Short-term and long-term effectiveness of powered toothbrushes in promoting periodontal health during orthodontic treatment: A systematic review and meta-analysis

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Introduction: Although powered toothbrushes have been reported to reduce gingivitis more than manual toothbrushes in the general population, the evidence regarding orthodontic patients has been inconclusive. Thus, we aimed to compare their effectiveness in relation to any available parameter regarding oral health in orthodontic patients with fixed appliances. **Methods:** Searches without restrictions for published and unpublished literature and hand searching took place up to August 2017. Oral-health relevant data from randomized controlled trials of at least 4-weeks duration comparing powered and manual tooth brushing without supervision were reviewed. Data were classified as short term (assessments at 1-3 months) and long term (assessments at >3 months), and the random-effects method was used to combine treatment effects. Individual study risk of bias was assessed using the Cochrane Risk of Bias Tool, and the quality of evidence was evaluated according to the Grades of Recommendation, Assessment, Development and Evaluation approach. **Results:** The initially identified articles were finally reduced to 9 randomized controlled trials investigating the periodontal health in 434 patients. Eight studies followed patients up to 3 months, and 1 up to 12 months during treatment. One study was at low and the rest at unclear risk of bias. Overall, in the short term, there was low-quality evidence that powered toothbrushes provide a statistically significant benefit compared with manual brushing with regard to the gingival index (weighted mean difference, −0.079; 95% confidence interval, −0.146 to −0.012; $P = 0.021$) and indexes assessing gingival bleeding (standardized mean difference, −0.637; 95% confidence interval, −1.092 to −0.183; $P = 0.006$). In the long term, only 1 available study showed a statistically significant benefit of powered over manual toothbrushes with regard to gingival index and bleeding. No differences were observed in probing pocket depth and relative attachment loss. For the rotation-oscillation brushes that involved the greatest body of evidence, statistically significant reductions in gingival index and bleeding were demonstrated only in the long-term study. No included study provided quantified measurements regarding caries activity. **Conclusions:** Overall, powered toothbrushes may promote gingival health better than manual toothbrushes in orthodontic patients. However, no type demonstrated clear superiority. Better study standardization and reporting in longer follow-up studies are necessary to elucidate the clinical relevance of these results. (Am J Orthod Dentofacial Orthop 2017;152:753-66)

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The risk of enamel decalcification and damage to periodontal supporting tissues are long recognized as problems during orthodontic treatment and remain major concerns, especially in patients with fixed orthodontic appliances.[1] Fixed appliances encourage oral biofilm accumulation, since bands, brackets, orthodontic wires, and accessories act as plaque traps.[2] Moreover, meticulous toothbrushing and interproximal care become much more difficult and time-consuming processes requiring skill and manual dexterity to complete efficiently.[3] Thus, the presence of fixed appliances

increases biofilm retention, and an ecologic shift to periopathogenic oral flora may occur, recognizable clinically as deterioration in periodontal clinical parameters. Furthermore, under certain conditions, a cariogenic environment may develop, and enamel decalcification can also be observed.[1,3]

In this respect, attainment and maintenance of effective daily oral hygiene practices, periodic instruction and motivation, and monitoring of dental and periodontal statuses throughout treatment are critical elements for oral tissue health and overall success of orthodontic treatment.[3,4] Specifically, the mechanical removal of microbial biofilm is essential in maintaining the microbial ecosystem in equilibrium with healthy tissues.[5] The primary means of mechanical biofilm control are toothbrushes, complemented by interdental cleaning aids, and secondarily by other devices such as oral irrigators, chewing sticks, and so on.[6]

With regard to powered toothbrushes, a recent Cochrane Collaboration systematic review suggested that, in the general population, certain types of these devices are more effective in reducing oral biofilm and preventing gingivitis than manual toothbrushes, in both the short and long terms.[7] However, this review did not focus specifically on orthodontic patients. Concerning patients with fixed orthodontic appliances, quantitative data synthesis of the then-available data to Kaklamanos and Kalfas[8] suggested that the relevant information was insufficient to draw robust conclusions regarding their comparative advantages and that any inferences for clinical practice were precluded. They also suggested the need for future trials with a standardized methodology to increase the relevance to the clinical situation under investigation. However, after that publication, the effectiveness of powered compared with manual toothbrushes in orthodontic patients has not been investigated in an evidence-based manner.

The objective of this systematic review was to systematically investigate and appraise the quality of the most up-to-date evidence regarding the effectiveness of powered toothbrushes compared with manual ones in maintaining oral tissue health during orthodontic treatment.

MATERIAL AND METHODS

Protocol and registration

This review was based on a specific protocol developed and piloted following the guidelines outlined in the PRISMA-P statement[9] and registered in PROSPERO (CRD42015027997). Furthermore, conduct and reporting followed the guidelines of the *Cochrane Handbook for Systematic Reviews of Interventions*[10] and the PRISMA statement,[11] respectively.

Eligibility criteria

The eligibility criteria were based on the PICOS (participants, intervention, comparison, outcomes, study design) acronym. We included randomized controlled trials of at least 4-weeks duration comparing powered and manual toothbrushing without supervision as part of normal everyday oral hygiene procedures. Thus, split-mouth studies were excluded.[8] Animal studies, noncomparative studies (case reports and case series), systematic reviews, and meta-analyses were also excluded (Supplementary Table I).

Information sources, search strategy and study selection

Overall, 8 databases were searched up to August 2017. One author (S.A.A.M.) developed detailed search strategies for each database. They were based on the strategy developed for MEDLINE but revised appropriately for each database to take account of the differences in controlled vocabulary and syntax rules (Supplementary Table II).

No restrictions were placed on language, date, and status of publication. In addition, efforts to obtain additional and ongoing trials were made, and the reference lists of all eligible studies and relevant reviews were searched.

Two authors (S.A.A.M. and E.G.K.) assessed the retrieved records for inclusion independently. They were not blinded to the identity of the authors, institutions, or results of the research. Subsequently, they obtained and assessed, again independently, the full report of records considered by either reviewer to meet the inclusion criteria. Disagreements were resolved by discussion or consultation with the third author (A.E.A.).

Data collection and data items

The same 2 authors performed data extraction independently, and any disagreements were again resolved by discussion or consultation with the third author. Predetermined and prepiloted data collection forms were used to record the desired information (Supplementary Table I).

The eligible studies were considered to be "short term" if the experimental period was up to 3 months and "long term" beyond that period. The mode of action of the powered toothbrushes was categorized according to the study of Kaklamanos and Kalfas.[8] Data on gingivitis were extracted in the form of indexes recording qualitative changes in the gingivae and assessing gingival bleeding (absence or presence based on scoring criteria)[12] (Supplementary Table I). When a study recorded outcomes at various time points, only the latest measurements were extracted. Only when a study falling under the "long-term" category included measurements

that could be analyzed within the "short-term" data category was information from 2 time points noted. If we needed clarifications on the published data or additional material, attempts to contact the corresponding authors were made.

Risk of bias in individual studies

Two authors (S.A.A.M. and E.G.K.) assessed the risk of bias in individual studies, independently and in duplicate, using the Cochrane Collaboration's Risk of Bias assessment tool for randomized controlled trials and approach.[10] Any disagreements were resolved by discussion or consultation with the third author (A.E.A.).

Summary measures and approach to synthesis

From the retrieved publications, data from different indexes that measured, with high correlation, the same concept on different scales were extracted. Thus, to enable quantitative synthesis, the effects of the interventions for continuous outcomes were expressed as standardized values (standardized mean differences with relevant 95% confidence intervals [CI]).[13] Where, in a particular comparison, only 1 index was recorded, the intervention effect was expressed as the weighted mean difference together with the 95% CI. For dichotomous outcomes, the effects of interventions were expressed as relative risk with the 95% CI.

