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Comparative Evaluation of Plaque Removal Efficiency of Electric, Manual, and Sonic Toothbrushes in Children Aged 6 To 12 Years: A Randomized Controlled Trial

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ABSTRACT

Background: Maintaining good oral hygiene in children is crucial for preventing dental caries and gum diseases. Effective plaque removal plays a key role in ensuring optimal oral health, and the type of toothbrush used can significantly influence plaque control. Although manual toothbrushes remain widely used, electric and sonic toothbrushes have gained popularity due to their advanced cleaning mechanisms. However, limited research has compared the effectiveness of these toothbrush types in younger children.

Aim: To assess and compare the plaque removal efficacy of manual, electric, and sonic toothbrushes in children aged 6 to 12 years.

Materials and Methods: A randomized controlled trial was conducted among 78 children, categorized into three groups: manual, electric, and sonic toothbrush users. All participants followed the Bass brushing technique for two minutes under supervision. Plaque Index (PI), Patient Hygiene Performance (PHP) Index, and Decayed, Missing, and Filled Teeth (DMFT) Index were measured at baseline, 3 months, and 6 months. Anxiety levels were evaluated using Ayesha's Oddbods Anxiety Scale. Data analysis was carried out using SPSS software version 27.

Results: The manual toothbrush group showed a significant increase in GI (0.35 ± 0.485 to 2.42 ± 0.504 at 3 months) and DMFT (0.62 ± 0.571 to 4.27 ± 2.164 at 3 months), with slight improvement at 6 months (GI: 2.54 ± 0.508, DMFT: 3.46 ± 0.508). The electric toothbrush group demonstrated better plaque control, with GI improving from 1.65 ± 0.485 to 2.46 ± 0.508 and DMFT reducing from 2.50 ± 0.510 to 1.23 ± 0.430 at 6 months. The sonic toothbrush group showed the most significant improvements, with GI decreasing from 1.88 ± 0.653 to 1.50 ± 0.510 and DMFT from 2.50 ± 0.510 to 1.23 ± 0.430 at 6 months. Anxiety levels significantly decreased in the sonic toothbrush group (36.65 ± 7.725 to 22.04 ± 4.521). Statistical analysis (Repeated Measures ANOVA, effect size analysis and Paired t test) confirmed significant differences ($p < 0.05$) among groups, demonstrating the superior effectiveness of electric and sonic toothbrushes.

Conclusion: Electric and sonic toothbrushes proved more effective than manual toothbrushes in enhancing oral health. Additionally, sonic toothbrushes offered the added benefit of reducing dental anxiety in children.

Keywords: *Dental Plaque, Toothbrushing, Dental Caries, Pediatric Dentistry, Oral Hygiene*

1. INTRODUCTION

Maintaining oral hygiene was essential for children's overall health, with effective plaque control playing a vital role in

preventing dental caries and gum diseases. Young children, particularly those between 4 and 9 years old, were more susceptible to plaque accumulation due to their developing motor skills and limited ability to brush effectively (1). The choice of a suitable toothbrush significantly impacted their oral health outcomes. While both manual and electric toothbrushes were commonly used, the comparative effectiveness of different toothbrush types, including sonic toothbrushes, remained an area of ongoing research (2).

Manual toothbrushes were widely used due to their affordability and availability. However, their effectiveness was highly dependent on proper brushing techniques, duration, and parental supervision, which could be inconsistent in younger children (3). Since children often lacked the necessary motor coordination for thorough plaque removal, they may have been at a higher risk of developing caries if manual brushing was not done correctly (4).

Electric toothbrushes, including oscillating-rotating and sonic types, were introduced as alternatives to manual toothbrushes to improve plaque removal. Several studies suggested that electric toothbrushes offered better cleaning efficiency, particularly for children who struggled with manual dexterity (5). Research indicated that powered toothbrushes could significantly reduce plaque and gingival inflammation compared to manual brushing, making them a preferable choice for younger users (6).

