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Research Article

Meta Analysis and Systematic Review for Electric (Powered) Versus Manual Toothbrushes among Pediatric and Adult Orthodontic Patients

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Abstract

Pediatric oral hygiene has been a topic of great concern due to the continuing prevalence of oral diseases, such as dental caries. Additional challenges such as orthodontic brackets among pediatric patients have further complicated these efforts to improve oral hygiene and reduce caries lesions. Many methods of improving dental hygiene, including mouth washing, flossing and tooth brushing have been evaluated through the use of systematic reviews and meta analyses. However, some of these methods, such as the use of powered or electric toothbrushes have been less well studied among pediatric patients with orthodontic brackets. To address this deficiency, the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) protocol was utilized to screen peer-reviewed articles from the National Library of Medicine (NLM) using the PubMed database. From the independent, blind reviewers n = 660 peer-reviewed articles were identified from these searches. Applying detailed exclusion and inclusion criteria, a total of n = 19/660 or 2.9% were included in the systematic review and meta analysis. These studies published between 1996 and 2023 encompassed a total of n = 965 patients, which revealed an average relative effect (RE) in plaque reduction of 18.7% comparing powered or electric toothbrushing with manual toothbrushing controls.

Keywords: *Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA); National Library of Medicine (NLM); Relative Effect (RE); Plaque Reduction*

Background

Pediatric oral hygiene has been a topic of great concern due to the continuing prevalence of oral diseases, such as dental caries [1,2]. Despite enormous public health efforts aimed at improving oral health literacy and access, pervasive and persistent challenges and barriers remain that hinder progress towards reducing the most prevalent disease of early childhood - dental caries [3,4]. However, evidence-based reviews have revealed that consistent and persistent focus on prevention efforts among pediatric patients, as well as their parents or guardians, that include frequent and regular toothbrushing may be among the most effective and efficient methods clinically proven to reduce this burden among this patient population [5,6].

However, despite the advances made in many industrialized countries there are additional challenges, such as the placement of orthodontic brackets among adolescent pediatric patients, that have further complicated these efforts to maintain or improve oral hygiene and reduce caries lesions and other associated complications [7,8]. Many of these studies have focused on white spot lesions (WSL), which are known to represent the early stages of demineralization caused by an accumulation of biofilm and dental plaque that may surround any type of fixed orthodontic appliances [9,10]. Although many studies have focused on resins and varnishes to reduce or prevent WSLs, these may not be uniformly available or ubiquitously applied and require the intervention and application by an oral healthcare provider, thereby introducing additional barriers to access and equitable distribution among this specific patient population [11-13].

Many methods of improving pediatric dental hygiene during this phase of adolescence, including mouthwashing, interdental brushing or flossing, and tooth brushing have been evaluated through the use of systematic reviews and meta analyses [14,15]. Although systematic reviews and meta analyses have demonstrated clinically relevant improvements in pediatric oral hygiene with the use of mouthwashing, these studies also clearly demonstrate that these protocols are mainly effective only in combination with frequent and regular tooth brushing strategies, which provides the majority of oral biofilm and dental plaque reduction [16-18]. Similarly, flossing or interdental brushing has also been shown to reduce pediatric caries and improve oral health, although this has also been demonstrated to be the most effective when combined with consistent employment of regular toothbrushing - particularly among adolescent orthodontic patients [19,20].

Indeed, overwhelming evidence for the use of toothbrushing to reduce caries and improve oral health among pediatric patients of all backgrounds has been published [21,22]. Moreover, recent reviews have also demonstrated that the use of powered or electric toothbrushes may be more effective at reducing plaque and biofilm than manual toothbrushing - even among pediatric patients as young as four years of age [23,24]. However, although compelling evidence comparing manual versus powered toothbrushing among patients with orthodontic brackets exists, some evidence has suggested more limited analysis has been performed on the adolescent pediatric patient population, specifically [25-27].

Based upon this information, the primary objective of this study was to evaluate and analyze the clinical evidence (randomized controlled trials) in order to prepare a systematic review and meta-analysis comparing studies that evaluate the use manual versus electric toothbrushes among pediatric adolescent orthodontic patients.

