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NAM Rosema
R Adam
JM Grender
E Van der Sluijs
SC Supranoto
GA Van der Weijden

Gingival abrasion and recession in manual and oscillating–rotating power brush users

Authors' affiliations:

*NAM Rosema, E Van der Sluijs, SC Supranoto,
GA Van der Weijden*, Department of
Periodontology, Academic Centre for
Dentistry Amsterdam, ACTA, University of
Amsterdam and VU University Amsterdam,
Amsterdam, The Netherlands
R Adam, Procter & Gamble, Kronberg,
Germany
JM Grender, Procter & Gamble, Mason,
OH, USA

Correspondence to:

N.A.M Rosema
Department of Periodontology Academic
Centre for Dentistry Amsterdam
University of Amsterdam and VU University
Amsterdam
Gutav Mahlerlaan 3004
1081 LA Amsterdam
The Netherlands
Tel.: +31 20 5980 307/322
E-mail: n.rosema@acta.nl

Abstract: *Objective:* To assess gingival recession (GR) in manual and power toothbrush users and evaluate the relationship between GR and gingival abrasion scores (GA). *Methods:* This was an observational (cross-sectional), single-centre, examiner-blind study involving a single-brushing exercise, with 181 young adult participants: 90 manual brush users and 91 oscillating–rotating power brush users. Participants were assessed for GR and GA as primary response variables. Secondary response variables were the level of gingival inflammation, plaque score reduction and brushing duration. Pearson correlation was used to describe the relationship between number of recession sites and number of abrasions. Prebrushing (baseline) and post-brushing GA and plaque scores were assessed and differences analysed using paired tests. Two-sample *t*-test was used to analyse group differences; ANCOVA was used for analyses of post-brushing changes with baseline as covariate. *Results:* Overall, 97.8% of the study population had at least one site of ≥1 mm of gingival recession. For the manual group, this percentage was 98.9%, and for the power group, this percentage was 96.7% (*P* = 0.621). Post-brushing, the power group showed a significantly smaller GA increase than the manual group (*P* = 0.004); however, there was no significant correlation between number of recession sites and number of abrasions for either group (*P* ≥ 0.327). *Conclusions:* Little gingival recession was observed in either toothbrush user group; the observed GR levels were comparable. Lower post-brushing gingival abrasion levels were seen in the power group. There was no correlation between gingival abrasion as a result of brushing and the observed gingival recession following use of either toothbrush.

Key words: gingival abrasion; gingival recession; gingivitis; plaque; toothbrushing

Introduction

Large cohort studies have demonstrated that high standards of oral hygiene are essential for the prevention of periodontal disease (1). The cornerstone for achieving good oral hygiene to ensure periodontal health and prevent caries development is well understood to be the maintenance of effective plaque control. The most common means of thoroughly removing plaque at home is toothbrushing.

There is substantial evidence showing that toothbrushing can control plaque, provided that cleaning is sufficiently thorough and performed at appropriate intervals. Therefore, brushing for at least 2 min, twice a day is generally recommended by dental professionals. In a recent review of

studies that included a total of 212 manual brushing experiments (2), an average reduction from baseline in plaque scores of 42% (range 30–53%) was reported. Although substantial plaque reductions can be achieved by manual brushing, there is nevertheless scope for improvements in the amount of plaque removed by mechanical means.

Since the 1980s, major advances have been made in power toothbrush technology, and a variety of power toothbrushes has been launched with the aim of improving plaque removal efficiency. Power brush design features aimed at greater efficiency include increased filament velocity and brush stroke frequency with modifications to filament patterns and brush head motion. A Cochrane systematic review on powered toothbrushes (3), which has been updated (4, 5), concluded that only for brushes with an oscillating–rotating brush head action was there consistent evidence to consider them clinically superior to manual brushes in terms of plaque removal and gingivitis reduction.

Given that a power brush can be more effective at plaque removal than a manual brush, the obvious question to be raised about power brushes is: "Are they as gentle as a manual brush?" Comparative clinical studies that have provided the main body of efficacy evidence in support of the oscillating–rotating brush have commonly also assessed brush safety. These studies have demonstrated an excellent safety profile for oscillating–rotating power toothbrushes. A recent systematic review specifically looked at safety of oscillating–rotating toothbrushes and concluded that there was consistent evidence from research spanning the preceding two decades to show that oscillating–rotating toothbrushes were safe when compared with manual brushes (6). Collectively, the studies indicated no clinically relevant concern to either hard or soft tissues posed by these power brushes.

While this safety evidence provides reassurance to power brush users and dental care professionals, it is understood that toothbrushing requires the application of shear forces to remove plaque from hard surfaces which concomitantly would have an impact on soft tissues (7, 8). Toothbrushing, or the eating of certain hard foods (e.g. crackers), commonly damages the superficial keratinized epithelial layer of the gingival tissue and can create a background of gingival lesions. Superficial gingival abrasions can be expected to heal naturally, but it is unclear to what extent gingival abrasion caused by toothbrushing is associated with gingival recession, that is, the migration of the gingival margin, apical to the cemento-enamel junction, resulting in root surface exposure. Gingival recession is a common finding in the adult population, can be localized or generalized and is considered to be of multifactorial aetiology (9–12). Potential causes of gingival recession include periodontal disease and tooth malpositioning, but toothbrushing trauma has been considered to play a role. Given the possibility of a relationship between toothbrushing, gingival abrasion and gingival recession, an assessment of gingival tissue abrasion and recession in manual and power brush users is required to help establish whether there could be an association between these factors.

Two approaches which can be utilized to investigate the relationship between these factors are randomized clinical trials and cross-sectional epidemiological studies. Randomized clinical trials have the advantage of assessing one variable while controlling all other factors. They are commonly viewed as the gold standard for assessing the safety and efficacy of a treatment. A second approach – an observational cross-sectional design – assesses the prevalence of a condition among a general population based on their normal behaviour. This design is valuable for assessing the relationship between an outcome and multiple risk factors. While a large body of published randomized clinical trials supports the safety of oscillating–rotating brushes, few observational studies have been conducted (6).

