Prevention and treatment of peri-implant diseases

Cleaning of titanium dental implant surfaces

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Chapter 7

Mechanical self-performed oral hygiene of implant supported restorations: a systematic review

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G.A. van der Weijden

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Introduction

Biofilm accumulation is associated with inflammatory changes around implants (Zitzmann et al. 2001). Consequently, regular and effective plaque removal constitutes an important issue in the prevention of such responses. Several studies have shown that consistent professional maintenance and the standard of the patients’ home care are key factors for long term stability of dental implants and the prevention of biological complications (Bauman et al. 1991; Silverstein et al. 2006; Serino & Ström 2009).

In a longitudinal multicenter study, failing implants were associated with higher plaque biofilm levels than successful implants (van Steenberghe et al. 1993). In a prospective 15-year follow-up study, Lindquist et al. (1996) reported an association between poor oral hygiene and peri-implant bone loss. More bone loss was observed around implants supporting fixed bridges in edentulous patients with poor oral hygiene than in those with better oral hygiene (Lindquist et al. 1996). In a study analyzing risk variables for peri-implant disease in a Brazilian population, very poor oral hygiene was highly associated with peri-implantitis with an OR of 14.3 (95% CI: 2.0-4.1) (Ferreira et al. 2006). In the consensus meeting of the Sixth European Workshop on Periodontology regarding peri-implant diseases it was concluded that insufficient oral hygiene is an important risk factor for developing peri-implant infections (Heitz-Mayfield, 2008).

Several methods may be used for self-performed plaque control with implants and are based on the knowledge that is available with respect to cleaning of natural teeth. The mechanical plaque control may involve the use of manual or power toothbrushes as well as proximal cleaning dental devices (Eskow & Smith 1999). The purpose of this study was to review and evaluate the literature, in a systematic way, with respect to various self-performed mechanical, oral hygiene modalities around implant-supported dental restorations in relation to peri-implant soft tissue health.
Materials and Methods

This systematic review was conducted according to the guidelines of Transparent Reporting of Systematic Reviews and Meta-analyses (PRISMA-statement) (Moher et al. 2009).

Search strategy

Three internet sources were used to identify publications that met the inclusion criteria: the National Library of Medicine, Washington, D.C. (MEDLINE-PubMed), the Cochrane Central Register of Controlled Trials (CENTRAL) and EMBASE (Excerpta Medical Database by Elsevier). The final search was conducted up to October 1st 2013 and was designed to include any published study that evaluated self-performed mechanical home care of dental implants. The search strategy was customized according to the requirements of each database (for details on the search terms used see Box 1).

Screening and selection

Only papers written in English were included. The titles and abstracts were first screened independently by two reviewers (D.E.S & G.A.W) to identify eligible studies. When the abstract was not clear or no abstract was available but the title seemed to be relevant, the paper was selected for full-text reading. Following selection, full-text papers were carefully read by two reviewers (A.L & G.A.W). Disagreements were resolved by discussion. If disagreements persisted, the judgment of a third reviewer (D.E.S) was decisive. The papers that fulfilled all of the selection criteria were processed for data extraction. All reference lists of the selected studies were hand searched by two reviewers (A.L & D.E.S) for additional published work that could possibly meet the eligibility criteria of the study. The following eligibility criteria were used:

- Randomized controlled clinical trials (RCTs) or controlled clinical trials (CCTs) or cohort studies
- Conducted in humans
  - \( \geq 18 \) years of age
  - Good general health
  - Having at least one dental implant
- Intervention: self-performed mechanical cleaning of dental implant-supported restorations
• Clinical outcome parameters including plaque indices, bleeding indices, gingiva health indices, probing pocket depth and gingival recession.

Box 1. Search terms used for PubMed-MEDLINE, Cochrane-CENTRAL and EMBASE. The search strategy [<structure> AND <device>] was customized appropriately for each of the additional databases being used taking into account differences in controlled vocabulary and syntax rules.