Materials and Methods

Study approval

This study was reviewed and approved by the Office for the Protection of Research Subjects (OPRS) and the Institutional Review Board (IRB) at the University of Nevada Las Vegas (UNLV) as Research Exempt (Protocol 1779780-EXE: Analysis of secondary epidemiology data from existing public databases). The approval as an exemption is granted when the data are available in a public database (PubMed) and no particular individual or patient in any of the studies can be specifically identified.

Study protocol

The Preferred Reporting Items for Systematic Review and Meta Analysis (PRISMA) protocol and guidelines were used, as previously described [28,29]. Medical Subject Headings (MeSH) were used for controlled vocabulary searches and the indexing of published peer-reviewed evidence from the National Library of Medicine (NLM) using the PubMed database online portal, as previously described [23,24]. Boolean operators "AND" and "OR" were utilized to select articles using the search terms "Orthodontic", "Children", "Pediatric", "Electric toothbrush", "Powered toothbrush", and "Manual toothbrush".

All articles were then screened using the inclusion and exclusion criteria. The inclusion criteria required each article to be published within the last thirty years (1996-2025), involve at least some subjects that were 18 years of age or younger, had at least one group with fixed orthodontic appliances, and also at least one group that used electric or powered toothbrushes compared with another group that used traditional or manual toothbrushes. Exclusion criteria were applied to remove articles that dealt exclusively with adults (over 18 years of age), were *ex vivo* or *in vitro* (laboratory-based) in nature, involved physically or cognitively impaired individuals that were not brushing their own teeth, or studies that did not utilize an objective or standardized measure of plaque, such as the Turesky Quigley Hein plaque index (TQH-PI), Rustogi., *et al*. Modified Navy Plaque Index (RMNPI), the Silness-Loe plaque index (SLPI), or a similar standardized Visual Analog Scale (VAS).

Multiple-step review

Each of the study authors performed the search independently using the combinations of search terms and operators described above with all identified articles imported into the online system (Rayyan.ai) for comparison and analysis by study authors. Any articles identified by only one reviewer were marked for discussion, but were included in the total number of articles identified. Each author applied the exclusion criteria independently and articles that were marked for exclusion by all three reviewers were removed from the final analysis. Articles marked for exclusion by only one or two reviewers were marked for discussion and further review. All authors concurred with the final articles selected for review.

Data analysis

The freely available data from each previously published study was gathered and input into Microsoft Excel (Redmond, Washington, USA) for further analysis and graphical display. Almost all studies included data regarding the age of study participants (range and overall average, if available), overall length of the study observation time period, the number of study participants, as well as the baseline and endpoint plaque index scores. Comparisons between the baseline measurements with the changes observed between the control (manual) and experimental (powered or electric toothbrushing) groups were used to determine the relative effect (RE). Meta analysis of associations between the potential confounding variables, including the age of study participants, length of study, size of the clinical trial (number of participants), and type of plaque index scale used were performed using R^2 or the coefficient of determination, as previously described [23,24].

Results

Following the PRISMA protocol, screening of the database using the specified search terms “Orthodontic”, “Children”, “Pediatric”, “Electric toothbrush”, “Powered toothbrush”, “Manual toothbrush”, and the boolean operators (AND/OR) resulted in a total of n = 660 articles for review (Figure 1). Review of each article using the inclusion criteria (published within thirty years, at least one subset of subjects had to be 18 years of age or under with fixed orthodontic appliances, and comparisons between manual and electric or powered toothbrushes must be included in the analysis) led to the exclusion of n = 606 articles. The remaining n = 54 articles were screened using the exclusion criteria, which led to the removal of an additional n = 35 articles that dealt with laboratory-based studies, physically or cognitively impaired individuals, or studies that did not utilize an objective or standardized measure of plaque, such as the Turesky Quigley Hein plaque index (TQH-PI), Rustogi., *et al*. Modified Navy Plaque Index (RMNPI), or the Silness-Loe plaque index (SLPI). The total number of studies included in the final systematic review and analysis was n = 19/660 or 2.9%.

