Manual versus powered toothbrushing for oral health (Review)

Robinson P, Deacon SA, Deery C, Heanue M, Walmsley AD, Worthington HV, Glenny AM, Shaw BC

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[Intervention Review]

Manual versus powered toothbrushing for oral health

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ABSTRACT

Background

Removing dental plaque may play a key role maintaining oral health. There is conflicting evidence for the relative merits of manual and powered toothbrushing in achieving this.

Objectives

To compare manual and powered toothbrushes in relation to the removal of plaque, the health of the gingivae, staining and calculus, dependability, adverse effects and cost.

Search strategy

We searched the Cochrane Oral Health Group Trials Register (to July 2004) and CENTRAL (*The Cochrane Library* 2004, Issue 2); MEDLINE (January 1966 to week 2 June 2004); EMBASE (January 1980 to week 2 2004) and CINAHL (January 1982 to week 2 June 2004). Manufacturers were contacted for additional data.

Selection criteria

Trials were selected for the following criteria: design-random allocation of participants; participants - general public with uncompromised manual dexterity; intervention - unsupervised manual and powered toothbrushing for at least 4 weeks. Primary outcomes were the change in plaque and gingivitis over that period.

Data collection and analysis

Six authors independently extracted information. The effect measure for each meta-analysis was the standardised mean difference (SMD) with 95% confidence intervals (CI) using random-effects models. Potential sources of heterogeneity were examined, along with sensitivity analyses for quality and publication bias. For discussion purposes SMD was translated into percentage change.

Main results

Forty-two trials, involving 3855 participants, provided data.

Brushes with a rotation oscillation action removed plaque and reduced gingivitis more effectively than manual brushes in the short term and reduced gingivitis scores in studies over 3 months. For plaque at 1 to 3 months the SMD was -0.43 (95% CI: -0.72 to -0.14), for gingivitis SMD -0.62 (95% CI: -0.90 to -0.34) representing an 11% difference on the Quigley Hein plaque index and a 6% reduction on the Löe and Silness gingival index. At over 3 months the SMD for plaque was -1.29 (95% CI: -2.67 to 0.08) and for gingivitis was -0.51 (-0.76 to -0.25) representing a 17% reduction on the Ainamo Bay bleeding on probing index. There was heterogeneity between the trials for the short-term follow up. Sensitivity analyses revealed the results to be robust when selecting trials of high quality. There was no evidence of any publication bias.

No other powered designs were as consistently superior to manual toothbrushes.

Cost, reliability and side effects were inconsistently reported. Any reported side effects were localised and temporary.

Authors' conclusions

Powered toothbrushes with a rotation oscillation action reduce plaque and gingivitis more than manual toothbrushing.

Observation of methodological guidelines and greater standardisation of design would benefit both future trials and meta-analyses.

PLAIN LANGUAGE SUMMARY

Manual versus powered toothbrushing for oral health

When compared to manual toothbrushes, powered toothbrushes with a rotation oscillation action provide protection against gum inflammation in the long and short term and better plaque removal in the short term.

Removing dental plaque by toothbrushing helps prevent gum inflammation (gingivitis). Toothbrushing with a fluoride toothpaste prevents tooth decay.

Powered toothbrushes simulate manual toothbrushing in different ways (such as moving side to side or circular motions). The review of trials found that only rotation oscillation (where brush heads rotate in one direction and then the other) is better than manual toothbrushes at removing plaque and reducing gum inflammation, and is no more likely to cause injuries to gums. Long- term benefits of this for dental health are unclear.

BACKGROUND

Good oral hygiene (the removal of plaque) by effective toothbrushing has a key role in oral health. Dental plaque is the primary cause of gingivitis (gum inflammation) and is implicated in the progression to periodontitis (loss of periodontal attachment around the teeth) although the link between the two is complex and not well understood (Page 1997).

Plaque is also one of the main causal factors in dental caries, although the evidence of a relationship between oral cleanliness and caries is not clear-cut (Addy 1986; Richardson 1977). When teeth are brushed with a fluoride toothpaste ample evidence of a caries preventative effect is available, but this is due more to the effect of fluoride than brushing per se (Chesters 1992).

Effective toothbrushing depends on a number of factors including motivation, knowledge and manual dexterity.

Powered brushes simulate the manual motion of toothbrushes with lateral and rotary movements of the brush head. More recently, there has been a progression towards rotary action brushes (van der Weijden1993a). Brushes which operate at a higher frequency of

vibration have also been introduced (Johnson 1994; Terezhalmy 1995b).

Powered toothbrushes were first introduced commercially in the early 1960s (Chilton 1962a; Cross 1962; Elliot 1963; Hoover 1962) and have become established as an alternative to manual methods of toothbrushing. In the UK the volume of sales of powered toothbrushes has nearly doubled each year between 1999 and 2001, increasing from 2% of total sales of all toothbrushes in 1999 to 7% in 2001 (Personal communication, R Davies 2002).

One study has shown that 36 months after purchase, 62% of people were using their electric toothbrushes on a daily basis (Stålnacke 1995). The compliance level was high and was unrelated to any social factors of the population studied.

As the powered toothbrush is so popular the common question raised is which is better, the powered or manual?

OBJECTIVES

To compare manual and powered toothbrushes in everyday use, by people of any age, in relation to:

(1) removal of plaque;

(2) inflammation of the gingivae;

(3) removal of staining and calculus;

(4) dependability and cost;

(5) adverse effects.

METHODS

Criteria for considering studies for this review

Types of studies

The review is confined to randomised controlled trials comparing manual and powered toothbrushes. It excludes trials confined to comparisons between different kinds of powered brushes or those comparing different kinds of manual brushes.
Cross-over trials were eligible. Split-mouth trials were excluded, as these were not considered representative of 'everyday use'.

Types of participants

Individuals of any age with no reported disability that might affect toothbrushing were included. Individuals wearing orthodontic appliances were also included.

Types of interventions

The toothbrushes included in the review were all forms of manual brushes and all forms of powered brushes. Trials instituting combined interventions, e.g. brushing combined with the use of mouthrinses or irrigation, were excluded. However, trials where participants were permitted to continue with their usual adjuncts to oral hygiene, such as flossing, were included.
Trials were excluded where the brushing intervention was carried out or was supervised by a professional within 28 days prior to a follow-up assessment.
Trials of 28 days and over were eligible and a subgroup analysis was carried out on the duration of trials for the different outcome measurements.
Powered toothbrushes were divided into seven groups according to their mode of action.
Side to side action, indicates a brush head action that moves laterally side to side.
Counter oscillation, indicates a brush action in which adjacent tufts of bristles (usually 6 to 10 in number) rotate in one direction and then the other, independently. Each tuft rotating in the opposite direction to that adjacent to it.
Rotation oscillation, indicates a brush action in which the brush head rotates in one direction and then the other.
Circular, indicates a brush action in which the brush head rotates in one direction.
Ultrasonic, indicates a brush action where the bristles vibrate at ultrasonic frequencies (> 20 kHz).
Ionic, indicates a brush that aims to impart an electrical charge to the tooth surface with the intent of disrupting the attachment of dental plaque.
Unknown, indicates a brush action that the authors have been unable to establish based on the trial report or confirm with the manufacturers.
It was agreed that analysis of filament arrangement, orientation, size, shape and flexibility, brush head size and shape along with presence or absence and characteristics of a timer would prove difficult to define across time and brush types.

Types of outcome measures

The primary outcome measures employed were quantified levels of plaque and/or gingivitis. Where possible values recorded on arrival at the assessment were used. If necessary, measures of gingivitis taken after participants had been instructed or permitted to brush their teeth at the assessment visit were used as it was assumed that toothbrushing would not affect gingivitis within such a short period. However, measures of plaque taken after participants had been instructed or permitted to brush their teeth at the assessment visit were not used. It was assumed that plaque scores achieved during toothbrushing under these circumstances would not reflect scores achieved in normal home use.

Secondary outcome measures sought were levels of calculus and staining; dependability and cost of the brush used, including mechanical deterioration; and adverse effects such as hard or soft tissue injury and damage to orthodontic appliances and prostheses.

Search methods for identification of studies

The search attempted to identify all relevant randomised controlled trials (RCTs) irrespective of language.
For the original review we searched the following databases.

- The Cochrane Oral Health Group Trials Register (to 22 August 2002)
- The Cochrane Central Register of Controlled Trials (CENTRAL) (*The Cochrane Library* 2002, Issue 3)
- MEDLINE (1966 to week 5 2002)
- EMBASE (1980 to week 3 July 2002)
- CINAHL (1982 to June 2002).

An update search was undertaken on these databases as follows:

- The Cochrane Oral Health Group Trials Register (to 17 July 2004)
- The Cochrane Central Register of Controlled Trials (CENTRAL) (*The Cochrane Library* 2004, Issue 2)
- MEDLINE (1966 to week 2 June 2004)
- EMBASE (1980 to week 2 2004)
- CINAHL (1982 to week 2 June 2004).

For the identification of trials included in, or considered for this review, detailed search strategies were developed for each database. These were based on the search strategy developed for MEDLINE but revised appropriately for each database to take account of differences in controlled vocabulary and syntax rules.
The MEDLINE search strategy combined the subject search with phases one and two of the Cochrane Sensitive Search Strategy for RCTs (as published in Appendix 5b in the *Cochrane Reviewers' Handbook*). The subject search used a combination of controlled vocabulary and free text terms and is published in full in Appendix 1. Details of search strategies applied to other databases are presented in Appendix 2; Appendix 3; Appendix 4 and Appendix 5.
The following journals were identified as sources of frequently cited articles in the electronic search:
Journal of Clinical Dentistry (9 citations); *American Journal of Orthodontics and Dentofacial Orthopedics* (8 citations); *American Journal of Dentistry* (8 citations); *Journal of Clinical Periodontology* (20 citations); *Journal of Periodontology* (17 citations); *Journal of Dental Research* (42 citations). As these journals are included in the Oral Health Group's ongoing handsearching programme (www.ohg.cochrane.org), no further handsearching was undertaken.
All references cited in the included trials were checked. Identified manufacturers were contacted and additional published or unpublished trial reports requested.

The review is to be updated every 2 years using CENTRAL, the Cochrane Oral Health Group Trials Register, MEDLINE and EMBASE.

Data collection and analysis

Two authors independently reviewed the titles and abstracts identified in the search. If in the opinion of both authors an article clearly did not fulfil the defined exclusion criteria it was considered ineligible. Full reports of all trials of possible relevance were obtained for assessment. On receipt of the full article, two authors assessed each study independently using specifically designed data extraction forms.

Data extraction

Data extraction was performed independently by all authors on 10 pilot articles. The authors reported back on the design of the data extraction forms and their interpretation of the inclusion and exclusion criteria along with their understanding of the outcome measures. On the basis of this feedback the data extraction forms were altered and the inclusion, exclusion and outcome measures redefined to avoid misinterpretation.
The final data extraction protocol extracted the following information.
(1) Bibliographic details of the study.
(2) Funding source for the trial.
(3) Inclusion eligibility.
(4) Baseline characteristics of the participants in the study, including age, number of participants in the study and gender. Also, specific groups, such as dental students or orthodontic patients were noted, where mentioned.
(5) Intervention characteristics including type of brush and its mode of action, duration of use and delivery of instructions.
(6) Outcomes including plaque and gingivitis indices.
A trial was considered to have adequately generated a random sequence of allocation, if it fully reported the type of allocation generation and it satisfied the CONSORT guidelines as true randomisation (http://www.consort-statement.org/).
A trial was considered to have adequate blinding, if it stated that the method of outcome assessment did not allow the recording clinician to know to which group the participants had been allocated, with no other contradicting statement.
Attrition was considered to have been adequately reported if there was a clear indication of how many withdrawals occurred in each group during the trial and an attempt made to give reasons why the withdrawals occurred.
A trial was considered to have been funded by a brush manufacturer if it was reported that any material sponsorship from the manufacturer occurred, including the donation of brushes. It was considered unclear, if there was no statement on funding. A trial

was only considered to be unsponsored by a manufacturer if it clearly stated so.

Trials were considered as 'short term' or 'long term'. 'Short-term' data include follow up between 28 days and 3 months. 'Long-term' data include follow up beyond 3 months. Within each category of long term and short term, where a trial reported multiple end points, only the latest data were extracted.

Data from trials that reported follow up before, and after 3 months were included in the pre- and post-3 month meta-analysis. This was the only circumstance when data from the same trial were considered twice.

Many different indices of plaque and gingivitis were used across trials and some trials reported multiple indices. A frequencies table was prepared of the indices used and they were ranked based on common usage and simplicity. For plaque we extracted, where possible, data reported as the Turesky et al modification of the Quigley-Hein plaque index of 1962 (Quigley 1962; Turesky 1970). For gingival inflammation we extracted where possible data reported as the gingival index of Löe and Silness (Löe 1963) or, if unavailable, bleeding on probing (Ainamo 1975). Data for 'Russell's periodontal index' were excluded because this index fails to distinguish between gingivitis and periodontitis (Russell 1967).

Where available, data were extracted for whole mouth scores as opposed to part mouth scores. Where only part mouth scores were reported in a study, they were extracted and a sensitivity analysis carried out to consider their impact on the results of the review. Part mouth scoring was said to have occurred if plaque and or gingivitis were not recorded around all erupted teeth, except third molars.

Completed data extraction forms were compared. Where there was disagreement between authors with regard to any part of the extraction details it was resolved by discussion between the authors and a note made on the data collection forms. Any disagreement, unresolved between the two authors, was settled by majority vote of the entire panel of six authors. Authors were contacted for clarification where necessary.

Methodological quality

Quality assessment was carried out independently and in duplicate at the same time as data were extracted. Particular emphasis was placed on allocation concealment ranked using the Cochrane criteria: Grade A: Adequate, B: Unclear, C:Inadequate, and D: Not used.

Consideration was also given to:

(1) Generation of randomisation sequence
(2) A priori calculation of sample size
(3) Blind outcome assessment
(4) Comparability of groups at baseline
(5) Duration of study
(6) Attrition bias
(7) Reliability tests for outcome measures.

Agreement between authors, concerning methodological quality, was assessed by calculating Kappa values for full mouth recording; adequate allocation concealment; adequate random number generation; adequate blinding of outcome assessor and adequate reporting of attrition.

Numerical data extracted from the included trials were checked by a third author for accuracy and entered into Review Manager (RevMan).

Data synthesis

Choice of summary statistic and estimate of overall effect

Different indices for plaque measure the same concept on different scales, with high correlation between the different indices. The same is true for gingivitis. As it is not possible to combine the results from different indices, the effects were expressed as standardised values, which have no units, before combining. The standardised mean difference (SMD) was therefore calculated along with the appropriate 95% confidence intervals (CI) and was used as the effect measure for each meta-analysis (Deeks 2001).

Statistical values such as SMD have no inherent clinical meaning. Therefore we back-translated them using the clinical indices from a study where the difference was similar to the SMD. Such examples are given in the discussion. Random-effects models were performed throughout.

Assessment of heterogeneity and investigation of reasons for heterogeneity

Heterogeneity was assessed by inspection of a graphical display of the estimated treatment effects from the trials along with their 95% CI and by Cochran's test for heterogeneity undertaken before each meta-analysis. Subgroup analyses were undertaken for assessments based on full mouth recording versus those based on a partial recording and to examine the effects of concealed allocation, randomisation generation and blind outcome assessment on the overall estimates of effect for important outcomes.

Cross-over trials

It was planned to combine the data from cross-over trials with that of similar parallel group trials, using the techniques described by Elbourne et al (Elbourne 2002). Due to insufficient data this was not possible.

Investigation of publication and other biases

A funnel plot (plots of effect estimates versus the inverse of their standard errors) was drawn. Asymmetry of the funnel plot may indicate publication bias and other biases related to sample size, though it may also represent a true relationship between trial size

and effect size. A formal investigation of the degree of asymmetry was performed using the method proposed by Egger et al (Egger 1997). A further method proposed by Begg and Mazumdar which tests for publication bias by determining if there is a significant correlation between the effect estimates and their variances was also carried out (Begg 1994). Both methods were carried out using Stata version 7.0 (Stata Corporation, USA) using the program Metabias.

RESULTS

Description of studies

See: Characteristics of included studies; Characteristics of excluded studies.

In the original review the search identified 354 trials of which 139 were considered to be ineligible from the information provided in the title or abstract. Full articles were obtained for the remaining 215. From the full articles 152 trials proved ineligible. From the abstracts and full articles 29 trials had insufficient detail to be able to convincingly allocate them to the category of included or excluded trials. Thirty-six trials were eligible. Of these eligible trials, five cross-over and two parallel trials provided insufficient information for the data to be used in a meta-analysis, and were excluded. The authors of 36 trials with insufficient information were contacted and asked to provide the missing details required to include or exclude the data. Twenty-nine trials fulfilled all inclusion criteria and had results that could be entered for meta-analysis.

In the update, an additional 10 trials were identified as clearly meeting the inclusion criteria (Galgut 1996; Garcia-Godoy 2001; Hickman 2002; Pucher 1999; Sharma 2000; Soparkar 2000; Sowinski 2000; Toto 1966; Van Swol 1996; Zimmer 2002). For three further trials, identified in the original search, information was received from the authors allowing a judgment to be made on their inclusion (Haffajee 2001a; Lapiere unpublished; Singh unpublished). A total of 42 trials are included in this update.

A primary reason for the exclusion of each study is given in the Characteristics of excluded studies table. Many trials were ineligible for more than one reason. Trials or abstracts which proved to be duplicates of included studies are tabulated here, but entered in the included study references list, as such. For trials where authors had been contacted for further information and where no reply was received after 3 months, the study was considered ineligible for insufficient data available. Should the required data be supplied such trials will be addressed in the next review. A summary of the reasons for exclusion is given in Additional Table 1.

Table 1. Summary of characteristics of excluded studies

Reason for exclusion	Number (n = 245)
Less than 28 days	93
Not powered versus manual	65
Not RCT	27
Author contacted for more information, no reply after 3 months	15
Split mouth	15
Duplicate abstract or study	1
Potential high for compromised tooth brushing efficacy	8
Cross-over trial, authors contacted for more information, no reply after 3 months	5
Outcomes not under consideration	9
Combined intervention	9

Table 1. Summary of characteristics of excluded studies (*Continued*)

No movement of brush head	2
Laboratory study	11
Teeth brushed by another person	1
Not teeth	1
Not human	1
Abstract only	1

Of the 42 included trials, 30 were conducted in North America (Baab 1989; Barnes 1993; Cronin 1998; Dentino 2002; Emling 1991; Forgas-B 1998; Garcia-Godoy 2001; Glass 1965; Haffajee 2001a; Ho 1997; Johnson 1994; Khocht 1992; Lobene 1964a; O'Beirne 1996; Pucher 1999; Sharma 2000; Singh unpublished; Soparkar 1964; Soparkar 2000; Sowinski 2000; Terezhalmy 1995a; Toto 1966; Tritten 1996; Van Swol 1996; Walsh 1989; Warren 2001; Wilson 1993; Yankell 1996; Yankell 1997; Yukna 1993b); 11 in Europe (Ainamo 1997; Clerehugh 1998; Galgut 1996; Heasman 1999; Hickman 2002; Lapiere unpublished; Lazarescu 2003; McAllan 1976; Stoltze 1994; van der Weijden 1994; Zimmer 2002) and one in Israel (Stabholz 1996).

