

# The Relative Effectiveness of Six Powered Toothbrushes for Dental Plaque Removal

Aaron R. Biesbrock, DMD, PhD, MS   Patricia A. Walters, RDH, MS   Robert D. Bartizek, MS

The Procter & Gamble Company  
Health Care Research Center  
Mason, OH, USA

## Abstract

During the past three years, a number of new powered toothbrushes have been marketed in the United States. The objective of this study was to compare the single-use plaque removal efficacy of six powered toothbrushes: a new prototype (Crest® SpinBrush™ Pro), Crest® SpinBrush™, Oral-B® Battery, Colgate® Motion™, Oral-B® 3-D Excel, and a Crest experimental toothbrush design. This study was a randomized, controlled, examiner-blind, six-period crossover design, which examined plaque removal with six powered toothbrushes following a single use in 26 subjects. Plaque was scored before and after brushing for one minute using the Turesky, *et al.* Modification of the Quigley-Hein Index. For statistical comparison, the plaque scores were averaged on a per-subject basis. Each subject had a single whole-mouth average score for baseline and for the exam following a one-minute brushing with their assigned toothbrush. The difference (baseline minus post-brushing) in average scores was calculated and analyzed using an analysis of covariance for a crossover design, with baseline whole-mouth average score as the covariate, and terms in the model for subjects, periods, and treatments. Mean baseline plaque scores ranged from 1.770–1.897 for the six toothbrush treatment groups and were not statistically significantly different. Using the analysis of covariance, with respect to all surfaces examined, the new prototype powered toothbrush (Crest® SpinBrush™ Pro) delivered an adjusted mean difference between baseline and post-brushing plaque scores of 0.544, while the five remaining powered toothbrushes delivered an adjusted mean difference of 0.470–0.497. These results represent 10–16% greater plaque removal for the new prototype powered toothbrush. Overall, the six toothbrushes were not statistically significantly different ( $p = 0.199$ ). However, results of unadjusted pair-wise comparisons conducted per the study protocol found that the new prototype powered toothbrush removed greater levels of plaque than the Oral-B 3-D Excel, Colgate Motion, and Crest experimental toothbrush ( $p = 0.028$ ,  $p = 0.038$ , and  $p = 0.028$ , respectively). With respect to buccal and lingual surfaces, the new prototype powered toothbrush (Crest SpinBrush Pro) delivered very similar results relative to the control toothbrushes. Collectively, the results suggest that the new prototype powered toothbrush may offer enhanced plaque removal efficiency relative to the five other toothbrushes, and be at least as good as the five tested powered toothbrushes. (*J Clin Dent* 13:198–202, 2002.)

## Introduction

Clinical studies have consistently demonstrated that oscillating powered toothbrushes deliver superior plaque removal compared to manual toothbrushes, leading to growing acceptance in the dental community that oscillating powered toothbrushes offer superior plaque control relative to manual toothbrushes.<sup>1-15</sup> For example, the Braun/Oral-B® Plaque Remover (Braun GmbH, Kronberg, Germany) has been shown to remove plaque better than multiple manual toothbrushes in a series of post-brushing, short- and long-term studies.<sup>1-5</sup> In one representative post-brushing study, this powered toothbrush removed 29% more plaque than a manual toothbrush following a single toothbrushing.<sup>2</sup> In

another four-week study, a 42% reduction in plaque was observed at the end of the treatment period for the powered toothbrush relative to the manual control toothbrush (Butler 311®, John O. Butler Co., Chicago, IL, USA).<sup>3</sup> Similar results have been observed in studies of three-months duration, where statistically significant reductions in plaque were seen relative to the standard American Dental Association (ADA) reference manual toothbrush.<sup>4</sup> Importantly, in a large practice-based study examining 16,903 subjects, dental professionals reported that 80.5% of their patients had noticeable benefits with respect to plaque removal and improved gingival condition.<sup>16</sup> Study participants also noticed a first-person benefit, with 74% reporting an improvement in oral health. Following eight months of use, two-thirds of the 282 dentists interviewed considered the powered toothbrush the most effective method of toothbrushing. Previous research has demonstrated that the Crest® SpinBrush™ (The Procter & Gamble Co., Cincinnati, OH, USA) removed 3.6% more plaque than the Oral-B® Ultra Plaque Remover (Oral-B Laboratories, Boston, MA, USA).<sup>17</sup> This difference, while not statistically significant ( $p = 0.645$ ), supports that the Crest SpinBrush is at least as good as the Oral-B Ultra Plaque Remover with respect to plaque removal, following a single brushing on the basis of the 95% confidence interval.<sup>17</sup> In addition, the Crest SpinBrush has been reported to deliver superior plaque removal to a number of manual toothbrushes.<sup>12-15</sup>