The following terms were used in the search strategy:

```plaintext
[<structure>: [MeSH terms /all subheadings] Dental Implants OR [textwords] dental implant>

AND

<device: [MeSH terms /all subheadings] toothbrushing OR Dental Devices, Home Care OR [textwords] toothbrush OR toothbrushing OR toothbrush* OR Floss OR Dental floss OR Flossing OR Tape OR Dental tape OR Superfloss OR Ultrafloss OR Toothpick* OR woodstick* OR wooden interdental cleaner OR wedge stimulator* OR wooden stimulator* OR interproximal brushing OR interproximal brushes OR interproximal brush OR interproximal brush* OR interdental brushing OR interdental brushes OR interdental brush OR interdental brush* OR interdental cleaning devices OR interspace brushing OR interspace brushes OR interspace brush OR interspace brush* OR proxabrush OR oral irrigation OR oral irrigator OR oral irrigation jet OR water jet irrigator OR dental water jet OR water pick OR water pik OR waterpik OR perio pik OR pick pocket OR pickpocket OR pik pocket OR monojet oral irrigator OR subgingival irrigation OR subgingival tip OR dental irrigator OR dental irrigation OR Interdental cleaning devices OR Interproximal cleaning devices OR Interspace cleaning devices>]
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The asterisk (*) was used as a truncation symbol
Assessment of heterogeneity
The following factors were evaluated to assess heterogeneity:

- Study design
- Characteristics of the participants
- Clinical outcome parameters
- Funding

Quality assessment
Two reviewers (A.L & D.E.S) scored the methodological quality of included studies. This assessment was performed according to the method that has been described in detail by Keukenmester et al. (2013). In short, when random allocation, defined eligibility criteria, blinding of examiners, blinding of patients, balanced experimental groups, identical treatment between groups (except for the intervention), reporting of loss of follow-up and the subject as unit of statistical analysis were present, the study was classified as having a low risk of bias. When one of these criteria was missing, the study was considered to have a moderate risk of bias. When two or more of these criteria were missing, the study was considered to have a high risk of bias, as proposed by van der Weijden et al. (2009).

Data extraction and analysis
Studies were analyzed for similarities and suitability for meta-analysis. After a preliminary evaluation of the selected papers, it was found that considerable heterogeneity was present in the study designs, characteristics, outcome variables and results. It was, therefore, not possible to perform a quantitative analysis of the data and subsequent meta-analysis; accordingly a descriptive analysis of the data was performed.

Grading the ‘body of evidence’
The Grading of Recommendations Assessment, Development and Evaluation (GRADE) system as proposed by the GRADE working group (Guyatt et al. 2008) was used to rank the evidence emerging from this review regarding self-performed mechanical home care of dental implants. Two reviewers (A.L & G.A.W) rated the quality of the evidence as well as the strength of the recommendations according to the following aspects: risk of bias of the individual studies, consistency and precision among the study outcomes, directness of the study results and detection of publication bias. Any disagreement between the two reviewers was resolved after additional discussion.
Results

Search and selection
The PubMed-MEDLINE, Cochrane-CENTRAL and EMBASE searches identified in total 375 unique papers using the specified search terms (Figure 1). The initial screening of the titles and abstracts resulted in seven full-text papers that met the inclusion criteria. After reading the full-text articles, two papers were excluded, one because it was a survey (Orelud et al. 2012) and one because the mechanical cleaning was performed by a dental professional (Chongcharoen et al. 2012). Additional hand-searching of the reference lists from the selected studies did not yield any additional papers. Five papers were ultimately processed for data extraction.

Assessment of heterogeneity
Information regarding the study characteristics is provided in Table 1. The table includes a short summary of the study design, information regarding the participants (number, age, smoking habits, number of implants and type of implant-supported restoration) and the authors’ conclusions. Information regarding the changes within each group for the various outcome parameters is presented in Table 2.

Study design, characteristics of the participants and outcome parameters
Two studies were cohort studies (Vandekerckhove et al. 2004; Rasperini et al. 2008), two were randomized controlled clinical trials (Wolff et al. 1998; Tawse-Smith et al. 2002) and one study (Truhlar et al. 2000) was a multicentre controlled clinical trial.