Endpoint data from the pediatric orthodontic studies were analyzed in order to evaluate the relative effect (RE) of electric versus manual toothbrushes on plaque index scores (Figure 1). Study sample sizes ranged from n = 5 to n = 118 with a total number of subjects evaluated from all studies n = 965. The subject ages ranged between 10 and 43, although each of these studies had at least some part of the patient population as adolescents or teenagers 18 years of age or younger. The detailed analysis of these data revealed that the comparison

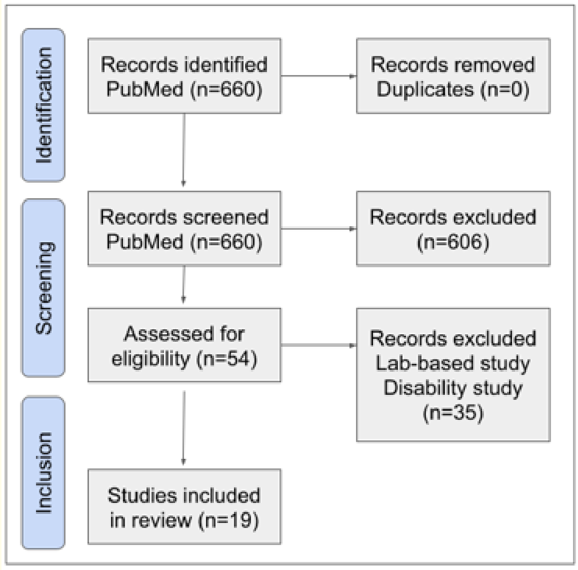

***Figure 1:** Flow diagram of PRISMA protocol for evidence review and screening. The initial search in PubMed resulted in the retrieval of n = 660 studies for review. After application of the inclusion criteria n = 606 were removed and n = 54 full records were retrieved. Following review and screening of exclusion criteria n = 35 were removed resulting in n = 19/660 or 2.9% included in this systematic review [30-48].*

between the percent change in the outcome variable (plaque index) between manual and electric toothbrushes from the baseline to the endpoint measurements ranged between -13.4% and 66.2%, resulting in an overall positive relative effect (RE) of 18.7%. In addition, the majority of studies (n = 16/19 or 84.2%) demonstrated an equivalent or positive relative effect of using electric or powered toothbrushes compared with manual or traditional toothbrushes to reduce plaque index scores. However, a small number of the studies evaluated (n = 3/19 or 15.8%) demonstrated a slight negative relative effect that ranged from -1.5% to - 13.4%.

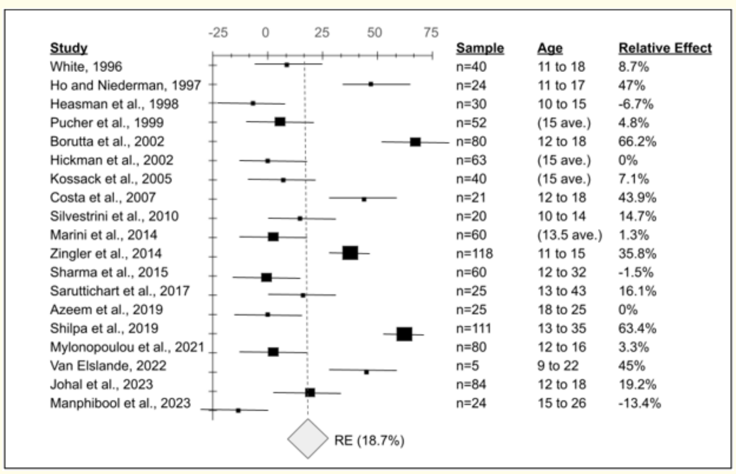

***Figure 2:** Forest plot of pediatric orthodontic studies comparing changes in plaque index with electric versus conventional toothbrushing. Study samples ranged between n = 5 to n = 118 (average n = 54) with subject ages ranging between 10 and 43 (average 15.3 years). The percent change in plaque index ranged between -13.4% and 66.2%, yielding a positive relative effect (RE) of 18.7% with the majority of studies (n = 16/19 or 84.2%) demonstrating positive or equivalent relative effects.*

To determine if any differences among study outcomes were associated with the age of the study participants, average or mean age for each study sample if provided (n = 15/19 or 78.9%) was plotted against the reduction in plaque index (Figure 3). This analysis revealed that the age of study participants was not significantly correlated with the primary measurement outcomes (plaque index reduction), with an overall coefficient of determination determined to be $R^2 = 0.011$. Although the majority of studies with age-specific information involved participants with an average age of less than 18 years (n = 11/15 or 73.3%), some of these studies did include participants up to 22 years of age. Moreover, three of the four studies with an average age of more than 18 years also included pediatric patients as young as 12 years of age.