Three trials were unpublished (Lapiere unpublished; Lazarescu 2003; Singh unpublished). The remainder were published between 1964 and 2004; four in the 1960s; one in the 1970s; two in the 1980s; 23 in the 1990s and eight since 2000. At least 28 were funded in some part by the manufacturer of one of the powered toothbrushes, the remainder were unclear about sponsorship.

The combined total number of participants included in the trials was 3967. The number of patients reported lost to follow up was 309 (7.8%).

Characteristics of participants

The characteristics of participants in each study are noted in the Characteristics of included studies table and in Additional Table 2. Out of the 42 eligible trials the four most frequently stated inclusion criteria were adults (79% of trials), no relevant medical history (62%), a stated minimum number of teeth (55%) and a criterion related to gingival or periodontal health or plaque at baseline (43%). Exclusion criteria for included trials were noted and summarised in Additional Table 3.

Table 2. Summary of inclusion criteria categories within included studies

Inclusion criteria	Number (n = 42)
Exclusion criteria related to medical history	29
Adults	34
Minimum number of teeth	24
Minimum periodontal baseline measures	18
Participants recruited from dental clinics	11
Concurrent fixed orthodontic treatment	5
Some participants aged less than 16 years	9
Volunteer university students	3
Dental students	1

Table 3. Summary of exclusion criteria categories within included studies

Exclusion criteria	Number (n = 42)
Pregnancy or lactation	5
Previous use of powered toothbrushes	4
Patients undergoing orthodontic treatment	6
Previous periodontal treatment	2
Dental students	2
Cervical restorations	1
Smoking	1
Maximum periodontal measure	4

Characteristics of interventions

The powered toothbrushes, included:
Braun, Interplak, Braun Plaque Remover with OD5 head, Braun Oral B 3D, Braun Oral B D9, PlaK Trac, Ultrasonex, GEC, Braun Oral B D7, Philips Jordan HP 735, Philips HP 550,Sonicare ultrasonic, Philips Sonicare, Epident, Braun Oral B D5, Philips 550, Touchtronic Teledyne Aqua Tec, Ronson, Dominion, Pulse Plaque Remover, Broxodent, Plaq and White, LPA/Broxo, Braun D17, Rowenta Dentiphant, Rowenta, Plaque Dentacontrol Plus, Sangi Co Electronic, Braun Oral B D10, Braun Oral B D15 Plaque Remover, Braun Plaque Remover 3D with orthodontic head, Hukuba ionic, Colgate Actibrush, HyG ionic, unspecified ionic, Ultra Sonex Ultima, Sunbeam cordless. These are summarised in Additional Table 4.

Table 4. Summary of toothbrush modes of action, number of trials and participants

Mode of action	Trial ID	Number of trials	n - attrition
Side to side	Glass 1965, Ho 1997, Johnson 1994, Lobene 1964, O'Beirne 1996, Tritten 1996, Walsh 1989, Yankell 1997	8	627
Counter oscillation	Baab 1989, Khocht 1992, Stabholz 1996, Wilson 1993, Yukna 1993	5	224
Rotation oscillation	Ainamo 1997, Barnes 1993, Clerehugh 1998, Cronin 1998, Dentino 2002, Heasman 1999, Lazarescu unpublished, Stoltze 1994, Warren 2001, Yankell 1997, van der Weijden 1994, Haffajee 2001a, Lapiere unpublished, Hickman 2002, Sharma 2000, Soparkar 2000, Sowinski 2000, Garcia-Godoy 2001	18	1444
Circular	Khocht 1992, McAllan 1976, Yankell 1996	3	168
Ultrasonic	Forgas Brockman 1998, Terezhalmy 1995, Zimmer 2002	3	171
Unknown	Emling 1991, Soparkar 1964, Toto 1966, Singh unpublished	4	870
Ionic	Van Swol 1996, Pucher 1999, Galgut 1996	3	179

Powered toothbrush, mode of action

The powered toothbrushes were subdivided into seven groups according to their mode of action.

Side to side action

Philips Sonicare and Sonicare brushes (Sonicare c/o Philips Oral Healthcare, 35301 SE Center Street, Snoqualmie, WA 98065; http://www.sonicare.com/);
Philips 550 (Philips Jordan, P.O. Box 324, 5500 AH Veldhoven, The Netherlands; http://www.philips-jordan.com/).

Counter oscillation

Interplak brush (Interplak Conair Corporation, 1 Cummings Point Road, Stamford, CT 06904; http://www.conair.com/products/).

Rotation oscillation

Braun Oral B 3D, D17, Plaque Remover with OD5 head, Oral B D9, Oral B D7, Oral B D5, Oral B D10, Braun Plaque Remover 3D with orthodontic head, Braun Oral B D15 Plaque Remover, (Braun Oral B Consumer Services, 1 Gillette Park, South Boston, MA; http://www.oralb.com/); Philips Jordan HP 735, Philips HP 550 (Philips Jordan P.O. Box 324, 5500 AH Veldhoven, The Netherlands; http://www.philips-jordan.com/); Colgate Actibrush (Consumer Affairs, Colgate-Palmolive (UK) Limited, Guildford Business Park, Middleton Road, Guildford, Surrey GU2 8JZ UK; http://www.colgate.co.uk/contact/index.shtml).

Circular

Rowenta Dentiphant, Rowenta, Plaque Dentacontrol Plus (Rowenta Werke GmbH, Franz Alban, Stützer, Germany; http://www.products.rowenta.de/row/index.html);
Teledyne Aqua Tech brushes (Corporate Headquarters 12333 West Olympic Boulevard Los Angeles, CA 90064; http://www.waterpik.com/oralhealth/).

Ultrasonic

Ultrasonex brush, Ultra Sonex Ultima (Salton-Maxim 1801 N. Stadium Boulevard, Columbia, MO 65202; http://www.salton-maxim.com/salton/ultrasonex/ultrasonex.asp).

Ionic

Sangi Co Electronic (Tokyo), Hukuba ionic and the HyG ionic (Hukuba Dental Corporation, 914-1 Nazukari, Nagareyama, Chiba, 270-01 Japan).

Unknown

Some companies are no longer trading or complete details of the relevant toothbrushes are not easily found. The following toothbrushes fall into this latter category: PlaK Trac, GEC, Epident, Touchtronic, Ronson, Dominion, Broxodent, Plaq and White, LPA/Broxo, Sunbeam cordless.

The names and addresses of the manufacturers have changed over the years and those quoted above are correct at the time of the present review. Some of the trials were conducted when another company made the powered toothbrush.
Eight trials including 627 participants at the end of the trial compared manual brushing versus side to side powered toothbrushing. Five trials provided data on 224 participants at the end of the trial compared manual brushing versus counter oscillating toothbrushing. Eighteen trials with 1444 participants at the end of the trial compared manual brushing versus rotation oscillation powered brushing. Three trials including 168 participants at the end of the trial compared manual brushing versus circular powered brushing and three trials of 171 participants at the end of the trial compared manual brushing versus ultrasonic powered brushing. Three trials with 179 participants at the end of the trial compared manual brushing versus ionic brushing. Four trials with 870 participants at the end of the trial compared manual brushing and a powered toothbrush with an unknown action.

Summary of trials by toothbrush action

See Additional Table 4. The trials that compared manual with a side to side action powered brush were: (Glass 1965; Ho 1997; Johnson 1994; Lobene 1964a; O'Beirne 1996; Tritten 1996; Walsh 1989; Yankell 1997). Counter oscillation: (Baab 1989; Khocht 1992; Stabholz 1996 (not included in meta-analysis); Wilson 1993; Yukna 1993b). Rotation oscillation: (Ainamo 1997; Barnes 1993; Clerehugh 1998; Cronin 1998; Dentino 2002; Garcia-Godoy 2001; Haffajee 2001a; Heasman 1999; Hickman 2002; Lapiere unpublished; Lazarescu 2003; Sharma 2000; Soparkar 2000; Sowinski 2000; Stoltze 1994; van der Weijden 1994; Warren 2001; Yankell 1997). Circular: (Khocht 1992; McAllan 1976; Yankell 1996). Ultrasonic: (Forgas-B 1998; Terezhalmy 1995a; Zimmer 2002). Ionic: (Galgut 1996; Pucher 1999; Van Swol 1996) and unknown (Emling 1991; Singh unpublished; Soparkar 1964; Toto 1966).

Characteristics of outcome measures

Thirty-four trials (2295 participants at the end of the trial) reported plaque at 1 to 3 months and 10 trials (705 participants at the end of the trial) at longer than 3 months. Thirty-nine (2870 participants at the end of the trial) reported gingivitis at 1 to 3 months and 12 (1372 participants at the end of the trial) at greater than 3 months.
Twenty-eight trials recorded whole mouth scores for plaque and gingivitis; five trials recorded part mouth scores for both variables. One trial recorded part mouth scores for plaque and whole mouth scores for gingivitis and four trials recorded whole mouth scores for plaque and part mouth scores for gingivitis. Two trials reported only plaque data, one for whole mouth scores and one for part mouth scores. One trial reported part mouth scores for gingivitis only.One study reported for both plaque and gingivitis but it has not been possible to ascertain whether the data relate to part or all

of the mouth (Singh unpublished).

Risk of bias in included studies

The agreement between the authors was generally good with Kappa values for adequacy of allocation concealment 0.49, adequate outcome assessor blinding 0.72, adequacy of reporting and handling of attrition 0.70 and mention of manufacturer funding 1.00.

Selection bias

The generation of randomisation sequence was adequate for 15 (35.7%) of the 42 trials, inadequate for two trials (4.8%) and unclear for 25 trials (59.5%). The concealment of allocation was adequate for 16 trials (38.1%), unclear for 24 (57.1%) and inadequate for 2 (4.8%).

Detection bias

The outcome assessor was adequately blinded in 38 trials (90.5%). The adequacy of blinding was unclear in five trials (7.1%). Blinding was not undertaken in one trial (2.4%).

Attrition bias

Intention-to-treat analysis was carried out in three trials (7.1%), unclear in two trials (4.8%) and not undertaken in 37 trials (88.1%).
The reported drop-out rate was 8.0%. Trials with follow up of less than 3 months had a drop-out rate of 5.9%. Trials with follow up of greater than 3 months had a drop-out rate of 10.6%.

Sponsorship

Funding by a manufacturer of at least one of the brushes under investigation was stated in 28 (67%) of the trials and unclear in 14 (33%).

Effects of interventions

As mentioned in the data synthesis section of the methods of the review, the differences in plaque and gingivitis reduction between the powered and manual brushes were expressed as standardised mean differences (SMDs) for both short-term and long-term studies. Significant differences in SMDs are reported below.

Side to side powered toothbrushes (Comparison 1 Outcomes 1.1 to 1.4)

There was no statistically significant difference between powered toothbrushes whose action was side to side and manual brushes with regard to the removal of plaque or reduction of gingivitis for both time periods. Six trials compared side to side powered brushes included in the meta-analysis for 1 to 3 month plaque, eight for 1 to 3 month gingivitis and only two trials included in both the meta-analyses for measures after 3 months.

Counter oscillation powered toothbrushes versus manual (Comparison 2 Outcomes 2.1 to 2.4)

There was no evidence that powered toothbrushes whose action was counter oscillation were more effective than manual brushes for the removal of plaque or reduction of gingivitis with the exception of being associated with less plaque in the long term, where the SMD was -0.63 (95% confidence interval (CI): -1.11 to -0.14). There were four trials included in the meta-analysis for 1 to 3 month plaque, four for 1 to 3 month gingivitis and only two trials included in both the meta-analyses for measures after 3 months.

Rotational oscillation powered toothbrushes versus manual (Comparison 3 Outcomes 3.1 to 3.4)

This comparison contained the greatest number of trials, with 15 trials included in the meta-analyses for early plaque, 16 for early gingivitis, and three trials included in the long-term comparison for plaque and four trials for long-term gingivitis.
To assist in the appreciation of the size of the benefit of the rotation oscillation brushes, SMDs have been converted to equivalent values in commonly used plaque and gingivitis indices.
Brushes that worked with a rotation oscillation action removed more plaque and reduced gingivitis more effectively than manual brushes in the short term. For plaque at 1 to 3 months the SMD was -0.43 (95% CI: -0.72 to -0.14), for gingivitis SMD -0.62 (95% CI: -0.90 to -0.34). These differences are the approximate equivalent of a reduction of 0.27 or 11% on the Quigley Hein plaque index and a reduction of 0.06 or 6% on the Löe and Silness gingival index. At over 3 months the SMD for plaque was -1.29 (95% CI: -2.67 to 0.08). Brushes of this design reduced gingivitis scores in studies over 3 months. SMD for gingivitis -0.51 (95% CI: -0.76 to -0.25). This difference is the equivalent of a 17% reduction on the Ainamo Bay bleeding on probing index. There was considerable heterogeneity between the trials in the meta-analyses for the short-term follow up, which is reported later in this section.

Circular powered toothbrushes versus manual (Comparison 4 Outcomes 4.1 to 4.4)

There was no evidence that brushes with a circular action removed plaque or reduced gingivitis more effectively than manual brushes in either time period. Three trials were included in both these analyses for early plaque and gingivitis evaluation, and only one trial in each of the meta-analyses for longer follow up.

Ultrasonic toothbrushes versus manual (Comparison 5 Outcomes 5.1 to 5.4)

Ultrasonic brushes reduced gingivitis in studies of less than 3 months. SMD was -0.64 (95% CI: -1.04 to -0.24). No other significant differences were noted between the effects of manual and ultrasonic brushes. There were three trials for each of the meta-

analyses for the short-term assessments of plaque and gingivitis, and one trial in both long-term meta-analyses.

Unknown versus manual (Comparison 6 Outcomes 6.1 to 6.4)

The analyses for plaque in the short term and for gingivitis in the long term each included one trial but neither analysis indicated a benefit from the powered brush. The analysis for brushes of unknown action in short-term studies of gingivitis comprised 3 trials. The effect was significant as the SMD was -0.38 (95% CI: -0.59 to -0.17).

Ionic toothbrushes versus manual (Comparison 7 Outcomes 7.1 to 7.4)

Three trials were included in the analysis for ionic brushes. All three studies were included in the short-term analysis of plaque and two for gingivitis. There was one long-term study of plaque and gingivitis. The short-term analyses indicated no effect on plaque or gingivitis. The analysis of the data from the single long-term trial showed a difference in favour of the ionic toothbrush on both plaque (SMD -1.01(95% CI: -1.53 to -0.49)) and gingivitis (SMD -0.78 (95% CI: -1.29 to -0.27)).

Investigation of heterogeneity

The heterogeneity in the short-term meta-analyses comparing rotation oscillation powered and manual brushing for both plaque and gingivitis was caused by one study with exceptionally low standard deviations for all indices (Stoltze 1994).

Sensitivity analyses

Sensitivity analyses were conducted to test whether the assumptions involved in the design of this review affected the findings. These analyses were undertaken by repeating the meta-analyses in the following cases: where a full mouth index had been used, where adequate concealment of randomisation occurred, where there was adequate generation of randomisation sequence, where there was blinding of the outcome assessor, if the trial was funded by a manufacturer, with adequate information about attrition and for trials that were not restricted to participants only wearing fixed orthodontic appliances. Sensitivity analyses were limited to the data on rotational oscillation powered toothbrushes (Comparison 3 Outcomes 3.1 and 3.2) because they were the ones that showed significant effects and contained the greatest number of trials.
All but two of the revised meta-analyses yielded similar effect estimates to the overall estimates, indicating that the results are robust and not distorted by the lesser quality trials (Additional Table 5). Only six trials on plaque adequately generated and concealed the allocation sequence and the revised analysis of these six studies did not detect a benefit with the powered brushes.

Table 5. Sensitivity analyses of trials of rotation oscillation versus manual (1-3 months)

Group selected	Index	Number of studies	SMD (95%CI)	Effect P-value	Het. Chi^2	Het. P-value	I^2 (%)
All studies	plaque	15	-0.43 (-0.72 to -0.14)	0.004	81.81	< 0.001	82.9
Full mouth recording	plaque	14	-0.46 (-0.77 to -0.16)	0.003	78.84	< 0.001	83.5
Adequate concealed allocation	plaque	6	-0.06 (-0.51 to 0.39)	0.81	27.72	< 0.001	82.0
Adequate random number generation	plaque	6	-0.07 (-0.51 to 0.37)	0.75	28.49	< 0.001	82.4
Outcome assessor blinded	plaque	13	-0.38 (-0.67 to -0.09)	0.010	63.98	< 0.001	81.2
Adequate reporting of attrition	plaque	13	-0.45 (-0.79 to -0.11)	0.010	80.17	< 0.001	85.0

Table 5. Sensitivity analyses of trials of rotation oscillation versus manual (1-3 months) (*Continued*)

Manufacturer funded	plaque	9	-0.39 (-0.80 to 0.02)	0.06	61.52	< 0.001	87.0
Trials not limited to patients wearing fixed orthodontic appliances	plaque	14	-0.46 (-0.76 to -0.16)	0.003	78.61	< 0.001	83.5
All studies	gingivitis	16	-0.62 (-0.90 to -0.34)	< 0.001	83.96	< 0.001	82.1
Full mouth recording	gingivitis	14	-0.70 (-1.01 to -0.40)	< 0.001	75.99	< 0.001	82.9
Adequate concealed allocation	gingivitis	6	-0.38 (-0.66 to -0.11)	0.007	10.71	0.06	53.3
Adequate random number generation	gingivitis	7	-0.40 (-0.64 to -0.17)	< 0.001	11.32	0.08	47.0
Outcome assessor blinded	gingivitis	14	-0.54 (-0.79 to -0.30)	< 0.001	52.34	< 0.001	75.2
Adequate reporting of attrition	gingivitis	14	-0.67 (-0.99 to -0.34)	< 0.001	82.43	< 0.001	84.2
Manufacturer funded	gingivitis	10	-0.69 (-0.98 to -0.40)	< 0.001	37.99	< 0.001	76.3
Trials not limited to patients wearing fixed orthodontic appliances	gingivitis	14	-0.70 (-1.01 to -0.39)	< 0.001	76.77	< 0.001	83.1

Publication bias

Publication bias was assessed for the meta-analyses for rotational oscillation powered toothbrushes versus manual for the 1 to 3 month assessments. The funnel plots for each appeared symmetric with no evidence of bias for either plaque or gingivitis using the Egger (weighted regression) method (P = 0.78, 0.52 respectively), or using the Begg (rank correlation) method (P = 0.72, 0.41).

Secondary outcomes

Cost

None of the included trials reported on the relative costs of manual compared with powered toothbrushes.

Reliability

One trial reported a mechanical failure of one of the 48 powered toothbrushes used (Clerehugh 1998) and one trial reported mechanical failure in four of 20 powered brushes (Yukna 1993b). No other mechanical failures were reported.

Calculus

Three trials (Dentino 2002; Glass 1965; van der Weijden 1994) reported on calculus, two reporting that there was no significant difference between the brush types (Glass 1965; van der Weijden 1994) and one reporting that, compared to the manual brush, the powered brush group showed a significant favourable difference in the accumulation of calculus at 6 months P = 0.0078 (Dentino 2002).

Stain

Three trials reported that there was no difference in the degree of staining on the teeth between the brush types (Dentino 2002; Glass 1965; Walsh 1989).