In a prospective cohort study Rasperini et al. (2008) (study IV) evaluated over a 12-month follow-up period an oscillating/rotating powered toothbrush in patients with implant-supported restorations in the aesthetic area. One third of the subjects were smokers. Papillary bleeding index, recession and probing pocket depth were measured at baseline and at 3, 6, and 12 months. An improvement on both bleeding score and clinical attachment level was reported over time (Table 2).

Similar results were also reported in another prospective cohort study by Vandekerckhove et al. (2004) (study V). This study assessed the efficacy of an oscillating/rotating powered toothbrush in patients rehabilitated with fixed prostheses on implants. Sulcus bleeding index, probing pocket depth, periodontal pocket bleeding index and gingival recession was measured at baseline and at 3, 6, and 12 months and showed that all parameters improved.
over the course of the study (Table 2). Changes of similar magnitude were observed over time on these parameters irrespective of the presence or absence of keratinized mucosa around the implants.

Tawse-Smith et al. (2002) (study I) compared in a 6-week single-blinded, randomized, cross-over study the clinical effectiveness of a manual and an oscillating/rotating powered toothbrush in a group of elderly, non-smoking, patients with implant-supported mandibular overdentures. Modified plaque and bleeding indexes were recorded at the start and end of the experimental period. The results of this study revealed comparable efficacy of the 2 types of toothbrushes with regard to mean plaque and bleeding scores (Table 2).

Truhlar et al. (2000) (study II) evaluated in a multicentre controlled clinical trial the effectiveness of a counter-rotational powered toothbrush with that of a conventional manual toothbrush and interdental aids on indexes of periodontal health in patients with implant-supported restorations. Plaque index, gingival index, probing pocket depth and recession were measured. The powered toothbrush was found to be superior to the conventional toothbrush in combination with interdental aids in reducing plaque and bleeding scores and probing pocket depth over a 2-year period (Table 3).

Similar results were also reported in a 6-month single-blinded, randomized, parallel study by Wolff et al. (1998) (study III) that compared a sonic toothbrush with a manual one. The sonic toothbrush was found to reduce plaque and bleeding significantly better than the manual toothbrush over time. Moreover, the sonic toothbrush was found to be more effective than the manual toothbrush in reducing probing depths and gingival inflammation over time, although differences in these parameters did not reach statistical significance (Table 2). However, the difference between the two groups at the end of the study was not significant for all parameters evaluated (Table 3).

Funding
In two studies (I, IV) the materials that were used were provided by companies. Three studies (II, III, V) reported involvement of a third party. This was either an industrial grant (II, III) or a co-author being related to the industry (V).

Quality assessment and grading the ‘body of evidence’
The quality assessment of the various studies is presented in Table 4. All studies were considered to have a high potential risk of bias. Studies I and II used the site as the experimental
unit for data analysis, while in studies III, IV and V the unit for data analysis was the subject. Only study I provide information about excluding subjects from further analysis because of non-compliance (per protocol analysis). Study III used an intention-to-treat analysis, including subjects in the analysis that used other cleaning devices next to the ones they were assigned to in the study.

The following criteria were used to rate the quality of evidence and strength of the recommendations according to GRADE (Guyatt et al. 2008): potential risk of bias, consistency, directness, precision of the estimate and publication bias. Only the controlled trials were included in this analysis (studies I, II, III). All studies had a high potential risk of bias. The available data for the powered toothbrush were rather consistent and rather precise. However, it is difficult to decide whether the results of the included studies can be generalized to other populations. As a result, the strength of recommendation was considered to be weak. A formal testing for publication bias, as proposed by Egger et al. (1997), could not be used owing to insufficient statistical power because of the limited number of studies.

Discussion