The random-effects method for meta-analysis was used to combine data from studies that reported similar measurements in appropriate statistical forms, since they were expected to differ across studies due to clinical diversity in terms of participant and intervention characteristics.[14,15] A combination of parallel and crossover trials was planned according the principles outlined by Elbourne et al.[16] When the statistical reporting of crossover trials lacked important information, the corresponding author was contacted for the necessary clarification. In case of synthesis of 3 or more trials, 95% prediction intervals were calculated to predict treatment effects in future trial settings.[15,17] To identify the presence and extent of between-study heterogeneity, the overlap of the 95% CIs for the results of individual studies was inspected graphically, and the I^2 statistic was calculated.[10]

All analyses were performed with comprehensive meta-analysis software (version 2.2.04; BioStat Solutions, Englewood, NJ). Significance (α) was set at 0.05, except for 0.10 used for the heterogeneity tests.[18]

Risk of bias across studies and additional analyses

If a sufficient number of studies were identified, analyses were planned for small-study effect and publication bias.[10] If deemed possible, exploratory subgroup analyses were planned according to participant and intervention characteristics.

In addition, the quality of evidence at the longest follow-up available for key outcomes was assessed based on the grades of recommendation, assessment, development, and evaluation (GRADE) approach.[19]

RESULTS

Study selection and characteristics

The flow of records through the reviewing process is shown in Figure 1. Initially, 1505 references were identified, 463 were excluded as duplicates, and 1005 more were excluded on the basis of their title and abstract. From the 37 records that remained, 10 studies were excluded because they were not randomized, 5 because they presented only data on plaque, 1 due to an inadequate follow-up period, and 3 more because they combined the use of the toothbrushes with other interventions. Moreover, we excluded 5 crossover trials with inadequate washout periods and 4 with inadequate statistical information. Finally, 9 full-text trial reports were included in this systematic review.[20-28]

The characteristics of these studies are presented in Tables I and II. The articles were published between 1997 and 2015; the authors had recruited 434 patients and investigated periodontal health. No study provided quantified measurements regarding caries activity. Of the 9 trials, 6 involved a rotation-oscillation action toothbrush,[21,24-27] 1 a side-to-side action toothbrush,[20] 1 an ionic toothbrush,[22] 1 a toothbrush with bristles pulsating at a frequency of 6000 strokes per minute,[23] and another investigated 2 powered toothbrushes, 1 with an oscillating head and 1 that was sonic.[28]

Regarding the study duration, only the study of Park et al[26] followed patients for 1 year, with the rest not more than 2 months. Moreover, 2 studies reported a priori calculations of sample sizes[21,24] and considered in some way examining the reliability of the measurements carried out.[1,23] Also, 4 studies used some type of compliance monitoring.[21-24]

The inflammatory response of the periodontal tissues was assessed using the gingival index of Löe and Silness[29] in the studies providing short-term data.[20-25,28] This assessment was supplemented by indexes assessing gingival bleeding such as the Eastman interdental bleeding index,[21,24,28,30] the gingival bleeding index of Ainamo and Bay,[26,27,31] bleeding on probing,[20,32] the papillary bleeding score of Loesche,[23,33] and the sulcus bleeding index of Muhlemann and Son.[25,34] In the long term study,[26] periodontal inflammation was assessed by the gingival index of Löe and Silness[29] and the gingival bleeding index of Ainamo and Bay.[31]

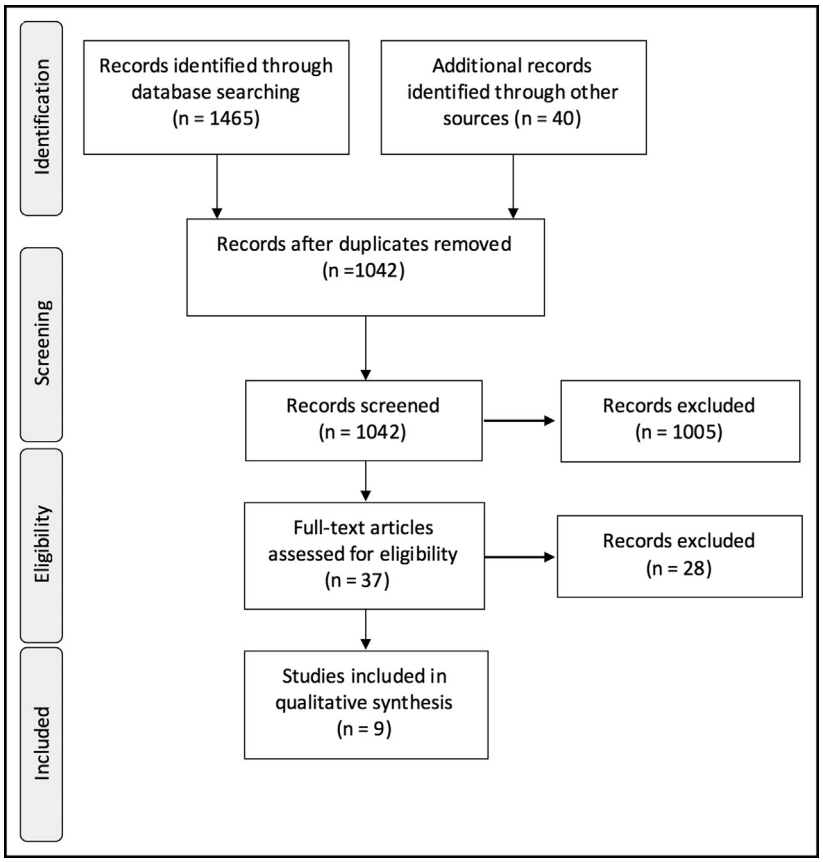

Fig 1. Flow of records through the reviewing process.

The anatomic conditions of the periodontal tissues were reported as pocket depth,[20,26] relative attachment loss,[26] and gingival hypertrophy.[27] Patient-reported outcomes could not be retrieved apart from information on possible adverse reactions.[22,28] In addition, the trial investigators provided more comprehensive assessments on unwanted effects of the intervention in 4 studies.[21-24] Data on costs or cost-effectiveness could not be retrieved from the studies included in this systematic review.

Risk of bias within studies

Table III presents the summary findings of the risk of bias assessment for the studies; more details can be found in Supplementary Table III.

Only 1 study was judged to have a low overall risk of bias.[21] Most of the rest were classified with an overall unclear risk of bias, mainly because of uncertainties regarding random sequence generation and allocation concealment.[20,22-28] Blinding of the participants and the personnel providing the instructions was not feasible apart from 1 publication.[22] However, in the context of our research design, there was no reason to believe that bias could be introduced because of absence of blinding in these cases. On the contrary, investigation of the procedures regarding blinding of the outcome assessment showed unclear risks for some trials.[25-28] Risks from incomplete outcome data because of dropouts were unclear in 3 studies.[20,22,23]

Results of individual studies, meta-analysis, and additional analysis

In the short term, powered toothbrushes provided an overall statistically significant benefit compared with manual toothbrushes with regard to the Löe and Silness gingival index (weighted mean difference, −0.079; 95% CI, −0.146 to −0.012; 95% prediction interval, −0.300 to 0.142; $P = 0.021$; n = 374; I^2, = 83%) (Fig 2).[20-25,28] In addition, an overall statistically significant benefit with regard to the indexes assessing gingival bleeding was detected (standardized mean difference, −0.637; 95% CI, −1.092 to −0.183; 95% prediction interval, −2.106 to 0.832; $P = 0.06$; n = 342; $I^2 = 76\%$) (Fig 3).[20,21,23-25,27,28] In the long