Sonic toothbrushes, a subtype of electric toothbrushes, generated high-frequency vibrations that created fluid motion, potentially enhancing plaque removal beyond direct bristle contact (7). Some studies suggested that sonic toothbrushes may have provided superior plaque control compared to manual and oscillating-rotating electric toothbrushes, particularly in hard-to-reach areas (8).

Despite the growing evidence supporting electric and sonic toothbrushes, more research was needed to determine their comparative effectiveness in young children. Factors such as compliance, ease of use, comfort, and parental guidance played a crucial role in determining which type of toothbrush was most effective for children in this age group (9).

This study aimed to compare the plaque removal effectiveness of manual, electric, and sonic toothbrushes in children aged 4 to 9 years, using standardized plaque index assessments. By identifying the most efficient toothbrush type, this research sought to provide evidence-based recommendations for parents and oral health professionals, ultimately contributing to better pediatric oral hygiene practices and the prevention of dental caries.

2. MATERIALS AND METHOD:

Study Design and Participants

This randomized controlled trial (RCT) was conducted in the Department of Pediatric Dentistry, Saveetha Dental College, Chennai, India. Ethical approval was obtained from the Institutional Ethics Committee (IHEC/SDC/UG-1948/23/PEDO/188), and informed consent was secured from caregivers before the commencement of the trial. Additionally, approval was obtained from the concerned school authorities. The study adhered to the CONSORT guidelines for reporting randomized trials.

Inclusion and Exclusion Criteria

Inclusion Criteria

- Children aged 6 to 12 years with more than 10 erupted teeth in oral cavity
- Children who had not received professional dental cleaning in the six months before the study and did not have systemic diseases influencing oral hygiene.
- Participants (or their guardians) willing to adhere to the prescribed oral hygiene regimen and attend follow-up visits.

Exclusion Criteria

- Children with systemic conditions, orthodontic appliances, developmental defects, or recent antibiotic use (within the past three months).
- Children with severe physical or cognitive impairments that could affect compliance with oral hygiene instructions.

Randomization and Blinding

A computer-generated randomization sequence was used to assign participants to different groups. The investigator responsible for assessing plaque scores was blinded to the type of toothbrush used to minimize bias.

Intervention (Tooth Brushing Protocol)

The study included three intervention groups based on the type of toothbrush used. Group 1 (Manual Toothbrush - M) used a soft-bristled manual toothbrush (Oral-B Kids Manual Toothbrush, Tom & Jerry, Extra Soft Bristles) with fluoridated toothpaste (1000 ppm fluoride). Group 2 (Electric Toothbrush - E) used a rotating-oscillating electric toothbrush (Oral-B Pro 3 Rechargeable Rotating Electric Toothbrush) equipped with soft crisscross bristles, designed to remove up to 100% more

plaque than a manual toothbrush. Group 3 (Sonic Toothbrush - S) used a high-frequency sonic toothbrush (Philips Sonicare Electric Toothbrush HX3641/13), which operated at 24,000–40,000 strokes per minute and featured a built-in pressure sensor and a curved power tip to enhance plaque removal, particularly in posterior regions. It was reported to remove up to three times more plaque than a manual toothbrush. In all groups, brushing was performed for two minutes using the Bass technique with a pea-sized amount of 1000 ppm fluoridated toothpaste under supervision.

Training and Accessibility

Oral hygiene instructions were provided in both written and verbal formats to ensure clear understanding. Caregivers were trained to assist and supervise children's brushing routines. Hands-on demonstrations were conducted to reinforce learning.

