DE Slot
L Wiggelinkhuizen
NAM Rosema
GA Van der Weijden

The efficacy of manual toothbrushes following a brushing exercise: a systematic review

Authors' affiliations:
DE Slot, NAM Rosema, GA Van der Weijden, Department of Periodontology, Academic Centre for Dentistry Amsterdam (ACTA), Amsterdam, The Netherlands
L Wiggelinkhuizen, School of Dental Hygiene, Hogeschool Utrecht, University of Applied Sciences, Utrecht, The Netherlands

Correspondence to:
D.E. (Dagmar Else) 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
Tel.: +31 20 5980 179/307
E-mail: d.slot@acta.nl

Dates:
Accepted 4 April 2012

To cite this article:
Int J Dent Hygiene **10**, 2012; 187–197
DOI: 10.1111/j.1601-5037.2012.00557.x
Slot DE, Wiggelinkhuizen L, Rosema NAM, Van der Weijden GA. The efficacy of manual toothbrushes following a brushing exercise: a systematic review.

Abstract: *Aim:* To determine the efficacy of manual tooth brushing with respect to toothbrush design and brushing duration. *Material and Methods:* The PubMed–MEDLINE and Cochrane CENTRAL were searched through October 2010 to identify appropriate studies. The outcome measurement was dental plaque removal following subject brushing. *Results:* The search yielded 2119 titles and abstracts. Ultimately, 59 papers with 212 brushing exercises as separate legs of the experiments and meeting the eligibility criteria were selected. Overall, a brushing exercise provides a 42% (21) plaque score reduction (95% CI: 41.23; 42.03). Of the brushing studies providing data as assessed according to the Quigley and Hein plaque index, the weighted mean reduction from baseline in plaque scores was 30% (95% CI: 26.79; 33.21). A weighted mean plaque score reduction of 53% (95% CI: 49.51; 56.49) was observed in the experiments using the Navy plaque index. Subanalysis between the different bristle tuft configurations illustrated variation in plaque removal ability (24–61%). The angled bristle design numerically showed the highest mean plaque reduction with either index. A subanalysis of brushing duration revealed after 1 min, a mean reduction of 27% and after 2 min, 41%. *Conclusion:* The efficacy in plaque removal following a brushing exercise is a reduction from baseline plaque scores of 42% on average, with a variation of 30–53% dependent on the plaque index used. The available evidence indicates that bristle tuft arrangement (flat trim, multilevel, angled) and brushing duration are factors that contribute to the variation in observed efficacy.

[Correction added on 5 July 2012, after first online publication: In Table 1a, the overall effect of a brushing exercise was estimated at 50% (33) plaque score reduction (95% CI: 46.54; 55.40). This was corrected to 42% (21) plaque score reduction (95% CI 41.23; 42.03) in the abstract and throughout the manuscript]

Key words: brushing exercise; dental plaque; manual brushing; systematic review.

Introduction

During the 18th century, the bristle toothbrush came into use. Forerunners of today's brushes were developed in the 1930s. These nylon toothbrushes with plastic handles were easy to manufacture and therefore more affordable, making toothbrushing a common practice in Western society. Ever since, much imagination and inventiveness has been applied

to toothbrush design, and now there are numerous manual toothbrushes available on the market. There is, however, still insufficient evidence that one specific toothbrush design is superior to another.

Modern toothbrushes have bristle patterns designed to enhance plaque removal from hard-to-reach areas of the dentition, in particular from proximal areas. Designs are based on the premise that the majority of persons in any population use a simple horizontal brushing action. Over time, the design of the brush head has evolved, and multiple tufts of bristles, sometimes angled in different directions, are now used. Today, prospective users can readily find a toothbrush with a handle size appropriate to their hand size, and much emphasis has been placed on new ergonomic designs (1–3).

Since Löe *et al.* (4) published their 'experimental gingivitis in man', it has been demonstrated that the accumulation of bacterial plaque plays an essential role in the initiation and progress of periodontal disease. Based on a longitudinal study on the natural history of periodontitis in a dentally well-maintained male population (5), it was concluded by Lang *et al.* (6) that persistent gingivitis represents a risk factor for periodontal attachment loss and for tooth loss. Regular mechanical removal of bacterial plaque appears to be a prerequisite to prevent periodontal disease and maintain oral health (7, 8). Procedures for the control of supragingival plaque are as old as recorded history. Currently, the use of a toothbrush and fluoridated toothpaste in developed countries is almost universal (3).

The choice of brush is usually a matter of individual preference rather than a demonstrated superiority of any one type (9). The enthusiastic use of the toothbrush is, however, not synonymous with a high standard of oral hygiene. Adults, despite their apparent efforts, appear not to be as effective in their plaque removal as might be expected. Most individuals reduce plaque scores with approximately 50% during toothbrushing (1). A 1-min brushing exercise in participants adhering to their customary brushing method, but all using the same toothbrush, observed a plaque score reduction of approximately 39% (9). The results of the studies described above collectively indicate that most participants are not effective brushers and probably live with considerable amounts of plaque on their teeth, despite brushing at least once a day. What currently is lacking is a systematic review that, through the process of systematically locating, appraising and synthesizing evidence from individual trials, provides a reliable overview of toothbrushing efficacy.

Therefore, the aim of this study was to systematically collect the evidence concerning the efficacy of manual toothbrushing with respect to toothbrush design and brushing duration.

Material and methods

This systematic review was conducted in accordance with the guidelines of Transparent Reporting of Systematic Reviews and Meta-analyses (PRISMA statement) (10, 11).

Box 1: Search strategy developed for PubMed–MEDLINE which was customized for the COCHRANE CENTRAL database

<intervention AND outcome>

<(**Intervention:** [MeSH terms/all subheadings] Toothbrushing OR [text words] toothbrush OR toothbrushing OR toothbrush*)

AND

(**Outcome:** [MeSH terms/all subheadings] dental plaque OR dental plaque index OR dental deposits OR [text words] plaque OR plaque removal OR plaque index OR dental plaque OR dental deposit* OR dental deposits OR dental deposit)>

Focused question

What is the efficacy of a brushing exercise when comparing pre- and post-brushing plaque scores in adult participants using 'single-headed' manual toothbrushes with various bristle tuft configurations and different brushing durations?

Search strategy

Two Internet sources of evidence were used to search for appropriate papers fulfilling the study purpose: The National Library of Medicine, Washington, DC (PubMed–MEDLINE), and the Cochrane Central Register of Controlled Trials (CENTRAL). Both databases were searched for studies conducted in the period up to and including October 2010. The search was designed to be inclusive for any published paper that evaluated the effect on dental plaque in a brushing exercise in healthy adults. The databases were searched using the terms for the search strategy as presented in Box 1.

