

Plaque Removal Efficacy of a Novel Manual Toothbrush with MicroPulse™ Bristles and an Advanced Split-Head Design

Paul Warren, LDS Maureen Thompson, RDH MaryAnn Cugini, RDH

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

Abstract

- **Objective:** To assess the plaque removing efficacy and safety of a novel manual toothbrush (Oral-B® Pulsar™ —PUL) compared to leading manual and battery toothbrushes.
- **Methodology:** Three clinical studies were conducted, each having a randomized, examiner-blind, crossover design. Study 1 compared PUL to a newly marketed manual toothbrush, Colgate® 360™ (COL), Study 2 compared PUL to the Oral-B® Advantage® Plus (AP) and Oral-B® CrossAction® (CA) manual toothbrushes, and Study 3 compared PUL to two battery toothbrushes, Oral-B® CrossAction® Power (CAP) and Crest® SpinBrush™ Pro (SBP). Before each brushing visit, subjects refrained from all oral hygiene procedures for 23-25 hours, received an oral tissue examination, and pre-brushing plaque was scored based on the Rustogi *et al*, modified Navy Plaque Index. After subjects brushed with the assigned toothbrush in their usual manner for one minute, oral tissues were then re-examined and post-brushing plaque scores recorded. Subjects with pre-brushing whole mouth mean plaque scores ≥ 0.6 continued in the study after the first visit. Following a brief washout period between additional visits, the above procedures were repeated in the remaining treatment periods. The examiners who made all clinical measurements were blinded to the treatment sequence.
- **Results:** All toothbrushes significantly ($p = 0.0001$) reduced plaque levels from all areas after a single brushing. Study 1 showed a significant difference for PUL in all areas, whole mouth, margin, and approximal ($p < 0.05$) compared to COL. In Study 2, PUL removed significantly more whole mouth ($p < 0.01$) and approximal plaque ($p < 0.005$) than AP as scored by two examiners, but did not show a significant advantage versus CA. In Study 3, PUL removed significantly more plaque than CAP and SBP for whole mouth (both $p = 0.0001$), marginal (both $p = 0.0001$), and approximal ($p < 0.005$, $p = 0.0001$, respectively) areas. All toothbrushes were found to be safe with no evidence of hard or soft tissue trauma.
- **Conclusion:** The new Oral-B Pulsar toothbrush removed significantly more plaque than Colgate 360 and Oral-B Advantage Plus. Additionally, Pulsar removed significantly more plaque than two battery brushes, Oral-B CrossAction Power and Crest SpinBrush Pro.

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Introduction

Efficient plaque removal from all tooth surfaces is essential for effective oral hygiene, the maintenance of periodontal health, and the prevention of caries.¹⁻⁴ Appropriate tooth brushing behavior can directly improve plaque removal efficiency, but generally people do not brush their teeth for the optimal period of time and do not use a technique that completely removes plaque, in particular from hard-to-reach approximal surfaces and the gingival margins, known to be associated with the development of gingivitis.⁵⁻⁷

The challenge for toothbrush manufacturers is to produce a product that is capable of maximizing plaque removal with minimum brushing time and without being dependent on good technique. The technological advances in toothbrush design that have resulted from the competitive approach of manufacturers have been impressive, with brushes (both manual and power) showing some ingenious features aimed at improving cleaning effectiveness. For example, Oral-B® CrossAction® (CA, Procter & Gamble, Cincinnati, OH, USA), a widely used manual toothbrush, has a unique array of bristles (CrissCross™) angled in opposing directions designed to enhance interproximal penetration and cleaning effectiveness.⁸ The success of this design feature is reflected in the high levels of plaque removal from all tooth surfaces consistently demonstrated with CA in clinical studies.⁹⁻¹² One battery toothbrush, Crest® SpinBrush™ Pro (SBP,

model formerly distributed by Procter & Gamble, Cincinnati, OH, USA) featured a dual-moving brush head (one oscillating and the other translating back and forth) and a contoured bristle profile designed to enhance interproximal cleaning. Plaque removal efficacy with this brush has been shown to be at least as good as that seen with some powered toothbrushes, and superiority over manual toothbrushes has also been demonstrated.¹³⁻¹⁶