Adverse events - Tissue trauma

There was no apparent relationship between the use of powered toothbrushes and soft tissue trauma. In part this finding was due to the very small number of adverse events reported in the trials. Eight trials did not report on adverse events (Haffajee 2001a; Ho 1997; Lazarescu 2003; Lobene 1964a; McAllan 1976; Soparkar 1964; Van Swol 1996; Zimmer 2002). Of the 34 that did report on adverse events, 23 reported no trauma to soft and/or hard tissues (Ainamo 1997; Clerehugh 1998; Dentino 2002; Emling 1991; Forgas-B 1998; Galgut 1996; Garcia-Godoy 2001; Glass 1965; Heasman 1999; Hickman 2002; Pucher 1999; Sharma 2000; Singh unpublished; Soparkar 2000; Sowinski 2000; Stabholz 1996; Stoltze 1994; Toto 1966; Walsh 1989; Warren 2001; Wilson 1993; Yankell 1996; Yankell 1997) and six reported no significant differences between powered and manual toothbrushes, or that tissue trauma was negligible (Baab 1989; Barnes 1993; Cronin 1998; Lapiere unpublished; O'Beirne 1996; Terezhalmy 1995a).

Therefore, of the original 42 studies, there were five that described differences in tissue trauma between participants using manual and powered toothbrushes. One trial reported five cases of gingival abrasion in the manual and one case of abrasion in the powered group (Tritten 1996), another reported 12 cases of gingival abrasion in the manual and five cases of gingival abrasion in the powered group (van der Weijden 1994). One trial reported seven soft tissue abnormalities in six participants in the manual group and 10 abnormalities in seven participants in the powered group (Johnson 1994). In the trial by Yukna et al (Yukna 1993b) four cases of abrasion were reported in the powered toothbrush group and one in the manual group. Khocht (Khocht 1992) reported soft tissue changes in four participants using the manual toothbrush, six using the experimental powered toothbrush and one participant using a control powered toothbrush. These soft tissue changes were seen as transient irritations that were possibly/probably due to the product.

DISCUSSION

We brush our teeth for many reasons: to feel fresh and confident; to have a nice smile; to avoid bad breath and to avoid disease. The selection of one's toothbrush is largely a matter of personal preference, affordability, availability and professional recommendation. Powered toothbrushes may have a particular appeal to some because they represent a newer 'high tech' solution to an everyday task.

This systematic review has found that powered toothbrushes with a rotation oscillation action removed plaque and reduced gingivitis more than manual brushes in the short term and of gingivitis in the long term.

In the course of this revision we questioned the inclusion of one study of plaque over 3 months. Excluding this study does not substantially change our estimate of the treatment effect. However, because there are fewer studies in the analysis the 95% confidence intervals are wider (-2.67, 0.08). The findings of this analysis are no longer statistically significant although the upper limit of the 95% confidence interval only just exceeds equivalence. The line of equivalence is a reference point on the Forest plots. If the confidence intervals include the line of equivalence, then it is more likely that any apparent differences between the effects of the brushes can be explained by the play of chance. In this case, the confidence interval was close to the line of equivalence and almost met our threshold for accepting that there was a benefit from the powered brush.

Other forms of powered brushes produced a less consistent reduction of plaque and gingivitis.

Few data were reported on the costs or reliability of the brushes or the side effects of their use. When reported, injuries to the gums

were minor and transient. Randomised controlled trials may not be the best research design for investigating these adverse outcomes. Expert groups have suggested that powered toothbrushes are safe if used correctly but further research is required in these areas (Lang 1998).

There is overwhelming evidence that toothbrushing reduces gingivitis (Lang 1973). It may prevent periodontitis and certainly prevents tooth decay if carried out in conjunction with fluoride toothpaste. These benefits occur whether the brush is manual or powered and the results of this review do not indicate that toothbrushing is only worthwhile with a powered toothbrush.

As mentioned in the results section, standardised mean differences (SMDs) may be converted to the corresponding values of particular clinical indices. The plaque scores in short-term trials of rotation oscillation brushes was -0.43. Using this level of effectiveness as an example, in the trial by Cronin (Cronin 1998) a similar standardised mean difference (-0.45) corresponded to a mean difference in the Turesky modification of the Quigley Hein index of 0.27. The mean plaque score among those using manual brushes in the trial by Cronin was 2.55 and thus the difference is 11%.

For gingival scores the SMD in short-term trials of rotation oscillation brushes was -0.62. Again, using this level of effectiveness, in the trial by Cronin (Cronin 1998) the SMD of -0.54 corresponded to a mean difference in the Löe and Sillness gingival index of 0.06. The mean gingival index score for those using manual brushes in the trial was 0.97 and thus the difference is 6%.

The same approach can be used to assess the effect of rotation oscillation powered toothbrushes on long-term reductions in gingivitis, and indicates benefits of 17%. Had a weighted mean difference method been used for pooling the data rather than a standardised mean difference, similar results and conclusions would have been reached .

Doubt persists in what level of plaque removal and reduction in gingivitis will result in clinically significant improvements in periodontal health.

The results of the review can be related to destructive periodontal disease (periodontitis) only with some difficulty. Some authorities have advocated the use of arbitrary thresholds to make superiority claims for a specific product. For example, Imrey has proposed that a product cannot be claimed to be superior unless it provides a 20% improvement in performance (not the case for any types of brush in this review, in terms of long-term plaque removal) (Imrey 1992; Imrey 1994). However, other authors have criticised the use of arbitrary thresholds and prefer a threshold for clinical significance to be decided in advance and selected on clinical grounds (D'Agostino 1992).

Many factors are associated with the occurrence of periodontitis including plaque, tobacco use and individual medical factors. Periodontitis takes many years to develop and the trials have much shorter follow up. There is no compelling evidence that plaque and gingivitis are reliable proxies for long-term destructive disease and it is difficult to estimate a clinical threshold for significant plaque reduction. We conclude that rotation oscillation brushes provide reductions for plaque removal but the clinical importance of these reductions cannot be assessed.

With 27 analyses in this study it is possible that some may appear significant by the play of chance. Isolated analyses appear to show a benefit for counter oscillation brushes against plaque in long-term studies, for ultrasonic brushes and those of unknown action against gingivitis in short-term studies and in one long-term study of ionic brushes against plaque and gingivitis. In each case these outcomes were the only ones associated with the use of these brushes. It is difficult to explain this inconsistency that a particular toothbrush design could effect plaque at one time but not at another and so the findings of these analyses may warrant further research.

One possible weakness of this review was the grouping of toothbrushes by their modes of action. Whilst this approach allowed more powerful meta-analysis it is possible that toothbrushes whose actions had subtle differences were more or less effective. Similarly, so many factors may influence the effectiveness of toothbrushes including filament arrangement, orientation, size, shape and flexibility, brush head size and shape along with presence or absence and characteristics of a timer, that not all of them could be isolated and analysed. Whether the brush has a battery or rechargeable power source may also be important.

Publication bias seems likely to be present in the reporting of these trials as manufacturers would like to have scientific support for the effectiveness of their powered toothbrushes. Studies sponsored by pharmaceutical companies are more likely to favour the sponsor (Lexchin 2003). However there was no evidence of this when publication bias was examined statistically, and no evidence of a difference in effect estimates when a sensitivity analysis was conducted for trials which did not mention commercial funding. It should be noted that the methods for detecting publication bias are relating effect size to sample size, and in this review the trials tend to be of similar size. Therefore other methods may be required to examine publication bias in short term, low cost studies.

Five eligible cross-over trials had to be excluded from the review as the data presented did not include the standard deviation of the paired differences, or alternative statistics which would enable this value to be estimated (Elbourne 2002). Attempts were made to contact all the trialists however they were unable to supply the necessary data. It is important that trialists analyse the data from cross-over trials appropriately and present relevant data in reports of trials.

AUTHORS' CONCLUSIONS

Implications for practice

This review has found that compared with manual toothbrushes, powered toothbrushes whose action is rotation oscillational reduce plaque and gingivitis by 11% and 6% respectively in the short term and gingivitis by 17% at greater than 3 months. The clinical significance of these reductions is not known.

The trials available for the review were too short term to demonstrate whether these effects achieve a reduction in destructive periodontal disease.

Individuals who prefer to use a powered toothbrush can be assured that powered toothbrushing is at least as effective as manual brushing and that there is no evidence that it will cause any more injuries to the gums than manual brushing.

As none of the trials we found compared the durability, reliability and cost of using manual versus powered brushes, it is presently not possible to make a clear recommendation on toothbrush superiority.

Implications for research

Trials of longer duration are required to fully evaluate the effects of powered toothbrushes. There are few adequate trials reporting over more than 3 months. Data on the long-term benefits of powered toothbrushes would be valuable in their own right and could be used to trial other outcomes such as the adverse effects and benefits in the prevention of periodontitis and dental caries. Moreover, more trials would lend greater power to systematic reviews of the effectiveness of powered toothbrushes.

The review revealed many idiosyncrasies in the design of the trials, in some cases data could not be included in this review. Whilst many of the trials were conducted before the current emphasis on experimental design, even the most recent trials lacked power calculations and had not been analysed on an intention-to-treat basis. Researchers in this field would be advised to study guidance on the design and reporting of clinical trials such as that provided in the CONSORT statement (http://www.consort-statement.org/).

Specific guidance exists for trials in the treatment or prevention of periodontal diseases (Imrey 1994) but greater standardisation of both the follow-up intervals and the indices used would benefit both trials and future meta-analyses. Thought should also be given to when the mouth should be examined in relation to when the teeth were last cleaned.

Some research designs created an artificial research environment that may have undermined the generalisability of the findings. In particular the external validity was questionable in trials with split-mouth designs where participants are asked to clean each side of their mouth with a different brush, in trials where interventions where used in combination and those where toothbrushing was supervised. Hence their exclusion from this meta-analysis.

More research with improved rigour is also needed on the relative benefits of powered and manual toothbrushes to prevent or remove extrinsic staining of the teeth and calculus.

Finally, empirical data on thresholds for clinically significant differences in plaque and gingivitis levels would help to determine whether oral hygiene aids provide important health benefits.

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* *Indicates the major publication for the study*

CHARACTERISTICS OF STUDIES

Characteristics of included studies *[ordered by study ID]*

Ainamo 1997

Methods	RCT, parallel, single blind, 12 months, n 112 with 1 drop out.
Participants	Finland, adults, 20 to 63 years, 64M:47F, bleeding on probing > 30% sites, no medical problems.
Interventions	Braun Oral B Plak Control versus Jordan soft, 2 mins twice daily. Use of timer not stated.
Outcomes	Ainamo and Bay Visible Plaque Index and modified gingival bleeding index. 3, 6 and 12 months. Whole mouth recording PI and GI.
Notes	No pre-examination instructions reported.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Baab 1989

Methods	RCT, parallel, single blind, 1 month, n 41, with 1 drop out.
Participants	USA, adults, 18 to 59 years, 24M:16F, > 20 teeth with moderate gingivitis, no medical problems.
Interventions	Interplak versus Butler 411, 3 mins twice daily. Use of timer not stated.
Outcomes	O'Leary plaque index, Löe and Silness gingival index, Ainamo and Bay gingival bleeding index. Ramfjord teeth for GI, whole mouth for PI. Gingival abrasion reported to be not significant. Plaque scores awaiting assessment.
Notes	Manufacturer funded. No pre-examination instructions reported.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Barnes 1993

Methods	RCT, parallel, single blind, 3 months, n 70 with 1 drop out.
Participants	USA, adults, 18 to 65 years, > 20 teeth, gingival index > 1.5, plaque index > 2.
Interventions	Braun Oral B Plaque Remover versus Johnson & Johnson Reach, as per normal use.
Outcomes	Quigley and Hein (Turesky) Plaque Index, Löe and Silness (Lobene) gingival index at full mouth sites. Soft tissue trauma, no difference between brushes. Whole mouth recording PI and GI.
Notes	Manufacturer funded. No pre-examination instructions reported.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Clerehugh 1998

Methods	RCT, parallel, single blind, 8 weeks, n 84 with 5 drop outs.
Participants	UK, children and adolescents, 10 to 20 years, orthodontic patients in practice, fixed appliances, gingival bleeding at 30% sites, no medical conditions.
Interventions	Braun Plaque Remover with OD 5 head versus Reach medium compact head, 2 mins twice daily. Timer used.
Outcomes	Orthodontic modification of Silness and Löe plaque index, Eastman bleeding index at all buccal sites at 4, 8 weeks. No evidence of trauma. One mechanical brush failed.
Notes	Manufacturer funded. Participants asked to brush in the morning and under supervision prior to assessment.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

Cronin 1998

Methods	RCT, parallel, single blind, 3 months, n 114, 9 drop outs unclear.
Participants	USA, adults, > 18 teeth, no medical problems, 18 to 65 years.

Cronin 1998 (*Continued*)

Interventions	Braun Oral B 3D Plaque Remover versus standard ADA reference manual, 2 mins twice daily. Timer used.
Outcomes	Quigley and Hein (Turesky) plaque index, Löe and Silness gingivitis and bleeding index, at 14, 35 and 90 days, at all sites. Gingival recession recorded, no change seen. No other adverse effects. Whole mouth recording PI and GI.
Notes	Manufacturer funded. Participants asked to refrain from brushing 12 to 14 hours prior to assessment.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

Dentino 2002

Methods	RCT, parallel, single blind, 6 months, n 172 with 15 drop outs.
Participants	USA, adults, mild to moderate gingivitis with > 20 teeth, no previous powered brush experience. Excluded if pregnant/lactating.
Interventions	Braun Oral B D9 versus ADA accepted standard soft bristle manual, 2 mins twice daily. Use of timer not stated.
Outcomes	Quigley and Hein (Turesky) Plaque index and Lobene gingival index at 3 and 6 months. Powered brush removed more calculus. No difference in stain removal reported. PI and GI whole mouth.
Notes	Manufacturer funded. Participants asked to brush teeth (non-supervised) immediately prior to 6-month plaque assessment.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

Emling 1991

Methods	RCT, parallel, single blind, 30 days, n 60 with 3 drop outs.
Participants	USA, adults, no medical problems, no current ortho, not pregnant, > 17 teeth, 18 to 60 years.
Interventions	PlaK Trac versus Colgate ADA approved, twice daily. Use of timer not stated.

Emling 1991 (*Continued*)

Outcomes	Quigley and Hein (Turesky) Plaque index. Yankell, interproximal plaque index, Löe and Sillness gingival index. Ramfjord teeth for both PI and GI.
Notes	Pre-brushing measurements used.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Forgas-B 1998

Methods	RCT, parallel, single blind, 30 days, n 62 with 6 drop outs.
Participants	USA, adults, mean age 37 years +/- 10 years, > 16 teeth, plaque index > 2, no medical problems, 21M: 35F.
Interventions	Ultrasonex versus manual Oral B, twice daily. Use of timer not stated.
Outcomes	Quigley and Hein (Turesky) Plaque index, Eastman gingival bleeding index at 30 days. Ramfjord teeth for PI and GI. Soft tissue trauma reported, no difference between groups.
Notes	Manufacturer funded. Participants asked to refrain from brushing for 12 to 14 hours before assessment.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Galgut 1996

Methods	RCT, parallel, single blind, 28 days, n 70 with 7 drop outs.
Participants	UK, Caucasians, male, 19 to 36 years.
Interventions	Sangi Co Electronic (Active) versus Sangi Co Electronic (non-active), 3 minutes when brushing. No frequency stated. Use of timer not stated.
Outcomes	Quigley and Hein (Turesky) Plaque index, Loe and Silness Gingival index at 2, 4 weeks. Whole mouth recording for indices. No adverse events recorded.
Notes	Manufacturer funded. Assessment after 24 hours of no brushing.

Galgut 1996 (*Continued*)

Risk of bias		
Item	**Authors' judgement**	**Description**
Allocation concealment?	Yes	A - Adequate

Garcia-Godoy 2001

Methods	RCT, parallel, single blind, 30 days, n 70 with 4 drop outs.
Participants	USA, children, 6 to 11 years, able to understand procedure.
Interventions	Braun Oral B D10 per manufacturers instructions versus ADA approved manual brush as normal.
Outcomes	Quigley and Hein (Turesky) Plaque index. Whole mouth. No adverse events recorded.
Notes	Manufacturer funded. Assessment after 12 to 18 hours from last brushing.

Risk of bias		
Item	**Authors' judgement**	**Description**
Allocation concealment?	Yes	A - Adequate

Glass 1965

Methods	RCT, parallel, single blind, 11 months, n 250 with 84 drop outs.
Participants	USA, dental students, male, 20 to 29 years.
Interventions	GEC powered versus Pycopay brand manual twice daily. Use of timer not stated.
Outcomes	Glass debris and gingival indices at 6 weeks, 7 and 11 months at all sites. Stain and calculus reported to be no different between brush types. Whole mouth recording PI and GI. No soft tissue trauma reported.
Notes	Manufacturer funded. No pre-examination instructions reported.

Risk of bias		
Item	**Authors' judgement**	**Description**
Allocation concealment?	Unclear	B - Unclear

Haffajee 2001a

Methods	RCT, parallel, single blind, 6 months, n 52 with 4 drop outs.
Participants	USA, systemically healthy participants with adult periodontitis, 20 to 64 years, minimum of 20 teeth.
Interventions	Crest Complete versus Braun Oral-B D15 Plaque Remover. Frequency unclear. Use of timer not stated.
Outcomes	Turesky plaque index , Löe and Silness gingival index, bleeding on probing and probing attachment level at baseline, 3 and 6 months. Measurements taken for 6 sites per tooth for up to 28 teeth.
Notes	Manufacturer funded. No pre-examination instructions reported.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

Heasman 1999

Methods	RCT, parallel, single blind, 6 weeks, n 75 with 1 drop out.
Participants	UK, adult, > permanent 20 teeth, 18 to 25 years, no medical problems.
Interventions	Braun Oral B D7 versus Philips Jordan HP 735 versus Oral B Advantage B35, > 90 seconds twice daily. Use of timer not stated.
Outcomes	Quigley and Hein (Turesky) plaque index at 24 hours and 6 weeks, Löe and Silness gingival index at 6 weeks, all sites. Whole mouth recording PI and GI.
Notes	Assessment done within 3 to 4 hours of last brushing. Two powered groups combined for meta-analysis.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Hickman 2002

Methods	RCT, parallel, blinding unclear, 8 weeks, n 63 with 3 drop outs.
Participants	UK, orthodontic patients, 10 to 20 years, medically fit.

