




SYSTEMATIC REVIEW

Mechanical plaque removal of periodontal maintenance patients: A systematic review and network meta-analysis

Dagmar E. Slot¹  | Cees Valkenburg^{1,2}  | G.A. (Fridus) Van der Weijden¹ 

¹Department of Periodontology, Academic Centre for Dentistry Amsterdam (ACTA), University of Amsterdam and Vrije Universiteit Amsterdam, Amsterdam, The Netherlands

²General dentist and clinical epidemiologist, Hoevelaken, The Netherlands

Correspondence

Dagmar E. Slot, Department of Periodontology, Academic Centre for Dentistry Amsterdam (ACTA), University of Amsterdam and VU University Amsterdam, Gustav Mahlerlaan 3004, 1081 LA Amsterdam, The Netherlands.
Email: d.slot@acta.nl

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Abstract

Aim: This systematic review synthesizes the available clinical evidence concerning efficacy of mechanical oral hygiene devices in periodontal maintenance patients.

Material and Methods: Three databases were searched up to October 2019 for clinical trials conducted in adult patients in periodontal maintenance which evaluated the effect of toothbrushes or an interdental device on plaque removal and parameters of periodontal diseases. Descriptive analysis and network meta-analysis (NMA) were performed.

Results: Sixteen eligible publications, including 17 relevant comparisons, were retrieved. Four out of five comparisons found no clinical difference between a manual and power toothbrush. Of the interdental cleaning devices, the interdental brushes (IDBs) reduced plaque scores more effectively than a manual toothbrush alone. For the oral irrigator, two out of three comparisons indicated a positive effect on gingivitis scores, and probing pocket depth. The NMA demonstrated that for plaque removal the adjuvant use of IDBs was significantly more effective than the manual toothbrush alone. For the reduction of gingival inflammation, no product ranked higher than the manual toothbrush.

Conclusion: Due to the scarcity of studies that met the inclusion criteria for each of the oral hygiene devices and the low certainty of the resultant evidence, no strong “evidence-based” conclusion can be drawn concerning any specific oral hygiene device for patient self-care in periodontal maintenance.

KEYWORDS

interdental devices, maintenance, supportive periodontal therapy, toothbrush

1 | INTRODUCTION

Periodontitis is a ubiquitous and inflammatory condition that represents a significant public health burden (Chapple et al., 2015). Severe periodontitis affects over 11% of adults; is a major cause of tooth loss that negatively impacts speech, nutrition, quality of life and self-esteem; and has systemic inflammatory consequences (Kassebaum et al., 2014). Periodontitis is bacterially induced, and the responding chronic inflammatory process results in loss of the connective tissues and bone that support teeth (Lang, 2014). Periodontal

treatment consists of a phase of active periodontal therapy (APT), which is followed by supportive periodontal therapy (SPT) to reduce the risk of re-infection and progression of the disease. SPT includes a periodontal re-evaluation and risk assessment and supragingival and subgingival removal of bacterial plaque and calculus. Evaluation of oral hygiene performance and motivation and re-instruction in oral hygiene practices are necessary for the long-term success of periodontal treatment (Tonetti, Chapple, Jepsen, & Sanz, 2015; Tonetti, Eickholz, et al., 2015). Effective plaque control practices are particularly important for periodontitis patients because they

have demonstrated susceptibility to periodontal inflammation. The importance of self-performed plaque control cannot be properly inferred from the systematic reviews that are currently available because patient motivation and instruction in oral hygiene practices were combined with SPT in most of the studies (Sanz et al., 2015). However, substantial periodontal deterioration was observed in the patients enrolled in a maintenance regimen that was solely based on self-performed plaque control without SPT (Sanz et al., 2015; Trombelli, Franceschetti, & Farina, 2015).

As plaque is considered the major aetiological factor of periodontal diseases, patient cooperation in daily plaque removal is critical to the long-term success of dental and periodontal treatment (Chapple et al., 2015). With respect to recommendations for oral hygiene practices, there is a wide range of variability between what is known and what is practised. This may be due to the lack of translation of relevant scientific evidence into information that is useful for the dental care professional and the patient. It is however important that professional recommendations incorporate the best available scientific evidence to maximize successful patient care outcomes. This evidence-based approach improves the quality of health care by assimilating scientific evidence into practice and by reducing variations in practice patterns (Lehane et al., 2018). One concern is that most studies on home care products for mechanical plaque control are performed on gingivitis patients (Van der Weijden & Slot, 2015). Even though these studies have demonstrated desired outcomes, the results may not be directly applicable to periodontitis patients with periodontal pockets. Currently, there has been no systematic evaluation or significant syntheses of knowledge about the clinical effect of toothbrushes and interdental cleaning devices among periodontitis patients during periodontal maintenance. Therefore, the aim of this systematic review is to synthesize the available evidence concerning mechanical oral hygiene devices in periodontal maintenance patients.

2 | MATERIALS AND METHODS

This systematic review was prepared in accordance with the Cochrane Handbook for Systematic Reviews of Interventions (Higgins & Green, 2011), and the recommendations for strengthening the reporting of systematic reviews and meta-analyses (PRISMA) (Moher, Liberati, Tetzlaff, & Altman, 2009) were followed. Additional relevant materials used were the PRISMA statement explanation and elaboration document (homepage PRISMA), the PRISMA statement extension for abstracts (Beller et al., 2013), and the PRISMA extension when a network analysis is involved (Hutton et al., 2015). The protocol that details the review method was developed a priori after an initial discussion among the members of the research team and the organizers of the 16th European Workshop on Periodontology. It is registered under number 137441 with PROSPERO, the International Prospective Register of Systematic Reviews (homepage PROSPERO).

Clinical Relevance

Scientific rationale for the study: Daily oral self-care is critical to the long-term success of periodontal therapy. Currently, no synthesis of the available literature is available concerning mechanical oral home care during periodontal maintenance.

Principal findings: No clinical differences between a power toothbrush and manual toothbrush were found. There is some (mainly indirect) evidence that indicates that the adjunct use of interdental brushes is effective for improving plaque score reduction.

Practical implications: Periodontal maintenance patients can be advised to use either a power or manual toothbrush. For interdental cleaning, interdental brushes are the device of choice. As alternative, an oral irrigator may be considered.

2.1 | Focused PICOS question

Based on (randomized) controlled clinical trials (study design), what is, in periodontal maintenance patients (patient), the effect on plaque removal and parameters of periodontal diseases (outcome) of the following:

1. Power toothbrushes (PTBs) (intervention) as compared to manual toothbrushes (MTBs) (control)?
2. interdental oral hygiene devices (intervention) compared to no interdental cleaning (control) as adjunct to toothbrushing?
3. Different interdental cleaning devices (intervention/control) as adjunct to toothbrushing

TABLE 1 Search Strategy

Search terms used for PubMed-MEDLINE and Cochrane-CENTRAL.

The search strategy was customized according to the database being searched.

The following strategy was used in the search: { [<patient>] AND [<intervention>]}

[< patient: during periodontal maintenance>]

{<(Periodont* AND (maintain* OR mainten*))

OR

(maintenance programme) OR (maintenance phase) OR (treated adult periodontitis patients) OR (supportive periodontal therapy) OR (supportive periodontal care)>

AND

[<intervention>]

<(mechanical plaque removal) OR (mechanical plaque control) OR toothbrush OR floss OR toothpick OR woodstick OR (interdental brush) OR (oral irrigator) OR waterpik>}

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

2.2 | Search strategy

A structured search strategy was designed to retrieve all relevant studies. The National Library of Medicine, Washington, D.C.(MEDLINE-PubMed), the Cochrane-CENTRAL Register of Controlled Trials(CENTRAL), and EMBASE (Excerpta Medical Database by Elsevier) were searched from inception up to October 2019 for appropriate papers that answered the focused questions. Furthermore, the reference lists of the included studies were hand searched to identify additional potentially relevant studies. No further hand searching was performed except with the Cochrane worldwide hand searching programme, which is uploaded to CENTRAL. Table 1 contains details regarding the search terms that were used.