Recently, the Oral-B® 3-D and 3-D Excel (D17) (Oral-B Laboratories, Boston, MA, USA), were developed as upgrades to the Oral-B Plaque Remover and Ultra Plaque Remover. The Braun/Oral-B 3-D and 3-D Excel both incorporate a pulsating motion to the oscillating brush head with 20,000 and 40,000 pulsating movements/minute, respectively, while maintaining 3,800 strokes/minute. The Oral-B 3-D and 3-D Excel have been shown to be superior to both manual toothbrushes and powered toothbrushes. In a study of three-months duration, the 3-D was shown to statistically significantly remove more plaque, reduce gingivitis, and reduce bleeding relative to the ADA reference manual toothbrush.<sup>18</sup> In addition, the 3-D has been shown to remove more plaque relative to the Braun/Oral-B Ultra Plaque Remover in a 14-day clinical study.<sup>19</sup> Specifically, the Ultra Plaque Remover and 3-D removed 57.3% and 61.3% of plaque, respectively, following two minutes of brushing. While the apparent difference in plaque removal efficacy of the powered toothbrushes

was quite small, it was statistically significant. In a second three-month study, the 3-D Excel was also shown to statistically significantly remove more plaque, reduce gingivitis, and reduce bleeding relative to the ADA reference manual toothbrush.<sup>20</sup> In addition, it has been shown to reduce bleeding relative to a premium powered toothbrush (Sonicare®, Philips Oral Healthcare, Inc., Snoqualmie, WA, USA).<sup>21</sup>

A number of plaque removal clinical models, including short-term single-brushing studies and longer-term 1–3 month multiple brushing designs, have been used to compare toothbrushes for efficacy. In general, the results from these models appear to be relatively similar with respect to measuring toothbrush plaque removal efficacy. Recently, a novel prototype powered toothbrush has been developed with a design that fundamentally differs from other marketed powered toothbrushes. The brush head of this new experimental toothbrush incorporates a dual moving head design, with one oscillating and the other translating back and forth. This design feature is meant to allow the person brushing to utilize this toothbrush with optimal manual brushing technique, while gaining the cleaning advantages of powered bristles. The objective of this study was to compare the plaque removal efficacy of six powered toothbrushes, including this new prototype powered toothbrush, following a single use in a six-period crossover study. Four of the powered toothbrushes (Crest SpinBrush, Oral-B Battery, Colgate® Motion™ [Colgate-Palmolive Co., New York, NY, USA], and Oral-B 3-D Excel) are recent entries into the marketplace (within the past three years), and the remaining two are experimental powered toothbrushes.

### Materials and Methods

This study was a randomized, controlled, examiner-blind, six-period crossover design that examined plaque removal with six powered toothbrushes—Crest SpinBrush, Oral-B 3-D Excel, Oral-B Battery, Colgate Motion, Crest experimental brush, and Crest SpinBrush Pro—following a single use. In this study, the design was adapted from previously reported single-use brushing studies.<sup>7</sup> During the course of this study, subjects brushed once for one minute with each powered toothbrush. Study participation was on a voluntary basis following written informed consent of the subjects. A population of 26 healthy adults between the ages of 18 and 70 years, with a minimum of 15 gradable teeth, was recruited. Prospective subjects were excluded from the study for the following reasons: obvious periodontal disease, orthodontic appliances or removable prosthesis, five or more carious lesions requiring treatment, pregnancy, or inability to comply with the study protocol.

Subjects refrained from all oral hygiene procedures and chewing gum for 12 hours prior to their appointment. In addition, the subjects did not eat, drink, or smoke the morning of their appointment. All subjects were appointed between 7:30 a.m. and 12:30 p.m. to facilitate compliance with the study requirements. As subjects reported to the clinic facility, they were randomly assigned to one of the six treatment sequences according to a computer-generated randomization plan (specific Latin Square which balanced for first-order carryover effects) prepared in advance of the study.

