J Clin Periodontol 2007; 34: 130–136 doi: 10.1111/j.1600-051X.2006.01022.x

Journal of Clinical Periodontology

Comparison of new and 3-month-old brush heads in the removal of plaque using a powered toothbrush

Louise M. E. Hogan[1,2], Christopher G. Daly[1] and Brad H. Curtis[3]

[1]Discipline of Periodontics, Faculty of Dentistry, University of Sydney, Sydney, Australia; [2]Periodontics Unit, Westmead Centre for Oral Health, Westmead Hospital, Westmead, Australia; [3]Community Oral Health and Epidemiology, Faculty of Dentistry, University of Sydney, Sydney, Australia

Hogan LME, Daly CG, Curtis BH. Comparison of new and 3-month-old brush heads in the removal of plaque using a powered toothbrush. J Clin Periodontol 2007; 34: 130–136. doi: 10.1111/j.1600-051X.2006.01022.x.

Abstract

Aim: To compare the effectiveness of new and 3-month-old worn brush heads in plaque removal using a rotation–oscillation-powered toothbrush.

Material and Methods: A single examiner blinded, randomized, cross-over study was conducted in which 34 adults attended the clinic on two occasions following 48-h periods of no oral hygiene. Following plaque scoring, subjects brushed for 2 min. with either a new brush or a brush they had used for 3 months and plaque was then re-scored. Bristle wear was assessed by measuring brushing surface areas on digital images.

Results: The mean plaque score percentage reductions with new brush heads were not significantly different from those achieved with 3-month-old heads for total surfaces (new = 38.1%; worn = 37.1%; $p = 0.83$) and approximal surfaces (new = 31.3%; worn = 30.8%; $p = 0.9$). Brushing surface area increases of the 3-month-old heads ranged from 0% to 135% (mean 26.9%). Compared with new brush heads, no significant differences were found for plaque score reductions for heads with minor, moderate or marked wear.

Conclusion: Rotation–oscillation-powered toothbrushes with 3-month-old brush heads exhibiting various degrees of wear were as effective as new brush heads in plaque removal. Bristle age and wear on a powered toothbrush may not impede the effectiveness of plaque removal.

Key words: oral hygiene; plaque removal; powered toothbrush; toothbrush wear

Accepted for publication 1 October 2006

Effective oral hygiene performed regularly by the patient disrupts the plaque biofilm on the tooth surface and is considered an important factor in helping to reduce the incidence of dental caries and chronic periodontal disease in both the short and long term (Axelsson et al. 2004). For both manual and powered toothbrushes, the plaque biofilm is disrupted and removed from the tooth surface by the mechanical cleaning action of the bristles. Once these bristles become worn, it has been assumed on the basis of in vitro (Kreifeldt et al. 1980) and in vivo studies (Glaze & Wade 1986) that toothbrushes have a reduced capacity to remove plaque and require replacement. Also, surveys of dental professionals have found that the majority identify splayed bristles as the main sign of toothbrush wear and recommend replacement of manual brushes every 2–3 months (Abraham et al. 1990, Daly & Marshall 1996, Daly et al. 2000). However, growing evidence from more recently published studies indicates that the wear status of a manual toothbrush may not be critical in effective plaque removal (Daly et al. 1996, Sforza et al. 2000, Tan & Daly 2002). In these studies, there was no difference in efficacy of plaque removal between new brushes and brushes that had been used routinely at home for periods of 9–12 weeks. In contrast, several studies that have compared new manual toothbrushes with brushes that have been artificially worn in vitro have found a statistically significant

Conflict of interest and source of funding statement

The authors declare that they have no conflict of interest.

The authors acknowledge a grant from the Dental Board of New South Wales to support this investigation.

difference (Kreifeldt et al. 1980, Warren et al. 2002). It is possible that extreme wear may be produced artificially that does not reflect the normal situation in vivo.

A recent Cochrane report found evidence to support a modest superiority in plaque removal for powered toothbrushes with a rotation–oscillation action as compared with manual brushes (Robinson et al. 2005). Although manufacturers of powered toothbrush heads recommend in their labelling that the heads should be replaced every 3 months, there are little scientific data available to support that this will assist in plaque removal. Studies of manual toothbrushes may not be directly applicable to powered toothbrushes as dissimilar bristle arrangement and reduced force applied to the teeth during use (Van der Weijden et al. 1996) may result in a different pattern and rate of bristle wear.

