

## Comparison of the effectiveness between power toothbrushes and manual toothbrushes for oral health: a systematic review and meta-analysis

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### ABSTRACT

**Objective:** Power toothbrushes is considered an effective tool for maintaining oral health; however, its efficacy as compared to manual toothbrushes is still not completely clarified. This article aims to evaluate the efficacy of power toothbrushes compared with the manual toothbrushes in terms of plaque, gingivitis and bleeding reduction.

**Methods:** An electronic search was performed on PUBMED, Web of Science, Wiley and Research Gate. Studies comparing the effectiveness of plaque, gingivitis and bleeding reduction between power and manual toothbrushes were included. Results and effect sizes analysis are presented as standard mean difference (SMD), and subgroup analysis stratified by mode of action of the power toothbrush was performed. Study quality and risk of bias were assessed using the Cochrane assessment tool.

**Results:** A total of 21 randomized clinical studies were included. Power toothbrushes were significantly more effective in reducing plaque index (26 trials: SMD=0.86, 95% CI: 0.58 to 1.14,  $I^2=91.5%$ ,  $p<.0001$ ), gingival index (14 trials: SMD=0.47, 95% CI: 0.12 to 0.82,  $I^2=88.7%$ ,  $p<.0001$ ), and bleeding index (11 trials: SMD=0.92, 95% CI: 0.43 to 1.40,  $I^2=91.8%$ ,  $p<.0001$ ) compared with the manual toothbrushes, except that there was no significant differences between the oscillating-rotating toothbrushes and manual toothbrushes regarding gingivitis reduction (7 trials: SMD=0.07, 95% CI: -0.20 to 0.33,  $I^2=57.2%$ ,  $p=.03$ ).

**Conclusions:** Power toothbrushes is more effective in reducing dental plaque, gingivitis and bleeding compared with the manual toothbrush.

### ARTICLE HISTORY

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### KEYWORDS

Oral health; powered toothbrush; plaque; gingivitis; meta-analysis

### Introduction

Dental plaque accumulation has been demonstrated to be associated with oral health, since the increasing growth of biofilm on teeth may lead to dental diseases, and persistent gingivitis represents a risk factor for periodontal attachment loss and tooth loss [1]. Furthermore, inherited genetics, environmental factors, lifestyles choices and other diseases also impact the development of dental plaque [2,3]. Thus, regular plaque removal became great important for everyone to achieve health benefits. However, it is considered that insufficient frequency of brushing, poor brushing technique and inadequate brushing duration with conventional toothbrush make it challenging to prevent periodontal disease and maintain oral health.

Power toothbrush is keeping updating all the time to improve its efficacy and user experience since the first introduction, which can be noticed in the development of its mechanism, brush head designs, modes of action, ergonomic features, etc. [4,5]. Generally, the power toothbrush family is constituted of battery-powered brush and rechargeable

brush, with modes of action represented by oscillating-rotating (including rotating, counter-oscillating, back and forth and side to side) and sonic (including ultrasonic). As technology improved and people's high demand for oral health, power toothbrushes show an increase in popularity for both the developed and developing countries. Nevertheless, its advantages as compared to the manual toothbrush is still not quite clear.

Previous systematic review and meta-analysis [6–8] based on large studies have already assessed the effectiveness of power toothbrushes; however, they had no a clear selection criteria so that they also included the patients during periodontal therapy, children without scorable teeth, or participants with other situations that may influence the assessment of toothbrush; and their latest included studies were up to 2016. Therefore, we used the strict criteria mentioned under method section and perform an up-to-date systematic review and meta-analysis to assess the efficacy of power toothbrushes represented by sonic and oscillating-rotating power compared with manual toothbrush in terms of plaque, gingivitis and bleeding reduction.

## Methods

This manuscript was performed according to the PRISMA guidelines for reporting systematic review and meta-analysis.

### Data sources and search strategy

PUBMED, Web of Science, Wiley and Research Gate were systematically searched for all articles published in English up to 4 April 2019. The search strategy used in PUBMED was consisted of a free text search of the sequence: toothbrush AND (dental plaque OR gingival bleeding) combined with control clinical trial OR randomized controlled trial [article types] AND humans [species] AND English [languages]. Other databases applied the consistent search strategy. All titles and abstracts from the initial search were screened by three reviewers (WTL, XLL and JX). If the title and abstract did not contain enough information to include or exclude the study from the analysis, the study was reviewed in full text. Additional strategies included hand searches of journals that were not included in the electronic sources, internet searches for grey literature, and screening of reference lists of retrieved studies.

### Selection criteria

Studies were deemed eligible for inclusion if conformed to the following criteria: (1) randomized control trial (RCT) with healthy participants; (2) participants with a minimum of 15 gradable teeth; (3) clear statement of the assessment index for dental plaque, gingivitis and bleeding; (4) compare the plaque, gingival or bleeding index between the power toothbrushes and manual toothbrushes; (5) accessible data of the endpoints.

Studies with the following features were excluded from this meta-analysis: (1) participants with orthodontic appliances, severe periodontal diseases (gingivitis or periodontitis), or severe oral diseases such as tumours of the soft or hard tissues of the oral cavity or any systemic disease such as diabetes or autoimmune disease; (2) pregnant at the time of the experiment, or taking medication that could impact the outcomes; (3) contain other aids such as floss or water flosser; (4) studies without crucial and assessable data for statistical analysis or non-original studies such as review, letter and comment were also excluded.

For relevant studies that did not provide necessary data for analysis, we contacted the corresponding author of the articles for information. If we did not receive author's response in a reasonable amount of time, the study was excluded from the meta-analysis.