The present cross-sectional epidemiological study with a group of regular users of a manual toothbrush and a group regularly using an oscillating–rotating toothbrush was designed to assess and compare groups in terms of both the level of existing gingival recession and the extent of gingival abrasion before and after a single-toothbrushing exercise. Differences between brush groups for existing gingival recession and the relationship between gingival abrasion and observed recession were primary outcome measures. Periodontal condition (i.e. probing pocket depth, PPD; bleeding on marginal probing, BOMP) as well as plaque scores, brushing duration, brush age and responses by participants to questions about their brush and brushing habits was assessed as secondary response variables.

Material and methods

Ethical conduct of the study and study population

The study was conducted in accordance with the ethical principles that have their origin in the Declaration of Helsinki and are consistent with Good Clinical Practice guidelines. Medical ethics approval was obtained through the Academic Medical Centre (AMC), Amsterdam, (METC 10/131 # 10 17 1129) prior to the start of the study and was registered in the Dutch Trial Register (NTR2457). The study took place at the dental clinic at the Department of Periodontology of the Academic Centre for Dentistry Amsterdam (ACTA), the Netherlands, in the period between August 2010 and April 2011. Before the start of any study procedures, participants in the study were informed about the purpose, procedures and duration of the study, and a signed informed consent was required.

The study participants were non-dental students of universities and colleges in and around Amsterdam who were invited to take part by e-mail and flyer advertising. When participants responded to the invitation by a phone call, they underwent a first selection process. During this phone call, the researchers reviewed the inclusion/exclusion criteria. To be included in the study, each participant needed to be at least 18 years of age and not older than 35 years, be a continuous power brush user or manual brush user for at least 1 year prior to the screening, be in good general health as determined by the

investigator, have a minimum of five evaluable teeth per quadrant, have a rechargeable brush with oscillating–rotating technique if a power brush user, agree to fully charge the brush handle prior to the clinical assessments visit and agree to refrain from brushing their teeth and from performing any other oral hygiene procedures 48 h prior to the visit. Specific care was taken during the selection phone call not to ask questions in such a way that the required answer would be obvious. For example, to avoid desired answers, the question regarding the toothbrush type and toothbrush use was open-ended questions. If participants mentioned that they solely used either a manual or a power brush with oscillating–rotating technology, then they were considered eligible for the study. As many power brush users cannot be considered as 100% power brush users (for reasons such as flat battery or manual toothbrush use during holiday), power brush users were included when they used their power brush on a minimum of 5 days a week (week average being 10 of 14 brushing exercises).

Participants were excluded from study participation if the participant was a 'hybrid' brusher; for example, manual in the morning, powered in the evening (or *vice versa*). Participants were also excluded for self-reported pregnancy or nursing, self-reported active treatment for periodontal disease, evidence of carious lesions requiring immediate treatment and the use of antibiotics 3 months prior to study initiation. Further exclusion criteria were orthodontic appliances or removable partial dentures, (peri)oral piercings, a need for antibiotic prophylaxis prior to a dental visit, and any disease or condition that could be expected to interfere with examination or outcomes of the study. Participation in any other oral/dental products clinical study was also an exclusion criterion.

Participants were asked to bring their regular 'at home use' brush, manual or power, to the study centre, and participants from the power brush group were reminded to fully charge their brush handle prior to their visit.

Study products

For the single-brushing exercise at the study centre, participants used their own manual or oscillating–rotating power toothbrush and were supplied with Zendium Classic toothpaste (Sara Lee H&BC, Veenendaal, The Netherlands).

Study design

This was a single-centre, examiner-blind, cross-sectional study that consisted of a single visit. The two groups of participants, manual brush users (MBU group) and power brush users (PBU group), attended the study centre where they were asked to read and sign the informed consent form and were given a signed copy. Eligibility according to study inclusion and exclusion criteria was re-assessed, and participants were required to verify that they had refrained from brushing their teeth and performing any other oral hygiene procedures for 48 h prior to the visit to allow plaque to accumulate. Power toothbrush users were checked for having their brush handle fully charged.

Participants who satisfied study inclusion and exclusion criteria and who were willing and eligible to continue to participate in the study were assessed for clinical measurements. Gingivitis was assessed first, using the BOMP index. This assessment was carried out by one examiner (SCS). Next, the gingivae and the teeth were stained with Mira-2-Tone solution (Mira-2-Ton® Hager & Werken GmbH & Co. KG. Duisburg, Germany), and prebrushing gingival abrasion was assessed. Immediately, after the abrasion assessment, prebrushing plaque was measured. Participants were then asked to brush their teeth with their own manual or power brush in their own habitual manner. Participants did not receive any instruction with respect to the amount of dentifrice to use, brushing technique or brushing duration. All brushing took place in a different area from the clinical assessments, so the examiners were not aware of the brush type used by the participant. Following the brushing episode, gums and teeth were restained with Mira-2-Tone solution and post-brushing assessments of both abrasions and plaque were carried out. These abrasion and plaque assessments were carried out by a second examiner (EVDS). Next, participants were assessed by a third examiner (NAMR) for gingival recession and pocket dept measurements.

After completion of the clinical assessments, any adverse events and general comments, if applicable, were recorded. Finally, participants completed a questionnaire regarding their brushing habits and thoughts about their brush, after which their brushes/brushheads were collected for examination.

Clinical assessments

Throughout the study, all clinical examinations were performed by the same three examiners (SCS, EVDS, NAMR) under the same conditions, with each examiner being responsible for his/her assigned parameters. The examiners were blinded to what kind of brush was used by the participant. All clinical examinations were performed full mouth, but with third molars not included. Apart from GA scores, all parameters were assessed at six sites per tooth being the disto-vestibular, vestibular, mesio-vestibular, disto-lingual, lingual and the mesio-lingual aspect of each tooth.

Gingivitis was assessed as bleeding on marginal probing (BOMP) using the index as described by Van der Weijden *et al.* (13) and Lie *et al.* (14). Each gingival site was scored upon probing using the following scale: 0 = non-bleeding, 1 = pin-prick bleeding, 2 = excessive bleeding.