Only one study to date has examined the effects of wear on plaque removal using a modern powered toothbrush (Conforti et al. 2003). This clinical trial found no significant differences for whole-mouth or approximal plaque scores for new as compared with 3-month-old brush heads. However, in a subgroup whose bristle wear was judged as being ''heavy'' or ''extreme'', the new brush heads achieved a higher plaque reduction for both the full-mouth and approximal plaque scores. Given that this research was carried out by a toothbrush manufacturer and private research institutions, there is a need for independent, university-based studies to further investigate the effect of brush head wear on plaque removal with powered toothbrushes to assist dental professionals in giving evidence-based advice to their patients.

The aim of this study, therefore, was to test the hypothesis that there is no difference in plaque removal between a new and a 3-month-old brush head using a rotation–oscillation-powered toothbrush. A second aim was to examine the relationship between brush head wear and plaque removal with a powered toothbrush.

Material and Methods

Experimental design

A single (examiner) blinded, randomized, cross-over clinical trial was conducted with adult participants. Ethical approval for the study was given by the Sydney South West Area Health Service Ethics Review Committee and by the Human Research Ethics Committees of the University of Sydney and the Western Sydney Area Health Service. Research was conducted in accordance with the World Medical Association Declaration of Helsinki (version VI, 2002 http://www.wma.net/e/policy/b3.htm accessed 31st March 2005). Volunteers were given written and verbal explanations regarding participation in the study and were required to sign a witnessed consent form.

Population screening

Thirty-five volunteers were sought among staff and adult patients of the Westmead Centre for Oral Health and the Sydney Dental Hospital. All participants were required to be non-smokers and to not require antibiotic prophylaxis for the study treatment. For eligibility for inclusion in the study, subjects were required to have a central or lateral incisor, first or second pre-molar and first or second molar present in each quadrant. These teeth constituted the 12 test teeth for the study. These teeth had to be caries-free, without restorations on facial, lingual/palatal or approximal surfaces and to have probing depths <4 mm. Participants were excluded if they were wearing oral prostheses, orthodontic brackets or appliances.

Toothbrush

The toothbrush used in this study was a Braun Oral-B® D9 electrically rechargeable rotation–oscillation-powered toothbrush (Braun GmgH, Kronberg, Taunus, Germany; Oral-B Laboratories, Gillette, Mississauga, ON, Canada) with an oscillating frequency of 63 Hz 7600 oscillations per minute and an oscillating angle of 55°. The brush heads used were Oral-B FlexiSoft® EB 17-8 (Oral-B Laboratories, Gillette). The brush head had the following specifications: diameter 13.2 mm, 26 tufts in total (10 Indicator, eight FlexiSoft, eight white), made up of monofilaments each with a diameter of 0.006 mm. The monofilament length was 8.3 mm for the ''Inter-dental Tips'' and 7.2 mm for all other monofilaments.

Experimental steps

Each subject was issued with a powered toothbrush and a new brush head with written directions on its use. They were instructed to use the allocated powered toothbrush and brush head exclusively for the next 3 months (12 weeks) but were not directed on the frequency or duration of daily toothbrushing. At this initial appointment, each patient was given a supragingival scaling and polishing to remove supragingival deposits and extrinsic stains. At the end of the 3-month period, the worn brush heads were returned in containers to prevent accidental distortion of the bristles during transport. The brushing surface of each brush head was then photographed.

Assessment of plaque removal by the used, as compared with the new brush heads, was then performed in an examiner-blinded cross-over study. Each subject tested both the worn and a new brush head. Subjects attended the clinic for two plaque assessment visits, each a minimum of 2 weeks apart. Before each visit, they were instructed to refrain from all mechanical or chemical oral hygiene procedures for 48 h and to bring their fully charged toothbrush handle with them to the clinic.

At each of these visits, subjects rinsed for 15 s with 5 ml of erythrosine solution (1% w/v) to disclose plaque and then rinsed with 20 ml of water for 20 s. The pre-brushing plaque was then scored by the examiner. Subjects were then given either a new brush head or the brush head that they had used previously for 3 months. A coin toss performed by a dental assistant was used to determine random allocation of the brush head. A measured amount of toothpaste to cover the diameter of the brush head was then placed on the brush and subjects were instructed to brush without a mirror for 2 min. At the completion of brushing, the subjects rinsed with 20 ml of water for 20 s. The examiner, who had been absent from the clinic during the brush head allocation and brushing, then returned for re-disclosing and re-scoring of plaque. At the subject's second plaque assessment visit, identical procedures were followed, except that the brush head allocation was reversed.