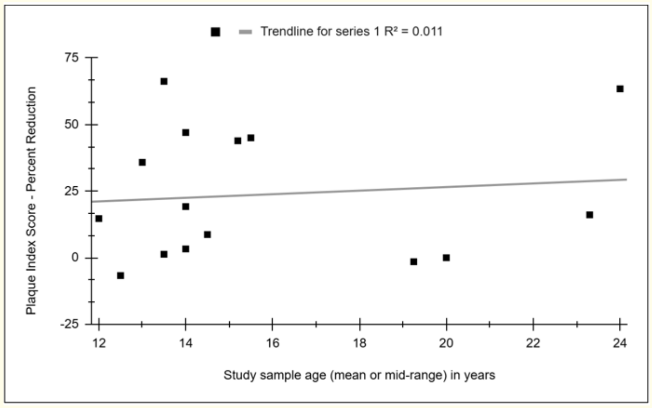

Figure 3: *Meta analysis of study outcomes (reduction in plaque index) compared with the age of the study participants. These data demonstrated no significant association with plaque index reduction, R2 = 0.011. Most studies included mainly pediatric patients with an average age <18 years (n = 11/15 or 73.3%), although all studies except one included at least some pediatric patients.*

More detailed analysis was performed to determine if the length of study was associated with the study outcomes (Figure 4). This revealed that the majority of studies had published and well-defined timelines (n = 16/19 or 84.2%), which ranged from two weeks (14 days) to a full year (365 days). In addition, this analysis revealed that no statistically significant associations were found between the length of the study and the observed reduction in plaque index scores among the participants, $R^2 = 0.011$. Finally, this analysis also revealed that most of the studies included in this analysis (n = 11/16 or 68.8%) were between one month and three months in length. The remaining studies that provided the length of the observation period ranged between four months and one full year.

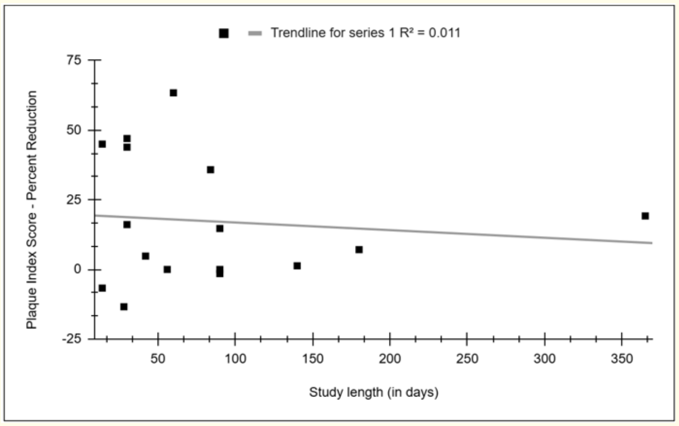

Figure 4: *Meta analysis of study outcomes (plaque index score) compared with study length. Most studies analyzed included timelines (n = 16/19 or 84.2%), ranging between 14 and 365 days - with the majority (n = 11/16 or 68.8%) lasting between one and three months. No statistically significant associations were observed between the reduction in plaque index score and length of the study, $R^2 = 0.011$.*

Comparison of the study outcomes (reduction in plaque index) with the study size (number of participants) was also analyzed (Figure 5). These data revealed a weak positive correlation between the number of study participants and the percent reduction in plaque index score observed, R = 0.268. Although the coefficient of determination was not statistically significant (R2 = 0.072), these data may suggest that study size may have played a confounding role in the study outcomes. For example, two of the three studies that showed no reduction in plaque index scores with electric toothbrushes had relatively smaller sample sizes (n<30), whereas all of the larger studies (n>80) found significant differences.