Gingival abrasions (GA) were assessed according to the method as described by Van der Weijden *et al.* (15). After the gums were dried with compressed air, Mira-2-Ton® (Hager & Werken GmbH & Co. KG, Duisburg, Germany) disclosing solution was applied for better visualization of areas where the surface of the oral epithelium had been abraded. The gingival tissues were divided into three areas: marginal (cervical free gingiva), interdental (papillary free gingiva) and mid-gingival (attached gingiva) (see Fig. 1). The lesions were assessed as small (≤2 mm), medium (3–5 mm) and large (>5 mm) using a
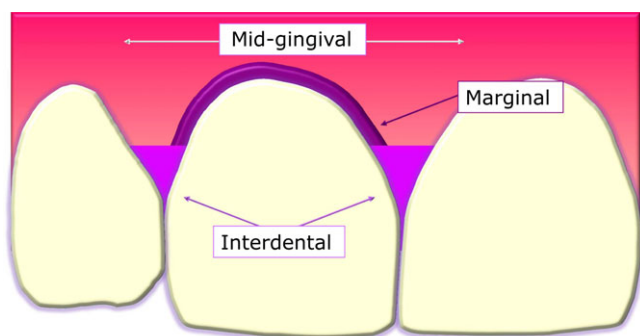
Fig. 1. Different areas for scoring gingival abrasion according to Van der Weijden et al. (15).

PQW Williams periodontal probe (Hu-Friedy, Chicago, IL, USA).

Plaque was disclosed using Mira-2-Ton® (Hager & Werken GmbH & Co. KG, Duisburg, Germany) and scored according to the Turesky modification of the Quigley and Hein plaque index (TMQHPI) as described by Paraskevas et al. (16–18). The amount of plaque was evaluated on a 6-point scale (0 = no plaque to 5 = plaque covering more than two-thirds of the tooth surface).

Brushing duration was inconspicuously measured in seconds with a stopwatch, while the participants were brushing.

Gingival recession (GR) was measured as the visible distance from the cemento-enamel junction to the gingival margin using a PQW Williams periodontal probe (Hu-Friedy, Chicago, IL, USA). Positive measurements, indicating recession, only were recorded.

Pocket depth (PPD) was assessed as the distance from the gingival margin to the apical end of the probed pocket using a PQW Williams probe (Hu-Friedy, Chicago, IL, USA). Upon completion of clinical assessments, all manual toothbrushes as well as all brushheads were collected, and the age of the brush or brushhead was assessed by asking the participants the number of weeks the brush or brushhead had been used.

After completion of the study, all manual toothbrushes as well as all brushheads were assessed for brush wear according to the method described by Conforti et al. (19) on a 0–4 scale. Three examiners (NAMR, SCS and GVA) assessed all brushes independently and resolved judging differences by discussion until a unanimous decision was reached.

Statistical analysis

For this cross-sectional study which did not test for significant differences, no specific sample size calculations were carried out a priori. Approximately 100 manual brush users and 100 power brush users were expected to be sufficient to provide a clinically relevant outcome.

For the continuous variables prebrushing and post-brushing endpoint, the mean and standard deviation were calculated for each brush group, and frequencies and percentages were used to summarize the categorical endpoints for both groups. A

statistical model was used to explore the relationship between gingival recession and number of small (≤ 2 mm) prebrushing abrasions, with baseline factors (e.g. BOMP, TMQHPI, age and brush type) included in the model to account for additional variation.

Pearson correlation was used to assess the relationship between number of sites with recession and the prebrushing, post-brushing and pre- to post-brushing increase in the number of small abrasions in each brush group. A two-sample t-test for unequal variances was used to compare GR, BOMP and PPD between brush groups. A Mann–Whitney U test was used to compare group prebrushing GA values. Within-group changes in GA and TMQHPI from pre- to post-brushing were compared using a Sign test (non-parametric test for direction). A non-parametric analysis of covariance (ANCOVA) with prebrushing (baseline) score as a covariate was used to compare post-brushing group changes in GA. An ANCOVA was used to compare brushes for TMQHPI reductions with baseline plaque scores as the covariate to investigate the effect of a single brushing. A Fisher's exact test or chi-square test was used to analyse the association between brush type and the number of participants with the presence or absence of recession defined as at least 1 site ≥ 1 mm, at least one site ≥ 2 mm, and at least one site ≥ 3 mm. Statistical tests were all two-sided and used a 0.05 significance level.

Results

A total of 184 participants met the study entrance criteria and were invited for the single study visit. Of these participants, three were excluded because at the study visit, they appeared to be using a power toothbrush that did not have the required oscillating–rotating technology. In total, 181 participants completed the study and were included in the analyses. Of these participants, 90 were manual brush users and 91 were power brush users. Participants' demographic and habitual characteristics are summarized in Table 1.

With regard to the primary response variables, whole-mouth mean GR scores were 0.08 mm for the PBU group and 0.10 mm for the MBU group. No significant ($P = 0.121$) group difference was observed (Table 2). With regard to the GA values, the average prebrushing scores were comparable ($P \geq 0.263$) for both groups (Table 3). Both groups showed a significant ($P < 0.001$) increase in total number of abrasions post-brushing. The MBU group had a median increase of 12.5, while the PBU group had a median increase of 10 abrasions. The groups differed significantly ($P = 0.004$) on their increase. Small abrasions were more common than medium or large abrasions, and the analysis on abrasion size showed greater increase ($P = 0.005$) in the number of small abrasions for the MBU group as compared to the PBU group (median of 12 versus 11 abrasions, respectively). The increase in the number of large abrasions was also significantly ($P = 0.005$) higher in the MBU group as compared to the PBU group; however, medium size abrasion increases did not differ significantly ($P = 0.773$) between groups (Table 3). When brush types were categorized