Screening and selection

The papers were screened independently by two reviewers (LW and NAMR). Only papers written in the English language were accepted. Case reports, abstracts, letters and narrative/historical reviews were not included. Initially, they were screened by title and abstract. If the search keywords were present in the title and/or the abstract, the paper was selected for full-text reading. If the relevant information on the eligibility criteria was not available in the abstract or if the title appeared relevant but the abstract was not available, the paper was also selected for full-text reading for eligibility screening. Then, full-text papers that fulfilled the eligibility criteria were identified for inclusion in this study. All reference lists of selected studies were handsearched for additional papers that might meet the study eligibility criteria. Any disagreement between the two reviewers was resolved after additional discussion. If a disagreement persisted, the judgment of a third reviewer (DES) was decisive.

Eligibility criteria

The following eligibility criteria were imposed:

- Randomized clinical trials (RCTs) or controlled clinical trials (CCTs)

- Participants:
  - Humans
  - In good general health (no systemic disorders or pregnancy)
  - ≥18 years of age
- Manual toothbrushes single-headed
- Brushing by the participants
- No concurrent usage of other oral hygiene aids like dental flossing and interdental brush
- Full mouth plaque scores
- Plaque indices of interest:
  - Quigley and Hein plaque index 1962 [Q&H] (12) or Turesky modification of the Quigley and Hein plaque index 1970 [TQ&H] (13) or Lobene modification of the Quigley and Hein plaque index 1982 [LQ&H] (14) or
  - Navy plaque index 1972 [Navy] (15) or Rustogi modified Navy plaque index 1992 [RMN] (16) or
  - Silness and Löe plaque index 1964 [S&L] (17)
- Pre- and post-brushing plaque scores of a brushing exercise and/or the (percentage) change in plaque scores
- No orthodontic appliances
- No removable or partial dentures.

Assessment of heterogeneity

Factors used to evaluate the heterogeneity of outcomes of different studies are as follows:

- Study protocol:
  - Study design
  - Plaque index
  - Participant entry criteria
  - Period of plaque accumulation before the brushing experiment
- Brushing regimen:
  - Toothbrush bristle configuration (brush trim)
  - Duration of brushing
  - Instruction/method of brushing

Quality assessment

The Cochrane Handbook tool for assessing the risk of bias judges various aspects of the study reports to estimate the potential risk of bias (18). The four domains that are scored are adequate sequence generation, allocation concealment, blinding, and incomplete outcome data addressed. Considering the study design that was eligible for this systematic review, the latter domain was not applicable. Allocation concealment is one aspect of bias protection shown to have a great impact on bias (19). Where a trial has unclear methods, for example for allocation concealment, it should be at best of moderate risk of bias. For the appraisal of study quality, allocation concealment was not considered as an item to estimate the risk of bias. Although the authors recognize that this is an important issue, they also are aware that reporting on allocation concealment in the dental literature has not been a critical item up until the recent past. Therefore, including this item in the quality assessment would result in an overestimation of the risk of bias. In addition, sequence generation, which indeed is critical, has in the past been most commonly reported just as being 'randomized'.

Therefore, three criteria were selected to estimate the potential risk of bias [Appendix S1 (20–75)]: (i) randomization, (ii) clearly defined inclusion criteria for recruitment and (iii) blinding to the examiner (blinding to the participant in a brushing study is not feasible). An aspect of the score list was given a 'yes' for an informative description of the item at issue for a study design that met the quality standard, a 'no' for an informative description and a study design that did not meet the quality standard and a '?' for missing or insufficient information. When random allocation, defined eligibility criteria and blinding of examiner were present, the study was classified as having a low risk of bias. If examiner blinding was missing, the study was considered to have a high potential risk of bias. If one of the other two criteria was missing, the potential risk of bias was considered moderate. If both of these were missing, the potential risk of bias was also considered to be high. Disagreement between the two reviewers was resolved after additional discussion. If a disagreement persisted, the judgment of a third reviewer (DES) was decisive.

Data extraction

From the papers that met the selection criteria, data were processed for analyses. Mean pre- and post-brushing plaque scores and standard deviations were, if possible, extracted with regard to the efficacy of a brushing exercise. This was done by the two independent reviewers (LW and NAMR). Some of the studies provided standard errors (SE) of the mean. Where possible, the authors calculated standard deviations based on the sample size ($SD = SE^{*}\sqrt{N}$).

Data analysis

Data are presented and ordered by plaque index. The modifications of original indices were categorized under the original index. If possible and where appropriate, the plaque scores were calculated by the authors of this review based on the data as provided by the individual selected studies. Based on pre- and post-brushing data, the percentage reduction from baseline in plaque scores was calculated for each individual experiment where needed. A weighted mean change in terms of percentage and the standard deviations of the weighted mean for the plaque score was calculated using the SPSS 16.0 statistical package (SPSS Inc., Chicago, IL, USA). To assign more weight to the studies that carry more information for this analysis, each experiment was assigned a weight by its sample size. It was determined *a priori* to perform subanalyses when a representative number of experiments were available (>10) by bristle tuft configuration (flat trim, multilevel and angled) and by brushing duration.

In addition, a meta-analysis was performed using mean scores and the standard deviations provided by the selected articles. A weighted mean difference (WMD) was calculated using a 'ran-

dom-effects' model for the difference between pre- and post-brushing using those experiments that provided sufficient data [Review Manager (RevMan) [Computer program], version 5.1, Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2011]. Assigning of weights to the studies in a 'random-effects' model is dependent on the variance that reflects the actual distribution of the true effects about their mean and on the sample size of that study. The studies within the forest plot are ordered by bristle configuration.

Results

Search and selection results

The PubMed–MEDLINE search yielded 2075 papers and the Cochrane CENTRAL search 911 papers, with 867 papers identical in the two searches. After extracting duplicate citations, 2119 papers remained to be screened. The screening of the titles and abstracts initially resulted in 120 articles selected for full-text reading. Of these, 61 papers had to be excluded because they did not fulfil the inclusion criteria of this study. An overview of this selection process and the reasons for exclusion after full-text reading are shown in Fig. 1. The most common reason for exclusion was the use of partial mouth scores, generally a split-mouth design. Appendix S2(a–i) shows the selected studies. Additional searching of reference lists of the selected studies resulted in one paper from the reference list (30) [Quigley & Hein (12)]. In various trials, more than one brush provided data on plaque removal efficacy. Finally, 59 papers with 212 brushing exercise experiments as separate legs were deemed suitable for this review.