More effective plaque removal has been consistently associated with power toothbrushes (specifically, those with an oscillating/rotating action^{17,18}) compared to manual brushes, but despite the clinical evidence and the ready availability of power toothbrushes, the majority of people continue to use manual brushes. A new development in the manual toothbrush category is the Oral-B® Pulsar™ (PUL, Procter & Gamble, Cincinnati, OH, USA), a novel toothbrush with bristles that pivot back and forth and pulse by means of the battery in the handle, that has been designed to be used as a normal manual brush.

A series of clinical tests were conducted to assess the cleaning effectiveness of this novel manual toothbrush. The first of three single-use crossover studies compared the plaque-removing efficacy and safety of PUL to a recently marketed manual toothbrush Colgate® 360™ (COL, Colgate-Palmolive Company, New York, NY, USA). A second study compared PUL to two established manual toothbrushes, Oral-B® Advantage® Plus (AP, Proc-

ter & Gamble, Cincinnati, OH, USA) and Oral-B CrossAction (CA). And a third study compared PUL to two battery toothbrushes, Oral-B® CrossAction® Power (CAP, Procter & Gamble, Cincinnati, OH, USA) and SBP. The presence of plaque was assessed using the Rustogi *et al.* modified Navy Plaque Index (RMNPI)¹⁹ because this index includes scores for gumline and interproximal tooth areas where plaque is known to accumulate.⁶

Materials and Methods

Subjects

For inclusion in each study, subjects were required to be in good health, aged between 18 and 70 years, with a minimum of 18 scorable teeth (not including third molars, teeth with orthodontic appliances, bridges, crowns, or implants). In addition, the subjects were required to be manual toothbrush users, willing to abstain from all oral hygiene procedures, including the use of interdental cleaning products, chewing gums and mouthrinses for 23–25 hours, and from eating or smoking for four hours prior to each brushing visit. Dental students and dental professionals were excluded from all studies. Other reasons for excluding subjects included the following: evidence of neglected dental health; evidence of major hard or soft tissue lesions or trauma at the baseline examination; peri- and/or intra-oral piercings; use of antibiotics or anti-inflammatory medications for at least three consecutive days within the last 28 days; any medical condition with a requirement of prophylactic antibiotics prior to dental treatment; and participation (within the last 30 days) in any other oral hygiene clinical study. The study protocols were approved by an independent Institutional Review Board before the start of the study, and all subjects gave signed informed consent before study entry.

Study Design

Each study had a randomized, examiner-blind, single-use, crossover design. Subjects who fulfilled the inclusion and exclusion criteria were enrolled in the investigation and received an oral hard and soft tissue examination. Soft and hard oral tissues examined were lips, tongue, gingivae, sublingual area, inner surfaces of cheeks, mucobuccal folds, hard and soft palate, and pharyngeal area. Assessments included color, texture, soft tissue abrasion, and any irregularities. Gross effects on hard tissues and dental restorations were noted. Plaque was evaluated after disclosing the teeth with Chrom-O-Red (Germiphene Corp., Brantford, Ontario, Canada) using the RMNPI, which divides each of the buccal and lingual surfaces of all scorable teeth into nine areas, and scores plaque as either present (scored as 1) or absent (scored as 0). Plaque scores for the whole mouth, the gingival margin, and approximal surfaces were computed for each subject by taking the ratio of the total number of tooth areas with plaque present to the total number of tooth areas scored.

