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ORIGINAL RESEARCH

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Efficacy of manual, musical and electric toothbrushes in plaque removal in children—a randomized clinical trial

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Abstract

Background: Tooth brushing is essential for oral hygiene in children, promoting plaque removal and preventing periodontal diseases. This study aimed to evaluate and compare the effectiveness of manual, musical and electric toothbrushes in removing supragingival plaque in children aged 6–12 years. **Methods**: A single-blind, randomized study enrolled 111 children aged 6–12 years who met the inclusion criteria. Participants were randomly assigned to three groups: group 1 (manual toothbrush), group 2 (musical toothbrush) and group 3 (electric toothbrush). They were instructed to brush their teeth twice daily for 2 minutes over a 45-day period. Plaque levels were assessed using the Quigley-Hein plaque index (PI) at baseline (day 0) and after 15, 30 and 45 days following 24 hours of no oral hygiene. At each visit, plaque removal was evaluated using a disclosing solution before and after supervised brushing. Statistical analyses included one-way Analysis of variance formula and paired *t*-tests to compare plaque scores within and between groups. **Results**: Intragroup comparisons showed significant plaque reduction from pre- to post-brushing at all time points for all groups, except group 3 on day 45, where the reduction was not statistically significant ($p = 0.083$). Intergroup analyses indicated variations in plaque removal efficacy, with electric and musical toothbrushes generally demonstrating greater plaque removal than manual toothbrushes, particularly at earlier follow-up visits. However, some differences were not statistically significant. **Conclusions**: Musical and electric toothbrushes were more effective than manual toothbrushes in reducing plaque in children aged 6–12 years. These findings support the use of interactive toothbrushes as effective tools for improving pediatric oral hygiene. Further research is needed to control for dietary habits and brushing adherence. **Clinical Trial Registration**: This study is registered with ClinicalTrials.gov in the United States (Reference No: NCT06541743).

Keywords

Children; Oral health; Toothbrushing; Dental plaque

1. Introduction

Tooth brushing is essential for maintaining oral hygiene, especially in children, who are at a critical stage for developing lifelong oral health habits. For school-aged children (6–12 years), establishing effective tooth brushing behaviours is vital for long-term dental health. Consistent and effective tooth brushing is crucial for reducing supragingival plaque, which is key to preventing periodontal diseases and ensuring good oral hygiene [1]. Despite the availability of various plaque control methods, tooth brushing remains the most effective and safest approach [1].

However, young children, particularly those under ten years of age, often struggle with the dexterity and motivation needed for proper tooth brushing, resulting in inadequate plaque removal. Regular tooth brushing, though effective, can become monotonous and fail to engage children, making it difficult to establish regular brushing habits [2]. Studies have shown that regular removal of supragingival plaque can significantly reduce both supra- and subgingival pathogenic species, underscoring the importance of effective plaque control [3, 4].

Innovative solutions such as electric and musical toothbrushes have been developed to address these challenges [5–7]. Electric toothbrushes enhance plaque removal through mechanical action, while musical toothbrushes aim to boost motivation and compliance by incorporating interactive elements like music and colourful designs [8]. Musical toothbrushes play music for two minutes, encouraging children to brush for the recommended duration and making the activity more enjoyable [9]. Previous research has shown varying levels of success with these advanced toothbrushes. For example, Pillay *et al.* [10] found that musical toothbrushes significantly improved plaque control compared to manual ones. Similarly, studies by Ganesh M *et al.* [9] and Subburaman N *et al.* [11] re-

ported substantial plaque reduction with musical toothbrushes. Haffajee AD *et al.* [12] observed that while both manual and powered toothbrushes improved clinical parameters, powered toothbrushes had a more significant impact on gingival health.

Despite these promising results, there is a lack of comprehensive comparative studies on the efficacy of manual, electric, and musical toothbrushes in children. This study aimed to address this gap by conducting a randomized clinical trial to evaluate and compare the effectiveness of these three types of toothbrushes in removing supragingival plaque in children aged 6–12 years.

To the best of our knowledge, this is the first clinical study comparing manual, musical and electric toothbrushes for their effectiveness in pediatric plaque removal. The findings will provide valuable insights into the most effective tools for promoting oral hygiene in children, potentially shaping future recommendations and practices in pediatric dentistry.