2.3 | Screening and selection

The titles and abstracts of the studies obtained from the searches were screened independently by two reviewers (DES and GAW) to select studies that potentially met the inclusion criteria. No language restrictions were imposed. The full-text versions of potentially relevant papers were obtained on the basis of the information provided in the title and abstract. If the title and abstract did not contain enough information to include or exclude the study from the analysis, the paper was also reviewed in full text. The papers were categorized (GAW and DES) as definitely eligible, definitely not eligible, or questionable. Disagreements concerning eligibility were resolved by consensus, and if disagreement persisted, the decision was resolved through arbitration by a third reviewer (CV). The papers that fulfilled all of the inclusion criteria were processed for data extraction.

Studies were deemed eligible for inclusion if they conformed to the following criteria:

- A randomized controlled clinical trial (RCT) or a controlled clinical trial (CCT) study design;
- Human participants of ≥ 18 years;
- In good general health (no systemic disorder);
- Periodontitis patients enrolled in periodontal maintenance care;
- Involved manual toothbrushes (MTBs), power toothbrushes (PTBs), or interdental cleaning devices;
- Evaluated the following outcome parameters of periodontal diseases. For primary outcomes, plaque index score (PI), gingival index score (GI), and bleeding score (BS). For secondary outcomes, probing pocket depth (PPD), clinical attachment level (CAL), and gingival recession (GR).

2.4 | Assessment of heterogeneity

The following factors were assessed to evaluate the heterogeneity of the outcomes of the different studies: study design and

evaluation period, subject characteristics, brushing regimen, and industry funding.

2.5 | Risk of bias assessment

Two reviewers (DES and CV) independently scored the individual methodological qualities of the included studies using the Cochrane risk of bias tool (Higgins et al., 2016). This scoring was based on seven domains and could be scored as unclear, low risk of bias or high risk of bias. The following items were evaluated: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and others. It was 'a priori' decided that the domain of performance bias was not included in the overall estimation of risk of bias. This is because it is not possible to blind study participants to the mechanical plaque control interventions (Worthington et al., 2019).

The consequence of removing performance bias from the risk of bias consideration, which is the criterion for the overall estimation of the potential risk of bias, was that a study was estimated to be at a high risk of bias if at least one domain had a high risk of bias, at an unclear risk of bias if at least one domain was unclear and none were high, and at a low risk of bias if all domains were assessed as being at low risk of bias. For split-mouth and crossover designs, the risk of bias assessment included additional considerations such as suitability of the design and the risk of carry-over or spill-over effects which were scored under "other biases." For further details see online Appendix S1.

2.6 | Data extraction

Two reviewers (DES and CV) used a specially designed data extraction form to extract details on the characteristics of the population, intervention, comparison, and outcomes were extracted independently from all the studies. Discrepancies were resolved through referral to the original article and subsequent discussion. If no consensus was reached, the judgement of a third reviewer (GAW) was decisive. Incomplete summary data were not a reason to exclude a study from the review. The analysis assumed that summary data were missing at random, so that only the available data were included. Means and standard deviations were extracted if available. Any data approximation in figures was avoided to ensure a precise estimate. If missing or incomplete numerical data were to be included in the meta-analysis, the original authors were contacted via the first or corresponding author if possible and respectfully asked if they could provide additional data.

Methods outlined by the Cochrane Handbook (Higgins & Green, 2011) were used for imputing missing standard deviation (SD). Imputed standard deviations were calculated for studies that provided a mean and confidence interval. If the sample size was large (>100 in each group), the 95% confidence interval was 3.92 standard errors wide ($3.92 = 2 \times 1.96$). The standard deviation for

each group is obtained by dividing the length of the confidence interval by 3.92, and then multiplying by the square root of the sample size. If the sample size was small (<60 in each group), then the confidence intervals were calculated using a value from a *t* distribution, obtained from the tables of the *t* distribution with degrees of freedom that were equal to the group sample size minus 1. If studies presented means and standard deviations separately from subgroups, this review considered them to be a single group. The formulae as presented in Table 7.7.a of the Cochrane handbook (Higgins & Green, 2011) for combining groups were used. It produces the *SD* of outcome measurements as if the combined group had never been divided. An approximation to this standard deviation was obtained by using the usual pooled standard deviation, which provides a slight underestimate of the desired standard deviation. If the *SD* could not be calculated, data were imputed from a similar study. In the case of Newman et al. (1994), the *SD* was imputed primarily from Jolkovsky et al. (1990) or Flemmig et al. (1995). From the studies presenting individual data, a subsequent mean and *SD* was calculated.

2.7 | Data analysis

In summary, a descriptive data presentation was used for all presented comparisons in the included studies. A network meta-analysis (NMA) approach was performed to incorporate direct and indirect comparisons that have one treatment in common (Bafeta, Trinquart, Seror, & Ravaut, 2014; Ioannidis, 2009; John, Michalowicz, Kotsakis, & Chu, 2017; Leucht et al., 2016; Salanti, Kavvoura, & Ioannidis, 2008). Treatments were ranked (Rücker & Schwarzer, 2015, 2017) through a frequentist weighted least squares method, as described by Rücker (Rücker & Schwarzer, Rücker, Schwarzer, Krahn & König, 2016).

The direct evidence proportion described in König, Krahn, and Binder (2013) was used to calculate the indirect evidence (Rücker et al., 2016). A decomposition of heterogeneity within designs and between designs was provided (Dias, Welton, Caldwell, & Ades, 2010). A net heat plot graphical tool as proposed by Krahn, Binder, and König (2013) was used to review the network geometry and to locate inconsistency. In the network graph, each cluster of mechanical cleaning devices is drawn by a node, and direct comparisons between them are represented by links between the nodes. The line thickness is proportional to the inverse standard error of the direct treatment comparison. For the transitivity assumption (Escribano et al., 2016; Hutton et al., 2015), the different mechanical treatments were analysed from a common comparator. All computations were performed using R (<https://www.r-project.org>) with the packages meta (Schwarzer, 2007), metafor (Viechtbauer, 2010), and netmeta (Rücker et al., 2016).

For the clinical significance assessment, distribution-based methods were used to determine the clinical relevance of study

results (Armijo-Olivo, Warren, Fuentes, & Magee, 2011; Cohen, 1992; Guyatt, Osoba, Wu, Wyrwich, & Norman, 2002; Lemieux, Beaton, Hogg-Johnson, Bordeleau, & Goodwin, 2007; Musselman, 2007). Based on the relationship among the mean difference of the variable, minimal important differences (MIDs) and effect sizes (ES), the clinical relevance judgement was scored as not clinically relevant (NCR), potentially clinically relevant (PCR) or clinically relevant (CR) (Lemieux et al., 2007; Musselman, 2007). The MID was determined by multiplying the effect size of the difference obtained between groups that were considered to be important (0.2 or 0.5 ES according to Cohen) by the pooled baseline standard deviation between the two groups (Cohen, 1988; Lemieux et al., 2007).

2.8 | Grading the body of evidence

The grading of recommendations assessment, development, and evaluation (GRADE) system was used to rank the evidence. Two reviewers (DES and GAW) rated the certainty of the evidence and the strength and direction (GRADE; Guyatt et al., 2008; Smiley et al., 2015) of the recommendations according to the following aspects: risk of bias, consistency of results, directness of evidence, precision of data, publication bias, and magnitude of the effect. Any disagreement between the reviewers was resolved after additional discussion.

3 | RESULTS

3.1 | Search and selection results

The search of the MEDLINE-PubMed, EMBASE, and Cochrane-CENTRAL databases resulted in 325 unique papers (for details, see Figure 1). The screening of the titles and abstracts resulted for both reviewers in the same 21 papers, for which the texts were obtained and read in full. See online Appendix S2 for the 5 excluded papers and consequent reasons. Altogether, 16 eligible studies were included (Bergenholtz & Brithon, 1980; Bergenholtz & Olsson, 1984; Bogren et al., 2007, 2008; Boyd, Murray, & Robertson, 1989; Flemmig et al., 1995; Haffajee, Smith, et al., 2001; Haffajee, Thompson, Torresyap, Guerrero, & Socransky, 2001; Howorko, Gutek, Naidoo, & Hoover, 1993; Jolkovsky et al., 1990; Kiger, Nylund, & Feller, 1991; Larsen, Slot, Van Zoelen, Barendregt, & Van der Weijden, 2017; Murray, Boyd, & Robertson, 1989; Newman et al., 1994; Rösing, Daudt, Festugatto, & Oppermann, 2006; Steenackers, Vijt, Leroy, Vree, & Boever, 2001). Some studies presented the same experiment (Borgen et al. 2008, Haffajee, Thompson, et al., 2001, Haffajee, Smith, et al., 2001, Boyd et al., 1989, Murray et al., 1989). The studies included in this systematic review described 17 comparisons were in total, five comparisons evaluated the effect of a PTB and an MTB, while the other 12 evaluated an interdental cleaning regimen.