Qualified subjects were randomly assigned to a treatment sequence group that determined the order in which the brushes were assigned for the study visits. Subjects were given their first randomly assigned toothbrush together with written study instructions and a standard fluoride dentifrice (Colgate® Cavity Protection toothpaste, Colgate-Palmolive Company, New York, NY, USA) to use twice each day. They were provided with diaries

to record their twice-daily home brushing sessions. Subjects were instructed to brush in their usual manner, but to not use any other oral hygiene products between visits. Subjects were scheduled to return in approximately four to seven days for the first brushing visit and similarly for subsequent visits. Subjects were required to abstain from all oral hygiene for 23 to 25 hours prior to each visit, and refrain from eating or smoking in the previous four hours. Subjects received oral assessments of all soft and hard tissues, and plaque was assessed after disclosure. Those subjects with a whole mouth mean pre-brushing plaque score of ≥ 0.6 as measured by the RMNPI continued in the study after the first visit. At each study visit, subjects brushed with their assigned product in their usual manner for one minute under supervision without access to a mirror. A controlled pre-measured amount of dentifrice was dispensed by the brushing supervisor. After brushing at each study visit, oral tissues were re-examined and, after disclosure, post-brushing plaque scores were recorded.

At each brushing visit, subjects were given the next toothbrush in their randomly assigned treatment sequence, with the same instructions as those given with their first randomly assigned toothbrush. All examinations of oral soft and hard tissues, and assessment of pre- and post-brushing plaque, were done by one examiner in Studies 1 and 3 (CRG), and two examiners in Study 2 (examiner 1 = NS; examiner 2 = CRG). The examiners were blind to the identity of the toothbrushes and the assignment of the treatment sequences.

Toothbrush Designs

PUL has the size and appearance of a manual toothbrush, but with a pressure-sensitive split head designed to adjust to the contours of the teeth to clean hard-to-reach places and moderate the amount of pressure applied to teeth and gums. In addition, the brush head has novel bristles (MicroPulse™) that independently pivot back and forth (designed to penetrate deep between teeth) and a battery-powered gentle pulse action (designed to lift up food and plaque and stimulate gums). Textured rubber components molded onto the MicroPulse bristles are intended to enhance cleaning ability (Figure 1).



Figure 1. Oral-B Pulsar.

Manual Test Brushes. The COL is a manual toothbrush with three soft elastomer polishing cups surrounded by tapered bristles and a raised cleaning tip. AP is a classic design, manual toothbrush with outer-angled bristles and a power tip. CA is an advanced design toothbrush with angled bristles, shorter inner tufts angled in opposing directions, dense elliptically shaped tufts, and a power tip of extra long bristles.

Battery Test Brushes. CAP combines an oscillating-rotating power head with CrissCross bristles for dual action. The SBP test brush featured a dual-moving head design, with one of the heads oscillating and the other translating back and forth.

Statistical Analysis

Based on previous studies of a similar design,⁹ sample sizes of 60-75 were required to ensure an 80% power (power = 1- β) or greater chance of detecting differences of ≥ 0.04 whole mouth RMNPI units, with α set at 0.05.

The objective of these studies was to evaluate and compare the plaque removal efficacy of toothbrushes following a period of acclimatization (4–6 days). The primary endpoint was the single brushing change in whole mouth RMNPI score; secondary endpoints included the brushing change in plaque scores for marginal and approximal areas. All hypothesis tests were conducted at the two-sided $\alpha = 0.05$ level of significance.

The baseline comparability of treatment sequence groups for age was analyzed using an analysis of variance (ANOVA), and for gender using a chi-square test for homogeneity. Treatment groups were compared for baseline RMNPI data comparability at each visit using an ANOVA. Changes for each endpoint within each treatment group were evaluated using a paired t-test. The presence of any carryover effects in the crossover design was assessed by appropriate tests between treatment sequence groups. The differences between treatment groups in pre- and post-use RMNPI scores for whole mouth, marginal, and approximal surfaces were analyzed using an ANOVA model that adjusted for period and residual (carryover) effects. Pair-wise comparisons between groups were conducted using the least-significant-difference method.

Results

Study Population

The subjects for each study were enrolled from the population of a large metropolitan area. Each study had a different subject population and was conducted at separate time periods. Study 1 enrolled and completed 81 subjects (25 males, 56 females; age range 18 to 67 years; mean age 40.14 years). Seventy-three subjects were enrolled in Study 2, sixty-seven subjects (23 males, 44 females; age range 19 to 65 years; mean age 37.7 years) completed the study and were included in the data analysis; six subjects were lost to follow-up. Seventy subjects were enrolled in Study 3. Sixty-four subjects (21 males, 43 females; age range 18 to 70 years; mean age 38.9 years) completed the study and were included in the data analysis; six subjects were lost to follow-up.

