵⁹																						
Williams et al. (2009) ⁶⁰																						
Ayad et al. (2012) ⁶¹ 2x																						
Klukowska et al. (2012) ⁶²																						
Klukowska et al. (2013) ⁶³																						
Klukowska et al. (2014-12w) ⁶⁶																						
Klukowska et al. (2014-6wCOL) ⁶⁷																						
Klukowska et al. (2014-6wPH) ⁶⁸																						
Ccahuana-Vasquez et al. (2015) ⁶⁹																						
Schmickler et al. (2016-non-rep) ⁷⁰ 2x																						
Starke et al. (2017) ⁷²																						
Schmalz et al. (2018-COL instr) ⁷³ 2x																						
Ccahuana-Vasquez et al. (2018) ⁷⁴																						
Mirza et al. (2019) ⁷⁶																						
Adam et al. (2020) ⁷⁷																						
Goyal et al. (2021) ⁷⁸																						
Goyal et al. (2009) ⁵⁹												17	Difference	0.00	(-0.04; 0.04)	0.89	97%	<0.00001	S16F	S16G	NA	NA
Williams et al. (2009) ⁶⁰																						
Ayad et al. (2012) ⁶¹ 2x																						
Klukowska et al. (2012) ⁶²																						
Klukowska et al. (2013) ⁶³																						
Klukowska et al. (2014-12w) ⁶⁶																						
Klukowska et al. (2014-6wCOL) ⁶⁷																						
Klukowska et al. (2014-6wPH) ⁶⁸																						
Ccahuana-Vasquez et al. (2015) ⁶⁹																						
Starke et al. (2017) ⁷²																						
Ccahuana-Vasquez et al. (2018) ⁷⁴																						
Lv et al. (2018) ⁷⁵ 2x																						
Mirza et al. (2019) ⁷⁶																						
Adam et al. (2020) ⁷⁷																						
Goyal et al. (2021) ⁷⁸																						

Note: *p*-Values are presented in bold if *p* ≤ 0.05. Interpretation of the heterogeneity: Potentially not important: 0%–40%; Moderate heterogeneity: 40%–60%; Substantial heterogeneity: 60%–80%; Considerable heterogeneity: 80%–100%. According to Sälzer et al. 2015³¹.

Abbreviations: ?, Unclear; NA, Not applicable; RIS, Required Information Size; TSA, Trial sequential analysis.

Determinants of quality	Plaque Index Score	Bleeding Index Score	Gingival Index Score
Study design (Online Appendix S1A,B)	RCT crossover or parallel design	RCT crossover or parallel design	RCT crossover or parallel design
# Studies N = 32	N = 38	N = 51	N = 38
# Comparisons N = 38 (Figure 1)			
# Studies in MA & TSA & CR			
Risk of bias (Online Appendix S3A,B)	Low-Moderate	Low-Moderate	Low
Consistency (Table 2, Online Appendix S3A,B)	Rather consistent	Rather consistent	Rather consistent
Directness (Longer term use)	Rather generalizable	Rather generalizable	Rather generalizable
Precision (Tables 4–10)	Precise	Precise	Precise
Reporting bias (Online appendix S10B,D, S11B,D,G, S14B,D,G, S15B,D,G and S16B,D,G)	Likely	Likely	Likely
Magnitude of the effect (Tables 4–10)	Very small	Very small	None or very small
Strength of the recommendation based on the quality and body of evidence	Moderate		
Direction of recommendation	There is a moderate certainty of a very small clinical relevant beneficial effect for an OR-PTB over a HFS-PTB.		