Subjects rinsed with a red disclosing solution, as directed by

the manufacturer's instructions, in a dedicated supervised brushing room to maintain blinding. They then moved to a separate clinical operator where they were examined by a product-blinded examiner for baseline overnight plaque using the Turesky, *et al.* Modification of the Quigley-Hein Index.<sup>22,23</sup> (Figure 1). The plaque examination was scored on the buccal and lingual surfaces of all teeth, with the exception of the third molars. The maximum number of teeth was 28 with 56 scorable sites, while the minimum number of teeth was 15 with 30 scorable sites. Subjects returned to the brushing room where they were instructed to brush their teeth with their assigned toothbrush for one minute, following their normal regimen, in the presence of a supervisor. A controlled pre-measured quantity of marketed 0.243% sodium fluoride dentifrice was dispensed to each subject by the supervisor to control dosing variability. Subjects were re-disclosed with the red disclosing solution and reported to the separate clinical operator where they were then re-examined by the same examiner.

Score	Description
0	No plaque
1	Isolated areas of plaque at gingival margin
2	Thin band on plaque at gingival margin ( $\leq 1$ mm)
3	Plaque covering up to 1/3 of the tooth surface
4	Plaque covering between 1/3 to 2/3 of the tooth surface
5	Plaque covering $\geq 2/3$ of the tooth surface

Figure 1. Turesky, *et al.* Modification of the Quigley-Hein Index.

For statistical comparison, the plaque scores were averaged on a per-subject basis. Each subject had a single whole-mouth average score for baseline and for the examination following a one-minute brushing with their assigned toothbrush. The difference (baseline minus post-brushing) in average scores was calculated and analyzed using an analysis of covariance (ANCOVA) for a crossover design, with baseline whole-mouth average score as the covariate and terms in the model for subjects, periods, and treatments. Per the study protocol, adjusted treatment group means were compared in a pair-wise fashion with no planned adjustment for multiple testing. Prior to analyzing for treatment effects using the model described above, a test for the presence of carryover effects was performed using an analysis of covariance for a crossover design, with baseline whole-mouth average score as the covariate and terms in the model for subjects, periods, treatments and carryover effects. In addition to the analysis of whole-mouth plaque scores, separate supplemental analyses were performed for average plaque scores on buccal and lingual sites. These supplemental analyses used the same statistical methods described above for whole-mouth scores. All statistical tests of hypotheses were two-sided and employed a level of significance of  $\alpha = 0.05$ .

### Results

Twenty-six subjects were randomized and completed this six-period crossover study. During the course of this study, subjects brushed once with each experimental powered toothbrush. Subjects ranged in age from 23 to 52 years, with a mean age of 36.1 years (Table I). Subjects were predominantly female (84.6%;

**Table I**  
Demographics

	N	Age (Mean ± SD)	Gender (Percent Female)
Subjects	26	36.1 ± 8.6	84.6%

Table I). No adverse events were reported during the conduct of this study, which is consistent with the previously reported safety profile of these toothbrushes. No statistically significant carry-over effects were found to exist for whole-mouth plaque scores ( $p = 0.886$ ), buccal plaque scores ( $p = 0.932$ ) or lingual plaque scores ( $p = 0.282$ ).

A summary of the supragingival plaque data for all surfaces examined is reported in Table II. Mean baseline plaque scores ranged from 1.770–1.897 for the six toothbrush treatment groups, and were not statistically significantly different. With respect to all surfaces examined, the new prototype powered toothbrush (Crest SpinBrush Pro) delivered an adjusted (analysis of covariance) mean difference between baseline and post-brushing plaque scores of 0.544, while the five remaining powered toothbrushes delivered an adjusted mean difference of 0.470–0.497. These results represent 10–16% greater plaque removal for the new prototype powered toothbrush. Overall, the six toothbrushes were not statistically significantly different ( $p = 0.199$ ). However, results of pair-wise comparisons conducted per the study protocol found that the new prototype powered toothbrush removed greater levels of plaque than the Oral-B 3-D Excel, Colgate Motion, and Crest experimental brush ( $p = 0.028$ ,  $p = 0.038$ , and  $p = 0.028$ , respectively).