2. Methodology

2.1 Study design

This study is designed as a randomized clinical trial to compare the efficacy of three types of toothbrushes—manual, musical and electric—in removing supragingival plaque among children aged 6–12 years. The study was conducted at College of Dentistry, Jouf University, Kingdom of Saudi Arabia and the duration was set for 3 months, beginning on 15 January 2024.

This study is registered with ClinicalTrials.gov in the United States (Reference No: NCT06541743).

2.2 Sample size calculation

Sample size estimation was done by using G*Power software (version 3.0, Heinrich-Heine-University Düsseldorf, Düsseldorf, NRW, Germany). Sample size was estimated for *F* test and Analysis of Variance (ANOVA): Repeated measures, between factors, for 3 groups and 4 follow up measurements was chosen. A minimum total sample size of 102 was found to be sufficient for an alpha of 0.05, power of 95%, 0.25 as effect size. As the proposed study is a trial of 60 days duration with 4 repeated measurements, so keeping in mind a 10% attrition, the sample size was inflated to 111 (37 per group).

2.3 Participant selection

A total of 111 healthy children participated in the study, each selected based on specific inclusion and exclusion criteria. Written consent was obtained from the parents or guardians of all participants.

Children and their attendees (*e.g.*, participants' parents and guardians) visiting the outpatient departments of university dental clinics were selected.

2.3.1 Inclusion criteria

- Children aged 6–12 years;
- Cooperative children [13]; and
- Children with a minimum of twenty teeth.

2.3.2 Exclusion criteria

- Children with poor oral hygiene characterized by extrinsic stains or calculus deposits;
- Presence of any oral lesions;
- Presence of severe crowding;
- Presence of fixed or removable orthodontic appliances; and
- Medically compromised patients.

2.4 Randomization and allocation

Participants were randomly allocated to one of three groups (n = 37 participants per group) using a computer-generated randomization sequence managed by the first examiner. The groups were defined as followed:

- Group 1 (Manual Toothbrush): The Oral-B Chhota Bheem Toothbrush is a manual toothbrush designed specifically for children. It features soft bristles and a small head with flat bristle design with a Chhota Bheem theme to make brushing more engaging.
- Group 2 (Musical Toothbrush): The Aqua White Musical Chhota Bheem Toothbrush includes a fun musical feature that plays a tune, encouraging children to brush for the recommended duration. It is designed with soft bristles and a small head with multi-angle cross bristles, also themed with Chhota Bheem to appeal to kids.
- Group 3 (Electric Toothbrush): The Oral-B Star Wars Kids Electric Toothbrush is a battery-powered toothbrush with a small rotating head, which helps enhance plaque removal with gentle oscillating-rotating technology, also themed with a Star Wars to make the brushing fun.

2.5 Blinding

To reduce bias, the second examiner, responsible for recording clinical parameters, was blinded to the group assignments.

2.6 Intervention

Participants and their attendees were instructed in the horizontal scrub technique and asked to adhere to a brushing regimen of two minutes [14], twice daily, for 45 days. Standard fluoride toothpaste and a diary for recording brushing experiences was also provided. Guardians supervised brushing to ensure compliance and prevent the use of other oral hygiene measures.

2.7 Outcome measures

The primary outcome measure was the Plaque Index (PI) by Quigley and Hein [15]: Score 0: no plaque; Score 1: isolated flecks of plaque at the gingival margin; Score 2: a continuous band of plaque up to 1 mm at the gingival margin; Score 3: plaque greater than 1 mm in width and covering up to one third of the tooth surface; Score 4: plaque covering from thirds to two thirds of the tooth surface, and Score 5: plaque covering more than two thirds of the tooth surface. Plaque assessments was conducted at baseline (day 0) and on days 15, 30 and 45. Participants were refrain from oral hygiene for 24 hours before each recall visit [9, 11]. Participants brushed their teeth for 2 min under supervision using the assigned toothbrush and toothpaste. Plaque disclosure was achieved using a 5 mL

disclosing solution for 15 seconds, followed by rinsing with 10 mL water for 10 seconds.

2.8 Data collection

All clinical data were documented using a standardized proforma, which included sections for demographic information, brushing adherence, plaque scores at each follow-up visit, and any relevant observations noted by guardians or supervisors. The principal investigator ensured the accuracy and confidentiality of the data, entering it into a data sheet immediately after collection.

