Comparison of Powered and Manual Toothbrushes for Plaque Removal by 4- to 5-year-old Children

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Abstract

Purpose: This study compared the small head Oralgiene 60 Second Time Machine powered toothbrush, used for 60 seconds, with the Braun Oral-B Mickey Mouse powered toothbrush and a manual toothbrush (Oral-B Rugrats 20), each used for 2 minutes, for efficacy in plaque removal and reduction of gingival inflammation in young children.
Methods: Fifty-eight children, ages 4 to 5 years old, were randomly assigned to one of the 3 toothbrush groups. At visit 1, plaque and gingival indices were recorded for all subjects. Then, the children did not brush for 24 hours. At visit 2, 24 hours later, plaque indices were recorded, the children brushed with their assigned toothbrush, and plaque indices were recorded again. Six weeks later, plaque and gingival indices were recorded again. The data was analyzed to detect plaque reduction after a one-time use (visit 2, prebrushing and postbrushing) as well as plaque and gingival inflammation reduction after 6 weeks of use.
Results: The Oralgiene toothbrush removed significantly more plaque during the one-time trial and reduced significantly more gingival inflammation during the 6-week trial. The Braun Oral B powered toothbrush removed significantly more plaque than the other toothbrushes during the 6-week trial. However, no clinically meaningful differences were found between any of the toothbrushes with regard to plaque removal or gingival scores.
Conclusions: There were no clinically meaningful differences found between any of the toothbrushes tested during either of the trials with regard to plaque removal or improvement in gingival health. (*Pediatr Dent.* 2004;26:225-230)

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Since the introduction of the electric toothbrush, many articles have been published evaluating its effectiveness in adults, persons with disabilities, and children undergoing orthodontics.[1-3] However, there has been limited research performed with healthy children. When Heasman and McCracken[4] published an extensive review of electric toothbrush studies in 1999, only 3 of the studies were conducted on healthy children. Ritsert and Binns[5] and Grossman and Proskin[6] found that an electric toothbrush was more effective in removing plaque than a manual toothbrush when used by children and adolescents. However, Crawford[7] found no significant difference in plaque and gingival scores when electric and manual toothbrushes were compared in well-motivated 9- to 15-year-olds.

The standard brushing time used in child and adult studies is 2 minutes.[6,8-10] Some studies have extended that time to 3 minutes.[11,12] MacGregor and Rugg-Gunn,[13] however, reported that the average time spent brushing by unsupervised 13-year-olds was only 1 minute. In another study, they reported that unsupervised 5-year-old children spent an average of 58 seconds brushing, with only 5% of that time spent on brushing the lingual surfaces of their dentition.[14]

Kotch et al[15] conducted a study comparing the Oralgiene 60 Second Time Machine powered toothbrush to another powered toothbrush, as well as to a manual toothbrush. The Oralgiene toothbrush was shown to be more effective in removing plaque, especially on palatal and interproximal surfaces. The study was conducted only on adults and allowed the participants to brush as long as they liked. In their marketing, Oralgiene claims that only 60 seconds are needed to brush properly. The company began marketing a smaller brush head for their toothbrush that is meant to be used by children under 6 years of age and only for 60 seconds.

Table 1. Plaque Index Scores*	
0	No plaque
1	Separate flecks of plaque at the cervical margin
2	A thin band of plaque at the cervical margin
3	A band of plaque wider than 1 mm but covering less than one third of the crown
4	Plaque covering at least one third but less than two thirds of the crown
5	Plaque covering more than two thirds of the crown

*Turesky et al.[17]

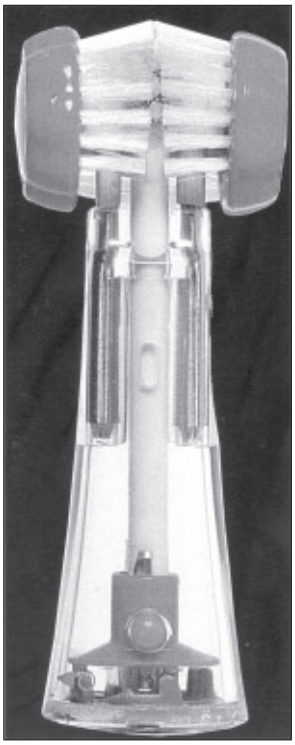

Figure 1. The Oralgiene 60 Second Time Machine powered toothbrush head.

Figure 2. The Braun Oral-B Mickey Mouse powered toothbrush head.