Plaque scoring

Plaque was scored at six sites (mesial, mid and distal of the facial and lingual/palatal aspects) on each of the 12 test teeth (one incisor, one pre-molar, one molar in each quadrant) using the Turesky et al. (1970) modification of the Quigley & Hein (1962) plaque index (PI). The mesial and distal sites on each

of the facial and lingual/palatal surfaces constituted the approximal tooth surfaces for the purposes of plaque scoring. These sites are the visible spaces between the teeth that are not directly under the contact point (Egelberg & Claffey 1998, Van der Weijden 1998). Plaque was disclosed before scoring by rinsing with erythrosine solution. All plaque scoring was performed by one examiner (L. H.), who was calibrated for plaque scoring before commencement of the study. Reproducibility during the study was assessed continuously by re-scoring 12 sites selected randomly by the dental assistant at each subject's examination.

Brush head wear

Toothbrush wear was assessed by measurement of the brushing surface area. Standardized digital photographs of each brush head were obtained using a customized jig for mounting a digital camera (Canon ® DC 8.1 V, Cannon Inc., Tokyo, Japan) and a powered toothbrush handle (Braun Oral-B® D9, Braun GmgH) onto which brushes could be fitted (Fig. 1). The digital images were downloaded onto a computer (Toshiba ® Satellite A10, Toshiba Corp., Tokyo, Japan). The outline of the brushing surface area on each of the bitmapped images was traced and the surface area within the outline was determined using NIH image software (Image J, public domain Java image program, Research Services Branch, National Institute of Mental Health, Besthesda, MD, USA). The reproducibility of the tracing procedure was assessed by preparing 20 tracings of each of five brush heads and calculating the means ($\pm$ SDs) for each brushing surface area. The reproducibility of the image analysis was determined by calculating the surface area of a randomly selected image 20 times.

Statistical analysis

The null hypothesis was that a new brush head on a powered toothbrush is no more effective at reducing plaque scores than a 3-month-old brush head. The Turesky et al. (1970) modification of the Quigley & Hein (1962) PI has a range of values from zero to five in numbers. As plaque scores were recorded at six sites on each of the 12 test teeth in each patient, a total score of 30 was possible for each tooth while a minimum score of zero (0×12 study teeth) and a maximum score of 360 (30×12 study teeth) was attainable for each subject. The efficiency of plaque removal was determined by comparing the total plaque score before brushing and after brushing and calculating the difference expressed as a percentage reduction. The desired sample size was calculated under the following parameters:

1. Based on previous studies of manual (Tan & Daly 2002) and powered toothbrushes (Conforti et al. 2003), a mean reduction in plaque scores of 20% was considered relevant and a standard deviation of 30% was considered likely.
2. We sought Type 1 error probability for a two-sided test of 5%.
3. Power 90% – for paired tests, it is the probability of correctly rejecting the null hypothesis of equal population means, given *n* pairs of patients and a Type 1 error probability α (chosen as 5%).

Using a PS® Power and Sample size calculation (V2.1.31, http://biostat.mc.vanderbilt.edu/twiki/bin/view/Main/PowerSampleSize), a projected sample size of 26 subjects (paired data) was calculated. To allow for losses to follow-up, 35 subjects were recruited. The pre-brushing scores for each of the two plaque assessment visits of the patients after 48-h periods of no oral hygiene were compared using a paired *t*-test. The differences between the ''before'' and ''after'' brushing scores, expressed as percentage reductions in plaque scores, were used as the variable of response for comparison of the new and 3-month-old brush heads. For each patient, the percentage plaque score reductions achieved with each brush were compared using a paired *t*-test.

Fig. 1. Customized jig for taking standardized digital photographs of the brush heads.