Table I. General characteristics of the studies included in the systematic review

Study	*Intervention characteristics*	*Included outcomes*	*Additional information*
Clerehugh et al[21] (1998) United Kingdom RCT (parallel, single blind) Duration: 8 weeks	Group 1: Braun Oral-B Plaque Remover (D5) + orthodontic brush head Group 2: Reach Compact Head Medium Oral hygiene: Oral hygiene instructions at the beginning, printed handout, brushing for 2 min, twice a day with fluoride dentifrice, use of 0.05% sodium fluoride solution. Timing brushing with either the built-in electronic timer or a timer. Recommendations: no use of antibiotics	LSGI, ElBI, safety assessments (doctor assesses trauma on soft/hard tissues and appliances) Assessment: baseline, 2 mo (patients allowed to brush in the morning and under supervision before measurements; thus, plaque measurements were not considered; full-mouth recordings).	A priori sample calculation: yes Examination reliability: NR, but the examiners "had considerable experience" Compliance monitoring: toothbrushing diary
Hickman et al[24] (2002) United Kingdom RCT (parallel, single blind) Duration: 8 weeks	Group 1: Braun Oral-B Plaque Remover (D5) + orthodontic brush head Group 2: Reach Compact Head Medium Oral hygiene: oral hygiene instructions at the beginning of the trial, printed handout, brushing for at least twice a day with fluoride dentifrice, use of fluoride solution. Timing brushing with either the built-in electronic timer or a timer. Recommendations: no use of interdental brushes	LSGI, ElBI, safety assessments (trauma on tissues) Assessment: baseline, 2 mo (patients brushed after breakfast as normal; full-mouth recordings)	A priori sample calculation: yes Examination reliability: NR Compliance monitoring: toothbrushing diary
Ho and Niederman[20] (1997) United States RCT (parallel, single blind) Duration: 4 weeks	Group 1: Sonicare sonic toothbrush Group 2: Oral-B P35 toothbrush Oral hygiene: oral hygiene instructions, brushing for 2 min, twice a day with fluoride dentifrice. Timing brushing with either the built-in electronic timer or a clock.	LSGI, BOP, pocket depth Assessment: baseline, 1 mo (no instructions on brushing before measurements; full-mouth recordings)	A priori sample calculation: NR Examination reliability: NR Compliance monitoring: NR
Park et al.[25] (2004) Korea RCT (parallel, single blind) Duration: 8 weeks	Group 1: Braun Oral-B Plaque Control D9511 + Ortho brush head Group 2: Butler G.U.M. 124 Oral hygiene: oral hygiene instructions at the beginning of trial, brushing at least twice a day for 2 min, change bristles every 4 weeks	LSGI, SBI Assessment: baseline, 2 mo Full mouth recordings	A priori sample calculation: NR Examination reliability: NR Compliance monitoring: NR

Table I. Continued

Study	*Intervention characteristics*	*Included outcomes*	*Additional information*
Park et al.[26] (2005) Korea RCT (parallel, single blind) Duration: 12 months	Group 1: Braun Oral-B Plaque Control + Ortho OD15-1 brush head Group 2: Butler G.U.M. 124 Oral hygiene: oral hygiene instructions at the beginning of trial, brushing at least twice a day for 2 min	LSGI, ABGBI, pocket depth, relative attachment loss Assessment: baseline, 12 mo Full mouth recordings	A priori sample calculation: NR Examination reliability: NR Compliance monitoring: NR
Pucher et al[22] (1999) United States RCT (parallel, double blind) Duration: 6 weeks	Group 1: Hukuba ionic toothbrush (active battery) Group 2: Hukuba ionic toothbrush (inactive battery) Oral hygiene: oral hygiene instructions at the beginning of trial, brushing at least twice a day for a minimum of 2 min with stabilized stannous fluoride (0.4%) toothpaste. Recommendations: not having an oral prophylaxis	LSGI, safety assessments (doctor assesses trauma on soft/hard tissues; patients asked about any adverse reactions) Assessment: Baseline, 6 wK (patients asked not to brush for 12 h before the initial measurement and brushing afterward; only data from recordings before brushing were used; full-mouth recordings)	A priori sample calculation: NR Examination reliability: NR Compliance monitoring: verified verbally and the toothbrush heads were examined for wear
Sharma et al[28] (2015) India RCT (parallel, single blind) Duration: 8 weeks	Group 1: Colgate 360° whole mouth clean Group 2: Colgate 360° sonic power Group 3: Colgate Ortho Oral hygiene: oral hygiene instructions at the beginning of trial, brushing at least twice a day, printed instructions, timer Recommendations: not having an oral prophylaxis, no flossing or mouthwash use during the study	LSGI, EIBI, safety assessments (patients asked if they experienced any soft or hard-tissue trauma from brushing with the allocated brush) Assessment: baseline, 2 mo (no mention of whether patients were allowed to brush before measurements; labial or buccal surfaces of teeth measured)	A priori sample calculation: NR Examination reliability: NR but mentioned that patients were examined by 1 examiner to minimize interexaminer bias Compliance monitoring: NR
Silvestrini Biavati et al.[27] (2010) Italy RCT (parallel, single blind) Duration: 8 weeks	Group 1: Oral B Professional Care 850 Group 2: Oral B Ortho P35 Oral hygiene: Oral hygiene instructions at the beginning of trial, reinforced at 2 weeks, printed handout, brushing at least twice a day Recommendations:	ABGBI, gingival hypertrophy Assessment: baseline, 2 mo (no mention of whether patients were allowed to brush before measurements; no clear information on sites recorded)	A priori sample calculation: NR Examination reliability: NR Compliance monitoring: NR

Table I. Continued

Study	Intervention characteristics	Included outcomes	Additional information
	not having an oral prophylaxis, no flossing or mouthwash use during the study		
Singh[23] (1999) United States RCT (parallel, single blind) Duration: 60 days	Group 1: Butler Pulse Plaque Remover, Group 2: Oral-B P35 toothbrush Oral hygiene: oral hygiene instructions at the beginning of trial, brushing for 2 min Recommendations: not having an oral prophylaxis	LSGI, PBS, safety assessments (doctor assesses trauma on soft tissues) Assessment: baseline, 2 mo (patients not allowed to brush 12-24 hours before measurements; postbrushing measurements were not considered; full-mouth recordings)	A priori sample calculation: NR Examination reliability: investigated Compliance monitoring: toothbrushing diary

RCT, Randomized controlled trial; *LSGI*, Löe and Silness gingival index; *EIBI*, Eastman interdental bleeding index; *BOP*, bleeding on probing; *PBS*, Loesche papillary bleeding score; *SBI*, Muhlemann and Son sulcus bleeding index; *ABGBI*, Ainamo and Bay gingival bleeding index; *NR*, not reported.

term, only 1 study showed a statistically significant benefit with regard to both the gingival index (weighted mean difference, −0.220; 95% CI, −0.424 to −0.016; $P = 0.035$; n = 40) and the gingival bleeding index (weighted mean difference, −1.630; 95% CI, −3.206 to −0.054; $P = 0.043$; n = 40).[26]

Analyses of data from the studies investigating rotation-oscillation toothbrushes, which formed the major body of evidence, did not detect an overall statistically significant benefit with regard to the gingival index (weighted mean difference, −0.061; 95% CI, −0.167 to −0.046; 95% prediction interval, −1.196 to 1.074; $P = 0.264$; n = 173; $I^2 = 60\%$) (Fig 4)[21,24,25] or the indexes assessing gingival bleeding (standardized mean difference, −0.217; 95% CI, −0.501 to −0.068; 95% prediction interval, -0.842 to 0.408; $P = 0.135$; n = 193; $I^2 = 0\%$) (Fig 5).[21,24,25,27] Overall, the quality of available evidence was considered to be low (Table IV).