Many previous studies in children have focused on plaque removal, however, Hugoson[16] found that 64% of 5-year-olds have gingivitis on 1 or more tooth surfaces. Therefore, it is also important to assess gingival health when evaluating toothbrushes used by this age group.

The purpose of this study was to compare the small head Oralgiene powered toothbrush, used for 60 seconds, with another electric toothbrush (Braun Oral-B Mickey Mouse) and a manual toothbrush (Oral-B Rugrats 20), each used for 2 minutes, for efficacy in plaque removal and gingivitis reduction in children under 6 years of age.

Methods

This study was approved by the University of Medicine and Dentistry of New Jersey Institutional Review Board. All toothbrushes used in the study were supplied by Oralgiene USA, Inc. Oralgiene was provided with a copy of the study results, however, the company was not involved in the data collection or interpretation of the results.

Table 2. Gingival Index Scores*	
0	Normal gingiva
1	Mild inflammation, no bleeding on probing
2	Moderate inflammation, bleeding on probing
3	Severe inflammation, tendency to spontaneous bleeding

*Loe.[18]

A 3-group, 3-treatment, single-blinded clinical trial was performed on 60 children, 4 to 5 years old. Written informed consent was obtained from the parents or legal guardians of all children involved in the study. The subjects were children who attended the Moriah School in Englewood, NJ. The principal investigator and one of the co-investigators performed the clinical aspects of the trial at the school. All examinations, instructions, and toothbrushing took place in the school nurse's office with the use of a portable dental chair and light. Exclusion criteria included a history of periodontal disease, mental handicap, physical handicap that restricts free movement of the hands, acute intraoral lesions, or the need for subacute bacterial endocarditis prophylaxis prior to dental treatment.

At baseline, an examination of the oral soft tissues and dentition was performed. Plaque was scored using the Turesky modification of the Quigley and Hein index (PI)[17] (Table 1). Gingival inflammation was scored using the Gingival Index (GI)[18] (Table 2). All PI and GI measurements were performed by the same investigator. GI was recorded at 6 sites around all of the teeth (mesiobuccal, midbuccal, distobuccal, mesiopalatal, midpalatal, distopalatal). PI values were recorded for the facial and lingual surfaces of all the teeth following use of a disclosing agent applied with a cotton applicator. Plaque and gingival indices were performed on all teeth which were present at the time of the examination. This included fully erupted primary teeth as well as partially erupted permanent teeth, as this is the typical dentition of 4- and 5-year-old children.

Using a random numbers table, each subject was randomly assigned to 1 of 3 treatment groups according to the toothbrush to be used during the study. The 3 toothbrushes were:

1. Oralgiene 60 Second Time Machine powered toothbrush (Figure 1);
2. Braun Oral-B Mickey Mouse powered toothbrush (Figure 2);
3. Oral-B Rugrats 20 manual toothbrush.

The technical specifications for each toothbrush are shown in Table 3. The subjects were told to use their regular toothpaste during the length of the study. The type of toothpaste used at home was determined from the original questionnaire and was distributed evenly among the treatment groups. After the baseline visit, the subjects were asked to refrain from tooth cleaning for the next 24 hours.

At visit 2, 24 hours later, the plaque indices were recorded again and the appropriate toothbrushes were given to each subject. Instructions on the use of the powered and manual

Table 3. Comparison of Toothbrush Specifications

Toothbrush	Oralgiene 60 Second Time Machine electric toothbrush (compact)	Oral B Mickey Mouse electric toothbrush	Oral B Rugrats 20 manual toothbrush
Number of tufts	52	21 (16 white and 5 blue)	23
Filaments per tuft	80	White=48Blue=68	20
Total number of filaments	4,160	1,108	460
Number of rows	White=1Blue=3	N/A	3
Weight	6.8 oz	4.3 oz	0.3 oz
Handle length	180 mm	130 mm	105 mm
Handle circumference	135 mm	90 mm	30 mm
Head size	20 mm diameter	12.4 mm diameter	9.5x 24 mm
Filament length	White=8.3–8.8 mm Blue=3.2±0.3 mm	White=6 mm Blue=7 mm	9.5±0.8 mm
Compressive load needed to activate	3.3 pounds	2.3 pounds	N/A
Oscillation frequency	360-410/min	5,600/min	N/A
Oscillation angle	72°	50°	N/A
Filament material	Nylon	Nylon	Nylon
Angle of bristles	45°	90°	90°
Bristle ends	Flat	Round	Round

toothbrushes were given by the principal investigator with the use of a pediatric dental typodont. The time for brushing was 1 minute for the Oralgiene powered brush and 2 minutes for the Braun Oral-B Mickey Mouse electric toothbrush and Oral-B Rugrats 20 manual toothbrush. The powered toothbrushes each had built-in timers and the manual toothbrushes were distributed with egg timers. The subjects were then asked to brush their own teeth, under supervision, to check compliance with the technique. The assignment of toothbrushes and brushing were performed without the presence of the examining investigator. The plaque indices were then recorded again.