The present systematic review focused on the mechanical self-performed oral hygiene of implant-supported restorations. Powered toothbrushes were found to result in an improvement in clinical parameters over time. Three controlled clinical trials (I, II, III) compared a powered to a manual toothbrush. Study I revealed comparable efficacy of the 2 types of toothbrushes in elderly edentulous subjects with implant-supported overdentures, while, in subjects rehabilitated with fixed prostheses, powered toothbrushes gave superior results compared to the manual toothbrushes over time (II, III). However, these studies differ in several aspects. Results obtained in edentulous subjects do not necessarily reflect the situation in partially-dentate subjects. Edentulism, subjects’ age and brushing dexterity may have influenced the results. It is also known that study duration affects outcomes when manual and powered toothbrushes are compared (Aass & Gjermo 2000). Hence, the short-term (6-week) design that was employed in study I may be less likely to demonstrate significant differences. Furthermore, this study had a cross-over design with a wash-out period of two weeks, while studies II and III used a parallel design, which is the simplest type of randomized trial. An advantage of a cross-over design is that each participant acts as his or her own control, eliminating between-participant variation. However, statistically, cross-over trials are not
appropriate due to the likelihood of a carry-over effect. Cross-over studies using therapeutic agents are at risk of showing a period effect that is greater than the effect of interest. A wash-out period of two weeks may not be sufficient and longer wash-out periods are preferable (Senn, 2002). Thus, the results of this study should be interpreted with caution.

Study II compared a powered toothbrush to a manual toothbrush in combination with interproximal aids. Study III included in the analysis subjects that used other devices next to the toothbrushes assigned to the participants in the study. In study V, in addition to the powered toothbrush, subjects were allowed to use their usual interdental cleaning devices. These additional procedures may have influenced the results obtained. Although the powered toothbrushes gave superior results than the manual toothbrushes over time (study II, III), the difference between the two groups at most visits was not significant (study I, III). Thus the comparison of a power toothbrush to a manual toothbrush in combination with additional interdental cleaning devices should be interpreted with diligence since the comparison is not truly valid.

There is paucity of studies investigating interproximal devices. None of the included studies evaluated interproximal cleaning as a separate intervention. Chongcharoen et al. (2012) evaluated in a randomized controlled, double-blind cross-over study the effectiveness of two different interdental brushes in cleaning the interproximal surfaces of implants placed in the posterior region of the mouth. All cleaning procedures were performed by a trained dental surgery assistant, which was the reason of exclusion from the present review. The purpose of this study was to evaluate the efficacy of the interdental brush itself and not the capacity of the subject to clean interproximally. Under these circumstances both devices were found to be effective in purely interproximal cleaning. However, the ability of subjects to properly use these devices was not evaluated.

While there has been extensive research into all aspects of dental implant placement, little has been done to investigate the essential aspect of the maintenance of implant-supported restorations by patients. The patient’s ability to perform regular and effective oral hygiene has an impact on the long-term success of implants (Cagna et al. 2011). It becomes obvious that there is a lack of evidence with respect to optimal self-performed oral hygiene around dental implants, especially in terms of the use of interproximal devices. Self-performed home care around implants is, at present, mainly based on the knowledge that is available from the periodontal literature, with respect to cleaning of natural teeth. However, often, implant-supported restorations present contours and shapes that render
plaque removal difficult, even by the most capable individuals (Cagna et al. 2011). Additionally a pocket around an implant is anatomically different from pocket around a natural tooth which may require specific attention. Consequently well performed clinical trials, evaluating different oral hygiene products alone or in combination, are needed regarding this topic.

Based on the limited available data, powered toothbrushes seem to be effective in cleaning both fixed and removable implant-supported restorations. No hard evidence was found that powered toothbrushing is superior to manual toothbrushing, although powered toothbrushing may help to overcome limitations in manual dexterity and accessibility.

Acknowledgements

Declaration of interest
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Authors’ contribution

A. Louropoulou contributed to the conception, design, acquisition, analysis, interpretation of data, drafted the manuscript.

D.E. Slot contributed to the design, analysis, interpretation of data, critically revised the manuscript for important intellectual content.

G.A. van der Weijden contributed to the conception, design, analysis, interpretation of data, critically revised the manuscript for important intellectual content.

All authors gave final approval and agree to be accountable for all aspects of the work in ensuring that questions relating to the accuracy or integrity of any part of the work are appropriately investigated and resolved.
References