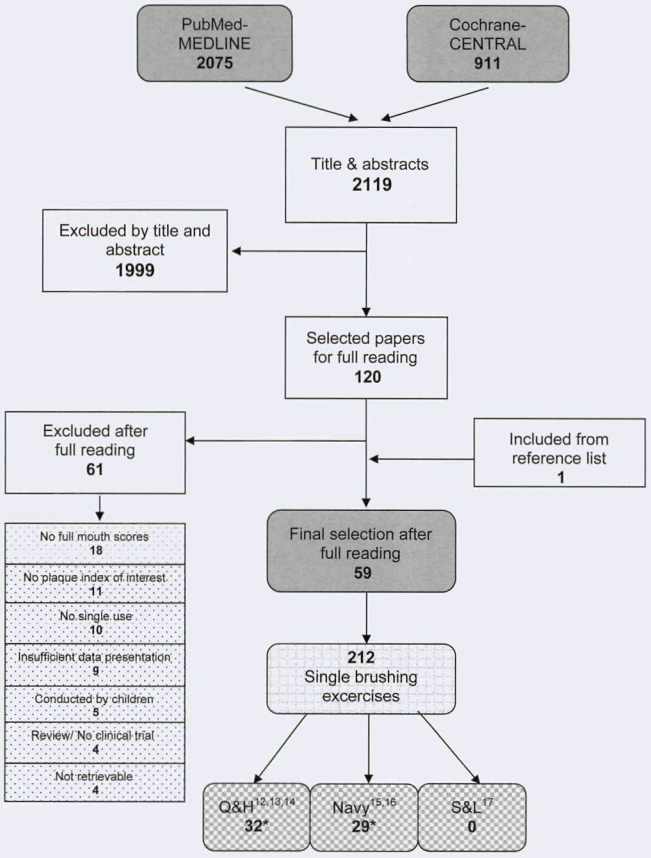

Fig. 1. Flowchart of search and selection results. Two studies have reported on plaque scores using both indices (32, 36).

Assessment of heterogeneity

After a preliminary evaluation of the selected papers, considerable heterogeneity was observed in study design, plaque indices used, participants' periodontal status, hours of plaque accumulation before the brushing experiment, type of toothbrush, brushing duration, and instruction and/or method of brushing. Appendix S2(a–i) shows an overview of these items in the selected studies.

Study design

Of the 59 selected brushing studies, 52 were randomized controlled trials (RCT) and seven were CCT. Forty-two of the RCTs had a crossover design, and four employed a parallel design. The design of the other six is not sufficiently described. Three CCTs utilized a parallel design (49, 56) and two a crossover design (16, 47). For the remaining two (9, 12), the study design was not clear.

Plaque indices

Of all 59 studies, three studies used the Q&H plaque index (12), 24 used the TQ&H plaque index (13) and five used the LQ&H (14). In 28 studies, the plaque scores were assessed with the RMN plaque index (16), and one study used the original Navy plaque index (15). The S&L plaque index (17) was not used in any of the experiments. Two studies used both the TQH plaque index and the RMN plaque index to assess brushing efficacy (Appendix S2a–i and Table 1) (30, 34).

Participant entry criteria

In 32 studies, the participants did not have periodontal disease or overt irritation or lesions of the hard or soft tissues of the mouth, while in one study, participants with mild gingivitis were enrolled. Thirty studies established entry criteria for the plaque index and/or gingival index, for example a minimum plaque index score, while 12 studies did not report anything concerning participant periodontal status (Appendix S2a–i).

Period of plaque accumulation before brushing experiment

In the majority of the studies (33), 23–25 h of plaque accumulation before the brushing exercise experiment was allowed. The other most common time of plaque accumulation was 12–18 h (17). Three studies allowed a plaque accumulation of 48 h (21, 55, 69). The other two brushing studies describe a plaque accumula-

Table 1. **Summary of the efficacy following brushing exercises ordered by plaque index and presented as a weighted mean percentage reduction in plaque index scores (standard deviations of the weighted mean in parentheses)**

(a) Total

Plaque index	No. of studies	No. of experiments	No. of participants	WM (SD)	95% CI*
Q&H (12–14)	32	121	5478	30% (18)	26.79; 33.21
Navy (15, 16)	29	91	5328	53% (17)	49.51; 56.49
S&L (17)	NA	NA	NA	NA	NA
Overall effect	59	212	10806	42% (21)	41.23; 42.03

(b) Subanalysis of brush head design

Plaque index	Bristle tuft configuration	No. of studies	No. of experiments	No. of participants	WM (SD)	95% CI*
Q&H (12–14)	Flat trim	23	74	3464	24% (11)	21.49; 26.51
	Multilevel	10	23	1020	33% (19)	25.23; 40.77
	Angled	7	11	599	39% (22)	26.00; 52.00
Navy (15, 16)	Flat trim	16	27	1764	47% (12)	42.47; 51.53
	Multilevel	19	33	2050	54% (15)	48.88; 59.12
	Angled	11	26	1489	61% (20)	53.31; 68.69

(c) Subanalysis of brushing duration

Plaque index	Minutes	No. of studies	No. of experiments	No. of participants	WM (SD)	95% CI*
Q&H (12–14)	1	20	83	4039	27% (17)	25.78; 26.80
	2	6	11	349	41% (13)	39.45; 42.26

NA, not applicable; WM, weighted mean; SD, standard deviation; Q&H, Quigley and Hein plaque index 1962 (12), Turesky modification of the Quigley and Hein plaque index 1970 (13), Lobene modification of the Quigley and Hein plaque index 1982 (14); Navy, Navy plaque index 1972 (15), Rustogi modified Navy plaque index 1992 (16); S&L, Silness and Löe plaque index 1964 (17); CI, confidence interval.
*As a measure of precision, the standard error of the weighted mean (which is a reflection of the variation among studies) was used relative to the number of experiments available to calculate the lower and upper limits of the 95% confidence interval of the weighted mean difference.

tion of 72 and 96 h. In four studies, the plaque accumulation period prior to the brushing exercise was not reported (64, 70, 73, 75).

Brushing regimen

Type of toothbrush (bristle tuft configuration)

The 59 studies included as separate legs 212 brushing exercise experiments. The majority of experiments (n = 100) used flat-trimmed toothbrushes. These were most often the Oral-B 35 toothbrush. A multilevel toothbrush was used in 57 experiments, while in 37 experiments, toothbrushes with an angled bristle tuft configuration were used, most frequently from Oral-B. In 18 experiments, the type of toothbrush was not specified or undeterminable, and these were classified as '?' or 'undeterminable' (Appendix S2a–i and Table 1).

Duration of brushing

The most common brushing time was 1 min in 150 experiments. Brushing time in other experiments varied between 15 s and 5 min. In five experiments, there was no time limit, but the brushing duration was based on individual habits. Eleven experiments did not mention anything about the time of brushing (Appendix S2a–i).

Instruction and/or method of brushing

In 39 studies, participants were allowed to brush according to their normal regimen without any instructions. In only four studies, brushing was supervised. Six studies used the (modified) Bass technique. In eight other studies, toothbrushing instructions were provided, but these were not specified. Six studies did not mention whether participants received any specific oral health instructions concerning the use of their toothbrushes (Appendix S2a–i).

Quality assessment

The estimated potential risk of bias of the selected papers is presented in Appendix S1. Based on a summary of these criteria, the risk of bias is considered low in 53 of the studies. The potential risk is considered moderate for three studies (16, 56) and high for three studies (12, 23, 47).