2.9 Statistical analysis

Data was analyzed using Statistical Package for Social Sciences version 21.0 (IBM Corp, Armonk, NY, USA). Descriptive statistics was used to calculate mean plaque scores. The mean age of study participants among three study groups was tested using one-way ANOVA test. One-way ANOVA test was also used to compare plaque index among the three groups at each assessment point (days 0, 15, 30 and 45). Paired *t* test was used for intragroup comparison of mean plaque scores from pre- to post-brushing at each follow up visit. The level of statistical significance was set at $p \leq 0.05$.

2.10 Potential risks and benefits

The study presents minimal risks, mainly limited to potential discomfort from brushing or allergic reactions to toothpaste. However, the potential benefits include improved oral hygiene awareness and a reduction in plaque, contributing to better oral health outcomes for the participants.

This detailed methodology ensures a clear, structured approach to conducting the trial, adhering to Consolidated Standards of Reporting Trials (CONSORT) guidelines for reporting randomized clinical trials [16] as shown in Fig. 1. The study aimed to contribute valuable insights into paediatric dental care practices and enhance oral health education for parents and guardians, aligning with the goals of the CONSORT guidelines for transparent reporting of clinical trials.

3. Results

Groups 1 and 2 each had 40.5% males and 59.5% females, while group 3 included 48.6% males and 51.4% females. Mean ages were similar across groups: 8.51 years in group 1, 9.08 years in group 2, and 8.97 years in group 3. No significant differences were found in gender distribution ($p = 0.719$, non-significant (NS)) or age ($p = 0.355$, NS) among the groups. Table 1 summarizes the distribution of the study population by gender and age, illustrating demographic characteristics of the 111 participants across the study groups.

The intragroup comparison of mean plaque scores for group 1 from pre- to post-brushing at each follow-up visit shows a significant reduction at all-time points. At baseline (day 0), the mean plaque score decreased from 1.95 (standard deviation (SD) = 0.74) pre-brushing to 1.32 (SD = 0.70) post-brushing ($p < 0.001$). On day 15, the mean score dropped from 1.59 (SD = 0.76) pre-brushing to 0.81 (SD = 0.70) post-brushing ($p < 0.001$). By day 30, scores reduced from 1.14 (SD = 0.67) to 0.49 (SD = 0.50) ($p < 0.001$), and on day 45, scores fell from 0.51 (SD = 0.60) to 0.22 (SD = 0.41) ($p < 0.001$). These significant reductions ($p < 0.001$ at all-time points) indicate that brushing consistently improved plaque removal in group 1, demonstrating the efficacy of the intervention over the study period.

The intragroup comparison of mean plaque scores for group 2 from pre- to post-brushing at each follow-up visit shows a consistent and significant reduction at all-time points. At baseline (day 0), the mean plaque score decreased from 1.95 (SD = 0.57) pre-brushing to 1.22 (SD = 0.75) post-brushing ($p < 0.001$). On day 15, the mean score dropped from 1.41 (SD = 0.59) pre-brushing to 0.59 (SD = 0.49) post-brushing ($p < 0.001$). By day 30, scores reduced from 0.86 (SD = 0.75) to 0.32 (SD = 0.47) ($p < 0.001$), and on day 45, scores fell from 0.46 (SD = 0.69) to 0.19 (SD = 0.39) ($p = 0.023$). These significant reductions ($p < 0.001$ for days 0, 15 and 30, and $p = 0.023$ for day 45) indicate that brushing consistently improved plaque removal in group 2, demonstrating the effectiveness of the musical toothbrush intervention over the study period.

In group 3, significant reductions in mean plaque scores were observed from pre- to post-brushing at baseline (day 0), day 15, and day 30 ($p < 0.001$), indicating effective plaque removal. However, on day 45, while there was a reduction from pre- to post-brushing, the difference was not statistically significant ($p = 0.083$), suggesting a potential plateau in plaque reduction efficacy over time.

Regarding plaque scores, significant reductions were observed in mean plaque scores within each group from pre-brushing to post-brushing at each follow-up visit (day 0, day 15, day 30 and day 45), as depicted in Table 2. The consistent reduction in plaque scores highlights the efficacy of brushing in removing supragingival plaque among children aged 6–12 years.