### Data extraction

Study details of included publications were extracted using a data extraction form. Data were extracted by a single reviewer (JZ), subsequently the second reviewer (XLC) checked the extracted data for accuracy, consistency and completeness. Discrepancies were resolved by referring to

the original article. The following data elements were extracted to a standardized data collection sheet: key patient characteristic, study design, inclusion and exclusion criteria, assessment index, follow-up period, endpoint of interests, region and research time for the study.

### Quality assessment and risk of bias

According to the Cochrane Handbook of Systematic Review of Interventions, RCTs were assessed by using Review Manager 5.3 based on seven perspectives (random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting and others) and scored as unclear, low or high risk of bias.

### Statistical analysis

All statistical analyses were performed by Stata 12.0 version (Stata Corporation, College Station, TX). Results and effect sizes analysis are presented as standard mean difference (SMD) due to the variation of assessment index used among the included studies. Numbers were treated with 95%CI confidence intervals (95%CI).  $I^2$  statistics and Chi-squared test were performed to assess heterogeneity.  $I^2$  describes the percentage of the variability in effect estimates that is due to heterogeneity rather than sampling error (chance). An  $I^2$  value  $>50\%$  or  $p$  value  $<.05$  was considered substantial heterogeneity, and a random effect model was selected; otherwise, a fixed effect model was applied. However, due to the significantly heterogeneity across the studies, a random effect model was applied in all the forest plot. Subgroup analysis was independently performed based on follow-up period, toothbrush brand and assessment index in the comparison between oscillating-rotating toothbrush versus manual toothbrush and between sonic toothbrush versus manual toothbrush.

## Results

### Study selection

According to the search criteria, 916 studies were originally enrolled with 891 from database searching and 25 from manual searching. In total, title and abstract of 560 articles were screened after excluding duplicates. Then, 443 articles were excluded for low relativity and inappropriate article styles such as review and comment, and 117 manuscripts were fully screened for eligibility. Finally, after excluding 96 without crucial endpoints and assessable data, 21 articles with a total of 2296 participants were included in this meta-analysis. Details are presented in Figure 1.

### Characteristics of enrolled studies

As presented in Table 1, a total of 21 randomized control trial (RCT) studies published from 1992 to 2018 [4,5,9–27] were enrolled for this meta-analysis, with six trials on sonic

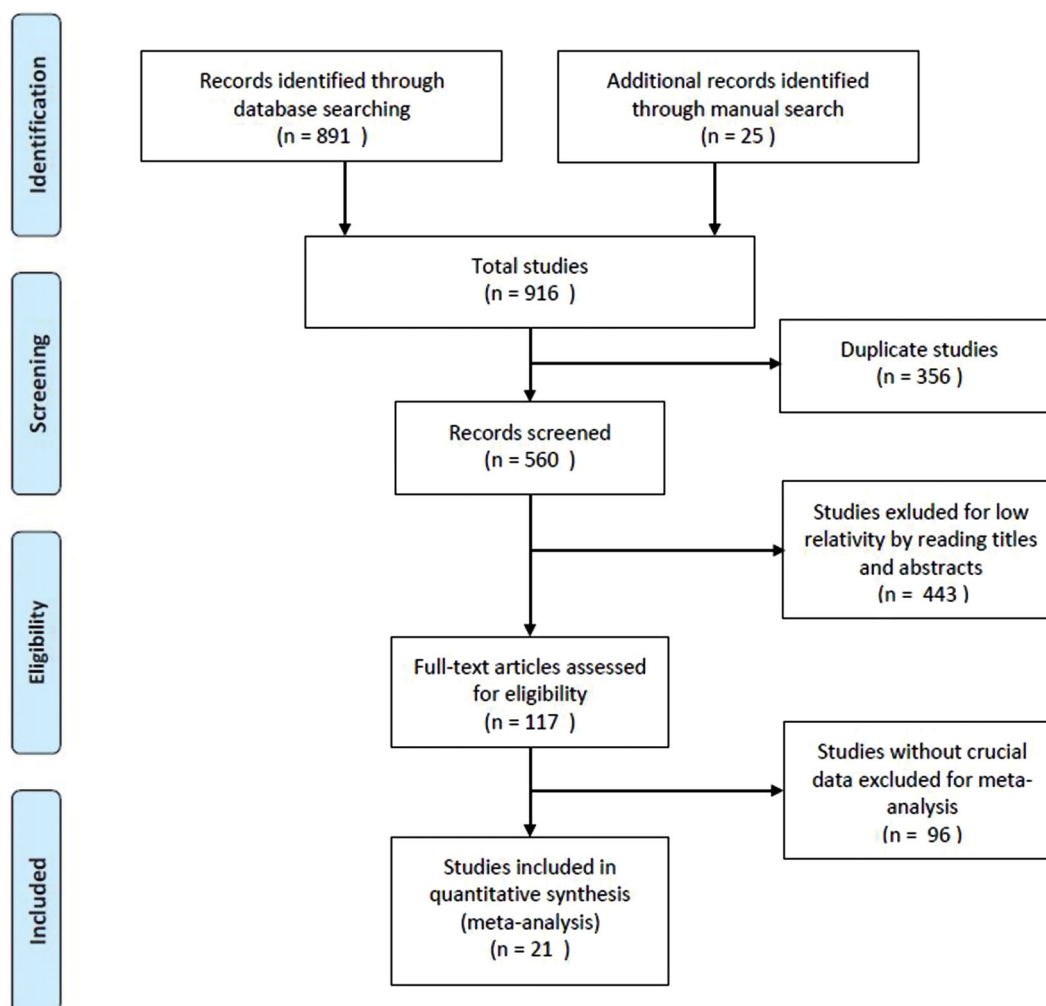


Figure 1. The selection process of enrolled studies.

toothbrushes, 16 on oscillating toothbrushes. All the studies focus on adult users, except one on teenage. The overall follow-up was ranged from 1 week to 8 months. Besides, there is a low risk of bias in most studies (Figure 2).

