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Sonic-powered toothbrushes and reversal of experimental gingivitis

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Abstract

Objective: To compare two sonic toothbrushes in relation to the reversal of experimental gingivitis.

Materials and Methods: Subjects refrained from brushing mandibular teeth for 21 days. During a 4-week treatment phase, the right or left side of the mouth was brushed with either the Sonic Complete (SC) or Sonicare Elite (SE) toothbrush as randomly allocated. Plaque and gingivitis were assessed on day 0, after 21 days of no oral hygiene and after 1, 2 and 4 weeks of brushing twice daily.

Results: Thirty-four subjects provided evaluable data. The experimentally induced gingivitis (EIG) resulted in higher bleeding and plaque scores compared with day 0. The mean plaque scores at day 21 changed from 3.09 to 1.30 for the SC, and from 3.02 to 1.21 for the SE. At the end of the treatment period, there was no significant difference between the two brushes. The mean bleeding scores changed from 1.87 (day 21) to 0.97 for the SC, and from 1.83 to 0.92 for the SE. For the assessments at 1, 2 and 4 weeks post-EIG, both brushes showed a significant decrease in bleeding scores. There were no statistically significant differences between brushes.

Key words: electric toothbrush, gingival abrasion, gingivitis, plaque

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Electric toothbrushes are now generally regarded to be more efficacious than manual toothbrushes in removing plaque, and maintaining or improving gingival condition (Warren & Chater 1996, Saxer &Yankell 1997).

In studies over the past decade, it has been shown that certain powered toothbrushes are effective in plaque removal and reducing signs of gingival inflammation (Schifter et al. 1983, Baab & Johnson 1989, Johnson & McInness 1994, Tritten & Armitage 1996, Sicilia et al. 2002, Forrest & Miller 2004). A recent Cochrane Review concluded, following a systematic review of 29 studies involving 2547 participants, that powered toothbrushes with a rotation–oscillating action are more effective than manual brushes. Toothbrushes with this mode of action reduced plaque by 7% and gingival bleeding by 17% when compared with manual brushes (Heanue et al. 2003).

One approach in powered toothbrush technology has been the development of sonic toothbrushes that have a high frequency of filament movement in excess of approximately 30,000 strokes per minute. Two recently introduced sonic toothbrushes are the Oral-B Sonic Complete® (SC; Oral-B Laboratories, Boston, MA, USA) re-chargeable toothbrush with a side-to-side filament operating at 517 Hz, and the Philips Sonicare® Elite (SE; Philips Oral Healthcare, Snoqualmie, WA, USA) based on a different technology, with a side-to-side motion operating at a frequency of 260 Hz (Platt et al. 2002). Some clinical studies have shown the Sonicare to be comparable or more effective than a manual toothbrush in removing plaque and reducing gingival inflammation (Johnson & McInness 1994, Tritten & Armitage 1996, Zimmer et al. 2000, Moritis et al. 2002).

As new models are developed, it is important to evaluate their safety and relative ability to remove plaque and improve gingival health so dental professionals are informed about the most effective toothbrushes available. The primary objective of the present study was therefore to compare the Oral-B SC and the Sonicare Elite (SE) for a difference in their relative ability to improve gingival condition using a reversal of the gingivitis model (Van der Weijden et al. 1998, Van der Weijden 2002), where subjects refrained from oral hygiene for 21 days to allow development of gingivitis before commencement of treatment. A secondary objective was to evaluate the two sonic toothbrushes for a difference in the relative potential to induce gingival abrasion.

Material and Methods

Toothbrush design

The Oral-B SC has an oval brush head with crisscross filaments. There is a 2 mm space between the brush head and the handle to allow the head to move freely. The SE toothbrush has a brush head with a curved side profile

Fig. 1. The brush heads of the two sonic toothbrushes. At the left side the Oral-B Sonic Complete (SC), at the right side the Sonicare Elite toothbrush (SE).

and a neck slightly angled relative to the handle (Fig. 1). The easy-start feature with the SE was deactivated prior to use, as recommended by the manufacturer. Both brushes give a signal after 30 s of brushing. All subjects were instructed to use the SE in the preset high-speed mode.

Subjects

Of the 37 subjects who entered the study, 34 subjects completed the protocol. Three individuals were withdrawn for reasons unrelated to the study products (one subject required antibiotics because of an illness, one subject because of the use of wood sticks and one subject because of an illness and lack of time). To participate, subjects were required to fulfil the following inclusion criteria: non-smokers; a minimum of five evaluable teeth in each quadrant in the lower jaw (with no partial dentures, orthodontic banding or wires); absence of oral lesions and or periodontal pockets >5 mm; and a level of gingival bleeding of more than 25%. All subjects were informed as to the aims and objectives of the study and gave written informed consent. This study was approved by the Medical Ethical Committee of the Academic Medical Centre (AMC) of Amsterdam (MEC 04/230).