With regard to probing pocket depth, a statistically significant benefit of powered over manual toothbrushes was observed in the short term (weighted mean difference, −0.760; 95% CI, −1.029 to 0.491; $P = 0.000$; n = 24).[20] However, in the long term, no difference was demonstrated (weighted mean difference, −0.140; 95% CI, −0.324 to 0.044; $P = 0.136$; n = 40).[26] Similarly, no differences were detected in the long term for relative attachment loss (weighted mean difference, −0.230; 95% CI, −0.590 to 0.130; n = 40; $P = 0.210$)[26] or in the short term for gingival hypertrophy (relative risk, 0.667; 95% CI, 0.140 to 3.172; n = 20; $P = 0.610$).[27] The quality of evidence was assessed as low (Supplementary Table IV).

Only 2 studies presented data on patient-reported outcomes in the form of information on possible adverse reactions, with no complaints reported.[22,28] Finally, in the 4 studies where the trial investigators provided more comprehensive assessments on unwanted effects of the intervention, there was no evidence of adverse events or safety considerations to the soft or hard tissues or the fixed orthodontic appliances due to participation in the study or use of study products.[21-24]

Risk of bias across studies

It was not possible to conduct analyses for small-study effects or publication bias.

DISCUSSION

Summary of evidence

Since controlling the deposition of oral biofilms is a primary element in oral health maintenance, it is a key challenge for the orthodontist to work with patients to

Table II. Participant characteristics of the studies in the systematic review

Study	*Inclusion and exclusion criteria*	*Patients included and analyzed (n)*
Clerehugh et al[21] (1998)	Inclusion criteria: 10-20 years old, edgewise fixed orthodontic appliance therapy simultaneously in both arches, brushing at least once a day, mean plaque score >1.25, gingival bleeding >30% of sites, in good general health Exclusion criteria: medical contraindications, mental or physical handicaps compromising manual dexterity, poor compliance, poor periodontal health, gross or uncontrolled caries, oral prophylaxis in the previous 4 weeks, use of antibacterial mouth rinses	84 subjects (37 M, 47 F) (78 patients, <16 years old) Group 1: 41 randomized (37 analyzed) Group 2: 43 randomized (42 analyzed)
Hickman et al[24] (2002)	Inclusion criteria: 10-20 years old, edgewise fixed orthodontic appliance therapy simultaneously in both arches, brushing at least once a day, gingival bleeding >20% of sites, in good general health Exclusion criteria: medical contraindications, poor manual dexterity, poor compliance, poor periodontal health, active caries, oral prophylaxis in previous 4 weeks, use of antibacterial mouth rinses, current use of a powered toothbrush	63 subjects (28 M, 35 F) Group 1: 33 randomized [age ($\bar{x}$±SD): 14.9 ± 1.4] (15 M, 18 F) (31 analyzed) Group 2: 30 randomized [age (x ± SD): 15.4 ± 2.1] (13 M, 17 F) (29 analyzed)
Ho and Niederman[20] (1997)	Inclusion criteria: 11-18 years old, fixed orthodontic appliance therapy simultaneously in both arches, LSGI >2 Exclusion criteria: no medical or physical problems impeding or compromising study participation, no intake of antibiotics, steroids, or nonsteroidal anti-inflammatory drugs	24 subjects (12 M, 12 F) Group 1: 12 randomized [age ($\bar{x}$) ≈ 15] (6 M, 6 F) (analysis unclear) Group 2: 12 randomized [age ($\bar{x}$) ≈ 15] (6 M, 6 F) (analysis unclear)
Park et al[25] (2004)	Inclusion criteria: medically healthy patients of the orthodontic clinic, having edgewise orthodontic appliances Exclusion criteria: pregnancy; antibiotic use	34 subjects (15 M [age ($\bar{x}$±SD): 18.8 ± 4.3], 19 F [age: 16.2 ± 4.1]) Group 1: 17 randomized (17 analyzed) Group 2: 17 randomized (15 analyzed)
Park et al[26] (2005)	Inclusion criteria: medically healthy, treatment with fixed orthodontic appliances Exclusion criteria: pregnancy, severe periodontal problem, antibiotic use	40 subjects [age ($\bar{x}$±SD): 19.8 ± 4.3] Group 1: 20 randomized (20 analyzed) Group 2: 20 randomized (20 analyzed)
Pucher et al[22] (1999)	Inclusion criteria: older than 12 y, minimum of 20 teeth Exclusion criteria: no taking of medications affecting plaque formation and no antibiotic use 3 months before the study or during the study	60 subjects Group 1: 30 randomized (27 analyzed; 11 M, 16 F; age ($\bar{x}$±SD): 13.89 ± 1.58) Group 1: 30 randomized (25 analyzed; 12 M, 13 F; age ($\bar{x}$±SD): 15.96 ± 3.69)
Sharma et al[28] (2015)	Inclusion criteria: patients who were to receive fixed orthodontic treatment with maxillary and mandibular preadjusted edgewise appliance therapy simultaneously, at least 20 teeth present, minimum of 16 brackets or bands on teeth, brushing habit of at least once per day, age13-32 years, no use of antibiotics in the past 2 months, absence of menstruation or pregnancy at the time of recording scores. Exclusion criteria: systemic disease, use of antibiotics, steroids, or nonsteroidal anti-inflammatory drugs within past 2 months or during the study, fewer than 5 teeth per quadrant, immunosuppressant drugs, medically compromised, mentally handicapped subjects, subjects with poor manual dexterity, poor compliance, subjects who received oral hygiene instructions from dental professional in past 6 months, severe gingival inflammation, no obvious periodontal disease (systemic or local) or attachment loss or pocketing, use of antibacterial mouth rinses, juvenile/aggressive periodontitis, previous or current use of powered or manual orthodontic toothbrushes, gross caries lesions, diagnosed with early onset periodontitis, smoking, tobacco products, pregnancy, acute illness	60 subjects Group 1: 20 randomized (6 M, 4 F) [age ($\bar{x}$): 20.6] Group 2: 20 randomized (2 M, 8 F) [age ($\bar{x}$): 19.25] Group 3: 20 randomized (6 M, 14 F) [age ($\bar{x}$): 17.9]

Table II. Continued

Study	Inclusion and exclusion criteria	Patients included and analyzed (n)
Silvestrini Biavati et al[27] (2015)	Inclusion criteria: permanent dentition, age less than 16 years Exclusion criteria: NR	20 subjects (8 M, 12 F) [age ($\bar{x}$): 11.4] Group 1: 10 randomized (6 M, 4 F) (10 analyzed) Group 2: 10 randomized (2 M, 8 F) (10 analyzed)
Singh[23] (1999)	Inclusion criteria: 11-19 years, minimum of 20 teeth, generalized to moderate gingivitis, in good health, band and brackets bonded for at least 6 weeks, bands and brackets on a minimum of 16 teeth, not having prophylaxis within the last month before the initial examination and during the study Exclusion criteria: use of steroidal, nonsteroidal anti-inflammatory drugs, and antibiotics within 2 weeks before the start of the study, acute illness, pregnancy, smoking, or use of other tobacco products	73 subjects Group 1: 35 analyzed Group 2: 30 analyzed

M, Male; *F*, female; *LSGI*, Löe and Silness gingival index.

improve oral hygiene to minimize the risks of periodontal deterioration and enamel decalcification.[1,2] Based on the most up-to-date data, powered toothbrushes may promote gingival health better than manual toothbrushes in orthodontic patients. However, no type has yet demonstrated clear superiority. Better study standardization and reporting in longer follow-ups are necessary.