Table 1. **Demographic and brushing habit characteristics of subjects**

	Manual brush (n = 90)	Power brush (n = 91)	P-value
Age: years			
Mean (SD)	22.6 (3.08)	22.7 (3.48)	0.798*
Minimum–maximum	18–34	18–35	
Male/Female: n	27/63	29/62	0.786†
Race: n (%)			
Asian Occidental	7 (7.8)	2 (2.2)	0.209‡
Asian Oriental	1 (1.1)	0 (0)	
African	0 (0)	2 (2.2)	
Caucasian	79 (87.8)	85 (93.4)	
North African	2 (2.2)	1 (1.1)	
Other	1 (1.1)	1 (1.1)	
Smoking status: n (%)			
Non-smoker/Smoker	82 (91.1)/	80 (87.9)/	0.483†
	8 (8.9)	11 (12.1)	
Brushing duration (s)			
Mean/Median	114.5/112	157.5/142	<0.001§
Minimum–Maximum	47–270	73–302	
Brush age (weeks)			
Mean/Median	13.0/8	10.9/8	0.365§
Minimum–Maximum	0–52	0–52	
Brush wear			
Mean/Median	1.9/2.0	1.7/2.0	0.192§
Minimum–Maximum	0–4	0–4	
Brush satisfaction (%)			
Unsatisfied	2 (2.2)	2 (2.2)	0.001‡
Neutral	24 (26.7)	9 (9.9)	
Satisfied	56 (62.2)	56 (61.5)	
Very satisfied	8 (8.9)	24 (26.4)	

SD, standard deviation.
*Two-sample t-test.
†Chi-square test.
‡Fisher's exact test.
§Wilcoxon rank-sum test.

for wear score (0–2 and 3–4), results on small gingival abrasions showed significantly less incremental changes for the PBU group as compared to the MBU group (Table 4).

The mean BOMP scores and PPD scores were comparable ($P \geq 0.390$) for both groups and are shown in Table 2. Pre- and post-brushing plaque scores (TMQHPI) are summarized in Table 5. The PBU group showed a significantly ($P < 0.001$) higher prebrushing plaque score as compared to the MBU group. Although both groups demonstrated a significant ($P < 0.001$) plaque reduction ($P < 0.001$) as a result of the single brushing, the PBU group removed significantly ($P < 0.001$) more plaque than the MBU group (adjusted means for power = 1.22 and manual = 1.05).

Table 6 shows the correlations between the total number of small (≤ 2 mm) gingival abrasions (prebrushing, post-brushing and increment) and the number of sites with recession (≥ 1 mm, ≥ 2 mm, ≥ 3 mm) in both brush groups. No significant ($P \geq 0.327$) correlations were found for either brush group. This can also be seen in Fig. 2, which plots the change in the number of small abrasions versus the number of sites with ≥ 1 mm recession. Table 7 shows the association between the number of participants with recession and brush type. No

Table 2. **Mean (SD), Median/Minimum–Maximum scores by brush group for whole-mouth gingival recession (GR), bleeding on marginal probing (BOMP) and probing pocket depth (PPD)**

	Mean (SD) scores		
Brush (N)	GR*	BOMP†	PPD‡
Manual (90)	0.097 (0.076)	0.66 (0.354)	1.53 (0.166)
Power (91)	0.083 (0.055)	0.63 (0.285)	1.51 (0.201)
P-value§	0.121	0.625	0.390

	Median/Minimum–Maximum		
	GR*	BOMP†	PPD‡
Manual (90)	0.077/0–0.46	0.61/0.18–1.82	1.50/1.18–2.12
Power (91)	0.077/0–0.29	0.59/0.08–1.42	1.48/1.17–2.21
P-value¶	0.327	0.946	0.210

SD, standard deviation.
*GR: distance in mm from cemento-enamel junction to gingival margin.
†BOMP: 0 = non-bleeding, 1 = pin-prick bleeding, 2 = excessive bleeding.
‡PPD: distance in mm from gingival margin to apical end of probing pocket.
§Two-sample t-test for unequal variances.
¶Mann–Whitney U test.

significant ($P \geq 0.119$) association was detected between brush type and number of participants with recession although the MBU group exhibited a higher percentage when compared to the PBU group.

The average (SD) brushing duration was 158 (56) s for the PBU group and 115 (41) s for the MBU group, and the median brushing times were 142 and 112 s for the PBU and MBU groups, respectively. The power brush users brushed significantly ($P < 0.001$) longer than the manual brush users. Toothbrush wear scores ranged from 0 to 4 for both groups. Three quarters (75.8%) of the PBU group and 67.8% of the MBU group showed light to medium wear, while 17.6% of the PBU group and 27.8% of the MBU group exhibited heavy to extreme wear. No significant ($P = 0.507$) association was detected between brush type and brush wear. The range for self-reported brush age for both groups was 0 to 52 weeks. The mean (SD) brush age was 10.9 (9.1) weeks for the PBU group and 13.0 (11.4) weeks for the MBU group, while the median age was 8 weeks for both groups. No significant ($P = 0.365$) difference was detected between groups based on self-reported brush age (Table 1).

A statistical model was generated to define the relationship between gingival recession and number of small abrasions and other baseline parameters (BOMP, TMQHPI, age and brush type). Of the factors used in the model, the only significant ($P < 0.001$) one was age, indicating a higher level of recession for increased age. Responses to the questionnaire showed a group difference ($P = 0.001$) in favour of the PBU group for brush satisfaction. 87.9% of PBU group and 71.1% of the MBU group reported to be Satisfied/Very Satisfied. No adverse events were reported by any participant in either brush group.

Table 3. **Mean (SD) and median of pre- and post-brushing gingival abrasions (GA) by brush group and GA increase group comparison, according to abrasion size: all, small (≤2 mm), medium (3 to 5 mm), large (>5 mm)**

Brush (N)	GA mean (SD)/median		GA increase mean (SD)/median	P-value*
	Prebrushing	Post-brushing		
All abrasions				
Manual (90)	11.5(7.57)/10	26.6(12.49)/24.5	15.1(11.41)/12.5[b]	0.004
Power (91)	10.6(7.32)/8	21.1(8.89)/22	10.5(6.63)/10[b]	
P-value	0.389[†]			
Small abrasions (≤2 mm)				
Manual (90)	10.7(6.85)/10	25.5(11.99)/24	14.8(11.28)/12[b]	0.005
Power (91)	9.9(7.01)/8	20.3(8.65)/20	10.4(6.61)/11[b]	
P-value	0.380[†]			
Medium abrasions (3 to 5 mm)				
Manual (90)	0.6(0.98)/0	0.7(0.93)/0	0.2(0.83)/0[c]	0.773
Power (91)	0.4(0.84)/0	0.6(0.92)/0	0.2(0.58)/0[d]	
P-value	0.263[†]			
Large abrasions (>5 mm)				
Manual (90)	0.3(0.54)/0	0.5(0.81)/0	0.2(0.65)/0[d]	0.005
Power (91)	0.2(0.55)/0	0.2(0.46)/0	0.0(0.39)/0[e]	
P-value	0.269[†]			

SD, standard deviation; CI, confidence interval.
*P-value for group comparison using non-parametric ANCOVA, with prebrushing GA as covariate.
Sign test for change from pre- to post-brushing: [b]$P < 0.001$, [c]$P = 0.047$, [d]$P = 0.002$, [e]$P = 1.000$.
[†]Prebrushing group comparison: Wilcoxon rank-sum test.