There were no significant differences between treatment sequence groups for gender (Study 1 $p = 0.152$; Study 2 $p = 0.151$; Study 3 $p = 0.876$) or age (Study 1 $p = 0.331$; Study 2 $p = 0.618$; Study 3 $p = 0.815$) in any of the three studies.

Efficacy

Pre- and post-brushing (pooled across visits) plaque data for all surfaces are summarized in Tables I-III. In each study, all toothbrushes were effective in removing plaque from all tooth

Table I
Change in Rustogi Modified Navy Plaque Index
Pre- to Post-Brushing Plaque Scores Study 1

	RMNPI Scores: Mean (SD) ^a		Mean Plaque Reduction (SD)
	Pre-Brushing	Post-Brushing	
Whole Mouth			
Pulsar	0.62 (0.03)	0.09 (0.05)	0.53 (0.04)
Colgate 360	0.62 (0.02)	0.11 (0.07)	0.51 (0.07)
Marginal			
Pulsar	1.00 (0.00)	0.20 (0.08)	0.81 (0.08)
Colgate 360	1.00 (0.00)	0.22 (0.11)	0.78 (0.11)
Approximal			
Pulsar	1.00 (0.00)	0.09 (0.08)	0.94 (0.08)
Colgate 360	1.00 (0.00)	0.12 (0.11)	0.88 (0.11)

^aChange in mean RMNPI score from pre- to post-brushing. Changes were statistically significant for each brush (paired t-test; $p = 0.0001$).

	p-value
Whole Mouth	
Pulsar * vs. Colgate 360	0.0042
Marginal	
Pulsar * vs. Colgate 360	0.004
Approximal	
Pulsar * vs. Colgate 360	0.0443

*Indicates statistically significant benefit for product.

Table II
Change in Rustogi Modified Navy Plaque Index
Pre-to Post-Brushing Plaque Scores Study 2

Examiner 1	RMNPI Scores: Mean (SD) ^a		Mean Plaque Reduction (SD)
	Pre-Brushing	Post-Brushing	
Whole Mouth			
Pulsar	0.63 (0.03)	0.15 (0.10)	0.48 (0.08)
Advantage Plus	0.62 (0.03)	0.19 (0.10)	0.44 (0.08)
CrossAction	0.62 (0.03)	0.12 (0.08)	0.50 (0.07)
Marginal			
Pulsar	1.00 (0.00)	0.32 (0.17)	0.68 (0.17)
Advantage Plus	1.00 (0.00)	0.40 (0.17)	0.60 (0.17)
CrossAction	1.00 (0.00)	0.27 (0.15)	0.73 (0.15)
Approximal			
Pulsar	1.00 (0.00)	0.14 (0.15)	0.86 (0.15)
Advantage Plus	1.00 (0.00)	0.20 (0.17)	0.80 (0.17)
CrossAction	1.00 (0.00)	0.10 (0.13)	0.90 (0.13)
Examiner 2			
Whole Mouth			
Pulsar	0.62 (0.02)	0.14 (0.08)	0.48 (0.07)
Advantage Plus	0.62 (0.02)	0.16 (0.09)	0.46 (0.08)
CrossAction	0.61 (0.03)	0.11 (0.07)	0.50 (0.06)
Marginal			
Pulsar	1.00 (0.00)	0.29 (0.14)	0.71 (0.14)
Advantage Plus	1.00 (0.00)	0.32 (0.15)	0.68 (0.15)
CrossAction	1.00 (0.00)	0.24 (0.12)	0.76 (0.12)
Approximal			
Pulsar	1.00 (0.00)	0.12 (0.11)	0.88 (0.11)
Advantage Plus	1.00 (0.00)	0.16 (0.13)	0.84 (0.13)
CrossAction	1.00 (0.00)	0.09 (0.10)	0.91 (0.10)

^aChange in mean RMNPI score from pre- to post-brushing. Changes were statistically significant for each brush (paired t-test; $p = 0.0001$).