The assessment index were different among studies. For plaque index, 11 studies applied Turesky Modification of the Quigley and Hein Index (TMQHI) [28,29]; five studies used Rustogi Modification of the Modified Navy Plaque Index (RMMNPI) [30]; two used Lobene and Soparker Modified Plaque Index (LSMPI) [29,31]; and three each used the O'Leary plaque indices [20], full mouth plaque score [27] and Loe and Silness Plaque Index (LSPI) [26]. For gingival index, five studies applied Lobene Modified Gingival Index (LMGI) [32] and four used Loe and Silness Gingival Index (LSGI) [33]. For bleeding index, two studies used van der Weijden Gingival Bleeding Index [34], and the rest five studies used different assessment tools [4,13,22,23,27].

### Plaque index

All the 21 enrolled studies has reported plaque reduction between the power toothbrushes and manual toothbrushes. As presented in Figure 3, power toothbrushes were significantly more effective in removing dental plaque than the

manual toothbrushes (SMD = 0.86, 95% CI: 0.58 to 1.14,  $I^2 = 91.5%$ ,  $p < .0001$ ).

A total of eight trials from six studies [4,9,13,16,19,23] compared the efficacy of dental plaque removal between sonic toothbrushes and manual toothbrushes, and 18 trials from 16 studies [5,10–12,14,15,17,18,20–27] compared plaque reduction between the oscillating-rotating toothbrushes and manual toothbrushes. The forest plot shows that both these two power toothbrushes significantly decreased plaque index compared with the manual toothbrushes (SMD = 1.51, 95% CI: 0.87 to 2.15,  $I^2 = 92.8%$ ,  $p < .0001$ ; SMD = 0.56, 95% CI: 0.32 to 0.80,  $I^2 = 84.2%$ ,  $p < .0001$ ).

### Gingival index

A total of 14 trials from nine enrolled studies [9,10,13,15–17, 19,23,26] reported gingival index between power toothbrushes and manual toothbrushes. As presented in Figure 4, power toothbrushes significantly reduced gingivitis (SMD = 0.47, 95% CI: 0.12 to 0.82,  $I^2 = 88.7%$ ,  $p < .0001$ ) compared with the manual toothbrushes.

Seven trials compared the gingival index between sonic toothbrushes and manual toothbrushes. The diamond implied that sonic toothbrushes was statistically more

Table 1. Characteristics of enrolled studies.

Study	Brand	Patient number	Mean age (SD)	Assessment criteria					Instruction for brushing
				Follow-up	Plaque	Gingivitis	Bleeding	Teeth for assessment	
DeLaurenti M 2017 [7]	S: Philips Sonicare Diamond Clean M: ADA	70 72	41.1 (12.30) 43.1 (12.00)	2–4 weeks	LSMPI	LMGI	van der Weijden Gingival Bleeding Index	All natural teeth except third molars	Twice daily
Dentino 2002 [8]	O: Braun Oral-B D9 M: ADA	76 81	18–61 18–59	6 months	TMQHI	LMGI		All natural teeth except third molars	2 min twice daily
Dorfer 2001 [10]	O: Dr. Johns Spin M: ADA	76 76	24.2 (7.3)	10–12 days	TMQHI			All natural teeth except third molars	NA
Dorfer CE 2009 [9]	O: NA M: ADA	43 43	33 (10) 32 (9)	6 months	TMQHI			All natural teeth except third molars	2 min twice daily
Erbe 2018 [11]	O: Oral-B Professional Care 6000 M: Oral-B Indicator 35	29 30	15.3 (1.02) 15.3 (1.21)	2 weeks	TMQH			All natural teeth except third molars	2 min twice daily and used the Oral-B app twice daily
Forgas-B 1998 [12]	S: UltraSonex M: Oral-B	30 26	37.8 (10.13) 37.23 (9.54)	30 days	RMMNPI		Eastman	All natural teeth except third molars	twice daily
Goyal CR 2012 [13]	S1: Waterpik Sonicare Professional Plus S2: Philips Sonicare FlexCare M: Oral-B Indicator	35 35 35	41.5 (7.51) 43.5 (8.61) 43.1 (8.22)	2–4 weeks	RMMNPI	LMGI	Gingival Bleeding Bleeding on probing was scored using a binary scale as either positive or negative	All natural teeth except third molars	twice daily
Haun 2002 [14]	O: Crest Spin Pro M: Oral-B CrossAction	121 121	39.4 (12.2)	9 periods	TMQHI			All natural teeth except third molars	1 min
Heasman 1999 [15]	O1: Philips Jordan HP 735 O2: Oral-B Advantage B35 M: Braun Oral-B D7	25 25 25	18–25	6 weeks	TMQHI	LSGI		All natural teeth except third molars	>90 seconds twice daily
Jenkins W 2017 [16]	S: Philips Sonicare FlexCare Platinum M: ADA	76 142	40.4 (11.5) 40.8 (11.7)	2–6 weeks	LSMPI	LMGI	van der Weijden Gingival Bleeding Index	All natural teeth except third molars	NA
Khocht 1992 [17]	O1: Epident O2: Interolak M: Oral-B 40	32 32 31	19–58 20–55 21–65	6 months	TMQHI	LSGI		All natural teeth except third molars	twice daily
Klukowska M 2012 [18]	O: Oral-B Vitality TriZone M: ADA	36 36	45.6 (8.63)	4 periods	TMQHI			All natural teeth except third molars	2 min twice daily
Nathoo 2012 [19]	S: Colgate ProClinical A1500 M: Oral-B Indicator	40 36	44 (18–65) 42 (20–66)	4–12 weeks	RMMNPI	LSGI		All natural teeth except third molars	2 min
Parizi 2011 [20]	O: Jordan M: Oral-B Advantage	15 15	21.2 (2.3) 20.3 (1.0)	1–2 weeks	O' Leary Plaque Indices			All teeth	2 min twice daily
Pizzo 2009 [21]	O: Oral-B Professional care 8500 M: Oral-B CrossAction	66 66	18–59	30 days	TMQHI			All natural teeth except third molars	60 sec
Raffaele 2016 [27]	O: Oral-MB Triumph 5000 M: Oral-B Indicator	30 30	35.3 (10) 35.7 (8.4)	1–6 months	Full mouth Plaque Score		Full Mouth Bleeding Score	All teeth	1 min twice daily
Rosema 2008 [22]	O: Oral-B Triumph Professional Care 9000 M: ADA	39 38	22.4 (2.93) 21.6 (2.54)	9 months	TMQHI;		Bleeding on marginal probing index	All natural teeth except third molars	2 min twice daily
Schmalz 2017 [23]	O: Oral-B Professional Care 7000 S: Philips Sonicare M: CPGABA elmex INTERX	46 45 48	22.98 (2.52) 23.66 (2.95) 23.7 (3.13)	2–12 weeks	TMQHI	LSGI	Loe-Silness Papilla Bleeding Index	All natural teeth except third molars	2–3 min twice daily
Sharma 2001 [24]	O: Braun Oral-B M: ADA	48 48	21–55	1 week	RMMNPI			All natural teeth except third molars	1 min twice daily
Terezhalmay 2005 [25]	O: Crest Spin M: Oral-B	75 75	23–62	>3 months	RMMNPI			All natural teeth except third molars	3 min twice daily
van der Weijden 1994 [26]	O: Braun Plak M: Butler Gum 311	42 35	22.2 22.3	8 months	LSPI	LMGI		All teeth	2 min