Figure 1. Databases search and literature selection

- **Identification**
  - Cochrane-CENTRAL: 219
  - PubMed-MEDLINE: 172
  - EMBASE: 308

- **Screening**
  - Unique titles & abstracts: 375
  - Excluded by title and abstract: 368

- **Eligibility**
  - Excluded after full-text reading: 2
  - Selected for full-text reading: 7
  - Included from the reference list: 0

- **Included**
  - Final Selection: 5
  - Cohort studies: 2
  - (Randomized) controlled clinical trials: 3
Table 1. Summary of studies evaluating the self-performed mechanical plaque control

<table>
<thead>
<tr>
<th>No Author (reference)</th>
<th>Study design</th>
<th>Subjects' characteristics</th>
<th>Groups</th>
<th>Authors' Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Tawse-Smith et al. (17)</td>
<td>RCT Cross-over</td>
<td>Elderly subjects n=40 (36)</td>
<td></td>
<td>Manual and powered brushes were found to be of comparable efficacy with regard to improvement in peri-implant plaque and bleeding indices.</td>
</tr>
<tr>
<td></td>
<td>2w- WOP Single blind 6 weeks</td>
<td>Mean age: 65.8 (55-80)</td>
<td>- Oscillating/rotating powered toothbrush (Braun Oral-B Plaque Remover 3-D)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Smoking Non-smokers</td>
<td>- Manual toothbrush (Oral-B Squish-grip brush)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Patients fully edentulous with 2 unsplinted mandibular implants supporting a complete removable overdenture opposed by a maxillary complete denture</td>
<td>2x daily for 30s</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>No of implants</td>
<td>- Oscillating/rotating powered toothbrush (Braun Oral-B Plaque Remover 3-D)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>- Manual toothbrush (Oral-B Squish-grip brush)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>2x daily for 30s</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Type of implant-supported restoration</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>No of implants</td>
<td></td>
<td></td>
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</tbody>
</table>
### Table: Controlled Clinical Trials

<table>
<thead>
<tr>
<th>Author (reference)</th>
<th>Study design</th>
<th>Subjects’ characteristics</th>
<th>Groups</th>
<th>Authors’ Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>II. Truhlar et al. (18)</strong></td>
<td>CT Parallel Multicenter 24 months</td>
<td>n =? Mean age: ? Smoking: ? Patients rehabilitated partially or fully with implant-supported restorations 2,966 implants</td>
<td>- Counter-rotational powered toothbrush (Interplak Power Toothbrush Conair Corp.) - Soft manual toothbrush (TrueSoft Lactona Co.) and either regular dental floss or specialized implant dental floss and end-tufted brushes (End-Tuft Lactona Co.) or interproximal brushes (Proxabrush John O. Butler Co.)</td>
<td>The counter-rotational powered toothbrush was more effective than a manual toothbrush plus interproximal aids, both in terms of clinical indexes and implant survival.</td>
</tr>
<tr>
<td><strong>III. Wolff et al. (19)</strong></td>
<td>RCT Parallel Single blind 24 weeks</td>
<td>Adults n = 31 Mean age: 56.3 (21-75) Smoking: ? Type of restoration: ? 96 implants</td>
<td>- Sonic toothbrush (Sonicare®, Optriva Corp., Bellevue, WA) - Manual toothbrush (Crest® Complete, The Proctor &amp; Gamble Co., Cincinetti, OH)</td>
<td>Sonic toothbrushing significantly reduced plaque, gingival inflammation and bleeding, and probing pocket depths around implants over the 6-month trial period.</td>
</tr>
<tr>
<td>No Author (reference)</td>
<td>Study design Duration</td>
<td>Subjects’ characteristics</td>
<td>Groups</td>
<td>Authors’ Conclusions</td>
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<tr>
<td>IV. Rasperini et al. (20)</td>
<td>Prospective Cohort 12 months</td>
<td>Adults n=100 (98) Mean age: 56 (?) One third smokers Implants in the esthetic area between the 1st premolars Patients rehabilitated partially or fully with fixed prosthesis</td>
<td>- Oscillating/rotating toothbrush (Braun Oral-B Professional Care 7000, Proctor &amp; Gamble, Ohio, USA) 2x daily</td>
<td>All parameters improved over the course of the study. The electric toothbrush appears to be safe for patients with fixed prostheses on implants in the aesthetic area.</td>
</tr>
<tr>
<td>V. Vanderkerckhove et al. (21)</td>
<td>Prospective Cohort 12 months</td>
<td>Adults n=100 (80) Mean age: 56.3 (18-80) Smoking: ? Patients rehabilitated partially or fully with fixed prosthesis</td>
<td>- Oscillating/rotating powered toothbrush (Braun Oral-B Plaque Control Ultra (D9), Kronberg, Germany) Regular interdental cleaning which mostly consisted of interdental brushes and Superfloss 2x daily for 2min</td>
<td>All parameters improved over the course of the study. The powered toothbrush investigated is effective for patients rehabilitated by means of oral implant-supported prostheses.</td>
</tr>
</tbody>
</table>

RCT: randomized controlled clinical trial; CT: controlled clinical trial; WOP: wash-out period
Table 2. Extracted data of the selected studies by plaque indices, bleeding indices, gingival health indices, probing pocket depths and recessions.