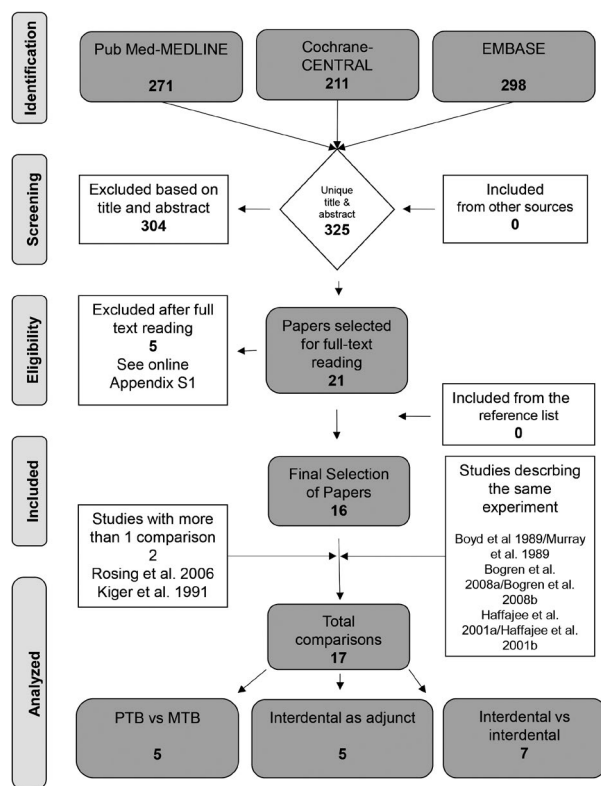


FIGURE 1 Flow of the search and selection process

3.2 | Heterogeneity

3.2.1 | Design and participants

Information regarding heterogeneity in the study design is depicted in detail in Table 2. As is evident, the included studies exhibited extensive heterogeneity. For example, the number of participants varied between 9 and 124, with an age range of 18 to 82. All but one (Boyd et al., 1989; Murray et al., 1989) are randomized controlled clinical trials. The study settings were mainly dental universities with two multicentre studies (Bogren et al., 2007, 2008; Newman et al., 1994) and one private periodontal clinic (Larsen et al., 2017). The majority of the studies were funded by the industry, two did not mention funding (Bergenholtz & Olsen, 1984; Rosing et al., 2006), and one was sponsored by NIDCR (Bogren et al., 2007, 2008).

The evaluation period varied from single use to two weeks up to three years. The time in periodontal maintenance after APT and SPT ranged from three months to one year. Two studies provided the mean numbers of months in SPT (Rosing et al., 2006; Steenackers et al., 2001), which were 31 and 62 months. The criteria for periodontal status of the included participants differed with respect to the minimum of teeth, BI, GI, CAL, and the number of pockets deeper than 4 or 5 mm.

3.2.2 | Power toothbrush

The studies that evaluated a PTB involved different toothbrush brands and modes of action: Oral-B (Bogren et al., 2007, 2008; Haffajee, Smith, et al., 2001; Haffajee, Thompson, et al., 2001), Philips (Steenackers et al., 2001), Rotadent (Boyd et al., 1989; Murray et al., 1989) and Interplak (Howorko et al., 1993). The MTB that served as a control in the majority of studies had mainly soft and end rounded filaments that were multi-tufted, and had a flat trim bristle design. No interdental oral hygiene was allowed in two of the toothbrush comparison studies (Howorko et al., 1993; Steenackers et al., 2001), while interdental oral hygiene was tailored per individual participant in two other studies (Bogren et al., 2007, 2008; Haffajee, Smith, et al., 2001; Haffajee, Thompson, et al., 2001). In one study, the participants in the MTB group were instructed to use an interdental cleaning device while the PTB group did not (Boyd et al., 1989; Murray et al., 1989). Sodium fluoride toothpaste was provided for participants in two studies (Boyd et al., 1989; Haffajee, Smith, et al., 2001; Haffajee, Thompson, et al., 2001; Murray et al., 1989). In one study, the PTB group used a triclosan dentifrice while the MTB used a non-triclosan dentifrice (Bogren et al., 2007, 2008). Other studies did not provide details regarding the dentifrice used (Howorko et al., 1993; Steenackers et al., 2001).

3.2.3 | Interdental devices

Four comparisons evaluated interdental brushes (IDBs) in comparison with floss (Bergenholtz & Olsson, 1984; Kiger et al., 1991; Rosing et al., 2006) and one compared floss to the woodstick (Bergenholtz & Brithon, 1980). Two comparisons evaluated conical IDBs in comparison with cylindrical ones (I, Rosing et al., 2006). One comparison evaluate the adjunctive use of an IDB to MTB (Kiger et al., 1991) and three (Flemmig et al., 1995; Jolkovsky et al., 1990; Newman et al., 1994) evaluated the adjunctive use of the oral irrigator (OI) to a regular oral hygiene regimen. All used the brand Water Pik, including two different models (WP-30E, Flemmig et al., 1995; Newman et al., 1994 and WP-20, Jolkovsky et al., 1990), and the pickpocket tip was used in Jolkovsky et al., 1990. One study (Kiger et al., 1991) mentioned that all subjects were provided with sodium mono-fluorophosphate paste to use and two studies (Bergenholtz & Brithon, 1980; Bergenholtz & Olsson, 1984) used a fluoride dentifrice.

3.2.4 | Instruction and indices

In general, the instructions given to the participants varied from no specific instructions, the continuation of habitual oral hygiene, and the reinforcement of personal oral hygiene in all subsequent

TABLE 2 Overview of the studies processed for data extraction

Study ID Author Study design Duration Risk of bias(Appendix S1)	Patients #baseline(end) Age (mean/range)	Groups	Instruction	Conclusion of the original authors
I Larsen et al. (2017) 3 months RCT Parallel low	55 (51) Range:37–69 y Mean age:55 ♀:21, ♂: 30 SPT ? teeth ≥1 year IPT General healthy	Conical IDB Lactona Europe BV Netherlands Cylindrical IDB Lactona Europe BV Netherlands Ø:2.5–12 mm	According to Lindhe's textbook Max.5 days IDB use than renew No mouthwash Adjunct to regular toothbrushing habits	The conical IDBs are less effective than cylindrical IDBs with respect to lingual approximal plaque removal. Thus, in SPT patients the cylindrical shape should be the first choice of IDB to obtain and maintain gingival health around natural teeth
II Bogren et al. (2008), Bogren et al. (2007) 3 years RCT Parallel high	128(124) Range:34–82 Mean age:59♀ ♀:75, ♂: 53 SPT (PPD:min 4 ≥ 5 mm) ≥15 teeth ≥1 year after IPT General healthy	PTB + DF, triclosan Oral-B, USA Total Colgate, USA MTB + RDF Soft multi-tufted Protection Caries, Colgate, USA	PTB: according to manufacturer MTB: modified bass 2xday Daily per individual: floss, toothpicks, IDB	The study failed to demonstrate superior clinical and microbiological effects PTB + TCS DF compared with MTB + RDF manual in periodontitis-susceptible patients on regular maintenance therapy
III Rösing et al. (2006) Single use RCT Split mouth unclear	55 (50) Range:20–73 years Mean age:44 year ♀:21, ♂: 30 SPT ? teeth ±31 m after IPT General healthy	Conical IDB Johnson & Johnson, USA Cylindrical IDB Johnson & Johnson, USA Ø:??mm Floss waxed Johnson & Johnson, USA	1 min instruction	For individuals in SPT, IDBs, regardless of their shape (conical or cylindric), are more efficacious in interdental supragingival plaque removal than dental floss
IV Haffajee, Thompson, et al. (2001), Haffajee, Smith, et al. (2001) 6 months RCT Parallel high	52 (48) Range:20–64 Mean age:48♀ ♀:28♀, ♂: 20♀ SPT (>10%sites ≥ 4 mm/10%) CAL > 4 mm) ≥20 teeth 3–6 m after IPT General healthy	PTB Oral-B Kronberg, Germany MTB Crest complete P&G, USA DF: Crest regular P&G USA	PTB: visual presentation MTB: modified bass Show in mouth themselves 2xday interdental per individual; floss, toothpicks, IDB	The powered toothbrush significantly reduced mean gingival index and probing attachment level.