3. METHODOLOGY

This study employed a randomized controlled trial design, conducted over six months with assessments at baseline, 3 months, and 6 months. Participants were randomly assigned to one of three toothbrush groups (manual, electric, and sonic) using a computer-generated sequence to ensure unbiased group assignments. Trained examiners, blinded to group assignments, performed oral health assessments at each time point. The assessments included the Plaque Index (PI) to evaluate plaque accumulation on tooth surfaces, the Patient Hygiene Performance (PHP) Index to assess overall plaque accumulation, and the Decayed, Missing, and Filled Teeth (DMFT) Index to record dental caries experience. Anxiety levels related to toothbrushing were monitored using Ayesha's Oddbods Anxiety Scale. Participants received educational materials and instructions on proper brushing techniques at each stage. The manual toothbrush group used a soft-bristled manual toothbrush [Oral-B Kids Manual Toothbrush, Tom & Jerry, Extra Soft Bristles, USA] with fluoridated toothpaste. The electric toothbrush group used a rotating-oscillating electric toothbrush [Oral B Pro 3 Rechargeable Rotating Electric Toothbrush, USA]. The sonic toothbrush group used a high-frequency sonic toothbrush [Philips Sonicare Electric Toothbrush HX3641/13, Netherlands]. Initially, 90 participants were assessed for eligibility, but only 78 completed the study after exclusions.

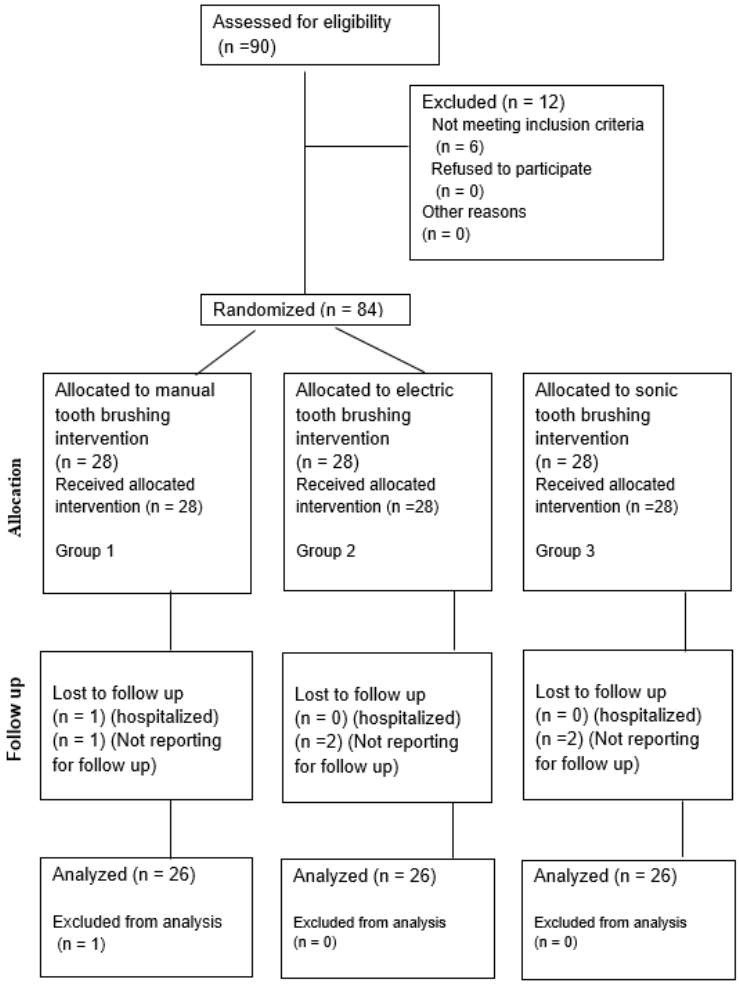

Figure 1: CONSORT diagram showing the flow of participants through each stage of a randomized trial.

This study adhered to CONSORT guidelines, ensuring transparency in participant selection, allocation, and analysis. Of the 90 children assessed for eligibility, 12 were excluded for not meeting inclusion criteria. The remaining 84 participants were randomized into three groups (manual, electric, and sonic toothbrushes, n = 28 each), with all receiving their assigned intervention. During follow-up, some participants were lost due to hospitalization or failure to report (manual: 2, electric: 2, sonic: 2). Ultimately, 26 participants per group were included in the final analysis, with exclusions properly recorded. Randomization and blinding of the outcome assessor helped reduce bias.