Study design

The study had a three-phase, randomized, examiner-blind, split-mouth design. The three phases comprised: a familiarization phase (so that subjects became acquainted with the use of both sonic toothbrushes), an experimental gingivitis phase (no oral hygiene for 21 days in the lower jaw so that a reasonable level of gingivitis developed i.e., 40% bleeding on marginal probing (BOMP)) and a treatment phase (for assessment of the effect of the sonic toothbrushes on gingival condition).

Phases

Familiarization phase. Subjects received both sonic toothbrushes, and were given brief verbal and written instructions according to the manufactures' instructions. Each subject also received a box of wood sticks (Oral-B extra fine, Gillette Gruppe Deutschland GmbH & Co. Kronberg im Taunus, Germany) for interdental cleaning and written instructions for their usage. Subjects were instructed to use the wood sticks once per day at all sites and brush twice daily for 2 min. using a standard dentifrice (Zendium Classic, RDA $\pm$ 76; Sara Lee DE International BV, Utrecht, the Netherlands). Each toothbrush was used on alternate days, and the time at which they brushed was recorded on a calendar. After 1 week, subjects received professional instruction in the use of the two sonic toothbrushes and were provided a new brush calendar. After a further 3 weeks, subjects returned for the start of the experimental gingivitis phase.

Experimental gingivitis phase. This phase started with an assessment (day 0) of plaque, gingival bleeding and gingival abrasion in the lower jaw. Subsequently, subjects received a dental prophylaxis so they entered the study with equally clean teeth. They were instructed to refrain from brushing the mandibular teeth for the next 21 days. During this period, they brushed, for further familiarization, their upper jaw on alternate days with one of the two brushes. Use of mouth rinses, dental floss or wood sticks was prohibited. After 21 days, they returned for the start of the treatment phase.

Treatment phase. Subjects were scored for plaque and gingival bleeding in the lower jaw (day 21). Only those with at least 40% of bleeding in each quadrant entered the treatment phase of the study. All subjects received a new brush head for each brush handle and a new brush calendar. During the 4-week treatment phase, subjects were instructed to brush their teeth with the supplied standard dentifrice according to a split-mouth design, whereby either the right or left side of the mouth was brushed for a period of 1 min. per side with the SC or SE, and the opposing side for 1 extra minute with the alternative brush, such as randomly assigned. Randomization of toothbrush allocation was performed using true random numbers that were generated by sampling and processing a source of entropy outside the computer. The source was atmospheric noise, which was sampled and fed into a computer, avoiding any buffering mechanisms in the operating system (www.random.org). To encourage compliance and ensure that subjects brushed the correct quadrant with the correct brush, a reminder photo sticker for the bathroom mirror was provided (Fig. 2). A timer was provided to keep track of time to ensure 15 s of brushing time per side (vestibular/lingual) of each quadrant. Use of any other oral hygiene measures such as mouth rinses, dental floss or wood sticks during this phase of the study was prohibited. Subjects returned after 1, 2 and 4 weeks of brushing for an assessment of the level of plaque, gingival bleeding and gingival abrasion in the lower jaw. At the end of the study (4-week brushing), all subjects completed a questionnaire designed to evaluate their preferences for, and attitudes towards, the two toothbrushes used.

Assessments

Throughout the study, subjects were instructed to brush between 2 and 3 h before their appointment to avoid the risk of increased bleeding on probing as a result of tooth brushing (Abbas et al. 1990).

The level of gingival inflammation was assessed using the BOMP index, where the gingival margin was probed at an angle of approximately 60° to the longitudinal axis of the tooth, and the absence or presence of bleeding was scored within 30 s of probing on a scale of 0–2 (0 = non-bleeding, 1 = pinprick bleeding, 2 = excess bleeding) (Van der Weijden et al. 1994, Lie et al. 1998).

Fig. 2. Example of the photo-reminder sticker, showing the side of the mouth to be brushed. Another sticker indicated the alternative assignment of brushes.