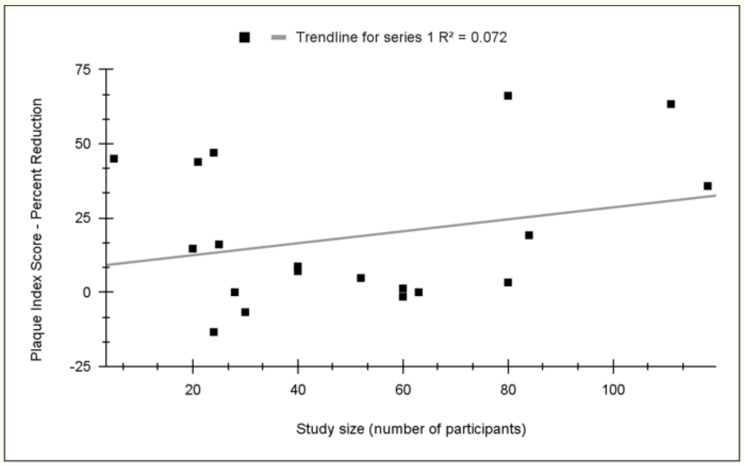

Figure 5: *Meta analysis of study outcomes and number of participants. A weak positive correlation (R2 = 0.268) was observed between the study size and reduction in plaque index score, although this was not statistically significant (R2 = 0.072). However, smaller studies (n<30) were more likely to show lower or no reduction in plaque index scores than larger studies (n>80).*

Comparisons were made to determine if there was any association between the type of plaque index score used and the study outcomes (Figure 6). This analysis demonstrated that the type of plaque index scoring system utilized (Turesky Quigley Hein plaque index (TQH-PI), the Silness-Loe plaque index (SLPI), or the Visual Analog Scale (VAS) was not significantly associated with the study outcomes $R^2 = 0.008$. In fact, studies using each of these scales had both high and low relative effect scores. For example, studies that used the Turesky Quigley Hein plaque index (TQH-PI), had relative effects that ranged between +1.3% to +66.2%, while those using the Silness-Loe plaque index (SLPI) observed relative effects ranging from -13.4% to +63.4%. The remaining studies that used the visual analog scale (VAS) reported relative effects that ranged between -6.7% to +45%.

Finally, assessments were made to determine the potential sources of bias among the selected studies within this systematic review and meta analyses (Table 1). This analysis revealed that the overwhelming majority of studies (n = 17/19 or 89.5%) included in this systematic review were randomized controlled or crossover trials, exhibiting low selection or enrollment bias. Furthermore, all studies included at least one blinded operator, which reduces the effects of reporter or observer bias. Finally, almost all studies (n = 18/19 or 94.7%) exhibited low or very low loss to follow up or attrition with n = 13/19 or 68.4% exhibiting no study withdrawals or drop outs.