4. RESULTS

The valid sample of the study consists of children aged 6 to 12 years, with the age distribution showing that 6-year-olds make up 11.5%, 7-year-olds and 8-year-olds each account for 15.4%, 9-year-olds constitute 11.5%, and 10-year-olds, 11-year-olds, and 12-year-olds each comprise 15.4% of the sample. In terms of gender, 57.7% of the valid sample are males, while 42.3% are females.

Group	Variable	Baseline (Mean ± SD)	3 months (Mean ± SD)	6 months (Mean ± SD)	P value
Manual	GI	0.35 ± 0.485	2.42 ± 0.504	2.54 ± 0.508	<0.001
	DMFT	0.62 ± 0.571	4.27 ± 2.164	3.46 ± 0.508	<0.001
	PHP	0.92 ± 0.628	3.42 ± 0.504	3.04 ± 0.824	<0.001
	Anxiety	7.88 ± 3.217	32.69 ± 5.144	26.15 ± 6.972	<0.001
Electric	GI	1.65 ± 0.485	2.46 ± 0.508	1.50 ± 0.510	<0.001
	DMFT	2.50 ± 0.510	2.15 ± 0.675	1.23 ± 0.430	<0.001
	PHP	3.08 ± 1.017	3.15 ± 0.543	3.27 ± 0.919	0.167
	Anxiety	11.73 ± 3.726	32.12 ± 5.324	19.42 ± 4.545	<0.001
Sonic	GI	1.88 ± 0.653	2.00 ± 0.894	1.50 ± 0.510	0.044
	DMFT	2.50 ± 0.510	2.15 ± 0.675	1.23 ± 0.430	<0.001
	PHP	3.46 ± 0.582	3.46 ± 0.582	3.46 ± 0.582	0.485
	Anxiety	36.65 ± 7.725	36.46 ± 6.088	22.04 ± 4.521	<0.001

Table 1: Intragroup comparison of oral health parameters and anxiety scores at baseline, 3 months, and 6 months for group 1 (manual toothbrush), group 2 (electric toothbrush) and group 3 (sonic toothbrush) in children

Table 1 shows that in the manual toothbrush group, there was a significant increase in gingival index (GI) and decayed, missing, and filled teeth (DMFT) scores from baseline to 3 months, with slight improvements at 6 months. Patient hygiene performance (PHP) also showed an initial decline followed by a slight improvement, while anxiety levels peaked at 3 months and then decreased. In contrast, the electric toothbrush group demonstrated improvements in GI and DMFT scores over time, with stable PHP scores and a similar anxiety pattern to the manual group. The sonic toothbrush group showed slight improvements in GI and significant reductions in DMFT, with consistent PHP scores and a notable decrease in anxiety levels from baseline to 6 months. Overall, both electric and sonic toothbrushes appeared to offer better oral health outcomes compared to manual toothbrushes, with the electric toothbrush showing more consistent improvements and the sonic toothbrush providing significant anxiety reduction.

Group	Variable	Baseline (Mean ± SD)	3 months (Mean ± SD)	6 months (Mean ± SD)	p-value
Manual	GI	0.35 ± 0.485	2.42 ± 0.504	2.54 ± 0.508	0
	DMFT	0.62 ± 0.571	4.27 ± 2.164	3.46 ± 0.508	0
	PHP	0.92 ± 0.628	3.42 ± 0.504	3.04 ± 0.824	0
	Anxiety	7.88 ± 3.217	32.69 ± 5.144	26.15 ± 6.972	0
Electric	GI	1.65 ± 0.485	2.46 ± 0.508	1.50 ± 0.510	0.015
	DMFT	2.50 ± 0.510	2.15 ± 0.675	1.23 ± 0.430	0
	PHP	3.08 ± 1.017	3.15 ± 0.543	3.27 ± 0.919	0.11
	Anxiety	11.73 ± 3.726	32.12 ± 5.324	19.42 ± 4.545	0
Sonic	GI	1.88 ± 0.653	2.00 ± 0.894	1.50 ± 0.510	0
	DMFT	2.50 ± 0.510	2.15 ± 0.675	1.23 ± 0.430	0
	PHP	3.46 ± 0.582	3.46 ± 0.582	3.46 ± 0.582	0.029
	Anxiety	36.65 ± 7.725	36.46 ± 6.088	22.04 ± 4.521	0