Hickman 2002 (*Continued*)

Interventions	Braun Plaque Remover 3D with Orthodontic head versus Reach compact head manual, 2 mins twice daily. Timer supplied.
Outcomes	Silness and Loe plaque index (Orthodontic modification) and Loe and Silness gingival index, full mouth at 4 and 8 weeks.
Notes	Manufacturer funded. Brush as normal post-breakfast.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

Ho 1997

Methods	RCT, parallel, single blind, 4 weeks, n 24, drop outs unclear.
Participants	USA, orthodontic patients, with fixed appliances, 11 to 18 years, gingival index > 2, no medical conditions.
Interventions	Sonicare Ultrasonic versus Oral B P35, 2 mins twice daily. Timer supplied.
Outcomes	Silness and Löe gingival and plaque indices on 6 sites per bonded tooth and bleeding on probing all at 4 weeks. Whole mouth recording PI and GI.
Notes	Manufacturer funded. No pre-examination instructions reported.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

Johnson 1994

Methods	RCT, parallel, single blind, 4 weeks, n 51 with 8 drop outs.
Participants	USA, adult, > 20 teeth, gingival index > 1.5 on Ramjford teeth, no medical conditions, 20 to 54 years.
Interventions	Philips Sonicare versus Oral B 30, 2 mins twice daily. Timer supplied.
Outcomes	Quigley and Hein (Turesky) on all sites, Ainamo and Bay gingival index and sulcular bleeding indices on Ramfjord at 1, 2, 4 weeks. Soft tissue trauma "abnormalities" 7 sites in 6 subjects for manual and 10 sites in 7 subjects for powered.

Johnson 1994 (*Continued*)

Notes	Manufacturer funded. Post-brushing evaluation.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Khocht 1992

Methods	RCT, parallel, single blind, 4 weeks, n 96 with 1 drop out.
Participants	USA, adults, > 15 teeth with no restorations affecting cervical region plaque score > 1.8 and gingival score > 0.9, no medical conditions.
Interventions	Epident and Interplak versus Oral B 40, twice daily. Use of timer not stated.
Outcomes	Quigley and Hein (Turesky) Plaque index and Loe and Silness gingivitis index at all sites at 28 days. Whole mouth recording for PI and GI. No reported soft tissue abrasion.
Notes	Manufacturer funded. Pre-brushing evaluation.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Lapiere unpublished

Methods	RCT, parallel, single blind, 12 weeks, n 48 with no drop outs stated.
Participants	Belgium, periodontal patients, 18 to 65 years, 20 natural teeth, no removable dentures, probing pocket depth > 2 mm but < 5 mm, free from subgingival calculus.
Interventions	Philips HP 550 versus P Oral B 35 versus Braun Oral B D5, 2 mins three times a day. Use of timer not stated.
Outcomes	Quigley and Hein (Turesky) Plaque index and Loe and Silness gingivitis index, whole mouth at 12 weeks.
Notes	Funding unclear. No pre-examination instructions reported. Data for two powered brushes combined as same mode of action.

Risk of bias

Lapiere unpublished (*Continued*)

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

Lazarescu 2003

Methods	RCT, parallel, single blind, 18 weeks, n 80 with 2 drop outs.
Participants	Romania, adults, > 20 teeth, medically fit and no previous powered brush experience.
Interventions	Philips/Jordan HP 735 versus Oral B 40 manual with normal brushing pattern. Use of timer not stated.
Outcomes	Quigley and Hein (Turesky) Plaque index at 6 sites per tooth and gingival bleeding index at proximal smooth surfaces at 18 weeks. Whole mouth recording PI and GI.
Notes	Manufacturer funded. Assumed pre-brushing evaluation.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

Lobene 1964a

Methods	RCT, parallel, single blind, n 185, 3 months, drop outs unclear.
Participants	USA, female college students, aged 17 to 21 years.
Interventions	General electric reciprocating action versus Oral B 40 manual with no instruction. Use of timer not stated.
Outcomes	Lobene Gingivitis index at 3 months. Whole mouth recording PI and GI.
Notes	Manufacturer funded. No pre-examination instructions reported.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

McAllan 1976

Methods	RCT, parallel, no blinding, 6 months, n 55 with 15 drop outs.
Participants	UK, children and adolescents attending paediatric department, 9 to 15 years, 24M: 31F.
Interventions	Touchtronic Teledyne Aqua Tec versus Gibbs short head manual. Use of timer not stated.
Outcomes	Silness and Löe plaque whole mouth and Löe and Silness gingival indices at first molars and lateral incisor teeth at 1, 2 and 6 months.
Notes	Manufacturer funded. No pre-examination instructions reported.

Risk of bias

Item	**Authors' judgement**	**Description**
Allocation concealment?	No	C - Inadequate

O'Beirne 1996

Methods	RCT, parallel, single blind, 8 weeks, n 40 drop outs unclear.
Participants	USA, adults with inflammatory periodontal disease, > 20 teeth and received periodontal treatment, 22M: 18F, 18 to 65 years.
Interventions	Sonicare Ultrasonex versus Oral B manual 2 mins twice daily. Timer supplied.
Outcomes	Löe and Silness gingival index, Barnett papillary bleeding index at 2, 4 and 8 weeks, at all sites. Whole mouth recording PI and GI. Minor gingival trauma seen in one participant in each group.
Notes	Part funded by manufacturer.

Risk of bias

Item	**Authors' judgement**	**Description**
Allocation concealment?	Yes	A - Adequate

Pucher 1999

Methods	RCT, parallel, double blind, 6 weeks, n 60 with 8 drop outs.
Participants	USA, orthodontic patients, >20 teeth, > 12 years, 23M: 29F after drop outs.
Interventions	Hukuba ionic (active) versus Hukuba ionic (non-active) with usual technique twice daily. Use of timer not stated.

Pucher 1999 (*Continued*)

Outcomes	Quigley and Hein (Turesky) plaque index, Loe and Silness gingival index, whole mouth at 6 weeks. No adverse events/ effects recorded.
Notes	Funding not stated. No brushing for 12 hours and pre-brushing data used.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

Sharma 2000

Methods	RCT, parallel, single blind, 30 days, n 62 with 1 drop out.
Participants	Canada, adults, 18 to 62 years, good general and oral health, 26M: 36F.
Interventions	Colgate Actibrush versus Colgate diamond headed manual for 1 min twice daily. Use of timer not stated.
Outcomes	Navy (Rustogi) plaque index, Loe and Silness (Chilton) gingival index, full mouth at 30 days, no adverse effects.
Notes	Manufacturer funded. No pre-examination brushing for 8 hours.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Singh unpublished

Methods	RCT, parallel, single blind, 60 days, n 73 with 8 drop outs.
Participants	USA, orthodontic patients, 11 to 19 years, >19 teeth, good health, no prophylaxis within last month.
Interventions	Pulse Plaque Remover versus Oral-B 35, 2 mins. Frequency not stated. Use of timer not stated.
Outcomes	Quigley and Hein (Turesky) plaque index, Papillary Bleeding Score (Loesche) for gingivitis.
Notes	Manufacturer funded. No pre-examination brushing for 12 to 24 hours.

Risk of bias

Item	Authors' judgement	Description

Singh unpublished (*Continued*)

Allocation concealment?	Unclear	B - Unclear

Soparkar 1964

Methods	RCT, parallel, single blind, 11 weeks, n 270 with 32 drop outs.
Participants	USA, college students non-dental.
Interventions	Unknown action powered versus manual with normal regimen. Use of timer not stated.
Outcomes	Quigley and Hein gingival index at 11 weeks. Anterior teeth only.
Notes	No pre-examination instructions reported.

Risk of bias

Item	**Authors' judgement**	**Description**
Allocation concealment?	Unclear	B - Unclear

Soparkar 2000

Methods	RCT, parallel, single blind, 30 days, n 66 with 3 drop outs.
Participants	USA, healthy adults, 18 to 70 years, 25 M: 38 F (data on drop outs not presented).
Interventions	Colgate Actibrush versus ADA approved manual brush, 1 min twice daily. Use of timer not stated.
Outcomes	Rustogi modification of Navy Plaque Index and Mandel-Chilton modification of Loe-Silness gingival index, all surfaces.
Notes	Manufacturer funded. No pre-examination brushing for 8 hours.

Risk of bias

Item	**Authors' judgement**	**Description**
Allocation concealment?	Unclear	B - Unclear

Sowinski 2000

Methods	RCT, parallel, single blind, 30 days, n 110 with no drop outs.
Participants	USA, adults, 18 to 70 years, >15 teeth, no Orthodontic appliances, no oral disease, 22M: 88 F.

Sowinski 2000 (*Continued*)

Interventions	Colgate Actibrush versus Colgate diamond head manual, 1 min twice daily. Use of timer not stated.
Outcomes	Quigley and Hein (Turesky) and Loe and Silness gingival index, full mouth at 30 days. No adverse events.
Notes	Manufacturer funded. No pre-examination brushing for 24 hours.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Stabholz 1996

Methods	RCT, parallel, single blinded, n 56 with 4 drop outs, 60 days.
Participants	Israel, general population, no medical conditions.
Interventions	Plaq and White A to Z technology versus Oral B 35 as per normal regimen. Use of timer not stated.
Outcomes	Quigley and Hein (Turesky) and Löe and Silness gingival and Eastman BOP indices on Ramfjord teeth at 15 and 30 days. No difference in soft tissue trauma between brush types.
Notes	Participants asked to refrain from brushing for 12 hours prior to each assessment.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Stoltze 1994

Methods	RCT, parallel, unclear blinding method used, n 40 with 2 drop outs, 6 weeks.
Participants	Denmark, young adults 18 to 30 years, with plaque and gingival scores > 1, > 20 teeth, no medical problems.
Interventions	Braun Oral B Plak Control D5 versus Tandex 40 manual, 2 mins twice daily. Use of timer not stated.
Outcomes	Silness and Löe plaque index, Löe and Silness gingival index at all sites, 1, 2 and 6 weeks. Whole mouth recording PI and GI. No gingival abrasion reported.
Notes	No pre-examination instructions reported.

Risk of bias

Stoltze 1994 (*Continued*)

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Terezhalmy 1995a

Methods	RCT, parallel, single blind, 6 months, n 60 with 14 drop outs.
Participants	USA, adults, good health and free of oral pathology.
Interventions	Ultra-sonex ultrasonic versus Oral B manual 3 min twice daily. Use of timer not stated.
Outcomes	Quigley and Hein (Turesky) plaque index and Löe and Silness gingival index at all sites and Eastman Bleeding on Probing index on contralateral Ramjford teeth. Assessed at 15 and 30 days and 6 months. No soft tissue trauma.
Notes	Participants asked to refrain from brushing 12 to 14 hours prior to assessment.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Toto 1966

Methods	RCT, parallel, blinding unclear, 120 days, n 527 with 17 drop outs.
Participants	USA, boarding school children , 6 to 18 years.
Interventions	Sunbeam cordless versus unspecified manual. Frequency not stated. Use of timer not stated.
Outcomes	PMA index, whole mouth.
Notes	Funding not clear. No pre-examination instructions.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Tritten 1996

Methods	RCT, parallel, single blind, 12 weeks, n 60 with 4 drop outs.
Participants	USA, adults 18 to 65 years, dental hospital patients, no professional cleaning previous 3 months, minimum 20 teeth, no previous periodontal treatment and unaware of active pregnancy.
Interventions	Sonicare versus Butler 311, 2 minutes twice daily. Timer supplied.
Outcomes	Quigley and Hein (Turesky) plaque index all teeth, Löe and Silness gingival index Ramfjord teeth. Gingival abrasion seen in five manual and one powered brush subjects.
Notes	Manufacturer funded. Pre-brushing evaluation.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

van der Weijden 1994

Methods	RCT, parallel, single blind, 8 months, n 87 with 10 drop outs.
Participants	Netherlands, non-dental students, bleeding on probing at least 35% of sites and modified gingival index of at least 1, no previous experience of electric toothbrush. Healthy. No ortho. No pockets > 5 mm.
Interventions	Braun Plak control versus Butler Gum 311 for 2 mins. Timer supplied.
Outcomes	Silness and Löe plaque index, Lobene gingival index at all sites at 1, 2, 5, 8 months. Whole mouth recording PI and GI. Twelve manual brush subjects and five powered brush subjects with gingival abrasion. Calculus scored no difference in change between groups.
Notes	Participants asked to brush thoroughly, but not within 1 hour of assessment.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Van Swol 1996

Methods	RCT, parallel, double blind, 6 months, n 72 with 7 drop outs.
Participants	USA, adult, > 20 teeth, not using mouthrinses, 9 M: 55 F.

Van Swol 1996 (*Continued*)

Interventions	HyG ionic brush (active) versus HyG ionic brush (non-active), usual time twice daily. Use of timer not stated.
Outcomes	Quigley and Hein plaque index and Loe and Silness gingival index, whole mouth at 3 and 6 months. Adverse events not reported despite being collected.
Notes	Manufacturer funded. No pre-examination instructions.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Walsh 1989

Methods	RCT, parallel, single blind, n 108, 6 months, drop outs unclear.
Participants	USA, adults from University and dental clinics, 18 to 65 years, > 20 teeth, no dental/medical problems, gingival index > 1 on six+ sites of 18 sites probed on Ramfjord teeth.
Interventions	LPA/Broxo powered versus Oral B 40 manual, twice daily. Use of timer not stated.
Outcomes	Silness and Löe plaque index on Ramfjord teeth, BOP on Ramfjord teeth at 3, 6 months. No soft tissue changes reported. Stain reported as no difference between brush types.
Notes	No pre-examination instructions reported.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	No	C - Inadequate

Warren 2001

Methods	RCT, parallel, single blind, 12 weeks, n 110 with 9 drop outs.
Participants	USA, adult volunteers, 18 to 65 years, > 18 teeth, plaque index > 1.8, non-smokers, with no medical problems.
Interventions	Braun Oral B D 17 versus ADA standard manual, 2 mins twice daily. Timer supplied.
Outcomes	Quigley and Hein (Turesky) plaque index, Löe and Silness gingival index and modified Löe and Silness Bleeding index, on all sites at 1, 3 months. Whole mouth recording PI and GI. No soft tissue changes reported.

Warren 2001 (*Continued*)

Notes	Manufacturer funded. Participants asked to refrain from brushing 12 to 18 hours prior to assessment.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

Wilson 1993

Methods	RCT, parallel, single blind, 12 months, n 32 with 3 drop outs.
Participants	USA, adults, 18+ years, minimum 20 teeth, at least 50% tooth surface plaque coverage (O'Leary), bleeding score > 0.75. Barnett-Muhleman Bleeding Index, no medical problems, no orthodontics, no untreated perio or pockets > 6 mm.
Interventions	Interplak, Bausch and Lomb versus Butler 311, 3 minutes. Use of timer not stated.
Outcomes	Quigley and Hein (Turesky) plaque index, Barnett Muhleman gingival index on all sites at 1, 2, 6, 9 and 12 months. Whole mouth recording PI and GI. No difference in gingival abrasion found between brush types.
Notes	Participants asked to brush 1 hour prior to assessment.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Yankell 1996

Methods	RCT, parallel, single blind, 4 weeks, n 66 with 1 drop out.
Participants	USA, children with 4 of 6 Ramfjord teeth present, no medical problems.
Interventions	Rowenta Dentiphant versus Oral B 20, 1 min twice daily. Use of timer not stated.
Outcomes	Quigley and Hein (Turesky) plaque and Löe and Silness (Lobene) gingival indices on Ramjford teeth at 2 and 4 weeks. No soft tissue changes reported.
Notes	Manufacturer funded. Pre-brushing evaluation.

Risk of bias

Yankell 1996 (*Continued*)

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Yankell 1997

Methods	RCT, parallel, single blind, 30 days, n 128 with 13 drop outs.
Participants	USA, adults, 18 to 50 years, > 18 teeth, no current orthodontic bands, no medical problems.
Interventions	Rowenta Plaque Dentacontrol Plus versus Sonicare versus Braun Oral B Ultra versus Oral B P35, 2 min twice daily. Timer specified for powered. Excluded Rowenta data which were 5 min twice daily.
Outcomes	Quigley and Hein (Turesky) plaque and Eastman bleeding indices on Ramfjord teeth and also Löe and Silness (Lobene) gingival index on whole mouth at 4 weeks. No soft tissue changes reported.
Notes	Rowenta data excluded due to extended brushing period. Participants asked to refrain from brushing 10 to 16 hours before evaluation.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Yukna 1993b

Methods	RCT, parallel, single blind, 6 months, n 42 with 2 drop outs.
Participants	USA, adults with past periodontal surgical treatment. Excluded if on antibiotics/NSAIDS or orthodontic appliances.
Interventions	Interplak, Bausch and Lomb versus unspecified manual brush. Use of timer not stated.
Outcomes	Quigley and Hein and O'Leary plaque indices, Lobene gingival index and Bleeding on probing. Whole mouth recording PI and GI. 4 of 20 powered brushes had mechanical failure.
Notes	Manufacturer funded.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Zimmer 2002

Methods	RCT, parallel, single blind, 8 weeks, n 64 with 1 dropout.
Participants	Germany, adults, 18 to 56 years good general health, no periodontal disease, 32M: 32F.
Interventions	Ultra Sonex Ultima versus Aronal compact manual, 3 mins twice daily. Timer supplied.
Outcomes	Quigley and Hein (Turesky) and Papillary bleeding index, full mouth at 4 and 8 weeks.
Notes	Manufacturer funded.