Abbreviations: CR, Clinical relevance; HFS-PTB, High-frequency sonic power toothbrush; MA, Meta-analysis; OR-PTB, Oscillating-rotating power toothbrush; TSA, Trial sequential analysis.

to have statistical significance without having clinical relevance.⁴³ Concluding that a result is statistically significant alone is inadequate because it does not speak to the magnitude of the effect. There is variation in the estimation of clinical relevance, potential clinical relevance and clinical irrelevance. When clinical relevance is translated to clinical judgement, it is unlikely that dental care professionals in routine examination would be able to detect small differences,⁴³ such as the difference between the two PTB products in the present review. Clinical judgement based on clinical knowledge takes precedence over the calculated methods for determining clinical relevance.⁴³ Thus, given that there is only a small statistically significant difference between the PTBs, this study does not firmly support the recommendation of one particular PTB over another. As such, the personal preferences of dental care professionals and patients will be decisive in choosing the best-suited PTB in a given case.

4.6 | Limitations and recommendations

Clinical observations are valid for the study conditions and applicable for the study population. The results may not predict how

TABLE 11 Estimated evidence profile appraisal of the strength of the recommendation, and the direction regarding the efficacy of the OR-PTB compared to the HFS-PTB on dental plaque removal and parameters of gingival inflammation

well an intervention will work in daily practice for a large variety of patients.⁹⁰ However, the recommendations that emerge from this review can help guide dental care professionals in providing evidence-based advice to their patients concerning PTB use.

There are several limitations to this study:

1. Intra-oral safety assessments were evaluated and a summary of the outcomes can be found in online Appendix S7. However, none of the studies included provided specific information on variables such as the impact of pressure indicators.
2. Although the present review includes 2805 total participants, the results of this systematic review should be extrapolated to specific patient populations with caution. Patients who have dental implants or orthodontic appliances, elderly patients and young children, for example, were not participants in any of the included studies.
3. Evidence suggests that oral prophylaxis and oral hygiene instructions may improve oral health.⁹¹ Oral prophylaxis was provided in 8 out of the 32 included studies, which may have affected the results.
4. As mentioned in the Cochrane systematic review,³ the cost and reliability of toothbrushes are important issues to consider

beyond efficacy. However, those items were not reported in their included trials and could, therefore, not be part of this review. Patient preference is one of the three components of making an evidence based decision and should, therefore, be included in clinical studies and systematic reviews.³

5. Technical improvements to PTBs are made over time. One direction for further research could be to evaluate the effects on plaque removal and parameters of gingival inflammation of PTBs over time to estimate the impact of these advances.

5 | CONCLUSION

For patients to maintain good plaque control and improve gingival health, there is a small but significant difference between oscillating-rotating power toothbrush and high-frequency sonic toothbrush as based on longer-term use studies. The direction of the recommendation is, therefore, that there is a moderate certainty of a small but clinically relevant advantage of OR-PTB over HFS-PTB. Both products were found to be safe, and 78% of participants prefer the OR-PTB.

6 | CLINICAL RELEVANCE

6.1 | Scientific rationale for the study

There is a need for a systematic evaluation of direct comparisons on the most commonly used power toothbrush designs for their effects on plaque control and parameters of gingival inflammation.

6.2 | Principal findings

With moderate certainty, there is a small but potentially clinically significant difference between the two types of power toothbrushes on PI, BS, GI scores.

6.3 | Practical Implications

Both types of power toothbrushes appear to be effective in improving plaque control and parameters of gingival inflammation. This study recommends, with moderate certainty, the OR-PTB over the HFS-PTB.

AUTHOR CONTRIBUTIONS

EvdS contributed to design, search and selection, analysis and interpretation and drafted the manuscript. DES contributed to conception and design, search and selection, analysis and interpretation and critically revised the manuscript. NLHH contributed to design, search and selection, analysis and interpretation and drafted the manuscript. CV contributed to analysis, interpretation and critically revised the manuscript. FvdW contributed to conception and design, analysis and

interpretation and critically revised the manuscript. All authors gave final approval and agreed to be accountable for all aspects of the work ensuring integrity and accuracy.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available in the [Supplementary Material](#) of this article.


ETHICS STATEMENT

Ethical approval was not required; the protocol was registered at PROSPERO (number CRD42020161883).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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