Results

Subjects

Thirty-four of the 35 subjects (11 male, 23 female; aged 18–65 years) completed the study. The 34 subjects comprised 24 patients, seven dental assistants and three dentists. The drop-out subject was a female patient, aged 30 years, who was excluded due to failure to attend for the plaque assessment visits. At the first plaque assessment visit, random allocation resulted in 18 subjects being allocated a new brush head and the other 16 subjects being allocated their 3-month-old brush head. No adverse events such as gingival abrasion

Table 1. Comparison of percentage plaque score reductions for the new and the 3-month-old brush heads

Surface	Plaque score reductions, mean (± SD)		Difference in plaque score reductions (p value)
	New brush head (%)	Worn brush head* (%)	
Facial (mid and approximal)	46.2 (± 22.64)	44.6 (± 22.29)	0.76
Facial (mid-tooth)	70.3 (± 26.40)	67.1 (± 24.45)	0.60
Facial (approximal)	38.5 (± 24.66)	37.0 (± 23.60)	0.80
Lingual/palatal (mid and approximal)	26.8 (± 18.26)	27.4 (± 19.67)	0.90
Lingual/palatal (mid)	43.4 (± 28.58)	44.2 (± 31.02)	0.91
Lingual/palatal (approximal)	23.9 (± 18.23)	23.3 (± 18.96)	0.90
Mid (lingual/palatal and facial)	57.5 (± 22.25)	56.0 (± 23.26)	0.78
Approximal (lingual/palatal and facial)	31.3 (± 19.1)	30.8 (± 18.69)	0.90
All surfaces	38.1 (± 18.10)	37.1 (± 18.57)	0.83

*3 months old.

were reported by, or observed in, any of the subjects at any of the clinic visits.

Measurement reproducibility

During the plaque scoring calibration exercises before study commencement, the examiner achieved a reproducibility of 86%. During the study, plaque was re-scored on 816 sites selected randomly. A reproducibility of 90% and a k score of 0.87 were achieved. Brush head wear was measured by outlining the perimeter of the brushing surface area and then calculating the area within the perimeter by computerized image analysis. The coefficient of variation for the outlining procedure was 1.3% and the coefficient of variation for image analysis was 0%.

Plaque scores

Each subject was required to abstain from all oral hygiene procedures for a 48-h period preceding each of the two plaque assessment visits. No statistically significant differences were found between the pre-brushing plaque scores for both 48-h periods ($p = 0.14$). Before brushing with the new brush heads, the mean (± SD) total plaque score was 257.9 (± 43.54), while before brushing with the 3-month-old brush heads, it was 272.0 (± 34.45). The percentage reductions in plaque scores achieved when brushing with the new brush heads were not significantly different from those achieved with the 3-month-old brush heads for any of the tooth surfaces (Table 1). The mean (± SD) percentage plaque score reductions on facial surfaces were 46.2% (± 22.6) for the new brush heads and 44.6% (± 22.2) for the 3-month-old brush heads ($p = 0.76$); on the lingual/palatal surfaces, they were 26.8% (± 18.2) for new and 27.4% (± 19.6) for 3-month-old brush heads ($p = 0.90$); and on the approximal surfaces (i.e. mesial and distal sites), they were 31.3% (± 19.1) for new and 30.8% (± 18.6) for 3-month-old brush heads ($p = 0.90$). Overall, no differences were found in plaque score reductions for total tooth surfaces with the new brush heads (38.1 ± 18.1%) or with the 3-month-old brush heads (37.1 ± 18.5%; $p = 0.83$).

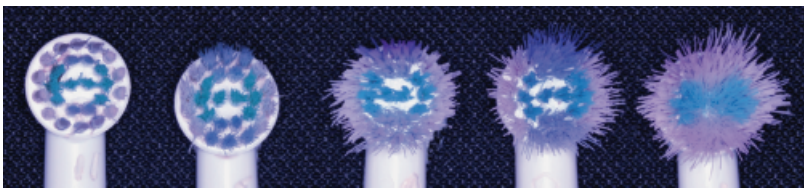

Fig. 2. Three-month-old brush heads exhibiting variations in bristle wear. The percentage increase in brushing surface area for the illustrated brush heads was (from left to right) 0%, 16%, 46%, 72% and 94%.