Table II (continued)

	Examiner 1 p-value	Examiner 2 p-value
Whole Mouth		
Pulsar* vs. Advantage Plus	0.0001	0.0084
Pulsar vs. CrossAction*	0.0098	0.0116
CrossAction* vs. Advantage Plus	0.0001	0.0001
Marginal		
Pulsar* vs. Advantage Plus	0.0001	0.0731
Pulsar vs. CrossAction*	0.0003	0.0011
CrossAction* vs. Advantage Plus	0.0001	0.0001
Approximal		
Pulsar* vs. Advantage Plus	0.0001	0.0039
Pulsar vs. CrossAction*	0.0053	0.0040
CrossAction* vs. Advantage Plus	0.0001	0.0001

*Indicates statistically significant benefit for product.

Table III

**Change in Rustogi Modified Navy Plaque Index
Pre- to Post-Brushing Plaque Scores Study 3**

Examiner 1	RMNPI Scores: Mean (SD) ^a		Mean Plaque Reduction (SD)
	Pre-Brushing	Post-Brushing	
Whole Mouth			
Pulsar	0.63 (0.03)	0.09 (0.06)	0.54 (0.05)
CrossAction Power	0.63 (0.03)	0.12 (0.07)	0.50 (0.06)
SpinBrush Pro	0.63 (0.03)	0.21 (0.08)	0.42 (0.06)
Marginal			
Pulsar	1.00 (0.00)	0.22 (0.11)	0.78 (0.11)
CrossAction Power	1.00 (0.00)	0.29 (0.14)	0.71 (0.14)
SpinBrush Pro	1.00 (0.00)	0.46 (0.14)	0.54 (0.14)
Approximal			
Pulsar	1.00 (0.00)	0.06 (0.07)	0.94 (0.08)
CrossAction Power	1.00 (0.00)	0.10 (0.11)	0.90 (0.11)
SpinBrush Pro	1.00 (0.00)	0.21 (0.14)	0.79 (0.14)

^aChange in mean RMNPI score from pre- to post-brushing. Changes were statistically significant for each brush (paired t-test; p = 0.0001).

	p-value
Whole mouth	
Pulsar* vs. CrossAction Power	0.0001
Pulsar* vs. SpinBrush Pro	0.0001
CrossAction Power* vs. SpinBrush Pro	0.0001
Marginal	
Pulsar* vs. CrossAction Power	0.0001
Pulsar* vs. SpinBrush Pro	0.0001
CrossAction Power* vs. SpinBrush Pro	0.0001
Approximal	
Pulsar* vs. CrossAction Power	0.0023
Pulsar* vs. SpinBrush Pro	0.0001
CrossAction Power* vs. SpinBrush Pro	0.0001

*Indicates statistically significant benefit for product.

surfaces after a single-use, with significant reductions reported in mean plaque scores from pre-brushing to post-brushing levels for whole mouth, marginal, and approximal surfaces (p = 0.0001 for all pre- to post-brushing changes). No significant carryover effects (p > 0.1) were found in any study.

Differences between brushes in Study 1 showed that PUL removed significantly more whole mouth plaque (p = 0.0042), approximal plaque (p = 0.0443), and marginal plaque (p = 0.004) than COL.

In Study 2, with two examiners, PUL removed significantly more whole mouth plaque (primary endpoint; p = 0.0001; p = 0.0084), approximal plaque (p = 0.0001; p = 0.0039), and

marginal plaque (p = 0.0001; p = 0.0731) when compared to AP. CA removed significantly more plaque from all areas than both AP and PUL (p < 0.012). Plaque scoring was in good agreement between examiners (overall Cohen’s Kappa of 0.8674).

Compared to CAP and SBP, PUL removed significantly more whole mouth plaque (primary endpoint; p = 0.0001 and 0.0001, respectively), marginal plaque (p = 0.0001 and 0.0001, respectively), and approximal plaque (p = 0.0023 and 0.0001, respectively). This study also demonstrated that CAP removed significantly more whole mouth (p = 0.0001), marginal (p = 0.0001), and approximal (p = 0.0001) plaque than SBP.