O: oscillating power toothbrush; S: sonic power toothbrush; M: manual toothbrush; ADA: American Dental Association recommended manual toothbrush; Pi: dental plaque index; Gi: gingivitis index; Bl: bleeding index; RMMNPI: Rustogi Modification of the Modified Navy Plaque Index; TMQHI: Turesky Modification of the Quigley and Hein Index; LSMPI: Lobe and Soparker Modified Plaque Index; LMGI: Lobe and Silness Bleeding Index; LSPI: Loe and Silness Plaque Index; LSGI: Loe and Silness Gingival Index; NA: not applicable.

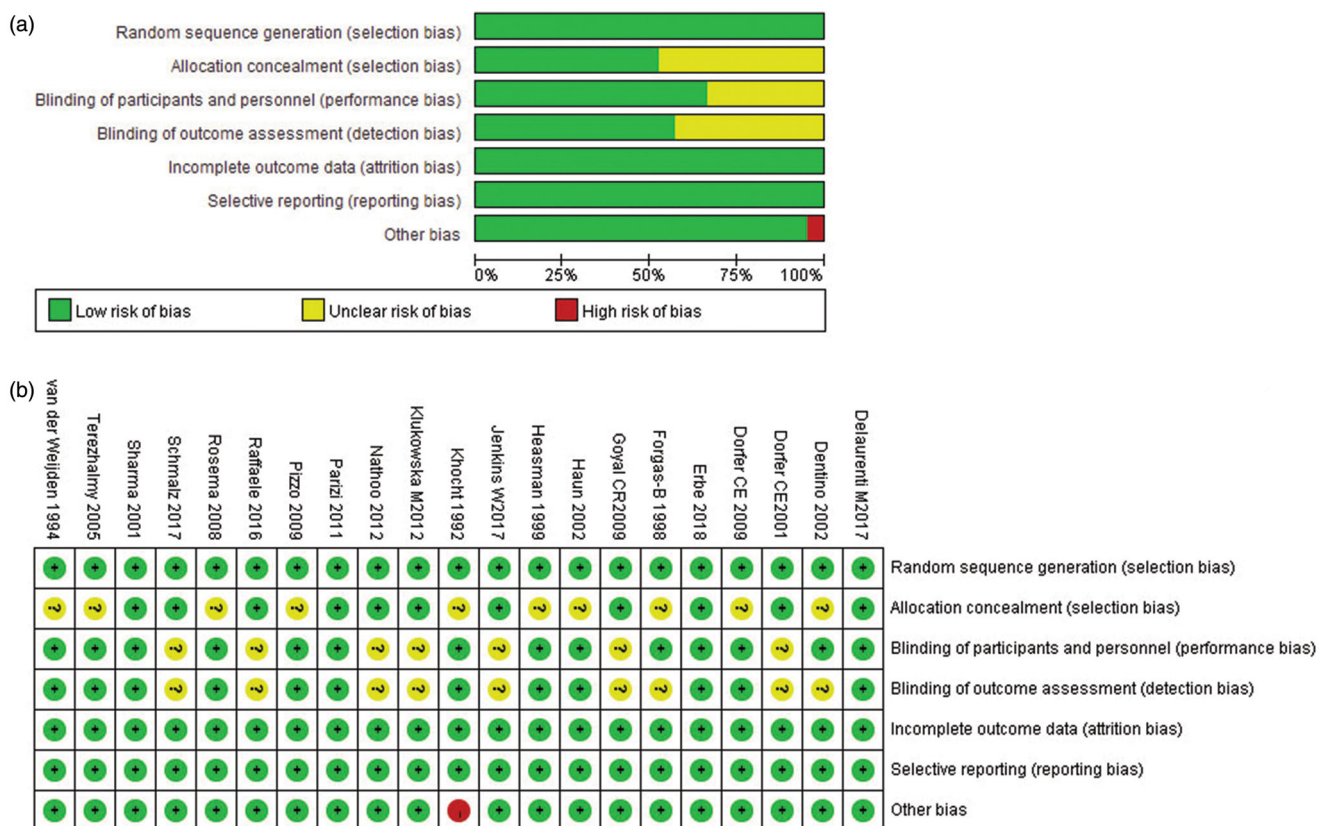


Figure 2. Risk of bias. (a) risk of bias graph; (b) risk of bias summary.