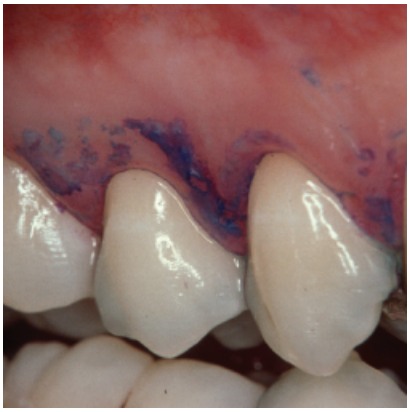

Fig. 3. A clinical photo of the gingival abrasion lesions.

For the assessment of gingival abrasion, the gums were disclosed by Mira-2-Tone disclosing solution for better visualization of areas where the surface of the oral epithelium has been abraded (Mira-2-Tone, Hager and Werken, GMBH & Co., Duisburg, Germany). Each quadrant was disclosed using a new cotton swab with fresh disclosing solution. The gingival tissues were divided into three areas (Figs 3 and 4): marginal (cervical-free gingiva), approximal (papillary-free gingiva) and mid-gingival (attached gingiva), and the number and site location of any gingival abrasions were then recorded (excluding the third molar and central incisor regions). A PQ-William's periodontal probe (Hu-Friedy Mfg. Co. Inc., Chicago, IL, US), placed across

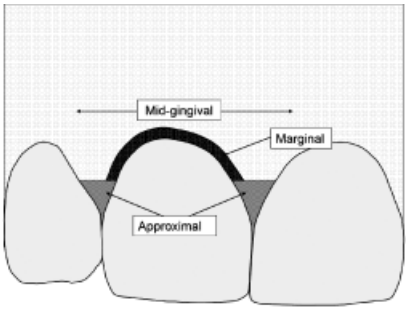

Fig. 4. Gingival abrasion.

the long axis of the lesions, was used to measure the size of the abrasions. The greatest diameter of the abrasion lesion determined the size. The number of abrasion sites was scored according to the method as described by Van der Weijden et al. (2004). The lesions were assessed as small ($\leqslant$2 mm), medium ($\geqslant$3 but $\leqslant$5 mm) and large ($>$5 mm). Those between 2 and 3 mm were assigned a score of small or medium according to the nearest mm mark on the probe.

Plaque was assessed after disclosing with Mira-2-Tone® (Hager & Werken GmbH & Co.,), using the Turesky et al. (1970) modification of the Quigley & Hein (1962) index scored at six sites per tooth as suggested by Lobene et al. (1982), where the absence or presence of plaque was recorded on a scale of 0–5 (0 = no plaque, 5 = plaque covered more than two-thirds of the tooth surface).

Throughout the study, all examinations were performed by one and the same examiner (P. A. V.) under the same conditions. The examiner was blind to treatment randomization, and records of earlier examinations were not available at each time of re-examination. Third molar and central incisor regions were excluded from the data analysis. The rationale of not to include central incisor regions is to avoid overlapping of adjacent quadrants during brushing.

Data analysis

The mean bleeding and plaque scores were calculated for all sites and for different tooth surfaces (all vestibular sites, all lingual sites, mid-vestibular sites, mid-lingual sites, approximal vestibular sites and approximal lingual sites). The mean number of gingival abrasion sites was calculated for different gingival regions and tooth types (front, pre-molars and molars) and were sorted by size. Comparisons between brushes were made for both plaque and bleeding indices using a three-level repeated measures analysis, with measurements at week 1, week 2 and week 4 as dependent variables and both scores before and after experimental gingivitis as covariates. Residual analyses were performed to confirm the validity of the calculated p-values. For explorative analysis, Wilcoxon's tests were used to compare data of various regions of interest. Gingival abrasion data were analysed using Wilcoxon's tests to compare scores for both brushes at each assessment. Overall scores were tested, and explorative analysis of scores for the size categories (small, medium, large) was performed. For analysis of the questionnaire data, Wilcoxon's tests were used in case of the VAS scores and binomial test for questions concerning binomial choices. Values of $p<0.05$ were considered as statistically significant.

The present study was able to discern a difference between bleeding scores of 0.20 with a standard deviation of 0.40 at a power of $>$80%.

Results

Subject population

The subject population comprised eight males and 26 females, with a mean age of 21.3 years (range, 18–31 years). All subjects were in good general health and were not taking any medication that could interfere with the study outcomes. All subjects who started the pre-trial phase had sufficient bleeding scores ($>$40%) at day 21. With respect to brush allocation for the split-mouth design, 17 subjects used the SC on the right side and 17 subjects used the SE on the right side. Compliance during the 4-week home-care regimen as based on returned brush calendars was almost 100% for all participants during the study.