From the initially identified records, only 9 full-text randomized trials were considered, providing data mainly on periodontal inflammatory response in the short term. It seems that considerable effort has been put into trials that were not randomized, even though it is widely accepted that well-designed and properly executed randomized controlled trials provide the best evidence on the efficacy of health care interventions.[35,36] Also many studies retrieved but not included in this review used a split-mouth design; thus, they could not be considered to represent everyday toothbrushing. Furthermore, several crossover studies involved an inappropriately small interim between the interventions that is necessary to eliminate the effect of the first intervention on the results of the second oral hygiene protocol. Finally, many studies that we found during the literature search only recorded the plaque index, even though reductions in plaque do not always directly reflect the benefit in periodontal health that is the primary goal of such interventions.[37]

Overall, powered toothbrushes provided a benefit compared with manual brushes in patients under orthodontic treatment with regard to the gingival index and the gingival bleeding assessment. The aforementioned data, retrieved after an extensive search that concentrated on orthodontic patients, add to the findings in a previous systematic review focusing on the general population[7] and the analysis conducted by Kaklamanos and Kalfas,[8] which suggested that the relevant scientific evidence was inconclusive. Additionally, such information may prove helpful regarding management decisions in individual patients, since it is has been shown that the deterioration observed during treatment with fixed orthodontic appliances in certain parameters associated with biofilm pathogenicity may be only partially reversed as far as 2 years after appliance removal.[38,39] Furthermore, a benefit of powered over manual toothbrushes was observed with regard to probing pocket depth but only in the short term. Regarding relative attachment loss and gingival hypertrophy, no benefits were noted. Finally, no differences could be identified between the 2 oral-hygiene modalities regarding other outcomes such as patient complaints, adverse events, and safety considerations.

Overall, the quality of evidence was considered to be low, giving an insight into the strength of the relevant

Table III. Summary of risk of bias assessment

Domain	Study								
	Clerehugh et al[21]	*Hickman et al*[24]	*Ho and Niederman*[20]	*Park et al*[25]	*Park et al*[26]	*Pucher et al*[22]	*Sharma et al*[28]	*Silvestrini Biavati et al*[27]	*Singh*[23]
1	Low	Unclear	Low	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear
2	Low	Unclear	Unclear	Unclear	Unclear	Low	Unclear	Unclear	Unclear
3	Low	Low	Low	Low	Low	Low	Low	Low	Low
4	Low	Low	Low	Unclear	Unclear	Low	Unclear	Unclear	Low
5	Low	Low	Unclear	Low	Low	Unclear	Unclear	Low	Unclear
6	Low	Low	Low	Low	Low	Low	Low	Low	Low
7	Low	Low	Low	Low	Low	Low	Low	Low	Low
Summary	Low	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear

1, Random sequence generation; *2*, allocation concealment; *3*, blinding of participants and personnel; *4*, blinding of outcome assessment; *5*, incomplete outcome data; *6*, selective outcome reporting; *7*, other potential threats to validity.

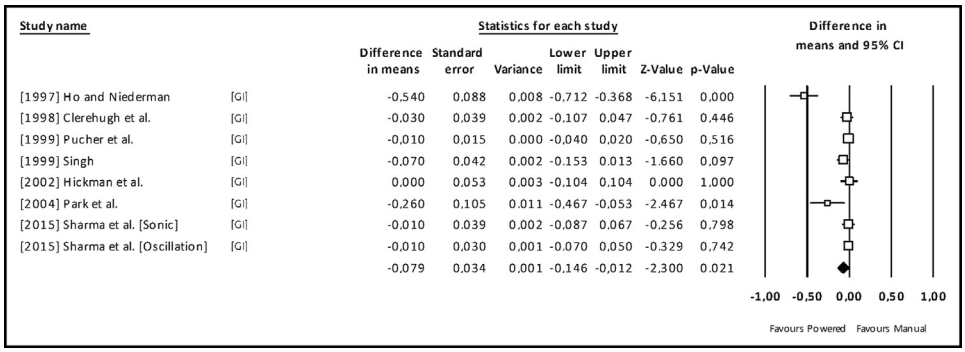

Fig 2. Powered vs manual toothbrushes (short term, gingival index [GI]).

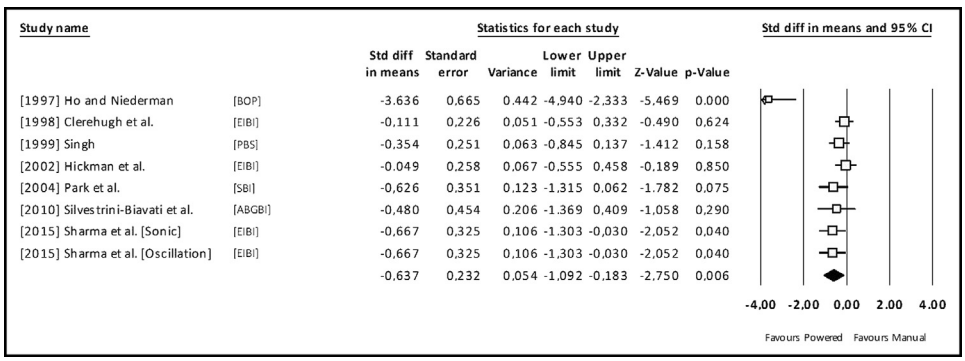

Fig 3. Powered vs manual toothbrushes (short term, gingival bleeding). *BOP*, Bleeding on probing; *EIBI*, Eastman interdental bleeding index; *PBS*, Loesche papillary bleeding score; *SBI*, Muhlemann and Son sulcus bleeding index; *ABGBI*, Ainamo and Bay gingival bleeding index.

recommendations. An important factor leading to the downgrading of the overall quality of evidence originated from the risk of bias assessment. In addition, although the superiority of power toothbrushes was an almost consistent finding in most meta-analyses, the results showed substantial heterogeneity. Finally, some assessments were based on data from only 1 study, increasing the imprecision of the observed estimates. For all of the above reasons, the clinical importance of the observed results cannot be unequivocally assessed.

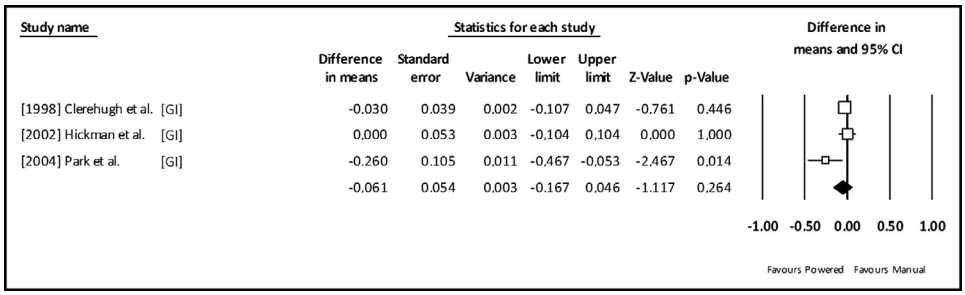

Fig 4. Rotation-oscillation powered vs manual toothbrushes (short term, gingival index [GI]).