(Continues)

TABLE 2 (Continued)

Study ID Author	Study design	Patients #baseline(end)	Age (mean/range)	Groups	Instruction	Conclusion of the original authors
V	Steenackers et al. (2001)	49(49)	Range: 22–66 Mean age: 35	PTB	2xp/d	In SPT, patients using an PTB did not significantly enhance plaque removal, but did decrease bleeding compared to baseline.
9 weeks				Philips Jordan 2-Action (HP735)	No instruction	The difference in bleeding percentages was not statistically significant compared to a MTB.
RCT		♀:31, ♂:18		Netherlands	Continue regular oral hygiene	
Parallel		SPT (<5 mm PPD)		MTB	No interdental cleaning	
high		≥20 teeth		Lactona M39		
		±62 m (range 9–180 m) after IPT		Netherlands		
		General healthy?				
VI	Flemmig et al. (1995)	40 (37)	Range: 19–75	OI	OI instruction use	Frequent supragingival irrigation with water in addition to regular oral hygiene appears to be a beneficial adjunct to periodontal supportive therapy in patients with moderate to severe signs of periodontitis.
6 months		Mean age: ??		WP-30E	1x p/d	
RCT		♀:??, ♂:??		Water Pik, USA	Continue regular oral hygiene	
Parallel		SPT (≥2 ≥ 5 mm PPD)		Control		
high		≥16 teeth				
		? after IPT				
		General healthy				
VII	Newman et al. (1994)	? (115)	Range: 18–75	OI	OI: 1x/d	Supragingival irrigation with water in periodontal maintenance patients provided additional beneficial outcomes over normal oral hygiene alone.
6 months		Mean age: ??		WP-30E	No mouthwash	
Parallel		♀:??, ♂:??		Water Pik, USA	Continue regular oral hygiene	
Multicentre		SPT (≥2 ≥ 5 mm PPD)		Control		
high		≥16 teeth				
		≥3 m after IPT				
		General healthy				
VIII	Horowoko et al. (1993)	20 (20)	Range: ??	PTB: Interplak, USA	Oral and written instructions	No difference in plaque removal between the PTB and MTB was observed.
2 weeks 2x		Mean age: ??		MTB: B311 Butler	PTB: manufacturer use	
RCT		♀:??, ♂:??			MTB: modified Bass	
Crossover		SPT			Instruction: use own frequency and time	
No washout		24 teeth			No floss/mouthwash	
high		? after IPT				
		General healthy				
IX	Kiger et al. (1991)	30 (30)	Range: ??	MTB-40 Oral-B, USA	Instructions were given	The interdental brush used in combination with a toothbrush is more effective in the removal of plaque from proximal tooth surfaces than a toothbrush used alone or in combination with dental floss.
1 month		Mean age: ??		IDB, Oral-B, USA		
RCT		♀:10, ♂: 20		Floss, unwaxed, Johnson & Johnson, USA		
Crossover		SPT		DF: MFP Colgate, USA		
high		? teeth				
		? after IPT				
		General healthy				

(Continues)

TABLE 2 (Continued)

Study ID Author	Study design Duration Risk of bias (Appendix S1)	Patients #baseline(end) Age (mean/range)	Groups	Instruction	Conclusion of the original authors
X Jolkovsky et al. (1990) 3 months Parallel unclear		30 (290) Range: 22–75 Mean age: 56 ♀:?, ♂:?? SPT ($\geq 2 \geq 4$ mm PPD, gingivitis, BOP) ? teeth ? after IPT General healthy	OI WP–20 + pickpocket Water Pik, USA Control	Written/verbal OI: 1x/d Continue regular oral hygiene	There was no statistical significant difference between groups at 3 months for plaque, PPD and gingival recession
XI Boyd et al. (1989), Murray et al. (1989) 12 months CCT Parallel high		40 (350) Range: 24–75 Mean age: 320y ♀: 28, ♂: 12 SPT ($\geq 2 \geq 4$ mm PPD, gingivitis, BOP) ? teeth 1 year after IPT General healthy	PTB: rotary electric, Rotadent MTB: oral-B end rounded soft bristle, USA DF: Crest, Procter & Gamble, USA	2xp/d Reinforcement of dental hygiene instruction baseline and every 3 months. MTB group: interdental per individual; floss, toothpicks, IDB	The rotary electric toothbrush is as effective for plaque removal and control of gingival inflammation as the combination of a MTB with interdental devices for patients in SPT.
XII Bergenholtz and Olsson (1984) 2 weeks 2x RCT Crossover No washout high		9 (9) Range: ? Mean age: 52.5 years ♀: 4, ♂: 5 SPT ? teeth ? after IPT General healthy?	MTB: Butler-GUM 411, USA IDB, Ø = 6 mm, rage Nilsson HB Sweden or Jordan, Norway Floss, waxed, Right kind, Butler, USA DF: fluoride, Colgate-Palmolive, Sweden	?xp/d Well motivated and familiar with the use of floss and IDB. Instructed and trained in the use of interdental cleaning.	The use of IDB is preferable to that of floss in cleaning interdental areas where the papilla is missing. No gingival damage or damage to the hard tissue of the teeth was observed after use of IDB or floss.
XIII Bergenholtz and Brithon (1980) 2 weeks 7x RCT Crossover No washout high		10 (10) Range: ? Mean age: 52.5 years ♀: 6, ♂: 4 SPT (GI ≤ 0.3) ? teeth ? after IPT General healthy?	MTB: Lactona M39, Sweden Woodstick: Jordan Floss: (un)waxed nylon DF: fluoride, Pepsodent, Gibbs AB, Sweden	2xp/d MTB Detailed instructing for floss and woodsticks	In general, dental floss had a higher plaque removing potential than triangular toothpicks, especially on lingual axial surfaces.

Abbreviations: ?, unknown; ♂, calculated by the authors of this review; BOP, bleeding upon pocket probing; CAL, clinical attachment level; DF, dentifrice; GI, gingival index; IDB, interdental brush; IPT, initial periodontal treatment; min, minimal; MTB, manual toothbrush; OI, oral irrigator; p/d, per day; PPD, probing pocket depth; PTB, power toothbrush; RDF, regular dentifrice; SPT, supportive periodontal treatment; y, year.

appointments that took place every three months. Two studies specifically mentioned that no mouthwash could be used (I, Howorko et al., 1993). A variety of PI and their modifications were used. The gingival index according to Löe (Löe, 1967; Löe & Sillness, 1963, Sillness & Löe 1964) was used in eight studies (Bergenholtz & Brithon, 1980; Bergenholtz & Olsson, 1984; Boyd et al., 1989; Flemmig et al., 1995; Haffajee, Smith, et al., 2001; Haffajee, Thompson, et al., 2001; Jolkovsky et al., 1990; Kiger et al., 1991; Murray et al., 1989; Newman et al., 1994) and six (Bergenholtz & Olsson, 1984; Bogren et al., 2007, 2008; Flemmig et al., 1995; Haffajee, Smith, et al., 2001; Haffajee, Thompson, et al., 2001; Larsen et al., 2017; Newman et al., 1994) of the eight studies assessed the level of periodontal inflammation based on the bleeding upon probing score.