Table 2. Total plaque score reductions expressed as a percentage (mean ± SD) are shown for 3-month-old (worn) brush heads and new brush heads in the same subjects ($n = 34$)

Brushing surface area increase of worn* brush heads (%)	Number of subjects (N)	Total surfaces mean (± SD) plaque score reduction with worn brushes (%) (± SD)	Total surfaces mean (± SD) plaque score reduction with new brushes (%) (± SD)	t value (df) (95% CI of difference) p value†
0–10	14	34.3 (± 16.16)	35.9 (± 19.53)	$t_{13} = 0.34$ (− 8.6 to 11.7) $p = 0.74$
11–40	11	33.1 (± 22.51)	38.1 (± 20.54)	$t_{10} = 0.59$ (− 14.0 to 24.0) $p = 0.57$
41–135	9	46.3 (± 15.23)	41.4 (± 13.44)	$t_8 = -1.27$ (− 13.7 to 4.0) $p = 0.24$

*3 months old.
†Paired t-test (new–worn); NS = $p > 0.05$.

Brush head wear

The 3-month-old brush heads exhibited increased brushing surface areas ranging from 0% to 135%. The overall mean increase (± SD) in the brushing surface area of the used brushes was 26.9% (± 32.4%). The 3-month-old brush heads showed a wide variation in bristle wear (Fig. 2). The effect of brush head wear on plaque removal was investigated by assessing percentage plaque score reductions achieved with brushes exhibiting varying degrees of wear in comparison with the plaque score reductions achieved by the same patients when using new brush heads. No significant differences in percentage plaque score reductions were found

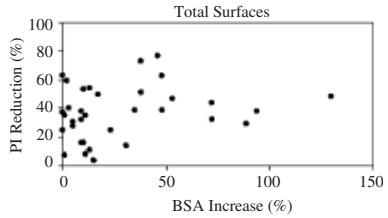

Fig. 3. The percentage plaque score reductions for total surfaces achieved with each of the 3-month-old brush heads are shown in relation to the increase in the brushing surface area (BSA) of each brush head ($n = 34$).

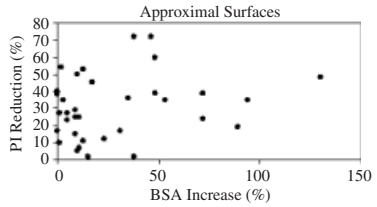

Fig. 4. The percentage plaque score reductions for approximal surfaces achieved with each of the 3-month-old brush heads are shown in relation to the increase in the brushing surface area (BSA) of each brush head ($n = 34$).

between new brush heads and 3-month-old brush heads exhibiting minor wear (0–10%, $n = 14$, $p = 0.74$), moderate wear (11–40%, $n = 11$, $p = 0.57$) or marked wear (41–135%, $n = 9$, $p = 0.24$) (Table 2). Plaque removal efficiency of the 3-month-old brush heads did not decrease with increasing bristle wear for either total surfaces (Fig. 3) or approximal surfaces (Fig. 4).

Discussion

This study found that 3-month-old, worn brush heads were no less effective than brand new brush heads when used on a rotation–oscillation-powered toothbrush to remove 48-h-old plaque. In this cross-over study, each subject tested both brush heads. This avoided any differences in brushing style that might occur when two different groups of subjects are utilized and allowed a direct comparison between 3-month-old and brand new brush heads in the same patient. In designing the study, the selection of parameters was made as follows: (1) a rotation–oscillation-powered toothbrush was utilized as this is the only type of powered brush identified in a Cochrane Review as removing more plaque than manual brushes (Robinson et al. 2005) and this type of brush was used in the only other study published to date on the effect of age and wear on plaque removal by powered brushes (Conforti et al. 2003); (2) the 12 test teeth were the same as those used in previous studies investigating plaque removal by 3-month-old and new manual toothbrushes (Sforza et al. 2000, Tan & Daly 2002); (3) the duration of brushing at the clinical visits was 2 min. as this interval has been well documented as being ideal for plaque removal using a rotation–oscillation-powered toothbrush (van der Weijden et al. 1993); and (4) the Turesky et al. (1970) modification of the Quigley & Hein (1962) PI was used as this index has been proposed as a consensus PI for toothbrush studies (Sicilia et al. 2002). The utilization of the 12 test teeth, apart from following the established protocols of previous studies (Daly et al. 1996, Sforza et al. 2000, Tan & Daly 2002), was necessary as the selection criteria for scoreable teeth to be caries-free, without restorations on facial, lingual/palatal or approximal surfaces and to have probing pocket depths of $\leqslant 4$ mm would have prevented recruitment of sufficient adult subjects including periodontal patients unless a younger, dentally unrestored and dentally fit population was used.