The percentage plaque reductions in each study for the whole mouth, marginal, and approximal surfaces are illustrated in Figures 2–4.

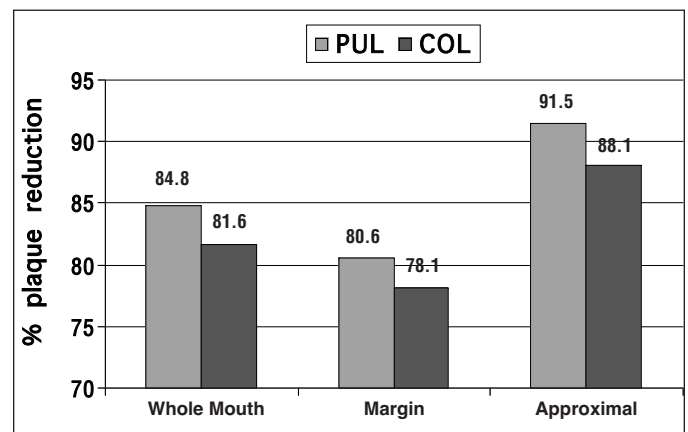


Figure 2. Mean percent change in plaque reduction: Study 1.

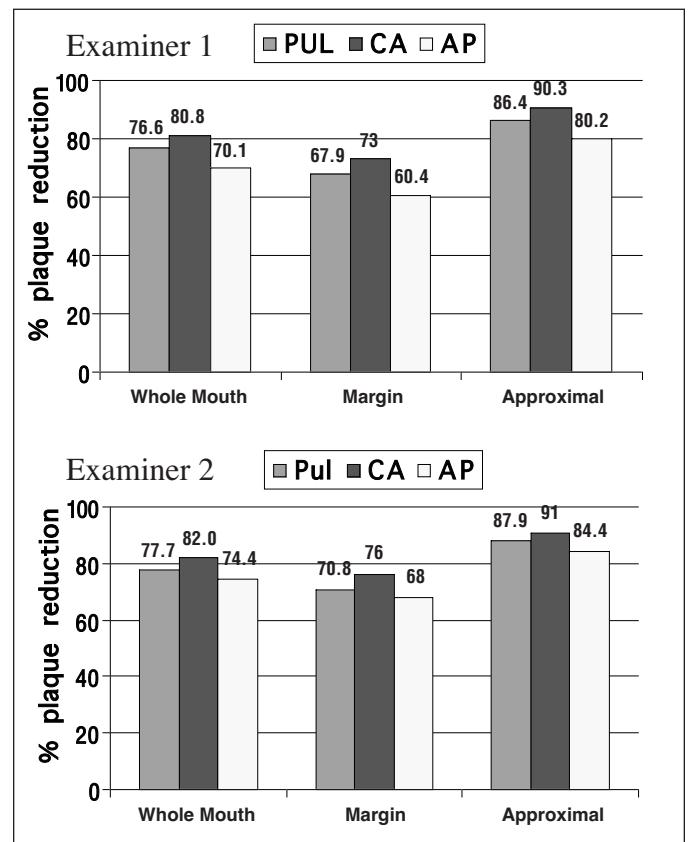


Figure 3. Mean percent change in plaque reduction: Study 2.

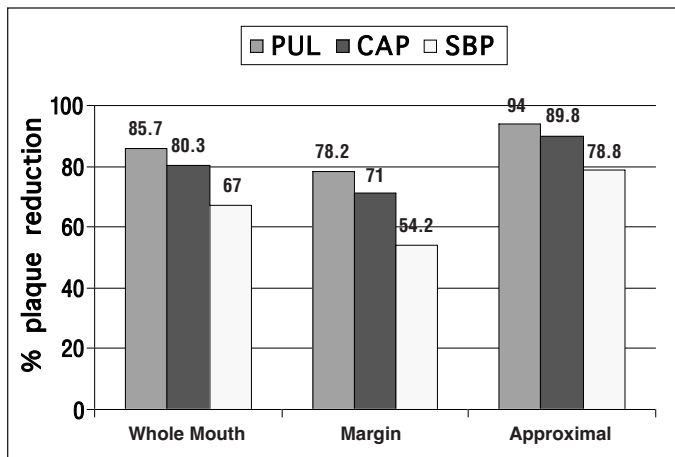


Figure 4. Mean percent change in plaque reduction: Study 3.