Risk of bias

Item	**Authors' judgement**	**Description**
Allocation concealment?	Yes	A - Adequate

GI = gingival index; PI = plaque index; RCT= randomised controlled trial

Characteristics of excluded studies *[ordered by study ID]*

Aass 2000	Less than 28 days
Adriaens 1999	Manual only
Agerholm 1991	Manual only
Ainamo 1991	Contacted authors for more information, no reply after 3 months
Albers 1988	Less than 28 days
Anaise 1976	Less than 28 days
Andreana 1998	No movement of powered head
Arceneaux 1996	Less than 28 days
Ash 1964	Not RCT
Ash 1967	Contacted authors for more information, no reply after 3 months
Bader 1995a	Not RCT
Bader 1997	Not powered versus manual toothbrushing
Bader 1999	Not powered versus manual toothbrushing

(*Continued*)

Barnes 1999	Not powered versus manual toothbrushing
Barnes 2003	Less than 28 days
Bartizek 2002	Less than 28 days
Bastos 1995	Not powered versus manual toothbrushing
Bhanji 2002	Outcome not under consideration
Biesbrock 2002	Not RCT
Biesbrock 2002a	Less than 28 days
Blahut 1993	Brush used by another person
Borutta 1997	Less than 28 days
Boyd 1989a	Not RCT
Boyd 1989b	Not RCT
Boyd 1994	Combined interventions
Boyd 1997	Less than 28 days
Braccini 1964	Not powered versus manual toothbrushing
Bratel 1988	Potential high for compromised self toothbrushing efficacy
Bratel 1991	Potential high for compromised self toothbrushing efficacy
Breuer 1989	Not powered versus manual toothbrushing
Buchmann 1987	Less than 28 days
Burch 1994	Combined intervention
Chaikin 1965	Less than 28 days
Chasens 1968	Not RCT
Chava 2000	Not powered versus manual toothbrushing
Chilton 1962	Split mouth
Christou 1998	Combined intervention

(*Continued*)

Ciancio 1990	Less than 28 days
Ciancio 1998	Contacted authors for more information, no reply after 3 months
Ciancio 2002a	Not RCT
Claydon 1995	Not powered versus manual toothbrushing
Cohen 1964	Potential high for compromised self toothbrushing efficacy
Conforti 2001	Not powered versus manual toothbrushing
Conforti 2003	Less than 28 days
Conroy 1965	Less than 28 days
Conroy 1966	Less than 28 days
Coontz 1983	Less than 28 days
Coontz 1985	Less than 28 days
Crawford 1975	Not RCT
Cronin 1996	Not powered versus manual toothbrushing
Cronin 1996a	Combined intervention
Cronin 2000	Less than 28 days
Cronin 2001	Data on number of participants in each group not presented. The study will be included once these data are determined.
Cronin 2002	Not powered versus manual toothbrushing
Cross 1962b	Less than 28 days
Danser 1998	Less than 28 days
Danser 1998a	Not powered versus manual toothbrushing
Danser 2000	Less than 28 days
Danser 2003	Split-mouth design
Derbyshire 1964	Less than 28 days

(*Continued*)

Doherty 1998	Not powered versus manual toothbrushing
Doherty 1999	Less than 28 days
Doll 1999	Less than 28 days
Donly 2002	Not powered versus manual toothbrushing
Dorfer 2001	Less than 28 days
Dorfer 2001a	Split-mouth design
Driesen 1998	Laboratory study design
Dunkin 1975	Less than 28 days
Elliott 1963	Less than 28 days
Ernst 1998	Not powered versus manual toothbrushing
Fishwick 1998	Not RCT
Fourel 1974	Split mouth
Fraleigh 1965	Split mouth
Gjebre 1995	Not powered versus manual toothbrushing
Glavind 1986	Not RCT
Golden 1964	Not powered versus manual toothbrushing
Goldman 1975	Less than 28 days
Grossman 1994	Less than 28 days
Grossman 1995	Not powered versus manual toothbrushing
Grossman 1996	Less than 28 days
Grossman 1997	Not powered versus manual toothbrushing
Haffajee 2001b	Outcomes not under consideration
Hall 1971	Potential high for compromised self toothbrushing efficacy
Hansen 1998	Laboratory study

(*Continued*)

Hansen 1999	Laboratory study
He 2001	Outcomes not under consideration
Heasman 1998	Not RCT inadequate control
Heasman 2001	Less than 28 days
Hefti 2000	Not powered versus manual toothbrushing
Heins 2002	Less than 28 days
Heintze 1996	Combined intervention
Hellstadius 1993	Not powered versus manual toothbrushing
Hirsch 1965	Laboratory study
Hoover 1962	Less than 28 days
Horowitz 1992	Not RCT
Hotta 1992	Less than 28 days
Howorko 1993	Less than 28 days
Hunt 2002	Not RCT
Isaacs 1998	Not powered versus manual toothbrushing
Isaacs 1999	Contacted authors for more information, no reply after 3 months
Jackson 1991	Not RCT
Jongenelis 1997	Less than 28 days
Kambhu 1993	Potential high for compromised self toothbrushing efficacy
Kanchanakamol 1992	Not powered versus manual toothbrushing
Kanchanakamol 1993	Not powered versus manual toothbrushing
Kaschny 1999	Not RCT
Kilicoglu 1997	Not powered versus manual toothbrushing
Killoy 1989	Contacted authors for more information, no reply after 3 months

(*Continued*)

Killoy 1993	Contacted authors for more information, no reply after 3 months
Kugel 2002	Not an RCT
Kugel 2002a	Not an RCT
Kuhner 1993	Not powered versus manual toothbrushing
Lamendola-Site 1998	No mechanical action of brush head
Lange 1978	Less than 28 days
Leftkowitz 1962	Less than 28 days
Lim 1995	Contacted authors for more information, no reply after 3 months
Long 1985	Split mouth
Love 1988	Contacted authors for more information, no reply after 3 months
Love 1993	Combined intervention
Lundergan 1988	Less than 28 days
Manhold 1965	Outcomes not under consideration
Mantokoudis 2001	Less than 28 days
Mayer 1978	Less than 28 days
Mayer 1988	Split mouth
McCracken 2000	Not powered versus manual toothbrushing
McDaniel 1997	Not powered versus manual toothbrushing
McInnes 1994	Outcomes not under consideration
McKendrick 1968	Not RCT
McKinney 1990	Not powered versus manual toothbrushing
McLey 1995	Not RCT
McLey 1997	Laboratory study
Moran 1995	Less than 28 days

(*Continued*)

Moran 1995b	Less than 28 days
Moritis 2002	Less than 28 days
Morris 1997	Contacted authors for more information, no reply after 3 months
Moschen 1999	Less than 28 days
Mueller 1987	Contacted authors for more information, after reply still not adequate to be included
Murray 1989	Outcomes not under consideration
Nathoo 2000	Not RCT
Niemi 1986	Less than 28 days
Niemi 1987	Less than 28 days
Niemi 1988	Less than 28 days
Noro 1995	Not powered versus manual toothbrushing
Nowak 2002	Not powered versus manual toothbrushing
Ohm 1967	Not RCT
Ojima 2003	Less than 28 days
Owen 1972	Cross-over study, contacted authors for more information, no reply after 3 months
Palmer 1999	Contacted authors for more information, no reply after 3 months
Park 1997	Not teeth (e.g. implants, enamel sections on dentures)
Plagmann 1978	Not human
Platt 2002	Less than 28 days
Powers 1967	Less than 28 days
Preber 1991	Less than 28 days
Priestland 1993	Not powered versus manual toothbrushing
Putt 1999	Not powered versus manual toothbrushing
Putt 2001	Not powered versus manual toothbrushing

(*Continued*)

Quigley 1962	Less than 28 days
Quirynen 1994	Split mouth
Raetzke 2001	Not powered versus manual toothbrushing
Rapley 1994	Laboratory study
Rashid 1998	Less than 28 days
Read 1981	Potential high for compromised self toothbrushing efficacy
Renton-Harper 1999	Not powered versus manual toothbrushing
Renton-Harper 2001	Less than 28 days
Reynolds 1998	Not powered versus manual toothbrushing
Robinson 1997	Not powered versus manual toothbrushing
Ruhlman 2001	Less than 28 days
Ruhlman 2002	Less than 28 days
Sarker 1997	Laboratory study
Sato 1995	Less than 28 days
Schemehorn 1995	Laboratory study
Schifter 1983	Less than 28 days
Schmage 1999	Split mouth
Schuler 1996	Abstract only
Schwarz 1990	Not powered versus manual toothbrushing
Sgan-Cohen 1995	Not powered versus manual toothbrushing
Sharma 1994	Not powered versus manual toothbrushing
Sharma 1998	Not powered versus manual toothbrushing
Sharma 1999	Not powered versus manual toothbrushing

(*Continued*)

Sharma 2000a	Not powered versus manual toothbrushing
Sharma 2000b	Not powered versus manual toothbrushing
Sharma 2001a	Split-mouth design
Sharma 2002	Outcomes not under consideration
Shaw 1983	Potential high for compromised self toothbrushing efficacy
Shibly 1997	Not powered versus manual toothbrushing
Siebert 2000	Not powered versus manual toothbrushing
Silverstone 1992	Contacted authors for more information, no reply after 3 months
Sjogren 1998	Less than 28 days
Smith 1964	Cross-over study, contacted authors for more information, no reply after 3 months
Stadtler 1984	Less than 28 days
Stout 1997	Outcome not under consideration
Swenson 1967	Contacted authors for more information, no reply after 3 months
Taylor 1995	Less than 28 days
Tenenbaum 1984	Less than 28 days
Terezhalmy 1994	Not RCT
Thienpont 2001	Cross-over study, contacted authors for more information, no reply after 3 months
Timmerman 1995	Less than 28 days
Timmerman 2001	Not powered versus manual toothbrushing
Timmerman 2001a	Not powered versus manual toothbrushing
Toh 1995	Not powered versus manual toothbrushing
Toto 1961	Not RCT
Toto 1967	Outcomes not under consideration
Trimpeneers 1996	Duplicate abstract of included study

(*Continued*)

Trimpeneers 1997	Cross-over study, contacted authors for more information, no reply after 3 months
Trombeli 1995	Less than 28 days
Tscharre-Z 1989	Combined interventions
Twetman 1997	Not powered versus manual toothbrushing
van der Weij 1993b	Not powered versus manual toothbrushing
van der Weijden 1993	Less than 28 days
van der Weijden 1995	Not powered versus manual toothbrushing
van der Weijden 1996	Less than 28 days
van der Weijden 1998	Split-mouth study
van der Weijden 1999	Not powered versus manual toothbrushing
van der Weijden 2001	Not powered versus manual toothbrushing
van der Weijden 2002	Not powered versus manual toothbrushing
van der Weijden1996a	Not powered versus manual toothbrushing
van der Weijden1996b	Not powered versus manual toothbrushing
van der Weijden2001a	Split-mouth study
van der Weijden2002a	Split-mouth study
van Venrooy 1985	Less than 28 days
Vervliet 1989	Split mouth
Walsh 1984	Less than 28 days
Warren 1998	Not RCT
Warren 2000	Not powered versus manual toothbrushing
White 1996	Not RCT
Whitmyer 1998	Potential high for compromised self toothbrushing efficacy
Wiedemann 2001	Split mouth

(*Continued*)

Wilcoxon 1991	Cross-over study, contacted authors for more information, no reply after 3 months
Willershausen 2001	Not RCT
Williams 2003	Less than 28 days
Williams 2003a	Less than 28 days
Wilson 1991	Contacted authors for more information, no reply after 3 months
Womack 1968	Not RCT
Ximenez-Fyvie 2000	Not powered versus manual toothbrushing
Yankell 1985	Not RCT
Yankell 1992	Not powered versus manual toothbrushing
Yankell 1994	Less than 28 days
Yankell 1995	Not powered versus manual toothbrushing
Yankell 1996a	Not powered versus manual toothbrushing
Yankell 1997a	Laboratory study
Yankell 1999	Laboratory study
Youngblood 1985	Laboratory study
Yukna 1993a	Combined intervention
Zimmer 1999	Less than 28 days

RCT = randomised controlled trial

DATA AND ANALYSES

Comparison 1. Side to side powered toothbrushes versus manual toothbrushes

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Plaque scores at 1 to 3 month at all sites	6	402	Std. Mean Difference (IV, Random, 95% CI)	-0.42 [-0.91, 0.07]
1.1 Quigley Hein (Turesky)	4	324	Std. Mean Difference (IV, Random, 95% CI)	-0.14 [-0.36, 0.08]
1.2 Silness and Löe	2	78	Std. Mean Difference (IV, Random, 95% CI)	-1.72 [-4.93, 1.49]
2 Gingival scores at 1 to 3 months at all sites	8	627	Std. Mean Difference (IV, Random, 95% CI)	-0.44 [-0.91, 0.02]
2.1 Löe and Silness	4	174	Std. Mean Difference (IV, Random, 95% CI)	-0.60 [-1.34, 0.14]
2.2 Lobene gingival index	3	410	Std. Mean Difference (IV, Random, 95% CI)	-0.39 [-1.24, 0.46]
2.3 BOP	1	43	Std. Mean Difference (IV, Random, 95% CI)	-0.10 [-0.70, 0.50]
3 Plaque scores at > 3 months	2	220	Std. Mean Difference (IV, Random, 95% CI)	0.03 [-0.23, 0.29]
3.1 Quigley Hein (Turesky)	1	166	Std. Mean Difference (IV, Random, 95% CI)	0.04 [-0.26, 0.34]
3.2 Silness and Löe	1	54	Std. Mean Difference (IV, Random, 95% CI)	Not estimable
4 Gingival scores at > 3 months	2	220	Std. Mean Difference (IV, Random, 95% CI)	0.12 [-0.14, 0.39]
4.1 Löe and Silness	1	54	Std. Mean Difference (IV, Random, 95% CI)	Not estimable
4.2 Lobene Gingival Index	1	166	Std. Mean Difference (IV, Random, 95% CI)	0.16 [-0.14, 0.47]

Comparison 2. Counter oscillation

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Plaque scores at 1 to 3 month at all sites	4	184	Std. Mean Difference (IV, Random, 95% CI)	-0.07 [-0.36, 0.22]
1.1 Quigley Hein (Turesky)	4	184	Std. Mean Difference (IV, Random, 95% CI)	-0.07 [-0.36, 0.22]
2 Gingivitis scores at 1 to 3 months at all sites	4	172	Std. Mean Difference (IV, Random, 95% CI)	-0.04 [-0.52, 0.45]
2.1 Gingival Index Löe	2	103	Std. Mean Difference (IV, Random, 95% CI)	-0.11 [-1.22, 0.99]
2.2 Lobene gingival index	1	40	Std. Mean Difference (IV, Random, 95% CI)	-0.03 [-0.65, 0.59]
2.3 BOP	1	29	Std. Mean Difference (IV, Random, 95% CI)	0.06 [-0.68, 0.79]
3 Plaque scores at > 3 months	2	69	Std. Mean Difference (IV, Random, 95% CI)	-0.63 [-1.11, -0.14]
3.1 Quigley Hein (Turesky)	2	69	Std. Mean Difference (IV, Random, 95% CI)	-0.63 [-1.11, -0.14]
4 Gingival scores at > 3 months	2	69	Std. Mean Difference (IV, Random, 95% CI)	-0.19 [-0.66, 0.29]
4.1 Lobene gingival index	1	40	Std. Mean Difference (IV, Random, 95% CI)	-0.18 [-0.80, 0.44]
4.2 BOP	1	29	Std. Mean Difference (IV, Random, 95% CI)	-0.19 [-0.93, 0.54]

Comparison 3. Rotation oscillation

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Plaque scores at 1 to 3 month at all sites	15	1181	Std. Mean Difference (IV, Random, 95% CI)	-0.43 [-0.72, -0.14]
1.1 Quigley Hein (Turesky)	10	834	Std. Mean Difference (IV, Random, 95% CI)	-0.35 [-0.73, 0.03]
1.2 Silness and Löe	2	115	Std. Mean Difference (IV, Random, 95% CI)	-1.17 [-2.74, 0.40]
1.3 Visible plaque index Ainamo Bay	1	111	Std. Mean Difference (IV, Random, 95% CI)	-0.26 [-0.63, 0.12]
1.4 Ortho modification of Silness and Löe	1	60	Std. Mean Difference (IV, Random, 95% CI)	Not estimable
1.5 Navy plaque index mod Rustogi	1	61	Std. Mean Difference (IV, Random, 95% CI)	-0.71 [-1.22, -0.19]
2 Gingival scores at 1 to 3 months at all sites	16	1256	Std. Mean Difference (IV, Random, 95% CI)	-0.62 [-0.90, -0.34]
2.1 Löe and Silness mod Lobene	1	69	Std. Mean Difference (IV, Random, 95% CI)	-0.67 [-1.16, -0.18]
2.2 Löe and Silness	9	663	Std. Mean Difference (IV, Random, 95% CI)	-0.74 [-1.16, -0.32]
2.3 Loe and Silness mod Chilton	2	124	Std. Mean Difference (IV, Random, 95% CI)	-1.23 [-1.90, -0.56]
2.4 Lobene gingival index	3	290	Std. Mean Difference (IV, Random, 95% CI)	-0.11 [-0.46, 0.24]
2.5 BOP Ainamo Bay	1	110	Std. Mean Difference (IV, Random, 95% CI)	-0.21 [-0.58, 0.17]
3 Plaque scores at > 3 months	3	266	Std. Mean Difference (IV, Random, 95% CI)	-1.29 [-2.67, 0.08]
3.1 Quigley Hein (Turesky)	1	78	Std. Mean Difference (IV, Random, 95% CI)	-2.95 [-3.60, -2.30]
3.2 Silness and Löe	1	77	Std. Mean Difference (IV, Random, 95% CI)	-0.73 [-1.19, -0.26]
3.3 Visible plaque index Ainamo Bay	1	111	Std. Mean Difference (IV, Random, 95% CI)	-0.28 [-0.66, 0.09]
4 Gingival scores at > 3 months	4	423	Std. Mean Difference (IV, Random, 95% CI)	-0.51 [-0.76, -0.25]
4.1 Lobene gingival index	2	234	Std. Mean Difference (IV, Random, 95% CI)	-0.36 [-0.63, -0.09]
4.2 BOP Ainamo Bay	2	189	Std. Mean Difference (IV, Random, 95% CI)	-0.66 [-1.08, -0.24]

Comparison 4. Circular

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Plaque scores at 1 to 3 month at all sites	3	168	Std. Mean Difference (IV, Random, 95% CI)	-0.06 [-0.36, 0.25]
1.1 Quigley Hein (Turesky)	2	128	Std. Mean Difference (IV, Random, 95% CI)	-0.02 [-0.37, 0.33]
1.2 Silness and Löe	1	40	Std. Mean Difference (IV, Random, 95% CI)	-0.17 [-0.80, 0.45]
2 Gingival scores at 1 to 3 months at all sites	3	168	Std. Mean Difference (IV, Random, 95% CI)	-0.39 [-0.95, 0.18]
2.1 GI Löe Silness	2	103	Std. Mean Difference (IV, Random, 95% CI)	-0.35 [-1.34, 0.64]
2.2 Lobene	1	65	Std. Mean Difference (IV, Random, 95% CI)	-0.50 [-0.99, -0.00]
3 Plaque scores at > 3 months	1	40	Std. Mean Difference (IV, Random, 95% CI)	0.04 [-0.58, 0.66]
3.1 Silness and Löe	1	40	Std. Mean Difference (IV, Random, 95% CI)	0.04 [-0.58, 0.66]

4 Gingival scores at > 3 months	1	40	Std. Mean Difference (IV, Random, 95% CI)	-0.30 [-0.92, 0.33]
4.1 Löe and Silness	1	40	Std. Mean Difference (IV, Random, 95% CI)	-0.30 [-0.92, 0.33]

Comparison 5. Ultrasonic

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Plaque scores at 1 to 3 month at all sites	3	171	Std. Mean Difference (IV, Random, 95% CI)	-1.13 [-2.42, 0.15]
1.1 Quigley Hein (Turesky)	3	171	Std. Mean Difference (IV, Random, 95% CI)	-1.13 [-2.42, 0.15]
2 Gingival scores at 1 to 3 months at all sites	3	171	Std. Mean Difference (IV, Random, 95% CI)	-0.64 [-1.04, -0.24]
2.1 Löe and Silness	2	108	Std. Mean Difference (IV, Random, 95% CI)	-0.55 [-1.17, 0.07]
2.2 Papillary bleeding index	1	63	Std. Mean Difference (IV, Random, 95% CI)	-0.82 [-1.34, -0.31]
3 Plaque scores at > 3 months at all sites	1	46	Std. Mean Difference (IV, Random, 95% CI)	0.20 [-0.38, 0.78]
3.1 Quigley Hein	1	46	Std. Mean Difference (IV, Random, 95% CI)	0.20 [-0.38, 0.78]
4 Gingival scores at > 3 months	1	46	Std. Mean Difference (IV, Random, 95% CI)	Not estimable
4.1 Löe and Silness	1	46	Std. Mean Difference (IV, Random, 95% CI)	Not estimable

Comparison 6. Unknown or other action

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Plaque scores at 1 to 3 months at all sites	1	57	Std. Mean Difference (IV, Random, 95% CI)	-0.32 [-0.84, 0.20]
1.1 Quigley Hein (Turesky)	1	57	Std. Mean Difference (IV, Random, 95% CI)	-0.32 [-0.84, 0.20]
2 Gingival scores at 1 to 3 months at all sites	3	360	Std. Mean Difference (IV, Random, 95% CI)	-0.38 [-0.59, -0.17]
2.1 Löe and Sillness	2	122	Std. Mean Difference (IV, Random, 95% CI)	-0.24 [-0.60, 0.12]
2.2 Quigley and Hein	1	238	Std. Mean Difference (IV, Random, 95% CI)	-0.46 [-0.73, -0.19]
3 Gingival scores > 3 months at all sites	1	510	Std. Mean Difference (IV, Random, 95% CI)	-0.16 [-0.34, 0.02]
3.1 PMA	1	510	Std. Mean Difference (IV, Random, 95% CI)	-0.16 [-0.34, 0.02]

Comparison 7. Ionic brushes

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Plaque scores at 1 to 3 months at all sites	3	179	Std. Mean Difference (IV, Fixed, 95% CI)	-0.28 [-0.58, 0.01]
1.1 Quigley Hein (Turesky)	3	179	Std. Mean Difference (IV, Fixed, 95% CI)	-0.28 [-0.58, 0.01]
2 Gingival scores at 1 to 3 months at all sites	2	116	Std. Mean Difference (IV, Fixed, 95% CI)	-0.14 [-0.51, 0.22]
2.1 Loe Silness	2	116	Std. Mean Difference (IV, Fixed, 95% CI)	-0.14 [-0.51, 0.22]
3 Plaque scores at > 3 months at all sites	1	64	Std. Mean Difference (IV, Fixed, 95% CI)	-1.01 [-1.53, -0.49]
3.1 Quigley Hein (Turesky)	1	64	Std. Mean Difference (IV, Fixed, 95% CI)	-1.01 [-1.53, -0.49]
4 Gingival scores at > 3 months at all sites	1	64	Std. Mean Difference (IV, Fixed, 95% CI)	-0.78 [-1.29, -0.27]
4.1 Loe and Silness	1	64	Std. Mean Difference (IV, Fixed, 95% CI)	-0.78 [-1.29, -0.27]

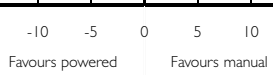
Analysis 1.1. Comparison 1 Side to side powered toothbrushes versus manual toothbrushes, Outcome 1 Plaque scores at 1 to 3 month at all sites.