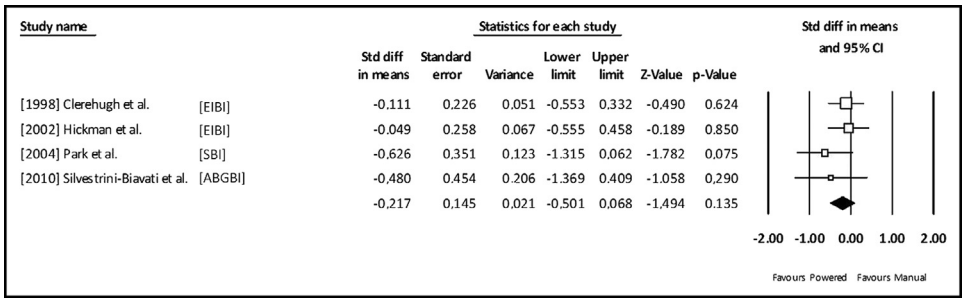

Fig 5. Rotation-oscillation powered vs manual toothbrushes (short term, gingival bleeding). *EIBI*, Eastman interdental bleeding index; *SBI*, Muhlemann and Son sulcus bleeding index; *ABGBI*, Ainamo and Bay gingival bleeding index.

Table IV. Quality of available evidence for inflammatory status

Quality assessment						*Patients (n)*		*Effect*	
Studies	*Risk of bias*	*Inconsistency*	*Indirectness*	*Imprecision*	*Other*	*PT*	*MT*	*Absolute (95% CI)*	*Quality*
Löe and Silness gingival index (short-term follow-up)									
7	Serious*	Serious†	Not serious	Not serious	None	199	175	MD 0.079 lower (0.146 lower to 0.12 lower) $P = 0.021$	⊕⊕◯◯ Low
Indexes assessing gingival bleeding (short-term follow-up)									
7	Serious*	Serious†	Not serious	Not serious	None	182	160	SMD 0.637 lower (1.092 lower to 0.183 lower) $P = 0.006$	⊕⊕◯◯ Low
Löe and Silness gingival index for rotation-oscillation powered toothbrushes (short-term follow-up)									
3	Serious*	Serious†	Not serious	Not serious	None	85	88	MD 0.061 lower (0.167 lower to 0.046 higher) $P = 0.264$	⊕⊕◯◯ Low
Indexes assessing gingival bleeding for rotation-oscillation powered toothbrushes (short-term follow-up)									
4	Serious*	Not serious	Not serious	Not serious	None	95	98	SMD 0.217 lower (1.501 lower to 0.068 higher) $P = 0.135$	⊕⊕⊕◯ Moderate

PT, Powered toothbrushes; *MT*, Manual toothbrushes; *MD*, mean difference; *SMD*, standardized mean difference.
*Most articles included were considered to be at unclear risk of bias; †results showed substantial heterogeneity.

Strengths and limitations

The strengths of this review include using a methodology following well-established guidelines and focusing exclusively on randomized controlled trials, a research design shown to be a valid method of assessing toothbrushing efficiency.[40] Our search strategy was exhaustive, covering electronic, manual, and gray literature, and comprehensive, including every possibly

relevant trial, irrespective of language, date, and status of publication. Every effort to decrease bias in the methodology was made. In addition, the random-effects model was used during exploratory quantitative data synthesis to incorporate any observed heterogeneity.[41]

There were also some limitations to this review, arising mainly from the nature and the characteristics of the data retrieved. The scarcity of relevant high-quality, hierarchical, evidence-based information from randomized controlled trials precluded extensive meta-analytic summaries; thus, in some, such quantitative syntheses could only be regarded as exploratory until additional research becomes available. However, current concepts support that data from even as few as 2 studies can be combined, if these can be meaningfully pooled,[42] since all other summarizing techniques are less transparent or are less likely to be valid.[43] Furthermore, analyses for small-study effects and publication bias[10] could not be carried out even though they were incorporated as possibilities according to the review protocol; neither could subgroup analyses be undertaken, except for separate analysis of the rotation-oscillation group of powered toothbrushes. Other factors that could influence the debriding effectiveness of toothbrushes—eg, the size, shape, and flexibility of the bristles; the arrangement and orientation of the filaments; the brush head size and shape; and timer mechanisms—could not be isolated and analyzed.[7]

Another limitation of the data retrieved in this study stems from the small number of patients analyzed. Randomized controlled trials require a priori power calculations.[35] Some trials followed the recommendation of the American Dental Association's acceptance program guidelines that "at least 30 subjects for each product will be entered into the study at baseline."[37] Although this guidance may be adequate for the conduct of uncontrolled longitudinal studies, it is not sufficient for trials that compare products for equivalence or superiority.[44]

In addition, most trials included in this review did not refer to the specific stages of the patients' treatment or the types of archwires at each examination, thus possibly curtailing the generalizability of the available evidence. Moreover, although the 4-week minimum follow-up interval used in our study is consistent with the American Dental Association's recommendation,[37] studies of at least 6 months of usual oral hygiene are needed to prevent the Hawthorne effect, where subjects change their behavior in response to their awareness of being observed.[45] Finally, the studies retrieved used surrogate outcomes to draw conclusions regarding the effectiveness of powered toothbrushes in promoting oral health; the importance, validity, and relationship to true outcomes (tooth loss or patient-centered outcomes) has not been totally clarified.[45]

Recommendations for future research

Further research would allow orthodontists to reach robust recommendations useful in the clinical setting. In this context, well-designed, standardized, properly executed, and reported randomized controlled trials provide the best evidence while diminishing, as much as possible, the risk of bias.[35,36] Long-term evaluation of the appropriate outcomes is extremely valuable.[45] In addition, data on the effect of powered toothbrushes on the prevention of the various forms of enamel demineralization are needed, as also is more information from the long-term study of adverse effects and patient-reported outcomes. Moreover, a patient-centered approach, incorporating assessment of outcomes such as satisfaction and quality of life, is a crucial part of treatment outcome and quality management; therefore, it should be included in any relevant study.[7]

Furthermore, research should also be directed to discern, if any, the effects of stages of treatment and types of archwires to increase the generalizability and the influence of different powered and manual toothbrush designs.[6,7] In addition, every effort should be made to increase the number of patients recruited, retained, and analyzed in such studies. More patients analyzed will diminish the chance of type II error; at the same time, more patients will increase the precision of effect estimates.[46] Finally, since resources are always limited in the context of health care systems, investigations of the cost-effectiveness of the various devices and the possible adverse effects and problems related to them are imperative.

CONCLUSIONS

Overall, powered toothbrushes may provide benefits over manual toothbrushes regarding gingival index and gingival bleeding assessments in orthodontic patients. However, no type demonstrated clear superiority. Better study standardization, more studies with a low risk of bias and sufficient sample size, and reporting of longer follow-ups are necessary to enrich the available evidence, increase the precision of the observed effect estimates, and unequivocally guide clinical decisions.