The subjects were asked to use their allocated toothbrushes at home for the next 5 to 7 weeks, brushing 2 times a day: morning and before bed. At visit 3, 6 weeks later, the examination was repeated and plaque and gingival indices recorded. The examinations at visits 1 and 3 were undertaken within 3 to 5 hours after the subjects had cleaned their teeth. At the end of visit 3, each subject had completed the trial.

Analysis of data

Sample size estimation was conducted to determine the necessary group sizes in order to assure detection of significant differences should they occur (alpha=0.05, power ≥0.8). Using the variability data associated with plaque index in the sample evaluated by Kotch et al[15] and estimating a medium effect size (Cohen's convention=0.32), it was determined that the minimum number of cases required was 51 participants, with 17 in each treatment group.

Prior to the study, an intrarater reliability test was performed using 6 subjects. Gingival indices were scored by the examiner. Each subject was then rescored in a different order by the same examiner. The same procedure was used for scoring the plaque indices following the use of a disclosing agent. Agreement was 93% for the gingival index; however, there was a problem with the attempt to evaluate intrarater reliability with the plaque index. Since the disclosing agent fades between measurement intervals, the outcome being measured changed, resulting in an inability to assess intrarater reliability with the disclosing agent. Given the excellent intrarater reliability with the gingival index, it was assumed that the observer would be internally consistent in his measurements across all study parameters.

Table 4. Comparison of Gingival Indices Among Assigned Toothbrushes

Assigned toothbrush	N baseline and visit 2	N 6-week follow-up	Gingival index at baseline	Gingival index at 6-week follow-up
Manual	20	20	0.14±0.11	0.11±0.11
Oral B	19	18	0.11±0.09	0.05±0.05
Oralgiene	20	20	0.13±0.1	0.06±0.06

Table 5. Comparison of Whole Mouth Plaque Indices Among Assigned Toothbrushes

Assigned toothbrush	N baseline and visit 2	N 6-week follow-up	Plaque index at baseline	Plaque index at visit 2: prebrushing	Plaque index at visit 2: postbrushing	Plaque index at 6-week follow-up
Manual	20	20	2.21±0.55	2.71±0.36	1.44±0.53	1.75±0.53
Oral B	19	18	2.17±0.42	2.56±0.35	1.29±0.32	1.52±0.45
Oralgiene	20	20	2.07±0.43	2.55±0.35	1.14±0.38	1.73±0.5

Table 6. Comparison of Facial and Lingual Surface Plaque Indices Among Assigned Toothbrushes

Assigned toothbrush	N baseline and visit 2	N 6-week follow-up	Plaque index at baseline	Plaque index at visit 2: prebrushing	Plaque index at visit 2: postbrushing	Plaque index at 6-week follow-up
Manual facial	402	402	2.9±1.30	3.51±1.14	1.78±1.41	2.37±1.35
Oral B facial	392	369	2.83±1.26	3.38±1.10	1.64±1.23	2.03±1.24
Oralgiene facial	401	401	2.67±1.17	3.38±1.08	1.65±1.19	2.35±1.21
Manual lingual	402	402	1.51±1.12	1.92±1.09	1.11±0.96	1.14±0.98
Oral B lingual	392	369	1.51±1.09	1.75±1.11	0.93±0.83	1.02±0.88
Oralgiene lingual	401	397	1.45±1.12	1.72±1.17	0.63±0.73	1.11±0.99

An analysis of variance (ANOVA) test at the 0.05 level of significance for independent groups was performed for baseline (visit 1) and visit 2 prebrushing findings to detect any preintervention differences which may have occurred despite random assignment to treatment groups. Generalized linear models were used to conduct analyses of covariance (ANCOVA) to control for any pretest differences if found.

Two separate split plot ANOVAs—one to compare baseline to visit 3 and one to compare visit 2 prebrushing and postbrushing—were conducted for each outcome variable (plaque and gingival indices). The first was a 2×3 ANOVA of time (visit 2 prebrushing and postbrushing) and treatment (toothbrush type: Oralgiene powered, Braun Oral B powered, or Oral-B manual toothbrush). The second was a 2×3 ANOVA of time and treatment, where the first level of time was baseline taken at visit 1 and the second level was measurements taken at visit 3, 6 weeks later. If scores between the treatment groups were different at baseline or visit 2 prebrushing, the second analysis used baseline or visit 2 prebrushing as a covariate when the 6-week observations among the 3 groups were compared.