Analysis of the PI scores and absolute reduction in PI scores (Tables 3,4,5) demonstrated a consistent pattern of plaque removal efficacy across all groups. While some comparisons showed statistically significant differences, particularly at earlier follow-up visits, others did not reach significance, indicating similar plaque removal outcomes across the different toothbrush types evaluated in the study. The analysis of plaque scores and absolute reduction in plaque scores from pre- to post-brushing at each follow-up visit among group 1, group 2 and group 3 subjects reveals notable patterns. In terms of pre-brushing plaque scores, significant reductions were observed over time in all groups ($p < 0.05$), except on day 0 and 45 ($p = 0.083$). Post-brushing plaque scores also showed consistent reductions across all groups over the study period, with significant reductions observed in group 1 on day 15 ($p = 0.047$), indicating efficacy in plaque removal. However, on day 45, post-brushing plaque scores did not show significant reductions in any group ($p = 0.842$). *Post hoc* pairwise comparisons showed that the mean PI score of group 1 participants was found to be significantly higher than that among group 3 participants. Additionally, the absolute reduction in plaque scores from pre- to post-brushing demonstrated similar trends, with significant reductions observed in all groups except for group 3 on day 45 ($p = 0.141$). These findings suggest that

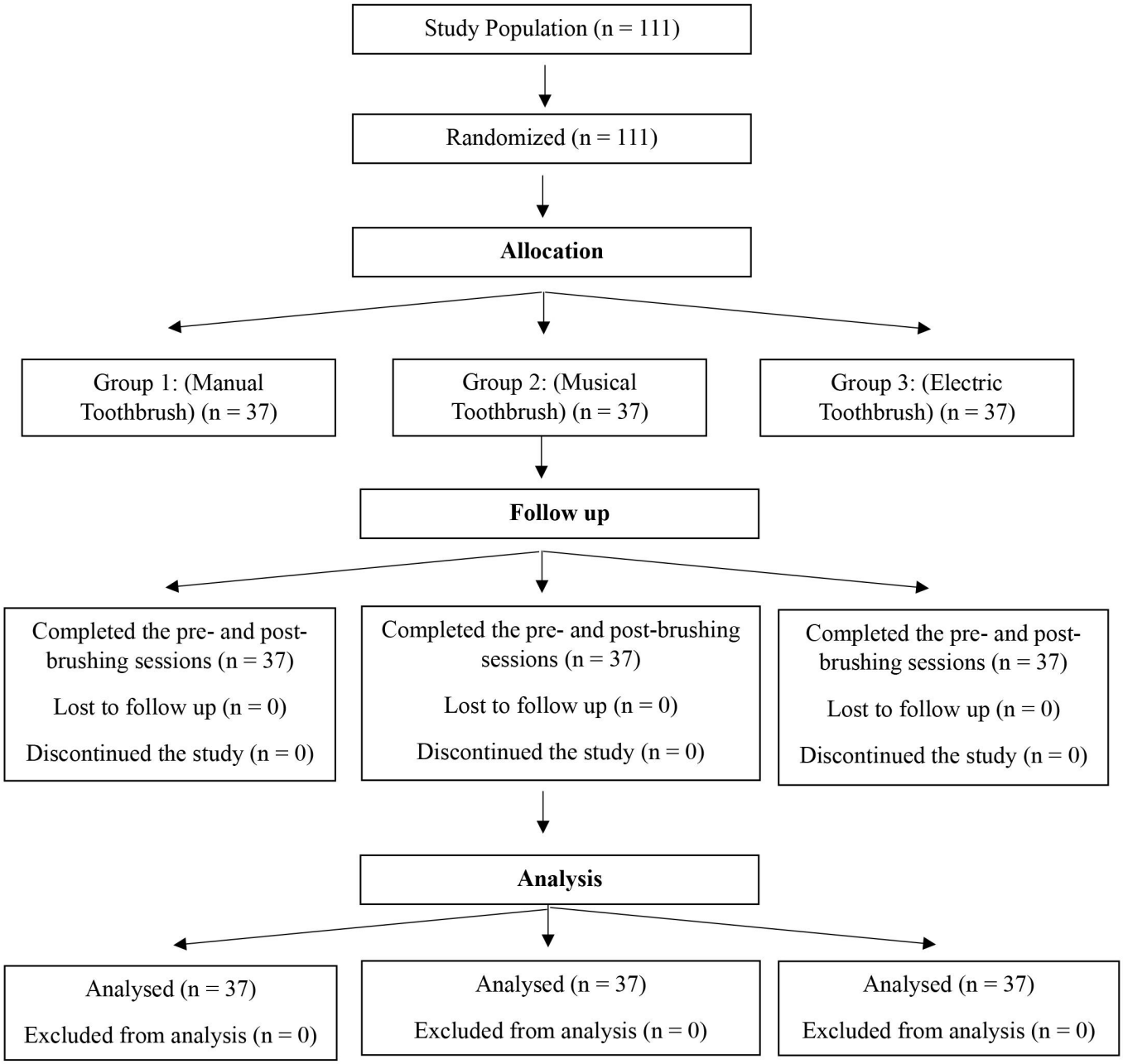

FIGURE 1. CONSORT flow diagram of the randomized controlled trial.