**Table II**  
Plaque Results: All Surfaces

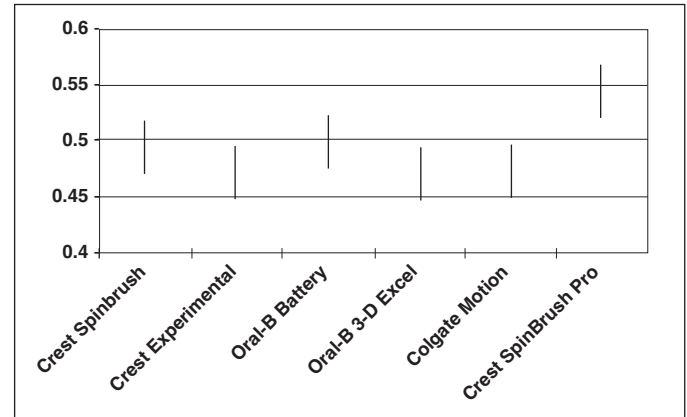
Treatment Group	N	Baseline Score (Mean ± SD)	Baseline minus Post-Brushing Difference (Adjusted Mean <sup>a</sup> ± SEM)	% Difference in Plaque Removal <sup>b</sup>
Crest SpinBrush	26	1.770 ± 0.449	0.494 ± 0.024	-10.1%
Crest Experimental	26	1.897 ± 0.506	0.470 ± 0.023	-15.7%*
Oral-B Battery	26	1.844 ± 0.499	0.497 ± 0.023	-9.5%
Oral-B 3-D Excel	26	1.881 ± 0.461	0.470 ± 0.023	-15.7%*
Colgate Motion	26	1.832 ± 0.443	0.475 ± 0.023	-14.5%*
Crest SpinBrush Pro	26	1.889 ± 0.520	0.544 ± 0.024	—

<sup>a</sup>Adjusted means and standard errors from analysis of covariance with baseline score as the covariate.

<sup>b</sup>% Difference in Plaque Removal =  $100\% \times (\text{Control} - \text{Crest SpinBrush Pro}) / \text{Control}$ .

\*Two-sided p-values based on pair-wise comparisons of adjusted means: Crest SpinBrush Pro vs. Oral-B 3-D Excel,  $p = 0.028$ ; Crest SpinBrush Pro vs. Colgate Motion,  $p = 0.038$ ; Crest SpinBrush Pro vs. Crest Experimental,  $p = 0.028$ .

The study results are illustrated by a graph of adjusted mean plaque removal scores (Figure 2). The adjusted mean plaque removal scores, plus or minus one standard error, are presented for each of the six toothbrushes evaluated in the study. The adjusted means of the first five toothbrushes cluster together and their standard errors overlap. In contrast, the adjusted mean plaque removal for the novel prototype powered toothbrush is greater than the other five toothbrushes, and its standard error does not overlap those of the others tested. A 95% one-sided confidence



**Figure 2.** Plaque removal adjusted means ± one standard error.

limit was calculated for the difference in the amount of plaque removed for each of the first five toothbrushes versus the new prototype powered toothbrush. The calculations showed that the amount of plaque removed by the new prototype powered toothbrush was, at worst, 4% less than the five other powered toothbrushes. A criterion proposed for what is known as an “at least as good” test of oral care products is that the 95% one-sided confidence limit on the product difference is below 10% of the control product mean.<sup>24</sup> Using this criterion, the new prototype powered toothbrush is as least as good as the other five powered toothbrushes.

For buccal surfaces (Table III), mean baseline plaque scores ranged from 1.493–1.645 for the six toothbrush treatment groups, and were not statistically significantly different. With respect to all surfaces examined, the new prototype powered toothbrush had an adjusted (via analysis of covariance) mean difference between baseline and post-brushing plaque scores of 0.605, while the five remaining powered toothbrushes delivered an adjusted mean difference of 0.533–0.566. These results represent 7–14% greater plaque removal on buccal surfaces for the new prototype powered toothbrush. Overall, the six toothbrushes were not sta-