3.2.5 | Risk of bias assessment

The estimated potential risk of bias of the included studies was assessed using the Cochrane tool (Higgins et al. 2016). For details, see Online Appendix S1. As the included studies either involved the use of an MTB or PTB or involved different interdental devices, blinding the participants to the intervention was not possible. Selection bias was

present in all but one study (I). The studies by Boyd et al. (1989) and Murray et al. (1989) used a random sequence generation, and the other studies provided no data concerning allocation concealment and were therefore estimated to be unclear with respect to selection bias. Based on the crossover study design, the studies (Bergenholtz & Brithon, 1980; Bergenholtz & Olsson, 1984; Howorko et al., 1993; Kiger et al., 1991) were downgraded because there was no washout period or no control for carry-over effects. All 4 studies with a crossover trial design were estimated as a high potential risk of bias. The overall estimation of the potential risk of bias was that ten studies (Bergenholtz & Brithon, 1980; Bergenholtz & Olsson, 1984; Bogren et al., 2007, 2008; Boyd et al., 1989; Flemmig et al., 1995; Haffajee, Smith, et al., 2001; Haffajee, Thompson, et al., 2001; Howorko et al., 1993; Kiger et al., 1991; Murray et al., 1989; Newman et al., 1994; Steenackers et al., 2001) had a high risk of bias, two had an unclear risk of bias (Jolkovsky et al., 1990; Rösing et al., 2006), and one had a low risk of bias (I).

3.3 | Study outcomes results—descriptive analysis

Online Appendix S3 presents the results of the data extraction for PI, GI and BI scores, PPD, CAL, and GR. The descriptive analysis is

TABLE 3 A descriptive summary of statistical significance levels of the use of intervention compared to the control on the parameters of interest

Study	Intervention	Plaque Score	Gingival Index	Bleeding Score	PPD	CAL	REC	Comparison
XI Boyd et al. (1989), Murray et al. (1989)	PTB	0	0	0	0	?	NA	MTB
IV Haffajee, Thompson, et al. (2001), Haffajee, Smith, et al. (2001)	PTB	0	0	+	0	0	NA	MTB
VIII Horowoko et al. (1993)	PTB	0	NA	NA	NA	NA	NA	MTB
V Steenackers et al. (2001)	PTB	0	NA	0	NA	NA	NA	MTB
II Bogren et al. (2008), Bogren et al. (2007)	PTB + DF, triclosan	0	NA	0	0	0	NA	MTB + RDF
IX Kiger et al. (1991)	Floss	0	0	NA	NA	NA	NA	MTB
IX Kiger et al. (1991)	IDB	0	0	NA	NA	NA	NA	MTB
VI Flemmig et al. (1995)	OI	0	+	+	+	NA	0	control
VII Newman et al. (1994)	OI	0	+	+	+	NA	0	control
X Jolkovsky et al. (1990)	OI	0	0	NA	0	NA	0	control
XII Bergenholtz and Brithon (1980)	Floss	+	0	NA	NA	NA	NA	Woodsticks
XIII Bergenholtz and Olsson (1984)	Floss	0	0	0	NA	NA	NA	IDB
IX Kiger et al. (1991)	Floss	0	0	NA	NA	NA	NA	IDB
III Rösing et al. (2006)	Floss	-	NA	NA	NA	NA	NA	IDB conical
III Rösing et al. (2006)	Floss	-	NA	NA	NA	NA	NA	IDB cylindrical
III Rösing et al. (2006)	IDB conical	0	NA	NA	NA	NA	NA	IDB cylindrical
I Larsen et al. (2017)	IDB conical	0	NA	-	0	NA	NA	IDB cylindrical

Note: For abbreviations, see Table 2.

REC, gingival recession.

depicted in Table 3. In total, 17 comparisons could be evaluated. The effect of a PTB to an MTB is evaluated in five comparisons. No difference was found between PTB and MTB with respect to any clinical parameters, with the exception of one comparison (Haffajee, Smith, et al., 2001; Haffajee, Thompson, et al., 2001). This study demonstrated a positive significant effect for bleeding on probing in favour of the PTB. No data were available for gingival recession.

Five comparisons evaluated the adjunctive effect of an interdental device for toothbrushing alone. Floss and the IDB were evaluated in the same study (Kiger et al., 1991), and both did not indicate an adjuvant significant effect on the PI and GI scores. Three comparisons (Flemmig et al., 1995; Jolkovsky et al., 1990; Newman et al., 1994) evaluated the adjunctive effect of an OI in addition to regular hygiene. Two (Flemmig et al., 1995; Newman et al., 1994) of the three comparisons demonstrated a positive significant effect on the GI, BI scores, and PPD when an OI was used. None of the three comparisons found a difference for the PI and GR.

Seven comparisons evaluated two different interdental cleaning devices. One comparison (Bergenholtz & Brithon, 1980) showed a significant effect of floss over a woodstick on plaque removal. Four comparisons evaluated the effect of floss compared to IDBs. In two out of four comparisons, an IDB significantly reduced the PI by more than dental floss did. The two comparisons (Larsen et al., 2017; Rösing et al., 2006) between various cylindrical or conical IDBs did not indicate a difference on plaque removal. The comparison that evaluated bleeding on probing indicates a significant adjunctive effect of the cylindrical IDB (Larsen et al., 2017).

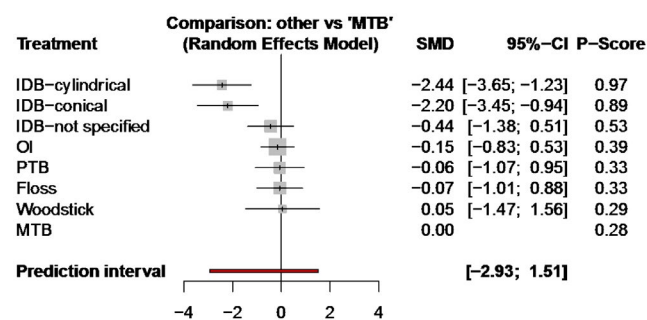


FIGURE 2 Forest plot of the Ranking of the oral hygiene devices based on the standardized mean difference (SMD) of END plaque scores sorted by ranking (the P-score of treatment) The frequentist P-scores allow ranking treatments on a continuous 0-1 scale. The P-score of treatment is defined as the mean extent of certainty that treatment is better than another treatment; scale: 0 (worst) to (best). At least under normal assumption the order depends largely on the point estimates (Rücker & Schwarzer, 2015) MTB, Manual toothbrush; PTB, power toothbrush; OI, oral irrigator; IDB, interdental brush; SMD, Standardized Mean Difference; 95%CI, 95% Confidence Interval [Colour figure can be viewed at wileyonlinelibrary.com]

3.4 | Network meta-analysis

Direct and indirect evidence was combined in an NMA to synthesize the treatment effects of the various oral hygiene devices relative to the MTB (for details see Appendix S4-S8). The net heat plot (see online Appendix S5) demonstrated no inconsistencies with respect to the NMA concerning PI. For the other parameters, this analysis was not possible due to the limited number of included papers. Figure 2 presents the forest plot of the NMA concerning PI. This figure demonstrates that the IDBs are ranked the highest and that the conical and cylindrical IDBs are significantly different from the MTB. The 95% confidence interval is [-3.65; -1.23] and [-3.45; -0.94] for cylindrical and conical IDBs, respectively. It also showed that dental floss, a PTB, the woodstick, and the OI provide no significant beneficial effect. The network graph (see online Appendix S5) depicts the origin of the evidence for the MTB as compared to other oral hygiene devices. Comparisons are represented by links between the nodes. It is apparent that the evidence for cylindrical and conical IDBs is based on indirect evidence and only one study is involved (Rösing et al.,

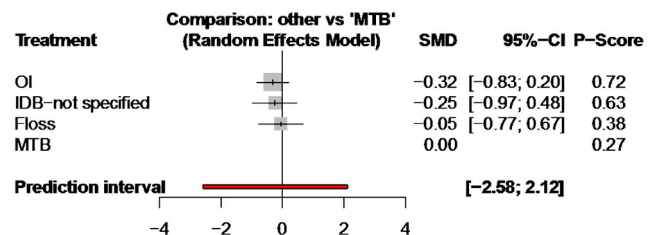


FIGURE 3 Forest plot of the Ranking of the oral hygiene devices based on the standardized mean difference (SMD) of END gingival index scores sorted by ranking (the P-score of treatment) Note: For footnote see figure 2. For abbreviations see figure 2. [Colour figure can be viewed at wileyonlinelibrary.com]

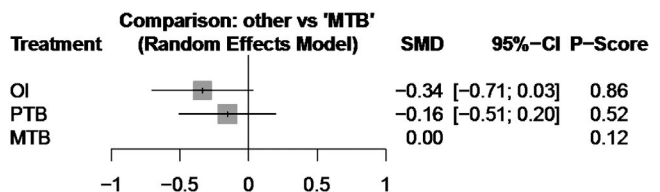


FIGURE 4 Forest plot of the Ranking of the oral hygiene devices based on the standardized mean difference (SMD) of END bleeding scores sorted by ranking (the P-score of treatment) Note: For footnote see figure 2. For abbreviations see figure 2.