Plaque removal effectiveness of the new and 3-month-old brush heads was expressed as mean percentage plaque score reductions according to the Turesky et al. (1970) modification of the Quigley & Hein (1962) PI. This index is recognized as a reliable index for measuring plaque removal after toothbrushing (Robinson et al. 2005). A major disadvantage of most plaque indices, including the Turesky one, is that they are subjective. This underpins the need for intra- and inter-examiner calibration and reproducibility exercises to be performed as part of any clinical trial assessing plaque removal with toothbrushing. In the current study, all plaque scoring was performed by a single examiner who achieved a k score of 0.87. A k score above 0.75 is considered substantial (Thompson & Walter 1988). In the only other study investigating the effect of brush head age and wear on plaque removal with a rotation–oscillation-powered toothbrush (Conforti et al. 2003), no information was given on the number of examiners performing the plaque scoring or on the level of plaque scoring reproducibility.

It has been shown that plaque removal is least effective on the approximal and lingual surfaces after manual toothbrushing (Cumming & Loe 1973, Lang et al. 1977, Rugg-Gunn et al. 1979). This was confirmed in the present study, with the highest mean percentage plaque removal achieved at the mid-facial sites and the lowest from the approximal lingual/palatal sites regardless of whether a new or a 3-month-old brush head was used. It is possible that the low percentage plaque score reductions were influenced by subjects brushing without a mirror. However, it is more likely that the inclusion of approximal plaque scoring accounted for the overall low percentage plaque reductions. This was due to two approximal but only one mid-site being scored on each tooth surface. Thus, the reduced plaque removal at approximal sites (approximately 31% plaque score reduction; Table 1) as compared with mid-sites ($>55\%$ plaque score reduction; Table 1) would be expected to have a marked effect on total plaque scores. Overall, both the new and 3-month-old brush heads were more effective on the facial than on lingual/palatal surfaces (Table 1).

Our findings are in agreement with studies of manual toothbrushes that have reported that 3-month-old brushes are no less efficient in removing plaque than brand-new ones (Sforza et al. 2000, Tan & Daly 2002). A shortcoming of the manual toothbrush studies was that neither assessed plaque removal at approximal sites. It has been suggested that the main advantage of a powered toothbrush over a manual toothbrush is their superior plaque removal at approximal sites (Egelberg & Claffey 1998, Van der Weijden 1998, Van der Weijden & Hioe 2005). Therefore, in the present study and that of Conforti et al. (2003), plaque removal at approximal sites was assessed in addition to plaque removal on mid-buccal and mid-lingual/palatal surfaces. Neither study found a statistically significant difference in plaque score reduction at approximal sites for the 3-month-old brush heads as compared with new brush heads. However, in the Conforti et al. (2003) study, 15 of the 46 subjects whose used brush heads were given the highest wear grading had lower percentage plaque reductions after brushing with the 3-month-old brush heads at approximal sites. Unfortunately, the grading of brush head wear in the Conforti et al. (2003)

Table 3. Aproximal plaque score reductions expressed as a percentage (mean ± SD) are shown for 3-month-old brush heads as compared with new brush heads in the same subjects ($n = 34$)

Brushing surface area increase of worn* brush heads (%)	Number of subjects (*N*)	Approximal mean (± SD) plaque score reduction with worn brushes (%) (± SD)	Approximal mean (± SD) plaque score reduction with new brushes (%) (± SD)	*t* value (df) (95% CI of difference) *p* value†
0–10	14	28.07 (± 14.82)	28.11 (± 20.53)	$t_{13} = 0.01$ (− 10.7 to 10.8) $p = 0.99$
11–40	11	25.41 (± 22.81)	30.36 (± 20.41)	$t_{10} = 0.57$ (− 14.4 to 24.3) $p = 0.58$
41–135	9	39.11 (± 17.60)	37.06 (± 13.66)	$t_8 = -4.22$ (− 13.3 to 9.2) $p = 0.68$

*3 months old.
†Paired *t*-test (new–worn); NS = $p > 0.05$; CI, confidence interval.

study was performed subjectively by three examiners evaluating the worn brush heads on a five-point visual scale. No inter- or intra-examiner reproducibility scores were presented for this exercise and therefore the degree of accuracy in assessing brush head wear in that study cannot be determined. In the present study, in which brush head wear was objectively assessed by digitally measuring the brushing surface area of the worn brush heads in a highly reproducible and accurate manner, no reduction in plaque removal efficiency was found for brushes with mild, moderate or marked wear at approximal sites as compared with brand new brush heads. Overall, plaque removal efficiency did not deteriorate with increasing bristle wear.