Outcome results

Appendix S2(a–i) presents the data extracts per study/experiment. The experiments are ordered by index and bristle type, and data are presented with respect to prebrushing, post-brushing and changes in plaque scores following brushing. Significant

changes are indicated in a separate column if a statistical analysis comparing pre- and post-brushing data was provided.

Table 1a provides the results of the weighted mean analyses. It summarizes the efficacy of a brushing exercise as percentage reduction from baseline in plaque scores as a weighted mean difference ordered by plaque index.

The overall treatment effect of a brushing exercise is estimated as a weighted mean 42% (21) (95% CI: 41.23; 42.03) plaque index score reduction from baseline (Table 1a). Of all studies that provided data with respect to the Q&H plaque index (12–14), the weighted mean plaque score reduction was 30% (95% CI: 26.79; 33.21). A subanalysis (Table 1b) of the different bristle configurations showed a variation of 24–39%. The angled bristle tuft toothbrush design numerically provided the highest mean plaque score reduction of 39%. The flat-trimmed toothbrushes scored the lowest mean plaque score reduction (24%).

In the experiments of the studies using the Navy plaque index (15, 16) scores of the overall treatment effect, a mean reduction of 53% (95% CI: 49.51; 56.49) was established. Subanalysis between the different bristle tuft configuration types also showed that there was variation in efficacy (47–61%). Again, the brushes with the angled bristle tuft configuration scored the highest mean plaque score reduction (61%).

In addition, subanalysis was also performed with respect to brushing duration (Table 1c). Only for studies that used the Quigley and Hein index (12–14) was there a sufficient number of experiments available to perform a subanalysis. This allowed for an estimate of efficacy after 1 and 2 min of brushing. The weighted mean plaque score reduction was 27% after 1 min and 41% after 2 min.

Available mean pre- and post-brushing scores and standard deviations allowed for a meta-analysis (MA) including 123 experiments to evaluate the efficacy of a brushing exercise. In total, 52 evaluated pre- and post-brushing plaque scores according to the Q&H plaque index and 71 by the Navy plaque index.

Table 2 shows a summary of the MA outcome, and detailed information regarding this meta-analysis can be found in the forest plots as presented in Appendix S3a,b. The efficacy of a toothbrushing exercise as assessed in weighted mean difference of the mean index scores was 0.86 [95% CI (0.57; 1.15)] for the Q&H plaque index (based on a scale of 0–5) and 0.30 [95% CI (0.27; 0.33)] for the Navy plaque index (based on a scale of 0–1)

Discussion

This review selected studies that evaluated the efficacy of a toothbrush by assessing pre- and post-brushing scores of a brushing exercise. In total, 212 brushing exercises as separate legs of experiments, including 10 806 participants, were used to calculate a weighted mean overall percentage plaque score reduction. The sheer magnitude of these numbers and the heterogeneity observed in the various study designs give the results particular value, because they reflect what may be generally expected from a routine oral hygiene exercise as encountered among patients in everyday practice. Heterogeneity in meta-analysis is a consequence of clinical or methodological diversity or both among studies and is to be expected. Statistical heterogeneity suggests that the studies are not all estimating the same quantity (18). Higgins (76) states that it would be surprising if multiple studies, performed by different teams in different places with different methods, all ended up estimating the same underlying parameter. The challenge is to decide on the most appropriate way to analyse heterogeneous studies. It may involve a random-effects meta-analysis that allows the study outcomes to vary in a normal distribution between studies. For this, a large data set is needed, which was the case in this review. Plaque score reductions as percentages are used in this review as the main outcome for the analysis. This approach involved a comprehensive assessment of efficacy as it allowed for a weighted mean analysis that was inclusive for many more studies than an approach based on mean plaque scores could have been. The results of this systematic review show that on average, approximately 42% (21) (95% CI: 41.23; 42.03) plaque score reduction is achieved following a brushing exercise (Table 1a). The results show that depending on the brush head configuration, a mean plaque score reduction of 24–61% can be expected (Table 1b).

Toothbrush manufacturers have taken great effort in considering many different aspects when designing new models to meet the challenge of enhancing plaque biofilm removal through improved toothbrushing efficacy. Few toothbrush manufacturers have also taken the effort to evaluate toothbrush efficacy. Product design changes can yield genuinely improved performance characteristics (63). A major shortcoming of conventional flat-trim toothbrushes has been a 'blocking effect' of tight bristle tufts, preventing individual tufts from reaching interproximal areas. Multilevel toothbrushes have been developed with alternating rows of tall and shorter bristle

Table 2. **Weighted mean difference and 95% confidence interval for those studies that provided a mean pre- and post-brushing plaque score analysed by plaque index using a 'random-effects' model**

			Test for overal effect		Test for heterogeneity	
Index	No. of experiments	WMD (random)	95% CI	*P*-value	*P*-value	I^2 (%)
Q&H (12–14)	52	0.86	0.57; 1.15	<0.00001	<0.00001	99
NAVY (15, 16)	71	0.30	0.27; 0.33	<0.00001	<0.00001	99

WMD, weighted mean difference; CI, confidence interval.

tufts acting independently, uninfluenced by adjacent bristles during brushing. Once independent motion is achieved, the longer bristles can effectively reach farther between the teeth (77). The results of the present review (Table 1) indicate that depending on the plaque index used, a 7% [Navy index (15)] to 9% [Q&H index (12)] improvement in efficacy can be achieved with a multilevel bristle tuft configuration as compared to the traditional flat trim.

The most recent development of angled rather than vertical bristle tuft arrangements appears to have made a significant contribution with respect to approximal plaque removal. Clinical studies have consistently demonstrated that a brush with an angled bristle tuft configuration is significantly more effective (8, 43, 78). Results (Table 1) show that depending on plaque index used, a 12% [Q&H index (12)] to 15% [Navy index (15)] improvement in efficacy can be achieved with this particular bristle tuft configuration as compared to a flat-trimmed design. This angulation appears to be an efficient novelty of brush head design, which is substantiated based on the results of the present review (79).

One classical study that particularly looked at the remaining plaque score was the study of Axelsson *et al.* (8), which reported on the 30-year outcome of preventive dental treatment in a group of carefully monitored participants. These participants were encouraged on a regular basis, but also enjoyed and recognized the benefit of maintaining a high standard of oral hygiene. The incidence of caries and periodontal disease as well as tooth mortality in this participant sample was very small. The overall plaque scores in this population were low (<20%), although it cannot be assumed that this was done by mechanical plaque removal by participants and the outcomes are probably confounded by several other factors. Morris *et al.* (80) reported on the 1998 UK Adult Dental Health survey and observed that the mean proportion of teeth with plaque deposits ranged from 30% to 44% after brushing. Although individual plaque levels vary widely, they seem to be fairly consistent over time with low variation (81).