Results

There were 60 subjects that participated at the beginning of the study. One subject dropped out after the first visit and was, therefore, not included in the results of this study. Another subject was unable to be present at the final phase of the study and was, hence, only included in a portion of the results. All plaque and gingival indices were performed on primary and erupting permanent teeth.

The whole-mouth mean gingival scores for each toothbrush type for each visit of the study are displayed in Table 4. There was a statistically significant interaction between the toothbrush type and changes in gingival score from baseline to the 6-week follow-up visit (P=.0001). The Oralgiene toothbrush resulted in a larger reduction in gingival score when compared to the manual and the Braun Oral B toothbrushes (×=0.07, 0.03, and 0.06, respectively). Since this study may have suffered from a "basement effect" because the GI was so low at baseline, no clinically meaningful decreases in gingival scores could be detected.

The whole-mouth mean plaque scores for each toothbrush type for each visit of the study are shown in Table 5. An ANCOVA analysis was conducted to control for visit 2 prebrushing differences while examining postbrushing plaque scores. The whole mouth plaque scores were significantly different at visit 2 postbrushing. Post hoc analysis via Scheffe showed that the whole-mouth adjusted mean plaque scores at visit 2 postbrushing for Oralgiene were significantly lower than those of the manual and Braun Oral B toothbrushes (P<.0001 and P=.028, respectively). Based on baseline plaque findings, a difference of 0.5 for PI was arbitrarily chosen as being clinically meaningful. Consequently, these observed differences in plaque reduction were not clinically meaningful.

An evaluation was also performed to see if there were any differences among toothbrushes when individual tooth surfaces were examined. The mean plaque scores at all 3 visits for facial surfaces are shown in Table 6. An ANOVA determined that all toothbrush types had significant reduction between visit 2 prebrushing and postbrushing facial surface plaque. However, no toothbrush type decreased facial plaque significantly (P=.990) more than the others.

The mean plaque scores at all 3 visits for lingual surfaces are shown in Table 6. An ANCOVA was conducted to control for pretest differences. The ANCOVA, using visit 2 prebrushing scores as the covariate, found the lingual plaque scores were significantly different among the 3 toothbrush groups. Post hoc analysis via Scheffe showed that the lingual adjusted mean plaque scores for Oralgiene were significantly lower than those of the manual and Braun Oral B ($P<.0001$ and $P=.040$, respectively) at visit 2 postbrushing. This reduction, however, was not clinically meaningful.

Plaque reduction was also tested over a 6-week trial period. An ANCOVA was conducted to control for pretest differences. Therefore, using an ANCOVA with baseline whole-mouth plaque scores as the covariate, the whole-mouth plaque scores at visit 3 were significantly different. Post hoc analysis via Scheffe showed that the whole-mouth adjusted mean plaque scores at visit 3 for Braun Oral B were significantly lower than those of the manual and Oralgiene ($P<.0001$). These differences in plaque reduction, however, were not clinically meaningful.

An ANCOVA was conducted to evaluate facial surface plaque scores. With the ANCOVA using baseline scores as the covariate, the facial plaque scores were significantly different. Post hoc analysis via Scheffe showed that the facial adjusted mean plaque scores at visit 3 for Braun Oral B were significantly lower than those of the manual and Oralgiene ($P<.0001$). These differences in plaque reduction, however, were not clinically meaningful.

An ANOVA which evaluated lingual plaque scores determined that there were no significant differences between toothbrush type for the amount of lingual plaque reduction achieved between baseline and the 6-week follow-up ($P=.0504$).

Tests for compressive load needed to activate the toothbrushes were performed using the Enduratec ELF 3200 Series Mechanical Test System with a 50-lb load cell maximum. Oralgiene was found to have a higher compressive load than Oral B (3.3 lbs and 2.3 lbs, respectively).

Discussion

The results from the one-time-use trial correspond with results of previous studies conducted by Savastino,[19] Lefkowitz and Robinson,[20] Conroy and Melfi,[21] Ritsert and Binns,[5] Hall and Conroy,[22] Grossman and Proskin,[6] and Jongenelis and Wiedemann.[9] All these previous studies showed that the powered toothbrush was more efficient in removing plaque when compared to a manual toothbrush. In the present study, however, comparisons were also made between 2 different powered toothbrushes.