effective than manual toothbrushes (SMD = 0.88, 95% CI: 0.38 to 1.38,  $I^2 = 89.3%$ ,  $p < .0001$ ). Seven trials compared the gingivitis reduction between oscillating-rotating toothbrushes and manual toothbrushes, however, no statistically difference was observed between the two groups (SMD = 0.07, 95% CI: -0.20 to 0.33,  $I^2 = 57.2%$ ,  $p < .05$ ).

**Bleeding index**

A total of 11 trials from eight studies [4,9,13,16,22,23,26,27] reported bleeding index between power toothbrushes and manual toothbrushes, and the forest plot illustrated that power toothbrushes significantly decreased bleeding index compared with the manual toothbrushes (SMD = 0.92, 95% CI: 0.43 to 1.40,  $I^2 = 91.8%$ ,  $p < .0001$ ). Furthermore, sonic and oscillating-rotating toothbrushes were both significantly more effective in bleeding reduction (SMD = 1.25, 95% CI: 0.59 to 1.91,  $I^2 = 93%$ ,  $p < .0001$ ; SMD = 0.35, 95% CI: 0.12 to 0.57,  $I^2 = 0%$ ,  $p = .703$ ). Details are presented in Figure 5.

**Subgroup analysis and sensitivity analysis**

Since significantly large heterogeneities were prevalent among the three endpoints, which could not be decreased even we stratified the data into the categories of sonic versus manual and oscillating-rotating versus manual. Thus, we decided to perform a further subgroup analysis based on follow-up time of the study, assessment index and toothbrush brand in each category of the endpoints.

In terms of plaque index between oscillating-rotating and manual toothbrushes, the subgroup of the studies assessed by TMQHI showed reduced heterogeneity ( $I^2 = 64.7%$ ,  $p = .002$ ), and the results still favoured oscillating-rotating toothbrushes (SMD = 0.327, 95% CI: 0.13 to 0.53). However, other subgroups did not present any significant changes regarding the effect size or heterogeneity. Details are presented in Table 2.

Besides, sensitivity analysis was performed to identify any studies that affected the pooled results. We found that the diamond was moved to the right side of the effect line (SMD = 0.23, 95% CI: 0.04 to 0.42) and the heterogeneity ( $I^2 = 0.0%$ ,  $p = .657$ ) would dramatically decrease when excluded the two trials by Khocht et al. [17] regarding gingival index.

**Discussion**

In the current study, a meta-analysis based on 21 RCT studies was performed, and we found that the power toothbrushes including sonic and oscillating-rotating were significantly more effective in reducing dental plaque, gingivitis and bleeding compared with the manual toothbrushes.

The World Health Organization [35] has concluded that oral diseases are a significant public health threat as well as the fourth most costly disease to treat with traditional methods in industrialized countries. Besides, a report by Centres for Disease Control and Prevention (CDC) [36] revealed that one out of two American above 30 years age has encountered periodontal disease, and the prevalence may be