**Table III**  
Plaque Results: Buccal Surfaces

Treatment Group	N	Baseline Score (Mean ± SD)	Baseline minus Post-Brushing Difference (Adjusted Mean <sup>a</sup> ± SEM)	% Difference in Plaque Removal <sup>b</sup>
Crest SpinBrush	26	1.493 ± 0.527	0.534 ± 0.029	-13.3%
Crest Experimental	26	1.620 ± 0.611	0.566 ± 0.029	-6.9%
Oral-B Battery	26	1.554 ± 0.624	0.533 ± 0.029	-13.5%
Oral-B 3-D Excel	26	1.588 ± 0.578	0.565 ± 0.029	-7.1%
Colgate Motion	26	1.542 ± 0.506	0.552 ± 0.029	-9.6%
Crest SpinBrush Pro	26	1.645 ± 0.665	0.605 ± 0.029	—

<sup>a</sup>Adjusted means and standard errors from analysis of covariance with baseline score as the covariate.

<sup>b</sup>% Difference in Plaque Removal =  $100\% \times (\text{Control} - \text{Crest SpinBrush Pro}) / \text{Control}$ .

tistically significantly different. None of the pair-wise comparisons had p-values below 0.05.

For lingual surfaces (Table IV), mean baseline plaque scores ranged from 2.048–2.177 for the six toothbrush treatment groups,

**Table IV**  
Plaque Results: Lingual Surfaces

Treatment Group	N	Baseline Score (Mean ± SD)	Baseline minus Post-Brushing Difference (Adjusted Mean <sup>a</sup> ± SEM)	% Difference in Plaque Removal <sup>b</sup>
Crest SpinBrush	26	2.048 ± 0.455	0.442 ± 0.032	-7.5%
Crest Experimental	26	2.175 ± 0.504	0.376 ± 0.032	-26.3%*
Oral-B Battery	26	2.137 ± 0.511	0.466 ± 0.032	-1.9%
Oral-B 3-D Excel	26	2.177 ± 0.463	0.382 ± 0.032	-24.3%*
Colgate Motion	26	2.123 ± 0.485	0.396 ± 0.032	-19.9%
Crest SpinBrush Pro	26	2.133 ± 0.487	0.475 ± 0.032	—

<sup>a</sup>Adjusted means and standard errors from analysis of covariance with baseline score as the covariate.

<sup>b</sup>% Difference in Plaque Removal = 100% × (Control – Crest SpinBrush Pro)/Control.

\*Two-sided p-values based on pair-wise comparisons of adjusted means: Crest SpinBrush Pro vs. Oral-B 3-D Excel, p = 0.039; Crest SpinBrush Pro vs. Crest Experimental, p = 0.028.

and were not statistically significantly different. With respect to all surfaces examined, the new prototype powered toothbrush delivered an adjusted (analysis of covariance) mean difference between baseline and post-brushing plaque scores of 0.475, while the five remaining powered toothbrushes delivered an adjusted mean difference of 0.376–0.466. These results represent 2–26% greater plaque removal on lingual surfaces for the new prototype powered toothbrush. Overall, the six toothbrushes were not statistically significantly different. However, results of pair-wise comparisons conducted per the study protocol, found that the new prototype powered toothbrush removed greater levels of plaque than the Oral-B 3-D Excel and Crest experimental toothbrush with p = 0.039 and p = 0.028, respectively.

## Discussion

The majority of reports throughout the literature have consistently demonstrated that powered toothbrushes deliver superior plaque removal compared to manual toothbrushes.<sup>1-15</sup> In addition, brushing with powered toothbrushes has been reported to reduce existing gingivitis and remove existing stain.<sup>3,6,8-11</sup> The clinical relevance and generalizability of efficacy results in controlled clinical trials is not always readily apparent. Recently, a large practice-based study examining the effectiveness of the Oral-B Ultra Plaque Remover in 16,903 dental patients has supported the generalizability of the observed clinical study results.<sup>16</sup> Following eight months of use, dental professionals reported that 80.5% of their patients had noticeable benefits with respect to plaque removal and improved gingival condition.