One other interesting aspect from this analysis is that the estimated magnitude of the effect size of toothbrushing appears to be dependent on the plaque index score used to assess the magnitude of the effect (Tables 1a and 2). The measurement quality at issue here is the ability to detect change where change really exists. This 'responsiveness' is partly a function of ease of use and interexamination reliability. Differences between the two indices probably reflect these factors as well as the sensitivity and precision of the index to differences in plaque scores that are influenced by toothbrushes. The Navy plaque index (15) and the Q&H plaque index (12) and their modifications are the two indices most commonly used for assessing plaque removal efficacy with a toothbrush. Although these indices score plaque in different ways, there appears to be a strong correlation between them (30, 34). The Q&H plaque index (12) emphasizes the differences in plaque accumulation in the gingival third of the tooth and tends to overscore the incisal half of the crown, at the expense of the gingival margin. The Navy plaque index (15) gives greater weight to plaque in the immediate gingival area (82).

The scores with both indices are descriptive. They do not represent a strictly linear scale but are ascending in severity. Score 0 is given when no plaque is found. Higher scores are assigned in ascending order corresponding roughly to increasing areas of tooth surfaces covered by plaque (83). Because plaque is colourless, it is usually visualized by staining prior to scoring. Plaque is then defined, in an operational sense, as 'stainable material' (84). For each index, various components are selected which most accurately reflect that portion of the soft accumulations which can be clinically related to the health of the periodontium (85). Ultimately, a reduction in plaque index scores should be followed by a reduction in gingival inflammation (16). This review does not allow the authors to draw any conclusion concerning the relevance or validation of a particular plaque index. As compared to the Q&H plaque index, the Navy Index (15) resulted in a larger difference between pre- and post-brushing scores (Table 1). Irrespective of the index used for assessing plaque scores [Q&H (12) and Navy (15)], it appears that there is room for improvement in the efficacy of manual toothbrushes in their capability of reducing plaque score during a brushing exercise.

Two studies used both these indices to assess the efficacy of their brushes under investigation. Table 3 shows the outcome of the studies relative to the plaque index. It is apparent that the Biesbrock *et al.*'s (30) study reflects what is also evident from the weighted mean results shown in Table 1, – a lower estimate of efficacy when assessing plaque according to the Q&H index (12). As an explanation, these authors state that the two different examiners for either index probably judged the amount of plaque to a different extent. This could be feasible, as the Cugini *et al.*'s (34) study used the same examiner for both indices and did not find a difference. However, it leaves the reviewers puzzled as to why, given that in the present review large numbers of participants were scored for both indices by various examiners, the estimate with the Q&H

Table 3. **The two studies that assessed the effect of a single brushing exercise with two different plaque indices**

Author	Brush	Q&H (12) (%)	Navy (15) (%)
Cugini *et al.* (34)	Oral-B cross action	56	57
	Colgate navigator	46	46
Biesbrock *et al.* (30)	Oral-B exceed	28	40
	Colgate 360°	24	37

Q&H, Quigley and Hein plaque index 1962 (12); Navy, Navy plaque index 1972 (15).

index (12) on average was well under the 50%. A comparison between the Q&H scores and the percentage of plaque covering the tooth surface area revealed that for each score of the Q&H index, the corresponding values for the plaque area were wide in range with significant crossover values. However, a strongly positive correlation was found between the Q&H score and the percentage of plaque area (81). In future studies, there clearly is a need to address the issue of whether the plaque index scores are true clinically relevant representative of the amount of plaque on the tooth surface.

Brushing exercise studies are commonly used for toothbrush evaluations (86). This model provides a useful indication of the plaque removal ability of a toothbrush and facilitates the control of confounding variables such as compliance (25). The approach is recommended for assessment under ideal conditions in which all participants comply with the use of the device to which they are randomly assigned (87). However, they do not replace the need for longer-duration studies where participants brush at home (88). Although data from brushing exercise studies can be regarded as providing limited information, a toothbrush that removes more plaque as assessed following a single-use brushing might be expected to offer improved plaque control over time and, as a result, have long-term benefits for gingival health (89, 90, 91). In fact, plaque removal results obtained in these studies have been shown in several cases to be in agreement with longer-term measures of plaque removal effectiveness and improvements in gingival health (22, 30, 33, 38).

Longer-duration studies will be more naturalistic as representative for a home-use evaluation.

Limitations of this review

- This systematic analysis does not incorporate data from manufacturers that chose not to publish full manuscripts but present data at scientific meetings. In the light of the many manufacturers that are producing toothbrushes worldwide, it is an impossible task to gather this information. If not all are contacted, a bias would be introduced. It was therefore decided *a priori* to restrict this review to published papers only.
- Another limitation may be the restriction to the English language. It is conceivable that authors are more likely to report in an international, English-language journal if results are positive, whereas negative findings are published in a local journal. While the potential impact of studies published in languages other than English in a meta-analysis may be minimal, it is difficult to predict in which cases this exclusion may bias a systematic review (20).
- In total, 32 studies reported that participants had no periodontitis. Of the remaining 27 studies, the periodontal status is not reported. It is known that more severe levels of periodontal disease do not respond well to manual brushing alone. In lack of this information, an unknown heterogeneity might have been introduced.
- Blinding of the examiners to the toothbrush is feasible; however, blinding to the timing of the examination (before or after) brushing deserves special attention. None of the studies have reported on this particular aspect.
- The efficacy of toothbrushing can be expressed as the plaque score or percentage of plaque covering the tooth surface. These two outcomes are different. One needs to distinguish between 'percentage points' as the absolute difference between the percentage of plaque covering the tooth surface pre- and post-brushing, and the 'percentage change' as the relative difference between the average pre- and post-brushing plaque scores. When discussing differences between outcomes, the weighted mean as calculated in this review is this relative change in plaque scores. One may question the construct validity of the plaque index scores. Do they actually measure the 'amount of plaque' on a tooth surface? On the other hand, experiments have revealed a relationship between the construct (plaque indices) and the disease (gingivitis) (2).
- In the weighted mean, all manual toothbrushes were included irrespective of whether they were flat, multilevel or angled. In a subanalysis, the weighted mean for each design has been separated. As not all of the selected studies had the different types of toothbrushes, this subanalysis is not suitable for a direct comparison but only allows for an indication of the numerical difference.

Conclusion

The efficacy of plaque removal following a brushing exercise is a reduction from baseline in plaque scores of 42% on average, with a range of 30–53% dependent on the plaque index used. The available evidence indicates that bristle tuft arrangement (flat trim, multilevel, angled) and brushing duration are factors that contribute to this variation in observed efficacy.

Clinical relevance

Scientific background

Toothbrushing is generally accepted as the most efficient oral hygiene method of cleaning one's teeth.

Rationale

What currently is lacking is a systematic review that, through the process of systematically locating, appraising and synthesizing evidence from individual trials, provides a reliable overview.

General findings

The overall treatment effect of a brushing exercise is estimated as a 42% reduction in plaque index scores from baseline. Depending on the plaque index score used, on average, plaque scores dropped 30–53%. Subanalysis of the efficacy in relation to brush head configurations and brushing duration shows a numerical advantage of multilevel and angled designs relative to flat trim.