Review: Manual versus powered toothbrushing for oral health

Comparison: 1 Side to side powered toothbrushes versus manual toothbrushes

Outcome: 1 Plaque scores at 1 to 3 month at all sites

Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
1 Quigley Hein (Turesky)							
Glass 1965	83	0.17 (0.2)	83	0.21 (0.29)		20.8 %	-0.16 [-0.46, 0.14]
Johnson 1994	24	1.38 (0.6)	19	1.56 (0.37)		16.8 %	-0.35 [-0.95, 0.26]
Tritten 1996	29	2.14 (0.39)	27	2.21 (0.29)		17.9 %	-0.20 [-0.73, 0.33]
Yankell 1997	31	2.72 (0.44)	28	2.66 (0.44)		18.1 %	0.13 [-0.38, 0.65]
Subtotal (95% CI)	**167**		**157**			**73.7 %**	**-0.14 [-0.36, 0.08]**
Heterogeneity: Tau² = 0.0; Chi² = 1.61, df = 3 (P = 0.66); I² =0.0%							
Test for overall effect: Z = 1.23 (P = 0.22)							
2 Silness and Le							
Ho 1997	12	1.15 (0.17)	12	2.33 (0.44)		8.5 %	-3.42 [-4.74, -2.09]
Walsh 1989	27	0.9 (0.7)	27	1 (0.7)		17.8 %	-0.14 [-0.67, 0.39]
Subtotal (95% CI)	**39**		**39**			**26.3 %**	**-1.72 [-4.93, 1.49]**



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Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
Heterogeneity: Tau² = 5.10; Chi² = 20.17, df = 1 (P<0.00001); I² =95%							
Test for overall effect: Z = 1.05 (P = 0.29)							
Total (95% CI)	**206**		**196**			**100.0 %**	**-0.42 [-0.91, 0.07]**
Heterogeneity: Tau² = 0.28; Chi² = 24.57, df = 5 (P = 0.00017); I² =80%							
Test for overall effect: Z = 1.67 (P = 0.094)							

Analysis 1.2. Comparison 1 Side to side powered toothbrushes versus manual toothbrushes, Outcome 2 Gingival scores at 1 to 3 months at all sites.

Review: Manual versus powered toothbrushing for oral health

Comparison: 1 Side to side powered toothbrushes versus manual toothbrushes

Outcome: 2 Gingival scores at 1 to 3 months at all sites

Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
1 Le and Silness							
Ho 1997	12	1.42 (0.27)	12	1.96 (0.14)		8.3 %	-2.42 [-3.52, -1.33]
O'Beirne 1996	20	0.43 (0.36)	20	0.53 (0.49)		12.1 %	-0.23 [-0.85, 0.39]
Tritten 1996	29	1.12 (0.24)	27	1.19 (0.21)		12.8 %	-0.31 [-0.83, 0.22]
Walsh 1989	27	1.2 (0.5)	27	1.2 (0.4)		12.8 %	0.0 [-0.53, 0.53]
Subtotal (95% CI)	**88**		**86**			**46.0 %**	**-0.60 [-1.34, 0.14]**
Heterogeneity: Tau² = 0.44; Chi² = 15.57, df = 3 (P = 0.001); I² =81%							
Test for overall effect: Z = 1.59 (P = 0.11)							
2 Lobene gingival index							
Glass 1965	83	1.4 (0.53)	83	1.37 (0.55)		14.4 %	0.06 [-0.25, 0.36]
Lobene 1964a	92	0.39 (0.24)	93	0.72 (0.32)		14.4 %	-1.16 [-1.47, -0.85]
Yankell 1997	31	2.13 (0.2)	28	2.14 (0.32)		13.0 %	-0.04 [-0.55, 0.47]
Subtotal (95% CI)	**206**		**204**			**41.8 %**	**-0.39 [-1.24, 0.46]**
Heterogeneity: Tau² = 0.52; Chi² = 33.03, df = 2 (P<0.00001); I² =94%							
Test for overall effect: Z = 0.90 (P = 0.37)							
3 BOP							
Johnson 1994	24	1.26 (0.18)	19	1.28 (0.21)		12.2 %	-0.10 [-0.70, 0.50]

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Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
Subtotal (95% CI)	**24**		**19**			**12.2 %**	**-0.10 [-0.70, 0.50]**
Heterogeneity: not applicable							
Test for overall effect: Z = 0.33 (P = 0.74)							
Total (95% CI)	**318**		**309**			**100.0 %**	**-0.44 [-0.91, 0.02]**
Heterogeneity: Tau² = 0.36; Chi² = 49.99, df = 7 (P<0.00001); I² =86%							
Test for overall effect: Z = 1.88 (P = 0.060)							

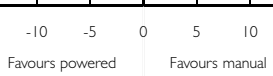
Analysis 1.3. Comparison 1 Side to side powered toothbrushes versus manual toothbrushes, Outcome 3 Plaque scores at > 3 months.

Review: Manual versus powered toothbrushing for oral health

Comparison: 1 Side to side powered toothbrushes versus manual toothbrushes

Outcome: 3 Plaque scores at > 3 months

Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
1 Quigley Hein (Turesky)							
Glass 1965	83	0.18 (0.22)	83	0.17 (0.28)		75.5 %	0.04 [-0.26, 0.34]
Subtotal (95% CI)	**83**		**83**			**75.5 %**	**0.04 [-0.26, 0.34]**
Heterogeneity: not applicable							
Test for overall effect: Z = 0.25 (P = 0.80)							
2 Silness and Le							
Walsh 1989	27	0.7 (0.7)	27	0.7 (0.7)		24.5 %	0.0 [-0.53, 0.53]
Subtotal (95% CI)	**27**		**27**			**24.5 %**	**0.0 [-0.53, 0.53]**
Heterogeneity: not applicable							
Test for overall effect: Z = 0.0 (P = 1.0)							
Total (95% CI)	**110**		**110**			**100.0 %**	**0.03 [-0.23, 0.29]**
Heterogeneity: Tau² = 0.0; Chi² = 0.02, df = 1 (P = 0.90); I² =0.0%							
Test for overall effect: Z = 0.22 (P = 0.82)							



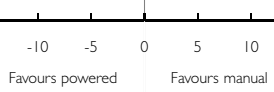
Analysis 1.4. Comparison 1 Side to side powered toothbrushes versus manual toothbrushes, Outcome 4 Gingival scores at > 3 months.

Review: Manual versus powered toothbrushing for oral health

Comparison: 1 Side to side powered toothbrushes versus manual toothbrushes

Outcome: 4 Gingival scores at > 3 months

Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
1 Le and Silness							
Walsh 1989	27	1.1 (0.4)	27	1.1 (0.4)		24.6 %	0.0 [-0.53, 0.53]
Subtotal (95% CI)	**27**		**27**			**24.6 %**	**0.0 [-0.53, 0.53]**
Heterogeneity: not applicable							
Test for overall effect: Z = 0.0 (P = 1.0)							
2 Lobene Gingival Index							
Glass 1965	83	1.35 (0.57)	83	1.26 (0.54)		75.4 %	0.16 [-0.14, 0.47]
Subtotal (95% CI)	**83**		**83**			**75.4 %**	**0.16 [-0.14, 0.47]**
Heterogeneity: not applicable							
Test for overall effect: Z = 1.04 (P = 0.30)							
Total (95% CI)	**110**		**110**			**100.0 %**	**0.12 [-0.14, 0.39]**
Heterogeneity: $Tau^2 = 0.0$; $Chi^2 = 0.27$, df = 1 (P = 0.61); $I^2 = 0.0\%$							
Test for overall effect: Z = 0.90 (P = 0.37)							



Analysis 2.1. Comparison 2 Counter oscillation, Outcome 1 Plaque scores at 1 to 3 month at all sites.

Review: Manual versus powered toothbrushing for oral health

Comparison: 2 Counter oscillation

Outcome: 1 Plaque scores at 1 to 3 month at all sites

Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
1 Quigley Hein (Turesky)							
Khocht 1992	32	1.84 (0.32)	31	1.86 (0.46)		34.4 %	-0.05 [-0.54, 0.44]
Stabholz 1996	26	2.03 (0.56)	26	2 (0.45)		28.4 %	0.06 [-0.49, 0.60]
Wilson 1993	16	2.01 (0.69)	13	2.27 (0.6)		15.3 %	-0.39 [-1.13, 0.35]
Yukna 1993b	20	0.58 (0.41)	20	0.6 (0.33)		21.8 %	-0.05 [-0.67, 0.57]
Total (95% CI)	**94**		**90**			**100.0 %**	**-0.07 [-0.36, 0.22]**

Heterogeneity: $Tau^2 = 0.0$; $Chi^2 = 0.93$, df = 3 (P = 0.82); $I^2 = 0.0\%$

Test for overall effect: Z = 0.49 (P = 0.63)

Analysis 2.2. Comparison 2 Counter oscillation, Outcome 2 Gingivitis scores at 1 to 3 months at all sites.

Review: Manual versus powered toothbrushing for oral health

Comparison: 2 Counter oscillation

Outcome: 2 Gingivitis scores at 1 to 3 months at all sites

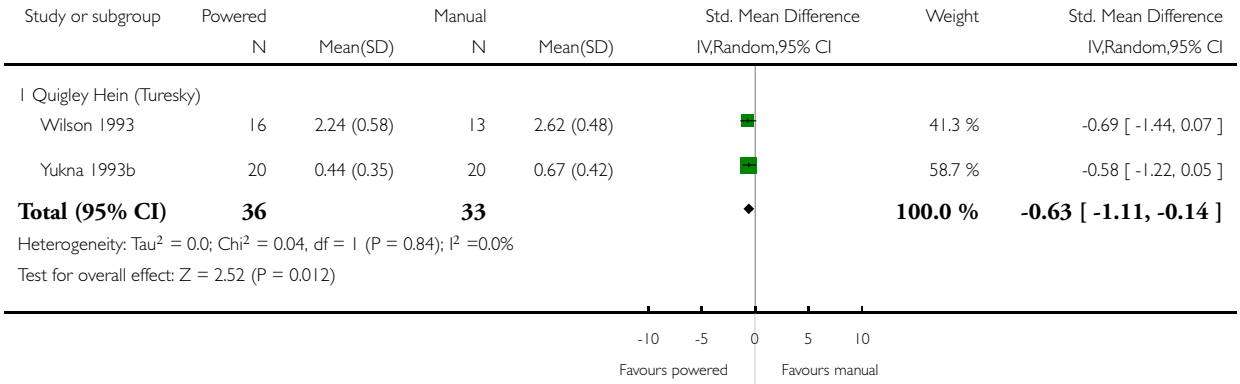
Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
1 Gingival Index Le							
Baab 1989	20	1.28 (0.27)	20	1.43 (0.13)		24.3 %	-0.69 [-1.33, -0.05]
Khocht 1992	32	1.06 (0.16)	31	0.99 (0.16)		29.2 %	0.43 [-0.07, 0.93]
Subtotal (95% CI)	**52**		**51**			**53.5 %**	**-0.11 [-1.22, 0.99]**
Heterogeneity: $Tau^2 = 0.55$; $Chi^2 = 7.38$, df = 1 (P = 0.01); $I^2 = 86\%$							
Test for overall effect: Z = 0.20 (P = 0.84)							
2 Lobene gingival index							
Yukna 1993b	20	0.32 (0.33)	20	0.33 (0.31)		25.0 %	-0.03 [-0.65, 0.59]
Subtotal (95% CI)	**20**		**20**			**25.0 %**	**-0.03 [-0.65, 0.59]**
Heterogeneity: not applicable							
Test for overall effect: Z = 0.10 (P = 0.92)							
3 BOP							
Wilson 1993	16	0.93 (0.36)	13	0.91 (0.33)		21.5 %	0.06 [-0.68, 0.79]
Subtotal (95% CI)	**16**		**13**			**21.5 %**	**0.06 [-0.68, 0.79]**
Heterogeneity: not applicable							
Test for overall effect: Z = 0.15 (P = 0.88)							
Total (95% CI)	**88**		**84**			**100.0 %**	**-0.04 [-0.52, 0.45]**
Heterogeneity: $Tau^2 = 0.14$; $Chi^2 = 7.41$, df = 3 (P = 0.06); $I^2 = 60\%$							
Test for overall effect: Z = 0.16 (P = 0.88)							

Analysis 2.3. Comparison 2 Counter oscillation, Outcome 3 Plaque scores at > 3 months.

Review: Manual versus powered toothbrushing for oral health

Comparison: 2 Counter oscillation

Outcome: 3 Plaque scores at > 3 months

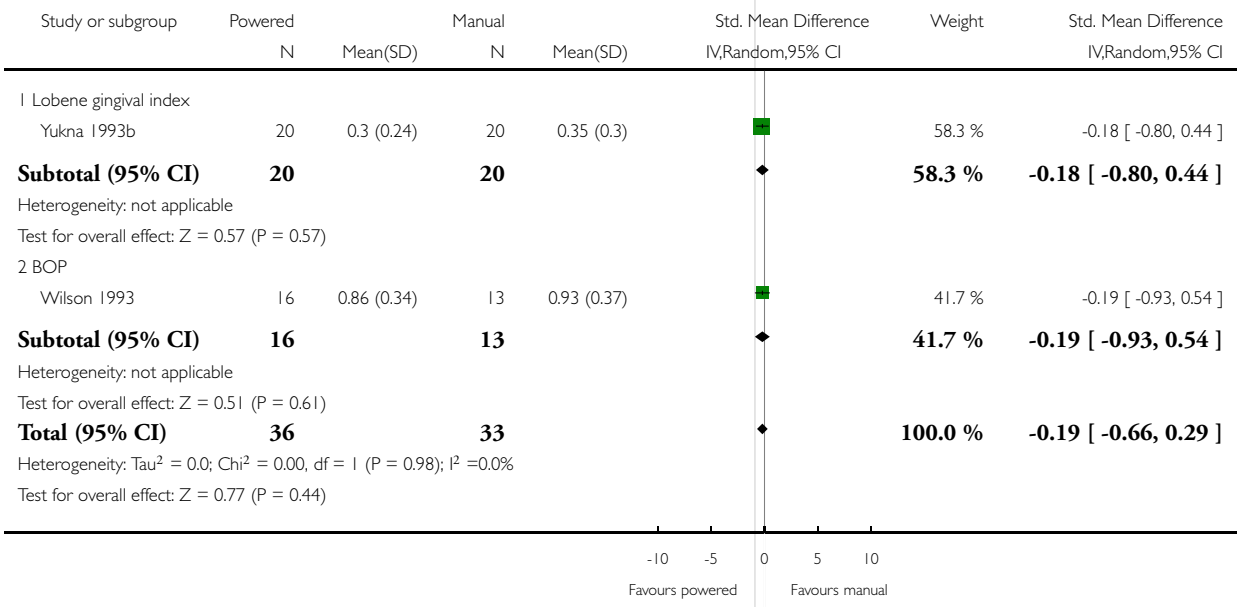


Analysis 2.4. Comparison 2 Counter oscillation, Outcome 4 Gingival scores at > 3 months.

Review: Manual versus powered toothbrushing for oral health

Comparison: 2 Counter oscillation

Outcome: 4 Gingival scores at > 3 months



Analysis 3.1. Comparison 3 Rotation oscillation, Outcome 1 Plaque scores at 1 to 3 month at all sites.

Review: Manual versus powered toothbrushing for oral health

Comparison: 3 Rotation oscillation

Outcome: 1 Plaque scores at 1 to 3 month at all sites

Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
1 Quigley Hein (Turesky)							
Barnes 1993	34	2.45 (0.38)	35	2.7 (0.55)		6.7 %	-0.52 [-1.00, -0.04]
Cronin 1998	55	2.28 (0.65)	50	2.55 (0.54)		7.2 %	-0.45 [-0.83, -0.06]
Dentino 2002	76	1.57 (0.46)	81	1.8 (0.4)		7.5 %	-0.53 [-0.85, -0.21]
Garcia-Godoy 2001	34	2.33 (0.53)	32	2.55 (0.56)		6.7 %	-0.40 [-0.89, 0.09]
Haffajee 2001a	22	1.18 (0.11)	26	1.05 (0.09)		6.0 %	1.28 [0.66, 1.91]
Heasman 1999	50	1.26 (0.52)	24	1.53 (0.5)		6.7 %	-0.52 [-1.01, -0.03]
Lapiere unpublished	33	0.52 (0.46)	15	0.56 (0.5)		6.1 %	-0.08 [-0.69, 0.53]
Sowinski 2000	55	1.67 (0.37)	55	2.28 (0.38)		7.0 %	-1.62 [-2.05, -1.18]
Warren 2001	52	2.29 (0.46)	49	2.47 (0.5)		7.2 %	-0.37 [-0.77, 0.02]
Yankell 1997	28	2.66 (0.39)	28	2.66 (0.44)		6.5 %	0.0 [-0.52, 0.52]
Subtotal (95% CI)	**439**		**395**			**67.6 %**	**-0.35 [-0.73, 0.03]**
Heterogeneity: $Tau^2 = 0.31$; $Chi^2 = 62.01$, df = 9 (P<0.00001); $I^2 = 85\%$							
Test for overall effect: Z = 1.80 (P = 0.073)							
2 Silness and Le							
Stoltze 1994	20	0.6 (0.27)	18	1.1 (0.21)		5.1 %	-2.01 [-2.81, -1.21]
van der Weijden 1994	42	0.87 (0.35)	35	1.01 (0.33)		6.9 %	-0.41 [-0.86, 0.05]
Subtotal (95% CI)	**62**		**53**			**12.0 %**	**-1.17 [-2.74, 0.40]**
Heterogeneity: $Tau^2 = 1.18$; $Chi^2 = 11.78$, df = 1 (P = 0.00060); $I^2 = 92\%$							
Test for overall effect: Z = 1.46 (P = 0.14)							
3 Visible plaque index Ainamo Bay							
Ainamo 1997	55	0.39 (0.16)	56	0.43 (0.15)		7.3 %	-0.26 [-0.63, 0.12]
Subtotal (95% CI)	**55**		**56**			**7.3 %**	**-0.26 [-0.63, 0.12]**
Heterogeneity: not applicable							
Test for overall effect: Z = 1.34 (P = 0.18)							
4 Ortho modification of Silness and Le							
Hickman 2002	31	0.46 (0.24)	29	0.46 (0.26)		6.6 %	0.0 [-0.51, 0.51]
Subtotal (95% CI)	**31**		**29**			**6.6 %**	**0.0 [-0.51, 0.51]**

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Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
Heterogeneity: not applicable							
Test for overall effect: Z = 0.0 (P = 1.0)							
5 Navy plaque index mod Rustogi							
Sharma 2000	31	0.48 (0.07)	30	0.53 (0.07)		6.5 %	-0.71 [-1.22, -0.19]
Subtotal (95% CI)	**31**		**30**			**6.5 %**	**-0.71 [-1.22, -0.19]**
Heterogeneity: not applicable							
Test for overall effect: Z = 2.67 (P = 0.0077)							
Total (95% CI)	**618**		**563**			**100.0 %**	**-0.43 [-0.72, -0.14]**
Heterogeneity: Tau² = 0.27; Chi² = 81.81, df = 14 (P<0.00001); I² =83%							
Test for overall effect: Z = 2.90 (P = 0.0037)							

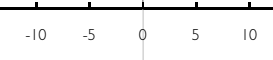
Analysis 3.2. Comparison 3 Rotation oscillation, Outcome 2 Gingival scores at 1 to 3 months at all sites.