Table 4. **Mean (SD) and median of pre- and post-brushing gingival abrasions (GA) by brush group and GA increase group comparison, according to brush wear categorization: *no to medium wear (0, 1, 2) and heavy to extreme wear (3, 4)*. Small abrasions (≤2 mm)**

Brush (N)	GA mean (SD)/median		GA increase mean (SD)/median	P-value*
	Prebrushing	Post-brushing		
Manual (65) Wear score 0–2	10.2 (7.00)/10	25.7 (13.20)/23	15.5 (12.78)/12	
Manual (25) Wear score 3–4	12.0 (6.45)/12	24.8 (8.21)/25	12.9 (5.61)/12	
P-value*	0.144	0.857	0.875	
				0.039[†]
				0.017[‡]
Power (75) Wear score 0–2	9.4 (6.85)/8	20.2 (8.66)/20	10.8 (7.00)/11.0	
Power (16) Wear score 3–4	12.3 (7.50)/12	20.6 (8.91)/21.5	8.3 (3.82)/8.5	
P-value*	0.147	0.843	0.147	

SD, standard deviation.
*Group comparison: Mann–Whitney *U* test.
†P-value for Power versus Manual group comparison using non-parametric ANCOVA, with prebrushing GA as covariate, for Wear score 0–2.
‡P-value for Power versus Manual group comparison using non-parametric ANCOVA, with prebrushing GA as covariate, for Wear score 3–4.

Discussion

Toothbrushes are required to have some level of filament stiffness, and some force is necessary if plaque deposits are to be effectively dislodged from dental surfaces during brushing. The efficient plaque removal seen with the power toothbrush (notably the oscillating–rotating model) relative to a manual toothbrush (3–5) raises the possibility that improved efficacy is achieved at the expense of safety, specifically trauma to soft tissues.

Gingival tissue can reasonably be expected to be at risk from trauma with any evidence of harmful brushing effects likely to become apparent on examination of the gingivae for abrasion damage. Disclosing agents allow stained gingival lesions to be readily identified in order to distinguish abrasions from non-traumatized tissue (7, 8). Minor superficial abrasions of gingival tissue are reversible with no permanent harmful effects and are an inevitable, but acceptable, consequence of brushing to achieve good oral hygiene. Deeper lesions, however, can damage the gingivae and are therefore unacceptable. They could reflect a poor or overzealous brushing technique or toothbrush abuse (20, 21) with the need for advice and instruction from a dental professional. Toothbrush grip (22), brushhead shape (23) and daily toothbrushing frequency (24) have all been thought to have an influence on gingival abrasion. It is generally accepted that stiffer filaments cause more gingival abrasion (25–27) and the need for end-rounded, rather than sharply-pointed, toothbrush filaments is well estab-

Table 5. Mean (SD) pre- and post-brushing plaque scores (TMQHPI) by brush group and plaque reduction group comparison

Brush (N)	Plaque score: mean (SD)		Plaque reduction: adjusted* mean (SD)	P-value (95% CI)[†]
	Prebrushing	Post-brushing		
Manual (90)	2.50 (0.366)	1.51 (0.349)[‡]	1.05 (0.268)	<0.001 (0.09, 0.26)
Power (91)	2.80 (0.450)	1.56 (0.471)[‡]	1.22 (0.301)	
P-value	<0.001[§]			

SD, standard deviation; CI, confidence interval.
*Treatment means adjusted for baseline plaque and brush by baseline plaque interaction ($P = 0.095$).
[†]P-value (CI) for plaque reduction group comparison using ANCOVA with prebrushing plaque as covariate.
[‡]Sign test for change from pre- to post-brushing: $P < 0.001$.
[§]Two-sample t-test for unequal variances.

Table 6. Correlation between number of sites with recession (≥1 mm, ≥2 mm, and ≥3 mm) and total number of small (≤2 mm) gingival abrasions in each brush group

Type of recession	Brush type	Number of sites with recession: mean/ median (min, max)	Correlation Coefficient (P-value)*		
			Prebrushing	Post-brushing	Post-pre Difference
At least 1 site ≥1 mm	Manual	14.0/11(1, 57)	0.021 (0.848)	0.033 (0.761)	0.022 (0.836)
	Power	12.5/12(1, 32)	0.031 (0.776)	−0.004 (0.973)	−0.038 (0.727)
At least 1 site ≥2 mm	Manual	3.7/2(1, 17)	0.055 (0.707)	0.111 (0.446)	0.085 (0.561)
	Power	3.1/2(1, 13)	0.001 (0.996)	−0.147 (0.370)	−0.161 (0.327)
At least 1 site ≥3 mm	Manual	2.4/2(1, 5)	−0.022 (0.953)	0.081 (0.825)	0.099 (0.785)
	Power	1.6/1(1, 4)	0.116 (0.784)	0.292 (0.484)	0.159 (0.707)