Safety

No adverse events were reported during any study, and there was no evidence of hard or soft tissue damage with any toothbrush.

Discussion

The manual toothbrush today has many different bristle patterns and designs, but perhaps one of the most significant advances in manual toothbrush design in recent years has been the introduction of CrossAction technology.⁸ The effectiveness of this innovative design technology has been established in several published studies.⁹⁻¹² The development of the PUL brush with MicroPulse bristles represents the next phase in toothbrush design. As with any toothbrush, the first stage of the plaque removal process involves getting the bristles in contact with the area to be cleaned. These bristles are molded from elastomer, with rounded, tapered tips that are better designed than conventional bristles to reach and access interproximal spaces. The studies described here were designed to assess effectiveness by measuring plaque removal, particularly from gingival margins and approximal tooth surfaces, because these hard-to-reach areas are the sites where inefficient plaque removal can lead to the development of gingivitis.^{5,7,20,21} The high percentage of plaque removed by PUL from the approximal surfaces in each of the studies (Study 1—91.5%; Study 2—86.4%, 87.9%; Study 3—94%) provides evidence that the textured elements incorporated in the brush design reach effectively into these areas.

While cleaning efficacy is an important outcome of brush design, a second area to which changes in brush design may contribute relates to frequency and duration of brushing. Assessments of oral sensory attributes have found that positively impacting the perceptual cues during brushing may enhance brushing compliance, and may in fact improve efficacy.^{8,22} Sensory experiences, such as the mouth feel after brushing and bristle action on teeth and gum tissues during brushing, are some of the attributes that have been tested in this area. Providing positive sensory cues during brushing enhances the experience, and can give the user some feedback as to the cleaning action of the toothbrush. The addition of bristle vibrations delivered by the battery in the handle of PUL was designed to enhance the overall feeling of brushing and positively influence these sensory attributes.

Single-use studies with the manual toothbrush have proven to be of direct value in predicting long-term (*e.g.*, three month) performance in clinical trials.^{9,10,23} Single-use studies have a number of key design features to increase the reliability of the findings, such as a crossover design (that took into account any carryover effects) allowing all subjects to use each brush, a long period (23–25 hours) before plaque is assessed minimizing effects of individual variation in the rate of plaque formation,²¹ a brushing time at study visits of one minute to approximate to normal use, and examiners who were blind to treatment sequence assignment. The positive results from these studies are a strong indication that PUL is a manual toothbrush worthy of long-term clinical evaluation to assess the extent of its benefits on gingival inflammation.

The initial single-use clinical studies with PUL provide evidence that certain technological modifications are of real value as they can lead to improvements in plaque removal and patient compliance that are directly relevant to ensuring good oral hygiene.

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For further correspondence with the author(s) of this paper, contact Dr. Paul Warren — warren.p.1@pg.com.