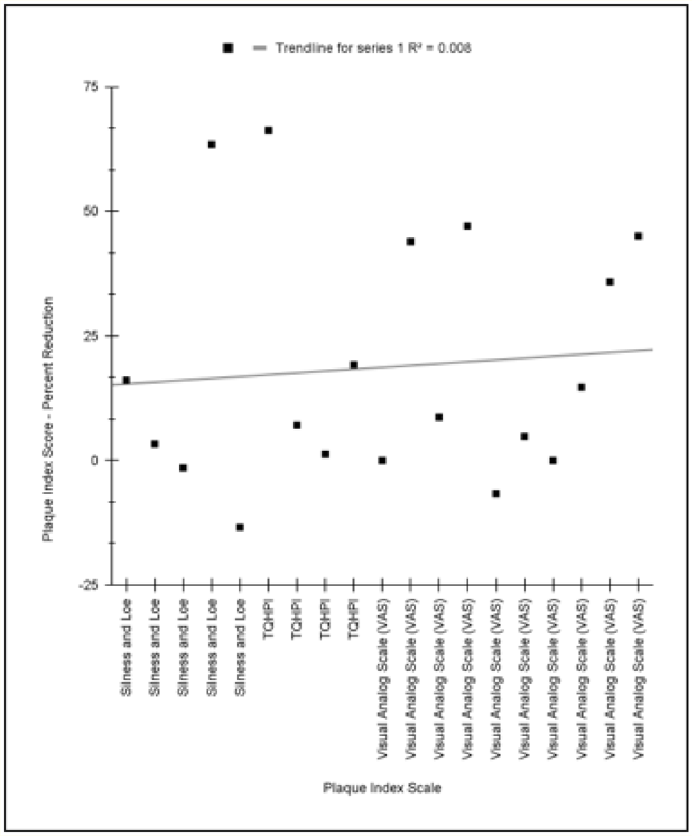

Figure 6: *Meta analysis of study outcomes and the type of plaque index scale used. This analysis demonstrated no significant association between the plaque index scale with the study outcomes R2 = 0.008, such as the Turesky Quigley Hein plaque index (TQH-PI) studies (range: +1.3% to +66.2%), the Silness-Loe plaque index (SLPI) studies (range: -13.4% to +63.4%), and the visual analog scale (VAS) studies (range: -6.7% to +45%).*

Study	Selection bias (Enrollment)	Observer bias (Reporter)	Attrition bias (Loss to follow up)
White, 1996 [30]	Low (RCT)	Moderate (Single blinded operator)	High (20% overall loss)
Ho and Niederman, 1997 [31]	Low (RCT)	Moderate (Single blinded operator)	Very low (0% overall loss)
Heasman., *et al*. 1998 [32]	Low (RCT)	Low (multiple blinded operators)	Very low (0% overall loss)
Pucher., *et al*. 1999	Low (RCT)	Low (double blinded study)	Very low (0% overall loss)
Borutta., *et al*. 2002	Low (RCT)	Low (Two independent operators)	Low (13.3% overall loss)
Hickman., *et al*. 2002	Low (RCT)	Moderate (Single blinded operator)	Low (5% overall loss)

Kossack., *et al*. 2005	Low (Blinded Crossover Trial)	Moderate (Single blinding)	Very low (0% overall loss)
Costa., *et al*. 2007	Low (RCT)	Moderate (Single blinded operator)	Very low (0% overall loss)
Silvestrini., *et al*. 2010	Low (RCT)	Low (multiple blinded operators)	Very low (0% overall loss)
Marini., *et al*. 2014	Low (RCT)	Moderate (Single blinded operator)	Very low (0% overall loss)
Zingler., *et al*. 2014	Low (RCT)	Moderate (Single blinded operator)	Low (8% overall loss)
Sharma., *et al*. 2015	Low (RCT)	Moderate (Single blinded operator)	Very low (0% overall loss)
Saruttichart., *et al*. 2017	Low (RCT)	Low (Two independent operators)	Very low (0% overall loss)
Azeem., *et al*. 2019	Moderate (Split mouth study)	Moderate (Single blinded operator)	Very low (0% overall loss)
Shilpa., *et al*. 2019	Low (RCT)	Low (multiple blinded operators)	Very low (0% overall loss)
Mylonopoulou., *et al*. 2021	Low (RCT)	Moderate (Single blinded operator)	Very low (0% overall loss)
Van Elslande, 2022	High (Convenience Sampling)	Moderate (Single blinded operator)	Very low (0% overall loss)
Johal., *et al*. 2023	Low (RCT)	Moderate (Single blinded operator)	Low (8.7% overall loss)
Manphibool., *et al*. 2023	Low (RCT)	Low (Two independent operators)	Low (4.2% overall loss)

Table 1: *Analysis of potential sources of study sample bias.*

Discussion

The purpose of this review was to gather and synthesize the published evidence from clinical trials to determine the potential effects of electric versus manual toothbrushing among pediatric adolescent patients undergoing orthodontic therapy. These data demonstrated that a significant number of studies encompassing nearly 1,000 patients have been published that provide clinical evidence for a nearly 20% reduction in dental biofilm and plaque among the pediatric and adolescent patients that used powered or electric toothbrushes compared with traditional or manual toothbrushes. This new information may be important for review by public health and oral care professionals for several reasons.

First, and most importantly, there are few systematic reviews and meta analyses that have focused specifically on comparisons of electric versus manual toothbrushing among pediatric and adolescent patient populations specifically undergoing orthodontic therapy with fixed appliances [23,25,26]. Moreover, of these systematic reviews that focused specifically on pediatric orthodontic patient populations, the inclusion criteria utilized within these studies resulted in many fewer clinical trials and published evidence for analysis that generally ranged from a select few (three or four) to as many as a dozen [49,50]. This suggests that the current study encompassing nearly twenty clinical trials may represent a more broad and robust collection of clinical evidence to more accurately reflect the known effects and benefits of electric versus manual toothbrushes, specifically among this patient population [51,52].