TABLE 1. Demographic distribution of study population by gender and age (n = 111).

Groups	Gender		Age			
	Males n (%)	Females n (%)	Mean age (in years)	Std. Deviation	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Group 1	15 (40.5%)	22 (59.5%)	8.51	2.03	7.83	9.19
Group 2	15 (40.5%)	22 (59.5%)	9.08	1.68	8.52	9.64
Group 3	18 (48.6%)	19 (51.4%)	8.97	1.62	8.43	9.51
Total	48 (43.2%)	63 (56.8%)	--	--	--	--
p value	0.719, NS		0.355, NS			

NS: Non-significant; Std. Deviation: Standard Deviation; n: Number of participants .

TABLE 2. Intragroup comparison of mean plaque scores pre- and post-brushing at each follow-up visit across study groups.

	Group 1			Group 2			Group 3		
	Mean	SD	*p* value	Mean	SD	*p* value	Mean	SD	*p* value
At day 0									
Pre	1.95	0.74	<0.001, S	1.95	0.57	<0.001, S	1.95	0.62	<0.001, S
Post	1.32	0.70		1.22	0.75		1.16	0.86	
At day 15									
Pre	1.59	0.76	<0.001, S	1.41	0.59	<0.001, S	1.22	0.58	<0.001, S
Post	0.81	0.70		0.59	0.49		0.46	0.60	
At day 30									
Pre	1.14	0.67	<0.001, S	0.86	0.75	<0.001, S	0.68	0.62	<0.001, S
Post	0.49	0.50		0.32	0.47		0.27	0.45	
At day 45									
Pre	0.51	0.60	<0.001, S	0.46	0.69	0.023, S	0.24	0.49	0.083, NS
Post	0.22	0.41		0.19	0.39		0.16	0.37	

S: Significant; NS: Non-significant; SD: Standard deviation.

TABLE 3. Intergroup comparison of pre-brushing PI scores.

Pre-brushing PI scores	Mean	SD	95% Confidence Interval for Mean		*p* value	*Post hoc* pairwise comparison
			Lower Bound	Upper Bound		
At day 0						
Gr 1	1.95	0.74	1.70	2.19		
Gr 2	1.95	0.57	1.75	2.14	0.999, NS	-
Gr 3	1.95	0.62	1.74	2.15		
At day 15						
Gr 1	1.59	0.76	1.34	1.85		Gr 1 versus Gr 2—0.429, NS Gr 1 versus Gr 3—0.038, S Gr 2 versus Gr 3—0.429, NS
Gr 2	1.41	0.59	1.21	1.61	0.049, S	
Gr 3	1.22	0.58	1.02	1.41		
At day 30						
Gr 1	1.14	0.67	0.91	1.36		Gr 1 versus Gr 2—0.211, NS Gr 1 versus Gr 3—0.013, S Gr 2 versus Gr 3—0.463, NS
Gr 2	0.86	0.75	0.61	1.12	0.018, S	
Gr 3	0.68	0.62	0.47	0.88		
At day 45						
Gr 1	0.51	0.60	0.31	0.72		
Gr 2	0.46	0.69	0.23	0.69	0.130, NS	-
Gr 3	0.24	0.49	0.08	0.41		

S: Significant; NS: Non-significant; PI: Plaque index; SD: Standard deviation; Gr: Group.

TABLE 4. Intergroup comparison of post-brushing PI scores.