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Supplementary Table I. Eligibility criteria and clarifications on the items collected per domain for this systematic review (finalized after the piloting of the study selection process)

Domain	*Inclusion criteria*	*Exclusion criteria*
Participants	Subjects of any age wearing full labial fixed orthodontic appliances, as long as they did not have any physical or mental handicap that could compromise manual dexterity and the efficiency of oral hygiene procedures.	
Interventions	Any powered toothbrush as part of normal everyday oral hygiene procedures, irrespective of the type or mode of action. Studies where the participants used various forms of interdental cleansing as part of the normal oral hygiene procedures were considered. Powered toothbrushes were categorized as follows (1). 1. Side-to-side acting toothbrush: toothbrush whose head moves laterally side to side. 2. Counter-oscillation acting toothbrush: toothbrush whose head has adjacent tufts rotating in 1 direction and then the other, independently. Each tuft rotates in the opposite direction to the one adjacent to it. 3. Rotation-oscillation acting toothbrush: toothbrush whose head rotates in 1 direction and then the other. 4. Circular acting toothbrush: toothbrush whose head rotates in 1 direction. 5. Ultrasonic toothbrush: toothbrushes whose head has bristles vibrating at ultrasonic frequencies (>20 kHz). 6. Ionic toothbrush: Toothbrush that emits ions onto the tooth surface to disrupt the oral biofilm attachment. 7. Unknown action toothbrush or toothbrush with other mechanisms of action: the mode of action of the toothbrush either could not be established or did not belong to the above categories.	Studies or study groups involving interventions that combine tooth brushing with the use of irrigation devices Studies or study groups where oral hygiene procedures were combined with the use of antimicrobial mouth rinses or other chemical substances in various formulations and methods of application (except those used in usual oral hygiene regimens, eg, fluoride in toothpastes). Studies or study groups testing educational, psychological, or motivational methods to enhance oral hygiene (except usual oral hygiene instructions). Trials involving scaling during the experimental period.
Comparisons	Any kind of manual toothbrush as part of normal everyday oral hygiene procedures, irrespective of the type. Studies where the participants used various forms of interdental cleansing as part of the normal oral hygiene procedures were also considered.	Studies or study groups involving interventions that combine tooth brushing with the use of irrigation devices. Studies or study groups where oral hygiene. Procedures are combined with the use of antimicrobial mouth rinses or other chemical substances in various formulations and methods of application (except those used in usual oral hygiene regimens,eg, fluoride in toothpastes). Studies or study groups testing educational, psychological, or motivational methods to enhance oral hygiene (except usual oral hygiene instruction). Trials involving scaling during the experimental period.
Outcomes	Primarily, quantified measurements (mean values and respective standard deviations or other measures used to quantify the degree of dispersion of a set of data values) on clinical parameters regarding the inflammatory status of the periodontal tissues (gingival inflammation, bleeding on probing), clinical parameters regarding the anatomical conditions of the periodontal tissues (pocket depth, probing attachment levels, gingival hypertrophy), and clinical parameters regarding caries activity (white spot lesions, carious lesions).	

Supplementary Table I. Continued

Domain	*Inclusion criteria*	*Exclusion criteria*
	Secondarily, patient reported outcomes, safety assessments and adverse effects to tissues and or biomaterials, as well as cost estimations. Where needed, numeric data when transformed into the desired formats and tested statistically using software (MedCalc, Osltend, Belgium) and QuickCalcs (GraphPad Software, San Diego, Calif). When the study methodology included brushing in the clinic at the evaluation visit, it was not regarded as similar to everyday use. However, recordings of clinical parameters were used, since they were not expected to affect results to a meaningful extent.	
Study design	Randomized clinical trials comparing power and manual toothbrushes over an experimental period of at least 4 weeks. Crossover studies were also included as long as a washout period of at least 1 month was incorporated between the experimental periods to reduce the risk of carryover effect and provided adequate statistical data.	Studies between different kinds of powered or manual toothbrushes. Split-mouth studies, with a design not representing everyday oral hygiene procedures. Animal studies. Noncomparative studies (case reports and case series). Systematic reviews and meta-analyses.

Supplementary Table II. Strategy for database search (up to August 2017)

Database	*Search strategy*	*Hits*
PubMed http://www.ncbi.nlm.nih.gov/pubmed	((((((((((((randomized controlled trial[pt]) OR controlled clinical trial [pt]) OR randomized[tiab]) OR placebo[tiab]) OR drug therapy [sh]) OR randomly[tiab]) OR trial[tiab]) OR groups[tiab])) NOT ((animals[mh] NOT humans[mh])))) AND orthodon*) AND ((((((((((((((((brush*) OR toothbrush*) OR floss*) OR interdent*) OR interproxim*) OR irrigat*) OR jet) OR pik) OR water jet) OR waterjet) OR water pik) OR waterpik) OR water flosser) OR waterflosser) OR Siwak) OR Miswak) OR mechanic*)) AND ((((((((((((gingiv*) OR bleed*) OR periodont*) OR plaque*) OR biofilm*) OR decalcification*) OR caries) OR carious) OR lesions) OR white) OR spot*) OR WSL) OR health) OR hygiene)	506
Cochrane Central Register of Controlled Trials http://onlinelibrary.wiley.com/cochranelibrary/search	orthodon* AND (brush* OR toothbrush* OR floss* OR interdent* OR interproxim* OR irrigat* OR jet OR pik OR water jet OR waterjet OR water pik OR waterpik OR water flosser OR waterflosser OR Siwak OR Miswak OR mechanic*) AND (gingiv* OR bleed* OR periodont* OR plaque* OR biofilm* OR decalcification* OR caries OR carious OR lesions OR white OR spot* OR WSL OR health OR hygiene) in Title, Abstract, Keywords in Trials	189
Cochrane Database of Systematic Reviews http://0-ovidsp.tx.ovid.com.amclb.iii.com/sp-3.16.0b/ovidweb.cgi	orthodon* {Including Limited Related Terms}	42
Scopus https://www.scopus.com/search/form.url?zone=TopNavBar&origin=searchbasic	TITLE-ABS-KEY (orthodon* AND (brush* OR toothbrush* OR irrigati* OR jet OR pik OR water AND jet OR water AND pik OR water AND flosser OR floss* OR interdent* OR siwak OR mechanic* OR waterjet OR waterpik OR waterflosser) AND (random*))	86
Web of Scienc Core Collection http://apps.webofknowledge.com/	TOPIC: (((“randomized controlled trial” OR “controlled clinical trial” OR randomized OR placebo OR drug therapy OR randomly OR trial OR groups) AND (orthodon*) AND (brush* OR toothbrush* OR floss* OR interdent* OR interproxim* OR irrigat* OR jet OR pik OR “water jet” OR waterjet OR “water pik” OR waterpik OR “water flosser” OR waterflosser OR Siwak OR Miswak OR mechanic*) AND (gingiv* OR bleed* OR periodont* OR plaque* OR biofilm* OR decalcification* OR caries OR carious OR lesions OR white OR spot* OR WSL OR health OR hygiene))) Refined by: RESEARCH AREAS: (DENTISTRY ORAL SURGERY MEDICINE) Timespan: All years. Search language = Auto	609
Arab World Research Source http://0-web.a.ebscohost.com.amclb.iii.com/ehost/search/advanced?sid=ff64c697-1ea0-41dc-9afe-961bc654cd05%40sessionmgr4002&vid=0&hid=4114	orthodon*AND (brush* OR toothbrush* OR irrigati* OR jet OR pik OR water jet OR water pik OR water flosser OR floss* OR interdent* OR siwak OR mechanic* OR waterjet OR waterpik OR waterflosser) AND (random*)	0
Clinical Trials.gov http://clinicaltrials.gov/	orthodontic AND (brush OR brushes OR brushing OR toothbrush OR toothbrushes OR toothbrushing OR floss OR flosser OR flossing OR interdental OR interproximal OR irrigation OR jet OR pik OR Siwak OR Miswak OR mechanic OR mechanical) [completed studies]	16
ProQuest Dissertations and Theses Global	ti(orthodon* AND (brush* OR toothbrush* OR floss* OR interdent* OR interproxim* OR irrigat* OR jet OR pik OR Siwak OR Miswak OR mechanic*))	17