Bleeding

During the experimental gingivitis phase (days 0–21), the bleeding index increased notably and at day 21, scores were 1.87 and 1.83 for the SC and SE, respectively (Table 1). After 4 weeks of product use, bleeding levels changed from 1.87 (day 21) to 0.97 for the SC and from 1.83 (day 21) to 0.92 for the SE, respectively. No statistically significant differences were found between brushes at any time point in the study.

Plaque

During the experimental gingivitis phase (days 0–21), the plaque index scores increased notably (Table 1). Plaque was significantly reduced by the first week of treatment by both toothbrushes. After 1 and 2 weeks of brushing, plaque levels were significantly lower with the SE compared with the SC (Table 1). After 4 weeks of product use, mean plaque scores were reduced below day 0 values with both toothbrushes, but at this point no statistical difference was found between the two brushes.

Gingival abrasion

The overall gingival abrasion scores ranged between 1.88 and 2.44 for the SC and between 1.26 and 1.88 for the SE (Table 2). No statistical differences at any time point were found between the two brushes. Explorative analyses are also shown in Table 2. Most abrasion sites were small, a few were medium and large sites were uncommon with either toothbrush.

Response to questionnaire

At the end of the last visit, all subjects completed a questionnaire designed to evaluate their attitudes towards the toothbrushes used in the study. Nearly all subjects stated that both toothbrushes were able to clean the teeth properly. Asking which one was best in removing plaque, 10 subjects chose the SC, 21 subjects chose the SE and three subjects had no preference ($p = 0.071$). Furthermore, subjects were asked to mark out a point on 10 cm long uncallibrated line reflecting their personal attitudes. The average VAS scores for both brushes in terms of pleasant use (0 = unpleasant, 10 = very pleasant) were 7.3 for the SE and 7.0 for the SC ($p = 0.573$). In response to the question which brush they would prefer to take home, 13 of the subjects stated the SC and 21 the SE ($p = 0.229$).

Table 1. Overall plaque and bleeding scores for both brushes at each assessment and statistically comparison between brushes

$N = 34$	Experimental gingivitis phase		Treatment phase		
	day 0	day 21	1 week brushing	2 weeks brushing	4 weeks brushing
Bleeding					
Oral-B SC	0.70 (0.39)	1.87 (0.19)	1.44 (0.29)	1.14 (0.40)	0.97 (0.41)
SE	0.65 (0.35)	1.83 (0.21)	1.41 (0.37)	1.16 (0.34)	0.92 (0.39)
p-value (ANOVA)		0.2339*	0.9695†	0.5079†	0.5328†
Plaque					
Oral-B SC	1.45 (0.56)	3.09 (0.51)	1.66 (0.59)	1.48 (0.53)	1.30 (0.53)
SE	1.45 (0.62)	3.02 (0.48)	1.36 (0.60)	1.28 (0.57)	1.21 (0.58)
p-value (ANOVA)		0.4195*	0.0006†	0.0246†	0.2667†

Standard deviation in parentheses.
*ANOVA covariated for pre-experimental gingivitis scores.
†ANOVA covariated for pre-experimental gingivitis and post-experimental gingivitis scores.
SC, Sonic Complete; SE, Sonicare Elite.

Table 2. Mean # of gingival abrasion sites for both brushes at each assessment and statistically comparison between brushes (each brush assessed in one quadrant in the lower jaw)

Size gingival abrasion ($N = 34$)	Pre-experimental gingivitis: day 0	Treatment phase		
		1 week brushing	2 weeks brushing	4 weeks brushing
Small ($\leqslant 2$ mm)				
Oral-B SC	1.56 (2.00)	1.79 (2.29)	2.24 (2.65)	1.53 (3.22)
SE	2.15 (1.92)	1.65(1.97)	1.53 (2.22)	1.00 (1.95)
p-value (Wilcoxon's)	0.125	0.792	0.179	0.149
Medium ($\geqslant 3$ to < 5)				
Oral-B SC	0.29 (0.52)	0.08 (0.29)	0.18 (0.46)	0.38 (0.78)
SE	0.29 (0.80)	0.15 (0.36)	0.26 (0.51)	0.21 (0.54)
p-value (Wilcoxon's)	0.564	0.480	0.499	0.357
Large ($\geqslant 5$ mm)				
Oral-B SC	0.15 (0.36)	0.00 (0.00)	0.03 (0.17)	0.00 (0.00)
SE	0.03 (0.17)	0.03 (0.17)	0.08 (0.29)	0.06 (0.24)
p-value (Wilcoxon's)	0.102	0.317	0.157	0.157
Total				
Oral-B SC	2.00 (2.32)	1.88 (2.31)	2.44 (2.71)	1.91 (3.74)
SE	2.47 (2.22)	1.82 (2.18)	1.88 (2.37)	1.26 (2.22)
p-value (Wilcoxon's)	0.259	0.909	0.273	0.257

Standard deviation in parentheses.
SC, Sonic Complete; SE, Sonicare Elite.