*P-values for Pearson correlation (r) between number of recession sites and total number of small abrasions.
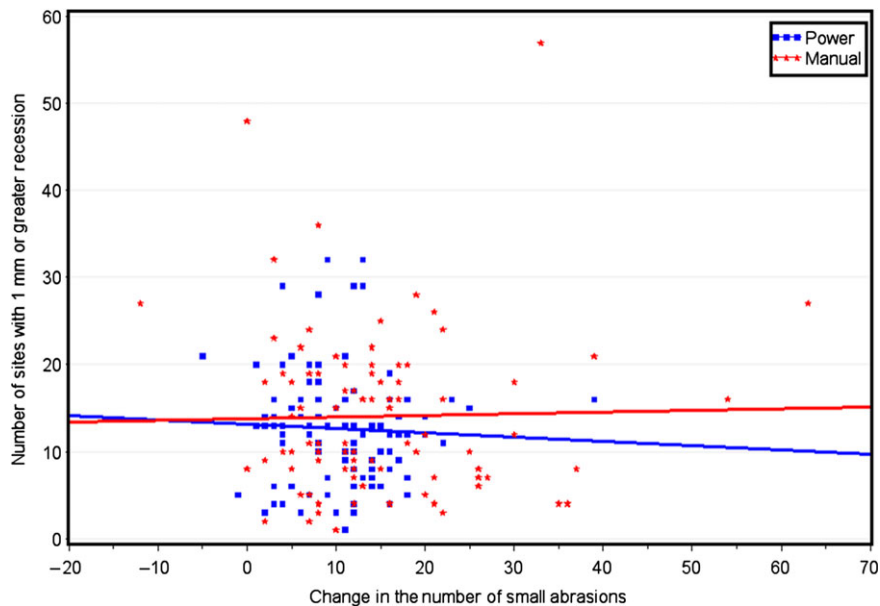

Fig. 2. Change in the number of small abrasions versus number of sites with >1 mm recession.

lished (7, 8, 28). Although it is apparent that a number of factors can increase gingival abrasion, brushing force does not appear to be a factor (8) and there is even evidence that less force is used with a power brush than a manual brush (29).

Available data appear to support the view that abrasions are no more common with a power brush than with a manual brush and may even be less common. For example, there was evidence of more gingival abrasions with a manual brush compared with a power brush in a single use professional brushing study using a split-mouth design (23). In another study, with a crossover design in which panellists brushed their own teeth, the same conclusion was drawn (30). A comparable incidence of gingival abrasion for manual and power brushes was reported in a study with 50 participants who brushed for

Table 7. **Association between brush type (manual or power) and the number of subjects with recession (at least 1 site ≥1 mm, ≥2 mm, ≥3 mm)**

Type of recession	Total number (%) of subjects with recession	Brush type	Number (%) of subjects with recession	Association: *P*-value*
None	4 (2.2)	Manual	1 (1.1)	Not applicable
		Power	3 (3.3)	
At least 1 site ≥1 mm	177 (97.8)	Manual	89 (98.9)	0.621
		Power	88 (96.7)	
At least 1 site ≥2 mm	88 (48.6)	Manual	49 (54.4)	0.119
		Power	39 (42.9)	
At least 1 site ≥3 mm	18 (9.9)	Manual	10 (11.1)	0.602
		Power	8 (8.8)	

*Fisher's exact test for recession type at least 1 site ≥1 mm; chi-square test for recession type at least 1 site ≥2 and ≥3 mm.

3 weeks every other day with either a manual or power (oscillating–rotating) brush, before being assessed in a random split-mouth order (8). Another, 1-year longitudinal, study with 32 patients showed that over the long-term a power brush did not cause more abrasion than a manual brush (31). These results are in line with a conclusion drawn in a systematic review on safety of toothbrushes (6). Regarding gingival abrasion after brushing, no significant differences were observed between oscillating–rotating powered toothbrushes as compared to manual brushes. In the present observational study, participants had brushed as part of their home care oral hygiene routine for at least 1 year with either a manual brush or an oscillating–rotating power brush. There was no difference between groups in abrasion scores before the single-brushing exercise ($P = 0.389$). Post-brushing, both groups showed a significant increase in scores overall, but the PBU group showed a smaller increase compared to the manual group ($P = 0.004$).

Gingival recession in the adult population is common and considered to have multiple aetiologies (9–12). Oral hygiene habits may be important, but there are contrasting findings in two separate 5-year longitudinal studies. The progression of recession in adult participants was prevented by the elimination of traumatic oral hygiene habits (32), whereas an increase in gingival recession sites in a student population was seen despite a reduction in damaging toothbrushing habits and improved standards of oral hygiene (33). Gingival recession has been related to increased brushing frequency with a hard toothbrush (34), and it is possible that certain individuals and teeth may be predisposed to toothbrushing trauma (21). Based on a review of short-term studies, a direct relationship between traumatic home care and gingival recession was not established, and long-term studies did not support the development of recession following toothbrushing (35, 36). As gingival recession is generally the result of multiple aetiologies, it is difficult to identify which of the cause related factors has the greatest share in onset and/or progression. In a review of studies published between 1966 and 2005, Rajapakse *et al.* (12) assessed the evidence to determine whether toothbrushing influenced the development and progression of non-inflammatory gingival recession and concluded that the data to support or refute the association between toothbrushing and gingival recession were inconclusive.

While establishing the precise relationship between toothbrushing and recession has proved problematic, there is some consistent evidence from comparative clinical studies that power brush users do not show more progression of recession than manual toothbrush users. In a randomized parallel group clinical comparison of gingival recession changes with an oscillating–rotating toothbrush or a manual brush, evidence of significantly reduced gingival recession was found in both brush groups after 6 months (37). These reductions may have been due to an improved brushing technique (i.e. Hawthorne effect) but are also consistent with other observations showing decrease in recession when the traumatic nature of self-performed oral hygiene has been pointed out to the patient (32, 38–40). Van der Weijden *et al.* (6) examined the literature concerning the relative soft and/or hard tissue safety outcomes with the use of oscillating-rotating powered toothbrushes compared to manual toothbrushes, and their meta-analysis on changes of gingival recession showed no significant difference among toothbrush groups.