Table 2: Intergroup comparison of oral health parameters and anxiety scores at baseline, 3 months, and 6 months for group 1 (manual toothbrush), group 2 (electric toothbrush) and group 3 (sonic toothbrush) in children

The intergroup ANOVA comparison shown in a table of oral health parameters and anxiety scores among children using manual, electric, and sonic toothbrushes revealed distinct trends. The manual toothbrush group showed significant increases in gingival index (GI) and decayed, missing, and filled teeth (DMFT) scores from baseline to 3 months, with slight improvements at 6 months, while patient hygiene performance (PHP) scores initially declined and then improved slightly. Anxiety levels peaked at 3 months and decreased by 6 months. In contrast, the electric toothbrush group demonstrated improvements in GI and DMFT scores over time, with stable PHP scores and a similar anxiety pattern. The sonic toothbrush group showed slight improvements in GI, significant reductions in DMFT, consistent PHP scores, and a notable decrease in anxiety levels from baseline to 6 months. Overall, both electric and sonic toothbrushes outperformed manual toothbrushes in oral health outcomes, with the sonic toothbrush offering additional benefits in reducing anxiety among children.

5. DISCUSSION:

The study's findings align with prior research that underscores the benefits of powered toothbrushes—both electric and sonic—over manual toothbrushes in improving oral health among children. Electric and sonic toothbrushes offer significant advantages over manual toothbrushes, particularly for children with developing motor skills. Their automated motion ensures consistent and efficient plaque removal, reducing the risk of cavities and gingival inflammation. Additionally, studies have shown that manual toothbrushes are more prone to bacterial contamination due to improper storage, while the rapid bristle movements of powered toothbrushes aid in quicker drying, limiting microbial growth (11,13, 25)

Previous studies (14,15) have highlighted the superior plaque-removal ability of electric and sonic toothbrushes. This study further supports these claims by evaluating gingival health, plaque control, and anxiety levels in children aged 6 to 12 years. Sonic toothbrushes offer significant benefits for children, making them an effective choice for improving oral health. Their high-frequency vibrations (24,000–40,000 strokes per minute) create a hydrodynamic effect, which enhances plaque removal even in hard-to-reach areas (16). Additionally, the gentle vibrations provide a more comfortable brushing experience, helping to reduce dental anxiety in young children (17). Moreover, sonic toothbrushes stimulate the gums, improving circulation and reducing gingival inflammation, which contributes to better overall gum health (18).

In contrast, the electric toothbrush group showed progressive improvements in GI and DMFT scores with stable PHP scores. These findings support previous studies that have demonstrated the greater effectiveness of electric toothbrushes in plaque control and gingival health compared to manual brushing (12,13). The oscillating and rotating bristles likely contributed to

improved plaque removal, minimizing the need for precise manual dexterity, which can be a challenge for younger children. However, anxiety levels followed a similar pattern to the manual toothbrush group, peaking at 3 months before declining, suggesting that while electric toothbrushes improve plaque control, they may not significantly impact dental anxiety.(14)

The manual toothbrush group showed a significant rise in gingival index (GI) and decayed, missing, and filled teeth (DMFT) scores between baseline and 3 months, followed by minor improvements at 6 months. This aligns with earlier research (19) suggesting that children using manual toothbrushes may struggle with plaque removal due to inconsistent brushing techniques and developing motor skills. Patient hygiene performance (PHP) scores initially declined before showing slight improvement, emphasizing the importance of brushing technique and parental supervision. Additionally, anxiety levels peaked at 3 months before declining at 6 months, indicating an adaptation to the brushing routine over time (19).