Discussion

The experimental gingivitis model has been used previously to assess the effect of toothbrushes on gingival health (Van der Weijden et al. 1998, 202, Putt et al. 2001, Rosema et al. 2005). Throughout the treatment phase, the SC and the SE reduced plaque levels and improved gingival condition and after 4 weeks of product use no significant difference was found between brushes in their ability to resolve experimental gingivitis.

Perhaps as important as efficacy in plaque removal are the results from the panellist preference part of this study. The advantage in terms of plaque removal associated with the use of an electric toothbrush is dependent on good compliance and continued use. Any dissatisfaction is likely to lead to discontinuation and loss of potential advantages. All subjects completed a questionnaire designed to evaluate their attitudes to both toothbrushes used in the study. In response to the question which brush they should take home if possible, 13 of the subjects stated that they preferred the SC, and 21 chose the SE. The reason for this is not fully understood but could be a result of different brush head designs and operating frequencies. The SE uses magnetic fields to induce the high-frequency motion, while the SC uses a rotary motor to induce the brush head motion. Also, these different mechanisms could influence efficacy perception.

Two previous studies using the same experimental gingivitis model compared an earlier Sonicare device and the Oral-B oscillating–rotating toothbrush. In both studies, the oscillating–rotating

brush was more effective in improving the level of gingival health (Putt et al. 2001, Van der Weijden et al. 2002), confirming the findings of an earlier 6-week crossover study (Isaacs et al. 1998), where improvement in gingival condition was 8.6% greater with the oscillating–rotating brush. Tritten & Armitage (1996) compared the Sonicare with a traditional manual toothbrush in a 12-week parallel group study and concluded that both brushes were equally effective in reducing gingival inflammation. Rosema et al. (2005) compared the SE with the Oral-B ProfessionalCare 7000 and again found the oscillating–rotating pulsation brush to be more effective. As yet, no previous study has assessed the effect of the latest model, SE, on the gingival condition as compared with a regular manual toothbrush.

Moritis et al. (2002) compared the SE with a soft-filamented manual toothbrush (Oral-B 35) in a single-blind two-arm study with respect to plaque removal. The SE achieved a mean plaque reduction (Quigley & Hein 1962) of 36.0% and the Oral-B 35 manual toothbrush scored a reduction of 25.7%. From the Moritis et al. (2002) study, it may be concluded that the use of the SE results in a significantly greater reduction in plaque than use of a manual toothbrush. However, in the light of the review by Jepsen (1998), which stated that commonly a plaque reduction of approximal 50% can be expected from manual tooth brushing, neither brush achieved an acceptable level of plaque removal.

A previous study (Van der Weijden et al. 2004) has shown that ''small'' lesions (1–2 mm) are the most frequently observed sites of abrasion as a result of brushing. The mean score of small abrasions varied in the present study between 5.04 and 9.96 on a four-quadrant basis (Table 2, multiplied by 4). In comparison, Rosema et al. (2005) using a similar design found between 2.84 and 6.84 (also multiplied by 4) small sites of abrasion. The score represents the appearance of the gingiva approximately 3 h post-unsupervised brushing. In former studies, the pre-brushing scores, after 24–48 h of non-brushing, varied between 3.3 and 6.0 (Danser et al. 1998a, b, Van der Weijden et al. 2001, 2004, Versteeg et al. 2005). These studies were panellist supervised brushing studies and assessed the post-brushing abrasion scores immediately after brushing. In these studies, the mean number of gingival abrasion sites post-brushing on a full-mouth basis varied between 6.8 and 18.4. So, in the present study, the incidence of abrasion is lower compared with the incidence in supervised brushing studies and in the range of pre-brushing scores of former studies. This shows that both brushes in the present study can be considered safe.

In conclusion, the results of the present study show that there was no significant difference between the sonic brushes in their ability to resolve experimental gingivitis. Under the conditions of the trial, both brushes were safe to oral tissues.

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Clinical Reference

Scientific rationale: Powered toothbrushes have been shown to be more effective than manual toothbrushes.

Principal findings: This short-term study showed that there was no significant difference between the two sonic brushes in their ability to resolve experimental gingivitis.

Practical implication: Both sonic toothbrush designs are beneficial to the gingival condition and therefore offer oral health care advantages to the user.