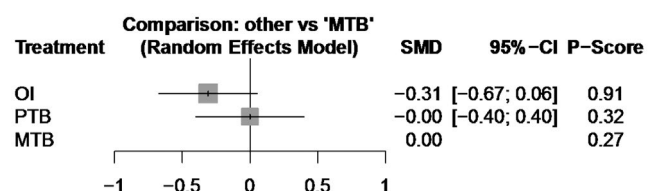


FIGURE 5 Forest plot of the Ranking of the oral hygiene devices based on the standardized mean difference (SMD) of PPD scores sorted by ranking (the P-score of treatment) Note: For footnote see figure 2. For abbreviations see figure 2.

TABLE 4 Clinical relevance assessment

Study, Author (year)	Data entry		Standardized effect size									
	Outcome measure Comparison	Mean Difference	Confidence Interval for Difference		Effect Size (Cohen's d)	Bias corrected (Hedges)	Effect Size based on control group SD	Interpretation Effect Size	MID (0.2)	MID (0.5)	Final decision clinical relevance	
			lower	upper								
IX Kiger et al. (1991)	PI Floss-MTB	-0.02	-0.18	0.14	-0.07	-0.07	-0.07	SES	0.07	0.165	NCR	
IX Kiger et al. (1991)	PI IDB-MTB	-0.13	-0.27	0.01	-0.47	-0.47	-0.48	MES	0.066	0.165	PCR	
III Rösing et al. (2006)	PI IDBcon-Floss	-0.56	-0.65	-0.47	-2.36	-2.34	-2.07	LEF	0.0679	0.1698	CR	
III Rösing et al. (2006)	PI IDBcyl-Floss	-0.60	-0.69	-0.51	-2.75	-2.73	-2.22	LEF	0.052	0.1301	CR	
I Larsen et al. (2017)	PI IDBcon-IDBcyl	0.09	0.01	0.17	0.62	0.61	0.60	MES	0.0361	0.0902	PCR	
X Jolkovsky et al. (1990)	PI OI-MTB	-0.04	-0.29	0.21	-0.12	-0.12	-0.11	SES	0.0721	0.1803	NCR	
IX Kiger et al. (1991)	GI Floss-MTB	-0.01	-0.11	0.09	-0.05	-0.05	-0.05	SES	0.038	0.095	NCR	
IX Kiger et al. (1991)	GI IDB-MTB	-0.05	-0.16	0.06	-0.24	-0.24	-0.26	SES	0.038	0.095	PCR	
X Jolkovsky et al. (1990)	GI OI-MTB	0.02	-0.26	0.30	0.05	0.05	0.06	SES	0.0482	0.1204	NCR	
I Larsen et al. (2017)	BI IDBcon-IDBcyl	0.03	-0.01	0.07	0.40	0.39	0.43	MES	0.0221	0.0551	PCR	
II Bogren et al. (2008), Bogren et al. (2007)	BI PTB-MTB	-2	-6.56	2.56	-0.16	-0.16	-0.15	SES	3.9482	9.8705	NCR	
I Larsen et al. (2017)	PPD IDBcon-IDBcyl	-0.06	-0.21	0.09	-0.22	-0.22	-0.25	SES	0.0741	0.1852	NCR	
X Jolkovsky et al. (1990)	PPD OI-MTB	0.01	-0.26	0.28	0.03	0.03	0.03	SES	0.0712	0.1779	NCR	
II Bogren et al. (2008), Bogren et al. (2007)	PPD PTB_MTB	0	-0.16	0.16	0.00	0.00	0.00	SES	0.0847	0.2118	NCR	

Note: For abbreviations, see Table 2.

CR: clinically relevant; when both the calculated effect size (according to Cohen) is ≥ 0.40 and the mean difference between groups is higher than both MIDs (minimal important differences).

PCR: potentially clinically relevant; if ES is small/ moderate and one of the MIDs is accomplished.

NCR: not clinically relevant; if ES is small and one of the MID is accomplished or if both (ES and MID) are not accomplished or clinical criterion determines NCR.

MID: minimal important difference; a mean difference between groups that is higher than the MID can be considered as clinically relevant (Lemieux et al., 2007; Musselman, 2007).

SES: small effect size; $0.20 (0-0.39)$.

MES: medium effect size; $0.50 (0.4-0.79)$.

LEF: large effect size; ≥ 0.80 .

2006). The prediction interval as depicted in Figure 2 is an estimate of the interval in which a future observation will fall with a certain probability. The wide interval $[-2.93; 1.51]$, which also includes zero, underscores that given what has already been observed, there is much uncertainty about predictions where future observations are expected to fall. It is also uncertain whether these observations will be significantly different from those obtained with an MTB.

Figures 3–5 demonstrate the forest plots for the NMA related to the gingival index scores, BI scores, and PPD, respectively. Although not all studies on oral hygiene devices could be included in each of these plots, it is apparent that none of them demonstrate a significant effect over the effect of an MTB. The prediction interval as depicted in Figure 3 for the gingival index $[-2.58; 2.12]$ is narrower than for the PI (see Figure 2) but also contains zero, which indicates that future studies are likely to find no significant effect that is different from the effect from an MTB.

3.5 | Clinical significance assessment

Because of a lack of available baseline data, calculation of the clinical significance or relevance was only possible for six studies (I, Bogren et al., 2008; Bogren et al., 2007; Jolkovsky et al., 1990; Kiger et al., 1991; Rösing et al., 2006). Table 4 shows that of the six comparisons regarding PI, three on the gingival index were computed, while two were computed for bleeding tendency and three were computed regarding PPD. The final clinical relevance judgement was estimated to be potentially clinically relevant for four

comparisons from two studies (Kiger et al., 1991; Larsen et al., 2017). Two of these evaluated the IDB as adjunct MTB on PI and GI (Kiger et al., 1991) and the other two evaluated the cylindrical IDB as compared to a conical IDB in reducing PI and BI scores (Larsen et al., 2017). Only one study (Rösing et al., 2006) was estimated to provide clinically relevant data which included the comparisons of cylindrical and conical IDBs to floss. This study (Rösing et al., 2006) showed that as adjunct toothbrushing dental floss was less effective than an IDB.

3.6 | Grading the body of evidence

Table 5 depicts a summary of the various aspects that were used to rate the evidence and the strength of the recommendations according to the GRADE working group based on both the descriptive and network meta-analysis. The estimated risk of bias in the studies varied from low, unclear, to high. Reporting bias was considered to be possible, although the formal testing for publication bias as proposed by Egger, Davey Smith, Schneider, and Minder (1997) with a minimum of 10 comparisons on a comparison could not be performed. The data from the included studies that evaluated different toothbrushes indicate low certainty evidence for no additional effect of a PTB over an MTB. In addition, there was moderate certainty evidence for no additional effect of dental floss. There is low certainty for a very small effect of an OI while there was moderate certainty for a small effect of the IDB as adjunct to toothbrushing. Periodontal maintenance care patients can be recommended to either use a PTB

TABLE 5 Summary of Findings table based on the quality and body of evidence on the estimated evidence profile and appraisal of the strength of the recommendation regarding the efficacy of mechanical self-care during maintenance of periodontal care

	Power toothbrushes	Dental floss	Oral Irrigator	Interdental brushes
Study design (Table 2)	CCT/RCT	RCT	RCT	RCT
# experiments descriptive analysis (Table 3)	5	6	3	7
Risk of bias (online Appendix S1)	Unclear-high	Unclear	Unclear-high	Low-unclear
Consistency	Rather consistent	Rather consistent	Rather consistent	Rather consistent
Directness	Direct	Direct	Direct	Direct/indirect
Precision	Imprecise	Imprecise	Imprecise	Imprecise
Reporting bias	Possible	Possible	Possible	Possible
Magnitude of the effect (Figure 2–5)	No effect	No effect	Small in favour of	Small in favour of
Strength and direction of the recommendation	Low certainty evidence for no additional effect	Moderate certainty evidence for no additional effect	Low certainty evidence for a small additional effect	Moderate certainty evidence for a small additional effect
Overall recommendation	Periodontal maintenance patients can be advised to use either a power or manual toothbrush. For interdental cleaning, interdental brushes are the device of choice. As alternative, an oral irrigator may be considered.			