Post-brushing PI scores	Mean	SD	95% Confidence Interval for Mean		*p* value	*Post hoc* pairwise comparison
			Lower Bound	Upper Bound		
At day 0						
Gr 1	1.32	0.70	1.09	1.56		
Gr 2	1.22	0.75	0.97	1.47	0.660, NS	-
Gr 3	1.16	0.86	0.87	1.45		
At day 15						
Gr 1	0.81	0.70	0.58	1.04		Gr 1 versus Gr 2—0.280, NS
Gr 2	0.59	0.49	0.43	0.76	0.047, S	Gr 1 versus Gr 3—0.038, S
Gr 3	0.46	0.60	0.26	0.66		Gr 2 versus Gr 3—0.605, NS
At day 30						
Gr 1	0.49	0.50	0.32	0.66		
Gr 2	0.32	0.47	0.17	0.48	0.133, NS	-
Gr 3	0.27	0.45	0.12	0.42		
At day 45						
Gr 1	0.22	0.41	0.08	0.36		
Gr 2	0.19	0.39	0.06	0.32	0.842, NS	-
Gr 3	0.16	0.37	0.04	0.29		

S: Significant; NS: Non-significant; PI: Plaque index; SD: Standard deviation; Gr: Group.

TABLE 5. Absolute reduction in PI scores from pre-brushing to post-brushing at each follow up visit.

	Mean	SD	95% Confidence Interval for Mean		*p* value
			Lower Bound	Upper Bound	
At day 0					
Gr 1	0.62	0.59	0.42	0.81	
Gr 2	0.72	0.56	0.54	0.91	0.474, NS
Gr 3	0.78	0.58	0.58	0.97	
At day 15					
Gr 1	0.78	0.58	0.58	0.97	
Gr 2	0.81	0.51	0.63	0.98	0.910, NS
Gr 3	0.75	0.49	0.59	0.92	
At day 30					
Gr 1	0.64	0.58	0.45	0.84	
Gr 2	0.54	0.60	0.33	0.74	0.202, NS
Gr 3	0.40	0.55	0.22	0.58	
At day 45					
Gr 1	0.29	0.46	0.14	0.45	
Gr 2	0.27	0.69	0.03	0.50	0.141, NS
Gr 3	0.08	0.27	−0.01	0.17	

NS: Non-significant; SD: Standard deviation; Gr: Group.

while all groups showed improvements in plaque removal following brushing, the efficacy varied over time and between groups.

4. Discussion

This study was conducted to assess the supragingival plaque removal potential of three different types of toothbrushes among children aged 6–12 years. By analyzing gender distribution, mean participant age and both intragroup and intergroup comparisons of plaque scores, it aimed to provide a comprehensive understanding of the effectiveness of manual, electric and musical toothbrushes in plaque removal.

The horizontal scrub method, commonly used by children due to its ease of learning, was adopted in this study. Research has shown that young children typically prefer this technique and struggle with more complex methods [17–19]. Furthermore, horizontal scrubbing aligns with the motor skill development of this age group, making it a suitable choice.

The Quigley-Hein Plaque Index, a validated tool for assessing plaque levels, was used to ensure consistency and comparability with prior studies [20, 21]. This index evaluates plaque presence and distribution across multiple tooth surfaces, providing a detailed assessment of brushing efficacy [20, 21]. By employing this standardized measure, the study contributes to a standardized body of evidence for comparing toothbrushes and brushing techniques.

To standardize plaque build-up, a 24-hour plaque accumulation period was implemented before each assessment in the current study. This approach, supported by studies [22, 23] allows for reproducible results within a short timeframe and mitigates the "Hawthorne effect" [24]. However, a potential limitation is the variability in daily habits, diet and brushing techniques among participants, even with a controlled pre-brushing period. Future studies could explore varying accumulation periods to determine their impact on toothbrush efficacy.

The demographic analysis of the study groups shows an even distribution of gender and age, ensuring that observed differences in plaque reduction are attributable to the type of toothbrush rather than demographic factors. Age is a key consideration in pediatric oral hygiene studies, as brushing skills, adherence and plaque removal effectiveness vary with developmental stages [25]. Including children aged 6–12 years is appropriate, as this age range captures the transition from supervised to independent brushing, reflecting real-world usage [26]. This approach aligns with guidelines from the American Academy on Pediatric Dentistry which emphasize age-appropriate oral hygiene practices and the importance of parental supervision, particularly for younger children [27]. Previous research supports this by highlighting the inconsistent adherence to brushing practices in children and the positive impact of supervision and motivational elements on improving outcomes [28]. In current study, parental supervision and adherence monitoring likely contributed to the overall improvement in plaque scores across all groups, consistent with findings from Damle SG *et al.* [29]. The results further emphasize the importance of early intervention in establishing effective oral hygiene habits during childhood. Teaching children proper oral care not only prevents tooth decay and gingival diseases but also lays the foundation for lifelong dental health. By instilling these habits early, we equip children with the tools to maintain healthy oral cavity throughout their lives [30].