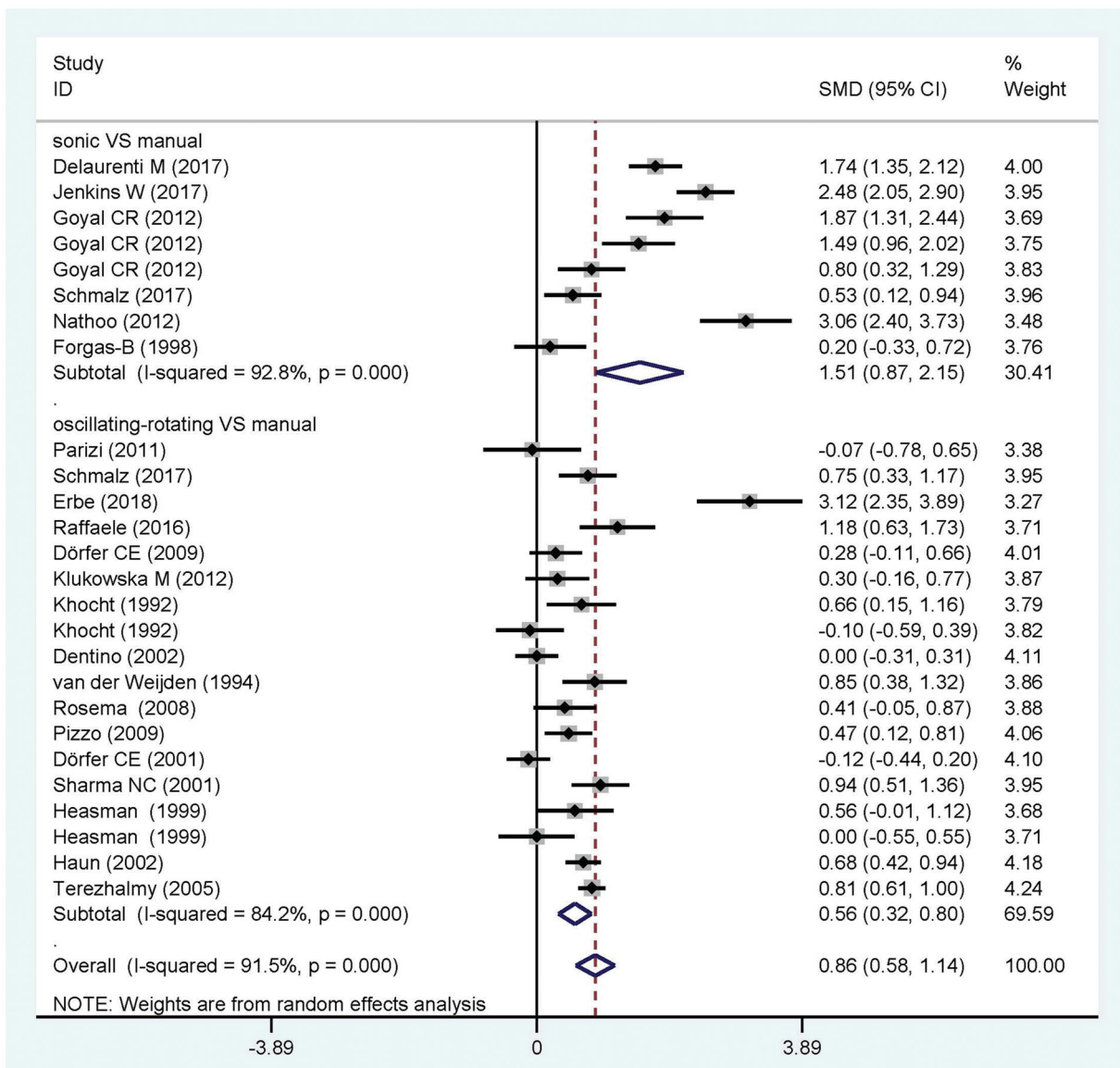


Figure 3. Forest plot of plaque index.

increased if including gingivitis in the range of the disease [37]. Therefore, maintaining oral health is of critical importance.

On the other side, dental plaque is one of the factors that threaten oral health. Certain researches have demonstrated that acidogenic by-products of dental plaque biofilms are strongly correlated with dental carries and plaque-induced gingivitis, which may progress to periodontal diseases without thorough removal on a consistent basis [38–41]. Therefore, controlling the dental plaque accumulation on teeth and gingival tissue is crucial to prevent further periodontal diseases. However, due to the lack of brushing skills and adequate duration, a majority of manual toothbrush user may not completely remove interdental plaque leading to a serious situation in long term. Therefore, power toothbrush has emerged as an advanced home-used tool for oral hygiene, which can optimize plaque control and further prevent the inflammatory effects that require significant dental or medical interventions.

The current study presented consistent results as the previous that both oscillating-rotating and sonic power toothbrushes are effective in reducing dental plaque and gingivitis compared with the manual toothbrushes. The earliest work compared the efficacy between power and manual toothbrush was conducted by Yaacob et al. [7] and published in 2014. It is a profound review based on a large amount of studies and performed several subgroup analyses; however, it was lack of a clear inclusion or exclusion criteria for participant selection, so that it may include the participants with severe periodontal diseases, using medications such as anti-inflammatory drugs, without enough teeth for assessment, or using dental floss, which may affect the outcomes for assessment. A systematic review study by Rosema et al. [8] also published in 2014 has designed detailed inclusion criteria, but it only focussed on oscillating-rotating power toothbrushes and meta-analysis was not conducted. A recent meta-analysis by de Jager et al. [6] published in 2017 only compared the outcomes between sonic power and manual