For example, two of the most recent systematic reviews that evaluated orthodontic patients encompassed only nine and eleven studies, respectively - the larger of which reviewed results from a total of n = 436 patients [23,24]. This systematic review and meta analysis analyzed nearly double the number of studies (nineteen in total) that enrolled and evaluated almost twice as many patients (nearly 1,000) for clinical evaluation. In fact, the only other recent systematic review of electric toothbrushing among this patient population specifically excluded subjects with orthodontic appliances, suggesting this may be the largest and most comprehensive study of this type to date [50,57].

Importantly, this review also incorporated studies that compared electric or powered versus manual toothbrushing among both pediatric and adult patients with fixed orthodontic appliances [53,54]. This may be an important feature that distinguishes this study as other systematic reviews and meta analyses may have excluded clinical evidence that also evaluated adult patients within the study parameters, which may have limited the overall number of publications available for evaluation and analysis, thereby limiting the conclusions and generalizability that could be made from these previous studies]55,56]. Moreover, studies that focused exclusively on adult patients may have not only reduced the overall study sample size but may have also missed the difficulties and associated challenges that face younger pediatric patients not only in the application of consistent and evidence-based oral prevention practices, but also in the selection and choosing of oral healthcare products directly, which may be more often selected by a parent or guardian [57,58].

Another important facet of this current systematic review and meta analysis is the focus specifically on electric versus manual toothbrushes among patients with fixed orthodontic appliances [59,60]. For example, many previous studies have focused on other prevention efforts used in conjunction with fixed orthodontic therapy, such as the use of dental sealants that may or may not be used depending upon the oral healthcare provider as well as the request of the patient, parent or guardian [62-63]. Furthermore, studies have focused on alternative prevention methods such as fluoride varnishes in conjunction with fixed appliances, which are also dependent upon the intervention of a trained oral healthcare provider and not under the direct control of the patient - unlike the daily use of manual or electric toothbrushes [64-66].

Finally, this study also evaluated the length of study, which is also an important component that further enables more robust analyses of this data. For instance, the accumulation and aggregation of these studies clearly demonstrated that the effects of switching to an electric or powered toothbrush was evident immediately (baseline measurements), which is similar to other evidence that has also been generated among other clinical studies using non-orthodontic patients [67,68]. Moreover, these effects are sustained long-term for studies that lasted from four months to as long as one full calendar year, which suggests that these reductions can be sustained over time and may provide lasting clinical benefits for patients that choose to switch to an electric or powered toothbrush upon the placement of fixed orthodontic appliances [69,70].

However, there are several potential confounding factors and variables that should be carefully considered when evaluating this type of systematic review. First, this study evaluated the potential benefits and clinical reduction of dental plaque using powered toothbrushes, but was not able to find sufficient evidence for any one type or specific model of electric toothbrush - suggesting that potential variability may have influenced some of the results in studies that utilized different brands of toothbrushes [71,72]. Other limitations might include the amount of hygiene instruction or demonstration included in each of these studies, which may significantly impact the depth and durability of any clinical benefits observed from these observations [73,74]. Finally, limited information was available regarding the oral health behaviors and other established hygiene habits prior to initiation of each study so the potential may exist that results from patients with higher levels of oral health literacy and more extensive oral health prevention behaviors could have had the potential to skew some of these results [75,76].

Conclusion

This systematic review combined multiple clinical trials involving teenage and adolescent patients undergoing orthodontic therapy to evaluate electric versus manual toothbrushing in order to determine the overall relative effects and potential clinical benefits in plaque reduction. This analysis greatly increased both the number of studies and the number of overall patients evaluated, which clearly demonstrates electric or powered toothbrushing is associated with a robust reduction in plaque index scores among this patient population. Moreover, these effects can be seen immediately and are often sustained over the long-term, suggesting that patient and parental education regarding these potential benefits may be an important component of the oral health discussions leading up to and during orthodontic treatment and care involving fixed orthodontic appliances.

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