Review: Manual versus powered toothbrushing for oral health

Comparison: 3 Rotation oscillation

Outcome: 2 Gingival scores at 1 to 3 months at all sites

Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
1 Le and Silness mod Lobene							
Barnes 1993	34	2.24 (0.42)	35	2.58 (0.57)		6.4 %	-0.67 [-1.16, -0.18]
Subtotal (95% CI)	**34**		**35**			**6.4 %**	**-0.67 [-1.16, -0.18]**
Heterogeneity: not applicable							
Test for overall effect: Z = 2.70 (P = 0.0069)							
2 Le and Silness							
Clerehugh 1998	37	1.67 (0.18)	42	1.7 (0.17)		6.6 %	-0.17 [-0.61, 0.27]
Cronin 1998	55	0.94 (0.12)	50	1 (0.1)		6.8 %	-0.54 [-0.93, -0.15]
Haffajee 2001a	22	0.67 (0.06)	26	0.74 (0.05)		5.6 %	-1.26 [-1.88, -0.63]
Heasman 1999	50	1.55 (0.21)	24	1.64 (0.22)		6.3 %	-0.42 [-0.91, 0.07]
Hickman 2002	31	1.12 (0.18)	29	1.12 (0.23)		6.3 %	0.0 [-0.51, 0.51]
Lapiere unpublished	33	0.17 (0.1)	15	0.2 (0.14)		5.7 %	-0.26 [-0.87, 0.35]
Sowinski 2000	55	0.83 (0.26)	55	1.12 (0.2)		6.7 %	-1.24 [-1.65, -0.83]



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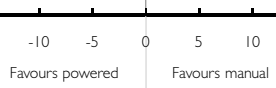
Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
Stoltze 1994	20	0.9 (0.04)	18	1.1 (0.08)		4.0 %	-3.15 [-4.13, -2.17]
Warren 2001	52	0.89 (0.12)	49	0.94 (0.13)		6.8 %	-0.40 [-0.79, 0.00]
Subtotal (95% CI)	**355**		**308**			**54.8 %**	**-0.74 [-1.16, -0.32]**
Heterogeneity: Tau² = 0.34; Chi² = 51.38, df = 8 (P<0.00001); I² =84%							
Test for overall effect: Z = 3.43 (P = 0.00060)							
3 Loe and Silness mod Chilton							
Sharma 2000	31	1.74 (0.16)	30	1.89 (0.17)		6.1 %	-0.90 [-1.43, -0.37]
Soparkar 2000	33	1.03 (0.14)	30	1.27 (0.16)		5.9 %	-1.58 [-2.15, -1.01]
Subtotal (95% CI)	**64**		**60**			**12.1 %**	**-1.23 [-1.90, -0.56]**
Heterogeneity: Tau² = 0.16; Chi² = 2.97, df = 1 (P = 0.08); I² =66%							
Test for overall effect: Z = 3.60 (P = 0.00032)							
4 Lobene gingival index							
Dentino 2002	76	0.49 (0.25)	81	0.59 (0.26)		7.1 %	-0.39 [-0.71, -0.07]
van der Weijden 1994	42	1.15 (0.26)	35	1.12 (0.24)		6.5 %	0.12 [-0.33, 0.57]
Yankell 1997	28	2.16 (0.28)	28	2.14 (0.32)		6.2 %	0.07 [-0.46, 0.59]
Subtotal (95% CI)	**146**		**144**			**19.8 %**	**-0.11 [-0.46, 0.24]**
Heterogeneity: Tau² = 0.05; Chi² = 4.22, df = 2 (P = 0.12); I² =53%							
Test for overall effect: Z = 0.61 (P = 0.54)							
5 BOP Ainamo Bay							
Ainamo 1997	55	0.24 (0.1)	55	0.26 (0.09)		6.9 %	-0.21 [-0.58, 0.17]
Subtotal (95% CI)	**55**		**55**			**6.9 %**	**-0.21 [-0.58, 0.17]**
Heterogeneity: not applicable							
Test for overall effect: Z = 1.09 (P = 0.27)							
Total (95% CI)	**654**		**602**			**100.0 %**	**-0.62 [-0.90, -0.34]**
Heterogeneity: Tau² = 0.26; Chi² = 83.96, df = 15 (P<0.00001); I² =82%							
Test for overall effect: Z = 4.33 (P = 0.000015)							



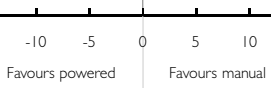
Analysis 3.3. Comparison 3 Rotation oscillation, Outcome 3 Plaque scores at > 3 months.

Review: Manual versus powered toothbrushing for oral health

Comparison: 3 Rotation oscillation

Outcome: 3 Plaque scores at > 3 months

Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
1 Quigley Hein (Turesky)							
Lazarescu 2003	40	1.5 (0.24)	38	2.2 (0.23)		32.4 %	-2.95 [-3.60, -2.30]
Subtotal (95% CI)	**40**		**38**			**32.4 %**	**-2.95 [-3.60, -2.30]**
Heterogeneity: not applicable							
Test for overall effect: Z = 8.89 (P < 0.00001)							
2 Silness and Le							
van der Weijden 1994	42	0.55 (0.25)	35	0.73 (0.24)		33.6 %	-0.73 [-1.19, -0.26]
Subtotal (95% CI)	**42**		**35**			**33.6 %**	**-0.73 [-1.19, -0.26]**
Heterogeneity: not applicable							
Test for overall effect: Z = 3.07 (P = 0.0022)							
3 Visible plaque index Ainamo Bay							
Ainamo 1997	55	0.34 (0.16)	56	0.39 (0.19)		34.0 %	-0.28 [-0.66, 0.09]
Subtotal (95% CI)	**55**		**56**			**34.0 %**	**-0.28 [-0.66, 0.09]**
Heterogeneity: not applicable							
Test for overall effect: Z = 1.48 (P = 0.14)							
Total (95% CI)	**137**		**129**			**100.0 %**	**-1.29 [-2.67, 0.08]**
Heterogeneity: Tau^2 = 1.42; Chi^2 = 49.08, df = 2 (P<0.00001); I^2 =96%							
Test for overall effect: Z = 1.84 (P = 0.066)							



Analysis 3.4. Comparison 3 Rotation oscillation, Outcome 4 Gingival scores at > 3 months.

Review: Manual versus powered toothbrushing for oral health

Comparison: 3 Rotation oscillation

Outcome: 4 Gingival scores at > 3 months

Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
1 Lobene gingival index							
Dentino 2002	76	0.52 (0.22)	81	0.58 (0.23)		32.2 %	-0.27 [-0.58, 0.05]
van der Weijden 1994	42	0.8 (0.24)	35	0.94 (0.26)		20.9 %	-0.56 [-1.01, -0.10]
Subtotal (95% CI)	**118**		**116**			**53.1 %**	**-0.36 [-0.63, -0.09]**
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 1.05$, df = 1 (P = 0.30); $I^2 = 5\%$							
Test for overall effect: Z = 2.64 (P = 0.0083)							
2 BOP Ainamo Bay							
Ainamo 1997	55	0.2 (0.08)	56	0.24 (0.09)		26.6 %	-0.47 [-0.84, -0.09]
Lazarescu 2003	40	0.07 (0.05)	38	0.12 (0.06)		20.3 %	-0.90 [-1.37, -0.43]
Subtotal (95% CI)	**95**		**94**			**46.9 %**	**-0.66 [-1.08, -0.24]**
Heterogeneity: $Tau^2 = 0.05$; $Chi^2 = 1.99$, df = 1 (P = 0.16); $I^2 = 50\%$							
Test for overall effect: Z = 3.07 (P = 0.0021)							
Total (95% CI)	**213**		**210**			**100.0 %**	**-0.51 [-0.76, -0.25]**
Heterogeneity: $Tau^2 = 0.03$; $Chi^2 = 4.99$, df = 3 (P = 0.17); $I^2 = 40\%$							
Test for overall effect: Z = 3.89 (P = 0.00010)							

Analysis 4.1. Comparison 4 Circular, Outcome 1 Plaque scores at 1 to 3 month at all sites.

Review: Manual versus powered toothbrushing for oral health

Comparison: 4 Circular

Outcome: 1 Plaque scores at 1 to 3 month at all sites

Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
1 Quigley Hein (Turesky)							
Khocht 1992	32	1.83 (0.42)	31	1.86 (0.46)		37.5 %	-0.07 [-0.56, 0.43]
Yankell 1996	32	2.79 (0.39)	33	2.78 (0.43)		38.8 %	0.02 [-0.46, 0.51]
Subtotal (95% CI)	**64**		**64**			**76.3 %**	**-0.02 [-0.37, 0.33]**
Heterogeneity: $Tau^2 = 0.0$; $Chi^2 = 0.07$, df = 1 (P = 0.80); $I^2 = 0.0\%$							
Test for overall effect: Z = 0.12 (P = 0.91)							
2 Silness and Le							
McAllan 1976	21	0.54 (0.23)	19	0.58 (0.22)		23.7 %	-0.17 [-0.80, 0.45]
Subtotal (95% CI)	**21**		**19**			**23.7 %**	**-0.17 [-0.80, 0.45]**
Heterogeneity: not applicable							
Test for overall effect: Z = 0.55 (P = 0.58)							
Total (95% CI)	**85**		**83**			**100.0 %**	**-0.06 [-0.36, 0.25]**
Heterogeneity: $Tau^2 = 0.0$; $Chi^2 = 0.24$, df = 2 (P = 0.88); $I^2 = 0.0\%$							
Test for overall effect: Z = 0.37 (P = 0.71)							

Analysis 4.2. Comparison 4 Circular, Outcome 2 Gingival scores at 1 to 3 months at all sites.

Review: Manual versus powered toothbrushing for oral health

Comparison: 4 Circular

Outcome: 2 Gingival scores at 1 to 3 months at all sites

Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
1 GI Le Silness							
Khocht 1992	32	1.01 (0.14)	31	0.99 (0.16)		35.3 %	0.13 [-0.36, 0.63]
McAllan 1976	21	0.28 (0.09)	19	0.4 (0.17)		29.4 %	-0.88 [-1.53, -0.23]
Subtotal (95% CI)	**53**		**50**			**64.7 %**	**-0.35 [-1.34, 0.64]**
Heterogeneity: $Tau^2 = 0.42$; $Chi^2 = 5.84$, df = 1 (P = 0.02); $I^2 = 83\%$							
Test for overall effect: Z = 0.69 (P = 0.49)							
2 Lobene							
Yankell 1996	32	2 (0.54)	33	2.21 (0.25)		35.3 %	-0.50 [-0.99, 0.00]
Subtotal (95% CI)	**32**		**33**			**35.3 %**	**-0.50 [-0.99, 0.00]**
Heterogeneity: not applicable							
Test for overall effect: Z = 1.97 (P = 0.049)							
Total (95% CI)	**85**		**83**			**100.0 %**	**-0.39 [-0.95, 0.18]**
Heterogeneity: $Tau^2 = 0.17$; $Chi^2 = 6.48$, df = 2 (P = 0.04); $I^2 = 69\%$							
Test for overall effect: Z = 1.34 (P = 0.18)							

Analysis 4.3. Comparison 4 Circular, Outcome 3 Plaque scores at > 3 months.

Review: Manual versus powered toothbrushing for oral health

Comparison: 4 Circular

Outcome: 3 Plaque scores at > 3 months

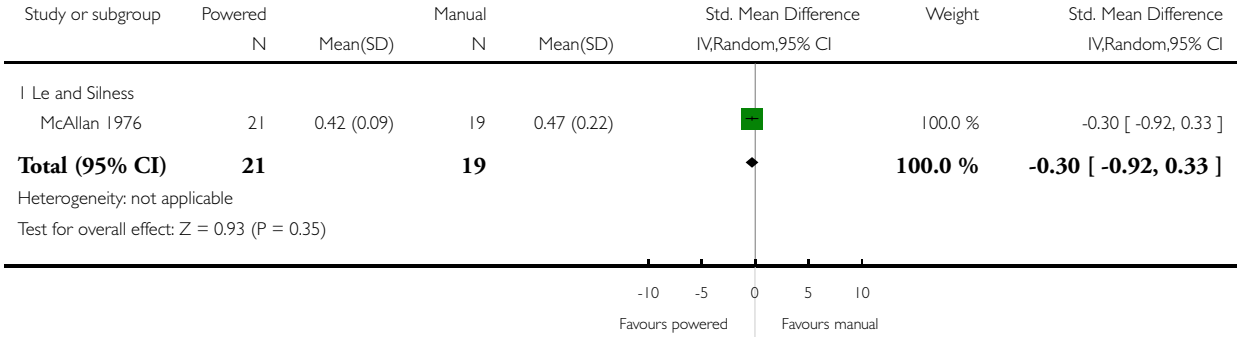
Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
1 Silness and Le							
McAllan 1976	21	0.51 (0.23)	19	0.5 (0.22)		100.0 %	0.04 [-0.58, 0.66]
Total (95% CI)	**21**		**19**			**100.0 %**	**0.04 [-0.58, 0.66]**
Heterogeneity: not applicable							
Test for overall effect: Z = 0.14 (P = 0.89)							

Analysis 4.4. Comparison 4 Circular, Outcome 4 Gingival scores at > 3 months.

Review: Manual versus powered toothbrushing for oral health

Comparison: 4 Circular

Outcome: 4 Gingival scores at > 3 months

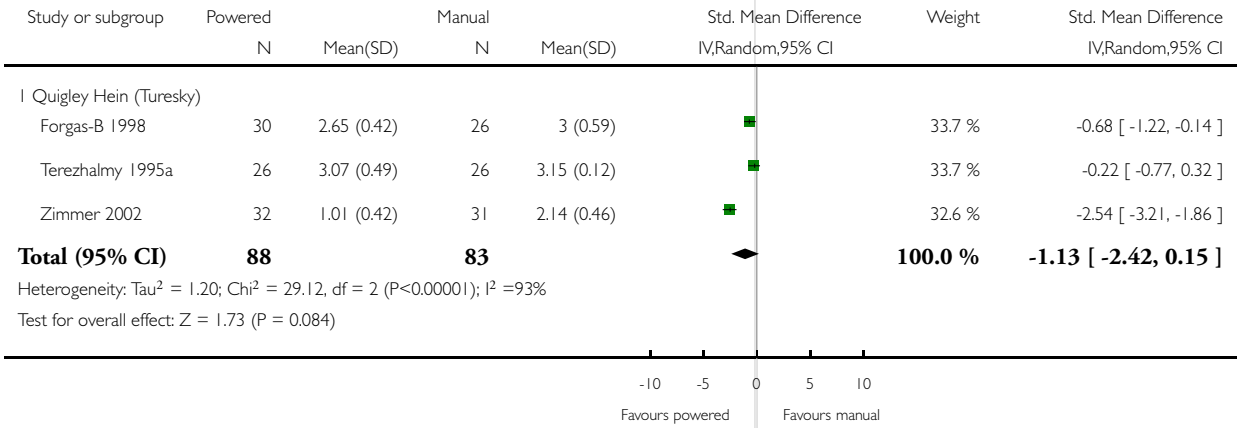


Analysis 5.1. Comparison 5 Ultrasonic, Outcome 1 Plaque scores at 1 to 3 month at all sites.

Review: Manual versus powered toothbrushing for oral health

Comparison: 5 Ultrasonic

Outcome: 1 Plaque scores at 1 to 3 month at all sites



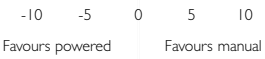
Analysis 5.2. Comparison 5 Ultrasonic, Outcome 2 Gingival scores at 1 to 3 months at all sites.

Review: Manual versus powered toothbrushing for oral health

Comparison: 5 Ultrasonic

Outcome: 2 Gingival scores at 1 to 3 months at all sites

Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
1 Le and Silness							
Forgas-B 1998	30	1.47 (0.31)	26	1.55 (0.34)		34.1 %	-0.24 [-0.77, 0.28]
Terezhalmy 1995a	26	0.71 (0.26)	26	0.89 (0.12)		30.9 %	-0.88 [-1.45, -0.30]
Subtotal (95% CI)	**56**		**52**			**65.0 %**	**-0.55 [-1.17, 0.07]**
Heterogeneity: $Tau^2 = 0.12$; $Chi^2 = 2.54$, df = 1 (P = 0.11); $I^2 = 61\%$							
Test for overall effect: Z = 1.74 (P = 0.082)							
2 Papillary bleeding index							
Zimmer 2002	32	0.44 (0.49)	31	0.86 (0.52)		35.0 %	-0.82 [-1.34, -0.31]
Subtotal (95% CI)	**32**		**31**			**35.0 %**	**-0.82 [-1.34, -0.31]**
Heterogeneity: not applicable							
Test for overall effect: Z = 3.12 (P = 0.0018)							
Total (95% CI)	**88**		**83**			**100.0 %**	**-0.64 [-1.04, -0.24]**
Heterogeneity: $Tau^2 = 0.05$; $Chi^2 = 3.30$, df = 2 (P = 0.19); $I^2 = 39\%$							
Test for overall effect: Z = 3.15 (P = 0.0016)							



Analysis 5.3. Comparison 5 Ultrasonic, Outcome 3 Plaque scores at > 3 months at all sites.