With regard to the recession data from the present cross-sectional study, some degree of recession was commonly observed. Of all participants, 97.8% had recession of at least 1 mm. However, there was no group difference in whole-mouth mean GR scores ($P = 0.121$). When participants were categorized according to recession size (i.e. at least 1 site ≥1 mm, ≥2 mm, ≥3 mm) for each of these categories, no significant association was found between the number of participants with recession and the type of brush (Table 6). Furthermore, there was no significant correlation between the number of recession sites of any size category and the total number of small (≤2 mm) gingival abrasions for either group (either pre- or post-brushing or for the pre- to post-brushing increase). Therefore, gingival abrasion did not explain the observed gingival recession. Gingival abrasion reflects the 'instant' effect of toothbrushing on gingival tissue. Apparently, more than this is necessary to induce gingival recession. Other periodontal health (i.e. gingivitis) measures in this population did not differentiate between the groups or reveal an association with recession; that is, the mean BOMP was approximately 0.6, and mean PPD was approximately 1.5 mm, in both groups, without group differences ($P \geq 0.390$). A positive relation between recession and age

has been demonstrated previously (9, 34, 41), and also in this study, the only baseline factor that was found to have a relationship with recession turned out to be age. A higher level of recession was found with increased age (ANCOVA: $P < 0.001$).

Taken together with the results of earlier controlled trials, the present findings from this non-controlled observational study support the view that the brushing action of an oscillating–rotating power brush is not more abrasive to gingival tissue than a manual brush. In fact, the powered brush induced less small abrasions then the manual brush irrespective the wear score (Tables 3 and 4). This may add to the existing data that oscillating–rotating power brushes are safe to use. The well-documented (3–5) efficient plaque removal of the oscillating–rotating power brush relative to a manual brush was also evident in this study, which showed that on a single-brushing exercise, the PBU group removed more plaque than the MBU group ($P < 0.001$). A longer brushing duration for users of a power brush has been reported (42), and in this study, the power group was found to brush significantly longer than the manual group in the single-brushing exercise (158 s versus 115 s, $P < 0.001$). The increased brushing duration seen for the power group could have contributed to the improved plaque removal efficacy. However, numerous studies have shown greater plaque removal with the oscillating–rotating technology compared to standard manual brushes when equal brushing time was used (43, 44). Also, as suggested by the wear data, the brushes used by the power brush group appeared to be in better condition – which may contribute to better efficacy (45) – than those in the manual brush group. The percentage of brushes with heavy to extreme wear was numerically lower in the power brush group than the manual brush group (17.6% versus 27.8%).

Limitations

The lack of a proper 'a priori' power calculation may be considered as a limitation of this study which may lead to the assumption that this study is underpowered because no significant correlation was detected. However, the GA data show statistically significant differences in incremental changes between groups after brushing which rejects the hypothesis that this study may be considered as being underpowered.

Summary and conclusion

This was a cross-sectional study of abrasion and recession in manual and oscillating–rotating power brush users. It was an uncontrolled observational study that reflected normal brushing behaviour in young adults (18–35 years). The results of the study offered evidence that gingival recession in a young adult population could not be accounted for in terms of gingival abrasion for users of either the oscillating–rotating power brush or the manual brush. In support of power brush safety, this study also showed that the oscillating–rotating power brush did not induce more recession or caused more abrasion than the manual brush.

The plaque removal advantage of the oscillating–rotating power brush compared to the manual brush, now well established through randomized controlled studies, was confirmed in the present single-brushing exercise when participants were asked to brush in their own habitual manner. It can be concluded therefore that the oral hygiene benefits of brushing with an advanced power brush are achieved at no more risk to gingival tissue than a manual toothbrush. Patients and dental care professionals recommending dental products can be confident that with normal everyday use, oscillating–rotating power brushes are at least as safe to soft oral tissue as manual toothbrushes.

References

1 Van der Weijden F, Slot DE. Oral hygiene in the prevention of periodontal diseases: the evidence. *Periodontol 2000* 2011; **55**: 104–123.

2 Slot DE, Wiggelinkhuizen L, Rosema NAM, Van der Weijden GA. The efficacy of manual toothbrushes following a brushing exercise: a systematic review. *Int J Dent Hyg* 2012; **10**: 187–197.

3 Heanue M, Deacon SA, Deery C *et al*. Manual versus powered toothbrushing for oral health. *Cochrane Database Syst Rev* 2003; **1**: CD002281.

4 Robinson P, Deacon SA, Deery C *et al*. Manual versus powered toothbrushing for oral health. *Cochrane Database Syst Rev* 2005; **2**: CD002281.

5 Yacoob M, Deacon SA, Deery C *et al*. Manual vs powered toothbrushes for oral health: Updated Cochrane Review. Abstract #106, British Society for Oral and Dental Research, Sheffield, England; September 2011.

6 Van der Weijden FA, Campbell SL, Dörfer CE, González-Cabezas C, Slot DE. Safety of oscillating-rotating powered brushes compared to manual toothbrushes: a systematic review. *J Periodontol* 2011; **82**: 5–24.

7 Breitenmoser J, Mörmann W, Mühlemann HR. Damaging effects of toothbrush bristle end form on gingiva. *J Periodontol* 1979; **50**: 212–216.

8 Danser MM, Timmerman MF, Ijzerman Y, Bulthuis H, van der Velden U, van der Weijden GA. Evaluation of the incidence of gingival abrasion as a result of toothbrushing. *J Clin Periodontol* 1998; **25**: 701–706.

9 Gorman WJ. Prevalence and etiology of gingival recession. *J Periodontol* 1967; **38**: 316–322.

10 Smith RG. Gingival recession. Reappraisal of an enigmatic condition and a new index for monitoring. *J Clin Periodontol* 1997; **24**: 201–205.

11 Kassab MM, Cohen RE. The etiology and prevalence of gingival recession. *J Am Dent Assoc* 2003; **134**: 220–225.

12 Rajapakse PS, McCracken GI, Gwynnett E, Steen ND, Guentsch A, Heasman PA. Does tooth brushing influence the development and progression of non-inflammatory gingival recession? A systematic review *J Clin Periodontol* 2007; **34**: 1046–1061.

13 Van der Weijden GA, Timmerman MF, Nijboer A, Reijerse E, Van der Velden U. Comparison of different approaches to assess bleeding on probing as indicators of gingivitis. *J Clin Periodontol* 1994; **21**: 589–594.