Abbreviation: CCT, controlled clinical trial; RCT, randomized controlled clinical trial.

or MTB. For interdental cleaning, IDBs are the device of choice. As alternative, an OI may be considered.

4 | DISCUSSION

Dental care professionals must make daily decisions about the clinical care and the recommendations that they provide for their patients. The significant variety of oral hygiene products makes it difficult to choose the most appropriate oral hygiene devices. To aid this decision process, the present review systematically searched for studies that evaluated the effect of mechanical oral hygiene devices in periodontal maintenance patients. For this review, only (randomized) controlled clinical trials were sought. The reason for this is that they are considered to provide the best available evidence from which the strongest inferences can be drawn. Especially in studies that involve oral hygiene products the risk of a novelty or Hawthorne effect is large. Consequently, we selected only studies that had a control group (van der Weijden, Danser, Nijboer, Timmerman, & Velden, 1993). Based on both the descriptive and network meta-analysis, the results for the clinical parameters of periodontal diseases indicate that the PTB does not differ from the MTB. In addition, dental floss has no adjunct effect to toothbrushing only, and the OI provides only a very small beneficial effect. With respect to the removal of dental plaque, IDBs are currently the most favourable interdental cleaning devices.

Managing gingivitis is a primary preventive strategy for periodontitis (Chapple et al., 2015). However, studies that have dealt with the role of oral hygiene in the treatment of periodontitis were not evaluated in the former two meta-reviews that were prepared for the 11th European Workshop on Periodontology (Sälzer, Slot, Van der Weijden, & Dörfer, 2015; Van der Weijden & Slot, 2015). The present review aimed for interventions for secondary prevention; that is to say patients with periodontitis that have been treated and who may have gingival inflammation in periodontal maintenance. The primary outcomes were changes in plaque levels, gingival inflammation, and bleeding on probing tendency. Gingival bleeding is an early sign of periodontal diseases and a leading risk marker for existing periodontal inflammation that accounts for the onset and progression of periodontitis (Tonetti, Greenwell, & Kornman, 2018; Tonetti & Sanz, 2019). Changes in PPD and CAL were considered as secondary outcomes.

4.1 | Network analysis

Network meta-analysis (NMA) is an extension of standard pairwise meta-analysis and combines direct and indirect comparisons between products (Ioannidis, 2009; Lu & Ades, 2004; Mills, Thorlund, & Ioannidis, 2013; Salanti et al., 2008) which can sometimes provide more precise estimates of treatment effects to support decision-making (Neupane, Richer, Bonner, Kibret, & Beyene, 2014). Therefore, NMA has been recommended as the highest level of evidence for treatment guidelines (John et al., 2017). The geometry of

the network in the present review demonstrates that not all treatments are represented equally that some (head to head) comparisons have been ignored, and that some comparators were preferred.

One appealing feature of a NMA is the rank ordering of interventions (Bafeta et al., 2014). For the present review, interventions were ranked against the MTB. The cylindrical and conical IDBs proved to be significantly more effective at plaque removal (see Figure 2) which was estimated to be clinically relevant (see Table 4). The OI ranked highest for the reduction of gingival inflammation. However, the difference from an MTB was not significant. Another specific issue in NMA is the importance of the transitivity assumption to validate the NMA (Escibano et al., 2016; Hutton et al., 2015; Rouse, Chaimani, & Li, 2017). It was assumed for the present NMA that periodontal maintenance patients represented a homogeneous study population in all included studies. Also that regular oral hygiene methods equalled an MTB, although this was not specified in the OI studies Newman et al. (1994) and Jolkovsky et al. (1990).

4.2 | Toothbrush

Based on the evidence from the systematic reviews, toothbrushing is effective in reducing levels of dental plaque (Van der Weijden & Slot, 2015). Toothbrushes vary in size; design; and the length, hardness, and arrangement of the bristles. Some manufacturers have claimed superiority in modifications such as bristle placement, length, and stiffness. The claims are primarily based on plaque removal. Other considerations for toothbrush recommendations include for instance ease of use by the patient and the perception that the brush works well. The search uncovered no studies that compared different types of MTBs. PTBs with various mechanical motions and features are available. These built-in motions allow the patient to concentrate on the right placement of the brush instead of worrying about the right brushing technique. PTBs are superior to MTBs in dealing with gingivitis (van der Weijden & Slot, 2015). The present review found no difference between MTBs and PTBs in studies that assessed the effect on PI and gingivitis scores in periodontal maintenance patients. This was evident from both the descriptive analysis as well as from the NMA. Although in periodontitis patients showing low compliance with oral hygiene, it has been shown that it can be worthwhile recommending a PTB (Hellstadius, Asman, & Gustafsson, 1993).

4.3 | Interdental cleaning devices

Based on consensus, interproximal cleaning is essential to maintain interproximal gingival health, in particular for secondary prevention (Chapple et al., 2015). The rationale for considering interdental cleaning as a separate item is based on how toothbrushing does not efficiently reach into the interdental areas between adjacent teeth, which results in parts of the teeth remaining unclean (Sälzer et al., 2015). Numerous interdental cleaning devices with different levels of efficacy are available. Since patients have different types of

interdental spaces, various suitable devices should be selected for each individual patient.

Several classical systematic reviews on interdental cleaning devices are published on floss (Berchier, Slot, Haps, & Weijden, 2008; Hujoel, Cunha-Cruz, Banting, & Loesche, 2006; Sambunjak et al., 2011), Woodsticks (Hoenderdos, Slot, Paraskevas, & Van der Weijden, 2008), IDBs (Poklepovic et al., 2013; Slot, Dörfer, & Weijden, 2008), OI Hussein, Slot, & Weijden, 2008). A recent published Bayesian network meta-analysis quantitatively evaluated interdental oral hygiene aids and provided a global ranking of their efficacy. IDB and OI ranked high for reducing gingival bleeding, whereas toothpicks and floss ranked last (Kotsakis et al., 2018). For selection of the included papers, the periodontal status was not taken into account. An even more recent traditional Cochrane systematic review concluded that using floss or IDB in addition to toothbrushing may reduce gingivitis or plaque, or both, more than toothbrushing alone. Interdental brushes may be more effective than floss (Worthington et al., 2019). The adjuvant use of an IDBs was proved to be significantly more effective in plaque removal than toothbrushing alone (see Figure 2).

4.4 | Floss

Dental floss is the most widely recommended tool for removing plaque from proximal tooth surfaces. However, many people find flossing difficult, technically demanding, and time-consuming (Kiger et al., 1991) and it might be difficult in areas with previous periodontal breakdown (Rösing et al., 2006). Dental care professionals should spend time to motivate and properly instruct the individual patient about flossing because its effectiveness is technique sensitive.

Three systematic reviews are published (Berchier et al., 2008; Hujoel et al., 2006; Sambunjak et al., 2011) specifically evaluating the effect of dental floss. According to a systematic review with meta-review, there is only weak evidence in favour of using dental floss in addition to toothbrushing to prevent gingivitis, and the magnitude of any effect is small. Most studies could not demonstrate that flossing was effective in plaque removal (Sälzer et al., 2015). Similarly, a recent systematic review with network meta-analysis also concluded that unsupervised flossing does not yield substantial reduction in gingival inflammation (Kotsakis et al., 2018). Also, this review found no adjuvant effect of flossing to toothbrushing in studies that assessed the effect on PI and GI in periodontal maintenance patients.

4.5 | Interdental brush

Concave surfaces in the central part of the interdental space and furcations that are present in periodontal patients who have experienced significant CAL and GR cannot be thoroughly cleaned with the toothbrush alone. These areas deserve special attention during daily oral hygiene and can be effectively reached by IDBs (Poklepovic et al., 2013; Slot et al., 2008). IDBs have been

demonstrated to remove plaque as far as 2–2.5 mm below the gingival margin (Waerhaug, 1976). Study participants have found the IDB to be easier to use than dental floss (Christou, Timmerman, Velden, & Weijden, 1998; Kiger et al., 1991).