We observed a wide variation in the brushing surface areas of the 3-month-old brush heads, with surface area increases ranging from 0% to 135%. A similar variation in bristle wear has been identified in studies of manual toothbrushes (Bergstrom 1973, Daly et al. 1996, Mckendrick et al. 1971, Sforza et al. 2000, Tan & Daly 2002) and it is generally assumed that individuals who brush with the highest force produce the highest bristle wear (Pugh 1978). It has been shown that considerably less force is used with a rotation–oscillation-powered brush as compared with a manual toothbrush but there is still a wide variation in the brushing force of individuals using powered brushes (Van der Weijden et al. 1996). Although it is possible that brand new brushes may lead to more gingival abrasion than a worn brush in which bristles have become splayed and softened, no gingival abrasion was found for either brush. The incidence of gingival abrasion occurring with rotation–oscillation-powered brushes has been reported to be low and similar to that found with a manual toothbrush (Van der Weijden et al. 1994).

Within the constraints of this clinical trial, it is concluded that 3-month-old brush heads are as effective as new brush heads in plaque removal on a rotation–oscillation-powered toothbrush even when the brush heads display marked wear. Taken together, the findings of this study and those investigating 3-month-old manual toothbrushes (Sforza et al. 2000, Tan & Daly 2002) suggest that toothbrush bristle wear per se should no longer be considered a valid reason for toothbrush head renewal. These findings challenge the recommendations of toothbrush manufacturers that powered toothbrush heads need to be replaced every 3 months and should assist dental professionals in making evidence-based recommendations to patients.

References

Abraham, N., Cirincione, U. & Glass, R. (1990) Dentists' and hygienists attitudes toward toothbrush replacement and maintenance. *Clinical Preventive Dentistry* **12**, 28–33.

Axelsson, P., Nystrom, B. & Lindhe, J. (2004) The long-term effect of a plaque control program on tooth mortality, caries and periodontal disease in adults. Results after 30 years of maintenance. *Journal of Clinical Periodontology* **31**, 749–757.

Bergstrom, J. (1973) Wear and hygiene status of toothbrushes in relation to some social background factors. *Swedish Dental Journal* **66**, 383–390.

Conforti, J., Cordero, R., Liebman, J. & Bowman, J. (2003) An investigation into the effects of three months' clinical wear on toothbrush efficacy: results from two independent studies. *Journal of Clinical Dentistry* **14**, 29–33.

Cumming, B. R. & Loe, H. (1973) Consistency of plaque distribution in individuals without special home care instructions. *Journal of Periodontal Research* **8**, 94–100.

Daly, C., Chapple, C. & Cameron, A. (1996) Effect of toothbrush wear on plaque control. *Journal of Clinical Periodontology* **23**, 45–49.

Daly, C. & Marshall, R. (1996) Attitudes to toothbrush renewal: a survey of Australian periodontists and dental hygienists. *Periodontology* **17**, 118–121.

Daly, C., Marshall, R. & Lazarus, R. (2000) Australian dentists' views on toothbrush wear and renewal. *Australian Dental Journal* **45**, 254–256.

Egelberg, J. & Claffey, N. (1998) Role of mechanical dental plaque removal in prevention and therapy of caries and periodontal diseases. Consensus Report of Group B. In: Lang, N., Attstrom, R. & Loe, H. (eds). *Proceedings of the European Workshop on Mechanical Plaque Control*, pp. 169–172. Berlin: Quintessence.

Glaze, P. & Wade, B. (1986) Toothbrush age and wear as it relates to plaque control. *Journal of Clinical Periodontology* **13**, 52–56.

Kreifeldt, J., Hill, P. & Calisti, L. (1980) A systematic study of the plaque removal efficiency of worn toothbrushes. *Journal of Dental Research* **59**, 2047–2055.

Lang, N. P., Cummings, B. R. & Loe, H. (1977) Oral hygiene and gingival health in Danish dental students and faculty. *Community Dentistry and Oral Epidemiology* **5**, 237–242.

McKendrick, A., McHugh, W. & Barbenel, L. (1971) Toothbrush age and wear. An analysis. *British Dental Journal* **130**, 66–68.