Practical implications

Brushes with multilevel and angled brush head tuft configuration seem to have the potential to be more efficient than flat-trim toothbrushes. Also, if the brushing time is increased, the efficacy appears to be higher.

Acknowledgements

The authors would like to thank Shelly Campbell (Teneriffe Research Associates, Lee's Summit, MO) for her assistance in improving the English text. The authors also gratefully acknowledge the support of Joost Bouwman, head librarian of the ACTA, who helped retrieve the full-text papers. Without his help, this study would have been an almost impossible task.

Conflict of interest and source of funding

The authors declare that they have no conflicts of interest. This study was self-funded by the authors and their institutions.

References

1 Jepsen S. The role of manual toothbrushes in effective plaque control: advantages and limitations. In: Lang NP, Attström R, Löe H, eds. *Proceedings of the European Workshop on Mechanical Plaque Control.* London: Quintessence, 1998, pp. 121–137.

2 Löe H. *Half a Century of Plaque Removal. What's Next? Millennium Lecture EuroPerio 2000.* London: The Parthenon Publishing Group; 2000.

3 Van der Weijden GA, Hioe KP. A systematic review of the effectiveness of self-performed mechanical plaque removal in adults with gingivitis using a manual toothbrush. *J Clin Periodontol* 2005; **32(Suppl 6):** 214–228.

4 Löe H, Theilade E, Jensen SB. Experimental gingivitis in man. *J Periodontol* 1965; **36:** 177–187.

5 Schätzle M, Löe H, Lang NP, Bürgin W, Anerud A, Boysen H. The clinical course of chronic periodontitis. *J Clin Periodontol* 2004; **31:** 1122–1127.

6 Lang NP, Schätzle MA, Löe H. Gingivitis as a risk factor in periodontal disease. *J Clin Periodontol* 2009; **36(Suppl 10):** 3–8.

7 Axelsson P, Lindhe J. The effect of a preventive programme on dental plaque, gingivitis and caries in schoolchildren. Results after one and two years. *J Clin Periodontol* 1974; **1:** 126–138.

8 Axelsson P, Nyström B, Lindhe J. The long-term effect of a plaque control program on tooth mortality, caries and periodontal disease in adults. Results after 30 years of maintenance. *J Clin Periodontol* 2004; **31:** 749–757.

9 *Van der Weijden GA, Timmerman MF, Danser MM, Van der Velden U. Relationship between the plaque removal efficacy of a manual toothbrush and brushing force. *J Clin Periodontol* 1998; **25:** 413–416.

10 PRISMA statement, Preferred Reporting Items for Systematic Reviews and Meta-Analyses. http://www.prisma-statement.org/

11 Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *J Clin Epidemiol* 2009; **62:** 1006–1012.

12 *Quigley GA, Hein JW. Comparative cleansing efficacy of manual and power brushing. *J Am Dent Assoc* 1962; **65:** 26–29.

13 Turesky S, Gilmore ND, Glickman L. Reduced plaque formation by the chloromethyl analogue of victamin C. *J Periodontol* 1970; **41:** 41–43.

14 Lobene RR, Soparkar PM, Newman BS. Use of dental floss. Effect on plaque and gingivitis. *Clin Prev Dent* 1982; **4:** 5–8.

15 Elliott JR, Bowers GM, Clemmer BA, Rovelstad GH. III Evaluation of an oral physiotherapy center in the reduction of bacterial plaque and periodontal disease. *J Periodontol* 1972; **43:** 221–224.

16 *Rustogi KN, Curtis JP, Volpe AR, Kemp JH, McCool JJ, Korn LR. Refinement of the Modified Navy Plaque Index to increase plaque scoring efficiency in gumline and interproximal tooth areas. *J Clin Dent* 1992; **3(Suppl C):** C9–C12.

17 Silness J, Löe H. Periodontal disease in pregnancy. II. Correlation between oral hygiene and periodontal condition. *Acta Odontol Scand* 1964; **22:** 121–135.

18 Higgins JPT, Green S (eds). *Cochrane Handbook for Systematic Reviews of Interventions*, Version 5.0.2 [updated September 2009]. The Cochrane Collaboration, 2009. Available from http://www.cochrane-handbook.org.

19 Pildal J, Hróbjartsson A, Jørgensen KJ, Hilden J, Altman DG, Gøtzsche PC. Impact of allocation concealment on conclusions drawn from meta-analyses of randomized trials. *Int J Epidemiol* 2007; **36:** 847–857.

20 *Sharma NC, Qaqish J, Walters PA, Grender J, Biesbrock AR. A clinical evaluation of the plaque removal efficacy of five manual toothbrushes. *J Clin Dent* 2010; **21:** 8–12.

21 *Jayakumar A, Padmini H, Haritha A, Reddy KP. Role of dentifrice in plaque removal: a clinical trial. *Indian J Dent Res* 2010; **21:** 213–217.

22 *He T, Li S, Sun L. Clinical comparison of the plaque removal efficacy of a manual toothbrush with criss-cross bristle design. *Am J Dent* 2009; **22:** 200–202.

23 *Creeth JE, Gallagher A, Sowinski J *et al.* The effect of brushing time and dentifrice on dental plaque removal in vivo. *J Dent Hyg* 2009; **83:** 111–116.

24 *Terézhalmy GT, Walters P, Bartizek RD, Grender JM, Biesbrock AR. Replicate single-use comparative study of plaque removal with two contemporary manual toothbrushes. *Am J Dent* 2009; **22:** 189–192.

25 *Pizzo G, Licata ME, Pizzo I, D'Angelo M. Plaque removal efficacy of power and manual toothbrushes: a comparative study. *Clin Oral Investig* 2010; **14:** 375–381.

26 *Sowinski J, Petrone DM, Wachs GN *et al.* Efficacy of three toothbrushes on established gingivitis and plaque. *Am J Dent* 2008; **21:** 339–345.

27 *Terézhalmy GT, Bartizek RD, Biesbrock AR. Plaque-removal efficacy of four types of dental floss. *J Periodontol* 2008; **79:** 245–251.

28 *Ghassemi A, Vorwerk LM, Hooper WJ, Putt MS, Milleman KR. A four-week clinical study to evaluate and compare the effectiveness of a baking soda dentifrice and an antimicrobial dentifrice in reducing plaque. *J Clin Dent* 2008; **19:** 120–126.

29 *Putt MS, Milleman KR, Ghassemi A *et al.* Enhancement of plaque removal efficacy by tooth brushing with baking soda dentifrices: results of five clinical studies. *J Clin Dent* 2008; **19:** 111–119.

30 *Biesbrock AR, Bartizek RD, Walters PA. Improved plaque removal efficacy with a new manual toothbrush. *J Contemp Dent Pract* 2008; **9:** 1–8.