The structure of IDBs differs in geometric shape: they could be cylindrical, conical or waist-shaped and vary with respect to the stiffness of filaments. Improper use or inappropriate size selection may result in dentin hypersensitivity and soft tissue damage (Bourgeois, Carrouel, Llodra, Bravo, & Viennot, 2015). According to a meta-review, there is moderate certainty evidence that IDBs can significantly reduce PI and gingival inflammation in gingivitis patients. Also, the present review has confirmed that IDBs are the most effective method to remove interdental plaque and consequently improve gingival health in patients in periodontal maintenance. The cylindrical IDB ranks highest in the NMA for effective plaque removal, directly followed by the conical shaped IDB. However, the supporting evidence from the NMA concerns an indirect comparison with the MTB.

4.6 | Oral Irrigator

There are also OI's for daily home use by patients. These work by directing a high-pressure stream of water that is either steady or pulsating through a nozzle to the tooth surface. Fluid flow may be either pulsed or continuous. An ex vivo scanning electron microscopic study has demonstrated that the hydraulic forces and pulsation of a dental water jet can remove the biofilm above or below the cemento–enamel junction (Gorur, Lyle, Schaudinn, & Costerton, 2009). OI can also be useful in delivering antimicrobial agents into periodontal pockets; however, no studies in this respect emerged from this search.

A meta-review has concluded that the OI improves gingival health more than toothbrushing alone but however does not concomitantly reduce visible plaque (Sälzer et al., 2015). The evidence from this review shows a tendency in the same direction. The forest plot of the NMA for BI scores and PPD shows 95% confidence intervals of [−0.71; 0.03] and [−0.67; 0.06] respectively which were nearly significant. The exact mechanisms of action for the abovementioned findings for OIs were unclear. In the included studies with periodontal maintenance patients, the NMA indicates an indirect effect on PI in favour of IDBs over the OI. However, when a similar comparison is made on gingivitis patients, a single use of the OI removed significantly more plaque than IDBs (Lyle, Goyal, Qaqish, & Schuller, 2016). This effect was not substantiated after two weeks of use (Goyal, Lyle, Qaqish, & Schuller, 2016). In one of the included studies (Jolkovsky et al., 1990), a nozzle on the OI was used that is specifically designed to direct the water stream sub-gingivally. Further research is needed to evaluate the benefit of this particular design.

4.7 | Clinical significance assessment

Statistical significance analysis only provides a dichotomous answer. It may or may not be statistically significant and does not offer an

indication of the importance of the study's result (Armijo-Olivo et al., 2011; Sterne & Smith, 2001). A result can be clinically relevant but might be neglected if statistical significance was not attained due to small sample sizes and high inter-subject variability. Clinical relevance or clinical significance assessment indicates whether the results are meaningful. In the absence of normative values for the outcomes of interest, other methods must be sought for assessing clinical relevance, such as the effect sizes (ES) (Cohen, 1992), minimal important difference (MID) (Guyatt et al., 2002; Lemieux et al., 2007), and clinically relevant judgement (Lemieux et al., 2007; Musselman, 2007). Assessing and reporting the clinical relevance of the outcome in addition to the analysis of statistical significance can help to simplify the transfer of knowledge from research into practice (Armijo-Olivo et al., 2011). The clinical significance assessment (Lemieux et al., 2007; Musselman et al., 2007) could be performed on the studies that provided baseline information (see Table 4). A mean difference between groups higher than the MID can be considered to be clinically relevant (Lemieux et al., 2007; Musselman et al., 2007). Only one study (Rösing et al., 2006) was considered to be clinically relevant and two (Kiger et al., 1991; Larsen et al., 2017) as potentially clinically relevant. All three studies involved IDBs.

4.8 | Limitations

This study is not exempt from limitations:

One problem with running studies on participants that have been treated for periodontitis is that it is ethically sensitive whether toothbrushes can be evaluated in the absence of interdental cleaning. This makes it difficult to single out the effect of toothbrushing alone. This also counts for evaluating the additional effect of interdental cleaning as the instruction of no interdental aid can be seen as unethical in the current standards of care.

In studies evaluating the IDB, only open interproximal areas large enough to receive the interdental brush were included as test sites. This implies that for patients who also have interdental spaces that do not allow access for an IDB, other interdental cleaning devices will be required.

For the workshop, the request was to search for studies with a minimum duration of six months. It was decided to deviate from this prerequisite because the focus of the current systematic review had plaque removal as primary outcome. The study follow-up subsequently does not require a minimum duration. For instance, single-use studies are also suitable for assessing plaque removal capability, and they facilitate the control of confounding variables such as patient compliance (Egelberg & Claffey, 1998). The studies included in this review that evaluated parameters of periodontitis (PPD and CAL) have all except one (Jolkovski et al., 1990) a minimum duration of 6 months.

The data that were available from the selected studies did not allow for a conventional meta-analysis in which two products are compared. For this review, the NMA was therefore the most

appropriate statistical method of analysis. Since with the NMA transitivity is an important aspect, the reader should realize that not all MTBs are equally effective (Slot, Wiggelinkhuizen, Rosema, & Weijden, 2012). The impact of this aspect on the outcome of the NMA could not be established.

Scarcity or a lack of evidence does not imply that products may not be effective. Dental care professionals in clinical practice should tailor the best oral hygiene devices and methods according to patients' skill levels and preferences because patient acceptance is crucial for sustained long-term use (Steenackers et al., 2001).

Considering the scarcity of evidence with respect to effective and optimal self-performed oral hygiene in periodontal patients in maintenance home care, recommendations must also be based on the knowledge that is available from studies of gingivitis patients.

This review relied on studies of toothbrushing and oral hygiene products some of which that are no longer available. Whether the data related to these products can be extrapolated to today's products is in question.

In a crossover trial, each participant serves as their own control. With this study design, between-patient variation is removed from the treatment comparison, which results in increased precision (Schwarzer, Carpenter, & Rücker, 2015). Because the results of crossover trials are generally similar to those of parallel-arm trials (Lathyris, Trikalinos, & Ioannidis, 2007), the results of the crossover trials included in this NMA were treated as parallel-arm trials. However, treatment-period interaction and the carry-over effects of crossover trials may jeopardize the validity of such simple inferences.

In our assessment of the overall risk of bias in the included studies, we did not include the domain of performance bias. All studies were at high risk of this aspect because it is not possible to blind study participants to the interventions of interest in an ethical experimental situation.

5 | CONCLUSION

Due to the scarcity of studies that met the inclusion criteria for each of the oral hygiene devices and the low certainty of the resultant evidence, no strong "evidence-based" conclusion can be drawn concerning any specific oral hygiene device for patient self-care in periodontal maintenance. Only for IDBs as adjuvant to toothbrushing a small but significant effect on PI was found although this emerges from indirect evidence. There appears to be an urgent need for studies evaluating self-care protocols in periodontal maintenance patients.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest. Van der Weijden, Slot, and their research team at ACTA have previously received either external advisor fees, lecturer fees, or research grants from toothbrush, dentifrice, and interdental devices manufacturers. Those manufacturers included: Braun AG, Colgate, Dentaïd, GABA, Lactona, Oral-B, Philips, Procter & Gamble, Sara Lee, TePe, Sunstar, Water Pik, and Unilever.

AUTHOR CONTRIBUTIONS

All authors gave final approval and agreed to be accountable for all aspects of work ensuring integrity and accuracy. DES contributed to conception and design, search and selection, analysis, interpretation, and drafted the manuscript. CV contributed to design, search and selection, statistics, analysis and interpretation, and critically revised the manuscript. GAW contributed to conception and design, search and selection, analysis and interpretation, and critically revised the manuscript.

ETHICS APPROVAL

Not applicable/not required.

ORCID

Dagmar E. Slot  <https://orcid.org/0000-0001-7234-0037>

Cees Valkenburg  <https://orcid.org/0000-0002-6656-6934>

G.A. (Fridus) Van der Weijden  <https://orcid.org/0000-0002-5075-8384>

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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