The sonic toothbrush group yielded the most favorable results, with slight improvements in GI, significant reductions in DMFT, stable PHP scores, and a notable decrease in anxiety levels from baseline to 6 months. The hydrodynamic effect of sonic toothbrushes, as noted by (19), likely contributed to superior plaque removal, particularly in hard-to-reach areas. Additionally, the gentle vibrations may have helped reduce anxiety by offering a more comfortable brushing experience (20). The decline in anxiety levels in this group suggests that sonic toothbrushes may be particularly useful for children with dental-related fear.

Although the results reinforce the advantages of powered toothbrushes for pediatric oral hygiene, factors such as cost, accessibility, and the need for parental supervision should be considered when making recommendations. As pointed out, long-term studies with larger sample sizes are necessary to fully understand the sustained effects of different toothbrushes on oral health and anxiety. Further research should also explore the role of parental involvement in children's brushing habits to develop more effective strategies for improving pediatric oral hygiene (21,22).

The study by Mathew MG and Gurunathan D highlighted that powered toothbrushes, including electric and sonic models, were more effective than manual toothbrushes in plaque removal due to their oscillating and high-frequency vibrations, which disrupted plaque biofilm more efficiently. Additionally, their user-friendly design required less manual effort and technique precision, making them ideal for children who struggle with proper brushing techniques. This improved brushing consistency, leading to better oral hygiene outcomes over time (23,24,25).

The studies by Govindaraju L and Gurunathan D (2017) and Govindaraj A and Gurunathan D (2019) highlight key advantages of electric and sonic toothbrushes over manual ones. Research on chewable toothbrushes emphasized the importance of effective plaque removal, noting that young children often struggle with proper brushing techniques. This limitation makes electric and sonic toothbrushes more beneficial, as their automated motion ensures thorough plaque removal with minimal reliance on manual dexterity. Additionally, the study on toothbrush contamination revealed that manual toothbrushes are more prone to bacterial accumulation due to improper storage and maintenance. In contrast, sonic and electric toothbrushes, with their rapid bristle movements and quicker drying, may help reduce microbial growth, lowering the risk of oral infections. Given these advantages, future research should focus on the long-term effects of different toothbrushes on bacterial contamination and plaque control. Additionally, exploring technological advancements, such as pressure sensors and interactive guidance in electric and sonic toothbrushes, could enhance children's brushing habits and overall oral health outcomes (26,27).

Limitations: The study duration may not be adequate to assess the long-term effects of manual, electric, and sonic toothbrushes on plaque control, gingival health, and overall oral hygiene maintenance. A more extended follow-up period would provide a comprehensive understanding of sustained oral health benefits. Additionally, factors such as parental supervision, brushing frequency, and individual motivation were not strictly standardized, which may have influenced the outcomes. The study primarily focused on plaque removal efficiency; however, other critical aspects, including enamel wear, toothbrush durability, and children's acceptance or preference, were not evaluated. Future research should include larger cohorts with longer follow-up periods to validate and expand upon the current findings.

6. CONCLUSION

This study demonstrated that electric and sonic toothbrushes offer superior plaque removal compared to manual toothbrushes in children aged 6 to 12 years. The electric toothbrush group showed steady improvements in plaque and gingival health, while the sonic toothbrush group exhibited the most significant reduction in DMFT scores and dental anxiety. The findings emphasize the need for evidence-based recommendations in pediatric oral care. Future research should explore long-term effects, cost-effectiveness, and parental involvement in children's oral hygiene practices to enhance pediatric dental health strategies.

Author's contribution: Aarthi. K - Contributed to data collection, data acquisition and interpretation, and drafting; Dr. Ramesh R- Contributed to conception, design, and critically revising the manuscript. All authors gave final approval and agreed to be accountable for all aspects of the work.

Conflict of interest: The authors declare no conflict of interest.

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