Review: Manual versus powered toothbrushing for oral health

Comparison: 5 Ultrasonic

Outcome: 3 Plaque scores at > 3 months at all sites

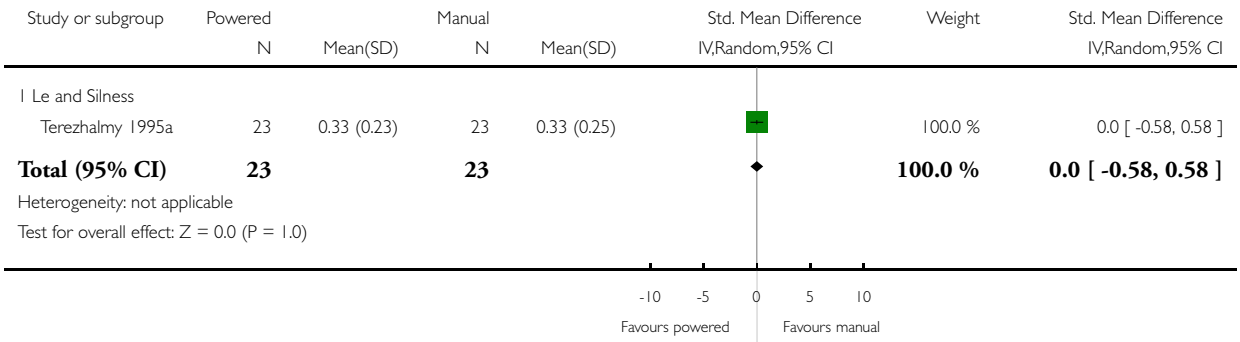
Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
1 Quigley Hein							
Terezhalmy 1995a	23	0.82 (0.32)	23	0.76 (0.27)		100.0 %	0.20 [-0.38, 0.78]
Total (95% CI)	**23**		**23**			**100.0 %**	**0.20 [-0.38, 0.78]**
Heterogeneity: not applicable							
Test for overall effect: Z = 0.67 (P = 0.50)							

Analysis 5.4. Comparison 5 Ultrasonic, Outcome 4 Gingival scores at > 3 months.

Review: Manual versus powered toothbrushing for oral health

Comparison: 5 Ultrasonic

Outcome: 4 Gingival scores at > 3 months

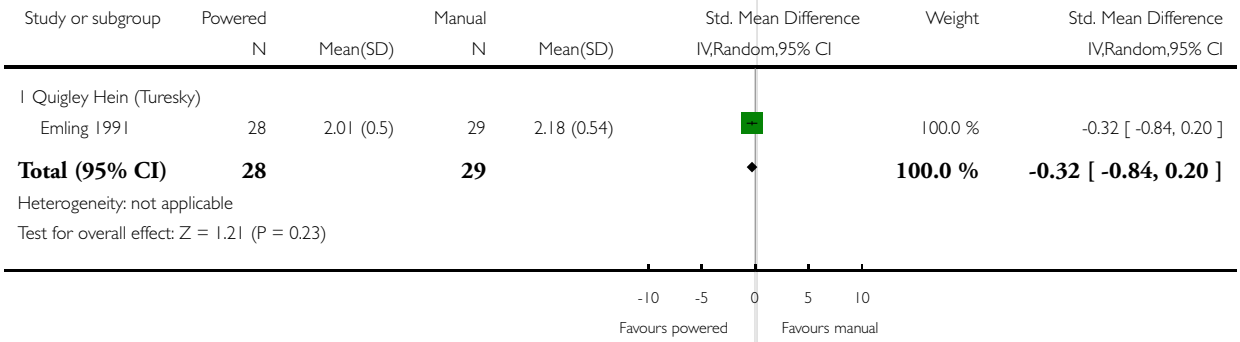


Analysis 6.1. Comparison 6 Unknown or other action, Outcome 1 Plaque scores at 1 to 3 months at all sites.

Review: Manual versus powered toothbrushing for oral health

Comparison: 6 Unknown or other action

Outcome: 1 Plaque scores at 1 to 3 months at all sites



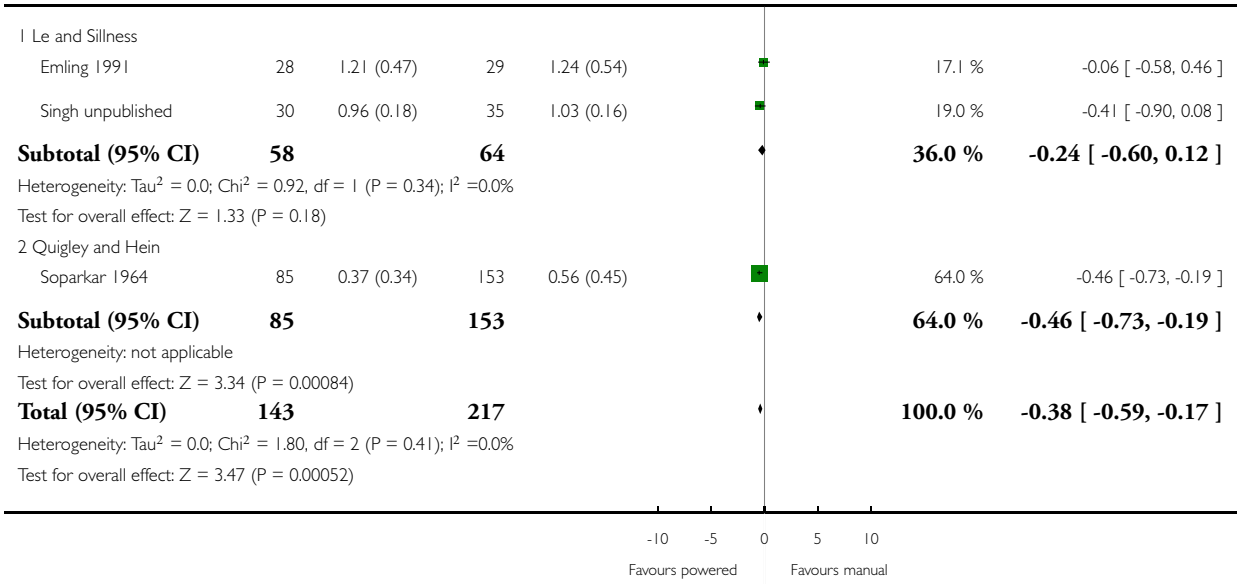
Analysis 6.2. Comparison 6 Unknown or other action, Outcome 2 Gingival scores at 1 to 3 months at all sites.

Review: Manual versus powered toothbrushing for oral health

Comparison: 6 Unknown or other action

Outcome: 2 Gingival scores at 1 to 3 months at all sites

Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
1 Le and Sillness							
Emling 1991	28	1.21 (0.47)	29	1.24 (0.54)		17.1 %	-0.06 [-0.58, 0.46]
Singh unpublished	30	0.96 (0.18)	35	1.03 (0.16)		19.0 %	-0.41 [-0.90, 0.08]
Subtotal (95% CI)	**58**		**64**			**36.0 %**	**-0.24 [-0.60, 0.12]**
Heterogeneity: $Tau^2 = 0.0$; $Chi^2 = 0.92$, df = 1 (P = 0.34); $I^2 = 0.0\%$							
Test for overall effect: Z = 1.33 (P = 0.18)							
2 Quigley and Hein							
Soparkar 1964	85	0.37 (0.34)	153	0.56 (0.45)		64.0 %	-0.46 [-0.73, -0.19]
Subtotal (95% CI)	**85**		**153**			**64.0 %**	**-0.46 [-0.73, -0.19]**
Heterogeneity: not applicable							
Test for overall effect: Z = 3.34 (P = 0.00084)							
Total (95% CI)	**143**		**217**			**100.0 %**	**-0.38 [-0.59, -0.17]**
Heterogeneity: $Tau^2 = 0.0$; $Chi^2 = 1.80$, df = 2 (P = 0.41); $I^2 = 0.0\%$							
Test for overall effect: Z = 3.47 (P = 0.00052)							



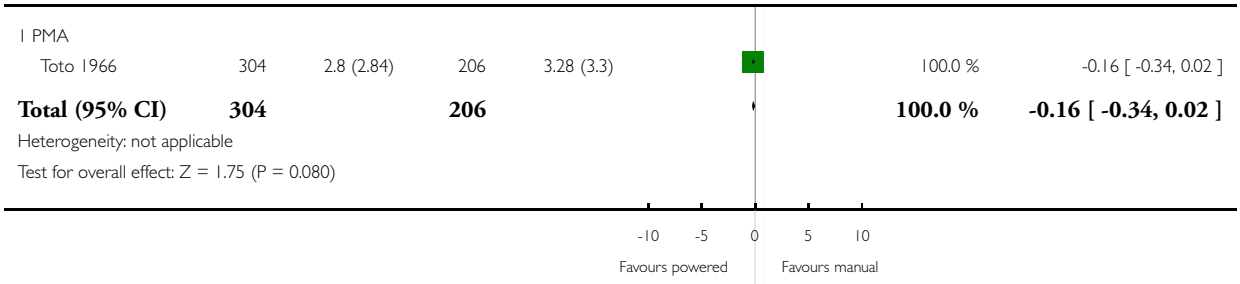
Analysis 6.3. Comparison 6 Unknown or other action, Outcome 3 Gingival scores > 3 months at all sites.

Review: Manual versus powered toothbrushing for oral health

Comparison: 6 Unknown or other action

Outcome: 3 Gingival scores > 3 months at all sites

Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
1 PMA							
Toto 1966	304	2.8 (2.84)	206	3.28 (3.3)		100.0 %	-0.16 [-0.34, 0.02]
Total (95% CI)	**304**		**206**			**100.0 %**	**-0.16 [-0.34, 0.02]**
Heterogeneity: not applicable							
Test for overall effect: Z = 1.75 (P = 0.080)							



Analysis 7.1. Comparison 7 Ionic brushes, Outcome 1 Plaque scores at 1 to 3 months at all sites.

Review: Manual versus powered toothbrushing for oral health

Comparison: 7 Ionic brushes

Outcome: 1 Plaque scores at 1 to 3 months at all sites

Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Fixed,95% CI	Weight	Std. Mean Difference IV,Fixed,95% CI
1 Quigley Hein (Turesky)							
Galgut 1996	31	28.1 (26.3)	32	34.6 (25.1)		35.3 %	-0.25 [-0.75, 0.25]
Pucher 1999	27	2.18 (0.23)	25	2.28 (0.39)		29.0 %	-0.31 [-0.86, 0.24]
Van Swol 1996	34	1.26 (0.46)	30	1.38 (0.33)		35.7 %	-0.29 [-0.79, 0.20]
Total (95% CI)	**92**		**87**			**100.0 %**	**-0.28 [-0.58, 0.01]**

Heterogeneity: $Chi^2 = 0.03$, df = 2 (P = 0.99); I^2 =0.0%

Test for overall effect: Z = 1.88 (P = 0.060)

Analysis 7.2. Comparison 7 Ionic brushes, Outcome 2 Gingival scores at 1 to 3 months at all sites.

Review: Manual versus powered toothbrushing for oral health

Comparison: 7 Ionic brushes

Outcome: 2 Gingival scores at 1 to 3 months at all sites

Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Fixed,95% CI	Weight	Std. Mean Difference IV,Fixed,95% CI
1 Loe Silness							
Pucher 1999	27	1.05 (0.06)	25	1.06 (0.05)		44.8 %	-0.18 [-0.72, 0.37]
Van Swol 1996	34	0.87 (0.34)	30	0.91 (0.36)		55.2 %	-0.11 [-0.60, 0.38]
Total (95% CI)	**61**		**55**			**100.0 %**	**-0.14 [-0.51, 0.22]**

Heterogeneity: $Chi^2 = 0.03$, df = 1 (P = 0.86); I^2 =0.0%

Test for overall effect: Z = 0.76 (P = 0.45)

Analysis 7.3. Comparison 7 Ionic brushes, Outcome 3 Plaque scores at > 3 months at all sites.

Review: Manual versus powered toothbrushing for oral health

Comparison: 7 Ionic brushes

Outcome: 3 Plaque scores at > 3 months at all sites

Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Fixed,95% CI	Weight	Std. Mean Difference IV,Fixed,95% CI
1 Quigley Hein (Turesky)							
Van Swol 1996	34	1.13 (0.44)	30	1.63 (0.54)		100.0 %	-1.01 [-1.53, -0.49]
Total (95% CI)	**34**		**30**			**100.0 %**	**-1.01 [-1.53, -0.49]**
Heterogeneity: not applicable							
Test for overall effect: Z = 3.78 (P = 0.00016)							

Analysis 7.4. Comparison 7 Ionic brushes, Outcome 4 Gingival scores at > 3 months at all sites.

Review: Manual versus powered toothbrushing for oral health

Comparison: 7 Ionic brushes

Outcome: 4 Gingival scores at > 3 months at all sites

Study or subgroup	Powered N	Mean(SD)	Manual N	Mean(SD)	Std. Mean Difference IV,Fixed,95% CI	Weight	Std. Mean Difference IV,Fixed,95% CI
1 Loe and Silness							
Van Swol 1996	34	0.82 (0.4)	30	1.18 (0.51)		100.0 %	-0.78 [-1.29, -0.27]
Total (95% CI)	**34**		**30**			**100.0 %**	**-0.78 [-1.29, -0.27]**
Heterogeneity: not applicable							
Test for overall effect: Z = 3.00 (P = 0.0027)							

APPENDICES

Appendix 1. MEDLINE (OVID) search strategy

1.exp Toothbrushing/
2.toothbrush$.mp. [mp=title, abstract, registry number word, mesh subject heading]
3.((tooth or teeth) adj3 clean$).mp. [mp=title, abstract, registry number word, mesh subject heading]
4.1 or 2 or 3
5.manual$.mp. [mp=title, abstract, registry number word, mesh subject heading]
6.conventional$.mp. [mp=title, abstract, registry number word, mesh subject heading]
7.handbrush$.mp. [mp=title, abstract, registry number word, mesh subject heading]
8.5 or 6 or 7
9.power$.mp. [mp=title, abstract, registry number word, mesh subject heading]
10.mechanical$.mp. [mp=title, abstract, registry number word, mesh subject heading]
11.electric$.mp. [mp=title, abstract, registry number word, mesh subject heading]
12.electronic$.mp. [mp=title, abstract, registry number word, mesh subject heading]
13.ultrasonic$.mp. [mp=title, abstract, registry number word, mesh subject heading]
14.sonic$.mp. [mp=title, abstract, registry number word, mesh subject heading]
15."motor driven".mp. [mp=title, abstract, registry number word, mesh subject heading]
16."battery operated".mp. [mp=title, abstract, registry number word, mesh subject heading]
17.automatic$.mp. [mp=title, abstract, registry number word, mesh subject heading]
18.9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17
19.4 and 8 and 18

Appendix 2. Cochrane Oral Health Group Trials Register search strategy

(toothbrush* AND (manual OR conventional OR handbrush) AND (power* OR mechanical* OR electri* OR electronic* OR "motor driven" OR ultrasonic* OR automatic* OR oscillat* OR *sonic* OR "Counter rota*" OR "battery operat*" OR "battery-powered"))

Appendix 3. CENTRAL search strategy

1. TOOTHBRUSHING:ME
2. toothbrush*
3. ((tooth OR teeth) NEAR clean*)
4. OR/1-3
5. manual OR conventional* OR handbrush*
6. power* OR mechanical* OR electric* OR electronic OR ultrasonic* OR sonic* OR motor driven OR battery operated OR battery power* OR automatic*
7. 4 AND 5 AND 6

Appendix 4. CINAHL (OVID) search strategy

1. exp toothbrushes/
2. toothbrush$
3. ((tooth or teeth) adj3 clean$)
4. 1 or 2 or 3
5. manual$
6. conventional$
7. handbrush$
8. 5 or 6 or 7
9. power$
10. mechanical$
11. electric$
12. electronic$

13. ultrasonic$
14. sonic$
15. “motor driven”
16. “battery operated”
17. automatic$
18. 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17
19. 4 and 8 and 18

Appendix 5. EMBASE (OVID) search strategy

1. Tooth brushing/
2. (toothbrush$ or (tooth adj brush$))
3. ((tooth or teeth) adj3 clean$)
4. 1 or 2 or 3
5. manual$
6. conventional$
7. handbrush$
8. 5 or 6 or 7
9. power$
10. mechanical$
11. electric$
12. electronic$
13. ultrasonic$
14. sonic$
15. “motor driven”
16. “battery operated”
17. automatic$
18. 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17
19. 4 and 8 and 18

WHAT'S NEW

Last assessed as up-to-date: 16 February 2005.

20 August 2008	Amended	Converted to new review format.

HISTORY

Protocol first published: Issue 2, 2000

Review first published: Issue 1, 2003

17 February 2005	New citation required and conclusions have changed	Substantive amendment. More studies have been included for brushes that work with a rotation oscillation action. The update confirms that these brushes removed more plaque and reduced gingivitis more effectively than manual brushes in the short term. Brushes of this design reduced gingivitis scores over 3 months. A refinement of the data analysis for brushes that work with a rotation oscillation action excluded one study from the current review for plaque over 3 months. Excluding this study does not substantially change our estimate of the treatment effect. However, because there are fewer studies in the analysis the 95% confidence intervals are wider and the findings are no longer statistically significant for this analysis. Trials of ionic brushes that impart a charge to the tooth surface have been included for the first time. The analyses show no benefit from these brushes on plaque or gingivitis in studies lasting 1 to 3 months but effects in studies over 3 months. This inconsistency cannot be explained but only one study was included in the long-term analyses.
17 February 2005	New search has been performed	This review has been repeated, 2 years after it was first completed. The original review included 29 trials involving 2547 subjects. 42 trials are now included, involving 3855 participants.

CONTRIBUTIONS OF AUTHORS

Bill Shaw and Helen Worthington wrote the protocol. Anne-Marie Glenny, Bill Shaw, Mike Heanue, Peter Robinson and Damien Walmsley co-ordinated the review. Bill Shaw and Peter Robinson wrote the letters to the authors. Bill Shaw, Scott Deacon, Chris Deery, Mike Heanue, Peter Robinson and Damien Walmsley independently and in duplicate assessed the eligibility of trials, extracted data and assessed the quality of the trials. Damien Walmsley and Peter Robinson provided the background and sourced information on brush action and plaque and gingival indices. Helen Worthington conducted the statistical analysis. Scott Deacon, Anne-Marie Glenny and Mike Heanue checked and entered data. Peter Robinson and Mike Heanue wrote the review. Proof reading and numerical consistency checked by Anne-Marie Glenny and Chris Deery.

DECLARATIONS OF INTEREST

Bill Shaw and Helen Worthington were co-researchers on a randomised controlled trial sponsored by Braun AG (Clerehugh 1998) through a grant to the University of Manchester. Damien Walmsley was a consultant and undertook laboratory trials of powered toothbrushes sponsored by Braun AG through a grant to the University of Birmingham.

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External sources

- No sources of support supplied

INDEX TERMS

Medical Subject Headings (MeSH)

*Dental Devices, Home Care [adverse effects; economics]; Dental Plaque [complications; *prevention & control]; Gingival Diseases [prevention & control]; Gingivitis [*prevention & control]; Oral Health; Periodontal Diseases [prevention & control]; Randomized Controlled Trials as Topic; Toothbrushing [*instrumentation; methods]

MeSH check words

Humans