<table>
<thead>
<tr>
<th>Model</th>
<th>Study no</th>
<th>Index (reference)</th>
<th>Intervention Groups</th>
<th>Mean (SD)</th>
<th>Statistically significant within groups</th>
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<tbody>
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<td></td>
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<td></td>
<td>Baseline</td>
<td>End</td>
<td>Difference</td>
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<tr>
<td><strong>Plaque index</strong></td>
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<tr>
<td><strong>CONTROLLED CLINICAL TRIALS</strong></td>
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<td></td>
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<tr>
<td>I</td>
<td>I</td>
<td>Modified plaque index by Mombelli (26)</td>
<td>Powered toothbrush</td>
<td>0.9 (0.67)</td>
<td>0.9 (0.73)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Manual toothbrush</td>
<td>0.8 (0.64)</td>
<td>0.8 (0.67)</td>
</tr>
<tr>
<td>II</td>
<td>II</td>
<td>Silness and Löe plaque index (27)</td>
<td>Powered toothbrush</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>III</td>
<td>III</td>
<td>Silness and Löe plaque index (27)</td>
<td>Sonic toothbrush</td>
<td>1.31 (0.48)</td>
<td>0.46 (0.50)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Manual toothbrush</td>
<td>1.27 (0.47)</td>
<td>0.60 (0.45)</td>
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</table>
## Bleeding index

<table>
<thead>
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<th>Model</th>
<th>Study no</th>
<th>Index (reference)</th>
<th>Intervention Groups</th>
<th>Mean (SD)</th>
<th>Statistically significant within groups</th>
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<td>Baseline</td>
<td>End</td>
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<td>CONTROLLED CLINICAL TRIALS</td>
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<td>Baseline</td>
<td>End</td>
</tr>
<tr>
<td>I</td>
<td>I</td>
<td>Modified sulcus bleeding index by Mombelli (26)</td>
<td>Powered toothbrush</td>
<td>0.4 (0.38)</td>
<td>0.5 (0.52)</td>
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<td></td>
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<td></td>
<td>Manual toothbrush</td>
<td>0.4 (0.49)</td>
<td>0.5 (0.51)</td>
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<tr>
<td>III</td>
<td>III</td>
<td>Gingival bleeding index by Pihlström (28)</td>
<td>Sonic toothbrush</td>
<td>1.47 (0.31)</td>
<td>0.66 (0.64)</td>
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<td></td>
<td>Manual toothbrush</td>
<td>1.46 (0.72)</td>
<td>0.67 (0.56)</td>
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<tr>
<td>COHORT TRIALS</td>
<td>IV</td>
<td>Papillary bleeding index (29)</td>
<td>Powered toothbrush</td>
<td>1.5 (1.6)</td>
<td>0.7 (1.0)</td>
</tr>
<tr>
<td></td>
<td>V</td>
<td>Sulcus bleeding index (29)</td>
<td>Powered toothbrush and interdental aids</td>
<td>0.31 (?)</td>
<td>0.14 (?)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Periodontal bleeding index (30)</td>
<td></td>
<td>0.55 (?)</td>
<td>0.38 (?)</td>
</tr>
<tr>
<td>Model</td>
<td>Study no</td>
<td>Index (reference)</td>
<td>Intervention Groups</td>
<td>Mean (SD)</td>
<td>Statistically significant within groups</td>
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<td>Baseline</td>
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<td>II</td>
<td>II</td>
<td>Loe and Silness gingival index (31)</td>
<td>Sonic toothbrush</td>
<td>1.46 (0.27)</td>
<td>0.87 (0.54)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Manual toothbrush</td>
<td>1.58 (0.42)</td>
<td>0.94 (0.49)</td>
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<tr>
<td>III</td>
<td>Probing pocket depth (18)</td>
<td>Powered toothbrush</td>
<td>?</td>
<td>?</td>
<td>?</td>
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<tr>
<td>III</td>
<td>Probing pocket depth (19)</td>
<td>Sonic toothbrush</td>
<td>3.32 (0.70)</td>
<td>2.87 (0.76)</td>
<td>- 0.43*</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Manual toothbrush</td>
<td>3.10 (0.75)</td>
<td>2.73 (0.68)</td>
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</table>
### Probing pocket depth

<table>
<thead>
<tr>
<th>Model</th>
<th>Study no</th>
<th>Index (reference)</th>
<th>Intervention Groups</th>
<th>Mean (SD)</th>
<th>Statistically significant within groups</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COHORT TRIALS</strong></td>
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</tr>
<tr>
<td>IV</td>
<td>Probing pocket depth (20)</td>
<td>Powered toothbrush</td>
<td>3.8 (1.1)</td>
<td>3.5 (1.2)</td>
<td>- 0.3◊</td>
</tr>
<tr>
<td>V</td>
<td>Probing pocket depth (21)</td>
<td>Powered toothbrush and interdental aids</td>
<td>3.32 (?)</td>
<td>3.02 (?)</td>
<td>- 0.3◊</td>
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</tbody>
</table>

### Recession

<table>
<thead>
<tr>
<th>Model</th>
<th>Study no</th>
<th>Index (reference)</th>
<th>Intervention Groups</th>
<th>Mean (SD)</th>
<th>Statistically significant within groups</th>