Pugh, B. (1978) Toothbrush wear, brushing forces and cleaning performance. *Journal of the Society of Cosmetic Chemists* **29**, 423–431.

Quigley, G. & Hein, J. (1962) Compressive cleansing efficiency of manual and power brushing. *Journal of the American Dental Association* **65**, 26–29.

Robinson, P. G., Deacon, S. A., Deery, C., Heanue, M., Walmsley, A. D., Worthington, H. V., Glenny, A. M. & Shaw, W. C. (2005) Manual *versus* powered toothbrushing for oral health. *The Cochrane Database of Systematic Reviews* Issue 2. Art. No.: CD002281. DOI: 10.1002/14651858.CD002281.

Rugg-Gunn, A. J., Macgreggor, I. D., Edgar, W. M. & Ferguson, M. W. (1979) Toothbrushing behavior in relation to plaque and gingivitis in adolescent school children. *Journal of Periodontal Research* **14**, 231–238.

Sforza, N., Rimondini, L., di Menna, F. & Camorali, C. (2000) Plaque removal by

worn toothbrush. *Journal of Clinical Periodontology* **27**, 212–216.

Sicilia, A., Arregui, I., Gallego, M., Cabezas, B. & Cuesta, S. (2002) A systematic review of powered vs. manual toothbrushes in periodontal cause-related therapy. *Journal of Clinical Periodontology* **29**, 39–55.

Tan, E. & Daly, C. (2002) Comparison of new and 3-month-old toothbrushes in plaque removal. *Journal of Clinical Periodontology* **29**, 645–650.

Thompson, W. & Walter, S. (1988) Kappa and the concept of independent errors. *Journal of Clinical Epidemiology* **41**, 969–970.

Turesky, S., Gilmore, N. D. & Glickman, L. (1970) Reduced plaque formation by chloromethyl analogue of vitamine C. *Journal of Periodontology* **41**, 41–43.

Van der Weijden, G. A. & Hioe, K. P. A. (2005) A systematic review of the effectiveness of self performed mechanical plaque removal in adults with gingivitis using a manual toothbrush. *Journal of Clinical Periodontology* **32** (Suppl. 6), 214–228.

Van der Weijden, G., Timmerman, M., Nijboer, A., Lie, M. & Van der Velden, U. (1993) A comparative study of electric toothbrushes for the effectiveness of plaque removal in relation to toothbrushing duration. Timer study. *Journal of Clinical Periodontology* **20**, 476–491.

Van der Weijden, G., Timmerman, M. & Reijerse, E. (1996) Toothbrushing force in relation to plaque removal. *Journal of Clinical Periodontology* **23**, 724–729.

Van der Weijden, G., Timmerman, M., Reijerse, E., Danser, M., Mantel, M., Nijboer, A. & van der Velden, U. (1994) The long-term effect of an oscillating/rotating electric toothbrush on gingivitis. An 8-month clinical trial. *Journal of Clinical Periodontology* **21**, 139–145.

Van der Weijden, G. A., Timmerman, M. F., Danser, M. M. & Van der Velden, U. (1998) The role of electric toothbrushes: advantages and limitations. In: Lang, N., Attstrom, R. & Loe, H. (eds). *Proceedings of the European Workshop on Mechanical Plaque Control*, pp. 138–155. Berlin: Quintessence.

Warren, P., Jacobs, D., Low, M., Charter, B. & King, D. (2002) A clinical investigation in to the effect of toothbrush wear on efficacy. *Journal of Clinical Dentistry* **13**, 119–124.

Address:
Assoc. Prof. C G Daly
Faculty of Dentistry
University of Sydney
2 Chalmers St
Surry Hills
NSW 2010, Australia
E-mail: cdaly@dentistry.usyd.edu.au

Clinical Relevance

Scientific rationale for study: Clinical studies of manual toothbrushes have shown that 3-month-old toothbrushes are as effective in plaque removal as new brushes. However, there is a lack of evidence regarding the efficiency of new and 3-month-old worn brush heads on a powered toothbrush.

Principal findings: There was no difference in plaque removal efficiency between new and 3-month-old brush heads on a rotation–oscillation-powered toothbrush.

Practical implications: Bristle wear induced by a period of 3 months of home use on a powered toothbrush does not impede plaque removal efficiency. Replacement of powered toothbrush heads every 3 months may not be warranted.