31 *Terézhalmy GT, Biesbrock AR, Walters PA, Grender JM, Bartizek RD. Clinical evaluation of brushing time and plaque removal

potential of two manual toothbrushes. *Int J Dent Hyg* 2008; **6:** 321–327.

32 *Hague AL, Carr MP. Efficacy of an automated flossing device in different regions of the mouth. *J Periodontol* 2007; **78:** 1529–1537.

33 *Warren P, Thompson M, Cugini M. Plaque removal efficacy of a novel manual toothbrush with MicroPulse bristles and an advanced split-head design. *J Clin Dent* 2007; **18:** 49–54.

34 *Cugini M, Thompson M, Warren PR. Correlations between two plaque indices in assessment of toothbrush effectiveness. *J Contemp Dent Pract* 2006; **7:** 1–9.

35 *Farrell S, Terézhalmy GT, Bartizek RD, Biesbrock AR. Comparative plaque removal efficacy of a dual-action power toothbrush and a manual tooth: effects by tooth type. *Am J Dent* 2006; **19:** 195–200.

36 *Sharma NC, Lyle DM, Qaqish JG, Galustians J. Evaluation of the plaque removal efficacy of three power toothbrushes. *J Int Acad Periodontol* 2006; **8:** 83–88.

37 *Harpenau L, Meyers G, Lyon C, Chambers D, Lundergan W. Blinded clinical evaluation of a new manual toothbrush. *J Clin Dent* 2006; **17:** 1–4.

38 *Terézhalmy GT, Bartizek RD, Biesbrock AR. Relative plaque removal of three toothbrushes in a nine-period crossover study. *J Periodontol* 2005; **76:** 2230–2235.

39 *Singh S, Rustogi KN, Chaknis P, Petrone ME, DeVizio W, Proskin HM. Comparative efficacy of a new battery-powered toothbrush and a commercially available manual toothbrush on the removal of established supragingival plaque: a single-use crossover study in adults. *J Clin Dent* 2005; **16:** 57–61.

40 *Goyal CR, Qaqish JG, Sharma NC, Warren PR, Cugini M, Thompson MC. Plaque removal efficacy of a novel tooth wipe. *J Clin Dent* 2005; **16:** 44–46.

41 *Terezhalmy GT, Bsoul SA, Bartizek RD, Biesbrock AR. Plaque removal efficacy of a prototype manual toothbrush versus an ADA reference manual toothbrush with and without dental floss. *J Contemp Dent Pract* 2005; **6:** 1–13.

42 *Biesbrock AR, Bartizek RD. Plaque removal efficacy of a prototype power toothbrush compared to a control manual toothbrush. *Am J Dent* 2005; **18:** 116–120.

43 *Sharma NC, Qaqish JG, Galustians HJ, Cugini M, Thompson MC, Warren PR. Plaque removal efficacy and safety of the next generation of manual toothbrush with angled bristle technology: results from three comparative clinical studies. *Am J Dent* 2005; **18:** 3–7.

44 *Nathoo S, Chaknis P, Petrone M, DeVizio W, Volpe AR. A clinical comparison of the gingivitis reduction and plaque-removal efficacy of a new manual toothbrush. *Compend Contin Educ Dent* 2004; **10(Suppl 2):** 37–45.

45 *Mankodi S, Wachs GN, Petrone DM *et al.* Comparison of the clinical efficacy of a new manual toothbrush on gingivitis reduction and plaque removal. *Compend Contin Educ Dent* 2004; **10(Suppl 2):** 28–36.

46 *Williams K, Ferrante A, Dockter K, Haun J, Biesbrock AR, Bartizek RD. One- and 3-minute plaque removal by a battery-powered versus a manual toothbrush. *J Periodontol* 2004; **75:** 1107–1113.

47 *Schäfer F, Nicholson JA, Gerritsen N, Wright RL, Gillam DG, Hall C. The effect of oral care feed-back devices on plaque removal and attitudes towards oral care. *Int Dent J* 2003; **6(Suppl 1):** 404–408.

48 *Williams K, Haun J, Dockter K, Ferrante A, Bartizek RD, Biesbrock AR. Plaque removal efficacy of a prototype power toothbrush compared to a positive control manual toothbrush. *Am J Dent* 2003; **16:** 223–227.

49 *Lazarescu D, Boccaneala S, Illiescu A, De Boever JA. Efficacy of plaque removal and learning effect of a powered and a manual toothbrush. *J Clin Periodontol* 2003; **30:** 726–731.

50 *Nathoo S, Wachs GN, Petrone DM *et al.* Comparison of plaque removal efficacy of a battery-powered toothbrush and a manual toothbrush: a single-use clinical study in New Jersey. *J Clin Dent* 2003; **14:** 34–37.

51 *Haun J, Williams K, Friesen L *et al.* Plaque removal efficacy of a new experimental battery-powered toothbrush relative to two advanced-design manual toothbrushes. *J Clin Dent* 2002; **13:** 191–197.

52 *Moritis K, Delaurenti M, Johnson MR, Berg J, Boghosian AA. Comparison of the Sonicare Elite and a manual toothbrush in the evaluation of plaque reduction. *Am J Dent* 2002; **15:** 23B–25B.

53 *Bartizek RD, Biesbrock AR. Dental plaque removal efficacy of a battery-powered toothbrush vs. a control Japanese manual toothbrush. *Am J Dent* 2002; **15:** 33A–36A.

54 *Heins P, Bartizek RD, Walters PA, Biesbrock AR. Plaque removal efficacy of a battery-operated power toothbrush compared to two control manual toothbrushes in single use studies. *Am J Dent* 2002; **15:** 28A–32A.

55 *Dörfer CE, von Bethlenfalvy ER, Staehle HJ, Pioch T. Comparison of the safety and efficacy of an oscillating/rotating battery-powered toothbrush and a standard manual toothbrush. *Am J Dent* 2001; **14:** 25B–28B.

56 *Bustillo E, Cartwright S, Battista GW *et al.* Effectiveness of a battery-powered toothbrush on plaque removal: comparison with four manual toothbrushes. *Compend Contin Educ Dent Suppl* 2000; **31:** S25–9.

57 *Nathoo S, Rustogi KN, Petrone ME *et al.* Comparative efficacy of the Colgate Actibrush battery-powered toothbrush vs Oral-B CrossAction toothbrush on established plaque and gingivitis: a 6-week clinical study. *Compend Contin Educ Dent Suppl* 2000; (31): S19–24.

58 *Sharma NC, Qaqish JG, Galustians HJ *et al.* An advanced toothbrush with improved plaque removal efficacy. *Am J Dent* 2000; **13:** 15A–19A.

59 *Ruhlman CD, Bartizek RD, Biesbrock AR. Plaque removal efficacy of a battery-operated toothbrush compared to a manual toothbrush. *Am J Dent* 2001; **14:** 191–194.

60 *Singh SM, Battista GW, Rustogi KN *et al.* The comparative plaque removal efficacy of two advanced manual toothbrush designs in two independent clinical studies. *J Clin Dent* 2001; **12:** 83–86.