Supplementary Table III. Details of risk of bias assessment

Study	*Rating*	*Reasons for rating*
Clerehugh et al[4] (1998)	1. Low	The exact method of randomization is mentioned, "subjects were randomly allocated to groups using the minimization methods."
	2 Low	Minimization is a convincing method of allocation concealment, "subjects were randomly allocated to groups using the minimization methods.
	3. Low	Blinding of the participants was not possible. The Clinical Trial Coordinator was not blinded to allocation. However, the review authors believe that the outcome is not likely to be influenced by lack of blinding.
	4. Unclear	Statement that the investigator was blinded. However, there are no details on the measures taken to prevent the investigator from assuming group allocation during supervised brushing, "and the Clinical Trial Investigator remained blind to the toothbrush group allocation."
	5. Low	Dropouts are described and explained.
	6. Low	All important outcomes are adequately reported.
	7. Low	The study appears to be free of other sources of bias.
Hickman et al[7] (2002)	1. Unclear	The exact method of randomization is not mentioned, "randomly assigned, prepared by the trial statistician."
	2. Unclear	No statement that the envelopes were opaque and sequentially numbered.
	3. Low	Blinding of the participants was not possible. The Clinical Trial Coordinator was not blinded to allocation. However, the review authors believed that the outcome was not likely to be influenced by lack of blinding.
	4. Low	Statement that the investigator was blinded. No other reason to infer that the investigator could assume group allocation, "The trial researcher was blinded to the group allocation."
	5. Low	Dropouts are described and explained.
	6. Low	All important outcomes are adequately reported.
	7. Low	The study appears to be free of other sources of bias.
Ho and Niederman[3] (1997)	1. Low	The exact method of randomization is mentioned. "subjects to the two groups was done through use of two tables of random numbers."
	2. Unclear	No information on the measures taken to conceal allocation.
	3. Low	Blinding of the participants was not possible. The investigator providing oral hygiene instructions was not blinded to allocation. However, the review authors believed that the outcome was not likely to be influenced by lack of blinding.
	4. Low	Statement that the investigator was blinded. No other reason to infer that the investigator could assume group allocation, "A single investigator blinded."
	5. Unclear	It is not clear whether losses occurred.
	6. Low	All important outcomes are adequately reported.
	7. Low	The study appears to be free of other sources of bias.
Park et al[8] (2004)	1. Unclear	The exact method of randomization is not mentioned,"randomly assigned."
	2. Unclear	No information on the measures taken to conceal allocation.
	3. Low	Blinding of the participants was not possible. The investigator providing oral hygiene instructions was not blinded to allocation. However, the review authors believed that the outcome was not likely to be influenced by lack of blinding.
	4. Unclear	Insufficient information in the paper.
	5. Low	No dropouts occurred.
	6. Low	All important outcomes are adequately reported.
	7. Low	The study appears to be free of other sources of bias.
Park et al[9] (2005)	1. Unclear	The exact method of randomization is not mentioned, "randomly assigned."
	2. Unclear	No information on the measures taken to conceal allocation.
	3. Low	Blinding of the participants was not possible. The investigator providing oral hygiene instructions was not blinded to allocation. However, the review authors believed that the outcome was not likely to be influenced by lack of blinding.
	4. Unclear	Insufficient information in the paper.
	5. Low	No dropouts occurred.
	6. Low	All important outcomes are adequately reported.
	7. Low	The study appears to be free of other sources of bias.

Supplementary Table III. Continued

Study	*Rating*	*Reasons for rating*
Pucher et al[5] (1999)	1. Unclear	The exact method of randomization is not mentioned, "randomly assigned."
	2. Low	No statement on the packages being sequentially administered. No other reason to infer that the investigator could assume group allocation, "The patients were given a prepackaged, coded toothbrush."
	3. Low	Participants could be blinded to group allocation. No mention on personnel blinding. However, the review authors believed that the outcome was not likely to be influenced by possible lack of blinding.
	4. Low	Statement that the investigator was blinded. No other reason to infer that the investigator could assume group allocation, "both participants and the examiner were unaware of which toothbrush the participants were using."
	5. Unclear	Losses are described but not explained.
	6. Low	All important outcomes are adequately reported.
	7. Low	The study appears to be free of other sources of bias.
Sharma et al[11] (2015)	1. Unclear	The exact method of randomization is not mentioned, "divided."
	2. Unclear	The exact method is not mentioned.
	3. Low	Blinding of the participants was not possible. The investigator providing oral hygiene instructions was not blinded to allocation. However, the review authors believed that the outcome was not likely to be influenced by lack of blinding.
	4. Unclear	Insufficient information in the paper.
	5. Unclear	No explicit mention, but it seems that no dropouts occurred.
	6. Low	All important outcomes are adequately reported.
	7. Low	The study appears to be free of other sources of bias.
Silvestrini Biavati et al[10] (2010)	1. Unclear	The exact method of randomization is not mentioned, "randomly divided."
	2. Unclear	The exact method is not mentioned.
	3. Low	Blinding of the participants was not possible. The investigator providing oral hygiene instructions was not blinded to allocation. However, the review authors believed that the outcome was not likely to be influenced by lack of blinding.
	4. Unclear	Insufficient information in the paper.
	5. Low	No dropouts occurred.
	6. Low	All important outcomes are adequately reported.
	7. Low	The study appears to be free of other sources of bias.
Singh[6] (1999)	1. Unclear	The exact method of randomization is not mentioned, "randomly assigned."
	2. Unclear	The exact method is not mentioned.
	3. Low	Blinding of the participants was not possible. The investigator providing oral hygiene instructions was not blinded to allocation. However, the review authors believed that the outcome was not likely to be influenced by lack of blinding.
	4. Low	Statement that the investigator was blinded. No other reason to infer that the investigator could assume group allocation, "The examiner were blinded with respects to the methods used for brushing."
	5. Unclear	Dropouts are mentioned but are not described adequately or explained.
	6. Low	All important outcomes are adequately reported.
	7. Low	The study appears to be free of other sources of bias.

1, Random sequence generation; *2*, allocation concealment; *3*, blinding of participants and personnel; *4*, blinding of outcome assessment; *5*, incomplete outcome data; *6*, selective outcome reporting; *7*, other potential threats to validity.

Supplementary Table IV. Quality of available evidence for the indexes assessing probing pocket depth, relative attachment loss, and gingival hypertrophy

Quality assessment						*Patients (n)*		*Effect*	
Studies	*Risk of bias*	*Inconsistency*	*Indirectness*	*Imprecision*	*Other*	*PT*	*MT*	*Absolute (95% CI)*	*Quality*
Probing pocket depth (short-term follow-up; assessed with mm)									
1	Serious*	Not serious	Not serious	Serious†	None	12	12	MD 0.760 lower (1.029 lower to 0.491lower) $P = 0.000$	⊕⊕◯◯ Low
Probing pocket depth (long-term follow-up; assessed with mm)									
1	Serious*	Not serious	Not serious	Serious†	None	20	20	MD 0.140 lower (0.324 lower to 0.044 higher) $P = 0.136$	⊕⊕◯◯ Low
Relative attachment loss (long-term follow-up; assessed with mm)									
1	Serious*	Not serious	Not serious	Serious†	None	20	20	MD 0.230 lower (0.590 lower to 0.130 higher) $P = 0.210$	⊕⊕◯◯ Low
Gingival hypertrophy (short-term follow-up; assessed with presence or absence of hypertrophy)									
1	Serious*	Not serious	Not serious	Serious†	None	10	10	RR 0.217 0.667 lower (0.140 lower to 3.172 higher) $P = 0.610$	⊕⊕◯◯ Low

PT, Powered toothbrushes; *MT*, manual toothbrushes; *MD*, Mean difference; *RR*, relative risk.
*The study was considered to be at unclear risk of bias; †the result was based on very few patients.

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