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<td><strong>CONTROLLED CLINICAL TRIALS</strong></td>
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<tr>
<td>II</td>
<td>Recession (18)</td>
<td>Powered toothbrush</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td><strong>COHORT TRIALS</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>Recession (20)</td>
<td>Powered toothbrush</td>
<td>11.9 (2.5)</td>
<td>11.7 (2.3)</td>
<td>- 0.2◊</td>
</tr>
<tr>
<td>V</td>
<td>Recession (21)</td>
<td>Powered toothbrush and interdental aids</td>
<td>0.97 (?)</td>
<td>0.87 (?)</td>
<td>- 0.1◊</td>
</tr>
</tbody>
</table>

* Reduction in clinical parameter is adjusted for baseline
◊ calculated by the authors of this review

?: no data available
**Table 3.** A descriptive summary of the statistical significance of powered toothbrushes to a comparison

<table>
<thead>
<tr>
<th>Study no</th>
<th>Test group</th>
<th>Control group</th>
<th>Plaque Index</th>
<th>Bleeding Index</th>
<th>Gingival Index</th>
<th>Probing Pocket Depth</th>
<th>Recession</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Powered toothbrush</td>
<td>Manual toothbrush</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>Powered toothbrush</td>
<td>Manual toothbrush and interproximal aids</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>III</td>
<td>Sonic toothbrush</td>
<td>Manual toothbrush</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

+: significant difference at the end of the study period in favor of the test group; 0: no significant difference at the end of the study between the groups.
Table 4. Methodological validity and quality scores of the included studies

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Quality criteria</strong></td>
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<tr>
<td>Internal validity</td>
<td></td>
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<tr>
<td>Random allocation *</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>Allocation concealment</td>
<td>?</td>
<td>-</td>
<td>?</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>Blinded to patient *</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>Blinded to examiner *</td>
<td>+</td>
<td>?</td>
<td>+</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>Balanced experimental groups *</td>
<td>+</td>
<td>?</td>
<td>+</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>Reported loss to follow up *</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>No (%) of drop-outs</td>
<td>4(10%)</td>
<td>-</td>
<td>0</td>
<td>2(2%)</td>
<td>20(20%)</td>
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<tr>
<td>Treatment identical, except for intervention *</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>External validity</td>
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<tr>
<td>Representative population group</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Eligibility criteria defined *</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><strong>Author's estimated risk of bias</strong></td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>High</td>
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<td>High</td>
<td>High</td>
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<tr>
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<td>--------------------------</td>
<td>----------------------</td>
<td>-------------------</td>
<td>----------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td><strong>Statistical validity</strong></td>
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<tr>
<td>Research model used</td>
<td>Cross-over</td>
<td>Multicenter</td>
<td>Parallel</td>
<td>Cohort</td>
<td>Cohort</td>
</tr>
<tr>
<td>Sample size calculation and power</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Point estimates</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Measures of variability presented for the primary outcome</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Unit of analysis *</td>
<td>Site</td>
<td>Site</td>
<td>Subject</td>
<td>Subject</td>
<td>Subject</td>
</tr>
<tr>
<td>Include a per protocol analysis</td>
<td>+</td>
<td>?</td>
<td>-</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Include an intention-to-treat analysis</td>
<td>-</td>
<td>?</td>
<td>+</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td><strong>Author's estimated risk of bias</strong></td>
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<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

Criteria were designated for each domain of internal validity, external validity and statistical methods. Each aspect of the score list was given a rating of ‘+’ for an informative description of the item at issue and a study design meeting the quality standard, ‘-’ for an informative description without a study design that met the quality criteria and ‘?’ for lacking or insufficient information.

+: yes; -: no; ?: not specified/unclear

◊: percentage of drop-outs calculated by the authors of this review

NA: not applicable

* reporting criteria for estimating the potential risk of bias