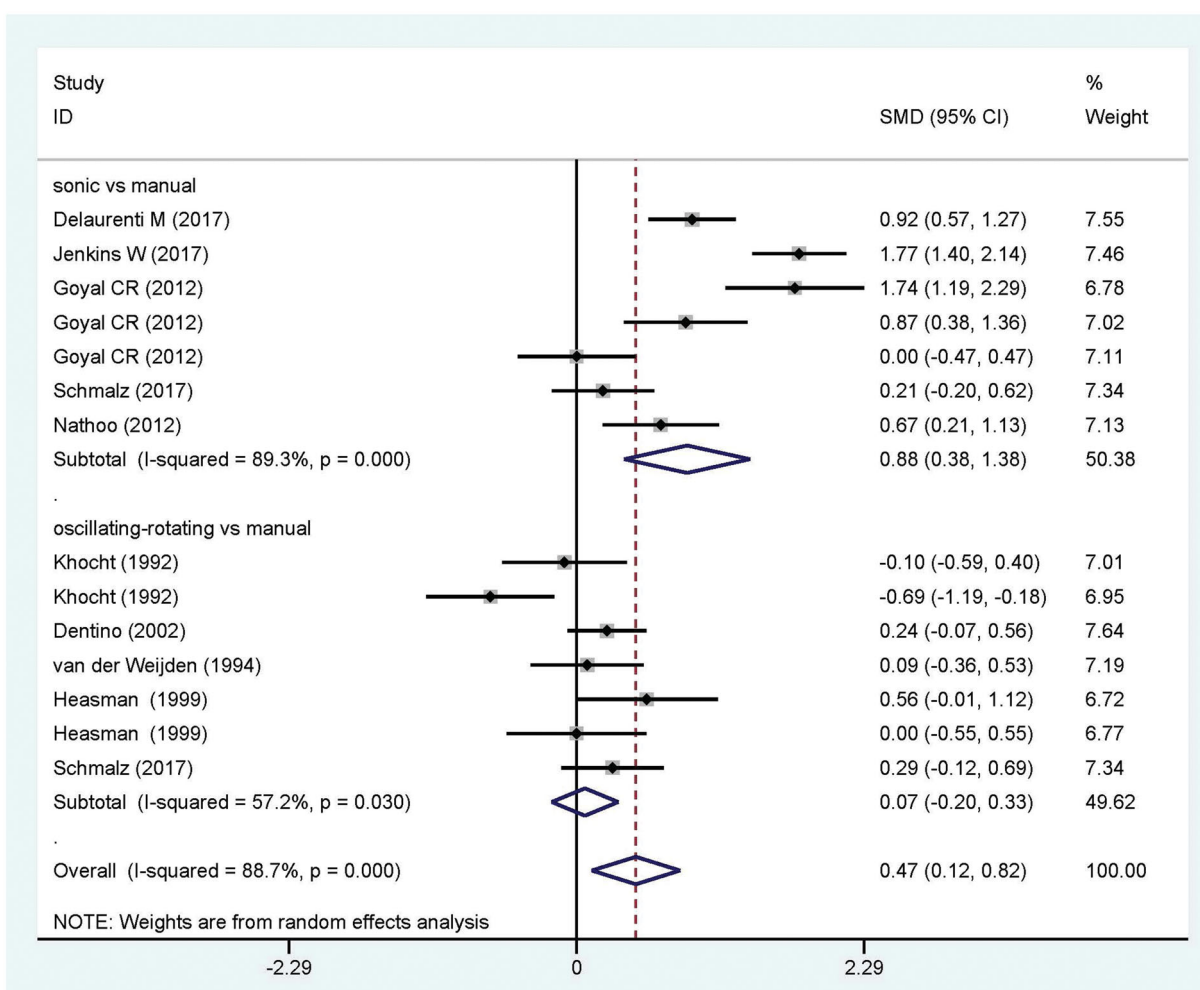


Figure 4. Forest plot of gingival index.

toothbrush, with the final electronic search on August 8, 2016. Therefore, we performed this systematic review and meta-analysis with a strict inclusion criteria and up-to-date researches. In the current study, we combined the outcomes of both oscillating-rotating and sonic power toothbrushes and compared with manual toothbrushes, which is absent in the work by Rosena et al. [8] and de Jager et al. [6]. Besides, among the 21 included studies, five of them were published after 2016. Since power toothbrush is keeping improving to ensure better efficacy and user experience, updated products may deliver better outcome for reducing dental plaque and gingivitis. In the included study by Erbe et al. [5] published in 2018, the oscillating-rotating power toothbrush was designed to connect with Bluetooth 4.0 so that users would be guided to brush their teeth by referring to the real-time instant tracking on the mobile application and fall into the habit of daily oral hygiene, thus, ensuring the effectiveness of the toothbrush. Additionally, there is more dental plaque reduction in this included study compared with others as presented in the forest plot (Figure 3).

On the other side, heterogeneity was substantial across the endpoints; therefore, subgroup analysis and sensitivity analysis were performed to minimize and find out the sources of the heterogeneity. When stratified the studies

reporting oscillating-rotating toothbrushes on plaque index according to their assessment index, heterogeneity of the TMQHI subgroup showed notable decrease. TMQHI [29,42] is the frequently used standard for evaluating dental plaque with 0–5 scores among the enrolled studies. Other assessment index included RMMNPI [30], which separates the teeth into several regions to check the existence of dental plaque with score 0 as absent and score 1 as present; O’Leary Plaque Index [43], Full Mouth Plaque Score [27] and LSPI [44] only applied to few studies. Therefore, we considered that the large heterogeneity may be triggered by the difference of assessment index.

Furthermore, we observed that two trials by Khocht et al. [17] significantly affected the pooled result in the subgroup of oscillating-rotating versus manual toothbrushes regarding gingival index. It is interesting that in Khocht et al.’s study [17], the manual toothbrushes presented lower as well as the largest reduction of gingival score compared with the two oscillating-rotating power toothbrushes. After went through the article and compared with other studies, we found that the participants assigned to manual group were introduced with the modified Bass technique and instructed to brush until they felt their teeth were clean, while in other studies the participants were only instructed to brush their teeth for