14 Lie MA, Timmerman MF, Van der Velden U, Van der Weijden GA. Evaluation of 2 methods to assess gingival bleeding in smokers and non-smokers in natural and experimental gingivitis. *J Clin Periodontol* 1998; **25**: 695–700.

15 Van der Weijden GA, Timmerman MF, Versteeg P, Piscaer M, Van der Velden U. High and low brushing force in relation to efficacy and gingival abrasion. *J Clin Periodontol* 2004; **31**: 620–624.

16 Quigley GA, Hein JW. Comparative cleansing efficiency of manual and power brushing. *J Am Dent Assoc* 1962; **65**: 26–29.

17 Turesky S, Gilmore ND, Glickman I. Reduced formation by chloromethyl analogue of vitamin C. *J Periodontol* 1970; **41**: 41–43.

18 Paraskevas S, Timmerman MF, van der Velden U, van der Weijden GA. Additional effect of dentifrices on the instant efficacy of toothbrushing. *J Periodontol* 2006; **77**: 1522–1527.

19 Conforti NJ, Cordero RE, Liebman J et al. An investigation into the effect of three months' clinical wear on toothbrush efficacy: results from two independent studies. *J Clin Dent* 2003; **14**: 29–33.

20 Smukler H, Landsberg J. The toothbrush and gingival traumatic injury. *J Periodontol* 1984; **55**: 713–719.

21 Addy M, Hunter ML. Can tooth brushing damage your health? Effects on oral and dental tissues. *Int Dent J* 2003; **53** (Suppl 3): 177–186.

22 Niemi ML, Ainamo J, Etemadzadeh H. The effect of toothbrush grip on gingival abrasion and plaque removal during toothbrushing. *J Clin Periodontol* 1987; **14**: 19–21.

23 Niemi ML, Ainamo J, Etemadzadeh H. Gingival abrasion and plaque removal with manual versus electric toothbrushing. *J Clin Periodontol* 1986; **13**: 709–713.

24 Sanges G, Gjermo P. Prevalence of oral soft and hard tissue lesions related to mechanical toothcleansing procedures. *Community Dent Oral Epidemiol* 1976; **4**: 77–83.

25 Niemi ML, Sandholm L, Ainamo J. Frequency of gingival lesions after standardized brushing as related to stiffness of toothbrush and abrasiveness of dentifrice. *J Clin Periodontol* 1984; **11**: 254–261.

26 Zimmer S, Öztürk M, Barthel CR, Bizhang M, Jordan RA. Cleaning efficacy and soft tissue trauma after use of manual toothbrushes with different bristle stiffness. *J Periodontol* 2011; **82**: 267–271.

27 Greggianin BF, Oliveira SC, Haas AN, Oppermann RV. The incidence of gingival fissures associated with toothbrushing: crossover 28-day randomized trial. *J Clin Periodontol* 2013; **40**: 319–326.

28 Drisko C, Henderson R, Yancy J. A review of current toothbrush bristle end-rounding studies. *Compend Contin Educ Dent* 1995; **16**: 694, 696, 698; quiz 708.

29 Van der Weijden GA, Timmerman MF, Reijerse E, Snoek CM, van der Velden U. Toothbrushing force in relation to plaque removal. *J Clin Periodontol* 1996; **23**: 724–729.

30 Niemi ML. Gingival abrasion and plaque removal after toothbrushing with an electric and a manual toothbrush. *Acta Odontol Scand* 1987; **45**: 367–370.

31 Wilson S, Levine D, Dequincey G, Killoy WJ. Effects of two toothbrushes on plaque, gingivitis, gingival abrasion, and recession: a 1-year longitudinal study. *Compend Suppl* 1993; **16**: S569–S579.

32 Schoo WH, van der Velden U. Marginal soft tissue recessions with and without attached gingiva. A five year longitudinal study. *J Periodontal Res* 1985; **20**: 209–211.

33 Daprile G, Gatto MR, Checchi L. The evolution of buccal gingival recessions in a student population: a 5-year follow-up. *J Periodontol* 2007; **78**: 611–614.

34 Khocht A, Simon G, Person P, Denepitiya JL. Gingival recession in relation to history of hard toothbrush use. *J Periodontol* 1993; **64**: 900–905.

35 Litonjua LA, Andreana S, Bush PJ, Cohen RE. Toothbrushing and gingival recession. *Int Dent J* 2003; **53**: 67–72.

36 McCracken GI, Heasman L, Stacey F et al. The impact of powered and manual toothbrushing on incipient gingival recession. *J Clin Periodontol* 2009; **36**: 950–957.

37 Dörfer CE, Joerss D, Wolff D. A Prospective Clinical Study to evaluate the effect of manual and power toothbrushes on pre-existing gingival recessions. *J Contemp Dent Pract* 2009; **10**: 1–8.

38 Hirschfeld I. Toothbrush trauma recession. A clinical study. *J Dent Res* 1931; **11**: 61–63.

39 Everett FG. The case of disappearing clefts. *J Periodontol* 1968; **39**: 296–297.

40 Lindhe J, Nyman S. Alterations of the position of the marginal soft tissue following periodontal surgery. *J Clin Periodontol* 1980; **7**: 525–530.

41 Serino G, Wennström JL, Lindhe J, Eneroth L. The prevalence and distribution of gingival recession in subjects with a high standard of oral hygiene. *J Clin Periodontol* 1994; **21**: 57–63.

42 Rosema NAM, Timmerman MF, Versteeg PAVan Palenstein Helderman WH, Van der Velden U, Van der Weijden GA. Comparison of the use of different modes of mechanical oral hygiene in prevention of plaque and gingivitis. *J Periodontol* 2008; **79**: 1386–1394.

43 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* 1998;**11** (Spec No):S17–S21.

44 Dentino AR, Derderian G, Wolf M et al. Six-month comparison of powered versus manual toothbrushing for safety and efficacy in the absence of professional instruction in mechanical plaque control. *J Periodontol* 2002; **73**: 770–778.

45 Rosema N, Hennequin-Hoenderdos N, Versteeg P, van Palenstein Helderman W, van der Velden U, van der Weijden G. Plaque-removing efficacy of new and used manual toothbrushes - a professional brushing study. *Int J Dent Hyg* 2013; **11**: 237–243.