While powered toothbrushes are generally reported to be more effective than manual toothbrushes for plaque removal, comparisons of effectiveness between many of the newer powered toothbrushes are lacking. In this current study, the new prototype powered toothbrush (Crest SpinBrush Pro) removed 10–16% more plaque than five powered toothbrushes. Importantly, results of pair-wise comparisons conducted per the study protocol found that the new prototype powered toothbrush removed greater levels of plaque than the Oral-B 3-D Excel, Colgate Motion, and Crest experimental toothbrush with p = 0.028, p = 0.038, and

p = 0.028, respectively. Per the study protocol, these p-values were not adjusted for multiple comparisons, thus it cannot properly be concluded that the brushes are statistically significantly different. However, the comparisons are evidence of likely differences that may warrant further testing. The Oral-B 3D Excel seems to be a clinical benchmark as it has been reported to deliver superior plaque reductions to a number of powered toothbrushes.<sup>19,21</sup> It has been shown to remove more plaque relative to the Oral-B Ultra Plaque Remover in a 14-day clinical study.<sup>19</sup> The Oral-B Ultra Plaque Remover had previously been shown to remove more plaque and stain relative to the Oral-B Plaque Remover. In addition, the Oral-B 3-D Excel has been shown to reduce bleeding relative to a premium powered toothbrush (Sonicare).<sup>21</sup> Results of two independent studies have reported that the Crest SpinBrush removes more plaque relative to the battery-operated powered toothbrush (Colgate<sup>®</sup> Actibrush<sup>™</sup>, Colgate-Palmolive Co., New York, NY, USA).<sup>25,26</sup> The Colgate Actibrush has been shown to be in parity to the base Oral-B Plaque Remover with regard to plaque removal.<sup>27</sup> Collectively, the results suggest that the new prototype powered toothbrush (Crest SpinBrush Pro) may offer enhanced plaque removal efficiency relative to the five other toothbrushes, and at least as good as the five tested powered toothbrushes.

**Acknowledgements:** The authors would like to acknowledge the significant contributions to the execution and analysis of this study made by Krista Topmiller. This study was supported by the Procter & Gamble Company.

*For further correspondence with the author(s) of this paper, contact Dr. Aaron R. Biesbrock—biesbrock.ar@pg.com.*

## References

- Warren PR, Chater B: The role of the electric toothbrush in the control of plaque and gingivitis: A review of 5 years of clinical experience with the Braun Oral-B Plaque Remover (D7). *Am J Dent* 9:S5–S11, 1996.
- van der Weijden FA, Danser MM, Nijboer A, Timmerman MF, van der Velden U: The plaque-removing efficacy of an oscillating/rotating toothbrush. *J Clin Periodontol* 20:273–278, 1993.
- van der Weijden FA, Timmerman MF, Piscoer M, Ijzerman Y, Warren PR, van der Velden U: A comparison of the efficacy of a novel electric toothbrush and a manual toothbrush in the treatment of gingivitis. *Am J Dent* 11:S23–S28, 1998.
- Cronin M, Dembling W, Warren PR, King DW: A 3-month clinical investigation comparing the safety and efficacy of a novel electric toothbrush (Braun Oral-3D Plaque Remover) with a manual toothbrush. *Am J Dent* 11:S17–S21, 1998.
- van der Weijden GA, Timmerman MF, Nijboer A, Lie MA, van der Velden U: A comparative study of electric toothbrushes for the effectiveness of plaque removal in relation to toothbrushing duration. Timer study. *J Clin Periodontol* 20:476–481, 1993.
- Yankell SL, Emling RC: A thirty-day evaluation of the Rowenta Dentiphant powered toothbrush in children for safety and efficacy. *J Clin Dent* 7:96–100, 1996.
- Bustillo E, Cartwright S, Battista GW, Petrone DM, Petrone ME, Rustogi KN, Chaknis P, Volpe AR: Effectiveness of a battery-powered toothbrush on plaque removal: Comparison with four manual toothbrushes. *Compend Cont Educ Dent* 21:S25–S29, 2000.
- Nathoo S, Rustogi KN, Petrone ME, DeVizio W, Zhang YP, Volpe AR, Proskin HM: Comparative efficacy of the Colgate Actibrush battery-powered toothbrush vs. Oral-B CrossAction toothbrush on established plaque and gingivitis: A 6-week clinical study. *Compend Cont Educ Dent* 21:S19–S24, 2000.
- Sowinski JA, Battista GW, Petrone DM, Petrone ME, Rustogi KN, Chaknis P, DeVizio W, Volpe AR: Comparative efficacy of the Colgate Actibrush