References

- Hancock EB, Newell DH: Preventive strategies and supportive treatment. *Periodontol 2000* 25:59–76, 2001.
- Briner WW: Plaque in relation to dental caries and periodontal disease. *Int Dent J* 21:293–301, 1971.
- Haffajee AD, Arguello EI, Ximenez-Fyvie LA, Socransky SS: Controlling the plaque biofilm. *Int Dent J* 53 (Suppl):191–199, 2003.
- Axelsson P, Lindhe J: Effect of controlled oral hygiene procedures on caries and periodontal disease in adults. *J Clin Periodontol* 5:133–151, 1978.
- Cancro LP, Fischman SL: The expected effect on oral health of dental plaque control through mechanical removal. *Periodontol 2000* 8:60–74, 1995.
- Furuichi Y, Lindhe J, Ramberg P, Volpe AR: Patterns of *de novo* plaque formation in the human dentition. *J Clin Periodontol* 19:423–433, 1992.
- Cumming BR, L  e H: Consistency of plaque distribution in individuals without special home care instruction. *J Periodontol Res* 8:94–100, 1973.
- Beals D, Ngo T, Feng Y, Cook D, Grau DG, Weber DA: Development and laboratory evaluation of a new toothbrush with a novel brush head design. *Am J Dent* 13 (Spec Iss): 5A–14A, 2000.
- Sharma NC, Qaqish JG, Galustians HJ, King DW, Low ML, Jacobs DM, Weber DA: An advanced toothbrush with improved plaque removal efficacy. *Am J Dent* 13 (Spec Iss):15A–19A, 2000.
- Cronin MJ, Dembling WZ, Low ML, Jacobs DM, Weber DA: A comparative clinical investigation of a novel toothbrush designed to enhance plaque removal efficacy. *Am J Dent* 13 (Spec Iss):21A–26A, 2000.
- Sharma NC, Qaqish JG, Galustians HJ, Cugini M, Thompson MC, Warren PR: Plaque removal efficacy and safety of the next generation of manual toothbrush with angled bristle technology: Results from three comparative clinical studies. *Am J Dent* 18:3–7, 2005.
- Cugini MA, Warren PR: The Oral-B CrossAction manual toothbrush: A 5-year literature review. *J Can Dent Assoc* 72:323, 2006.
- Biesbrock AR: A second generation battery-powered toothbrush. *J Clin Dent* 13:185–186, 2002.
- Haun J, Williams K, Friesen I, Ferrante A, Walters PA, Bartizek RD, Biesbrock AR: Plaque removal efficacy of a new experimental battery-powered toothbrush relative to two advanced-design manual toothbrushes. *J Clin Dent* 13:191–97, 2002.
- Papas AS, Martuscelli G, Singh ML, Stone C, Bartizek RD, Topmiller KJ, Biesbrock AR, Walters PA: A study to assess the safety and tolerability of

- three toothbrushes. *J Clin Dent* 13:203–206, 2002.
16. Biesbrock AR, Walters PA, Bartizek RD: The relative effectiveness of six powered toothbrushes for dental plaque removal. *J Clin Dent* 13:198–202, 2002.
 17. Heanue M, Deacon SA, Deery C, Robinson PG, Walmsley AD, Worthington HV, Shaw WC: Manual versus powered tooth brushing for oral health (Cochrane Review). In: *The Cochrane Library*, Issue 1. Oxford: Update Software; 2003.
 18. Robinson PG, Deacon SA, Deery C, Heanue M, Walmsley AD, Worthington HV, Glenny AM, Shaw WC: Manual versus powered tooth brushing for oral health. *The Cochrane Database of Systematic Reviews* 2005, Issue 2. Art. No.: CD002281.pub2.
 19. Rustogi KN, Curtis JP, Volpe AR, Kemp JH, McCool JJ, Korn LR: Refinement of the Modified Navy Plaque Index to increase plaque scoring efficiency in gumline and interproximal tooth areas. *J Clin Dent* 3 (Suppl C):C9–C12, 1992.
 20. Saxer UP, Yankell SL: Impact of improved toothbrushes on dental disease. II. *Quintessence Int* 28:573–593, 1997.
 21. Yankell SL, Tawil G, Green PA: Overnight plaque formation. *J Prev Dent* 6:313–315, 1980.
 22. Bergman R, Wong-Paredes M: Perceptual sensory attributes and benefits of a novel toothbrush. *J Dent Res* 79 (Spec Iss):1245, 2000.
 23. Sharma NC, Qaquish JG, Galustians HJ, King DW, Low MAL, Jacobs DM, Weber DA: A 3-month comparative investigation of the safety and efficacy of a new toothbrush: Results from two independent clinical studies. *Am J Dent* 13(Spec Iss):27A–32A, 2000.