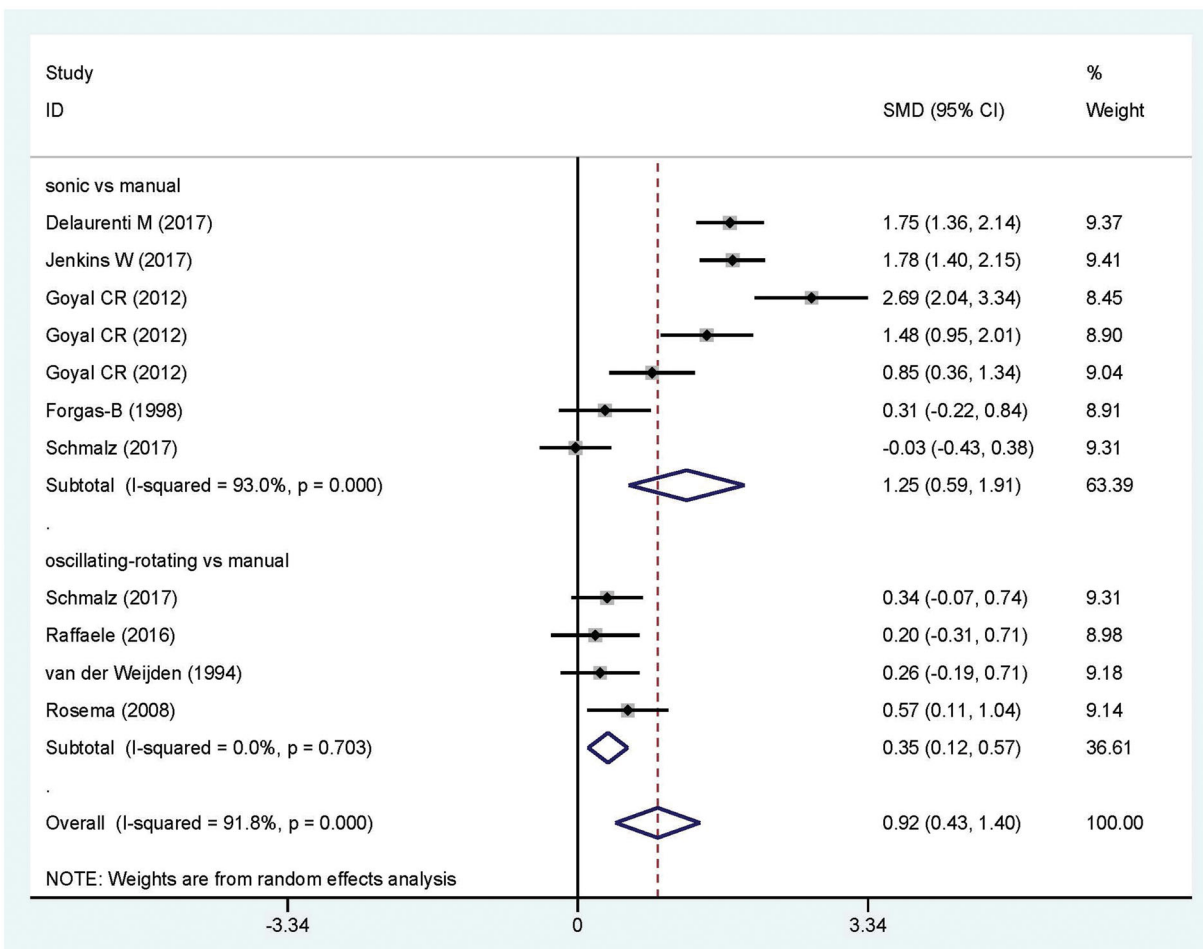


Figure 5. Forest plot of bleeding index.

Table 2. Subgroup analysis based on follow-up.

Outcome	Subgroup	No. of studies	Effect estimate	Heterogeneity		
Plaque (oscillating-rotating vs. manual)	Follow-up	≥2 months	10	0.57 (0.17, 0.97)	$I^2=88%$ $p<.05$	
		<2 month	8	0.55 (0.28, 0.82)	$I^2=76%$ $p<.05$	
	Assessment criteria	TMQHI	11	0.33 (0.13, 0.53)	$I^2=65%$ $p<.05$	
		RMMNPI	4	1.54 (0.57, 2.51)	$I^2=94%$ $p<.05$	
		O' Leary Plaque Indices	1	-0.07 (-0.78, 0.65)	NA	
		Full mouth Plaque Score	1	1.18 (0.63, 1.73)	NA	
		LSPI	1	0.85 (0.38, 1.32)	NA	
	Total		18	0.56 (0.32, 0.80)	$I^2=84%$ $p<.05$	
	Plaque (sonic vs. manual)	Follow-up	≥1 months	4	1.46 (1.00, 1.93)	$I^2=72%$ $p<.05$
			<1 month	4	1.54 (0.24, 2.85)	$I^2=96%$ $p<.05$
Assessment criteria		RMMNPI	5	1.47 (0.58, 2.36)	$I^2=92%$ $p<.05$	
		LSMPI	2	2.10 (1.38, 2.83)	$I^2=84%$ $p<.05$	
		TMQHI	1	0.53 (0.12, 0.94)	NA	
Total			8	1.51 (0.87, 2.15)	$I^2=83%$ $p<.05$	
Gingivitis (oscillating-rotating vs. manual)	Follow-up	<1 month	3	-0.15 (-0.70, 0.41)	$I^2=76%$ $p<.05$	
		>1 month	4	0.21 (-0.00, 0.43)	$I^2=0%$ $p<.05$	
	Assessment criteria	LSGI	5	0.01 (-0.39, 0.41)	$I^2=69%$ $p<.05$	
		LMGI	2	0.19 (-0.07, 0.45)	$I^2=0%$ $p=.06$	
	Total		7	0.07 (-0.20, 0.33)	$I^2=57%$ $p<.05$	
	Gingivitis (sonic vs. manual)	Follow-up	2 weeks	5	1.05 (0.44, 1.67)	$I^2=90%$ $p<.05$
4 weeks			2	0.42 (-0.02, 0.87)	$I^2=52%$ $p=.15$	
Assessment criteria		LSGI	1	0.67 (0.21, 1.13)	NA	
		LMGI	6	0.92 (0.34, 1.50)	$I^2=91%$ $p<.05$	
Total			7	0.47 (0.12, 0.82)	$I^2=89%$ $p<.05$	

RMMNPI: Rustogi Modification of the Modified Navy Plaque Index; TMQHI: Turesky Modification of the Quigley and Hein Index; LSMPI: Lobene and Soparker Modified Plaque Index; LMGI: Lobene Modified Gingival Index; LSPI: Loe and Silness Plaque Index; LSGI: Loe and Silness Gingivitis Index; LSBI: Loe and Silness Bleeding Index, NA: not applicable.

2 min according to the manufacturer's recommendation. Therefore, the users may intentionally clean their teeth, which may lead to the better results in the manual group and the insignificant differences between the power and manual group.

There are some limitations within the study. Firstly, large heterogeneity was frequent across all the endpoints of interest, and subgroup analysis failed to decrease the heterogeneity in most subgroups. Secondly, the assessment standards were different in the combined studies, which may be a source of the heterogeneity.

In conclusion, the current study demonstrated the effectiveness of power toothbrushes in reducing plaque, gingivitis and bleeding index compared with the manual toothbrushes, providing evidence with clinicians on which they based for recommendation as well as consumers who intends to try a way for maintaining oral health.

### Disclosure statement

No potential conflict of interest was reported by the authors.

### Availability of data and materials

The datasets analysed during the current study are available from the corresponding author on reasonable request.

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