The balanced gender distribution in this study is also significant, as oral hygiene behaviors, adherence to brushing routines, and plaque accumulation can vary by gender. For example, Kudirkaite I *et al.* [31] reported that girls tend to have better oral hygiene practices, likely due to higher adherence rates. However, a study conducted by Gambhir N *et al.* [32] found no significant gender-based differences in plaque indices. By maintaining an even gender distribution, this study minimizes the potential influence of gender-related variability on its findings.

This study observed significant reductions in plaque scores across all groups—manual, electric and musical toothbrushes—at each follow-up, demonstrating their effectiveness in plaque removal. Intragroup comparisons revealed a consistent trend of plaque reduction over the 45-day period, suggesting sustained efficacy regardless of the toothbrush type. These findings are consistent with previous research, including the classic Quigley and Hein study, which highlighted differences in plaque removal efficiency between manual and powered brushes [15]. Similarly, Prusty AK *et al.* [33] found significant reductions in plaque, gingival and bleeding indices across manual, powered, and charcoal toothbrushes over a 12-week period, with no notable differences when proper brushing techniques were applied. The consistent plaque score reductions in current study reaffirm the effectiveness of all three toothbrush types in promoting long-term oral health among children. These results highlight the importance of proper brushing techniques and sustained use for effective plaque management in pediatric populations.

The post-brushing mean PI scores for groups 1 and 2 were compared across days 0, 15, 30 and 45, revealing significant differences ($p < 0.05$). This indicates that the musical toothbrush outperformed the manual toothbrush in removing supragingival plaque over the 45-day period. Pre-brushing comparisons also showed significant differences, except on day 45. This could be attributed to the initial excitement of using a new toothbrush, which likely motivated children to brush more frequently and regularly—a possible manifestation of the "Hawthorne effect" [24]. However, as time progressed, brushing likely became a habitual activity, reducing the impact of the toothbrush type. These findings align with earlier studies by Pillay R *et al.* [10], which demonstrated the effectiveness of musical toothbrushes in plaque removal among children aged 6 to 11 years. Similar results were reported by Ganesh M *et al.* [9] and Subburaman N *et al.* [11], showing a notable reduction in plaque build-up with musical toothbrushes.

Several methods exist for removing bacterial plaque from teeth, but toothbrushes remain the most efficient and widely used tool [34]. The market offers a wide range of toothbrush options, with manual toothbrushes being the most straightforward and cost-effective choice, widely adopted by the majority of individuals [10]. Recently musical talking toothbrushes have been introduced to engage children with unique features. These toothbrushes play music during brushing, incorporating a built-in two-minute timer that provides clear cues for start

and stop times. This approach fosters a sense of happiness, excitement and energy, motivating children to brush thoroughly and adhere to recommended brushing times [9, 10]. Research consistently emphasizes the importance of adherence to brushing duration for effective plaque removal [10]. Musical toothbrushes have been shown to encourage children to brush longer and more effectively, fostering better oral hygiene habits [9]. Many children find brushing tedious and tend to avoid it, resulting in noncompliance. Parents often attempt to motivate their children through rewards, bribes or positive reinforcement but often face challenges in sustaining their interest. Innovative tools like musical toothbrushes address these challenges by making brushing a fun and engaging activity. These toothbrushes play music throughout the brushing process and stop after two minutes, providing structured cues while transforming brushing into an enjoyable routine [9–11]. Additionally, studies report that time constraints and children's uncooperative behavior are significant barriers to maintaining consistent brushing routines [9, 10]. To tackle these issues, parents have sought ways to make brushing enjoyable. Musical toothbrushes, perceived by children as tools of fantasy, captivate their interest while enhancing motor coordination and task learning through exposure to music [10].