- battery-powered toothbrush and Colgate Plus (manual) toothbrush on established plaque and gingivitis: A 30-day clinical study in New Jersey. *Compend Cont Educ Dent* 21:S4-S8, 2000.
10. Sharma N, Galustians HJ, Qaqish JG, Rustogi KN, Petrone ME, Volpe AR: Comparative efficacy on supragingival plaque and gingivitis of a manual toothbrush (Colgate Plus) and a battery-powered toothbrush (Colgate Actibrush) over a 30-day period. *Compend Cont Educ Dent* 21:S9-S13, 2000.
  11. Soparkar PM, Rustogi KN, Petrone ME, Volpe AR: Comparison of gingivitis and plaque efficacy of a battery-powered toothbrush and an ADA-provided manual toothbrush. *Compend Cont Educ Dent* 21:S14-S18, 2000.
  12. Biesbrock AR, Bayuk LM, Santana MV, Yates DS, Bartizek RD: The clinical effectiveness of a novel power toothbrush and its impact on oral health. *J Contemp Dent Pract* 3:1-10, 2002.
  13. Hou L, Walters P, Bartizek RD, Biesbrock AR: Plaque removal by a battery-powered toothbrush relative to a manual toothbrush. *J Dent Res* 81:A-398, 2002.
  14. Heins P, Bartizek RD, Walters PA, Biesbrock AR: Plaque removal efficacy of a battery-operated power toothbrush compared to two control manual toothbrushes in single-use studies. *Am J Dent* 15:28A-32A, 2002.
  15. Ruhlman CD, Bartizek RD, Biesbrock AR: Plaque removal efficacy of a battery-operated toothbrush compared to a manual toothbrush. *Am J Dent* 14: 191-194, 2001.
  16. Warren PR, Smith-Ray T, Cugini M, Chater BV: A practice-based study of a power toothbrush: Assessment of effectiveness and acceptance. *JADA* 131:389-394, 2000.
  17. Biesbrock AR, Walters P, Bartizek RD, Ruhlman D, Donly KJ: Dental plaque removal with a novel battery-powered toothbrush. *Am J Dent* 15:77-80, 2002.
  18. Cronin M, Dembling W, Warren PR, King DW: A 3-month clinical investigation comparing the safety and efficacy of a novel electric toothbrush (Braun Oral-B 3D Plaque Remover) with a manual toothbrush. *Am J Dent* 11:S17-S21, 1998.
  19. Ernst CP, Nauth C, Willershausen B, Warren PR: Clinical plaque removing efficacy of a new power toothbrush. *Am J Dent* 11:S13-S16, 1998.
  20. Warren PR, Cugini M, Marks P, King DW: Safety, efficacy and acceptability of a new power toothbrush: A 3-month comparative clinical investigation. *Am J Dent* 14:3-7, 2001.
  21. van der Weijden GA, Timmerman MF, Piscoer M, Ijzerman Y, van der Velden U: Effect of Sonicare and Braun D17 on experimentally induced gingivitis. *J Dent Res* 80:119, 2001.
  22. Quigley GA, Hein JW: Comparative cleaning efficacy of manual and power brushing. *JADA* 65:26-29, 1962.
  23. Turesky S, Gilmore ND, Glickman L: Reduced plaque formation by the chloromethyl analogue of vitamin C. *J Periodontol* 41:41-43, 1970.
  24. Kingman A: Statistical vs. clinical significance in product testing: Can they be designed to satisfy equivalence? *J Public Health Dent* 52:353-360, 1992.
  25. Ruhlman CD, Bartizek RD, Biesbrock AR: Comparative efficacy of two battery-powered toothbrushes on dental plaque removal. *J Clin Dent* 13:95-99, 2002.
  26. Donly KJ, Segura A, Walters P, Bartizek RD, Biesbrock AR: Dental plaque removal with two battery-powered toothbrushes. *Am J Dent* 2002, In Press
  27. Barnes V, Battista GW, Petrone D, Petrone ME, Chaknis P, DeVizio W, Volpe AR: Comparative efficacy of a new battery-powered toothbrush and an electric toothbrush on plaque removal. *Compend Cont Educ Dent* 21:S30-S33, 2000.