61 *Renton-Harper P, Addy M, Newcombe RG. Plaque removal with the uninstructed use of electric toothbrushes: comparison with a manual brush and toothpaste slurry. *J Clin Periodontol* 2001; **28:** 325–330.

62 *Heasman PA, Stacey F, Heasman L, Sellers P, Macgregor ID, Kelly PJ. A comparative study of the Philips HP 735, Braun/Oral B D7 and the Oral B 35 Advantage toothbrushes. *J Clin Periodontol* 1999; **26:** 85–90.

63 *McDaniel TF, Miller DL, Jones RM, Davis MS, Russell CM. Effects of toothbrush design and brushing proficiency on plaque removal. *Compend Contin Educ Dent* 1997; **18:** 572–577.

64 *Claydon N, Addy M. The use of planimetry to record and score the modified Navy index and other area-based plaque indices. A comparative toothbrush study. *J Clin Periodontol* 1995; **22:** 670–673.

65 *Yankell SL, Emling RC. A comparative clinical evaluation of the wisdom straight, plaque control and angled toothbrushes compared to the Oral-B 35. *J Clin Dent* 1995; **6:** 202–206.
66 *Balanyk TE, Sharma NC, Galustians J. A clinical study of comparative plaque removal performance of two manual toothbrushes. *J Clin Dent* 1993; **4(Suppl D):** D8–D12.
67 *Deasy MJ, Singh SM, Kemp JH, Curtis JP, Rustogi KN, Fung K. A clinical comparison of plaque removal performance of three manual toothbrushes. *J Clin Dent* 1993; **4(Suppl D):** D17–D21.
68 *Singh SM, Deasy MJ. Clinical plaque removal performance of two manual toothbrushes. *J Clin Dent* 1993; **4(Suppl D):** D13–D16.
69 *Reardon RC, Cronin M, Balbo F *et al.* Four clinical studies comparing the efficacy of flat-trim and multi-level trim commercial toothbrushes. *J Clin Dent* 1993; **4:** 101–105.
70 *Khocht A, Spindel L, Person P. A comparative clinical study of the safety and efficacy of three toothbrushes. *J Periodontol* 1992; **63:** 603–610.
71 *Singh SM, Rustogi KN, McCool JJ *et al.* Clinical studies regarding the plaque removal efficacy of manual toothbrushes. *J Clin Dent* 1992; **3(Suppl C):** C21–28.
72 *Sharma NC, Galustians J, Rustogi KN *et al.* Comparative plaque removal efficacy of three toothbrushes in two independent clinical studies. *J Clin Dent* 1992; **3(Suppl C):** C13–20.
73 *Finkelstein P, Grossman E. The clinical quantitative assessment of the mechanical cleaning efficiency of toothbrushes. *Clin Prev Dent* 1984; **6:** 7–12.
74 *Yankell SL, Green PA, Greco PM, Stoller NH, Miller MF. Test procedures and scoring criteria to evaluate toothbrush effectiveness. *Clin Prev Dent* 1984; **6:** 3–8.
75 *Barnes GP, Radi WR, Katz RV. Clinical effects on varying the numbers and distribution patterns of toothbrush bristle tufts on plaque removal. *J Prev Dent* 1976; **3:** 12–16.
76 Higgins JP. Commentary: Heterogeneity in meta-analysis should be expected and appropriately quantified. *Int J Epidemiol* 2008; **37:** 1158–1160.
77 Mintel TE, Crawford J. The search for a superior toothbrush design technology. *J Clin Dent* 1992; **3(Suppl C):** C1–C4.
78 Beals D, Ngo T, Feng Y, Cook D, Grau DG, Weber DA. Development and laboratory evaluation of a new toothbrush with a novel brush head design. *Am J Dent* 2000; **13:** 5A–14A.
79 Cronin MJ, Dembling WZ, Jacobs DM, Low MA, Warren PR. A comparative single-use clinical study of the efficacy of two manual toothbrushes with angled bristles. *Am J Dent* 2001; **14:** 263–266.
80 Morris AJ, Steele J, White DA. The oral cleanliness and periodontal health of UK adults in 1998. *Br Dent J* 2001; **191:** 186–192.
81 Söder B, Jin LJ, Söder P-Ö. A longitudinal investigation of the individual consistency of plaque levels in adults. *Acta Odontol Scand* 1995; **53:** 72–74.
82 Fischman SL. Clinical index systems used to assess the efficacy of mouthrinses on plaque and gingivitis. *J Clin Periodontol* 1988; **15:** 506–510.
83 Marthaler TM. Discussion: current status of indices of plaque. *J Clin Periodontol* 1986; **13:** 379–380.
84 Fischman SL. Current status of indices of plaque. *J Clin Periodontol* 1986; **13:** 371–374, 379–380.
85 Stallard RE. Formal and informal discussion. *J Periodontal Res Suppl* 1974; **14:** 24–30.
86 Van der Weijden GA, Timmerman MF. A systematic review on the clinical efficacy of subgingival debridement in the treatment of chronic periodontitis. *J Clin Periodontol* 2002; **29(Suppl 3):** 55–71.
87 Schaeken MJM, Sturm D, Master A, Jenkins W, Schmitt P. A randomized, single-use study to compare plaque removal ability of sonicare flexcare and oral-B Triumph professional care 9000. *Compend Contin Educ Dent* 2007; **28(Suppl 1):** 29–34.
88 *Williams K, Rapley K, Huan J *et al.* A study comparison the plaque removal efficacy of an advanced rotation – oscillation power toothbrush to a new sonic toothbrush. *J Clin Dent* 2008; **19:** 154–158.
89 Claydon N, Addy M. Comparison single-use plaque removal by toothbrushes of different designs. *J Clin Periodontol* 1996; **23:** 1112–1116.
90 Sharma NC, Goyal CR, Qaqish JG, Cugini MA, Thompson MC, Warren PR. Single-use plaque removal efficacy of three power toothbrushes. *J Dent* 2005; **33(Suppl 1):** 11–15.
91 *Sharma NC, Qaqish JG, Galustians HJ *et al.* Plaque removal efficacy of two electric toothbrushes with different brush head designs. *J Dent* 2005; **33(Suppl 1):** 17–21.

Supporting information

Additional supporting information may be found in the online version of this article.

Appendix S1. Quality assessment of the selected studies.

Appendix S2. Overview of Selected Studies and Parameters of Interest. Values are expressed as means with standard deviations in parentheses.

Appendix S3. Forrest plot of the meta-analysis of those studies that provided mean pre and brushing data ordered by bristle tuft configuration: (a) Quigley & Hein Plaque index (12–14); (b) Navy plaque index (15, 16).

Please note: Wiley-Blackwell is not responsible for the content or functionality of any supporting information supplied by the authors. Any queries (other than missing material) should be directed to the corresponding author for the article.

*Studies included from the search for this systematic review.