It was found that, in a one-time-use trial, the Oralgiene 60 Second Time Machine toothbrush removed significantly more plaque than the Braun Oral B Mickey Mouse toothbrush. Possible explanations for the greater success of the Oralgiene toothbrush might be found in the specifications of each toothbrush. The oscillation frequency of the Oralgiene is 336 to 410 times per minute as compared to the Braun Oral B, which is 5,600 times per minute. Oralgiene claims that this slower rate, which is comparable to the manual toothbrush, allows the bristles adequate time to straighten and penetrate between the teeth. The angle of the bristles for the Oralgiene is 45 degrees, as compared to the Braun Oral B which is 90 degrees. The 45-degree angle allows the bristles to reach under the loose gingiva that covers the cervical portion of the teeth. Finally, the bristle ends of the Oralgiene are flat while those of the Braun Oral B are rounded.

After 6 weeks, the results showed that the Braun Oral B electric toothbrush removed significantly more plaque than the Oralgiene toothbrush. Possible explanations for this finding are that the Oralgiene toothbrush is manipulated differently than other powered and manual toothbrushes. On the day of the one-time-use study, the children were given instructions on the use of all the toothbrushes. They were then asked to brush immediately after the instructions were given. At that point, the children understood how to use the Oralgiene toothbrush. Later, with no instructional reinforcement, the children may have used the Oralgiene toothbrush improperly and this may have led to a decrease in the toothbrush's efficacy. Another possible explanation may be found in the specifications of the toothbrushes. The Oralgiene toothbrush was found to have a larger handle, weigh more, and take a larger compressive load to activate the toothbrush. These factors may have contributed to the children having difficulty in using the toothbrush, which then could have resulted in less plaque reduction.

The present study also compared the efficacy of the toothbrushes for plaque removal on the facial and lingual surfaces. The Oralgiene toothbrush was more efficient in removing plaque on the lingual surface and the Braun Oral B toothbrush was more efficient on the facial surface. These results correspond with those of Kotch et al[15] who also found that the Oralgiene brush performed superiorly on lingual surfaces. A possible explanation for these results may be that the design of the Oralgiene toothbrush includes built-in bristles for the lingual surfaces, and these may help children correctly clean this surface.

In clinical research, "Once differences between groups have been determined to be statistically significant, there yet remains the question as to whether those differences are meaningful. This becomes a rather arbitrary but important interpretation of the findings with specific reference to the question being asked."[23] Clinicians and patients should not choose a toothbrush based on statistically significant differences alone, but rather on clinically meaningful differences. While Oralgiene may have performed significantly better in the one-time-use trial with regard to plaque removal, and Braun Oral B performed significantly better in the 6-week trial for plaque removal, neither of them were clinically better in either trial. The fact that the Oralgiene toothbrush was used for only 60 seconds, as compared to 2 minutes for the other 2 toothbrushes, becomes an important feature. According to Honkala,[24] the duration of brushing affects the amount of plaque removal. As previously discussed, unsupervised 5-year-old children brush for approximately 1 minute. Therefore, the reduced time required for the Oralgiene powered toothbrush could help address the issue of time-related compliance.

There are a number of issues with powered toothbrushes that require further research. Authors[25,26] agree that 3- to 5-year-old children do not have the motor skills to adequately brush their teeth without supervision. Manufacturers of powered toothbrushes are attempting to overcome this manual dexterity dilemma by improving the design of their brushes, which are marketed to children. Studies should be conducted to see what impact design differences have on the efficacy of each toothbrush (ie, oscillation frequency, bristle angle, bristle ends, handle size and weight, and finger pressure needed to activate the unit). Further understanding of each design feature may enable manufacturers to design better toothbrushes in the future.

Since all 3 toothbrushes showed a decrease in plaque scores, it is unlikely that the type of toothbrush contributed to this improvement. The plaque reduction could be due to other factors such as toothbrushing instructions that were given, awareness by children that they were participating in a study, or the timer that was given to the children. A repeat of this study may prove valuable if all 3 toothbrushes are used for the same amount of time, if the children use their toothbrushes without instructions from the investigator, or if the children using manual toothbrushes are not given a timer. If toothbrushing instructions are found to improve plaque and/or gingival scores over a 6-week period, it would demonstrate the importance of performing further studies to evaluate the long-term efficacy of oral hygiene instructions given to children in the dental office.

Conclusions

There were no clinically meaningful differences found between any of the toothbrushes tested during either of the trials with regard to plaque removal or improvement in gingival health.

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