Powered toothbrushes have evolved significantly with advancements in design, power sources and operation modes [35, 36]. Research, including systematic reviews, consistently shows that powered toothbrushes outperform manual brushes in reducing dental plaque, gingivitis and bleeding [7, 12, 37–39]. The mechanical rotation and consistent motion of powered toothbrush bristles offer superior cleaning, particularly in hard-to-reach areas like interproximal areas [15, 39]. Studies have demonstrated that powered toothbrushes are especially beneficial for pediatric patients and those undergoing orthodontic treatment [40, 41]. Improvements in plaque index scores are evident even in children as young as two years, with benefits persisting across age ranges from 2 to 17 years [40]. Additionally, clinically significant plaque reductions can be observed as early as the first day of use, with sustained effectiveness over time [40, 41]. Moreover, powered toothbrushes can remove up to 60% more plaque than manual toothbrushes, resulting in greater reductions in gingivitis [40]. Despite advancements in manual toothbrush design, they typically remove only about 50% of plaque on smooth surfaces and even less in interproximal areas, highlighting the advantage of powered brushes for comprehensive oral hygiene [41]. On the other hand, a 1998 study by Clinical Research Associates tested six toothbrushes, including sonic and ultrasonic powered types, and found no significant difference in plaque removal compared to manual toothbrushes [42]. Similarly, Bratel and Berggren, as well as others, observed no superiority of electric toothbrushes over manual brushes [43]. Similar findings were made by others when comparing manual brushes with electric brushes [44, 45]. However, a 2003 Cochrane Collaboration systematic review analyzed 29 clinical trials involving 2547 participants and concluded that powered toothbrushes with rotation-oscillation action were more effective than manual toothbrushes in reducing plaque and gingivitis. Other powered toothbrushes, however, showed no significant advantage. Despite these findings, the clinical relevance was deemed minimal, and further research was recommended [46]. Deacon SA *et al.* [47] conducted another systematic review with meta-analysis, focusing on randomized controlled trials. They concluded that oscillation-rotation powered brushes slightly outperformed side-to-side brushes in plaque and gingivitis reduction, but the benefits were statistically significant rather than clinically meaningful. As a result, no definitive preference for oscillation-rotation brushes was established over other powered toothbrush types [47]. In contrast, the current study found that electric toothbrushes demonstrated greater plaque reduction than manual and musical toothbrushes. This enhanced efficacy may be attributed to the oscillating-rotating motion of electric brushes, which provides a more thorough cleaning, especially for children still developing brushing techniques.

Overall, these findings provide compelling evidence supporting the integration of innovative toothbrush designs into pediatric oral health promotion strategies, ultimately contributing to enhanced plaque control and improved oral hygiene practices among children aged 6–12 years.

5. Limitations

The study's limitations must be considered when interpreting the findings. Despite adherence to methodological rigor and CONSORT guidelines, factors such as variations in brushing practices, compliance and individual oral hygiene behaviors may have influenced the results. Additionally, the inability to control participants' diets, enforce the exclusive use of the prescribed oral hygiene method, and account for individual plaque pathogenicity could introduce variability. Furthermore, the relatively short study duration may limit insights into the long-term effects on plaque control and oral health.

6. Conclusions

To conclude, this study highlights the crucial role of effective toothbrushing in removing plaque among children aged 6–12 years. It demonstrates that various toothbrush types, including manual, electric and innovative designs like musical toothbrushes, effectively reduce supragingival plaque build-up over 45 days. Importantly, the findings underscore the importance of early intervention in instilling optimal oral health habits during childhood, which can have lasting benefits for dental well-being throughout life.

Future research could explore additional factors influencing plaque removal efficacy, such as variations in brushing techniques and the integration of technological advancements in toothbrush design. Longitudinal studies would provide valuable insights into the sustained effects of different toothbrush types on oral health over extended periods. Incorporating microbial analysis in future studies could offer a more comprehensive understanding of toothbrush efficacy by linking plaque removal to changes in microbial composition.

Moreover, efforts to improve paediatric dental care practices should prioritize educating children on proper brushing techniques and encouraging consistent oral hygiene routines from a young age.

AVAILABILITY OF DATA AND MATERIALS

The data set used in the current study will be made available on request from the corresponding author.

AUTHOR CONTRIBUTIONS

AKB—was responsible for conceptualization, methodology, and writing of the original draft. RI—was responsible for project administration, supervision, writing, reviewing and editing. ASH and SMMA—analysed and interpreted the data. SM and NP—reviewed the paper for important intellectual content. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval (no. 5-3-46) was sought from the Local Committee of Bioethics at Jouf University, KSA. All necessary approvals were obtained prior to the initiation of the study to ensure ethical compliance and participant safety. All the procedures in this study were in compliance with the Helsinki Declaration (9th version, 2013). Written consent was obtained from the parents or guardians of all participants.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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